ZigBee Specification

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Accepted by	ZigBee Alliance Board of Directors.
Abstract	The ZigBee Specification describes the infrastructure and services available to applications operating on the ZigBee platform.
Keywords	ZigBee, Stack, Network, Application, Profile, Framework, Device description, Binding, Security

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Preface

The ZigBee Alliance is developing a very low-cost, very low power consumption, two-way, wireless communications standard. Solutions adopting the ZigBee standard will be embedded in consumer electronics, home and building automation, industrial controls, PC peripherals, medical sensor applications, toys and games.

Scope

This document contains specifications, interface descriptions, object descriptions, protocols and algorithms pertaining to the ZigBee protocol standard, including the application support sub-layer (APS), the ZigBee device objects (ZDO), ZigBee device profile (ZDP), the application framework, the network layer (NWK) and ZigBee security services.

Purpose

The purpose of this document is to provide a definitive description of the ZigBee protocol standard as a basis for future implementations, such that any number of implementers incorporating the ZigBee standard into platforms and devices on the basis of this document will produce interoperable, low-cost and highly usable products for the burgeoning wireless marketplace.

Stack architecture

The ZigBee stack architecture is made up of a set of blocks called layers. Each layer performs a specific set of services for the layer above: a data entity provides a data transmission service and a management entity provides all other services. Each service entity exposes an interface to the upper layer through a service access point (SAP), and each SAP supports a number of service primitives to achieve the required functionality.

The ZigBee stack architecture, which is depicted in Figure 1, is based on the standard Open Systems Interconnection (OSI) seven-layer model (see [B14]) but defines only those layers relevant to achieving functionality in the intended market space. The IEEE 802.15.4-2003 standard defines the lower two layers: the physical (PHY) layer and the medium access control (MAC) sub-layer. The ZigBee Alliance builds on this foundation by providing the network (NWK) layer and the framework for the application layer, which includes the application support sub-layer (APS), the ZigBee device objects (ZDO) and the manufacturer-defined application objects.

IEEE 802.15.4-2003 has two PHY layers that operate in two separate frequency ranges: 868/915 MHz and 2.4 GHz. The lower frequency PHY layer covers both the 868 MHz European band and the 915 MHz band that is used in countries such as the United States and Australia. The higher frequency PHY layer is used virtually worldwide. A complete description of the IEEE 802.15.4-2003 PHY layer can be found in [B1].

The IEEE 802.15.4-2003 MAC sub-layer controls access to the radio channel using a CSMA-CA mechanism. Its responsibilities may also include transmitting beacon frames, synchronization and providing a reliable transmission mechanism. A complete description of the IEEE 802.15.4-2003 MAC sub-layer can be found in [B1].

The responsibilities of the ZigBee NWK layer shall include mechanisms used to join and leave a network, to apply security to frames and to route frames to their intended destinations. In addition, the discovery and maintenance of routes between devices devolve to the NWK layer. Also the discovery of one-hop neighbors

and the storing of pertinent neighbor information are done at the NWK layer. The NWK layer of a ZigBee coordinator (see "Network topology") is responsible for starting a new network, when appropriate, and assigning addresses to newly associated devices

The ZigBee application layer consists of the APS, the Application Framework (AF), the ZDO and the manufacturer-defined application objects. The responsibilities of the APS sub-layer include maintaining tables for binding, which is the ability to match two devices together based on their services and their needs, and forwarding messages between bound devices. The responsibilities of the ZDO include defining the role of the device within the network (e.g., ZigBee coordinator or end device), initiating and/or responding to binding requests and establishing a secure relationship between network devices. The ZDO is also responsible for discovering devices on the network and determining which application services they provide.

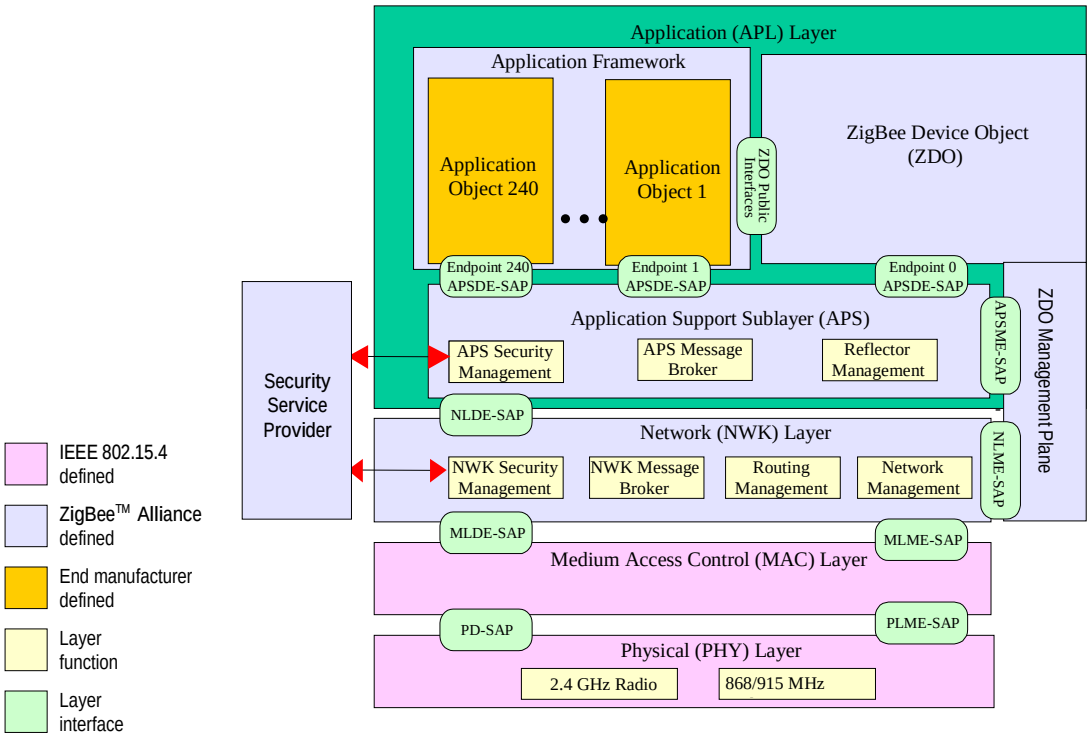

Figure 1 Outline ZigBee stack architecture

Network topology

The ZigBee network layer (NWK) supports star, tree and mesh topologies. In a star topology, the network is controlled by one single device called the ZigBee coordinator. The ZigBee coordinator is responsible for initiating and maintaining the devices on the network, and all other devices, known as end devices, directly communicate with the ZigBee coordinator. In mesh and tree topologies, the ZigBee coordinator is responsible for starting the network and for choosing certain key network parameters but the network may be extended through the use of ZigBee routers. In tree networks, routers move data and control messages through the network using a hierarchical routing strategy. Tree networks may employ beacon-oriented communication as described in the IEEE 802.15.4-2003 specification. Mesh networks shall allow full peer-to-peer communication. ZigBee routers in mesh networks shall not emit regular IEEE 802.15.4-2003 beacons.

This specification describes only intra-PAN networks, i.e., networks in which communications begin and terminate within the same network.

Definitions, Abbreviations, and References

Conformance Levels

The conformance level definitions shall follow those in Clause 13, section 1 of the IEEE Style Manual [B12].

Expected: A key word used to describe the behavior of the hardware or software in the design models assumed by this Specification. Other hardware and software design models may also be implemented.

May: A key word indicating a course of action permissible within the limits of the standard *(may* equals *is permitted)*.

Shall: A key word indicating mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted *(shall* equals *is required to)*.

Should: A key word indicating that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain course of action is deprecated but not prohibited *(should* equals *is recommended that)*.

Reserved Codes: A set of codes that are defined in this specification, but not otherwise used. Future specifications may implement the use of these codes. A product implementing this specification shall not generate these codes.

Reserved Fields: A set fields that are defined in this specification, but are not otherwise used. Products that implement this specification shall zero these fields and shall make no further assumptions about these fields nor perform processing based on their content. Products that implement future revisions of this specification may set these fields as defined by the specification.

ZigBee v1.0: The version of the ZigBee protocols governed by this specification. ZigBee v1.0 is the first officially recognized version of these protocols. The protocol version sub-field of the frame control field in the NWK header of all ZigBee v1.0 frames shall have a value of 0x01. Frames defined in later versions of the specification may set the protocol version sub-field of the frame control field to a different value. A ZigBee device that conforms to this specification shall discard all frames that carry a protocol version sub-field value other than 0x01.[1]

Strings and string operations

A string is a sequence of symbols over a specific set (e.g., the binary alphabet {0,1} or the set of all octets). The length of a string is the number of symbols it contains (over the same alphabet). The right-concatenation of two strings x and y of length m and n respectively (notation: $x \parallel y$), is the string z of length $m+n$ that coincides with x on its leftmost m symbols and with y on its rightmost n symbols. An octet is a symbol string of length 8. In our context, all octets are strings over the binary alphabet.

[1]CCB Comment 263

Transmission order

By convention, frame structures are presented such that the leftmost field as written in this document shall be transmitted or received first. All multiple octet fields shall be transmitted or received least significant octet first. Each individual octet shall be transmitted or received least significant bit first.

Integers, octets, and their representation

Throughout this specification, the representation of integers as octet strings and of octet strings as binary strings shall be fixed. All integers shall be represented as octet strings in most-significant-octet first order. This representation conforms to the convention in Section 4.3 of ANSI X9.63-2001 [B7]. All octets shall be represented as binary strings in most-significant-bit first order.

Entities

Throughout this specification, each entity shall be a DEV and shall be uniquely identified by its 64-bit IEEE device address [B1]. The parameter *entlen* shall have the integer value 64.

Definitions

For the purposes of this standard, the following terms and definitions apply. Terms not defined in this clause can be found in IEEE P802.15.4 §3 [B1] or in ANSI X9.63-2001 §2.1 [B7].

Access control list: a table used by a device to determine which devices are authorized to perform a specific function. This table may also store the security material (e.g., cryptographic keys, frame counts, key counts, security level information) used for securely communicating with other devices.

Active network key: the key used by a ZigBee device to secure outgoing NWK frames and that is available for use to process incoming NWK frames.

Alternate network key: a key available for use in lieu of the active Network key to process incoming NWK frames.

Application domain: this describes a broad area of applications, such as building automation**.**

Application object: a component of the top portion of the application layer defined by the manufacturer that actually implements the application.

Application segment: some application domains are split into application segments, for instance the lighting application segment within the home control application domain.

Application support sub-layer protocol data unit: a unit of data that is exchanged between the application support sub-layers of two peer entities.

APS command frame: an APS frame that contains neither source nor endpoints.

Association: the service provided by the IEEE 802.15.4-2003 MAC sub-layer that is used to establish membership in a network.

Attribute: a data entity which represents a physical quantity or state. This data is communicated to other devices using commands.

Beacon-enabled personal area network: a personal area network containing at least one device that transmits beacon frames at a regular interval.

Binding: the creation of a unidirectional logical link between a source endpoint/cluster identifier pair and a destination endpoint, which may exist on one or more devices.[2]

Broadcast: the transmission of a message to every device within a network.

Broadcast jitter: random delay time introduced by a device before relaying a broadcast transaction.

Broadcast transaction record: a local receipt of a broadcast message that was either initiated or relayed by a device.

Broadcast transaction table: collection of broadcast transaction records.

Cluster: is a container for one or more attributes under the KVP service type and is synonymous with "message" under the MSG service type.

Cluster identifier: a reference to the unique enumeration of clusters within a specific profile. The cluster identifier is an 8-bit number unique within the scope of the application domain segment and identifies a specific cluster. Cluster identifiers are identified as inputs or outputs in the simple descriptor for use in creating a binding table.

Component: a component consists of a physical object (e.g., switch, controller, etc.) and its corresponding application profile(s).

Coordinator: an IEEE 802.15.4-2003 device responsible for associating and disassociating devices into its PAN. A coordinator must be a full function device (FFD).

Data integrity: assurance that the data has not been modified from its original form.

Data key: a key shared between two devices for peer-to-peer data communications.

Device: any entity that contains an implementation of the ZigBee protocol stack.

Device application: a special application that is responsible for Device operation. The Device Application resides on Endpoint 0 by convention and contains logic to manage the Devices networking and general maintenance features.

Device description: a description of a specific device within an application segment and/or domain. For instance, the light sensor monochromatic device description is a member of the lighting application segment. The device description also has a unique identifier that is exchanged as part of the discovery process.

Direct addressing: a mode of addressing in which the destination of a frame is completely specified in the frame itself.

Direct binding: the procedure through which the uppers layers of a device which maintains a binding table in the APS can create or remove a binding link in that binding table.

Direct transmission: frame transmission using direct addressing.

Disassociation: the service provided by the IEEE 802.15.4-2003 MAC sub-layer that is used to discontinue the membership of a device in a network.

End application: applications that reside on Endpoints 1 through 240 on a Device. The End Applications implement features that are non-networking and ZigBee protocol related.

End device binding: the procedure for creating or removing a binding link initiated by each of the end devices that will form the link. The procedure may or may not involve user intervention.

[2]CCB Comment #127

Endpoint: a particular component within a unit. Each ZigBee device may support up to 240 such components.

Endpoint address: the address assigned to an endpoint. This address is assigned in addition to the unique, 64-bit IEEE address and 16-bit network address.

First hop indirect frame: a period in the transit of a frame that has been indirectly addressed when only the source address appears in the frame.

Indirect addressing: the ability for resource limited devices to communicate without having to know the address of the desired destination. Indirect transmissions shall include only the source endpoint-addressing field along with the Indirect Addressing bit set in the APDU and are directed to the ZigBee Coordinator by the source. The ZigBee Coordinator is expected to lookup the source address/endpoint/cluster ID within its binding table and re-issues the message to each corresponding destination address/endpoint.

Information base: a collection of variables that define certain behavior in a layer. These variables can be specified or obtained from a layer through its management service.

Key establishment: A mechanism that involves the execution of a protocol by two devices to derive a mutually shared secret key.

Key transport: A mechanism for communicating a key from one device to another device or other devices.

Key-transport key: A key used to protect key transport messages.

Key update: A mechanism implementing the replacement of a key shared amongst two or more devices by means of another key available to that same group.

Local coordinator: A ZigBee Coordinator or ZigBee Router, which is the IEEE 802.15.4 coordinator, which processed the association request for a specific End Device.

Link key: A key that is shared between two devices within a PAN.

Master key: A shared key used during the execution of a symmetric-key key establishment protocol. The master key is the basis for long-term security between the two devices, and may be used to generate link keys.

Mesh network: a network in which the routing of messages is performed as a decentralized, cooperative process involving many peer devices routing on each others' behalf.

Multihop network: a network, in particular a wireless network, in which there is no guarantee that the transmitter and the receiver of a given message are connected or linked to each other. This implies that intermediate devices must be used as routers.

Non-beacon-enabled personal area network: a personal area network that does not contain any devices that transmit beacon frames at a regular interval.

Neighbor table: a table used by a ZigBee device to keep track of other devices within the POS.

Network address: the address assigned to a device by the network layer and used by the network layer for routing messages between devices.

Network broadcast delivery time: time duration required by a broadcast transaction to reach every device of a given network.

Network protocol data unit: a unit of data that is exchanged between the network layers of two peer entities.

Network service data unit: Information that is delivered as a unit through a network service access point.

Node: a collection of independent device descriptions and applications residing in a single unit and sharing a common 802.15.4 radio.

Normal operating state: processing which occurs after all startup and initialization processing has occurred and prior to initiation of shutdown processing.

NULL: A parameter or variable value that mean unspecified, undefined or unknown.

Octet: eight bits of data, used as a synonym for a byte.

One-way function: A function that is computationally much easier to perform than its inverse.

Orphaned device: a device that has lost communication contact with or information about the ZigBee device through which it has its PAN membership.

PAN coordinator: The principal controller of an IEEE 802.15.4-2003-based network that is responsible for network formation and maintenance. The PAN coordinator must be a full function device (FFD).

PAN information base: A collection of variables in the IEEE 802.15.4-2003 standard that are passed between layers, in order to exchange information. This database may include the access control list, which stores the security material.

Personal operating space: the area within reception range of a single device.

Private method: attributes which are accessible to ZigBee device objects only and unavailable to the end applications.

Profile: a collection of device descriptions, which together form a cooperative application. For instance, a thermostat on one node communicates with a furnace on another node. Together, they cooperatively form a heating application profile.

Protocol data unit: the unit of data that is exchanged between two peer entities.

Proxy binding: the procedure through which a device can create or remove a binding link on the ZigBee coordinator between two devices (none of which may be the device itself).

Public method: attributes which are accessible to End Applications.

Radio: the IEEE 802.15.4-2003 radio that is part of every ZigBee device.

Route discovery: an operation in which a ZigBee coordinator or ZigBee router attempts to discover a route to a remote device by issuing a route request command frame.[3]

Route discovery table: a table used by a ZigBee coordinator or ZigBee router to store temporary information used during route discovery.

Route reply: a ZigBee network layer command frame used to reply to route requests.

Route request: a ZigBee network layer command frame used to discover paths through the network over which subsequent messages may be delivered.

Routing table: a table in which a ZigBee coordinator or ZigBee router stores information required to participate in the routing of frames.

Service discovery: the ability of a device to locate services of interest.

Symmetric-key key establishment: a mechanism by which two parties establish a shared secret, based on a pre-shared secret (a so-called master key).

Trust center: the device trusted by devices within a ZigBee network to distribute keys for the purpose of network and end-to-end application configuration management.

Unicast: the transmission of a message to a single device in a network.

[3]CCB Comment #126

Unit: a component or collection of components that share a single ZigBee radio. Each unit has a unique 64-bit IEEE address and a 16-bit network address.

ZigBee coordinator: an IEEE 802.15.4-2003 PAN coordinator.

ZigBee device object: the portion of the application layer responsible for defining the role of the device within the network (e.g., ZigBee coordinator or end device), initiating and/or responding to binding and discovery requests and establishing a secure relationship between network devices.

ZigBee end device: an IEEE 802.15.4-2003 RFD or FFD participating in a ZigBee network, which is neither the ZigBee coordinator nor a ZigBee router.

ZigBee router: an IEEE 802.15.4-2003 FFD participating in a ZigBee network, which is not the ZigBee coordinator but may act as an IEEE 802.15.4-2003 coordinator within its personal operating space, that is capable of routing messages between devices and supporting associations.

Acronyms and Abbreviations

For the purposes of this standard, the following acronyms and abbreviations apply.

AIB	Application support layer information base
AF	Application framework
APDU	Application support sub-layer protocol data unit
APL	Application layer
APS	Application support sub-layer
APSDE	Application support sub-layer data entity
APSDE-SAP	Application support sub-layer data entity – service access point
APSME	Application support sub-layer management entity - service access point
APSME-SAP	Application support sub-layer management entity – service access point
BRT	Broadcast retry timer
BTR	Broadcast transaction record
BTT	Broadcast transaction table
CCM*	Enhanced counter with CBC-MAC mode of operation
CSMA-CA	Carrier sense multiple access – collision avoidance
FFD	Full function device
GTS	Guaranteed time slot
IB	Information base
KVP	Key-value pair
LQI	Link quality indicator
LR-WPAN	Low rate wireless personal area network
MAC	Medium access control
MCPS-SAP	Medium access control common part sub-layer – service access point

MIC	Message integrity code
MLME-SAP	Medium access control sub-layer management entity – service access point
MSC	Message sequence chart
MSDU	Medium access control sub-layer service data unit
MSG	Message service type
NBDT	Network broadcast delivery time
NHLE	Next Higher Layer Entity
NIB	Network layer information base
NLDE	Network layer data entity
NLDE-SAP	Network layer data entity – service access point
NLME	Network layer management entity
NLME-SAP	Network layer management entity – service access point
NPDU	Network layer protocol data unit
NSDU	Network service data unit
NWK	Network
OSI	Open systems interconnection
PAN	Personal area network
PD-SAP	Physical layer data – service access point
PDU	Protocol data unit
PHY	Physical layer
PIB	Personal area network information base
PLME-SAP	Physical layer management entity – service access point
POS	Personal operating space
QoS	Quality of service
RC	Radius counter
RFD	Reduced function device
RREP	Route reply
RREQ	Route request
RN	Routing node
SAP	Service access point
SKG	Secret key generation
SKKE	Symmetric-key key establishment
SSP	Security services provider
SSS	Security services specification

WPAN	Wireless personal area network
XML	Extensible markup language
ZB	ZigBee
ZDO	ZigBee device object

Symbols and Notation

Notation follows from ANSI X9.63-2001, §2.2 [B7]

References

The following standards contain provisions, which, through reference in this document, constitute provisions of this standard. Normative references are given in "ZigBee/IEEE References" and "Normative References" and informative references are given in "Informative References". At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

ZigBee/IEEE References

[B1] Institute of Electrical and Electronics Engineers, Inc., IEEE Std. 802.15.4-2003, IEEE Standard for Information Technology — Telecommunications and Information Exchange between Systems — Local and Metropolitan Area Networks — Specific Requirements — Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (WPANs). New York: IEEE Press. 2003.

[B2] IEEE 754-1985, IEEE Standard for Binary Floating-Point Arithmetic, IEEE, 1985.

[B3] Document 03285r0: Suggestions for the Improvement of the IEEE 802.15.4 Standard, July 2003.

[B4] Document 02055r4: Network Requirements Definition, August 2003.

Normative References

[B5] ISO/IEC 639-1:2002 Codes for the representation of names of languages - Part 1: Alpha-2 code.

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[B11] NIST Pub 800-38A 2001 ED, Recommendation for Block Cipher Modes of Operation – Methods and Techniques, NIST Special Publication 800-38A, 2001 Edition, US Department of Commerce/N.I.S.T., December 2001. Available from http://csrc.nist.gov/.

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[B16] ISO/IEC 9646-1:1991, Information technology - Open Systems Interconnection - Conformance testing methodology and framework - Part 1: General concepts.

[B17] ISO/IEC 9646-7:1995, Information technology - Open Systems Interconnection - Conformance testing methodology and framework - Part 7. Implementation conformance statements.

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[B19] FIPS Pub 113, Computer Data Authentication, Federal Information Processing Standards Publication 113, US Department of Commerce/N.I.S.T., May 30, 1985. Available from http://csrc.nist.gov/.

[B20] R. Housley, D. Whiting, N. Ferguson, Counter with CBC-MAC (CCM), submitted to N.I.S.T., June 3, 2002. Available from http://csrc.nist.gov/encryption/modes/proposedmodes/.

[B21] J. Jonsson, On the Security of CTR + CBC-MAC, in Proceedings of Selected Areas in Cryptography – SAC 2002, K. Nyberg, H. Heys, Eds., Lecture Notes in Computer Science, Vol. 2595, pp. 76-93, Berlin: Springer, 2002.

[B22] J. Jonsson, On the Security of CTR + CBC-MAC, NIST Mode of Operation – Additional CCM Documentation. Available from http://csrc.nist.gov/encryption/modes/proposedmodes/.

[B23] P. Rogaway, D. Wagner, A Critique of CCM, IACR ePrint Archive 2003-070, April 13, 2003.

Chapter 1 Application Layer Specification

1.1 General description

The ZigBee stack architecture includes a number of layered components including the IEEE 802.15.4 2003 Medium Access Control (MAC) layer and Physical (PHY) layer and well as the ZigBee Network (NWK) layer. Each of these provide applications with its own set of services and capabilities. The portion of the stack covered by this document is roughly that labeled Application (APL) Layer in Figure 1.

As shown, the ZigBee application layer consists of the APS sub-layer, the ZDO (containing the ZDO management plane), and the manufacturer-defined application objects. The responsibilities of the APS sub-layer include maintaining tables for binding, which is the ability to match two devices together based on their services and their needs, and forwarding messages between bound devices. The responsibilities of the ZDO include defining the role of the device within the network (e.g., ZigBee coordinator or end device), discovering devices on the network and determining which application services they provide, initiating and/or responding to binding requests and establishing a secure relationship between network devices.

1.1.1 Application support sub-layer

The application support sub-layer (APS) provides an interface between the network layer (NWK) and the application layer (APL) through a general set of services that are used by both the ZDO and the manufacturer-defined application objects. The services are provided by two entities: the APS data entity (APSDE) through the APSDE service access point (APSDE-SAP) and the APS management entity (APSME) through the APSME service access point (APSME-SAP). The APSDE provides the data transmission service for the transport of application PDUs between two or more devices located on the same network. The APSME provides services for discovery and binding of devices and maintains a database of managed objects, known as the APS information base (AIB).

1.1.2 Application framework

The application framework in ZigBee is the environment in which application objects are hosted on ZigBee devices. Inside the application framework, the application objects send and receive data through the APSDE-SAP. Control and management of the application objects is performed through the ZDO public interfaces (see clause 1.5).

The data service, provided by APSDE-SAP, includes request, confirm, response and indication primitives for data transfer. The request primitive supports data transfers between peer application object entities. The confirm primitive reports the results of a request primitive call. The indication primitive is used to indicate the transfer of data from the APS to the destination application object entity.

Up to 240 distinct application objects can be defined, each interfacing on an endpoint indexed from 1 to 240. Two additional endpoints are defined for APSDE-SAP usage: endpoint 0 is reserved for the data interface to the ZDO and endpoint 255 is reserved for the data interface function to broadcast data to all application objects. Endpoints 241-254 are reserved for future use.[4]

Using these services offered by the APSDE-SAP, the application framework provides an application object two data services: a key value pair service and a generic message service. Each service will be discussed in the following sub-clauses.

[4]CCB Comment #227

1.1.2.1 Key value pair service

The key value pair (KVP) service allows attributes, defined in the application objects, to be manipulated by employing a state variable approach with get, get response, set and event transactions. The latter two transactions can be sent with a request for response, resulting in the corresponding set response and event response transactions, respectively. Additionally, KVP uses tagged data structures using compressed XML. Together, this solution provides an elegant command/control mechanism for small footprint devices with extensibility to enable gateways to expand to full XML.

The KVP service frame structure is described in sub-clause 1.3.5.

1.1.2.2 Message service

Many application areas targeted by ZigBee are addressed by proprietary protocols that do not map well to KVP. Additionally, some overhead is assumed in KVP since the state variable approach assumes support for any of the get, set or event actions requiring devices to maintain storage for state variables.

To address these cases, the generic message (MSG) service is supported. The MSG service type is transported via the same mechanisms used by KVP. The difference is that MSG does not assume any content in the APS data frame leaving that field free form for the profile developer to define.

The MSG service frame structure is described in sub-clause 1.3.4.5.2.

1.1.3 Addressing

1.1.3.1 Node addressing

In Figure 2, there are two nodes, each containing a single radio. One node contains two switches and the other contains 4 lamps.

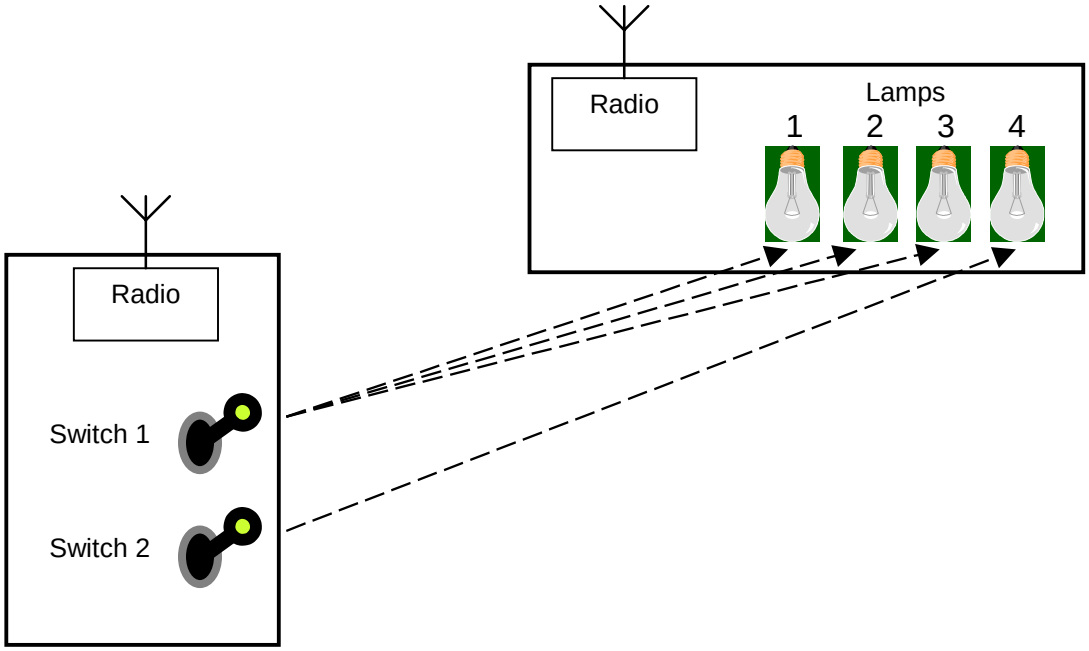

Figure 2 Multiple subunits in a single node

A node contains one or more device descriptions and has a single IEEE 802.15.4 radio. In Figure 2, the individual parts of the nodes (the switches and lamps) are subunits containing one device description in each subunit. Each node is given an address when it joins the ZigBee network.

1.1.3.2 Endpoint addressing

In Figure 2, it is required that switch 1 should control lamps 1, 2 and 3, while switch 2 should control only lamp 4. However, as the only addressable component is the radio, it is not possible to identify or address the individual subunits, so it would not be possible for switch 2 to turn on lamp 4 only.

ZigBee provides another level of sub-addressing, which is used in conjunction with the mechanisms of IEEE802.15.4. An endpoint number can be used to identify individual switches and lamps. For instance, in the example above, switch 1 could use endpoint 3, while switch 2 could use endpoint 21. Similarly, the lamps will each have their own endpoints. Endpoint 0 is reserved for device management and is used to address the descriptors in the node. Each identifiable subunit in a node (such as the switches and lamps) is assigned its own specific endpoint in the range 1-240.

Physical devices are described in terms of the data attributes that they contain. For instance, a thermostat might contain an output attribute “temperature” which represents the current temperature of a room. A furnace controller may take this attribute as an input and control the furnace according to the temperature value received from the thermostat. These two physical devices, including their attributes, would be described in the relevant device descriptions for those devices.

The simple room thermostat described has temperature-sensing circuitry, which can be queried by the external furnace controller. It advertises its service on an endpoint and the service is described in the simple description implemented on that endpoint.

A more complex version of the thermostat may also have an optional “heartbeat” report timer, which causes the device to report current room temperature after a set period. In this example, the ReportTime attribute

specifies when reports are to be sent and writing a suitable time value to this attribute sets the frequency of these temperature reports. This implementation would advertise its services (in a list of cluster identifiers) on a different endpoint.

In order to allow product differentiation in the marketplace, manufacturers may add clusters containing extra attributes of their own in the context of one or more private profiles. These manufacturer-specific clusters do not form part of this or any other ZigBee specification and interoperability is not guaranteed for these clusters. Such services would be advertised on different endpoints from those described above.

1.1.4 Application communication fundamentals

1.1.4.1 Profiles

Profiles are an agreement on messages, message formats and processing actions that enable applications residing on separate devices to send commands, request data and process commands/requests to create an interoperable, distributed application. For instance, a thermostat on one node communicates with a furnace on another node. Together, they cooperatively form a heating application profile. Profiles are developed by ZigBee vendors to address solutions to specific technology needs.

Profiles are simultaneously a means to unify interoperable technical solutions within the ZigBee standard, as well as to focus usability efforts within a given marketing area. For example, it is expected that vendors of lighting equipment will want to provide ZigBee profiles that interoperate with several varieties of lighting types or controller types. Additional information on profiles is provided in clause 1.2 of this document.

1.1.4.2 Clusters

Clusters are identified by a cluster identifier, which is associated with data flowing out of, or into, the device. Cluster identifiers are unique within the scope of a particular profile. Binding decisions are taken by matching an output cluster identifier to an input cluster identifier, assuming both are within the same profile. In the thermostat example above, binding takes place on temperature, between a device with a temperature cluster identifier as output and a device with a temperature cluster identifier as input. The binding table contains the 8-bit identifier for temperature along with the address of the source and destination devices.

1.1.5 Discovery

1.1.5.1 Device discovery

Device discovery is the process whereby a ZigBee device can discover other ZigBee devices by initiating queries that are broadcast or unicast addressed. There are two forms of device discovery requests: IEEE address requests and NWK address requests. The IEEE address request is unicast and assumes the NWK address is known. The NWK address request is broadcast and carries the known IEEE address as data payload.

Responses to the broadcast or unicast device discovery messages vary by logical device type as follows:

- ZigBee end devices: respond to the device discovery query by sending their IEEE or NWK address (depending on the request).
- ZigBee coordinator device: respond to the query by sending their IEEE or NWK addresses and the IEEE or NWK addresses of all devices that are associated with the ZigBee coordinator (depending on the request).
- ZigBee router devices: respond to the query by sending their IEEE or NWK addresses and the IEEE or NWK addresses of all devices that are associated with the ZigBee router (depending on the request).

A description of the procedure details, primitive calls, and applicable parameters is given in clause 1.4.

1.1.5.2 Service discovery

Service discovery is the process whereby services available on endpoints at the receiving device are discovered by external devices. Service discovery can be accomplished by issuing a query for each endpoint on a given device or by using a match service feature (either broadcast or unicast). Service discovery utilizes the complex, user, node or power descriptors plus the simple descriptor further addressed by the endpoint (for the connected application object).

The service discovery process in ZigBee is key to interfacing devices within the network. Through specific requests for descriptors on specified nodes, broadcast requests for service matching and the ability to ask a device which endpoints support application objects, a range of options are available for commissioning tools and applications. See clause 1.4 for details on service discovery.

1.1.6 Binding

In ZigBee, there is an application level concept using cluster identifiers (and the attributes contained in them) on the individual endpoints in different nodes. This is referred to as binding – the creation of logical links between complementary application devices and endpoints. In the example of sub-clause 1.1.3.2, a binding could be made between thermostat and the furnace controller. In Figure 2, switch 1 is bound with lamps 1-3, while switch 2 is bound with lamp 4 only.

The information about which cluster is bound between nodes is stored in a binding table. This is described fully in sub-clause 1.1.6 and is illustrated in Figure 3.

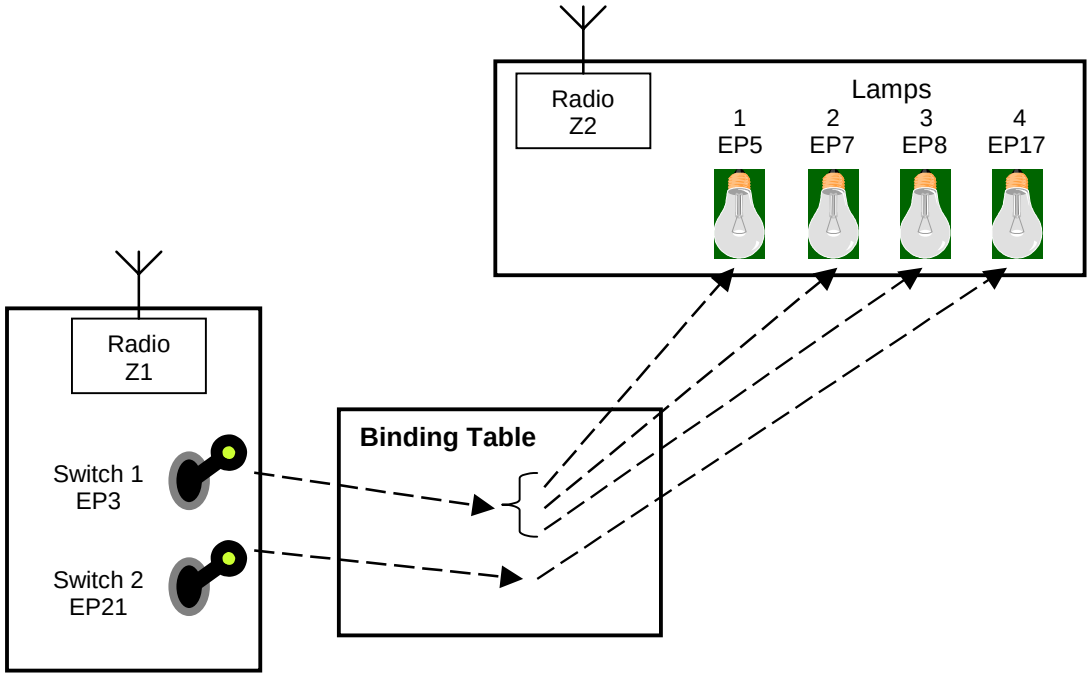

Figure 3 ZigBee binding and binding table

The use of a list of three entries in the binding table for switch 1 allows it to control three lamps, which could also be in separate nodes (with their own ZigBee radios). It is also possible for one lamp to be controlled by several switches: in this case there would be entries for each switch, all linked to the same lamp.

Binding is always performed after a communications link has been established. Once a link has been established, the implementation decides whether a new node should be part of the network. This will depend on the security in operation for the application and how it is implemented. Binding is only allowed if the implemented security on all devices allows this (see Chapter 3).

The binding table is implemented in the ZigBee coordinator. This is because it needs to be available all the time the network is operative and it is most probable that the ZigBee coordinator has a mains supply. Some applications may need a duplicate of the binding table to be available in the event that the device storing the table fails. Backup of the binding table and any other key ZigBee coordinator data is outside the scope of ZigBee version 1.0 and the responsibility of application software.

The details of the creation of binding links is covered in the ZigBee device profile (see clause 1.4).

1.1.7 Messaging

1.1.7.1 Direct addressing

Once devices have been associated, commands can be sent from one device to another. A command is sent to an application object at the destination address (radio address plus its endpoint). Details of the commands can be found in sub-clause 1.3.5. Note that binding is not a pre-requisite for using direct addressing.

Direct addressing assumes device discovery and service discovery have identified a particular device and endpoint, which supply a complementary service to the requestor. Specifically, direct addressing defines a means of directing messages to the device by including its full address and endpoint information.

1.1.7.2 Indirect addressing

Use of direct addressing requires the controlling device to have knowledge of the address, endpoint, cluster identifier and attribute identifier of the target device that it wishes to communicate with and to have this information committed to a binding table on the ZigBee coordinator prior to the creation of an indirectly addressed message between the device pair. A full IEEE 802.15.4 address amounts to 10 octets (PAN identifier plus 64-bit IEEE address) and a further octet is required for the endpoint. Extremely simple devices, such as battery-powered switches, may not want the overhead of storing this information, nor the software for acquiring this information. For these devices, indirect addressing will be more appropriate.

When a source device wishes to send a command to a destination using indirect addressing, instead of including the address of the destination device (which it does not know and has not stored), it omits the address and specifies indirect addressing via the APSDE-SAP. The included source address, source endpoint and cluster identifier in the indirect addressed message are translated via the binding table to those of the destination device(s) and the messages are relayed to each indicated destination.[5]

Where a cluster contains several attributes, the cluster identifier is used for addressing and the attribute identifier is used in the command itself to identify a particular attribute within the cluster. For further information, see sub-clause 1.3.4.5.1. Attributes are not used in the indirect addressing mechanism and are treated as a part of the data payload. The applications, however, can parse and utilize the attributes as defined within their profile.

1.1.7.3 Broadcast addressing

An application may broadcast messages to all endpoints on a given destination device. This form of broadcast addressing is called application broadcast. The destination address shall be the 16-bit network broadcast address and the broadcast flag shall be set in the APS frame control field. The source shall include the cluster identifier, profile identifier and source endpoint fields in the APS frame (see sub-clause 1.2.5).

[5]CCB Comment #171, 214

1.1.8 ZigBee device objects

The ZigBee device objects (ZDO), represents a base class of functionality that provides an interface between the application objects, the device profile and the APS. The ZDO is located between the application framework and the application support sub-layer. It satisfies common requirements of all applications operating in a ZigBee protocol stack. The ZDO is responsible for the following:

— Initializing the application support sub-layer (APS), the network layer (NWK), the security services specification (SSS).

— Assembling configuration information from the end applications to determine and implement discovery, security management, network management, and binding management.

The ZDO presents public interfaces to the application objects in the application framework layer for control of device and network functions by the application objects. The ZDO interfaces to the lower portions of the ZigBee protocol stack, on endpoint 0, through the APSDE-SAP for data and through the APSME-SAP for control messages. The public interface provides address management of the device, discovery, binding, and security functions within the application framework layer of the ZigBee protocol stack. These services are described in the following sub-clauses. The ZDO is fully described in clause 1.5.

1.1.8.1 Discovery management

Discovery management is provided to the application objects whereby, when queried, the IEEE address of the requested device shall be returned (if the device is a ZigBee end device), along with the device addresses of all associated devices (if the device is a ZigBee coordinator or router). This is referred to as device discovery, and is used for the discovery of ZigBee devices.

In addition to device discovery, service discovery is also provided to determine what services are offered on each endpoint, defined in a device, by the respective application objects. A device can discover active endpoints on individual devices or all devices and a device can discover specific services that match a given criteria (profile identifiers and cluster identifiers).

1.1.8.2 Binding management

Binding management is provided to the application objects in order to bind application objects on ZigBee devices to each other for clear and concise connections through all layers of the protocol stack and though the various connections provided by the ZigBee network nodes. Binding tables are constructed and populated according to the binding calls and results. End device bind, bind and unbind commands between devices is supported via the ZigBee device profile.

1.1.8.3 Security management

Security management is provided to the application objects for enabling or disabling the security portion of the system. If enabled, key management is performed for master keys, network keys, and the means to establish a link key. Primitives are defined in Chapter 3 to permit key establishment, key transport and authentication.

1.2 The ZigBee application support (APS) sub-layer

1.2.1 Scope

This clause specifies the portion of the application layer providing the service specification and interface to both the manufacturer-defined application objects and the ZigBee device objects. The specification includes

a data service and methods for discovery and binding, as well as a description of the application support sub-layer frame format and frame type specifications.

1.2.2 Purpose

The purpose of this clause is to define the set of requirements for the ZigBee application support (APS) sub-layer protocol. These requirements are based on both the driver functionality necessary to enable correct operation of the ZigBee network layer and the functionality required by the manufacturer-defined application objects. This specification shall provide a solution for all the requirements defined in the ZigBee Network Working Group Requirements Definition document [B4] including a fully specified primitive interface.

1.2.3 Application support (APS) sub-layer overview

The application support sub-layer provides the interface between the network layer and the application layer through a general set of services for use by both the ZigBee device object (ZDO) and the manufacturer-defined application objects. These services are offered via two entities: the data service and the management service. The APS data entity (APSDE) provides the data transmission service via its associated SAP, the APSDE-SAP. The APS management entity (APSME) provides the management service via its associated SAP, the APSME-SAP, and maintains a database of managed objects known as the APS information base (AIB).

1.2.3.1 Application support sub-layer data entity (APSDE)

The APSDE shall provide a data service to the network layer and both the ZDO and the application objects to enable the transport of application PDUs between two or more devices. The devices themselves must be located on the same network.

The APSDE will provide the following services:

- **Generation of the Application level PDU (APDU).** The APSDE shall take an application PDU and generate an APS PDU by adding the appropriate protocol overhead.
- **Binding.** This is the ability to match two devices together based on their services and their needs. Once two devices are bound, the APSDE shall be able to transfer a message received from one bound device over to the second device.

1.2.3.2 Application support sub-layer management entity (APSME)

The APSME shall provide a management service to allow an application to interact with the stack.

The APSME shall provide the ability to match two devices together based on their services and their needs. This service is called the binding service and the APSME shall be able to construct and maintain a table to store this information.

In addition, the APSME will provide the following services:

- **AIB Management.** The ability to get and set attributes in the device's AIB.
- **Security.** The ability to set up authentic relationships with other devices through the use of secure keys.

1.2.4 Service specification

The APS sub-layer provides an interface between a next higher layer entity (NHLE) and the NWK layer. The APS sub-layer conceptually includes a management entity called the APS sub-layer management entity (APSME). This entity provides the service interfaces through which sub-layer management functions may be invoked. The APSME is also responsible for maintaining a database of managed objects pertaining to the APS sub-layer. This database is referred to as the APS sub-layer information base (AIB).

Figure 4 depicts the components and interfaces of the APS sub-layer.

The APS sub-layer provides two services, accessed through two service access points (SAPs). These are the APS data service, accessed through the APS sub-layer data entity SAP (APSDE-SAP), and the APS management service, accessed though the APS sub-layer management entity SAP (APSME-SAP). These two services provide the interface between the NHLE and the NWK layer, via the NLDE-SAP and NLME-SAP interfaces (see clause 2.3). In addition to these external interfaces, there is also an implicit interface between the APSME and the APSDE that allows the APSME to use the APS data service.

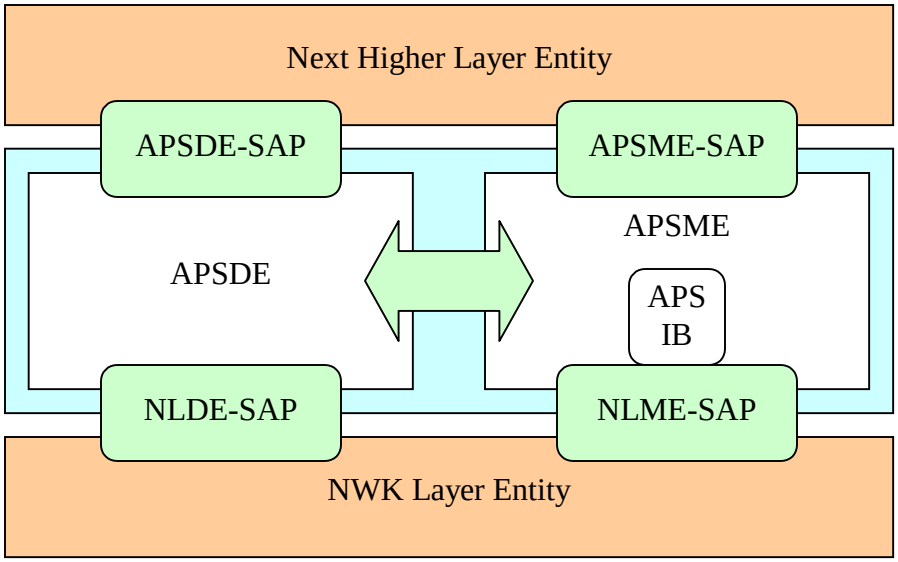

Figure 4 The APS sub-layer reference model

1.2.4.1 APS data service

The APS sub-layer data entity SAP (APSDE-SAP) supports the transport of application protocol data units between peer application entities. Table 1 lists the primitives supported by the APSDE-SAP. Each of these primitives will be discussed in the following sub-clauses.

Table 1 APSDE-SAP primitives

APSDE-SAP primitive	Request	Confirm	Indication
APSDE-DATA	1.2.4.1.1	1.2.4.1.2	1.2.4.1.3

1.2.4.1.1 APSDE-DATA.request

This primitive requests the transfer of a NHLE PDU (ASDU) from the local NHLE to a single peer NHLE entity.

1.2.4.1.1.1 Semantics of the service primitive

This semantics of this primitive are as follows:

APSDE-DATA.request	(DstAddrMode, DstAddress, DstEndpoint, ProfileId, ClusterId, SrcEndpoint, asduLength, asdu, TxOptions, DiscoverRoute, RadiusCounter)

Table 2 specifies the parameters for the APSDE-DATA.request primitive.

Table 2 APSDE-DATA.request parameters

Name	Type	Valid range	Description
DstAddrMode	Integer	0x00 – 0xff	The addressing mode for the destination address used in this primitive and of the APDU to be transferred. This parameter can take one of the non-reserved values from the following list: 0x00 = DstAddress and DstEndpoint not present. 0x01 = 16 bit short address for DstAddress and DstEndpoint present. 0x02 = 64 bit extended address for DstAddress and DstEndpoint present. 0x03 – 0xff = reserved.
DstAddress	Device address	As specified by the DstAddrMode parameter.	The individual device address of the entity to which the ASDU is being transferred.
DstEndpoint	Integer	0x00 – 0xff	The individual endpoint of the entity to which the ASDU is being transferred.
ProfileId	Integer	0x0000 – 0xffff[a]	The identifier of the profile for which this frame is intended.[b]
ClusterId	Integer	0x00 – 0xff	The identifier of the object to use in the binding operation if the frame is to be sent using indirect addressing. If indirect addressing is not being used, this parameter is ignored.
SrcEndpoint	Integer	0x00 – 0xfe	The individual endpoint of the entity from which the ASDU is being transferred.
asduLength	Integer	c	The number of octets comprising the ASDU to be transferred.

Table 2 APSDE-DATA.request parameters

Asdu	Set of octets	-	The set of octets comprising the ASDU to be transferred.
TxOptions	Bitmap	0000 0xxx (Where x can be 0 or 1)	The transmission options for the ASDU to be transferred. These are a bitwise OR of one or more of the following: 0x01 = Security enabled transmission. 0x02 = Use NWK key. 0x04 = Acknowledged transmission.
DiscoverRoute	Integer	0x00-0x02	The DiscoverRoute parameter supplies control information from the application layer to the network layer regarding actions to be taken in route discovery. The possible values are: 0x00 = suppress route discovery (use existing routing information for this request). 0x01 = enable route discovery (perform route discovery if there is not already an existing route for this request). 0x02 = force route discovery (explicitly request route discovery to occur before routing this request). The DiscoverRoute parameter has a value corresponding to the NLDE-DATA.request (see Chapter 2)[d].
RadiusCounter	Unsigned Integer	0x00-0xff	The distance, in hops, that a broadcast frame will be allowed to travel through the network.

[a]CCB Comment #168
[b]CCB Comment #208
[c]CCB Comment #336
[d]CCB Comment #256

1.2.4.1.1.2 When generated

This primitive is generated by a local NHLE whenever a data PDU (ASDU) is to be transferred to a peer NHLE.

1.2.4.1.1.3 Effect on receipt

On receipt of this primitive the APS sub-layer entity begins the transmission of the supplied ASDU.

If the DstAddrMode parameter is set to 0x00, the DstAddress and DstEndpoint parameters are ignored and the value of the DstEndpoint parameter is not placed in the resulting APDU; this option allows indirect addressing to be used. If the DstAddrMode parameter is set to 0x01, the DstAddress parameter contains a 16-bit short address and the DstEndpoint parameters are placed in the resulting APDU. If the DstAddrMode parameter is set to 0x02, the DstAddress parameter contains an extended, 64-bit IEEE address and the DstEndpoint parameters are placed in the resulting APDU.

The DiscoverRoute parameter is set by the application based on requested handling of route discovery at the Network Layer. The application may employ APS Acknowledgement or application-level message responses to determine whether messages are received reliably at the destination. Based on metrics managed within the application, the DiscoverRoute parameter may be used to request route discovery operations at the Network Layer to improve reliable delivery. If NWK broadcast messaging is employed (the DstAddress is set to 0xffff), the application can specify the RadiusCounter (0x00 targets all devices that are part of the network, a value of 0x01-0xff sets the radius of the broadcast message as measured from the source)[6]

If the APDU is to be transmitted using direct addressing (a destination address is present), the APSDE transmits the constructed frame by issuing the NLDE-DATA.request primitive to the NWK layer. On receipt of the NLDE-DATA.confirm primitive, the APSDE issues the APSDE-DATA.confirm primitive (see sub-clause 1.2.4.1.2) with a status equal to that received from the NWK layer.

If the APDU is to be transmitted using indirect addressing (indirect addressing value specified in the delivery mode sub-field / a destination address is not present) and this primitive was received by the APSDE of the ZigBee coordinator or router, a search is made in the binding table for devices bound to this device with the endpoint information specified in the SrcEndpoint parameter. If no bound devices are found, the APSDE issues the APSDE-DATA.confirm primitive with a status of NO_BOUND_DEVICE. If one or more bound devices were found, the APSDE constructs the ASDU with the destination address and endpoint information of the bound device and transmits the frame by issuing the NLDE-DATA.request primitive to the NWK layer. On receipt of the corresponding NLDE-DATA.confirm, the APSDE constructs and transmits the APDU for the next bound device, as described above; until no more bound devices remain. On receipt of the initial request, the APSDE issues the APSDE-DATA.confirm primitive with a status of SUCCESS to the originator indicating that the message will be reflected to each bound device indicated in the binding table.[7]

If the APDU is to be transmitted using indirect addressing and a non-ZigBee coordinator or ZigBee router device received this primitive, the APSDE constructs the ASDU, without a destination endpoint field, and issues the NLDE-DATA.request primitive to the NWK layer. On receipt of the NLDE-DATA.confirm primitive, the APSDE issues the APSDE-DATA.confirm primitive with a status equal to that received from the NWK layer.

1.2.4.1.2 APSDE-DATA.confirm

If the TxOptions parameter specifies that secured transmission is required, the ASL sub-layer shall use the security service provider (see sub-clause 3.2.4) to secure the ASDU. If the security processing fails, the APSDE shall issue the APSDE-DATA.confirm primitive with a status of SECURITY_FAIL.APSDE-DATA.confirm

This primitive reports the results of a request to transfer a data PDU (ASDU) from a local NHLE to a single peer NHLE.

[6]CCB Comment #256

[7]CCB Comment #173, 214, 254

1.2.4.1.2.1 Semantics of the service primitive

This semantics of this primitive are as follows:

APSDE-DATA.confirm	(DstAddrMode, DstAddress, DstEndpoint, SrcEndpoint, Status)

Table 3 specifies the parameters for the APSDE-DATA.confirm primitive.

Table 3 APSDE-DATA.confirm parameters

Name	Type	Valid range	Description
DstAddrMode	Integer	0x00 – 0xff	The addressing mode for the destination address used in this primitive and of the APDU to be transferred. This parameter can take one of the non-reserved values from the following list: 0x00 = DstAddress and DstEndpoint not present. 0x01 = 16 bit short address for DstAddress and DstEndpoint present. 0x02 = 64 bit extended address for DstAddress and DstEndpoint present. 0x03 – 0xff = reserved.
DstAddress	Device address	As specified by the DstAddrMode parameter.	The individual device address of the entity to which the ASDU is being transferred.
DstEndpoint	Integer	0x00 – 0xff	The individual endpoint of the entity to which the ASDU is being transferred.
SrcEndpoint	Integer	0x00 – 0xfe	The individual endpoint of the entity from which the ASDU is being transferred.
Status	Enumeration	SUCCESS, NO_BOUND_DEVICE, SECURITY_FAIL or any status values returned from the NLDE-DATA.confirm primitive.	The status of the corresponding request.

1.2.4.1.2.2 When generated

This primitive is generated by the local APS sub-layer entity in response to an APSDE-DATA.request primitive. This primitive returns a status of either SUCCESS, indicating that the request to transmit was successful, or an error code of NO_BOUND_DEVICE or SECURITY_FAIL or any status values returned from the NLDE-DATA.confirm primitive. The reasons for these status values are fully described in the next section.

1.2.4.1.2.3 Effect on receipt

On receipt of this primitive the next higher layer of the initiating device is notified of the result of its request to transmit. If the transmission attempt was successful, the status parameter will be set to SUCCESS. Otherwise, the status parameter will indicate the error.

1.2.4.1.3 APSDE-DATA.indication

This primitive indicates the transfer of a data PDU (ASDU) from the APS sub-layer to the local application entity.

1.2.4.1.3.1 Semantics of the service primitive

This semantics of this primitive are as follows:

APSDE-DATA.indication	(DstEndpoint, SrcAddrMode, SrcAddress, SrcEndpoint, ProfileId,[a] ClusterId, asduLength, asdu, WasBroadcast, SecurityStatus)

[a]CCB Comment #208

Table 4 specifies the parameters for the APSDE-DATA.indication primitive.

Table 4 APSDE-DATA.indication parameters

Name	Type	Valid range	Description
DstEndpoint	Integer	0x00 – 0xff	The target endpoint on the local entity to which the ASDU is being transferred.
SrcAddrMode	Integer	0x00 – 0xff	The addressing mode for the source address used in this primitive and of the APDU to be transferred. This parameter can take one of the non-reserved values from the following list: 0x00 = SrcAddress and SrcEndpoint not present. 0x01 = 16 bit short address for SrcAddress and SrcEndpoint present. 0x02 = 64 bit extended address for SrcAddress and SrcEndpoint present. 0x03 – 0xff = reserved.
SrcAddress	Device address	As specified by the SrcAddrMode parameter.	The individual device address of the entity from which the ASDU is being transferred.
SrcEndpoint	Integer	0x00 – 0xfe	The source endpoint from which the ASDU is being transferred.

Table 4 APSDE-DATA.indication parameters

ProfileId	Integer	0x0000 - 0xffff	The identifier of the profile from which this frame originated.[a]
ClusterId	Integer	0x00-0xff	The identifier of the received object.
asduLength	Integer	[b]	The number of octets comprising the ASDU being indicated by the APSDE.
asdu	Set of octets	-	The set of octets comprising the ASDU being indicated by the APSDE.
WasBroadcast	Boolean	TRUE or FALSE	TRUE if the transmission was a broadcast, FALSE otherwise.
SecurityStatus	Enumeration	UNSECURED, SECURED_NWK_KEY, SECURED_LINK_KEY	UNSECURED if the ASDU was received without any security. SECURED_NWK_KEY if the received. ASDU was secured with the NWK key. SECURED_LINK_KEY if the ASDU was secured with a link key.

[a]CCB Comment #208
[b]CCB Comment #336

1.2.4.1.3.2 When generated

This primitive is generated by the APS sub-layer and issued to the next higher layer on receipt of an appropriately addressed data frame from the local NWK layer entity. If the frame control field of the ASDU header indicates that the frame is secured, then security processing shall be done as specified in sub-clause 3.2.4.

1.2.4.1.3.3 Effect on receipt

On receipt of this primitive the next higher layer is notified of the arrival of data at the device.

1.2.4.2 APS management service

The APS management entity SAP (APSME-SAP) supports the transport of management commands between the next higher layer and the APSME. Table 5 summarizes the primitives supported by the APSME through the APSME-SAP interface. See the following sub-clauses for more details on the individual primitives.

Table 5 Summary of the primitives accessed through the APSME-SAP

Name	Request	Indication	Response	Confirm
APSME-BIND	1.2.4.3.1		1.2.4.3.2	
APSME-GET	1.2.4.4.1		1.2.4.4.2	
APSME-SET	1.2.4.4.3		1.2.4.4.4	
APSME-UNBIND	1.2.4.3.3		1.2.4.3.4	

1.2.4.3 Binding Primitives

This set of primitives defines how the next higher layer of a device can add (commit) a binding record to its local binding table or remove a binding record from its local binding table.[8]

1.2.4.3.1 APSME-BIND.request

This primitive allows the next higher layer to request to bind two devices together if issued on a ZigBee coordinator or on the device indicated by the SrcAddr of the request.[9]

1.2.4.3.1.1 Semantics of the service primitive

The semantics of this primitive are as follows:

APSME-BIND.request	(SrcAddr, SrcEndpoint, ClusterId, DstAddr, DstEndpoint)

Table 6 specifies the parameters for the APSME-BIND.request primitive.

Table 6 APSME-BIND.request parameters

Name	Type	Valid range	Description
SrcAddr	IEEE address	A valid 64-bit IEEE address	The source IEEE address for the binding entry.
SrcEndpoint	Integer	0x01 – 0xff	The source endpoint for the binding entry.
ClusterId	Integer	0x00 – 0xff	The identifier of the cluster on the source device that is to be bound to the destination device.
DstAddr	IEEE address	A valid 64-bit IEEE address	The destination IEEE address for the binding entry.
DstEndpoint	Integer	0x01 – 0xff	The destination endpoint for the binding entry.

1.2.4.3.1.2 When generated

This primitive is generated by the next higher layer and issued to the APS sub-layer in order to instigate a binding operation on a ZigBee coordinator or on the device indicated by the SrcAddr of the request.[10]

1.2.4.3.1.3 Effect on receipt

If the APS on a ZigBee coordinator or the device indicated by the SrcAddr of the request receives this primitive from the NHLE, the APSME attempts to create the specified entry directly in its binding table. If the entry could be created, the APSME issues the APSME-BIND.confirm primitive with the Status

[8] CCB Comment #172
[9] CCB Comment #173
[10] CCB Comment #173

parameter set to SUCCESS. If the entry could not be created due to a lack of capacity in the binding table, the APSME issues the APSME-BIND.confirm primitive with the Status parameter set to TABLE_FULL.[11]

1.2.4.3.2 APSME-BIND.confirm

This primitive allows the next higher layer to be notified of the results of its request to bind two devices directly or by proxy.

1.2.4.3.2.1 Semantics of the service primitive

The semantics of this primitive are as follows:

```
APSME-BIND.confirm      (
                        Status,
                        SrcAddr,
                        SrcEndpoint,
                        ClusterId,
                        DstAddr,
                        DstEndpoint
                        )
```

Table 7 specifies the parameters for the APSME-BIND.confirm primitive.

Table 7 APSME-BIND.confirm parameters

Name	Type	Valid range	Description
Status	Enumeration	SUCCESS, ILLEGAL_DEVICE, ILLEGAL_REQUEST, TABLE_FULL, NOT_SUPPORTED	The results of the binding request.
SrcAddr	IEEE address	A valid 64-bit IEEE address	The source IEEE address for the binding entry.
SrcEndpoint	Integer	0x01 – 0xff	The source endpoint for the binding entry.
ClusterId	Integer	0x00 – 0xff	The identifier of the cluster on the source device that is to be bound to the destination device.
DstAddr	IEEE address	A valid 64-bit IEEE address	The destination IEEE address for the binding entry.
DstEndpoint	Integer	0x01 – 0xff	The destination endpoint for the binding entry.

1.2.4.3.2.2 When generated

This primitive is generated by the APSME and issued to its NHLE in response to an APSME-BIND.request primitive. If the request was successful, the Status parameter will indicate a successful bind request. Otherwise, the status parameter indicates an error code of ILLEGAL_DEVICE, ILLEGAL_REQUEST or TABLE_FULL.

[11] CCB Comment #173, 264

1.2.4.3.2.3 Effect on receipt

On receipt of this primitive, the next higher layer is notified of the results of its bind request. If the bind request was successful, the Status parameter is set to SUCCESS. Otherwise, the Status parameter indicates the error.

1.2.4.3.3 APSME-UNBIND.request

This primitive allows the next higher layer on a ZigBee coordinator or on the device indicated by the SrcAddr of the request to request the unbinding of two devices.[12]

1.2.4.3.3.1 Semantics of the service primitive

The semantics of this primitive are as follows:

APSME-UNBIND.request	(SrcAddr, SrcEndpoint, ClusterId, DstAddr, DstEndpoint)

Table 8 specifies the parameters for the APSME-UNBIND.request primitive.

Table 8 APSME-UNBIND.request parameters

Name	Type	Valid range	Description
SrcAddr	IEEE address	A valid 64-bit IEEE address	The source IEEE address for the binding entry.
SrcEndpoint	Integer	0x01 – 0xff	The source endpoint for the binding entry.
ClusterId	Integer	0x00 – 0xff	The identifier of the cluster on the source device that is bound to the destination device.
DstAddr	IEEE address	A valid 64-bit IEEE address	The destination IEEE address for the binding entry.
DstEndpoint	Integer	0x01 – 0xff	The destination endpoint for the binding entry.

1.2.4.3.3.2 When generated

This primitive is generated by the next higher layer and issued to the APS sub-layer in order to instigate an unbind operation on a ZigBee coordinator or on the device indicated by the SrcAddr of the request.[13]

1.2.4.3.3.3 Effect on receipt

On receipt of this primitive by a device that is not currently joined to a network, the APSME issues the APSME-UNBIND.confirm primitive with the Status parameter set to ILLEGAL_REQUEST.

[12]CCB Comment #173
[13]CCB Comment #173

If the APS on a ZigBee coordinator or the device indicated by the SrcAddr of the request receives this primitive from the NHLE, the APSME searches for the specified entry in its binding table. If the entry exists, the APSME removes the entry and issues the APSME-UNBIND.confirm (see sub-clause 1.2.4.3.4) primitive with the Status parameter set to SUCCESS. If the entry could not be found, the APSME issues the APSME-UNBIND.confirm primitive with the Status parameter set to INVALID_BINDING. If the devices do not exist on the network, the APSME issues the APSME-BIND.confirm primitive with the Status parameter set to ILLEGAL_DEVICE.[14]

1.2.4.3.4 APSME-UNBIND.confirm

This primitive allows the next higher layer to be notified of the results of its request to unbind two devices directly or by proxy.

1.2.4.3.4.1 Semantics of the service primitive

The semantics of this primitive are as follows:

```
APSME-UNBIND.confirm    (
                        Status,
                        SrcAddr,
                        SrcEndpoint,
                        ClusterId,
                        DstAddr,
                        DstEndpoint
                        )
```

Table 9 specifies the parameters for the APSME-UNBIND.confirm primitive.

Table 9 APSME-UNBIND.confirm parameters

Name	Type	Valid range	Description
Status	Enumeration	SUCCESS, ILLEGAL_DEVICE, ILLEGAL_REQUEST, INVALID_BINDING	The results of the unbind request.
SrcAddr	IEEE address	A valid 64-bit IEEE address	The source IEEE address for the binding entry.
SrcEndpoint	Integer	0x01 – 0xff	The source endpoint for the binding entry.
ClusterId	Integer	0x00 – 0xff	The identifier of the cluster on the source device that is bound to the destination device.
DstAddr	IEEE address	A valid 64-bit IEEE address	The destination IEEE address for the binding entry.
DstEndpoint	Integer	0x01 – 0xff	The destination endpoint for the binding entry.

1.2.4.3.4.2 When generated

This primitive is generated by the APSME and issued to its NHLE in response to an APSME-UNBIND.request primitive. If the request was successful, the Status parameter will indicate a successful

[14] CCB Comment #173

unbind request. Otherwise, the status parameter indicates an error code of ILLEGAL_DEVICE, ILLEGAL_REQUEST, or INVALID_BINDING.

1.2.4.3.4.3 Effect on receipt

On receipt of this primitive, the next higher layer is notified of the results of its unbind request. If the unbind request was successful, the Status parameter is set to SUCCESS. Otherwise, the Status parameter indicates the error.

1.2.4.4 Information base maintenance

This set of primitives defines how the next higher layer of a device can read and write attributes in the AIB.

1.2.4.4.1 APSME-GET.request

This primitive allows the next higher layer to read the value of an attribute from the AIB.

1.2.4.4.1.1 Semantics of the service primitive

The semantics of this primitive is as follows:

APSME-GET.request	(AIBAttribute)

Table 10 specifies the parameters for this primitive.

Table 10 APSME-GET.request parameters

Name	Type	Valid Range	Description
AIBAttribute	Integer	See Table 17	The identifier of the AIB attribute to read.

1.2.4.4.1.2 When generated

This primitive is generated by the next higher layer and issued to its APSME in order to read an attribute from the AIB.

1.2.4.4.1.3 Effect on receipt

On receipt of this primitive, the APSME attempts to retrieve the requested AIB attribute from its database. If the identifier of the AIB attribute is not found in the database, the APSME issues the APSME-GET.confirm primitive with a status of UNSUPPORTED_ATTRIBUTE.

If the requested AIB attribute is successfully retrieved, the APSME issues the APSME-GET.confirm primitive with a status of SUCCESS such that it contains the AIB attribute identifier and value.

1.2.4.4.2 APSME-GET.confirm

This primitive reports the results of an attempt to read the value of an attribute from the AIB.

1.2.4.4.2.1 Semantics of the service primitive

The semantics of this primitive is as follows:

APSME-GET.confirm	(Status, AIBAttribute, AIBAttributeValue)

Table 11 specifies the parameters for this primitive.

Table 11 APSME-GET.confirm parameters

Name	Type	Valid Range	Description
Status	Enumeration	SUCCESS or UNSUPPORTED_ATTRIBUTE	The results of the request to read an AIB attribute value.
AIBAttribute	Integer	See Table 17.	The identifier of the AIB attribute that was read.
AIBAttributeValue	Various	Attribute Specific (see Table 17).	The value of the AIB attribute that was read.

1.2.4.4.2.2 When generated

This primitive is generated by the APSME and issued to its next higher layer in response to an APSME-GET.request primitive. This primitive returns a status of SUCCESS, indicating that the request to read an AIB attribute was successful, or an error code of UNSUPPORTED_ATTRIBUTE. The reasons for these status values are fully described in sub-clause 1.2.4.4.1.3.

1.2.4.4.2.3 Effect on receipt

On receipt of this primitive, the next higher layer is notified of the results of its request to read an AIB attribute. If the request to read an AIB attribute was successful, the Status parameter will be set to SUCCESS. Otherwise, the status parameter indicates the error.

1.2.4.4.3 APSME-SET.request

This primitive allows the next higher layer to write the value of an attribute into the AIB.

1.2.4.4.3.1 Semantics of the service primitive

The semantics of this primitive is as follows:

APSME-SET.request	(AIBAttribute, AIBAttributeValue)

Table 12 specifies the parameters for this primitive.

Table 12 APSME-SET.request parameters

Name	Type	Valid Range	Description
AIBAttribute	Integer	See Table 17.	The identifier of the AIB attribute to be written.
AIBAttributeValue	Various	Attribute Specific (see Table 17).	The value of the AIB attribute that should be written.

1.2.4.4.3.2 When generated

This primitive is to be generated by the next higher layer and issued to its APSME in order to write the value of an attribute in the AIB.

1.2.4.4.3.3 Effect on receipt

On receipt of this primitive the APSME attempts to write the given value to the indicated AIB attribute in its database. If the AIBAttribute parameter specifies an attribute that is not found in the database, the APSME issues the APSME-SET.confirm primitive with a status of UNSUPPORTED_ATTRIBUTE. If the AIBAttributeValue parameter specifies a value that is out of the valid range for the given attribute, the APSME issues the APSME-SET.confirm primitive with a status of INVALID_PARAMETER.

If the requested AIB attribute is successfully written, the APSME issues the APSME-SET.confirm primitive with a status of SUCCESS.

1.2.4.4.4 APSME-SET.confirm

This primitive reports the results of an attempt to write a value to an AIB attribute.

1.2.4.4.4.1 Semantics of the service primitive

The semantics of this primitive is as follows:

```
APSME-SET.confirm       (
                        Status,
                        AIBAttribute
                        )
```

Table 13 specifies the parameters for this primitive.

Table 13 APSME-SET.confirm parameters

Name	Type	Valid Range	Description
Status	Enumeration	SUCCESS, INVALID_PARAMETER or UNSUPPORTED_ATTRIBUTE	The result of the request to write the AIB Attribute.
AIBAttribute	Integer	See Table 17.	The identifier of the AIB attribute that was written.

1.2.4.4.4.2 When generated

This primitive is generated by the APSME and issued to its next higher layer in response to an APSME-SET.request primitive. This primitive returns a status of either SUCCESS, indicating that the requested

value was written to the indicated AIB attribute, or an error code of INVALID_PARAMETER or UNSUPPORTED_ATTRIBUTE. The reasons for these status values are fully described in sub-clause 1.2.4.4.3.3.

1.2.4.4.4.3 Effect on receipt

On receipt of this primitive, the next higher layer is notified of the results of its request to write the value of a AIB attribute. If the requested value was written to the indicated AIB attribute, the Status parameter will be set to SUCCESS. Otherwise, the Status parameter indicates the error.

1.2.5 Frame formats

This sub-clause specifies the format of the APS frame (APDU). Each APS frame consists of the following basic components:

— An APS header, which comprises frame control and addressing information.

— An APS payload, of variable length, which contains information specific to the frame type.

The frames in the APS sub-layer are described as a sequence of fields in a specific order. All frame formats in this sub-clause are depicted in the order in which they are transmitted by the NWK layer, from left to right, where the leftmost bit is transmitted first in time. Bits within each field are numbered from 0 (leftmost and least significant) to k-1 (rightmost and most significant), where the length of the field is k bits. Fields that are longer than a single octet are sent to the NWK layer in the order from the octet containing the lowest numbered bits to the octet containing the highest numbered bits.

1.2.5.1 General APDU frame format

The APS frame format is composed of an APS header and an APS payload. The fields of the APS header appear in a fixed order, however, the addressing fields may not be included in all frames. The general APS frame shall be formatted as illustrated in Figure 5.

<table>
<tr><th>Octets: 1</th><th>0/1</th><th>0/1</th><th>0/2</th><th>0/1</th><th>Variable</th></tr>
<tr><td rowspan="2">Frame control</td><td>Destination end-point</td><td>Cluster Identifier</td><td>Profile Identifier</td><td>Source endpoint</td><td rowspan="2">Frame payload</td></tr>
<tr><td colspan="4">Addressing fields</td></tr>
<tr><td colspan="5">APS header</td><td>APS payload</td></tr>
</table>

Figure 5 General APS frame format

1.2.5.1.1 Frame control Field

The frame control field is 8-bits in length and contains information defining the frame type, addressing fields and other control flags. The frame control field shall be formatted as illustrated in Figure 6.

Bits: 0-1	2-3	4	5	6	7
Frame type	Delivery mode	Indirect address mode[a]	Security	Ack. request	Reserved

[a]CCB Comment #210

Figure 6 Format of the frame control field

1.2.5.1.1.1 Frame type sub-field

The frame type sub-field is two bits in length and shall be set to one of the non-reserved values listed in Table 14.

Table 14 Values of the frame type sub-field

Frame type value b_1 b_0	Frame type name
00	Data
01	Command
10	Acknowledgement
11	Reserved

1.2.5.1.1.2 Delivery mode sub-field

The delivery mode sub-field is two bits in length and shall be set to one of the non-reserved values from Table 15.

Table 15 Values of the delivery mode sub-field

Delivery mode value b_3 b_2	Delivery mode name
00	Normal unicast delivery
01	Indirect addressing
10	Broadcast
11	Reserved

If the value is 0b01 then indirect addressing is in use and either the destination or source endpoint shall be omitted, depending on the value of the indirect address mode sub-field. If the value is 0b10 then the message is a broadcast. In this case the message will go to all devices and all endpoints.[15]

1.2.5.1.1.3 Indirect address mode sub-field

The indirect address mode sub-field is one bit in length and specifies whether the source or destination endpoint fields are present in the frame when the delivery mode sub-field is set to indicate indirect addressing. If this sub-field is set to 1, the destination endpoint field shall be omitted from the frame, indicating an indirect transmission to the ZigBee coordinator. If this sub-field is set to 0, the source endpoint field shall be omitted from the frame, indicating an indirect transmission from the ZigBee coordinator. If the delivery mode sub-field of the frame control field does not indicate indirect addressing, the indirect address mode sub-field shall be ignored.[16]

1.2.5.1.1.4 Security sub-field

The Security Services Provider (see Chapter 3) manages the security sub-field.

[15]CCB Comment #165. 210
[16]CCB Comment #210

1.2.5.1.1.5 Acknowledgement request sub-field

The acknowledgement request sub-field is one bit in length and specifies whether the current transmission requires an acknowledgement frame to be sent be the recipient on receipt of the frame. If this sub-field is set to 1, the recipient shall construct and send an acknowledgement frame back to the originator after determining that the frame is valid. If this sub-field is set to 0, the recipient shall not send an acknowledgement frame back to the originator after determining that the frame is valid.

1.2.5.1.2 Destination endpoint field

The destination endpoint field is 8-bits in length and specifies the endpoint of the final recipient of the frame. A destination endpoint value of 0x00 addresses the frame to the ZigBee device object (ZDO), resident in each device. A destination endpoint value of 0x01-0xf0 addresses the frame to an application operating on that endpoint. A destination endpoint value of 0xff addresses the frame to all active endpoints. All other endpoints (0xf1-0xfe) are reserved.

1.2.5.1.3 Cluster identifier field

The cluster identifier field is 8-bits in length and specifies the identifier of the cluster that is to be used in the binding operation on the ZigBee coordinator or on the device indicated by the SrcAddr of the request. The frame type sub-field of the frame control field specifies whether the cluster identifier field is present or not. It will be for data frames, but not for command frames.[17]

1.2.5.1.4 Profile identifier field

The profile identifier is 2 octets in length and specifies the ZigBee profile identifier for which the frame is intended and shall be used during the filtering of messages at each device that takes delivery of the frame. This field shall be present only for data or acknowledgement frames.[18]

1.2.5.1.5 Source endpoint field

The source endpoint field is 8-bits in length and specifies the endpoint of the initial originator of the frame. A source endpoint value of 0x00 indicates that the frame originated from the ZigBee device object (ZDO) resident in each device. A source endpoint value of 0x01-0xf0 indicates that the frame originated from an application operating on that endpoint. All other endpoints (0xf1-0xfe) are reserved.

If the delivery mode sub-field of the frame control field indicates a delivery mode of indirect addressing and the indirect address mode sub-field is set to 0, this field shall not be included in the frame[19]

1.2.5.1.6 Frame payload field

The frame payload field has a variable length and contains information specific to individual frame types.

1.2.5.2 Format of individual frame types

There are three defined frame types: data, APS command and acknowledgement. Each of these frame types is discussed in the following sub-clauses.[20]

[17]CCB Comment #173
[18]CCB Comment #186 208
[19]CCB Comment #165, 210
[20]CCB Comment #230

1.2.5.2.1 Data frame format

The data frame shall be formatted as illustrated in Figure 7.

Octets: 1	0/1	1	2[a]	0/[b]1	Variable
Frame control	Destination end-point	Cluster identifier	Profile identifier	Source endpoint	Data payload
APS header					APS payload

[a]CCB Comment #186, 208
[b]CCB Comment #188

Figure 7 Data frame format

The order of the fields of the data frame shall conform to the order of the general APS frame as illustrated in Figure 3.[21]

1.2.5.2.1.1 Data frame APS header field

The APS header field for a data frame shall contain the frame control, cluster identifier, profile identifier and source endpoint fields. The destination endpoint field shall be included in a data frame according to the value of the delivery mode sub-field of the frame control field.[22]

In the frame control field, the frame type sub-field shall contain the value that indicates a data frame, as shown in Table 14. The source endpoint present sub-field shall be set to 1. All other sub-fields shall be set appropriately according to the intended use of the data frame.

1.2.5.2.1.2 Data payload field

For an outgoing data frame, the data payload field shall contain the sequence of octets that the next higher layer has requested the APS data service to transmit. For an incoming data frame, the data payload field shall contain the sequence of octets that has been received by the APS data service and that is to be reflected to the destination devices or delivered to the next higher layer if the coordinator is one of the destinations.

1.2.5.2.2 APS command frame format

The APS command frame shall be formatted as illustrated in Figure 8.

Octets: 1	1	Variable
Frame control	APS command identifier	APS command payload
APS header	APS payload	

Figure 8 APS command frame format

The order of the fields of the APS command frame shall conform to the order of the general APS frame as illustrated in Figure 5.

[21]CCB Comment #186, 208
[22]ibid

1.2.5.2.2.1 APS command frame APS header field

The APS header field for an APS command frame shall contain the frame control and an APS Payload. The APS Payload portion of the APS Command Frame shall contain the APS Command Identifier followed by the APS Command Payload.

In the frame control field, the frame type sub-field shall contain the value that indicates an APS command frame, as shown in Table 14. The APS Command Payload shall be set appropriately according to the intended use of the APS command frame.

1.2.5.2.2.2 APS command identifier field

The APS command identifier field identifies the APS command being used.

1.2.5.2.2.3 APS command payload field

The APS command payload field of an APS command frame shall contain the APS command itself.

1.2.5.2.3 Acknowledgement frame format

The acknowledgement frame shall be formatted as illustrated in Figure 9.

Octets: 1	0/1	1	2	0/[a]1
Frame control	Destination endpoint	Cluster Id	Profile identi-fier[b]	Source endpoint
APS header				

[a]CCb Comment #165
[b]CCB Comment #186, 208

Figure 9 Acknowledgement frame format

The order of the fields of the acknowledgement frame shall conform to the order of the general APS frame as illustrated in Figure 5.[23]

1.2.5.2.3.1 Acknowledgement frame APS header field

The APS header field for an acknowledgement frame shall contain the frame control, cluster identifier and profile identifier fields. If the delivery mode indicates direct addressing both the source and destination endpoint fields shall be included in an acknowledgement frame. If the delivery mode indicates indirect addressing the source and destination endpoint fields shall be included in an acknowledgement frame according to the value of the indirect address mode sub-field of the frame control field.

In the frame control field, the frame type sub-field shall contain the value that indicates an acknowledgement frame, as shown in Table 14. All other sub-fielsds shall be set appropriately according to the intended use of the acknowledgement frame.

Where present, the source endpoint field shall reflect the value in the destination endpoint field of the frame that is being acknowledged. Similarly, where present, the destination endpoint field shall reflect the value in the source endpoint field of the frame that is being acknowledged.[24]

[23]CCB Comment #186, 208
[24]CCB Comment #165, 186, 208

1.2.6 Command frames

This specification defines no command frames. Refer to sub-clause 3.5.9 for a thorough description of the APS command frames and primitives related to security.

1.2.7 Constants and PIB attributes

1.2.7.1 APS Constants

The constants that define the characteristics of the APS sub-layer are presented in Table 16.

Table 16 APS sub-layer constants

Constant	Description	Value
apscMaxAddrMapEntries	The maximum number of Address Map entries.	1 (minimum value) Implementation-specific (maximum value)
apscMaxDescriptorSize	The maximum number of octets contained in a non-complex descriptor.	64
apscMaxDiscoverySize	The maximum number of octets that can be returned through the discovery process.	64
apscMaxFrameOverhead	The maximum number of octets added by the APS sub-layer to its payload.	6 (without security) 20 (with security)
apscMaxFrameRetries	The maximum number of retries allowed after a transmission failure.	3
apscAckWaitDuration	The maximum number of seconds to wait for an acknowledgement to a transmitted frame.	0.05 * (2**nwkcMaxDepth*) + (security encrypt/decrypt delay), where the (security encrypt/decrypt delay) = 0.1 (assume 0.05 per encrypt or decrypt cycle)[a]

[a]CCB Comment #166, #366

1.2.7.2 APS Information Base

The APS information base comprises the attributes required to manage the APS layer of a device. The attribtues of the AIB are listed in Table 17. The AIB also comprises of some additional attributes that are required to manage the security service provider. These attributes are listed in sub-clause 3.5.10.

Table 17 APS IB attributes

Attribute	Identifier	Type	Range	Description	Default
apsAddressMap	0xc0[a]	Set	Variable	The current set of 64 bit IEEE to 16 bit NWK address maps (see Table 18).	Null set
apsBindingTable[b]	0xc1	Set	Variable	The current set of binding table entries in the device (see sub-clause 1.2.8.1.1).	Null set

[a]CCB Comment #150
[b]CCB Comment #248

Table 18 Address Map

Entry Number	64 bit IEEE address	16 bit NWK address
0x00 - *apscMaxAddrMap-Entries*	0x00000000 – 0xffffffff	0x0000 – 0xffff

1.2.8 Functional description

1.2.8.1 Binding

The APS may maintain a binding table, which allows ZigBee devices to establish a designated destination for frames from a given source endpoint and with a given cluster ID. This table is employed by the indirect addressing mechanism.

1.2.8.1.1 Binding table implementation

A ZigBee coordinator or a device designated by as and containing a binding table shall be able to support a binding table of implementation specific length. The binding table shall implement the following mapping:

$$(a_s, e_s, c_s) = \{(a_{d1}, e_{d1}), (a_{d2}, e_{d2}) \ldots (a_{dn}, e_{dn})\}^{25}$$

Where:

a_s = the address of the device as the source of the binding link,

e_s = the endpoint identifier of the device as the source of the binding link,

[25]CCB Comment #173

c_s	= the cluster identifier used in the binding link,
a_{di}	= the i^{th} address of the device as the destination of the binding link,
e_{di}	= the i^{th} endpoint identifier of the device as the destination of the binding link

1.2.8.1.2 Binding

The APSME-BIND.request or APSME-UNBIND.request primitive executed on the ZigBee coordinator on the device designated by the SrcAddr initiates the procedure for creating or removing a binding link. Only those devices that are ZigBee coordinator capable and currently operating as the ZigBee coordinator or are the device indicated by the SrcAddr in the request shall initiate this procedure. If this procedure is initiated on any other device, the APSME shall terminate the procedure and notify the NHLE of the illegal request. This is achieved by issuing the APSME-BIND.confirm or APSME-UNBIND.confirm primitive with the Status parameter set to ILLEGAL_REQUEST.

When this procedure is initiated, the APSME of a ZigBee coordinator or the device designated by SrcAddr shall first extract the address and endpoint for both the source and destination of the binding link. With this information, the APSME shall either create a new entry or remove the corresponding entry from its binding table, depending on whether the bind or unbind procedure, respectively, was initiated.

If a bind operation was requested, the APSME shall create a new entry in the binding table. The ZigBee coordinator or device designated by the SrcAddr shall only create a new entry in the binding table if it has the capacity to do so. If capacity is not available, it shall terminate the procedure and notify the NHLE of the unavailable capacity. This is achieved by issuing the APSME-BIND.confirm primitive with the Status parameter set to TABLE_FULL.[26]

If an unbind operation was requested, the APSME shall search the binding table for an existing entry that matches the information contained in the initiation request. If an entry was not found, the APSME shall terminate the procedure and notify the NHLE of the invalid binding. This is achieved by issuing the APSME-UNBIND.confirm primitive with the Status parameter set to INVALID_BINDING. If an entry was found, the APSME shall remove the entry in the binding table.

If the binding link is successfully created or removed, the APSME shall notify the NHLE of the results of the direct binding attempt and the success of the procedure. This is achieved by issuing the APSME-BIND.confirm primitive with the binding results and the status parameter set to SUCCESS.

The procedure for a successful direct binding is illustrated in the MSC shown in Figure 10.

[26]CCB Comment #173

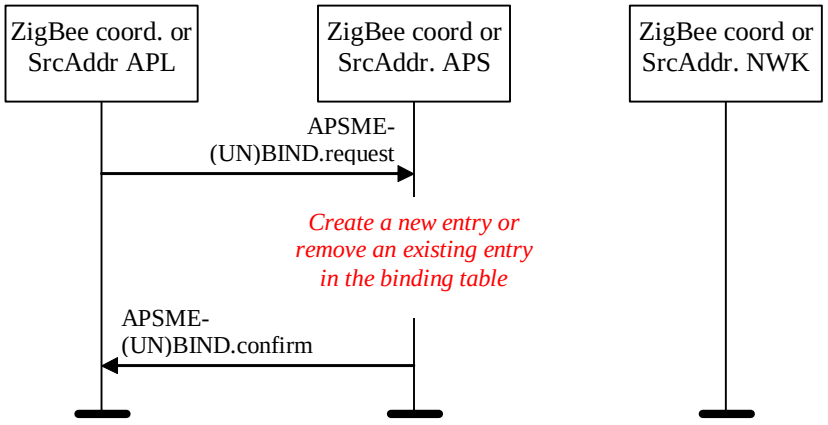

Figure 10 Direct binding on a ZigBee coordinator or SrcAddr device[27]

1.2.8.2 Transmission, reception and acknowledgement

This sub-clause describes the fundamental procedures for transmission, reception and acknowledgement

1.2.8.2.1 Transmission

Only those devices that are currently part of a network shall send frames from the APS sub-layer. If any other device receives a request to transmit a frame it shall discard the frame and notify the instigating layer of the error. An APSDE-DATA.confirm primitive with a status of CHANNEL_ACCESS_FAILURE indicates that the attempt at transmission of the frame was unsuccessful due to the channel being busy.

All frames handled by or generated within the APS sub-layer shall be constructed according to the general frame format specified in 6.1 and transmitted using the NWK layer data service[28]

Transmissions may be either direct or indirect. Direct transmissions shall include both destination and source endpoint fields. In this case, the delivery mode sub-field of the frame control field shall be set to either 0x00 (Normal Unicast) or 0x02 (Broadcast).

The APS layer of the device originating an indirect transmission where the binding table entry is stored at the ZigBee coordinator shall direct the transmission to the ZigBee coordinator, which shall handle the task of message reflection.

Indirect transmissions (i.e. those in which the delivery mode sub-field is set to 0b01) shall include only either the source endpoint field or the destination endpoint field, depending on the direction of transmission with respect to the ZigBee coordinator. If the indirect transmission is directed to the ZigBee coordinator, the indirect address mode sub-field shall be set to 1 and the destination endpoint field shall be omitted from the frame. Conversely, if the indirect transmission is directed from the ZigBee coordinator after message reflection, the indirect address mode sub-field shall be set to 0 and the source endpoint field shall be omitted from the frame.

For all devices where the binding table is stored on the source device, the APS layer of the source device originating the transmission shall employ direct transmission to the destination addresses indicated by the corresponding binding table entries. In this case, the delivery mode sub-field of the frame control field shall be set to 0x00.[29]

[27] ibid
[28] CCB Comment #208

The destination endpoint field, if present, shall contain the endpoint of the intended recipient of the APDU. The source endpoint field, if present, shall contain the endpoint of the originator of the APDU.

If security is required, then the frame shall be processed as described in clause 3.5.

When the frame is constructed and ready for transmission, it shall be passed to the NWK data service with a suitable destination and source address. An APDU transmission is initiated by issuing the NLDE-DATA.request primitive to the NWK layer and the results of the transmission returned via the NLDE-DATA.confirm primitive.

1.2.8.2.2 Reception and rejection

The APS sub-layer shall be able to filter frames arriving via the NWK layer data service and only present the frames that are of interest to the NHLE.

If the APSDE receives a secured frame, it shall process the frame as described in clause 3.5 to remove the security.

If the APSDE receives a frame containing both destination and source endpoints, it shall be assumed to be a direct transmission. In this case, the APSDE shall pass it directly to the NHLE.

If the APSDE of the ZigBee coordinator receives a frame containing only the source endpoint with the delivery mode sub-field of the frame control field set to the indirect addressing value (0x01) it shall be assumed to be an indirect transmission. If the device is not a ZigBee coordinator, the frame shall be discarded if the destination endpoint is not present and the delivery mode sub-field of the frame control field is set to the indirect addressing value (0x01).

If the APSDE of a ZigBee coordinator receives an indirect transmission, it shall search its binding table for an entry that matches the source address communicated from the NWK layer, the cluster identifier included in the received frame and the source endpoint included in the frame. If a match is not found, the frame shall be discarded. If a match is found, the APSDE shall build an APDU for each destination endpoint contained in the matching entry in the binding table. The APSDE shall then transmit each frame using the NWK data service.[30]

If the APSDE of a device receives a transmission, it shall pass it directly to the NHLE, unless it needs to be reflected.

1.2.8.2.3 Use of acknowledgements

A data or APS command frame shall be sent with its acknowledgement request sub-field set appropriately for the frame. An acknowledgement frame shall always be sent with the acknowledgement request sub-field set to 0. Similarly, any frame that is broadcast shall be sent with its acknowledgement request sub-field set to 0.

1.2.8.2.3.1 No acknowledgement

A frame that is received by its intended recipient with its acknowledgement request (AR) sub-field set to 0 shall not be acknowledged. The originating device shall assume that the transmission of the frame was successful. Figure 11 shows the scenario for transmitting a single frame of data from an originator to a recipient without requiring an acknowledgement. In this case, the originator transmits the data frame with the *AR* sub-field equal to 0.

[29]CCB Comment #173, 210
[30]CCB Comment #210

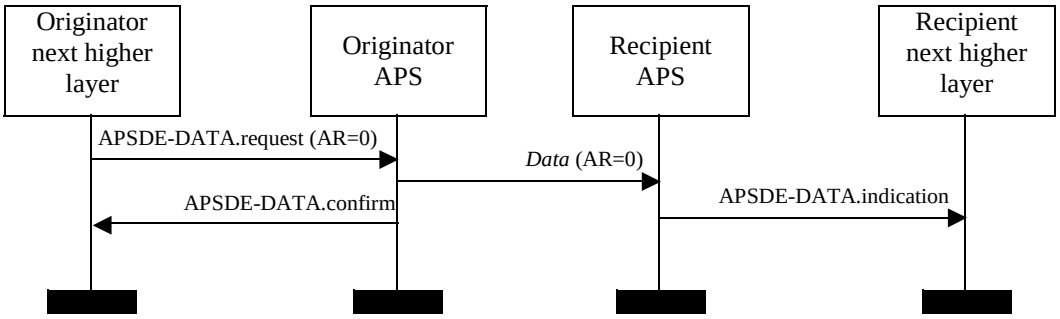

Figure 11 Successful data transmission without an acknowledgement

1.2.8.2.3.2 Acknowledgement

A frame that is received by its intended recipient with its acknowledgement request (AR) sub-field set to 1 shall be acknowledged. If the intended recipient correctly receives the frame, it shall generate and send an acknowledgement frame to the originator of the frame that is being acknowledged.

If the original transmission used indirect addressing, then the ZigBee coordinator shall send an acknowledgement to the originator, and then for each reflected message shall indicate to the recipient that it requires an acknowledgement by transmitting the data frame with the acknowledgement request sub-field of the frame control field set to 1.[31]

The transmission of an acknowledgement frame shall commence when the APS sub-layer determines that the frame is valid.

Figure 12 shows the scenario for transmitting a single frame of data from an originator to a recipient with an acknowledgement. In this case, the originator indicates to the recipient that it requires an acknowledgement by transmitting the data frame with the *AR* sub-field set to 1.

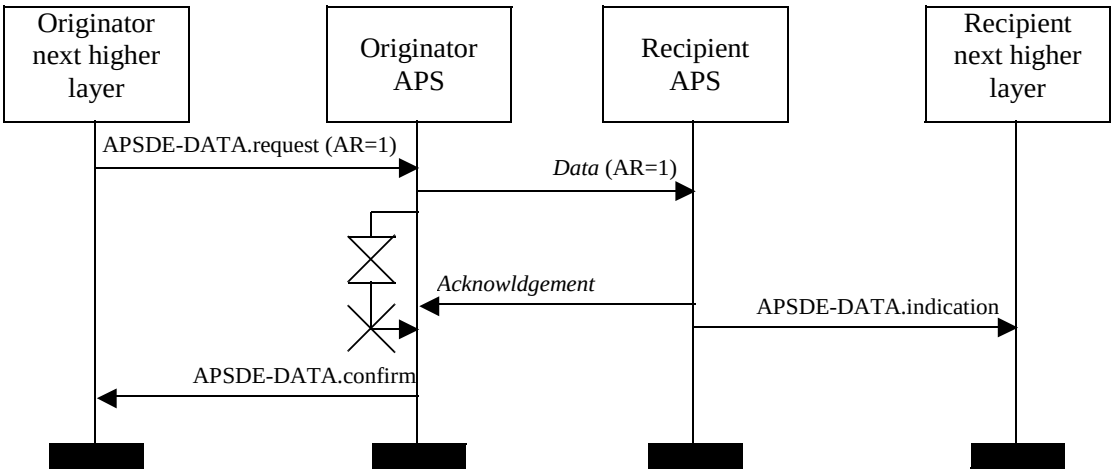

Figure 12 Successful data transmission with an acknowledgement

[31] CCB Comment #215

1.2.8.2.4 Retransmissions

A device that sends a frame with its acknowledgement request sub-field set to 0 shall assume that the transmission was successfully received and shall hence not perform the retransmission procedure.

A device that sends a frame with its acknowledgement request sub-field set to 1 shall wait for at most *apscAckWaitDuration* seconds for the corresponding acknowledgement frame to be received.

If an acknowledgement frame is received within *apscAckWaitDuration* seconds containing the same cluster identifier and has a source endpoint equal to the destination endpoint to which the original frame was transmitted, the transmission shall be considered successful and no further action shall be taken by the device. If an acknowledgement is not received within *apscAckWaitDuration* seconds or an acknowledgement is received within *apscAckWaitDuration* seconds but contains an unexpected cluster identifier or has a source endpoint that is not equal to the destination endpoint to which the original frame was transmitted, the device shall conclude that the single transmission attempt has failed.

If a single transmission attempt has failed, the device shall repeat the process of transmitting the frame and waiting for the acknowledgement, up to a maximum of *apscMaxFrameRetries* times. If an acknowledgement is still not received after *apscMaxFrameRetries* retransmissions, the APS sub-layer shall assume the transmission has failed and notify the next higher layer of the failure.

1.3 The ZigBee application framework

1.3.1 Creating a ZigBee profile

The key to communicating between devices on a ZigBee network is agreement on a profile.

An example of a profile would be home control lighting. This initial ZigBee profile permits a series of (initially) six device types to exchange control messages to form a wireless home automation application. These devices are architected to exchange well known messages (using the KVP service type) to effect control such as turning a lamp on or off, sending a light sensor measurement to a lighting controller or sending an alert message if an occupancy sensor detects movement.

Another example of a profile is the device profile that defines common actions between ZigBee devices. To illustrate, wireless networks rely on the ability for autonomous devices to join a network and discover other devices and services on devices within the network. Device and service discovery are features supported within the device profile using the MSG service type.

1.3.1.1 Getting a profile identifier from the ZigBee Alliance

ZigBee defines profiles in generally three separate classes: private, published and public. The exact definition and criteria for these classes are an administrative issue within the ZigBee Alliance and outside the scope of this document. For the purposes of this technical specification, the only criterion is for profile identifiers to be unique. To that end, every profile effort must start with a request to the ZigBee Alliance for allocation of a profile identifier. Once the profile identifier is obtained, that profile identifier permits the profile designer to define the following:

- Device descriptions
- Cluster identifiers
- Service types (KVP or MSG)

The application of profile identifiers to market space is a key criterion for issuance of a profile identifier from the ZigBee Alliance. The profile needs to cover a broad enough range of devices to permit

interoperability to occur between devices without being overly broad and resulting in a shortage of cluster identifiers to describe their interfaces. Conversely, the profile cannot be defined to be too narrow resulting in many devices described by individual profile identifiers resulting in a waste of the profile identifier addressing space and interoperability issues in describing how the devices are interfaced. Policy groups within the ZigBee Alliance will establish criteria on how profiles are to be defined and to help requestors tailor their profile identifier requests.

1.3.1.2 Defining device descriptions and clusters

The profile identifier is the main enumeration feature within the ZigBee protocol. Each unique profile identifier defines an associated enumeration of device descriptions and cluster identifiers. For example, for profile identifier “1”, there exists a pool of device descriptions described by a 16-bit value (meaning there are 65,536 possible device descriptions within each profile) and a pool of cluster identifiers described by an 8-bit value (meaning there are 256 possible cluster identifiers within each profile). For the KVP service type, each cluster identifier also supports a pool of attributes described by a 16-bit value (meaning, each profile identifier has 256 cluster identifiers and each of those cluster identifiers contains up to 65,536 attributes). It is the responsibility of the profile developer to define and allocate device descriptions, cluster identifiers and attributes within their allocated profile identifier. Note that the definition of device descriptions, cluster identifiers and attribute identifiers must be undertaken with care to ensure efficient creation of simple descriptors and simplified processing when exchanging messages.

Device descriptions and cluster identifiers must be accompanied by knowledge of the profile identifier to be processed. Prior to any messages being directed to a device, it is assumed by the ZigBee protocol that service discovery has been employed to determine profile support on devices and endpoints. Likewise, the binding process assumes similar service discovery and profile matching has occurred since the resulting match is distilled to source address, source endpoint, cluster identifier, destination address and destination endpoint.

1.3.1.3 Deploying the profile on endpoints

A single ZigBee device may contain support for many profiles, provide for subsets of various cluster identifiers defined within those profiles and may support multiple device descriptions. This capability is defined using a hierarchy of addressing within the device as follows:

— Device – the entire device is supported by a single radio with a unique IEEE and NWK address.

— Endpoints – this is an 8-bit field that describes different applications that are supported by a single radio. Endpoint 0x00 is used to address the device profile, which each ZigBee device must employ, endpoint 0xff is used to address all active endpoints (the broadcast endpoint) and endpoints 0xf1-0xfe are reserved. Consequently, a single physical ZigBee radio can support up to 240 applications on endpoints 0x01-0xf0.

It is an application decision as to how to deploy applications on a device endpoint and which endpoints to advertise. The only requirement is that simple descriptors be created for each endpoint and those descriptors made available for service discovery.

1.3.1.4 Enabling service discovery

Once a device is created to support specific profiles and made consistent with cluster identifier usage for device descriptions within those profiles, the applications can be deployed. To do this, each application is assigned to individual endpoints and each described using simple descriptors. It is via the simple descriptors and other service discovery mechanisms described in the ZigBee device profile that service discovery is enabled, binding of devices is supported and application messaging between complementary devices facilitated.

One important point is that service discovery is made on the basis of profile identifier, input cluster identifier list and output cluster identifier list (device description is notably missing). The device description is simply a convention for specifying mandatory and optional cluster identifier support within devices of that type for the indicated profile. Additionally, it is expected that the device description enumeration would be employed within PDAs or other assisted binding devices to provide external descriptions of device capabilities.

1.3.1.5 Mixing standard and proprietary profiles

As an example, a ZigBee device could be created with a single endpoint application written for a standard, published ZigBee profile identifier “XX”. If a manufacturer wanted to deploy a ZigBee device supporting the standard profile “XX” and also provide vendor specific extensions, these extensions would be advertised on a separate endpoint. Devices that support the standard profile identifier “XX” but not manufactured with the vendor extensions, would only advertise support for the single profile identifier “XX” and could not respond to or create messages using the vendor extensions.

1.3.1.6 Enabling backward compatibility

In the previous example, a device is created using a standard, published ZigBee profile identifier “XX” which contains the initial version of the standard profile. If the ZigBee Alliance were to update this standard profile to create new features and additions, the revisions would be incorporated into a new standard profile with a new profile identifier (say “XY”). Devices manufactured with just profile identifier “XX” would be backward compatible with newer devices manufactured later by having the newer devices advertise support for both profile identifier “XX” and profile identifier “XY”. In this manner, the newer device may communicate with older devices using profile identifier “XX”, however, also communicate with newer devices using profile identifier “XY” from within the same application. The service discovery feature within ZigBee enables devices on the network to determine the level of support.

1.3.2 Standard data type formats

ZigBee devices, such as thermostats, lamps, etc, are defined in terms of the attributes they contain, which can be written, read or reported using the set, get and event commands using the KVP service type or combined into application specific messages via the MSG service type. This section describes the data types and formats used for these attributes. Note that the individual device descriptions show valid values, ranges, and units for the attributes they represent.

ZigBee defines the standard data types listed in Table 19 and described in the following sub-clauses. In a KVP command frame, the attribute data type field (see sub-clause 1.3.4.5.1.2) shall contain the appropriate value of the data type identifier as listed in Table 19 that represents the data type of the attribute being referred to.

Table 19 ZigBee standard data types

Data type identifier $b_3b_2b_1b_0$	Data type	Length of data (octets)
0000	No data	0
0001	Unsigned 8-bit integer	1
0010	Signed 8-bit integer	1
0011	Unsigned 16-bit integer	2
0100	Signed 16-bit integer	2
0101 – 1010	Reserved	-
1011	Semi-precision	2

Table 19 ZigBee standard data types

1100	Absolute time	4
1101	Relative time	4
1110	Character string	Defined in first octet
1111	Octet string	Defined in first octet

1.3.2.1 No data type

The no data type is a special type to represent an attribute with no associated data.

1.3.2.2 Unsigned 8-bit integer

This is an unsigned 8-bit representation. The range is 0 - 255.

1.3.2.3 Signed 8-bit integer

This is an 8-bit twos complement representation. The range is –128 to +127.

1.3.2.4 Unsigned 16-bit integer

This is an unsigned 16-bit number. The range is 0 - 65535 and the minimum resolution is fixed at 1-bit.

1.3.2.5 Signed 16-bit integer

This is a 16-bit twos complement number. The range is – 32768 to + 32767 and the minimum resolution is fixed at 1-bit.

1.3.2.6 Semi-precision number

Some values, such as light level, have a very wide range. In this case, if the ambient light level is 1 Lux, the eye is very sensitive to an increase of light level by 1 Lux. However, if the ambient level is 100 Lux, an increase of 1 Lux is not noticeable. These values are best represented using the ZigBee semi-precision number, which allows the resolution to track the value being represented.

The ZigBee semi-precision number format is based on the IEEE 754 standard for binary floating-point arithmetic. This number format should be used very sparingly, when absolutely necessary, keeping in mind the code and processing required supporting it.

The value is calculated as:

$$\text{Value} = -1^{\text{Sign}} * (\text{Hidden} + \text{Mantissa}/1024) * 2^{(\text{Exponent}-15)}$$

	Sign	Exponent						Hidden		Mantissa									
	S	E_4	E_3	E_2	E_1	E_0		H	.	M_9	M_8	M_7	M_6	M_5	M_4	M_3	M_2	M_1	M_0
bit	15					10				9									0

Figure 13 – Format of the ZigBee semi-precision number

Note: The transmission order for the format in Figure 13 is bit 0 first.

For normalized numbers (>2^{-14}), the hidden bit = 1 and the resolution is constant at 11 bits (1 in 2048).

For un-normalized numbers, the hidden bit = 0. Note that this does not maintain 11-bit resolution and that the resolution becomes coarser as the number gets smaller.

The hidden bit is not sent over the link. It shall have the value '1' (i.e. normalized) in order to be classified as a ZigBee semi-precision number.

The sign bit is set to 0 for positive values, 1 for negative.

The exponent is 5 bits. The actual exponent of 2 is calculated as (exponent – 15).

Certain values are reserved for specific purposes:

— **Not a Number**: this is used for undefined values (e.g. at switch-on and before initialization) and is indicated by an exponent of 31 with a non-zero mantissa.

— **Infinity:** this is indicated by an exponent of 31 and a zero mantissa. The sign bit indicates whether this represents + infinity or – infinity, the figure of 0x7c00 representing + ∞ and 0xfc00 representing - ∞.

— **Zero:** this is indicated by both a zero exponent and zero mantissa. The sign bit indicates whether this is + or – zero, the value 0x0000 representing +zero and 0x8000 representing –zero.

— **Un-normalised numbers:** numbers <2^{-14} are indicated by a value of 0 for the exponent. The hidden bit is set to zero.

The maximum value represented by the mantissa is 0x3ff / 1024. The largest number that can be represented is therefore:

$$-1^{Sign} * (1 + 1023/1024) * 2^{(30-15)} = \pm 1.9990234 * 32768 = \pm 65504$$

Certain applications may choose to scale this value to allow representation of larger values (with a correspondingly more coarse resolution). For details, see the relevant device descriptions.

For example, a value of +2 is represented by $+2^{(16-15)} * 1.0$ = 0x4000, while a value of –2 is represented by 0xc000.

Similarly, a value of +0.625 is represented by $+2^{(17-15)} * 1.625$ = 0x4680, while –0.625 is represented by 0xc680.

1.3.2.7 Absolute time

This is an unsigned 32-bit integer representation for absolute time. Absolute time is measured in seconds from midnight, 1st January 2000.

1.3.2.8 Relative time

This is an unsigned 32-bit integer representation for relative time. Relative time is measured in milliseconds.

1.3.2.9 Character string

The character string data type contains data octets encoding characters according to the language and character set field of the complex descriptor. The character string data type shall be formatted as illustrated in Table 13.

Octets: 1	Variable
Character count	Character data

Figure 13 Format of the character string type

The character count sub-field is one octet in length and specifies the number of characters, encoded according to the language and character set field of the complex descriptor (see sub-clause 1.3.3.7.1), contained in the character data sub-field.

The character data sub-field is *e***n* octets in length, where *e* is the size of the character, as specified by the language and character set field of the complex descriptor, and *n* is the value of the character count sub-field. This sub-field contains the encoded characters that comprise the desired character string.

1.3.2.10 Octet string

The octet string data type contains data in an application-defined format, not defined in this specification. The octet string data type shall be formatted as illustrated in Figure 14.

Octets: 1	Variable
Octet count	Octet data

Figure 14 Format of the octet string type

The octet count sub-field is one octet in length and specifies the number of octets contained in the freeform data sub-field.

The octet data sub-field is *n* octets in length, where *n* is the value of the octet count sub-field. This sub-field contains the application-defined data.

1.3.3 ZigBee descriptors

ZigBee devices describe themselves using descriptor data structures. The actual data contained in these descriptors is defined in the individual device descriptions. There are five descriptors: node, node power, simple, complex and user, shown in Table 20.

Table 20 ZigBee descriptors

Descriptor name	Status	Description
Node	M	Type and capabilities of the node
Node power	M	Node power characteristics
Simple	M	Device descriptions contained in node
Complex	O	Further information about the device descriptions
User	O	User-definable descriptor

1.3.3.1 Transmission of descriptors

The node, node power, simple and user descriptors shall be transmitted in the order that they appear in their respective tables, i.e. the field at the top of the table is transmitted first and the field at the bottom of the table is transmitted last. Each individual field shall follow the transmission order specified in "Transmission order" on page 20.

The complex descriptor shall be formatted and transmitted as illustrated in Figure 15.

Octets: 1	Variable	…	Variable
Field count	Field 1	…	Field *n*

Figure 15 Format of the complex descriptor

Each field included in the complex descriptor shall be formatted as illustrated in Figure 16.

Octets: 1	Variable
Compressed XML tag	Field data

Figure 16 Format of an individual complex descriptor field

1.3.3.1.1 Field count field

The field count field is one octet in length and specifies the number of fields included in the descriptor, each formatted as illustrated in Figure 16.

1.3.3.1.1.1 Compressed XML tag field

The compressed XML tag field is one octet in length and specifies the XML tag for the current field. The compressed XML tags for the complex descriptor are listed in Table 32.

1.3.3.1.1.2 Field data field

The field data field has a variable length and contains the information specific to the current field, as indicated by the compressed XML tag field.

1.3.3.2 Discovery via descriptors

Descriptor information is queried in the ZDO management entity device and service discovery using the ZigBee device profile request primitive addressed to endpoint 0. For details of the discovery operation, see sub-clause 1.1.5. Information is returned via the ZigBee device profile indication primitive.

The node and node power descriptors apply to the complete node. The other descriptors must be specified for each endpoint defined in the node. If a node contains multiple subunits, these will be on separate endpoints and the specific descriptors for these endpoints are read by including the relevant endpoint number in the ZigBee device profile primitive.

1.3.3.3 Composite devices

A ZigBee node may contain a number of separate subunits, each of which has its own simple, complex or user descriptors. The mechanism for discovering this is described in ZigBee device profile service discovery section.

1.3.3.4 Node descriptor

The node descriptor contains information about the capabilities of the ZigBee node and is mandatory for each node. There shall be only one node descriptor in a node.

The fields of the node descriptor are shown in Table 21 in their order of transmission.

Table 21 Fields of the node descriptor

Field name	Length (bits)
Logical type	3
Reserved	5
APS flags	3
Frequency band	5
MAC capability flags	8
Manufacturer code	16
Maximum buffer size	8
Maximum transfer size	16

1.3.3.4.1 Logical type field

The logical type field of the node descriptor is three bits in length and specifies the device type of the ZigBee node. The logical type field shall be set to one of the non-reserved values listed in Table 22.

Table 22 Values of the logical type field

Logical type value $b_2b_1b_0$	Description
000	ZigBee coordinator
001	ZigBee router
010	ZigBee end device
011-111	Reserved

1.3.3.4.2 APS flags field

The APS flags field of the node descriptor is three bits in length and specifies the application support sub-layer capabilities of the node.

This field is currently not supported and shall be set to zero.

1.3.3.4.3 Frequency band field

The frequency band field of the node descriptor is five bits in length and specifies the frequency bands that are supported by the underlying IEEE 802.15.4 radio utilized by the node. For each frequency band supported by the underlying IEEE 802.15.4 radio, the corresponding bit of the frequency band field, as listed in Table 23, shall be set to 1. All other bits shall be set to 0.

Table 23 Values of the frequency band field

Frequency band field bit number	Supported frequency band
0	868 – 868.6 MHz
1	Reserved
2	902 – 928 MHz
3	2400 – 2483.5 MHz
4	Reserved

1.3.3.4.4 MAC capability flags field

The MAC capability flags field is eight bits in length and specifies the node capabilities, as required by the IEEE 802.15.4 MAC sub-layer [B1]. The MAC capability flags field shall be formatted as illustrated in Figure 17.

Bits: 0	1	2	3	4-5	6	7
Alternate PAN coordi-nator	Device type	Power source	Receiver on when idle	Reserved	Security capability	Reserved

Figure 17 Format of the MAC capability flags field

The alternate PAN coordinator sub-field is one bit in length and shall be set to 1 if this node is capable of becoming a PAN coordinator. Otherwise the alternative PAN coordinator sub-field shall be set to 0.

The device type sub-field is one bit in length and shall be set to 1 if this node is a full function device (FFD). Otherwise the device type sub-field shall be set to 0, indicating a reduced function device (RFD).

The power source sub-field is one bit in length and shall be set to 1 if the current power source is mains power. Otherwise the power source sub-field shall be set to 0. This information is derived from the node current power source field of the node power descriptor.

The receiver on when idle sub-field is one bit in length and shall be set to 1 if the device does not disable its receiver to conserve power during idle periods. Otherwise the receiver on when idle sub-field shall be set to 0 (see also sub-clause 1.3.3.5.)

The security capability sub-field is one bit in length and shall be set to 1 if the device is capable of sending and receiving frames secured using the security suite specified in [B1]. Otherwise the security capability sub-field shall be set to 0.

1.3.3.4.5 Manufacturer code field

The manufacturer code field of the node descriptor is sixteen bits in length and specifies a manufacturer code that is allocated by the ZigBee Alliance, relating the manufacturer to the device.

1.3.3.4.6 Maximum buffer size field

The maximum buffer size field of the node descriptor is eight bits in length, with a valid range of 0x00-0x7f, and specifies the maximum size, in octets, of the application support sub-layer data unit (ASDU) for this node. This is the maximum size of data or commands passed to or from the application by the application support sub-layer, before any fragmentation or re-assembly (fragmentation is not currently supported).

This field can be used as a high level indication for network management.

1.3.3.4.7 Maximum transfer size field

The maximum transfer size field of the node descriptor is sixteen bits in length, with a valid range of 0x0000-0x7fff, and specifies the maximum size, in octets, that can be transferred to or from this node in one single message transfer. This value can exceed the value of the node maximum buffer size field (see sub-clause 1.3.3.4.6).

This field is currently not supported and shall be set to zero.

1.3.3.5 Node power descriptor

The node power descriptor gives a dynamic indication of the power status of the node and is mandatory for each node. There shall be only one node power descriptor in a node.

The fields of the node power descriptor are shown in Table 24 in the order of their transmission.

Table 24 Fields of the node power descriptor

Field name	Length (bits)
Current power mode	4
Available power sources	4
Current power source	4
Current power source level	4

1.3.3.5.1 Current power mode field

The current power mode field of the node power descriptor is four bits in length and specifies the current sleep/power-saving mode of the node. The current power mode field shall be set to one of the non-reserved values listed in Table 25.

Table 25 Values of the current power mode field

Current power mode value $b_3b_2b_1b_0$	Description
0000	Receiver synchronized with the receiver on when idle sub-field of the node descriptor.
0001	Receiver comes on periodically as defined by the node power descriptor.
0010	Receiver comes on when stimulated, e.g. by a user pressing a button.
0011-1111	Reserved

1.3.3.5.2 Available power sources field

The available power sources field of the node power descriptor is four bits in length and specifies the power sources available on this node. For each power source supported on this node, the corresponding bit of the available power sources field, as listed in Table 26, shall be set to 1. All other bits shall be set to 0.

Table 26 Values of the available power sources field

Available power sources field bit number	Supported power source
0	Constant (mains) power
1	Rechargeable battery
2	Disposable battery
3	Reserved

1.3.3.5.3 Current power source field

The current power source field of the node power descriptor is four bits in length and specifies the current power source being utilized by the node. For the current power source selected, the corresponding bit of the current power source field, as listed in Table 27, shall be set to 1. All other bits shall be set to 0.

Table 27 Values of the current power sources field

Current power source field bit number	Current power source
0	Constant (mains) power
1	Rechargeable battery
2	Disposable battery
3	Reserved

1.3.3.5.4 Current power source level field

The current power source level field of the node power descriptor is four bits in length and specifies the level of charge of the power source. The current power source level field shall be set to one of the non-reserved values listed in Table 28.

Table 28 Values of the current power source level field

Current power source level field $b_3b_2b_1b_0$	Charge level
0000	Critical
0100	33%
1000	66%
1100	100%
All other values	Reserved

1.3.3.6 Simple descriptor

The simple descriptor contains information specific to each endpoint contained in this node. The simple descriptor is mandatory for each endpoint present in the node.

The fields of the simple descriptor are shown in Table 29 in their order of transmission. As this descriptor needs to be transmitted over air, the overall length of the simple descriptor shall be less than or equal to *maxCommandSize*.

Table 29 Fields of the simple descriptor

Field name	Length (bits)
Endpoint	8
Application profile identifier	16
Application device identifier	16
Application device version	4
Application flags	4
Application input cluster count	8
Application input cluster list	8*i* (where *i* is the value of the application input cluster count)
Application output cluster count	8
Application output cluster list	8*o* (where *o* is the value of the application input cluster count)

1.3.3.6.1 Endpoint field

The endpoint field of the simple descriptor is eight bits in length and specifies the endpoint within the node to which this description refers. Applications shall only use endpoints 1-240.

1.3.3.6.2 Application profile identifier field

The application profile identifier field of the simple descriptor is sixteen bits in length and specifies the profile that is supported on this endpoint. Profile identifiers shall be obtained from the ZigBee Alliance.

1.3.3.6.3 Application device identifier field

The application device identifier field of the simple descriptor is sixteen bits in length and specifies the device description supported on this endpoint. Device description identifiers shall be obtained from the ZigBee Alliance.

1.3.3.6.4 Application device version field

The application device version field of the simple descriptor is four bits in length and specifies the version of the device description supported on this endpoint. The application device version field shall be set to one of the non-reserved values listed in Table 30.

Table 30 Values of the application device version field

Application device version value $b_3b_2b_1b_0$	Description
0000	Version 1.0
0001–1111	Reserved

1.3.3.6.5 Application flags field

The application flags field of the simple descriptor is four bits in length and specifies application specific flags. For each feature supported by the application on this endpoint, the corresponding bit of the application flags field, as listed in Table 31, shall be set to 1. All other bits shall be set to 0.

Table 31 Values of the application flags field

Application flags field bit number	Supported feature
0	Complex descriptor available
1	User descriptor available
2-3	Reserved

1.3.3.6.6 Application input cluster count field

The application input cluster count field of the simple descriptor is eight bits in length and specifies the number of input clusters, supported on this endpoint, that will appear in the application input cluster list field. If the value of this field is zero, the application input cluster list field shall not be included.

1.3.3.6.7 Application input cluster list

The application input cluster list of the simple descriptor is 8**i* bits in length, where *i* is the value of the application input cluster count field, and specifies the list of input clusters supported on this endpoint, used during the binding procedure.

The application input cluster list field shall be included only if the value of the application input cluster count field is greater than zero.

1.3.3.6.8 Application output cluster count field

The application output cluster count field of the simple descriptor is eight bits in length and specifies the number of output clusters, supported on this endpoint, that will appear in the application output cluster list field. If the value of this field is zero, the application output cluster list field shall not be included.

1.3.3.6.9 Application output cluster list

The application output cluster list of the simple descriptor is 8**o* bits in length, where *o* is the value of the application output cluster count field, and specifies the list of output clusters supported on this endpoint, used during the binding procedure.

The application output cluster list field shall be included only if the value of the application output cluster count field is greater than zero.

1.3.3.7 Complex Descriptor

The complex descriptor contains extended information for each of the device descriptions contained in this node. The use of the complex descriptor is optional.

Due to the extended and complex nature of the data in this descriptor it is presented in XML form using compressed XML tags. Each field of the descriptor, shown in Table 32, can therefore be transmitted in any order. As this descriptor needs to be transmitted over air, the overall length of the complex descriptor shall be less than or equal to *maxCommandSize*.

Table 32 Fields of the complex descriptor

Field name	XML tag	Compressed XML tag value $b_3b_2b_1b_0$	Data type
Reserved	-	0000	-
Language and character set	<languageChar>	0001	See sub-clause 1.3.3.7.1.
Manufacturer name	<manufacturerName>	0010	Character string
Model name	<modelName>	0011	Character string
Serial number	<serialNumber>	0100	Character string
Device URL	<deviceURL>	0101	Character string
Icon	<icon>	0110	Undefined
Icon URL	<iconURL>	0111	Character string
Reserved	-	1000 – 1111	-

1.3.3.7.1 Language and character set field

The language and character set field is three octets in length and specifies the language and character set used by the character strings in the complex descriptor. The format of the language and character set field is illustrated in Figure 18.

Octets: 2	1
ISO 639-1 language code	Character set identifier

Figure 18 Format of the language and character set field

The ISO 639-1 language code sub-field is two octets in length and specifies the language used for character strings, as defined in [B5].

The character set identifier sub-field is one octet in length and specifies the encoding used by the characters in the character set. This sub-field shall be set to one of the non-reserved values listed in Table 33.

Table 33 Values of the character set identifier sub-field

Character set identifier value	Bits per character	Description
0x00	8	ISO 646, ASCII character set. Each character is fitted into the least significant 7 bits of an octet with the most significant bit set to zero (see also [B6]).
0x01 – 0xff	-	Reserved

If the language and character sets have not been specified, the language shall default to English (language code = “EN”) and the character set to ISO 646.

1.3.3.7.2 Manufacturer name field

The manufacturer name field has a variable length and contains a character string representing the name of the manufacturer of the device.

1.3.3.7.3 Model name field

The model name field has a variable length and contains a character string representing the name of the manufacturers model of the device.

1.3.3.7.4 Serial number field

The serial number field has a variable length and contains a character string representing the manufacturers serial number of the device.

1.3.3.7.5 Device URL field

The device URL field has a variable length and contains a character string representing the URL through which more information relating to the device can be obtained.

1.3.3.7.6 Icon field

The icon field has a variable length and contains the data for an icon that can represent the device on a computer, gateway or PDA. The format of the icon data is not specified in this document.

1.3.3.7.7 Icon URL field

The icon URL field has a variable length and contains a character string representing the URL through which the icon for the device can be obtained.

1.3.3.8 User descriptor

The user descriptor contains information that allows the user to identify the device using a user-friendly character string, such as “Bedroom TV” or “Stairs light”. The use of the user descriptor is optional. This descriptor contains a single field, which uses the character string data type (see sub-clause 1.3.2.9), and shall contain a maximum of 16 characters.

The fields of the user descriptor are shown in Table 34 in the order of their transmission.

Table 34 Fields of the user descriptor

Field name	Length (octets)
User description	16

1.3.4 AF frame formats

The general AF frame format is illustrated in Figure 19.

Bits: 4	4	Variable	Variable	Variable
Transaction count	Frame type	Transaction 1	…	Transaction *n*

Figure 19 Format of the general application framework command frame

The format of each transaction *i* field, where $1 \leq i \leq n$, is illustrated in Figure 20. Each transaction contains a transaction header and a transaction payload, the latter composed of frame type-specific data.

Bits: 8	Variable
Transaction sequence number	Transaction data
Transaction header	Transaction payload

Figure 20 Format of a transaction field

1.3.4.1 Transaction count field

The transaction count field is four bits in length and specifies the number of transactions, *n*, appearing in the general frame, each contiguously following the frame type field.

1.3.4.2 Frame type field

The frame type field is four bits in length and specifies the service type used by each of the following transactions. This field shall be set to one of the non-reserved values listed in Table 35.

Table 35 Values of the frame type field

Frame type value $b_3b_2b_1b_0$	Description
0000	Reserved
0001	Key value pair (KVP)
0010	Message (MSG)
0011 – 1111	Reserved

1.3.4.3 Transaction sequence number field

The transaction sequence number field is eight bits in length and specifies an identification number for the transaction so that a response command frame can be related to the request frame. The application object itself shall maintain an 8-bit counter that is copied into this field and incremented by one for each command sent. When a value of 0xff is reached, the next command shall re-start the counter with a value of 0x00.

If a device sends a KVP command requesting an acknowledgement, the target device shall respond with the relevant response command and include the transaction sequence number contained in the original request command. Similarly, this field can be used to implement acknowledged MSG commands in the same way.

The transaction sequence number field can be used by a controlling device, which may have issued multiple commands, so that it can match the incoming responses to the relevant command.

1.3.4.4 Transaction data field

The transaction data field has a variable length and contains the data for the individual transaction. The format and length of this field is dependent on the value of the frame type field and contains either a KVP frame (see sub-clause 1.3.4.5.1) or a MSG frame (see sub-clause 1.3.4.5.2).

1.3.4.5 Format of individual frame types

There are two defined frame types: key value pair (KVP) and message (MSG). Each of these frame types is discussed in the following sub-clauses.

1.3.4.5.1 Key value pair (KVP) frame format

The KVP frame type enables an application to manipulate attributes, defined by the application profile. Attributes have a designator (the key) and an associated value, which can be set or requested using the commands specified in sub-clause 1.3.5.

Commands are sent and received using the APS APSDE-DATA.request and APSDE-DATA.indication primitives, through the ASDU data field, as described in sub-clause 1.2.4.1.

Commands can be sent (or received) directly to (or from) an attribute in a target using direct addressing, or via the binding table, in a ZigBee coordinator, using indirect addressing. The APS cluster identifier shall match the cluster that contains the attribute being manipulated. The APS security suite shall indicate which security suite is required for the outgoing command.

The use of this interface changes according to the addressing method in use. More details can be found in clause 1.2.

The KVP command frame shall be formatted as illustrated in Figure 21.

Bits: 4	4	16	0/8	Variable
Command type identifier	Attribute data type	Attribute identifier	Error code	Attribute data

Figure 21 Format of the general KVP command frame

1.3.4.5.1.1 Command type identifier field

The command type identifier field is four bits in length and specifies the type of the command. This field shall be set to one of the non-reserved values listed in Table 36. Note that for messages sent indirectly via the ZigBee coordinator, only the set and event command types are permitted.[32]

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Table 36 Values of the command type identifier field

Command type identifier value $b_3b_2b_1b_0$	Description	Sub-clause
0000	Reserved	-
0001	Set	1.3.5.3
0010	Event	1.3.5.5
0011	Reserved	-
0100	Get with acknowledgement	1.3.5.1
0101	Set with acknowledgement	1.3.5.3
0110	Event with acknowledgement	1.3.5.5
0111	Reserved	-
1000	Get response	1.3.5.2
1001	Set response	1.3.5.4
1010	Event response	1.3.5.6
1011 – 1111	Reserved	-

1.3.4.5.1.2 Attribute data type field

The attribute data type field is four bits in length and specifies the type of the data in the attribute data field. This field shall be set to one of the non-reserved values listed in Table 19. The length of the attribute data field is either implied directly from the type or specified in the first octet of the attribute data field.

For more details of the available data types, see sub-clause 1.3.2.

1.3.4.5.1.3 Attribute identifier field

The attribute identifier field is sixteen bits in length and specifies the attribute within the target device on which the command is to operate. The value of this field is defined in the relevant device description.

1.3.4.5.1.4 Error code field

The error code field is eight bits in length and specifies the status of a transaction. This field, included only in response commands, shall be set to one of the non-reserved values listed in Table 37.

Table 37 Values of the error code field

Error code value	Description
0x00	Success
0x01	Invalid endpoint
0x02	Reserved

[32]CCB Comment #232

Table 37 Values of the error code field

0x03	Unsupported attribute
0x04	Invalid command type
0x05	Invalid attribute data length
0x06	Invalid attribute data
0x07 – 0x0f	Reserved
0x10-0xff	Application defined error

Note that other errors, such as invalid security suite or cluster identifier are signaled by the APS directly. For further details, see clause 1.2.

1.3.4.5.1.5 Attribute data field

The attribute data field has a variable length and contains information specific to the attribute referenced in the attribute identifier field. This field is dependent on the particular command, the data type of the attribute and the device description.

If not defined directly by the data type of the attribute being referred to, the length of this field shall be such that the length of the entire command frame is less than or equal to *maxCommandSize*, unless both source and destination support fragmentation.

For details, see the individual commands in the following sections.

1.3.4.5.2 MSG frame format

The MSG frame type enables an application profile to work with free form frame formats, defined by the application profile itself. This allows applications, which do not easily fit into the KVP structure, the flexibility to define commands, which better suit its needs.

MSG frames are sent using the APS APSDE-DATA.request primitive and received via the APSDE DATA.indication primitive as described in sub-clause 1.2.4.1.

The application object uses device descriptions to define the service type, and hence the frame type which supports the service, for each cluster. For MSG frames, the device description is also responsible for defining the usage of the message.

An MSG transaction frame shall be formatted as illustrated in Figure 22.

Bits: 8	**Variable**
Transaction length	Transaction data

Figure 22 Format of the MSG transaction frame

The MSG transaction frame does not implicitly support application level acknowledgements or command aggregation but is instead of free form frame for transporting data for messages defined in an application profile.

1.3.4.5.2.1 Transaction length field

The transaction length field is eight bits in length and specifies the number of octets contained in the following transaction data field.

1.3.4.5.2.2 Transaction data field

The transaction data field has a variable length, which shall be less than or equal to *maxCommandSize*, unless both source and destination support fragmentation, and contains message specific information, defined in a particular application profile.

1.3.5 KVP command frames

The following KVP commands are supported:

— Set, set with acknowledgement and get with acknowledgement commands for manipulating attribute values.

— Set response and get response command replies initiated by the reception of the set with acknowledgement and get with acknowledgement commands, respectively.

— Event and event with acknowledgement commands for informing another device that the value of an attribute has changed value.

— Event response command reply initiated by the reception of the event with acknowledgement command.

— Aggregations of the above commands for attributes within the same cluster. Aggregation is not currently supported.

The command format uses compressed XML (extensible markup language) based on WBXML (WAP Binary XML). In this compressed format, textual tags are compressed into a single octet tokenized format. Using the schemas in Annex F, the compressed XML can be inflated to a full textual XML description for use in other systems. It is not expected that uncompressed XML is sent over the ZigBee radio link in normal operation.

The set and event commands can be sent with an optional application level acknowledgement, allowing the originator to confirm that a command was actually received by the recipient. There is no get command available without an acknowledgement since the transaction naturally requires a response. Note that for messages sent indirectly via the ZigBee coordinator, only the set and event command types are permitted.[33]

1.3.5.1 Get with acknowledgement command frame

The get with acknowledgement command frame shall be formatted as illustrated in Figure 23.

Bits: 8	4	4	16
Transaction sequence number	Command type identifier	Attribute data type	Attribute identifier
Transaction header	Transaction payload		

Figure 23 Format of the get with acknowledgement command frame

[33]CCB Comment #232

1.3.5.1.1 When generated

The get with acknowledgement command frame is generated when a device wishes to read an attribute value from another device.

The transaction sequence number shall be set to the next value of the sequence number maintained by the application. The command type identifier field shall be set to 0100 (binary). The attribute data type shall be set to the type of the attribute being requested. The attribute identifier field shall contain the identifier of the attribute being requested.

1.3.5.1.2 Effect on receipt

On receipt of the get with acknowledgement command frame, the recipient device shall determine whether it defines the requested attribute. If not, the recipient device shall generate and send a get response command frame back to the originator with the error code field set to an appropriate value that indicates the error. If the attribute is defined, the recipient device shall generate and send a get response command frame back to the recipient with the requested attribute data.

1.3.5.2 Get response command frame

The get response command frame shall be formatted as illustrated in Figure 24.

Bits: 8	4	4	16	8	Variable
Transaction sequence number	Command type identifier	Attribute data type	Attribute identifier	Error code	Attribute data
Transaction header	Transaction payload				

Figure 24 Format of the get response command frame

1.3.5.2.1 When generated

The get response command frame is generated in response to the reception of a get with acknowledgement command frame.

The transaction sequence number shall be set to value of the transaction sequence number sent with the get with acknowledgement command frame. The command type identifier field shall be set to 1000 (binary). The attribute data type shall be set to the type of the attribute being requested. The attribute identifier field shall contain the identifier of the attribute being requested.

If the requested attribute was defined and the get with acknowledgement command frame contained no errors, the error code field shall contain 0x00, indicating a successful request. Otherwise, the error code field shall be set to one of the non-reserved values listed in Table 37.

The attribute data field shall contain the value of the attribute requested in the attribute identifier field and shall be a whole number of octets in the specified data type format. If the length of this field is not defined directly by the data type of the attribute being referred to, the first octet shall contain the length, in octets, of the rest of the data (see also Table 19). The actual meaning of the data is specified in the relevant device description.

1.3.5.2.2 Effect on receipt

On receipt of the get response command frame, the originator is notified of the success of their request to read the value of an attribute. If the error code field contains 0x00, the transaction was successful and the attribute value can be used. If the error code field does not contain the value 0x00, the transaction was unsuccessful.

1.3.5.3 Set/set with acknowledgement command frame

The set and set with acknowledgement command frames shall be formatted as illustrated in Figure 25.

Bits: 8	4	4	16	Variable
Transaction sequence number	Command type identifier	Attribute data type	Attribute identifier	Attribute data
Transaction header	Transaction payload			

Figure 25 Format of the set/set with acknowledgement command frame

1.3.5.3.1 When generated

The set and set with acknowledgement command frames are generated when a device wishes to write an attribute value to another device. The set with acknowledgement command frame is used when a response is required from the recipient.

The transaction sequence number shall be set to the next value of the sequence number maintained by the application. The command type identifier field shall be set to 0001 or 0101 (binary), for the set or set with acknowledgement command frames, respectively. The attribute data type shall be set to the type of the attribute being written. The attribute identifier field shall contain the identifier of the attribute being written.

The attribute data field shall contain the value to write to the attribute requested in the attribute identifier field and shall be a whole number of octets in the specified data format. If the length of this field is not defined directly by the data type of the attribute being referred to, the first octet shall contain the length, in octets, of the rest of the data (see also Table 19). The actual meaning of the data is specified in the relevant device description.

1.3.5.3.2 Effect on receipt

On receipt of the set command frame, the recipient device shall determine whether it defines the requested attribute. If not, the recipient device shall ignore the command. If the attribute is defined, the recipient device shall write the data in the attribute data field to the attribute specified in the attribute identifier field.

On receipt of the set with acknowledgement command frame, the recipient device shall determine whether it defines the requested attribute. If not, the recipient device shall generate and send a set response command frame back to the originator with the error code field set to an appropriate value that indicates the error. If the attribute is defined, the recipient device shall write the data in the attribute data field to the attribute specified in the attribute identifier field. It shall then generate and send a set response command frame back to the recipient with a suitable error code.

1.3.5.4 Set response command frame

The set response command frame shall be formatted as illustrated in Figure 26.

Bits: 8	4	4	16	8
Transaction sequence number	Command type identifier	Attribute data type	Attribute identifier	Error code
Transaction header	Transaction payload			

Figure 26 Format of the set response command frame

1.3.5.4.1 When generated

The set response command frame is generated in response to the reception of a set with acknowledgement command frame.

The transaction sequence number shall be set to value of the transaction sequence number sent with the set with acknowledgement command frame. The command type identifier field shall be set to 1001 (binary). The attribute data type shall be set to the type of the attribute that was written. The attribute identifier field shall contain the identifier of the attribute that was written.

If the requested attribute was defined and the set with acknowledgement command frame contained no errors, the error code field shall contain 0x00, indicating a successful request. Otherwise, the error code field shall be set to one of the non-reserved values listed in Table 37.

1.3.5.4.2 Effect on receipt

On receipt of the set response command frame, the originator is notified of the success of their request to write the value of an attribute. If the error code field contains 0x00, the transaction was successful and the attribute value was written. If the error code field does not contain the value 0x00, the transaction was unsuccessful.

1.3.5.5 Event/event with acknowledgement

The event and event with acknowledgement command frames shall be formatted as illustrated in Figure 27.

Bits: 8	4	4	16	Variable
Transaction sequence number	Command type identifier	Attribute data type	Attribute identifier	Attribute data
Transaction header	Transaction payload			

Figure 27 Format of the event/event with acknowledgement command frame

1.3.5.5.1 When generated

The event and event with acknowledgement command frames are generated when a device wishes to inform another device that the value of an attribute has changed. The event with acknowledgement command frame is used when a response is required from the recipient.

The transaction sequence number shall be set to the next value of the sequence number maintained by the application. The command type identifier field shall be set to 0010 or 0110 (binary), for the event or event with acknowledgement command frames, respectively. The attribute data type shall be set to the type of the attribute that has changed. The attribute identifier field shall contain the identifier of the attribute that has changed.

The attribute data field shall contain the changed value of the attribute specified in the attribute identifier field and shall be a whole number of octets in the specified data format. If the length of this field is not defined directly by the data type of the attribute being referred to, the first octet shall contain the length, in octets, of the rest of the data (see also Table 19). The actual meaning of the data is specified in the relevant device description.

1.3.5.5.2 Effect on receipt

On receipt of the event command frame, the recipient device is notified of the new value of the attribute specified in the attribute identifier field.

On receipt of the event with acknowledgement command frame, the recipient device is notified of the new value of the attribute specified in the attribute identifier field. It shall then generate and send an event response command frame back to the recipient with a suitable error code.

1.3.5.6 Event response command frame

The event response command frame shall be formatted as illustrated in Figure 28

Bits: 8	4	4	16	8
Transaction sequence number	Command type identifier	Attribute data type	Attribute identifier	Error code
Transaction header	Transaction payload			

Figure 28 Format of the event response command frame

1.3.5.6.1 When generated

The event response command frame is generated in response to the reception of an event with acknowledgement command frame.

The transaction sequence number shall be set to value of the transaction sequence number sent with the event with acknowledgement command frame. The command type identifier field shall be set to 1010 (binary). The attribute data type shall be set to the type of the attribute whose change was notified. The attribute identifier field shall contain the identifier of the attribute whose change was notified.

If the event with acknowledgement command frame contained no errors, the error code field shall contain 0x00, indicating a successful notification. Otherwise, the error code field shall contain one of the non-reserved values listed in Table 37.

1.3.5.6.2 Effect on receipt

On receipt of the event response command frame, the originator is notified of the success of their notification of the change in the value of an attribute. If the error code field contains 0x00, the transaction was successful. If the error code field does not contain the value 0x00, the transaction was unsuccessful.

1.3.6 Functional description

1.3.6.1 Aggregate transactions

The general application framework frame format allows the grouping individual transactions together in the same frame. Such a grouping of transactions is referred to as aggregation.

Only those transactions that share the same service type (i.e. KVP or MSG) and cluster identifier shall be aggregated and the combined aggregate frame shall not exceed the maximum permitted size.[34]

On receipt of an aggregated set of KVP transactions, the recipient shall process each transaction in turn and, for those transactions requiring a response, compile an aggregated set of response transactions and send them back to the originator.

The recipient shall ensure that this set of aggregated response transactions will fit within the size restrictions of an APS frame. If this is not possible, the recipient shall send the aggregated responses split over several frames, with each frame containing as many aggregated responses as will fit within the size restrictions of a single APS frame.[35]

1.3.6.2 Reception and rejection

The application framework shall be able to filter frames arriving via the APS sub-layer data service and only present the frames that are of interest to the applications implemented on each active endpoint.

The application framework receives data from the APS sub-layer via the APSDE-DATA.indication primitive and is targeted at a specific endpoint (DstEndpoint parameter) and a specific profile (ProfileId parameter).

If the application framework receives a frame for an inactive endpoint, the frame shall be discarded. Otherwise, the application framework shall determine whether the specified profile identifier matches the identifier of the profile implemented on the specified endpoint. If the profile identifier does not match, the application framework shall reject the frame. Otherwise, the application framework shall pass the payload of the received frame to the application implemented on the specified endpoint.[36]

1.4 The ZigBee device profile

1.4.1 Scope

This ZigBee Application Layer Specification describes how general ZigBee device features such as Binding, Device Discovery and Service Discovery are implemented within ZigBee Device Objects. The ZigBee Device Profile operates like any ZigBee profile by defining Device Descriptions and Clusters. Unlike application specific profiles, the Device Descriptions and Clusters within the ZigBee Device Profile define capabilities supported in all ZigBee devices. As with any profile document, this document details the mandatory and/or optional clusters.

1.4.2 Device Profile overview

The Device Profile supports four key inter-device communication functions within the ZigBee protocol:

— Device and Service Discovery

[34] CCB Comment #234
[35] CCB Comment #170
[36] CCB Comment #208

- End Device Bind Request Processing
- Bind and Unbind Command Processing
- Network Management

1.4.2.1 Device and service discovery overview

The following capabilities exist for device and service discovery:

- Device Discovery – Provides the ability for a device to determine the identity of other devices on the PAN. Device Discovery is supported for both the 64 bit IEEE address and the 16 bit Network address. Device Discovery messages can be used in one of two ways:
  - Broadcast addressed – All devices on the network shall respond according to the Logical Device Type and match criteria. ZigBee End Devices shall respond with just their address. ZigBee Coordinators and ZigBee Routers with associated devices shall respond with their address as the first entry followed by the addresses of their associated devices depending on the type of request. The responding devices shall employ APS acknowledged service on the unicast responses.
  - Unicast addressed – Only the specified device responds. ZigBee End Devices shall respond with just their address. ZigBee Coordinator or Routers shall reply with their address and the addresses of each of their associated devices

  For ZigBee Version 1.0, Device Discovery is a distributed operation where individual devices or their immediate parent devices respond to discovery requests. To enable future upgrades to a centralized or agent based discovery method, a "device address of interest" field has been added and the broadcast addressed discovery commands may be optionally unicast for ZigBee releases after Version 1.0.[37]
- Service Discovery – Provides the ability for a device to determine services offered by other devices on the PAN.
  - Service Discovery messages can be used in one of two ways:
    - Broadcast addressed –Due to the volume of information that could be returned, only the individual device shall respond which match criteria established in the request unless that device is a ZigBee Coordinator or ZigBee Router with sleeping associated device. In that case, the ZigBee Coordinator or ZigBee Router shall cache the Service Discovery information for the sleeping associated devices and respond on their behalf if the sleeping device matches criteria in the request. The responding devices shall also employ APS acknowledged service on the unicast responses.
    - Unicast addressed – Only the specified device shall respond. In the case of a ZigBee Coordinator or ZigBee Router, these devices shall cache the Service Discovery information for sleeping associated devices and respond on their behalf.
  - Service Discovery is supported with the following query types:
    - Active Endpoint – This command permits an enquiring device to determine the active endpoints. An active endpoint is one with an application supporting a single profile, described by a Simple Descriptor. The command may be broadcast or unicast addressed.
    - Match Simple Descriptor – This command permits enquiring devices to supply a Profile ID and, optionally, lists of input and/or output Cluster IDs and ask for a return of the identity of an endpoint on the destination device which match the supplied criteria. This command may be broadcast or unicast addressed. For broadcast addressed requests, the responding device shall employ APS acknowledged service on the unicast responses.

[37] CCB Comment #171

- Simple Descriptor – This commands permits an enquiring device to return the Simple Descriptor for the supplied endpoint. This command shall be unicast addressed.
- Node Descriptor - This commands permits an enquiring device to return the Node Descriptor from the specified device. This command shall be unicast addressed.
- Power Descriptor - This commands permits an enquiring device to return the Power Descriptor from the specified device. This command shall be unicast addressed.
- Complex Descriptor – This optional command permits an enquiring device to return the Complex Descriptor from the specified device. This command shall be unicast addressed.
- User Descriptor - This optional command permits an enquiring device to return the User Descriptor from the specified device. This command shall be unicast addressed.

For ZigBee Version 1.0, Service Discovery is a distributed operation where individual devices or their immediate parent devices respond to discovery requests. To enable future upgrades to a centralized or agent based discovery method, a "device address of interest" field has been added and the broadcast addressed discovery commands may be optionally unicast for ZigBee releases after Version 1.0.[38]

1.4.2.2 End device bind overview

The following capabilities exist for end device bind:

- End Device Bind
  - Provides the ability for an application to support “simple binding” where user intervention is employed to identify command/control device pairs. Typical usage would be where a user is asked to push buttons on two devices for installation purposes.
  - Provides the ability for an application to support a simplified method of binding where user intervention is employed to identify command/control device pairs. Typical usage would be where a user is asked to push buttons on two devices for installation purposes. Using this mechanism a second time allows the user to remove the binding table entry[39]

1.4.2.3 Bind and unbind overview

The following capabilities exist for directly configuring binding table entries:[40]

- Bind
  - Provides the ability for creation of a Binding Table entry that map control messages to their intended destination.
- Unbind
  - Provides the ability to remove Binding Table entries.

1.4.2.4 Network management overview

The following capabilities exist for network management:

Network management:

- Provides the ability to retrieve management information from the devices including:
  - Network discovery results

[38]CCB Comment #171
[39]CCB Comment #123, 236
[40]CCB Comment #236

- Link quality to neighbor nodes
- Routing table contents
- Binding table contents

— Provides the ability to set management information controls including:

- Network disassociate

1.4.2.5 Device Descriptions for the Device Profile

The ZigBee Device Profile utilizes a single Device Description. Each cluster specified as Mandatory shall be present in all ZigBee devices. The response behavior to some messages is logical device type specific. The support for Optional clusters is not dependent on the logical device type.

1.4.2.6 Service Type usage

The ZigBee Device Profile shall employ the Message (MSG) Service Type. See clause 1.3 for details.

1.4.2.7 Configuration and roles

The Device Profile assumes a client/server topology. A device making Device Discovery, Service Discovery, Binding or Network Management requests does so via a client role. A device which services these requests and responds does so via a server role. The client and server roles are non-exclusive in that a given device may supply both client and server roles.

The Device Profile describes devices in one of two configurations:

— Client – A client issues requests via Device Profile messages. Based on processing of those requests at the server, the client receives responses to the issued requests

— Server – A server is the target of requests via Device Profile messages processes those requests and issues responses.

1.4.2.8 Cluster ID format within the Device Profile

The following Cluster ID format shall be used within the Device Profile:

bits: 0 - 6	7
Message Number	Request/Response Bit Request = 0 Response = 1

Figure 29 Cluster ID Format for the Device Profile

1.4.3 Client services

The Device Profile Client Services supports the transport of device and service discovery requests, end device binding requests, bind requests unbind requests and network management requests from client to server. Additionally, Client Services support receipt of responses to these requests from the server.

1.4.3.1 Device and Service Discovery client services

Table 381 lists the primitives supported by Device Profile Device and Service Discovery Client Services. Each of these primitives will be discussed in the following sub-clauses.

Table 38 Device and Service Discovery Client Services primitives

Device and Service Discovery Client Services	Client Transmission	Server Processing
NWK_addr_req	O	M
IEEE_addr_req	O	M
Node_Desc_req	O	M
Power_Desc_req	O	M
Simple_Desc_req	O	M
Active_EP_req	O	M
Match_Desc_req	O	M
Complex_Desc_req	O	O[a]
User_Desc_req	O	O[b]
Discovery_Register_req	O	O[c]
End_Device_annce	O	O
User_Desc_set[d]	O	O[e]

[a]Must minimally return a status of NOT_SUPPORTED
[b]ibid
[c]Ibid
[d]CCB Comment #176
[e]Must minimally return a status of NOT_SUPPORTED

1.4.3.1.1 NWK_addr_req

1.4.3.1.1.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x00	NWK_addr_req	(IEEEAddr RequestType StartIndex)

Table 39 specifies the parameters for the NWK_addr_req primitive.

Table 39 NWK_addr_req parameters

Name	Type	Valid range	Description
IEEEAddr	IEEE Address	A valid 64-bit IEEE address	The IEEE address to be matched by the Remote Device
RequestType	Integer	0x00-0xff	Request type for this command: 0x00 – Single device response 0x01 – Extended response 0x02-0xff – reserved
StartIndex	Integer	0x00-0xff	If the Request type for this command is Extended response, the StartIndex provides the starting index for the requested elements of the associated devices list.

1.4.3.1.1.2 When generated

The NWK_addr_req is generated from Local Device devices wishing to inquire as to the 16 bit address of the Remote Device based on its known IEEE address. The destination addressing on this primitive shall be broadcast.

For future upgrade ability, the destination addressing may be permitted to be unicast. This would permit directing the message to a well-known destination that supports centralized or agent-based device discovery.

1.4.3.1.1.3 Effect on receipt

Upon receipt, a Remote Device shall compare the IEEEAddr to its local IEEE address. If there is no match, the request shall be discarded and no response generated. If a match is detected between the contained IEEEAddr and the Remote Device's IEEE address, the RequestType shall be used to create a response. If the RequestType is one of the reserved values, a status of INV_REQUESTTYPE shall be returned. If the RequestType is Single device response or Extended response, the Remote Device shall create a unicast message to the Local Device and include the Remote Device's 16-bit NWK address as the source address along with the matched IEEE Address in the response payload. If the RequestType was Single device response, the response message shall be sent with a SUCCESS status. Otherwise, if the RequestType was Extended response and the Remote Device is either the ZigBee coordinator or router with associated devices, the Remote Device shall first include the matched IEEE Address and NWK Address in the message payload and shall also supply a list of all 16 bit NWK addresses, starting with the entry StartIndex and continuing with whole entries until the maximum APS packet length is reached, for its associated devices along with a status of SUCCESS.[41]

[41] CCB Comment #171

1.4.3.1.2 IEEE_addr_req

1.4.3.1.2.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x01	IEEE_addr_req	(NWKAddrOfInterest RequestType StartIndex)

Table 40 specifies the parameters for the IEEE_addr_req primitive.

Table 40 IEEE_addr_req parameters

Name	Type	Valid range	Description
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address that is used for IEEE address mapping.
RequestType	Integer	0x00-0xff	Request type for this command: 0x00 – Single device response. 0x01 – Extended response. 0x02-0xff – reserved.
StartIndex	Integer	0x00-0xff	If the Request type for this command is Extended response, the StartIndex provides the starting index for the requested elements of the associated devices list.

1.4.3.1.2.2 When generated

The IEEE_addr_req is generated from Local Device devices wishing to inquire as to the 64 bit IEEE address of the Remote Device based on their known 16 bit address. The destination addressing on this primitive shall be unicast.

1.4.3.1.2.3 Effect on receipt

Upon receipt, a Remote Device shall create a unicast message to the source indicated by the IEEE_addr_req and include the Remote Device's 64-bit IEEE address as the first field within the IEEE_addr_rsp payload. Additionally, if the RequestType indicates an Extended Response and the Remote Device is the ZigBee coordinator or router with associated devices, the Remote Device shall first include its own 64-bit IEEE address and then shall also supply a list of all 16 bit IEEE addresses for its associated devices, starting with the entry StartIndex and continuing with whole entries until the maximum APS packet length is reached, with a status of SUCCESS.[42]

For ZigBee Version 1.0, the destination address and the NWKAddrofInterest shall be the same. For future upgrade ability, the destination address could be specified as a known address holding device discovery information and the NWKAddrOfInterest could be specified as a query parameter.

[42] Ibid

1.4.3.1.3 Node_Desc_req

1.4.3.1.3.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x02	Node_Desc_req	(NWKAddrOfInterest)

Table 41 specifies the parameters for the Node_Desc_req primitive.

Table 41 Node_Desc_req parameters

Name	Type	Valid range	Description
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address for the request.

1.4.3.1.3.2 When generated

The Node_Desc_req is generated from Local Devices wishing to inquire as to the Node Descriptor of the Remote Device. The destination addressing on this primitive can be unicast only.

1.4.3.1.3.3 Effect on receipt

Upon receipt, a Remote Device shall create a unicast message to the source indicated by the Node_Desc_req and include the Remote Device's Node Descriptor (see clause 1.4).

For ZigBee Version 1.0, the destination address and the NWKAddrofInterest shall be the same. For future upgrade ability, the destination address could be specified as a known address holding discovery information and the NWKAddrOfInterest could be specified as a query parameter.

1.4.3.1.4 Power_Desc_req

1.4.3.1.4.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x03	Power_Desc_req	(NWKAddrOfInterest)

Table 42 specifies the parameters for the Power_Desc_req primitive.

Table 42 Power_Desc_req parameters

Name	Type	Valid range	Description
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address for the request.

1.4.3.1.4.2 When generated

The Power_Desc_req is generated from Local Devices wishing to inquire as to the Power Descriptor of the Remote Device. The destination addressing on this primitive can be unicast only.

1.4.3.1.4.3 Effect on receipt

Upon receipt, a Remote Device shall create a unicast message to the source indicated by the Power_Desc_req and include the Remote Device's Power Descriptor (see clause 1.4).

For ZigBee Version 1.0, the destination address and the NWKAddrofInterest shall be the same. For future upgrade ability, the destination address could be specified as a known address holding discovery information and the NWKAddrOfInterest could be specified as a query parameter.

1.4.3.1.5 Simple_Desc_req

1.4.3.1.5.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x04	Simple_Desc_req	(NWKAddrOfInterest endpoint)

Table 43 specifies the parameters for the Simple_Desc_req primitive.

Table 43 Simple_Desc_req parameters

Name	Type	Valid range	Description
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address for the request.
endpoint	8 bits	1-240	The endpoint on the destination.

1.4.3.1.5.2 When generated

The Simple_Desc_Desc_req is generated from Local Devices wishing to acquire the Simple Descriptor on the Remote Device corresponding to the supplied endpoint. The destination addressing on this primitive can be unicast only.

1.4.3.1.5.3 Effect on receipt

Upon receipt, a Remote Device shall create a unicast message to the source indicated by the Simple_Desc_req and include the Remote Device's Simple Descriptor corresponding to the supplied endpoint (see clause 1.4).

For ZigBee Version 1.0, the destination address and the NWKAddrofInterest shall be the same. For future upgrade ability, the destination address could be specified as a known address holding discovery information and the NWKAddrOfInterest could be specified as a query parameter.

1.4.3.1.6 Active_EP_req

1.4.3.1.6.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x05	Active_EP_req	(NWKAddrOfInterest)

Table 44 specifies the parameters for the Active_EP_req primitive.

Table 44 Active_EP_req parameters

Name	Type	Valid range	Description
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address for the request.

1.4.3.1.6.2 When generated

The Active_EP_req is generated from Local Devices wishing to acquire the list of endpoints on the Remote Device with Simple Descriptors. The destination addressing on this primitive can be unicast only.

1.4.3.1.6.3 Effect on receipt

Upon receipt, a Remote Device shall create a unicast message to the source indicated by the Active_EP_req and include the Remote Device's list of active endpoints.

For ZigBee Version 1.0, the destination address and the NWKAddrofInterest shall be the same. For future upgrade ability, the destination address could be specified as a known address holding discovery information and the NWKAddrOfInterest could be specified as a query parameter.

1.4.3.1.7 Match_Desc_req

1.4.3.1.7.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x06	Match_Desc_req	(NWKAddrOfInterest ProfileID, NumInClusters InClusterList NumOutClusters OutClusterList)

Table 45 specifies the parameters for the Match_Desc_req primitive.

Table 45 Match_Desc_req parameters

Name	Type	Valid range	Description
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address for the request.
ProfileID	Integer	0x0000-0xffff	Profile ID to be matched at the destination.
NumInClusters	Integer	0x00-0xff	The number of Input Clusters provided for matching within the InClusterList.

Table 45 Match_Desc_req parameters

InClusterList	1 byte * NumInClusters		List of Input ClusterIDs to be used for matching. The InClusterList is the desired list to be matched by the Remote Device (the elements of the InClusterList are the supported output clusters of the Local Device)
NumOutClusters	Integer	0x00-0xff	The number of Output Clusters provided for matching within OutClusterList.
OutClusterList	1 byte * NumOutClusters		List of Output ClusterIDs to be used for matching. The OutClusterList is the desired list to be matched by the Remote Device (the elements of the OutClusterList are the supported input clusters of the Local Device)

1.4.3.1.7.2 When generated

The Match_Desc_req is generated from Local Devices wishing to find Remote Devices supporting the match criteria, identified by responses citing the Remote Device address, endpoint supplying the match. The destination addressing on this primitive can be broadcast or unicast.

1.4.3.1.7.3 Effect on receipt

Upon receipt, a Remote Device shall evaluate the Simple Descriptors on all active endpoints for a match. A match shall be detected if the ProfileID matches and any of the elements of InClusterList or OutClusterList match corresponding elements of the active endpoint Simple Descriptor AppInClusterList or AppOutClusterList (see clause 1.4). Note that the NumInClusters and NumOutClusters fields can be set to 0 (zero) and the InClusterList and OutClusterList omitted whereby the match shall be entirely performed on ProfileID. If a match is detected, the Remote Device shall create a unicast message to the Local Device citing the Local Device address, endpoint the match was detected. The elements of InClusterList and OutClusterList are the desired list of clusters to be matched from the Local Device. The Local Device shall provide its input cluster information as OutClusterList and shall provide its output cluster information as InClusterList.

For ZigBee Version 1.0, the destination address and the NWKAddrofInterest shall be the same. For future upgrade ability, the destination address could be specified as a known address holding discovery information and the NWKAddrOfInterest could be specified as a query parameter.

1.4.3.1.8 Complex_Desc_req

1.4.3.1.8.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x10	Complex_Desc_req	(NWKAddrOfInterest)

Table 46 specifies the parameters for the Complex_Desc_req primitive.

Table 46 Complex_Desc_req parameters

Name	Type	Valid range	Description
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address for the request.

1.4.3.1.8.2 When generated

The Complex_Desc_req is generated from Local Devices wishing to acquire the Complex Descriptor on the Remote Device. The destination addressing on this primitive can be unicast only.

1.4.3.1.8.3 Effect on receipt

Upon receipt, a Remote Device shall create a unicast message to the source indicated by the Complex_Desc_req and include the Remote Device's Complex Descriptor (if this optional descriptor is supported on the Remote Device). If the Remote Device does not support the Complex Descriptor, a status of NOT_SUPPORTED shall be returned.

For ZigBee Version 1.0, the destination address and the NWKAddrofInterest shall be the same. For future upgrade ability, the destination address could be specified as a known address holding discovery information and the NWKAddrOfInterest could be specified as a query parameter.

1.4.3.1.9 User_Desc_req

1.4.3.1.9.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x11	User_Desc_req	(NWKAddrOfInterest)

Table 47 specifies the parameters for the User_Desc_req primitive.

Table 47 User_Desc_req parameters

Name	Type	Valid range	Description
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address for the request.

1.4.3.1.9.2 When generated

The User_Desc_req is generated from Local Devices wishing to acquire the User Descriptor on the Remote Device. The destination addressing on this primitive can be unicast only.

1.4.3.1.9.3 Effect on receipt

Upon receipt, a Remote Device shall create a unicast message to the source indicated by the User_Desc_req and include the Remote Device's Complex Descriptor (if this optional descriptor is supported on the Remote Device). If the Remote Device does not support the User Descriptor, a status of NOT_SUPPORTED shall be returned.

For ZigBee Version 1.0, the destination address and the NWKAddrofInterest shall be the same. For future upgrade ability, the destination address could be specified as a known address holding discovery information and the NWKAddrOfInterest could be specified as a query parameter.

1.4.3.1.10 Discovery_Register_req

1.4.3.1.10.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x12	Discovery_Register_req	(NWKAddr IEEEAddr)

Table 48specifies the parameters for the Discovery_Register_req primitive.

Table 48 Discovery_Register_req parameters

Name	Type	Valid range	Description
NWKAddr	Device Address	16 bit NWK address	NWK address for the Local Device.
IEEEAddr	Device Address	64 bit IEEE address	IEEE address for the Local Device.

1.4.3.1.10.2 When generated

The Discovery_Register_req is provided as a post Version 1.0 feature to enable devices on the network to notify the ZigBee Coordinator that the device wishes to register its discovery information. The destination addressing on this primitive can be unicast only and the destination address shall be that of the ZigBee Coordinator.

1.4.3.1.10.3 Effect on receipt

Upon receipt, the Remote Device (ZigBee Coordinator) shall create a unicast message to the source indicated by the Discovery_Register_req and include the status of the request. If the ZigBee Coordinator does not support the Discovery_Register_req, a status of NOT_SUPPORTED shall be returned. Additionally, if the Discovery_Register_req is supported, the Remote Device (ZigBee Coordinator) is expected to utilize the Device and Service Discovery commands described in this document to upload the discovery information from the Local Device. Future discovery requests could then be directed to the ZigBee Coordinator which will be able to describe device and service information for the Local Device.

1.4.3.1.11 End_Device_annce

1.4.3.1.11.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x13	End_Device_annce	(NWKAddr IEEEAddr)

Table 49 specifies the parameters for the End_Device_annce primitive.

Table 49 End_Device_annce parameters

Name	Type	Valid range	Description
NWKAddr	Device Address	16 bit NWK address	NWK address for the Local Device.
IEEEAddr	Device Address	64 bit IEEE address	IEEE address for the Local Device.

1.4.3.1.11.2 When generated

The End_Device_annce is provided to enable ZigBee end devices on the network to notify the ZigBee coordinator that the end device has joined or re-joined the network, identifying the end devices 64 bit IEEE address and new 16 bit NWK address. The destination addressing on this primitive is broadcast.[43]

1.4.3.1.11.3 Effect on receipt

Upon receipt, the Remote Device (ZigBee coordinator or source device for the binding operation) shall utilize the IEEEAddr in the message for a match with any binding table entries held in the Remote Device. If a match is detected, the Remote Device shall update its APS Information Block Address Map with the updated NWKAddr corresponding to the IEEEAddr received. [44]

1.4.3.1.12 User_Desc_set

1.4.3.1.12.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x14	User_Desc_set	(NWKAddrOfInterest, UserDescription)

Table 50 specifies the parameters for the User_Desc_req primitive.

Table 50 User_Desc_set parameters

Name	Type	Valid range	Description
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address for the request.
UserDescription	ASCII character string	16 characters	The user description to configure.

1.4.3.1.12.2 When generated

The User_Desc_set command is generated from a local device wishing to configure the user descriptor on a remote device. This command shall only use unicast destination addressing.

[43] CCB Comment #169
[44] Ibid

1.4.3.1.12.3 Effect on receipt

On receipt of this command, the remote device shall configure the user descriptor with the supplied data. The results of this command shall be communicated back to the local device through the User_Desc_conf command.

If this command is not supported or if a user descriptor does not exist, the return status provided with the User_Desc_conf command shall be set to NOT_SUPPORTED. If a user descriptor exists, the remote device shall configure it with the data supplied in the UserDescription field of the User_Desc_set command and the return status provided with the User_Desc_conf command shall be set to SUCCESS.[45]

1.4.3.2 End Device Bind, Bind and Unbind client services

Table 51 lists the primitives supported by Device Profile End Device Bind, Bind and Unbind Client Services. Each of these primitives will be discussed in the following sub-clauses.

Table 51 End Device Bind, Bind and Unbind Client Services primitives

End Device Bind, Bind and Unbind Client Services	Client Transmission	Server Processing
End_Device_Bind_req	O	O[a]
Bind_req	O	O[b]
Unbind_req	O	O[c]

[a] Shall minimally respond with a status of NOT_SUPPORTED
[b] Shall minimally respond with a status of NOT_SUPPORTED
[c] Shall minimally respond with a status of NOT_SUPPORTED

1.4.3.2.1 End_Device_Bind_req

1.4.3.2.1.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x20	End_Device_Bind_req	(LocalCoordinator BindingTarget[a] Endpoint ProfileID NumInClusters InClusterList NumOutClusters OutClusterList)

[a]CCB Comment #171

[45]CCB Comment #176

Table 52 specifies the parameters for the End_Device_Bind_req primitive.

Table 52 End_Device_Bind_req parameters

Name	Type	Valid range	Description
BindingTarget	Device Address	16 bit address	The address of the target for the binding. This can be either the ZigBee coordinator or the device itself if it is a router.[a]
Endpoint	8 bits	1-240	The endpoint on the generating device.[b]
ProfileID	Integer	0x0000-0xffff	ProfileID which is to be matched between two End_Device_Bind_req received at the ZigBee Coordinator within the timeout value pre-configured in the ZigBee Coordinator.
NumInClusters	Integer	0x00-0xff	The number of Input Clusters provided for end device binding within the InClusterList.
InClusterList	1 byte * NumInClusters		List of Input ClusterIDs to be used for matching. The InClusterList is the desired list to be matched by the Remote Device (the elements of the InClusterList are the supported output clusters of the Local Device).
NumOutClusters	Integer	0x00-0xff	The number of Output Clusters provided for matching within OutClusterList.
OutClusterList	1 byte * NumOutClusters		List of Output ClusterIDs to be used for matching. The OutClusterList is the desired list to be matched by the Remote Device (the elements of the InClusterList are the supported output clusters of the Remote Device).

[a] CCB Comment #171
[b] CCB Comment #211

1.4.3.2.1.2 When generated

The End_Device_Bind_req is generated from Local Device devices wishing to perform End Device Bind with a Remote Device. The End_Device_Bind_req is generated, typically based on some user action like a button press. The destination addressing on this primitive shall be unicast and the destination address shall be that of the ZigBee Coordinator.

1.4.3.2.1.3 Effect on receipt

The ZigBee Coordinator shall retain the End_Device_Bind_req for a pre-configured timeout duration awaiting a second End_Device_Bind_req. If the second request does not appear within the timeout period, the ZigBee Coordinator shall generate a TIMEOUT status and return it with the End_Device_Bind_rsp to the originating Local Device. Assuming the second End_Device_Bind_req is received within the timeout period, it shall be matched with the first request on the basis of the ProfileID, InClusterList and OutClusterList.

If no match of the ProfileID is detected or if the ProfileID matches but none of the InClusterList or OutClusterList elements match, a status of NO_MATCH shall be supplied to both Local Devices via

End_Device_Bind_rsp to each device. If a match of Profile ID and at least one input or output clusterID is detected, an End_Device_Bind_rsp with status SUCCESS shall be issued to each Local Device which generated the End_Device_Bind_req.

The ZigBee coordinator shall then determine the 64-bit IEEE address of each local device. If these addresses are not known, the ZigBee coordinator shall determine them by using the IEEE_Addr_req command and corresponding IEEE_Addr_rsp command.

In order to facilitate a toggle action the ZigBee Coordinator shall then issue an Unbind_req command to the BindingTarget, specifying any one of the matched ClusterID values. If the returned status value is NO_ENTRY then the ZigBee Coordinator shall issue a Bind_req command for each matched ClusterID value. Otherwise the ZigBee Coordinator shall conclude that the binding records are instead to be removed and shall issue an Unbind_req command for any further matched ClusterID values.

The initial Unbind_req and any subsequent Bind_reqs or Unbind_reqs, containing the matched clusters, shall be directed to the BindingTarget, specified in the first End_Device_Bind_req command, and constructed as follows. The SrcAddress and DstAddress fields shall contain the 64-bit IEEE addresses derived, as described above, from the network addresses of the originators of the first and second End_Device_Bind_req commands, respectively. Similarly, the SrcEndp and DstEndp fields shall contain the endpoints contained in the first and second End_Device_Bind_req commands, respectively.[46]

1.4.3.2.2 Bind_req

1.4.3.2.2.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x21	Bind_req	(SrcAddress, SrcEndp, ClusterID, DstAddress, DstEndp)

Table 53 specifies the parameters for the Bind_req primitive.

Table 53 Bind_req parameters

Name	Type	Valid range	Description
SrcAddress	IEEE Address	A valid 64-bit IEEE address	The IEEE address for the source.
SrcEndp	Integer	0x01-0xf0	The source endpoint for the binding entry.
ClusterID	Integer	0x00-0xff	The identifier of the cluster on the source device that is bound to the destination.
DstAddress	IEEE Address	A valid 64-bit IEEE address	The IEEE address for the destination.
DstEndp	Integer	0x01-0xf0	The destination endpoint for the binding entry.

[46] CCB Comment #171, 233, 236

1.4.3.2.2.2 When generated

The Bind_req is generated from Local Device devices wishing to create a Binding Table entry for the source and destination addresses contained as parameters. The destination addressing on this primitive shall be unicast only and the destination address must be that of the ZigBee Coordinator or to the SrcAddress itself. The Binding Manager is optionally supported on the source device (unless that device is also the ZigBee Coordinator) so that device shall issue a NOT_SUPPORTED status to the Bind_req if not supported.

1.4.3.2.2.3 Effect on receipt

Upon receipt, a Remote Device (ZigBee Coordinator or the device designated by SrcAddress) shall create a Binding Table entry based on the parameters supplied in the Bind_req if the Binding Manager is supported. The Remote Device shall then respond with SUCCESS if the entry has been created by the Binding Manager, else the Remote Device shall respond with NOT_SUPPORTED.

1.4.3.2.3 Unbind_req

1.4.3.2.3.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x22	Unbind_req	(SrcAddress, SrcEndp, ClusterID, DstAddress, DstEndp)

Table 54 specifies the parameters for the Unbind_req primitive.

Table 54 Unbind_req parameters

Name	Type	Valid range	Description
SrcAddress	IEEE Address	A valid 64-bit IEEE address	The IEEE address for the source.
SrcEndp	Integer	0x01-0xf0	The source endpoint for the binding entry.
ClusterID	Integer	0x00-0xff	The identifier of the cluster on the source device that is bound to the destination.
DstAddress	IEEE Address	A valid 64-bit IEEE address	The IEEE address for the destination.
DstEndp	Integer	0x01-0xf0	The destination endpoint for the binding entry.

1.4.3.2.3.2 When generated

The Unbind_req is generated from Local Device devices wishing to remove a Binding Table entry for the source and destination addresses contained as parameters. The destination addressing on this primitive shall be unicast only and the destination address must be that of the ZigBee Coordinator or the SrcAddress.

1.4.3.2.3.3 Effect on receipt

The Remote Device shall evaluate whether this request is supported. If the request is not supported, a Status of NOT_SUPPORTED shall be returned. If the request is supported, the Remote Device (ZigBee Coordinator or the SrcAddress) shall remove a Binding Table entry based on the parameters supplied in the Unbind_req. If the SrcAddress is specified and the Binding Manager is unsupported on that remote device, a status of NOT_SUPPORTED shall be returned. If a Binding Table entry for the SrvAddress, SrcEndp, ClusterID, DstAddress, DstEndp contained as parameters does not exist, the Remote Device shall respond with NO_ENTRY. Otherwise, the Remote Device shall delete the indicated Binding Table entry and respond with SUCCESS.

1.4.3.3 Network Management Client Services

Table 55 lists the primitives supported by Device Profile Network Management Client Services. Each of these primitives will be discussed in the following sub-clauses.

Table 55 Network Management Client Services primitives

Network Management Client Services	Client Transmission	Server Processing
Mgmt_NWK_Disc_req	O	O[a]
Mgmt_Lqi_req	O	O[b]
Mgmt_Rtg_req	O	O[c]
Mgmt_Bind_req	O	O[d]
Mgmt_Leave_req	O	O[e]
Mgmt_Direct_Join_req	O	O[f]

[a] Shall minimally respond with a status of NOT_SUPPORTED
[b] Shall minimally respond with a status of NOT_SUPPORTED
[c] Shall minimally respond with a status of NOT_SUPPORTED
[d] Shall minimally respond with a status of NOT_SUPPORTED
[e] Shall minimally respond with a status of NOT_SUPPORTED
[f] Shall minimally respond with a status of NOT_SUPPORTED

1.4.3.3.1 Mgmt_NWK_Disc_req

1.4.3.3.1.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x30	Mgmt_NWK_Disc_req	(ScanChannels ScanDuration StartIndex[a])

[a]CCB Comment #243

Table 56 specifies the parameters for the Mgmt_NWK_Disc_req primitive.

Table 56 Mgmt_NWK_Disc_req parameters

Name	Type	Valid range	Description
ScanChannels	Bitmap	32 bit field	See sub-clause 2.3.2.1 for details on NLME-NETWORK-DISCOV-ERY.request ScanChannels parameter.
ScanDuration	Integer	0x00-0x0e	A value used to calculate the length of time to spend scanning each channel. The time spent scanning each channel is (aBaseSuperframeDuration * (2n + 1)) symbols, where n is the value of the ScanDuration parameter. For more information on MAC sub-layer scanning (see [B1]).[a]
StartIndex	Integer	0x00-0xff	Starting index within the resulting NLME-NETWORK-DISCOVERY.con-firm NetworkList to begin reporting for the Mgmt_NWK_Disc_rsp.

[a]CCB Comment #243

1.4.3.3.1.2 When generated

The Mgmt_NWK_Disc_req is generated from Local Device devices requesting that the Remote Device execute a Scan to report back networks in the vicinity of the Local Device. The destination addressing on this primitive shall be unicast.

1.4.3.3.1.3 Effect on receipt

The Remote Device shall execute an NLME-NETWORK-DISCOVERY.request using the ScanChannels and ScanDuration parameters supplied with the Mgmt_NWK_Disc_req command. The results of the Scan shall be reported back to the Local Device via the Mgmt_NWK_Disc_rsp command.

If this command is not supported in the Remote Device, the return status provided with the Mgmt_NWK_Disc_rsp shall be NOT_SUPPORTED. If the scan was successful, the Mgmt_NWK_Disc_rsp command shall contain a status of SUCCESS and the results of the scan shall be reported, beginning with the StartIndex element of the NetworkList. If the scan was unsuccessful, the Mgmt_NWK_Disc_rsp command shall contain the error code reported in the NLME-NETWORK-DISCOVERY.confirm primitive.[47]

1.4.3.3.2 Mgmt_Lqi_req

1.4.3.3.2.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x31	Mgmt_Lqi_req	(StartIndex)

[47]CCB Comment ##237, 243

Table 57 specifies the parameters for the Mgmt_Lqi_req primitive.

Table 57 Mgmt_Lqi_req parameters

Name	Type	Valid range	Description
StartIndex	Integer	0x00-0xff	Starting Index for the requested elements of the Neighbor Table.

1.4.3.3.2.2 When generated

The Mgmt_Lqi_req is generated from Local Device devices wishing to obtain a neighbor list for the Remote Device along with associated LQI values to each neighbor. The destination addressing on this primitive shall be unicast only and the destination address must be that of a ZigBee Coordinator or ZigBee Router.

1.4.3.3.2.3 Effect on receipt

Upon receipt, a Remote Device (ZigBee Router or ZigBee Coordinator) shall retrieve the entries of the neighbor table and associated LQI values via the NLME-GET.request primitive (for the *nwkNeighborTable* attribute) and report the resulting neighbor table (obtained via the NLME-GET.confirm primitive) via the Mgmt_Lqi_rsp command.

If this command is not supported in the Remote Device, the return status provided with the Mgmt_Lqi_rsp shall be NOT_SUPPORTED. If the neighbor table was obtained successfully, the Mgmt_Lqi_rsp command shall contain a status of SUCCESS and the neighbor table shall be reported, beginning with the element in the list enumerated as StartIndex. If the neighbor table was not obtained successfully, the Mgmt_Lqi_rsp command shall contain the error code reported in the NLME-GET.confirm primitive.[48]

1.4.3.3.3 Mgmt_Rtg_req

1.4.3.3.3.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x32	Mgmt_Rtg_req	(StartIndex)

Table 58 specifies the parameters for the Mgmt_Rtg_req primitive.

Table 58 Mgmt_Rtg_req parameters

Name	Type	Valid range	Description
StartIndex	Integer	0x00-0xff	Starting Index for the requested elements of the Routing Table.

1.4.3.3.3.2 When generated

The Mgmt_Rtg_req is generated from Local Device devices wishing to retrieve the contents of the Routing Table from the Remote Device. The destination addressing on this primitive shall be unicast only and the destination address must be that of the ZigBee Router or ZigBee Coordinator.

[48] CCB Comment #237, 247

1.4.3.3.3.3 Effect on receipt

Upon receipt, a Remote Device (ZigBee Coordinator or ZigBee Router) shall retrieve the entries of the routing table from the NWK layer via the NLME-GET.request primitive (for the *nwkRouteTable* attribute) and report the resulting routing table (obtained via the NLME-GET.confirm primitive) via the Mgmt_Rtg_rsp command.

If the Remote Device does not support this optional management request, it shall return a Status of NOT_SUPPORTED. If the routing table was obtained successfully, the Mgmt_Rtg_req command shall contain a status of SUCCESS and the routing table shall be reported, beginning with the element in the list enumerated as StartIndex. If the routing table was not obtained successfully, the Mgmt_Rtg_rsp command shall contain the error code reported in the NLME-GET.confirm primitive.[49]

1.4.3.3.4 Mgmt_Bind_req

1.4.3.3.4.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x33	Mgmt_Bind_req	(StartIndex)

Table 59 specifies the parameters for the Mgmt_Bind_req primitive.

Table 59 Mgmt_Bind_req parameters

Name	Type	Valid range	Description
StartIndex	Integer	0x00-0xff	Starting Index for the requested elements of the Binding Table.

1.4.3.3.4.2 When generated

The Mgmt_Bind_req is generated from Local Device devices wishing to retrieve the contents of the Binding Table from the Remote Device. The destination addressing on this primitive shall be unicast only and the destination address must be that of the ZigBee Router or ZigBee Coordinator.

1.4.3.3.4.3 Effect on receipt

Upon receipt, a Remote Device (ZigBee Coordinator or ZigBee Router) shall retrieve the entries of the binding table from the APS sub-layer via the APSME-GET.request primitive (for the *apsBindingTable* attribute) and report the resulting binding table (obtained via the APSME-GET.confirm primitive) via the Mgmt_Bind_rsp command.

If the Remote Device does not support this optional management request, it shall return a status of NOT_SUPPORTED. If the binding table was obtained successfully, the Mgmt_Bind_rsp command shall contain a status of SUCCESS and the binding table shall be reported, beginning with the element in the list enumerated as StartIndex. If the binding table was not obtained successfully, the Mgmt_Bind_rsp command shall contain the error code reported in the APSME-GET.confirm primitive.[50]

[49] CCB Comment #224, 237
[50] CCB Comment #237, 248

1.4.3.3.5 Mgmt_Leave_req

1.4.3.3.5.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x34	Mgmt_Leave_req	(DeviceAddress)

Table 60 specifies the parameters for the Mgmt_Leave_req primitive.

Table 60 Mgmt_Leave_req parameters

Name	Type	Valid range	Description
DeviceAddress	Device Address	An extended 64 bit, IEEE address	See sub-clause 2.3.8.1 for details on the DeviceAddress parameter within NLME-LEAVE.request.

1.4.3.3.5.2 When generated

The Mgmt_Leave_req is generated from Local Device devices requesting that a Remote Device leave the network or to request that another device leave the network. The Mgmt_Leave_req is generated by a management application which directs the request to a Remote Device where the NLME-LEAVE.request is to be executed using the parameter supplied by Mgmt_Leave_req.

1.4.3.3.5.3 Effect on receipt

Upon receipt, the remote device shall issue the NLME-LEAVE.request primitive using the DeviceAddress parameter supplied with the Mgmt_Leave_req command. The results of the leave attempt shall be reported back to the local device via the Mgmt_Leave_rsp command.

If the remote device does not support this optional management request, it shall return a status of NOT_SUPPORTED. If the leave attempt was executed successfully, the Mgmt_Leave_rsp command shall contain a status of SUCCESS. If the leave attempt was not executed successfully, the Mgmt_Leave_rsp command shall contain the error code reported in the NLME-LEAVE.confirm primitive.[51]

1.4.3.3.6 Mgmt_Direct_Join_req

1.4.3.3.6.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x35	Mgmt_Direct_Join_req	(DeviceAddress CapabilityInformation[a])

[a]CCB Comment #241, 249

[51]CCB Comment #237

Table 61 specifies the parameters for the Mgmt_Direct_Join_req primitive.

Table 61 Mgmt_Direct_Join_req parameters

Name	Type	Valid range	Description
DeviceAddress	Device Address	An extended 64 bit, IEEE address	See sub-clause 2.3.6.1 for details on the DeviceAddress parameter within NLME-JOIN.request.
CapabilityInformation	Bitmap	See Figure 32.	The operating capabilities of the device being directly joined.[a]

[a]CCB Comment #241, 249

1.4.3.3.6.2 When generated

The Mgmt_Direct_Join_req is generated from Local Device devices requesting that a Remote Device permit a device designated by DeviceAddress to join the network directly. The Mgmt_Direct_Join_req is generated by a management application which directs the request to a Remote Device where the NLME-DIRECT-JOIN.request is to be executed using the parameter supplied by Mgmt_Direct_Join_req. [52]

1.4.3.3.6.3 Effect on receipt

Upon receipt, the remote device shall issue the NLME-DIRECT-JOIN.request primitive using the DeviceAddress and CapabilityInformation parameters supplied with the Mgmt_Direct_Join_req command. The results of the direct join attempt shall be reported back to the local device via the Mgmt_Direct_Join_rsp command.

If the remote device does not support this optional management request, it shall return a status of NOT_SUPPORTED. If the direct join attempt was executed successfully, the Mgmt_Direct_Join_rsp command shall contain a status of SUCCESS. If the direct join attempt was not executed successfully, the Mgmt_Direct_Join_rsp command shall contain the error code reported in the NLME-DIRECT-JOIN.confirm primitive.[53]

1.4.4 Server services

The Device Profile Server Services supports the processing of device and service discovery requests, end device bind requests, bind requests, unbind requests and network management requests. Additionally, Server Services support transmission of these responses back to the requesting device. Table 6 lists the primitives supported by Device Profile Server Services.

1.4.4.1 Device and Service Discovery Server Services

Table 62 lists the primitives supported by Device Profile Device and Service Discovery Server Services. Each of these primitives will be discussed in the following sub-clauses.

Table 62 Device and Service Discovery Server Services primitives

Device and Service Discovery Server Services	Server Processing
NWK_addr_rsp	M
IEEE_addr_rsp	M

[52]CCB Comment #249

[53]CCB Comment #237, 241, 249

Table 62 Device and Service Discovery Server Services primitives

Node_Desc_rsp	M
Power_Desc_rsp	M
Simple_Desc_rsp	M
Active_EP_rsp	M
Match_Desc_rsp	M
Complex_Desc_rsp	O[a]
User_Desc_rsp	O[b]
Discovery_Register_rsp	O[c]
User_Desc_conf[d]	O[e]

[a] Must minimally respond with a status of NOT_SUPPORTED
[b] Must minimally respond with a status of NOT_SUPPORTED
[c] Must minimally respond with a status of NOT_SUPPORTED
[d] CCB Comment #169, 176
[e] Must minimally respond with a status of NOT_SUPPORTED

1.4.4.1.1 NWK_addr_rsp

1.4.4.1.1.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x80	NWK_addr_rsp	(Status IEEEAddrRemoteDev NWKAddrRemoteDev NumAssocDev StartIndex NWKAddrAssocDevList)

Table 63 specifies the parameters for the NWK_addr_rsp primitive.

Table 63 NWK_addr_rsp parameters

Name	Type	Valid range	Description
Status	Integer	SUCCESS, INV_REQUESTTYPE or DEVICE_NOT_FOUND	Valid status shall be one of the following: SUCCESS = 0x00. INV_REQUESTTYPE = 0x01. DEVICE_NOT_FOUND = 0x02. Reserved = 0x03-0xff. The status of the NWK_addr_req command.[a]
IEEEAddrRemoteDev	Device Address	An extended 64 bit, IEEE address	64 bit address for the Remote Device.

Table 63 NWK_addr_rsp parameters

NWKAddrRemoteDev	Device Address	A 16 bit, NWK address	16 bit address for the Remote Device.
NumAssocDev	Integer	0x00-0xff	Count of the number of associated devices to the Remote Device and the number of 16 bit short addresses to follow. NumAssocDev shall be 0 if there are no associated devices to Remote Device and the StartIndex and NWKAddrAssocDevList shall be null in this case.
StartIndex	Integer	0x00-0xff	Starting index into the list of associated devices for this report.
NWKAddrAssocDevList	Device Address List	List of 16 bit short addresses, each with range 0x0000-ffff, NumAssocDev in length	A list of 16 bit addresses, one corresponding to each associated device to the Remote Device. The count of the 16 bit addresses in NWKAddrAssocDevList is supplied in NumAssocDev.

[a]CCB Comment #223

1.4.4.1.1.2 When generated

The NWK_addr_rsp is generated from Remote Device devices receiving a broadcast NWK_addr_req who detect a match of the IEEEAddr parameter with their own IEEE address. The destination addressing on the response primitive is unicast.

1.4.4.1.1.3 Effect on receipt

Upon receipt, a Remote Device shall attempt to match the IEEEAddr in the NWK_addr_req with the Remote Device's IEEE address. If no match exists, the request shall be discarded and no response message processing performed. If a match is detected, the Remote Device shall create a unicast message to the source indicated by the NWK_addr_req. Included in the NWK_addr_rsp payload is the IEEE address that matched from the NWK_addr_req and the NWK address of the Remote Device. Additionally, if the Remote Device is the ZigBee coordinator or router with associated devices, the Remote Device shall supply a count of its associated devices along with a list of all 16 bit NWK addresses for its associated devices.[54]

The DEVICE_NOT_FOUND status shall be treated as reserved for Version 1.0 and is to be used only with future unicast forms of the NWK_addr_req primitive.

[54]CCB Comment #171

1.4.4.1.2 IEEE_addr_rsp

1.4.4.1.2.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x81	IEEE_addr_rsp	(Status IEEEAddrRemoteDev NWKAddrRemoteDev NumAssocDev StartIndex NWKAddrAssocDevList)

Table 64 specifies the parameters for the IEEE_addr_rsp primitive.

Table 64 IEEE_addr_rsp parameters

Name	Type	Valid range	Description
Status	Integer	SUCCESS, INV_REQUESTTYPE or DEVICE_NOT_FOUND	The status of the IEEE_addr_req command.[a]
IEEEAddrRemoteDev	Device Address	An extended 64 bit, IEEE address	64 bit address for the Remote Device.
NWKAddrRemoteDev	Device Address	A 16 bit, NWK address	16 bit address for the Remote Device.
NumAssocDev	Integer	0x00-0xff	Count of the number of associated devices to the Remote Device and the number of 16 bit short addresses to follow. NumAssocDev shall be 0 if the RequestType in the request is Extended Response and there are no associated devices to Remote Device and the NWKAddrAssocDev-List shall be null in this case. If the RequestType in the request is for a Single Device Response, this field and the ones following shall be NULL.
StartIndex	Integer	0x00-0xff	Starting index into the list of associated devices for this report.
NWKAddrAssocDevList	Device Address List	List of 16 bit short addresses, each with range 0x0000-ffff, NumAssocDev in length	A list of 16 bit addresses, one corresponding to each associated device to Remote Device. The count of the 16 bit addresses in NWKAddrAssocDevList is supplied in NumAssocDev. This field shall be NULL if the NumAssocDev is 0 or NULL.

[a]CCB Comment #223

1.4.4.1.2.2 When generated

The IEEE_addr_rsp is generated from Remote Devices in response to the unicast IEEE_addr_req inquiring as to the 64 bit IEEE address of the Remote Device. The destination addressing on this response primitive shall be unicast.

1.4.4.1.2.3 Effect on receipt

Upon receipt, a Remote Device shall create a unicast message to the source indicated by the IEEE_addr_req and report its IEEE address as the first entry in the response payload. Additionally, if the RequestType is Extended Response and the Remote Device is the ZigBee coordinator or router with associated devices, the Remote Device shall first include its own 64 bit IEEE address and then shall also supply a count of its associated devices along with a list of all 16 bit addresses for its associated devices beginning with StartIndex. If the RequestType is Extended Response and the Remote Device has no associated devices, the NumAssocDev field shall be 0 and the StartIndex plus NWKAddrAssocDevList shall be NULL. If the RequestType is Single Device Response, the NumAssocDev and NKWAddrAssocDevList shall both be NULL.[55]

The DEVICE_NOT_FOUND status shall be treated as reserved for Version 1.0 and is to be used only with future forms of the IEEE_addr_req primitive.

1.4.4.1.3 Node_Desc_rsp

1.4.4.1.3.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x82	Node_Desc_rsp	(Status NWKAddrOfInterest NodeDescriptor)

Table 65 specifies the parameters for the Node_Desc_rsp primitive.

Table 65 Node_Desc_rsp parameters

Name	Type	Valid range	Description
Status	Integer	SUCCESS or DEVICE_NOT_FOUND	The status of the Node_Desc_req command.[a]
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address for the request.
NodeDescriptor	Node Descriptor		See the Node Descriptor format in sub-clause 1.3.3.4.

[a]CCB Comment #223

1.4.4.1.3.2 When generated

The Node_Desc_rsp is generated by the Remote Device in response to a Node_Desc_req directed to the Remote Device. A Status of SUCCESS is supplied with the response.

[55]CCB Comment #171

1.4.4.1.3.3 Effect on receipt

The Node_Desc_req requests retrieval of the Remote Device's Node Descriptor. The Remote Device shall formulate a Node_Desc_rsp with a Status of SUCCESS, including the Remote Device's Node Descriptor and transmit the Node_Desc_rsp to the Local Device.

The DEVICE_NOT_FOUND status shall be treated as reserved for Version 1.0 and is to be used only with future forms of the primitive.

1.4.4.1.4 Power_Desc_rsp

1.4.4.1.4.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x83	Power_Desc_rsp	(Status NWKAddrOfInterest PowerDescriptor)

Table 66 specifies the parameters for the Power_Desc_rsp primitive.

Table 66 Power_Desc_rsp parameters

Name	Type	Valid range	Description
Status	Integer	SUCCESS or DEVICE_NOT_FOUND	The status of the Power_Desc_req command.[a]
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address for the request.
PowerDescriptor	Power Descriptor		See the Node Power Descriptor format in sub-clause 1.3.3.5.

[a]CCB Comment #223

1.4.4.1.4.2 When generated

The Power_Desc_rsp is generated by the Remote Device in response to a Power_Desc_req directed to the Remote Device. A Status of SUCCESS is supplied with the response.

1.4.4.1.4.3 Effect on receipt

The Power_Desc_req requests retrieval of the Remote Device's Node Power Descriptor. The Remote Device shall formulate a Power_Desc_rsp with a Status of SUCCESS, including the Remote Device's Node Power Descriptor and transmit the Power_Desc_rsp to the Local Device.

The DEVICE_NOT_FOUND status shall be treated as reserved for Version 1.0 and is to be used only with future forms of the primitive.

1.4.4.1.5 Simple_Desc_rsp

1.4.4.1.5.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x84	Simple_Desc_rsp	(Status NWKAddrOfInterest Length SimpleDescriptor)

Table 67 specifies the parameters for the Simple_Desc_rsp primitive.

Table 67 Simple_Desc_rsp parameters

Name	Type	Valid range	Description
Status	Integer	SUCCESS, INVALID_EP, NOT_ACTIVE or DEVICE_NOT_FOUND	The status of the Simple_Desc_req command.[a]
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address for the request.
Length	Integer	0x00-0xff	Length in bytes of the Simple Descriptor to follow.
SimpleDescriptor	Simple Descriptor		See the Simple Descriptor format in sub-clause 1.3.3.6. This field shall be NULL if a Status of INVALID_EP or NOT_ACTIVE is supplied.

[a]CCB Comment #223

1.4.4.1.5.2 When generated

The Simple_Desc_rsp is generated in response to a Simple_Desc_req. The request contains an endpoint for which the Simple Descriptor is requested.

1.4.4.1.5.3 Effect on receipt

When the Simple_Desc_req is presented, the endpoint is checked for valid range and then the endpoint parameter is checked with the list of Simple Descriptors in the Remote Device associated with active endpoints. If an endpoint value of 0 (zero) or greater than 240 is detected, the Status is set to INVALID_EP, the SimpleDescriptor field is set NULL and the Simple_Desc_rsp is supplied back to the requestor. If the endpoint field is valid but the endpoint field is not described by a Simple Descriptor on the Remote Device, the Status is set to NOT_ACTIVE, and the Simple Descriptor set to NULL and the response supplied. Else, the Status is set to SUCCESS, and the Simple Descriptor associated with the indicated endpoint is supplied in the response.

The DEVICE_NOT_FOUND status shall be treated as reserved for Version 1.0 and is to be used only with future forms of the primitive.

1.4.4.1.6 Active_EP_rsp

1.4.4.1.6.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x85	Active_EP_rsp	(Status NWKAddrOfInterest ActiveEPCount ActiveEPList)

Table 68 specifies the parameters for the Active_EP_rsp primitive.

Table 68 Active_EP_rsp parameters

Name	Type	Valid range	Description
Status	Integer	SUCCESS or DEVICE_NOT_FOUND	The status of the Active_EP_req command.[a]
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address for the request.
ActiveEPCount	Integer	0x00-0xff	The count of active endpoints on the Remote Device.
ActiveEPList			List of bytes each of which represents an 8 bit endpoint.

[a]CCB Comment #223

1.4.4.1.6.2 When generated

The Active_EP_rsp is generated in response to an Active_EP_req.

1.4.4.1.6.3 Effect on receipt

Upon receipt of the Active_EP_req, the Remote Device shall determine all endpoints supporting a Simple Descriptor within the Remote Device and shall provide the count within ActiveEPCount and shall supply the list of active endpoints as a string of bytes of length ActiveEPCount. A Status of SUCCESS is supplied along with the response parameters and returned in the Active_EP_rsp.

The DEVICE_NOT_FOUND status shall be treated as reserved for Version 1.0 and is to be used only with future forms of the primitive.

1.4.4.1.7 Match_Desc_rsp

1.4.4.1.7.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x86	Match_Desc_rsp	(Status NWKAddrOfInterest MatchLength MatchList)

Table 69 specifies the parameters for the Match_Desc_rsp primitive.

Table 69 Match_Desc_rsp parameters

Name	Type	Valid range	Description
Status	Integer	SUCCESS or DEVICE_NOT_FOUND	The status of the Match_Desc_req command.[a]
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address for the request.
MatchLength	Integer	0x00-0xff	The count of endpoints on the Remote Device that match the request criteria.
MatchList			List of bytes each of which represents an 8 bit endpoint.

[a]CCB Comment #223

1.4.4.1.7.2 When generated

The Match_Desc_rsp is generated when a Remote Device has received a Match_Desc_req and has verified a match of the ProfileID parameter and any of the elements of the InClusterList or OutClusterList with any Simple Descriptor held on the Remote Device.

1.4.4.1.7.3 Effect on receipt

When the Match_Desc_req is received, the Remote Device shall attempt to match the ProfileID, InClusterList or OutClusterList with all Simple Descriptors on the Remote Device. The ProfileID must match exactly, however, a match shall still be noted if any of the InClusterList or OutClusterList elements match. If no match is detected, the Match_Desc_req shall be discarded and no response provided. If a match is detected, the Remote Device shall create a response to the Local Device providing the count and list of endpoints along with a status of SUCCESS.

The DEVICE_NOT_FOUND status shall be treated as reserved for Version 1.0 and is to be used only with future forms of the primitive.

1.4.4.1.8 Complex_Desc_rsp

1.4.4.1.8.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x90	Complex_Desc_rsp	(Status NWKAddrOfInterest Length ComplexDescriptor)

Table 70 specifies the parameters for the Complex_Desc_rsp primitive.

Table 70 Complex_Desc_rsp parameters

Name	Type	Valid range	Description
Status	Integer	SUCCESS or NOT_SUPPORTED	The status of the Complex_Desc_req command.[a]
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address for the request.
Length	Integer	0x00-0xff	Length of the Complex Descriptor in bytes. This field shall be omitted if the Status is NOT_SUPPORTED.
ComplexDescriptor	Complex Descriptor		See the Complex Descriptor format in sub-clause 1.3.3.7. This field shall be NULL if the Status is NOT_SUPPORTED.

[a]CCB Comment #223

1.4.4.1.8.2 When generated

The Complex_Desc_rsp is generated by devices receiving the Complex_Desc_req and who support the optional Complex Descriptor (see sub-clause 1.3.3.7).

1.4.4.1.8.3 Effect on receipt

Upon receipt of the Complex_Desc_rsp, the Remote Device determines if the Complex Descriptor is supported. If the Complex Descriptor is not supported on the Remote Device, a Status of NOT_SUPPORTED is returned with the Complex_Desc_rsp. If the Complex Descriptor is supported, the Remote Device shall determine the Length of the Complex Descriptor in bytes and store that in the Length parameter of the response. The contents of the Complex Descriptor shall be included in the ComplexDescriptor parameter, a Status of SUCCESS applied and the Complex_Desc_rsp returned to the requesting Local Device.

The DEVICE_NOT_FOUND status shall be treated as reserved for Version 1.0 and is to be used only with future forms of the primitive.

1.4.4.1.9 User_Desc_rsp

1.4.4.1.9.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x91	User_Desc_rsp	(Status NWKAddrOfInterest Length UserDescriptor)

Table 71 specifies the parameters for the User_Desc_rsp primitive.

Table 71 User_Desc_rsp parameters

Name	Type	Valid range	Description
Status	Integer	SUCCESS or NOT_SUPPORTED	The status of the User_Desc_req command.[a]
NWKAddrOfInterest	Device Address	16 bit NWK address	NWK address for the request.
Length	Integer	0x00-0xff	Length of the User Descriptor in bytes. This field shall be omitted if the Status is NOT_SUPPORTED.
UserDescriptor	User Descriptor		See the User Descriptor format in sub-clause 1.3.3.8. This field shall be NULL if the Status is NOT_SUPPORTED.

[a]CCB Comment #223

1.4.4.1.9.2 When generated

The User_Desc_rsp is generated by devices receiving the User_Desc_req and who support the optional User Descriptor (see sub-clause 1.3.3.8).

1.4.4.1.9.3 Effect on receipt

Upon receipt of the User_Desc_rsp, the Remote Device determines if the User Descriptor is supported. If the User Descriptor is not supported on the Remote Device, a Status of NOT_SUPPORTED is returned with the User_Desc_rsp. If the User Descriptor is supported, the Remote Device shall determine the Length of the User Descriptor in bytes and store that in the Length parameter of the response. The contents of the User Descriptor shall be included in the UserDescriptor parameter, a Status of SUCCESS applied and the User_Desc_rsp returned to the requesting Local Device.

The DEVICE_NOT_FOUND status shall be treated as reserved for Version 1.0 and is to be used only with future forms of the primitive.

1.4.4.1.10 Discovery_Register_rsp

1.4.4.1.10.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x92	Discovery_Register_rsp	(Status)

Table 72 specifies the parameters for the Discovery_Register_rsp primitive.

Table 72 Discovery_Register_rsp parameters

Name	Type	Valid range	Description
Status	Integer	SUCCESS or NOT_SUPPORTED	The status of the Discovery_Register_req command.[a]

[a]CCB Comment #223

1.4.4.1.10.2 When generated

The Discovery_Register_rsp is generated by devices receiving the Discovery_Register_req and who support the optional post Version 1.0 discovery registration procedure.

1.4.4.1.10.3 Effect on receipt

Upon receipt of the Discovery_Register_rsp, the Remote Device determines if discovery registration is supported. For Version 1.0, a status of NOT_SUPPORTED shall be returned.[56]

1.4.4.1.11 User_Desc_conf

1.4.4.1.11.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0x94	User_Desc_conf	(Status)

Table 73 specifies the parameters for the User_Desc_conf primitive.

Table 73 User_Desc_conf parameters

Name	Type	Valid range	Description
Status	Integer	SUCCESS or NOT_SUPPORTED	The status of the User_Desc_set command.

1.4.4.1.11.2 When generated

The User_Desc_conf command is generated in response to a User_Desc_conf command. If this command is not supported or a user description does not exist, a status of NOT_SUPPORTED shall be returned. Otherwise, the Remote Device shall configure the user descriptor and return a status of SUCCESS.

1.4.4.1.11.3 Effect on receipt

The local device is notified of the results of its attempt to configure the user descriptor on a remote device.[57]

[56]CCB Comment #169
[57]CCB Comment #176

1.4.4.2 End Device Bind, Bind and Unbind server services

Table 74 lists the primitives supported by Device Profile End Device Bind, Bind and Unbind Server Services. Each of these primitives will be discussed in the following sub-clauses.

Table 74 End Device Bind, Bind and Unbind Server Services primitives

End Device Bind, Bind and Unbind Server Services	Server Processing
End_Device_Bind_rsp	O[a]
Bind_rsp	O[b]
Unbind_rsp	O[c]

[a] Must minimally respond with a status of NOT_SUPPORTED
[b] Must minimally respond with a status of NOT_SUPPORTED
[c] Must minimally respond with a status of NOT_SUPPORTED

1.4.4.2.1 End_Device_Bind_rsp

1.4.4.2.1.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0xA0	End_Device_Bind_rsp	(Status)

Table 75 specifies the parameters for the End_Device_Bind_rsp primitive.

Table 75 End_Device_Bind_rsp parameters

Name	Type	Valid range	Description
Status	Integer	SUCCESS, NOT_SUPPORTED, TIMEOUT or NO_MATCH	The status of the End_Device_Bind_req command.[a]

[a]CCB Comment #223

1.4.4.2.1.2 When generated

The End_Device_Bind_rsp is generated by the ZigBee Coordinator in response to an End_Device_Bind_req and contains the status of the request. A Status of NOT_SUPPORTED indicates that the request was directed to a device which was not the ZigBee Coordinator or that the ZigBee Coordinator does not support End Device Binding. Else, End_Device_Bind_req processing is performed as described below including transmission of the End_Device_Bind_rsp.

1.4.4.2.1.3 Effect on receipt

When an End_Device_Bind_req is received, determination is made if a Status of NOT_SUPPORTED is warranted as indicated in the previous section. Assuming this device is the ZigBee Coordinator, if this is the first End_Device_Bind_req submitted for evaluation, it shall be stored and a timer started which expires at a pre-configured timeout value. This timeout values shall be a configurable item on the ZigBee Coordinator. If

the timer expires before a second End_Device_Bind_req is received, a Status of TIMEOUT is returned. Else, if a second End_Device_Bind_req is received within the timeout window, the two End_Device_Bind_req's are compared for a match. A Status of NO_MATCH indicates that two End_Device_Bind_req were evaluated for a match but either the ProfileID parameters did not match or the ProfileID parameter matched but there was no match of any element of the InClusterList or OutClusterList. A Status of SUCCESS means that a match was detected and that a resulting Bind_req has been directed to the parent device of the Local Device supplying the End_Device_Bind_req which supplied matched elements of the OutClusterList.[58]

1.4.4.2.2 Bind_rsp

1.4.4.2.2.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0xA1	Bind_rsp	(Status)

Table 76 specifies the parameters for the Bind_rsp primitive.

Table 76 Bind_rsp parameters

Name	Type	Valid range	Description
Status	Integer	SUCCESS, NOT_SUPPORTED or TABLE_FULL	The status of the Bind_req command.[a]

[a]CCB Comment #223

1.4.4.2.2.2 When generated

The Bind_rsp is generated in response to a Bind_req. If the Bind_req is processed and the Binding Table entry committed on the Remote Device, a Status of SUCCESS is returned. If the Remote Device is not the ZigBee Coordinator or the SrcAddress, a Status of NOT_SUPPORTED is returned. If the Remote Device is the ZigBee Coordinator or SrcAddress but does not have Binding Table resources for the request, a Status of TABLE_FULL is returned.

1.4.4.2.2.3 Effect on receipt

Upon receipt, error checking is performed on the request as described in the previous section. Assuming the Status is SUCCESS, the parameters from the Bind_req are entered into the Binding Table at the Remote Device via the APSME-BIND.request primitive.

[58]CCB Comment 3171

1.4.4.2.3 Unbind_rsp

1.4.4.2.3.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0xA2	Unbind_rsp	(Status)

Table 77 specifies the parameters for the Unbind_req primitive.

Table 77 Unbind_rsp parameters

Name	Type	Valid range	Description
Status	Integer	SUCCESS, NOT_SUPPORTED or TABLE_FULL	The status of the Bind_req command.[a]

[a]CCB Comment #223

1.4.4.2.3.2 When generated

The Unbind_rsp is generated in response to an Unbind_req. If the Unbind_req is processed and the corresponding Binding Table entry is removed from the Remote Device, a Status of SUCCESS is returned. If the Remote Device is not the ZigBee Coordinator or the SrcAddress, a Status of NOT_SUPPORTED is returned. If the Remote Device is the ZigBee Coordinator or SrcAddress but does not have a Binding Table entry corresponding to the parameters received in the request, a Status of NO_ENTRY is returned.

1.4.4.2.3.3 Effect on receipt

Upon receipt, error checking is performed on the request as described in the previous section. Assuming the Status is SUCCESS, the parameters from the Unbind_req are used to find the corresponding entry to remove from the Binding Table at the Remote Device via the APSME-UNBIND.request primitive.

1.4.4.3 Network Management server services

Table 78 lists the primitives supported by Device Profile Network Management Server Services. Each of these primitives will be discussed in the following sub-clauses.

Table 78 Network Management Server Services primitives

Network Management Server Services	Server Processing
Mgmt_NWK_Disc_rsp	O[a]
Mgmt_Lqi_rsp	O[b]
Mgmt_Rtg_rsp	O[c]
Mgmt_Bind_rsp	O[d]
Mgmt_Leave_rsp	O[e]
Mgmt_Direct_Join_rsp	O[f]

[a] Must minimally respond with a status of NOT_SUPPORTED
[b] Must minimally respond with a status of NOT_SUPPORTED

[c] Must minimally respond with a status of NOT_SUPPORTED
[d] Must minimally respond with a status of NOT_SUPPORTED
[e] Must minimally respond with a status of NOT_SUPPORTED
[f] Must minimally respond with a status of NOT_SUPPORTED

1.4.4.3.1 Mgmt_NWK_Disc_rsp

1.4.4.3.1.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0xB0	Mgmt_NWK_Disc_rsp	(Status NetworkCount StartIndex NetworkListCount NetworkList)

Table 79 specifies the parameters for the Mgmt_NWK_Disc_rsp primitive.

Table 79 Mgmt_NWK_Disc_rsp parameters

Name	Type	Valid range	Description
Status	Integer	NOT_SUPPORTED or any status code returned from the NLME-NETWORK-DIS-COVERY.request primitive.	The status of the Mgmt_NWK_Disc_req command.[a]
NetworkCount	Integer	0x00-0xff	The total number of networks reported by the NLME-NETWORK-DISCOV-ERY.confirm.
StartIndex	Integer	0x00-0xff	The starting point in the NetworkList from the NLME-NETWORK-DISCOV-ERY.confirm where reporting begins for this response.
NetworkListCount	Integer	0x00-0xff	The number of network list descriptors reported within this response.
NetworkList	List of Net-work Descrip-tors	The list shall contain the number of elements given by the NetworkListCount parameter.	A list of descriptors, one for each of the networks discovered by the NLME-NET-WORK-DISCOVERY primitive. The list returned by NLME-NETWORK-DIS-COVERY.confirm shall be used for refer-ence and this response shall begin with the StartIndex element and continue for NetworkListCount which shall be defined to ensure that the resultant MSDU will be no greater than *aMaxMACFrameSize* octets in size (see [B1]).[b]

[a] CCB Comment #223, 237
[b] CCB Comment #366

1.4.4.3.1.2 When generated

The Mgmt_NWK_Disc_rsp is generated in response to an Mgmt_NWK_Disc_req. If this management command is not supported, a status of NOT_SUPPORTED shall be returned and all parameter fields after the Status field shall be omitted. Otherwise, the Remote Device shall implement the following processing:

"Perform an NLME-NETWORK-DISCOVERY.request using the ScanChannels parameter supplied with the Mgmt_NWK_Disc_req.

"Upon receipt of the NLME-NETWORK-DISCOVERY.confirm, report the NetworkList results, starting with the StartIndex element, via the Mgmt_NWK_Disc_rsp. Include the NetworkCount parameter from the NLME-NETWORK-DISCOVERY.confirm as the same parameter within Mgmt_NWK_Disc_rsp.

"Include as many NetworkList elements as possible while ensuring that the resulting MSDU will no greater than *aMaxMACFrameSize* octets in size[59]. Report the number of included NetworkList entries within NetworkListCount.[60]

1.4.4.3.1.3 Effect on receipt

The local device is notified of the results of its attempt to perform a remote network discovery.[61]

1.4.4.3.2 Mgmt_Lqi_rsp

1.4.4.3.2.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0xB1	Mgmt_Lqi_rsp	(Status NeighborTableEntries StartIndex NeighborTableListCount NeighborTableList)

Table 81 specifies the parameters for the Mgmt_Lqi_rsp primitive.

Table 80 Mgmt_Lqi_rsp parameters

Name	Type	Valid range	Description
Status	Integer	NOT_SUPPORTED or any status code returned from the NLME-GET.confirm primitive	The status of the Mgmt_Lqi_req command.[a]
NeighborTableEntries	Integer	0x00-0xff	Total number of Neighbor Table entries within the Remote Device.

[59]CCB COmment #366
[60]CCB Comment #237, 250
[61]CCB Comment #250

Table 80 Mgmt_Lqi_rsp parameters

StartIndex	Integer	0x00-0xff	Starting index within the Neighbor Table to begin reporting for the NeighborTableList.
NeighborTableListCount	Integer	0x00-0xff	Number of Neighbor Table entries included within NeighborTableList.
NeighborTableList	List of Neighbor Descriptors	The list shall contain the number elements given by the NeighborTableListCount	A list of descriptors, beginning with the StartIndex element and continuing for NeighborTableListCount, of the elements in the Remote Device's Neighbor Table including the device address and associated LQI (see Table 81 for details).[b]

[a]CCB Comment #223
[b]CCB Comment #237, 239

Table 81 NeighborTableList record format

Name	Type	Valid range	Description
PAN Id	Integer	0x0000-0x3fff	The 16-bit PAN identifier of the neighboring device.
Extended address	Integer	An extended 64-bit, IEEE address	64-bit IEEE address that is unique to every device.
Network address	Network address	Network address	The 16-bit network address of the neighboring device.
Device type	Integer	0x00-0x03	The type of the neighbor device: 0x00 = ZigBee coordinator. 0x01 = ZigBee router. 0x02 = ZigBee end device.
RxOnWhenIdle	Boolean	TRUE or FALSE	Indicates if neighbor's receiver is enabled during idle portions of the CAP[a]: TRUE = Receiver is off. FALSE = Receiver is on.
Relationship	Relationship	0x00-0x03	The relationship between the neighbor and the current device: 0x00=neighbor is the parent. 0x01 = neighbor is a child. 0x02 = neighbor is a sibling. 0x03 = None of the above.

Table 81 NeighborTableList record format

Depth	Integer	0x00-*nwkcMaxDepth*	The tree depth of the neighbor device. A value of 0x00 indicates that the device is the ZigBee coordinator for the network.
Permit joining	Boolean	TRUE or FALSE	An indication of whether the neighbor device is accepting join requests: TRUE = neighbor is accepting join requests. FALSE = neighbor is not accepting join requests.
LQI	Integer	0x00-0xff	The estimated link quality for RF transmissions from this device. See [B1] for discussion of how this is calculated.[b]

[a]CCB Comment 138
[b]CCB Comment #239

1.4.4.3.2.2 When generated

The Mgmt_Lqi_rsp is generated in response to an Mgmt_Lqi_req. If this management command is not supported, a status of NOT_SUPPORTED shall be returned and all parameter fields after the Status field shall be omitted. Otherwise, the Remote Device shall implement the following processing.

Upon receipt of and after support for the Mgmt_Lqi_req has been verified, the Remote Device shall perform an NLME-GET.request (for the *nwkNeighborTable* attribute) and process the resulting neighbor table (obtained via the NLME-GET.confirm primitive) to create the Mgmt_Lqi_rsp command. If *nwkNeighborTable* was successfully obtained but one or more of the fields required in the NeighborTableList record (see Table 81) are not supported (as they are optional), the Mgmt_Lqi_rsp shall return a status of NOT_SUPPORTED and all parameter fields after the Status field shall be omitted. Otherwise, the Mgmt_Lqi_rsp command shall contain the same status that was contained in the NLME-GET.confirm primitive and if this was not SUCCESS, all parameter fields after the status field shall be omitted.

From the *nwkNeighborTable* attribute, the neighbor table shall be accessed, starting with the index specified by StartIndex, shall be moved to the NeighborTableList field of the Mgmt_Lqi_rsp command. The entries reported from the neighbor table shall be those, starting with StartIndex and including whole NeighborTableList records (see Table 81) until the limit on MSDU size, i.e. *aMaxMACFrameSize* (see [B1])[62], is reached. Within the Mgmt_Lqi_Rsp command, the NeighborTableEntries field shall represent the total number of Neighbor Table entries in the Remote Device. The parameter NeighborTableListCount shall be the number of entries reported in the NeighborTableList field of the Mgmt_Lqi_rsp command.[63]

1.4.4.3.2.3 Effect on receipt

The local device is notified of the results of its attempt to obtain the neighbor table.[64]

[62]CCB Comment #366
[63]CCB Comment #239, 247, 250
[64]CCB Comment #250

1.4.4.3.3 Mgmt_Rtg_rsp

1.4.4.3.3.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0xB2	Mgmt_Rtg_rsp	(Status RoutingTableEntries StartIndex RoutingTableListCount RoutingTableList)

Table 82 specifies the parameters for the Mgmt_Rtg_rsp primitive.

Table 82 Mgmt_Rtg_rsp parameters

Name	Type	Valid range	Description
Status	Integer	NOT_SUPPORTED or any status code returned from the NLME-GET.confirm primitive	The status of the Mgmt_Rtg_req command.[a]
RoutingTableEntries	Integer	0x00-0xff	Total number of Routing Table entries within the Remote Device.
StartIndex	Integer	0x00-0xff	Starting index within the Routing Table to begin reporting for the RoutingTableList.
RoutingTableListCount	Integer	0x00-0xff	Number of Routing Table entries included within RoutingTableList.
RoutingTableList	List of Routing Descriptors	The list shall contain the number elements given by the RoutingTableListCount	A list of descriptors, beginning with the StartIndex element and continuing for RoutingTableListCount, of the elements in the Remote Device's Routing Table (see the Table 83 for details).[b]

[a]CCB Comment #223
[b]CCB Comment #237, 239

Table 83 RoutingTableList record format

Name	Type	Valid range	Description
Destination address	2 bytes	The 16-bit network address of this route.	Destination address.
Status	3 bits	The status of the route.	0x0=ACTIVE. 0x1=DISCOVERY_UNDERWAY. 0x2=DISCOVERY_FAILED. 0x3=INACTIVE. 0x4-0x7=RESERVED.

Next-hop address	2 bytes	The 16-bit network address of the next hop on the way to the destination.	Next-hop address.[a]

[a]CCB Comment #239

1.4.4.3.3.2 When generated

The Mgmt_Rtg_rsp is generated in response to an Mgmt_Rtg_req. If this management command is not supported, a status of NOT_SUPPORTED shall be returned and all parameter fields after the Status field shall be omitted. Otherwise, the Remote Device shall implement the following processing.

Upon receipt of and after support for the Mgmt_Rtg_req has been verified, the Remote Device shall perform an NLME-GET.request (for the *nwkRouteTable* attribute) and process the resulting NLME-GET.confirm (containing the *nwkRouteTable* attribute) to create the Mgmt_Rtg_rsp command. The Mgmt_Rtg_rsp command shall contain the same status that was contained in the NLME-GET.confirm primitive and if this was not SUCCESS, all parameter fields after the status field shall be omitted.

From the *nwkRouteTable* attribute, the routing table shall be accessed, starting with the index specified by StartIndex, and moved to the RoutingTableList field of the Mgmt_Rtg_rsp command. The entries reported from the routing table shall be those, starting with StartIndex and including whole RoutingTableList records (see Table 82) until MSDU size limit, i.e *aMaxMACFrameSize* (see [B1])[65], is reached. Within the Mgmt_Rtg_Rsp command, the RoutingTableEntries field shall represent the total number of Routing Table entries in the Remote Device. The RoutingTableListCount field shall be the number of entries reported in the RoutingTableList field of the Mgmt_Rtg_req command.[66]

1.4.4.3.3.3 Effect on receipt

The local device is notified of the results of its attempt to obtain the routing table.[67]

1.4.4.3.4 Mgmt_Bind_rsp

1.4.4.3.4.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0xB3	Mgmt_Bind_rsp	(Status BindingTableEntries StartIndex BindingTableListCount BindingTableList)

[65]CCB Comment #366
[66]CCB Comment #224, 237, 239, 250
[67]CCB Comment #250

Table 84 specifies the parameters for the Mgmt_Bind_rsp primitive.

Table 84 Mgmt_Bind_rsp parameters

Name	Type	Valid range	Description
Status	Integer	NOT_SUPPORTED or any status code returned from the APSME-GET.confirm primitive	The status of the Mgmt_Bind_req command.[a]
BindingTableEntries	Integer	0x00-0xff	Total number of Binding Table entries within the Remote Device.
StartIndex	Integer	0x00-0xff	Starting index within the Binding Table to begin reporting for the BindingTableList.
BindingTableListCount	Integer	0x00-0xff	Number of Binding Table entries included within BindingTableList.
BindingTableList	List of Binding Descriptors	The list shall contain the number elements given by the BindingTableListCount	A list of descriptors, beginning with the StartIndex element and continuing for BindingTableListCount, of the elements in the Remote Device's Binding Table (see Table 85 for details).[b]

[a]CCB Comment #223
[b]CCB Comment #237, 239

Table 85 BindingTableList record format

Name	Type	Valid range	Description
SrcAddr	IEEE address	A valid 64-bit IEEE address	The source IEEE address for the binding entry.
SrcEndpoint	Integer	0x01 - 0xff	The source endpoint for the binding entry.
ClusterId	Integer	0x00 - 0xff	The identifier of the cluster on the source device that is bound to the destination device.
DstAddr	IEEE address	A valid 64-bit IEEE address	The destination IEEE address for the binding entry.
DstEndpoint	Integer	0x01 - 0xff	The destination endpoint for the binding entry.[a]

[a]CCB Comment #239

1.4.4.3.4.2 When generated

The Mgmt_Bind_rsp is generated in response to a Mgmt_Bind_req. If this management command is not supported, a status of NOT_SUPPORTED shall be returned and all parameter fields after the Status field shall be omitted. Otherwise, the Remote Device shall implement the following processing.

Upon receipt of and after support for the Mgmt_Bind_req has been verified, the Remote Device shall perform an APSME-GET.request (for the *apsBindingTable* attribute) and process the resulting APSME-GET.confirm (containing the *apsBindingTable* attribute) to create the Mgmt_Bind_rsp command. The

Mgmt_Bind_rsp command shall contain the same status that was contained in the APSME-GET.confirm primitive and if this was not SUCCESS, all parameter fields after the status field shall be omitted.

From the *apsBindingTable* attribute, the binding table shall be accessed, starting with the index specified by StartIndex, and moved to the BindingTableList field of the Mgmt_Bind_rsp command. The entries reported from the binding table shall be those, starting with StartIndex and including whole BindingTableList records (see Table 85) until the MSDU size limit, i.e. *aMaxMACFrameSize* (see [B1])[68], is reached. Within the Mgmt_Bind_Rsp command, the BindingTableEntries field shall represent the total number of Binding Table entries in the Remote Device. The BindingTableListCount field shall be the number of entries reported in the BindingTableList field of the Mgmt_Bind_req command.[69]

1.4.4.3.4.3 Effect on receipt

The local device is notified of the results of its attempt to obtain the binding table.[70]

1.4.4.3.5 Mgmt_Leave_rsp

1.4.4.3.5.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0xB4	Mgmt_Leave_rsp	(Status)

Table 86 specifies the parameters for the Mgmt_Leave_rsp primitive.

Table 86 Mgmt_Leave_rsp parameters

Name	Type	Valid range	Description
Status	Integer	NOT_SUPPORTED or any status code returned from the NLME-LEAVE.confirm primitive	The status of the Mgmt_Leave_req command.[a]

[a]CCB Comment #223, 237

1.4.4.3.5.2 When generated

The Mgmt_Leave_rsp is generated in response to a Mgmt_Leave_req. If this management command is not supported, a status of NOT_SUPPORTED shall be returned. Otherwise, the Remote Device shall implement the following processing.

Upon receipt of and after support for the Mgmt_Leave_req has been verified, the Remote Device shall execute the NLME-LEAVE.request to disassociate from the currently associated network. The Mgmt_Leave_rsp shall contain the same status that was contained in the NLME-LEAVE.confirm primitive.

Once a device has disassociated, it shall execute pre-programmed logic to perform NLME-NETWORK-DISCOVERY and NLME-JOIN to join/re-join a network.[71]

[68]CCB Comment #366
[69]CCB Comment #237, 239, 248, 250
[70]CCB Comment #250
[71]CCB Comment #237, 250

1.4.4.3.5.3 Effect on receipt

The local device is notified of the results of its attempt to cause a remote device to leave the network.[72]

1.4.4.3.6 Mgmt_Direct_Join_rsp

1.4.4.3.6.1 Semantics of the service primitive

This semantics of this primitive are as follows:

ClusterID=0xB5	Mgmt_Direct_Join_rsp[a]	(Status)

[a]CCB Comment #209

Table 87 specifies the parameters for the Mgmt_Direct_Join_rsp primitive.

Table 87 Mgmt_Direct_Join_rsp parameters

Name	Type	Valid range	Description
Status	Integer	NOT_SUPPORTED or any status code returned from the NLME-DIRECT-JOIN.confirm primitive	The status of the Mgmt_Direct_Join_req command.[a]

[a]CCB Comment #223, 237

1.4.4.3.6.2 When generated

The Mgmt_Direct_Join_rsp is generated in response to a Mgmt_Direct_Join_req. If this management command is not supported, a status of NOT_SUPPORTED shall be returned. Otherwise, the Remote Device shall implement the following processing.

Upon receipt of and after support for the Mgmt_Direct_Join_req has been verified, the Remote Device shall execute the NLME-DIRECT-JOIN.request to directly associate the DeviceAddress contained in the Mgmt_Direct_Join_req to the network. The Mgmt_Direct_Join_rsp shall contain the same status that was contained in the NLME-DIRECT-JOIN.confirm primitive.[73]

1.4.4.3.6.3 Effect on receipt

Upon receipt and after support for the Mgmt_Direct_Join_req has been verified, the Remote Device shall execute the NLME-JOIN.request using the JoinDirectly parameter set to TRUE to directly associate the DeviceAddress contained in the Mgmt_Direct_Join_req to the network.

1.4.5 ZDP enumeration description

This sub-clause explains the meaning of the enumerations used in the ZDP. Table 88 shows a description of the ZDP enumeration values.[74]

[72]CCB Comment #250
[73]CCB Comment #237, 250
[74]CCB Comment #223

Table 88 ZDP enumerations description

Enumeration	Value	Description
SUCCESS	0x00	The requested operation or transmission was completed successfully.
-	0x01-0x7f	Reserved
INV_REQUESTTYPE	0x80	The supplied request type was invalid.
DEVICE_NOT_FOUND	0x81	Reserved
INVALID_EP	0x82	The supplied endpoint was equal to 0x00 or between 0xf1and 0xff.
NOT_ACTIVE	0x83	The requested endpoint is not described by a simple descriptor.
NOT_SUPPORTED	0x84	The requested optional feature is not supported on the target device.
TIMEOUT	0x85	A timeout has occurred with the requested operation.
NO_MATCH	0x86	The end device bind request was unsuccessful due to a failure to match any suitable clusters.
TABLE_FULL	0x87	The bind request was unsuccessful due to the coordinator or source device not having sufficient resources.
NO_ENTRY	0x88	The unbind request was unsuccessful due to the coordinator or source device not having an entry in its binding table to unbind.
-	0x89-0xff	Reserved

1.4.6 Conformance

When conformance to this Profile is claimed, all capabilities indicated mandatory for this Profile shall be supported in the specified manner (process mandatory). This also applies to optional and conditional capabilities, for which support is indicated, and subject to verification as part of the ZigBee certification program.

1.5 The ZigBee device objects (ZDO)

1.5.1 Scope

This document describes the concepts, structures and primitives needed to implement a ZigBee Device Objects application on top of a ZigBee Application Support Sub-layer (Reference [1]) and ZigBee Network Layer (Chapter 2).

ZigBee Device Objects is an application which employs network and application support layer primitives to implement ZigBee End Devices, ZigBee Routers and ZigBee Coordinators in Release 0.75 of the ZigBee protocol.

1.5.2 Device Object Descriptions

— The ZigBee Device Objects are an application solution residing within the Application Layer (APL) and above the Application Support Sub-layer (APS) in the ZigBee stack architecture as illustrated in Figure 1

. The ZigBee Device Objects are responsible for the following functions:

— Initializing the Application Support Sublayer (APS), Network Layer (NWK), Security Service Provider (SSP) and any other ZigBee device layer other than the end applications residing over Endpoints 1-240.

— Assembling configuration information from the end applications to determine and implement the functions described in the following sub-clauses.

1.5.2.1 Device and Service Discovery

This function shall support device and service discovery within a single PAN. Additionally, for ZigBee Coordinator, ZigBee Router and ZigBee End Device types, this function shall perform the following:

— For ZigBee End Devices which intend to sleep as indicated by :Config_Node_Power, Device and Service Discovery shall manage upload and storage of the NWK Address, IEEE Address, Active Endpoints, Simple Descriptors, Node Descriptor and Power Descriptor onto the associated ZigBee Coordinator or ZigBee Router to permit device and service discovery operations on these sleeping devices .

— For the ZigBee Coordinator and ZigBee Routers, this function shall respond to discovery requests on behalf of their associated sleeping ZigBee End Devices.

— For all ZigBee devices, Device and Service Discovery shall support device and service discovery requests from other devices and permit generation of requests from their local Application Objects. The following discovery features shall be supported:

    — Device Discovery

    — Based on a unicast inquiry of a ZigBee Coordinator or ZigBee Router's IEEE address, the IEEE Address of the requested device plus, optionally, the NWK Addresses of all associated devices shall be returned.

    — Based on a unicast inquiry of a ZigBee End Device's IEEE address, the IEEE Address of the requested device shall be returned.

    — Based on a broadcast inquiry of a ZigBee Coordinator or ZigBee Router's NWK Address with a supplied IEEE Address, the NWK Address of the requested device plus, optionally, the NWK Addresses of all associated devices shall be returned.

    — Based on a broadcast inquiry of a ZigBee End Device's NWK Address with a supplied IEEE Address, the NWK Address of the requested device shall be returned. The responding device shall employ APS acknowledged service for the unicast response to the broadcast inquiry.

— Service Discovery - Based on the following inputs, the corresponding responses shall be supplied:

    — NWK address plus Active Endpoint query type – Specified device shall return the endpoint number of all applications residing in that device.

    — NWK address or broadcast address plus Service Match including Profile ID and, optionally, Input and Output Clusters – Specified device matches Profile ID with all active endpoints to determine a match. If no input or output clusters are specified, the endpoints that match the request are returned. If input and/or output clusters are provided in the request,

those are matched as well and any matches are provided in the response with the list of endpoints on the device providing the match. The responding device shall employ APS acknowledged service for the unicast response to the broadcast inquiry.

— NWK address plus Node Descriptor or Power Descriptor query type – Specified device shall return the Node or Power Descriptor for the device.

— NWK address, Endpoint Number plus Simple Descriptor query type – Specified address shall return the Simple Descriptor associated with that Endpoint for the device.

— Optionally, NWK address plus Complex or User Descriptor query type – If supported, specified address shall return the Complex or User Descriptor for the device

1.5.2.2 Security Manager

This function determines whether security is enabled or disabled and, if enabled, shall perform the following:

— Establish Key

— Transport Key

— Authentication

The Security Manager function addresses the Security Services Specification (Reference [5]). Security Management, implemented by APSME primitive calls by ZDO, performs the following:

— Contacts the Trust Center (assumed to be located on the ZigBee Coordinator) to obtain the Master Key between this device and the Trust Center (step is omitted if this device is the ZigBee Coordinator or the Master Key with the Trust Center has been pre-configured). This step employs the Transport Key primitive.

— Establishes a Link Key with the Trust Center. This step employs the APSME-Establish-Key primitive.

— Obtains the NWK Key from the Trust Center using secured communication with the Trust Center. This step employs the APSME-Transport-Key primitive.

— Establishes Link Keys and master keys, as required, with specific devices in the network identified as messaging destinations. These steps employ the APSME-Key and APSME-Establish-Key primitives.

— Informs the trust center of any devices that join the network using the APSME-Device-Update primitives. This function is only performed if the device is a ZigBee router.

1.5.2.3 Network Manager

This function shall implement the ZigBee Coordinator, ZigBee Router or ZigBee End Device logical device types according to configuration settings established either via a programmed application or during installation. If the device type is a ZigBee Router or ZigBee End Device, this function shall provide the ability to select an existing PAN to join and implement orphaning procedures which permit the device to re-associate with the same ZigBee Coordinator or ZigBee Router if network communication is lost. If the device type is a ZigBee Coordinator or ZigBee Router, this function shall provide the ability to select an unused channel for creation of a new PAN. Note that is possible to deploy a network without a device pre-designated as ZigBee Coordinator where the first Full Function Device (FFD) activated device assumes the role of ZigBee Coordinator. The following description covers processing addressed by Network Management:

— Permits specification of a channel list for network scan procedures. Default is to specify use of all channels in the selected band of operation.

- Manages network scan procedures to determine neighboring networks and the identity of their ZigBee coordinators and routers.[75]
- Permits selection of a channel to start a PAN (ZigBee Coordinator) or selection of an existing PAN to join (ZigBee Router or ZigBee End Device).
- Supports orphaning procedures to rejoin the network.
- Supports direct join and join by proxy features provided by the Network Layer. For ZigBee Coordinators and ZigBee Routers, a local version of direct join shall be supported to enable the device to join via orphaning procedures.
- May support Management Entities that permit external network management.

1.5.2.4 Binding Manager

The Binding Manager performs the following:

- Establishes resource size for the Binding Table. The size of this resource is determined via a programmed application or via a configuration parameter defined during installation.
- Processes bind requests for adding or deleting entries from the APS binding table.
- Supports Bind and Unbind commands from external applications such as those that may be hosted on a PDA to support assisted binding. Bind and Unbind commands shall be supported via the ZigBee Device Profile (Reference [6]).
- For the ZigBee Coordinator, supports the End Device Bind that permits binding on the basis of button presses or other manual means.

1.5.2.5 Node Manager

For ZigBee Coordinators and ZigBee Routers, the Node Management function performs the following:

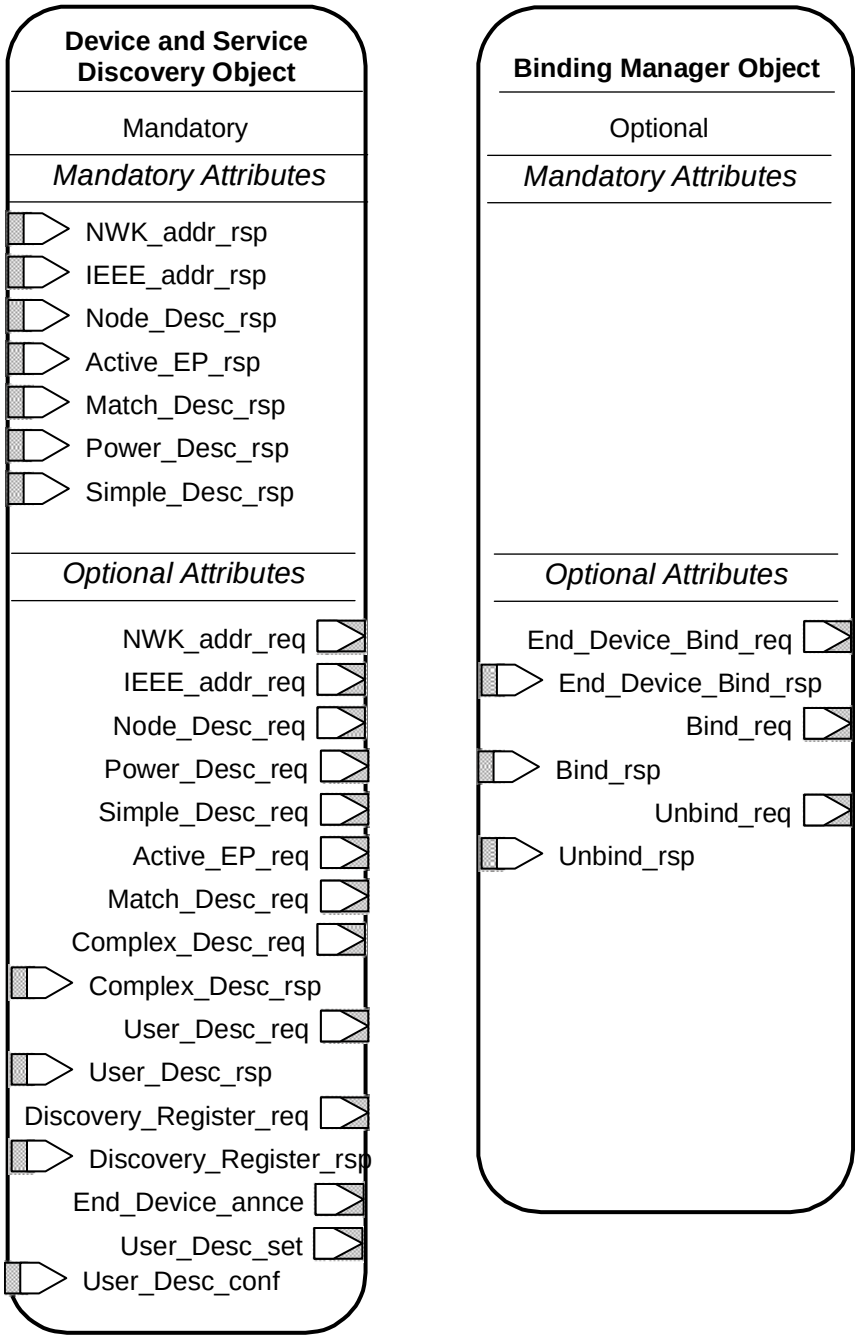
- Permits remote management commands to perform network discovery.
- Provides remote management commands to retrieve the routing table.
- Provides remote management commands to retrieve the binding table.
- Provides a remote management command to have the device leave the network or to direct that another device leave the network.
- Provides a remote management command to retrieve the LQI for neighbors of the remote device.

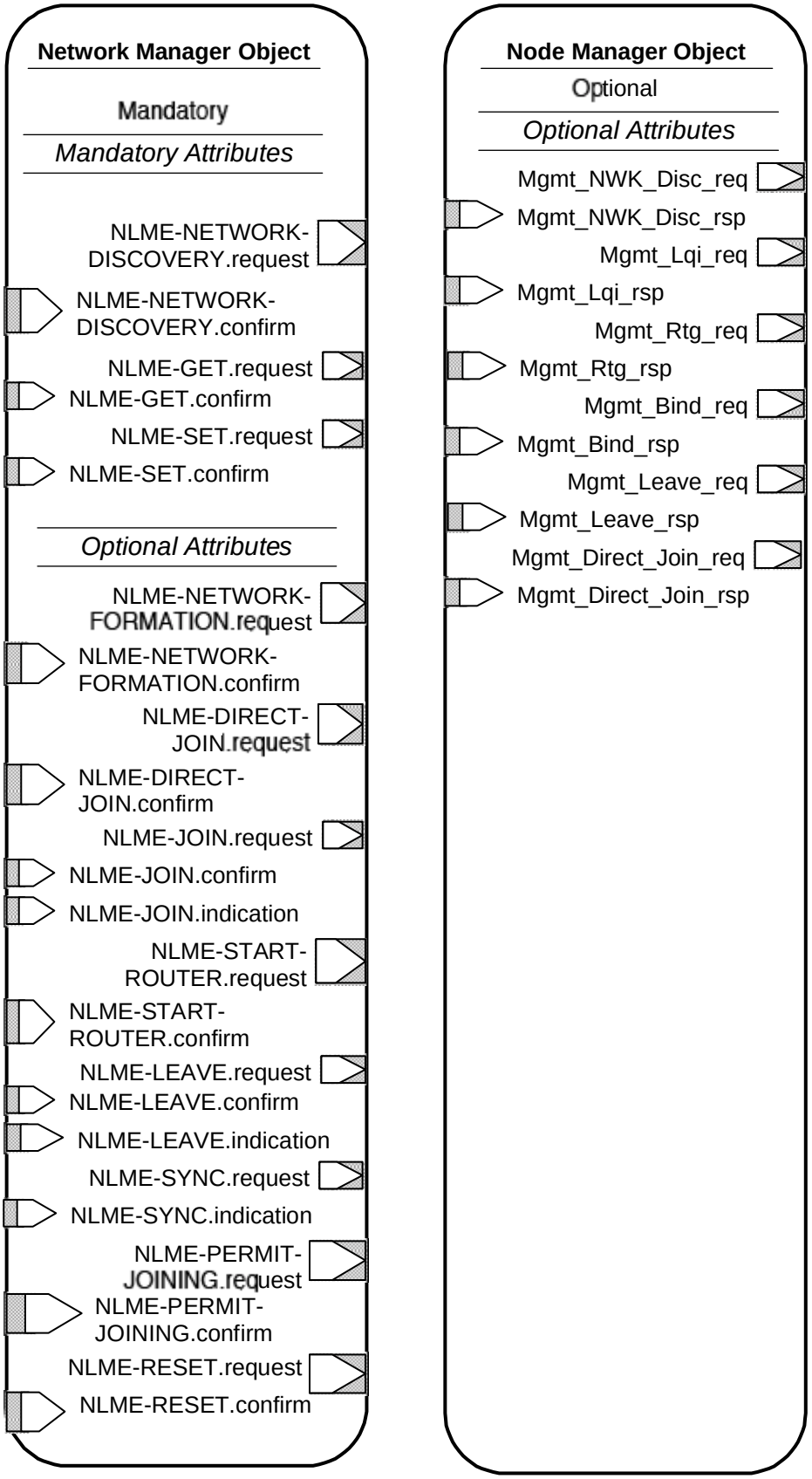
1.5.3 Layer Interface Description

Unlike other device descriptors for applications residing above Endpoints 1-240, the ZigBee Device Objects (ZDO) interface to the APS via the APSME-SAP and to NWK via the NLME-SAP in addition to the APSDE-SAP. ZDO communicates over Endpoint 0 using the APSDE-SAP via Profiles like all other applications. The Profile used by ZDO is the ZigBee Device Profile (Reference [6]).

[75] CCB Comment #171

1.5.4 System Usage





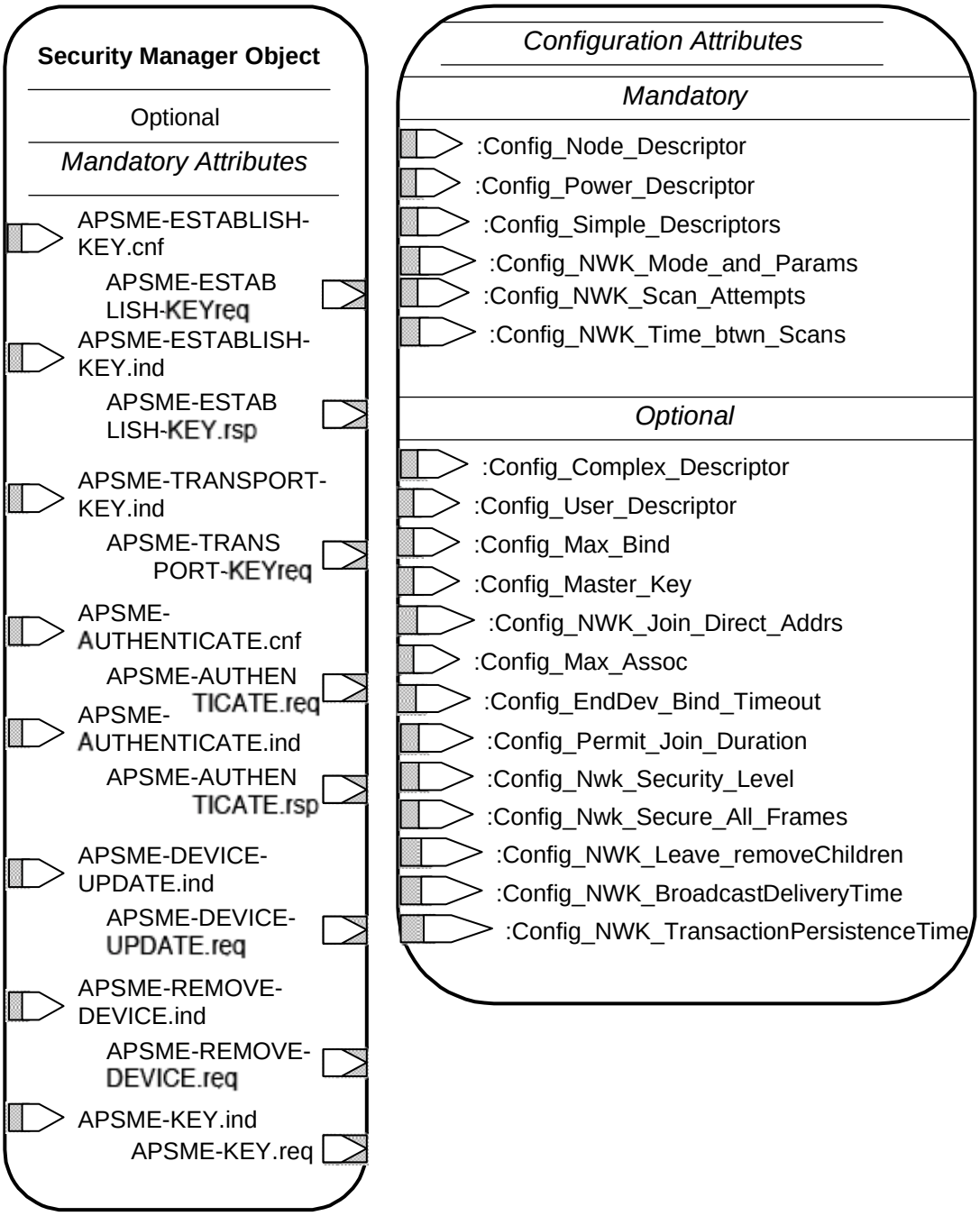


Figure 30 ZigBee Device Object details

1.5.5 Object Definition and Behavior

1.5.5.1 Object Overview

ZigBee Device Objects contains five Objects:

— Device and Service Discovery

— Network Manager

— Binding Manager

— Security Manager

— Node Manager

Table 89 ZigBee Device Objects

Object		Description
Name	**Status**	
:Device_and_Service_Discovery	M	Handles device and service discovery.
:Network_Manager	M	Handles network activities such as network discovery, leaving/joining a network, resetting a network connection and creating a network.
:Binding_Manager	O	Handles end device binding, binding and unbinding activities.
:Security_Manager	O	Handles security services such as key loading, key establishment, key transport and authentication.
:Node_Manager	O	Handles management functions.

1.5.5.2 Optional and Mandatory Objects and Attributes

Objects listed as Mandatory shall be present on all ZigBee devices. However, for certain ZigBee logical types, Objects listed as Optional for all ZigBee devices may be Mandatory in specific logical device types. For example, the NWK_Formation_req within the Network_Manager object is in a Mandatory object and is an Optional attribute, though the attribute is required for ZigBee Coordinator logical device types. The introduction section of each Device Object section will detail the support requirements for Objects and Attributes by logical device type.

1.5.5.3 Security key usage

ZigBee Device Objects may employ security for packets created by ZigBee Device Profile primitives. These application packets using APSDE on Endpoint 0 shall utilize the Network Key, as opposed to individual Link Keys.

Public and Private Methods

Methods that are accessible to any endpoint application on the device are called public methods. Private methods are only accessible to the Device Application on endpoint 0 and not to the end applications (which run on endpoints 1 through 240).

1.5.5.4 State Machine Functional Descriptions

1.5.5.4.1 ZigBee Coordinator

1.5.5.4.1.1 Initialization

Provision shall be made within the implementation to supply a single copy of desired network configuration parameters (:Config_NWK_Mode_and_Params) to the Network Object of ZigBee Device Objects. Additionally, provision shall be made to provide configuration elements to describe the Node Descriptor, Power Descriptor, Simple Descriptor for each active endpoint and application plus the list of active endpoints. These configuration shall be embodied in :Config_Node_Descriptor, :Config_Power_Descriptor and :Config_Simple_Descriptors.

If supported, provision shall be made to supply configuration elements for the Complex Descriptor, User Descriptor, the maximum number of bind entries and the master key. These elements shall be embodied in :Config_Complex_Descriptor, :Config_User_Descriptor, :Config_Max_Bind and :Config_Master_Key.

The device application shall use NLME-NETWORK-DISCOVERY.request with the ChannelList portion of :Config_NWK_Mode_and_Params to scan the specified channels. The resulting NLME-NETWORK-DISCOVERY.confirm shall supply a NetworkList detailing active PANs within that range. The device application shall compare the ChannelList to the NetworkList and select an unused channel. Specification of the algorithm for selection of the unused channel shall be left to the implementer. Once the unused channel is identified, the device application shall set the *nwkSecurityLevel* and *nwkSecureAllFrames* NIB attributes according to the values contained in the corresponding :Config attributes. It shall then employ the NLME-NETWORK-FORMATION.request using the parameters specified within :Config_NWK_Mode_and_Params to establish a PAN on that channel. The device application shall check the return status via the NLME-NETWORK-FORMATION.confirm to verify successful creation of the PAN. The :Config_Permit_Join_Duration shall be set according to the default parameter value supplied using the NLME-PERMIT-JOINING.request. Additionally, the *nwkNetworkBroadcastDeliveryTime* and *nwkTransactionPersistenceTime* Network Information Block parameters shall be set with :Config_NWK_BroadcastDeliveryTime and :Config_NWK_TransactionPersistenceTime respectively (see Chapter 2).

Provision shall be made to ensure APS primitive calls from the end applications over EP 1 through EP 240 return appropriate error status values prior to completion of the Initialization state by ZigBee Device Objects and transition to the normal operating state.[76]

1.5.5.4.1.2 Normal operating state

In this state, the ZigBee coordinator shall allow other devices to join the network based on the configuration items :Config_Permit_Join_Duration and :Config_Max_Assoc. When a new device joins the network, the device application shall be informed via the NLME-JOIN.indication. Should the device be admitted to the PAN, the ZigBee coordinator shall indicate this via the NLME-JOIN.confirm with success status.

The ZigBee coordinator shall respond to any device discovery or service discovery operations requested of its own device or any of its sleeping associated devices using the attributes described in Sections 5.4 of this document. The device application shall also ensure that the number of binding entries does not exceed the :Config_Max_Bind attribute.

[76] CCB Comment #169, 196, 252, 269

The ZigBee coordinator shall support the NLME-PERMIT-JOINING.request and NLME-PERMIT-JOINING.confirm to permit application control of network join processing.

The ZigBee coordinator shall support the NLME-LEAVE.request and NLME-LEAVE.indication employing the :Config_NWK_Leave_removeChildren attribute where appropriate to permit removal of associated devices under application control. Conditions that lead to removal of associated devices may include lack of security credentials, removal of the device via a privileged application or detection of exception.

The ZigBee coordinator shall maintain a list of currently associated devices and facilitate support of orphan scan processing to enable previously associated devices to rejoin the network. The ZigBee coordinator shall support the ability for devices to be directly included in the network via the NLME-DIRECT-JOIN.request and NLME-DIRECT-JOIN.confirm. This feature shall permit lists of ZigBee IEEE addresses to be provided to the ZigBee coordinator and for those addresses to be included as previously associated devices. It shall be possible for ZigBee devices with those addresses to directly join the network via orphaning procedures rather than associating directly.

The ZigBee coordinator shall process End_Device_Bind_req from ZigBee Routers and ZigBee End Devices. Upon receipt of an End_Device_Bind_req, the ZigBee Coordinator shall use the :Config_EndDev_Bind_Timeout value in the attribute and await a second End_Device_Bind_req. Should the second indication arrive within the timeout period, the ZigBee coordinator shall match the Profile ID in the two indications. If the Profile IDs in the two indications do not match, an appropriate error status is returned to each device via End_Device_Bind_rsp. Should the Profile IDs match, the ZigBee Coordinator shall match the AppInClusterLists and AppOutClusterLists in the two indications. Cluster IDs in the AppInClusterList of the first indication which match Cluster IDs in the AppOutClusterList of the second indication shall be saved in a list for inclusion in the End_Dev_Bind_rsp.

The ZigBee coordinator shall process End_Device_annce messages from ZigBee End Devices. Upon receipt of an End_Device_annce, the ZigBee coordinator shall check all internal tables holding 64 bit IEEE addresses for devices within the PAN for a match with the address supplied in the End_Device_annce message. At minimum, the Binding Table and Trust Center tables shall be checked. If a match is detected, the ZigBee coordinator shall update its APS Information Block address map entries corresponding to the matched 64 bit IEEE address to reflect the updated 16 bit NWK address contained in the End_Device_annce.[77]

1.5.5.4.1.3 Trust center operation

The Zigbee coordinator shall also function as the trust center when security is enabled on the network.

The trust center is notified of new devices on the network via the APSME-DEVICE-UPDATE.indication. The trust center can either choose to allow the device to remain on the network or force it out of the network using the APSME-REMOVE-DEVICE.req. This choice is made using a network access control policy that is beyond the scope of this specification.

If the trust center decides to allow the device to remain in the network, it shall establish a master key with that device using APSME-TRANSPORT-KEY.req, unless the master key is already available to both the device and trust center using out-of-band mechanisms.Upon exchange of the master key, the trust center shall use APSME-ESTABLISH-KEY.req to set up a link key with the device and shall respond to request for link key establishment using the APSME-ESTABLISH-KEY.rsp.

The trust center shall then provide the device with the NWK key using APSME-TRANSPORT-KEY.req. It shall also provide the NWK key upon receiving a request from the device via the APSME-KEY.indication.

The trust center shall support the establishment of link keys between any two devices by providing them with a common master key. Upon receipt of a APSME-KEY.indication requesting an application master key,

[77] CCB Comment #107, 169, 196

the trust center shall create a master key and transport it to both devices using the APSME-TRANSPORT-KEY.req.

The trust center shall periodically update the NWK key according to a policy whose details are beyond the scope of this specification. All devices on the network shall be updated with the new NWK key using the APSME-TRANSPORT-KEY.req

1.5.5.4.2 ZigBee Router

1.5.5.4.2.1 Initialization

Provision shall be made within the implementation to supply a single copy of desired network configuration parameters (:Config_NWK_Mode_and_Params) to the Network Object of ZigBee Device Objects.

If supported, provision shall be made to supply configuration elements for the Complex Descriptor, User Descriptor, the maximum number of bind entries and the master key. These elements shall be embodied in :Config_Complex_Descriptor, :Config_User_Descriptor, :Config_Max_Bind and :Config_Master_Key.

The device application shall use NLME-NETWORK-DISCOVERY.request with the ChannelList portion of :Config_NWK_Mode_and_Params then use the NLME-NETWORK-DISCOVERY.request attribute to scan the specified channels. The resulting NLME-NETWORK-DISCOVERY.confirm shall supply a NetworkList detailing active PANs within that range. The NLME-NETWORK-DISCOVERY.request procedure shall be implemented :Config_NWK_Scan_Attempts, each separated in time by :Config_NWK_Time_btwn_Scans. The purpose of repeating the NLME-NETWORK-DISCOVERY.request is to provide a more accurate neighbor list and associated link quality indications to the NWK layer. The device application shall compare the ChannelList to the NetworkList and select an existing PAN to join. Specification of the algorithm for selection of the PAN shall be left to the profile description and may include use of the PAN ID, operational mode of the network, identity of the ZigBee Router or Coordinator identified on the PAN, depth of the ZigBee Router on the PAN from the ZigBee Coordinator for the PAN, capacity of the ZigBee Router or Coordinator or the routing cost (these parameters are supplied by the NLME-NETWORK-DISCOVERY.confirm). Once the PAN to join is identified, the device application shall employ the NLME-JOIN.request to join the PAN on that channel. The device application shall check the return status via the NLME-JOIN.confirm to verify association to the selected ZigBee Router or ZigBee Coordinator on that PAN. The :Config_Permit_Join_Duration shall be set according to the default parameter value supplied using NLME-PERMIT-JOINING.request. The router shall support the NLME-START-ROUTER.request and NLME-START-ROUTER.confirm to begin operations as a router within the PAN it has joined. Additionally, the *nwkNetworkBroadcastDeliveryTime* and *nwkTransactionPersistenceTime* Network Information Block parameters shall be set with :Config_NWK_BroadcastDeliveryTime and :Config_NWK_TransactionPersistenceTime respectively (see Chapter 2).[78]

Provision shall be made to ensure APS primitive calls from the end applications over EP 1 through EP 240 return appropriate error status values prior to completion of the Initialization state by ZigBee Device Objects and transition to the normal operating state.

If the network has security enabled, the device shall wait for the trust center to supply it with a master key via the APSME-TRANSPORT-KEY.ind and then respond to a request from the trust center to establish a link key using the APSME-ESTABLISH-KEY.rsp. The device shall then wait for the trust center to provide it with a NWK key using APSME-TRANSPORT-KEY.ind. Upon successful acquisition of the NWK key, the device is authenticated and can start functioning as a router in the network.

The device application shall set the *nwkSecurityLevel* and *nwkSecureAllFrames* NIB attributes to the values used in the network and then start functioning as a router using NLME-START-ROUTER.req

[78] CCB Comment #169, 194, 196, 252, 269

1.5.5.4.2.2 Normal operating state

In this state, the ZigBee router shall allow other devices to join the network based on the configuration items :Config_Permit_Join_Duration and :Config_Max_Assoc. When a new device joins the network, the device application shall be informed via the NLME-JOIN.indication attribute. Should the device be admitted to the PAN, the ZigBee router shall indicate this via the NLME-JOIN.confirm with success status. If security is enabled on the network, the device application shall inform the trust center via the APSME-DEVICE-UPDATE.req.

The ZigBee router shall respond to any device discovery or service discovery operations requested of its own device or any of its sleeping associated devices using the attributes described in Sections 5.4 of this document. The device application shall also ensure that the number of binding entries does not exceed the :Config_Max_Bind attribute.

If security is supported, the ZigBee router shall support the :Config_Master_Key and shall employ the Master Key in key establishment procedures for Link Keys. Upon presentation of a remote destination address requiring secure communications, the ZigBee router shall support APSME-KEY.req to establish a master key with the remote device and APSME-ESTABLISH-KEY.request to present the request to the destination and shall support APSME-KEY-ESTABLISH.confirm and APSME-KEY-ESTABLISH.response to complete the key establishment of the Link Key. The ZigBee router shall provide the ability to store Link Keys for known destinations requiring secure communications and shall manage key storage for addition or deletion of Link Keys. The ZigBee router shall support APSME-TRANSPORT-KEY.ind to receive keys from the trust center. The ZigBee router shall request the trust center to update its NWK key via the APSME-KEY.req

The ZigBee router shall support the NLME-PERMIT-JOINING.request and NLME-PERMIT-JOINING.confirm to permit application control of network join processing.

The ZigBee router shall support the NLME-LEAVE.request and NLME-LEAVE.confirm employing the :Config_NWK_Leave_removeChildren attribute where appropriate to permit removal of associated devices under application control. Conditions that lead to removal of associated devices may include lack of security credentials, removal of the device via a privileged application or detection of exception.

The ZigBee router shall process End_Device_annce messages from ZigBee End Devices. Upon receipt of an End_Device_annce, the ZigBee router shall check all internal tables holding 64 bit IEEE addresses for devices within the PAN for a match with the address supplied in the End_Device_annce message. At minimum, any Binding Table entries held by the ZigBee router shall be checked. If a match is detected, the ZigBee router shall update its APS Information Block address map entries corresponding to the matched 64 bit IEEE address to reflect the updated 16 bit NWK address contained in the End_Device_annce.

The ZigBee router shall maintain a list of currently associated devices and facilitate support of orphan scan processing to enable previously associated devices to rejoin the network.[79]

1.5.5.4.3 ZigBee End Device

1.5.5.4.3.1 Initialization

Provision shall be made within the implementation to supply a single copy of desired network configuration parameters (:Config_NWK_Mode_and_Params) to the Network Object of ZigBee Device Objects.

If supported, provision shall be made to supply configuration elements for the Complex Descriptor, User Descriptor, the maximum number of bind entries and the master key. These elements shall be embodied in :Config_Complex_Descriptor, :Config_User_Descriptor, :Config_Max_Bind and :Config_Master_Key.

[79] CCB Comment #169, 196

The device application shall use NLME-NETWORK-DISCOVERY.request with the ChannelList portion of :Config_NWK_Mode_and_Params then use the NLME-NETWORK-DISCOVERY.request attribute to scan the specified channels. The resulting NLME-NETWORK-DISCOVERY.confirm shall supply a NetworkList detailing active PANs within that range. The NLME-NETWORK-DISCOVERY.request procedure shall be implemented :Config_NWK_Scan_Attempts, each separated in time by :Config_NWK_Time_btwn_Scans. The purpose of repeating the NLME-NETWORK-DISCOVERY.request is to provide a more accurate neighbor list and associated link quality indications to the NWK layer. The device application shall compare the ChannelList to the NetworkList and select an existing PAN to join. Specification of the algorithm for selection of the PAN shall be left to the profile descriptions and may include use of the PAN ID, operational mode of the network, identity of the ZigBee Router or Coordinator identified on the PAN, depth of the ZigBee Router on the PAN from the ZigBee Coordinator for the PAN, capacity of the ZigBee Router or Coordinator or the routing cost (these parameters are supplied by the NLME-NETWORK-DISCOVERY.confirm). Once the PAN to join is identified, the device application shall employ the NLME-JOIN.request to join the PAN on that channel. The device application shall check the return status via the NLME-JOIN.confirm to verify association to the selected ZigBee Router or ZigBee Coordinator on that PAN.

Once the End Device has successfully joined a network, the device shall issue an End_Device_annce providing its 64 bit IEEE address and 16 bit NWK address.

Provision shall be made to ensure APS primitive calls from the end applications over EP 1 through EP 240 return appropriate error status values prior to completion of the Initialization state by ZigBee Device Objects and transition to the normal operating state.

If the network has security enabled, the device shall wait for the trust center to supply it with a master key via the APSME-TRANSPORT-KEY.ind and then respond to a request from the trust center to establish a link key using the APSME-ESTABLISH-KEY.rsp. The device shall then wait for the trust center to provide it with a NWK key using APSME-TRANSPORT-KEY.ind. Upon succesful acquisition of the NWK key, the device is joined and authenticated.[80]

1.5.5.4.3.2 Normal operating state

The ZigBee end device shall respond to any device discovery or service discovery operations requested of its own device using the attributes described in Sections 5.4 of this document.

If security is enabled, the ZigBee end device shall support the :Config_Master_Key and shall employ the Master Key in key establishment procedures for Link Keys. Upon presentation of a remote destination address requiring secure communications, the ZigBee end device shall support APSME-KEY.req to establish a master key with the remote device and support APSME-ESTABLISH-KEY.request to present the request to the destination and shall support APSME-ESTABLISH-KEY.confirm and APSME-ESTABLISH-KEY.response to complete the key establishment of the Link Key. The ZigBee end device shall provide the ability to store Link Keys for known destinations requiring secure communications and shall manage key storage for addition or deletion of Link Keys. The ZigBee end device shall support APSME-TRANSPORT-KEY.ind to receive keys from the trust center. The ZigBee end device shall request the trust center to update its NWK key via the APSME-KEY.req

The ZigBee End Device shall process End_Device_annce messages from other ZigBee End Devices. Upon receipt of an End_Device_annce, the ZigBee End Device shall check all internal tables holding 64 bit IEEE addresses for devices within the PAN for a match with the address supplied in the End_Device_annce message. At minimum, any Binding Table entries held by the ZigBee End Device shall be checked. If a match is detected, the ZigBee End Device shall update its APS Information Block address map entries corresponding to the matched 64 bit IEEE address to reflect the updated 16 bit NWK address contained in the End_Device_annce.[81]

[80] CCB Comment #169, 196

1.5.5.5 Device and Service Discovery

The Device and Service Discovery function supports:

— Device Discovery

— Service Discovery

Device Management performs the above functions with the ZigBee Device Profile (Reference [6]).

1.5.5.5.1 Optional and Mandatory Attributes within Device and Service Discovery

All of the request attributes within the Device and Service Discovery Object are optional for all ZigBee logical device types. The responses listed as mandatory are mandatory for all ZigBee logical device types and the responses listed as optional are optional for all ZigBee logical device types. See clause 1.4 for a description of any of these attributes.

Table 90 Device and Service Discovery Attributes

Attribute	M/O	Type
NWK_addr_req	O	Public
NWK_addr_rsp	M	Public
IEEE_addr_req	O	Public
IEEE_addr_rsp	M	Public
Node_Desc_req	O	Public
Node_Desc_rsp	M	Public
Power_Desc_req	O	Public
Power_Desc_rsp	M	Public
Simple_Desc_req	O	Public
Simple_Desc_rsp	M	Public
Active_EP_req	O	Public
Active_EP_rsp	M	Public
Match_Desc_req	O	Public
Match_Desc_rsp	M	Public
Complex_Desc_req	O	Public
Complex_Desc_rsp	O	Public
User_Desc_req	O	Public
User_Desc_rsp	O	Public
Discovery_Register_req	O	Public
Discovery_Register_rsp	O	Public

[81]CCB Comment #169, 196

Table 90 Device and Service Discovery Attributes

End_Device_annce	O	Public
End_Device_annce_rsp	O	Public
User_Desc_set	O	Public
User_Desc_conf	O	Public[a]

[a]CCB Comment #169, 176

1.5.5.6 Security Manager

The security manager determines whether security is enabled or disabled and, if enabled, shall perform the following:

— Establish Key

— Transport Key

— Authentication

1.5.5.6.1 Optional and Mandatory Attributes within Security Manager

The Security Manager itself is an optional object for all ZigBee Device Types. If the Security Manager is present, all requests and responses are mandatory for all ZigBee device types. If the Security Manager is not present, none of the attributes in the Security Manager are present for any ZigBee logical device type. See Chapter 3 for a description of any of the primitives listed in Table 91.

Table 91 Security Manager Attributes

Attribute	M/O	Type
APSME-ESTABLISH-KEY.request	M	Public
APSME-ESTABLISH-KEY.response	M	Public
APSME-TRANSPORT-KEY.request	M	Public
APSME-TRANSPORT-KEY.response	M	Public
APSME-AUTHENTI-CATE.request	M	Public
APSME-AUTHENTI-CATE.response	M	Public
APSME-DEVICE-UPDATE.request	M	Private
APSME-REMOVE-DEVICE.request	M	Private
APSME-KEY.request	M	Private

1.5.5.7 Binding Manager

The Binding Management function supports:

— End Device Binding

— Bind and Unbind

Binding Management performs the above functions with ZigBee Device Profile commands plus APSME-SAP primitives to commit/remove binding table entries once the indication arrives on the Zigbee coordinator or router, supporting the binding table. [82]

1.5.5.7.1 Optional and Mandatory Attributes within Binding Manager

The Binding Manager is an optional object for all ZigBee Device Types.

If the Binding Manager is present, all requests are optional for all ZigBee logical device types. Additionally, responses shall be supported on the ZigBee Coordinator or responses shall be supported on ZigBee Routers and ZigBee End Devices which correspond to the source address for the binding table entries held on those devices.[83]

If the Binding Manager is not present, all requests and all responses for all ZigBee logical device types shall not be supported.

Table 92 Binding Manager Attributes

Attribute	Method	M/O	Type
End_Device_Bind_req	See clause 1.4.	O	Public
End_Device_Bind_rsp	See clause 1.4.	O	Public
Bind_req	See clause 1.4.	O	Public
Bind_rsp	See clause 1.4.	O	Public
Unbind_req	See clause 1.4.	O	Public
Unbind_rsp	See clause 1.4.	O	Public
APSME-BIND.request	See clause 1.2.	O	Private
APSME-BIND.confirm	See clause 1.2.	O	Private
APSME-UNBIND.request	See clause 1.2.	O	Private
APSME-UNBIND.confirm	See clause 1.2.	O	Private

1.5.5.8 Network Manager

The Network Management function supports:

— Network Discovery

— Network Formation

— Permit/Disable Associations

— Association and Disassociation

[82] CCB Comment #171

[83] CCB Comment #213

— Route Discovery

— Network Reset

— Radio Receiver State Enable/Disable

— Get and Set of Network Management Information Block Data

Network Management performs the above functions with NLME-SAP primitives (see Chapter 2).

1.5.5.8.1 Optional and Mandatory Attributes within Network Manager

The Network Manager is a mandatory object for all ZigBee Device Types.

The Network Discovery, Get and Set attributes (both requests and confirms) are mandatory for all ZigBee logical device types.

If the ZigBee logical device type is ZigBee Coordinator, the NWK Formation request and confirm, the NWK Leave request, NWK Leave indication, NWK Leave confirm, NWK Join indication, NWK Permit Joining request, NWK Permit Joining confirm, NWK Direct Join request, NWK Direct Join confirm plus the NWK Permit Joining request and NWK Permit Joining confirm shall be supported. The NWK Join request, NWK Join response, NWK Leave request and NWK Leave confirm shall not be supported.

If the ZigBee logical device type is ZigBee Router, the NWK Formation request and confirm shall not be supported. Additionally, the NWK Start Router request, NWK Start Router confirm, NWK Join request, NWK Join confirm, NWK Join indication, NWK Leave request, NWK Leave confirm, NWK Leave indication, NWK Direct Join request, NWK Direct Join confirm, NWK Permit Joining request and NWK Permit Joining confirm shall be supported.

If the ZigBee logical device type is ZigBee End Device, the NWK Formation request and confirm plus the NWK Start Router request and confirm shall not be supported. Additionally, the NWK Join indication, NWK Leave indication and NWK Permit Joining request shall not be supported. The NWK Join request, NWK Join confirm, NWK Leave request, NWK Leave confirm shall be supported.

For all ZigBee logical devices types, the NWK Sync request, indication and confirm plus NWK Reset request and confirm shall be optional.[84] See Chapter 2 for a description of any of the primitives listed in Table 93.

Table 93 Network Manager Attributes

Attribute	M/O	Type
NLME-GET.request	M	Private
NLME-GET.confirm	M	Private
NLME-SET.request	M	Private
NLME-SET.confirm	M	Private
NLME-NETWORK-DISCOVERY.request	M	Public
NLME-NETWORK-DISCOVERY.confirm	M	Public
NLME-NETWORK-FORMATION.request	O	Private
NLME-NETWORK-FORMATION.confirm	O	Private

[84] CCB Comment #196

Table 93 Network Manager Attributes

NLME-JOIN.request	O	Private
NLME-JOIN.confirm	O	Private
NLME-DIRECT-JOIN.request	O	Public
NLME-DIRECT-JOIN.confirm	O	Public[a]
NLME_LEAVE.request	O	Private
NLME-LEAVE.confirm	O	Private
NLME-RESET.request	O	Private
NLME-RESET.confirm	O	Private
NLME-SYNC.request	O	Public
NLME-SYNC.indication	O	Public[b]
NLME-SYNC.confirm	O	Public

[a]CCB Comment #196
[b]Ibid

1.5.5.9 Node Manager

The node manager supports the ability to request and respond to management functions. These management functions only provide visibility to external devices regarding the operating state of the device receiving the request.

1.5.5.9.1 Optional and Mandatory Attributes within Node Manager

The Node Manager is an optional object for all ZigBee Device Types. All request and response attributes within Node Manager are also optional if the Node Manager object is present. See clause 1.4 for a description of these attributes.

Table 94 Node manager attributes

Attribute	M/O	Type
Mgmt_NWK_Disc_req	O	Public
Mgmt_NWK_Disc_rsp	O	Public
Mgmt_Lqi_req	O	Public
Mgmt_Lqi_rsp	O	Public
Mgmt_Rtg_req	O	Public
Mgmt_Rtg_rsp	O	Public
Mgmt_Bind_req	O	Public
Mgmt_Bind_rsp	O	Public
Mgmt_Leave_req	O	Public

Table 94 Node manager attributes

Mgmt_Leave_rsp	O	Public
Mgmt_Direct_Join_req	O	Public
Mgmt_Direct_Join_rsp	O	Public

1.5.6 Configuration Attributes

This attribute is used to represent the minimum mandatory and/or optional attributes used as configuration attributes for a device.

Table 95 Configuration Attributes

Attribute	M/O	Type
:Config_Node_Descriptor	M	Public
:Config_Power_Descriptor	M	Public
:Config_Simple_Descriptors	M	Public
:Config_NWK_Mode_and_Params	M	Public
:Config_NWK_Scan_Attempts	M	Private
:Config_NWK_Time_btwn_Scans	M	Private
:Config_Complex_Descriptor	O	Public
:Config_User_Descriptor	O	Public
:Config_Max_Bind	O	Private
:Config_Master_Key	O	Private
:Config_EndDev_Bind_Timeout	O	Private
:Config_Permit_Join_Duration	O	Public
:Config_NWK_Security_Level	O	Private
:Config_NWK_Secure_All_Frames	O	Private

Table 95 Configuration Attributes

:Config_NWK_Leave_removeChildren	O	Private[a]
:Config_NWK_BroadcastDeliveryTime	O	Private[b]
:Config_NWK_TransactionPersistenceTime	O	Private[c]

[a]CCB Comment #107
[b]CCB Comment #269
[c]CCB Comment #252

1.5.6.1 Configuration Attribute Definitions

Attribute	Description	When updated
:Config_Node_Descriptor	Contents of the Node Descriptor for this device (see sub-clause 1.3.3.4).	The :Config_Node_Descriptor is either created when the application is first loaded or initialized with a commissioning tool prior to when the device begins operations in the network. It is used for service discovery to describe node features to external inquiring devices.
:Config_Power_Descriptor	Contents of the Power Descriptor for this device (see sub-clause 1.3.3.5).	The :Config_Power_Descriptor is either created when the application is first loaded or initialized with a commissioning tool prior to when the device begins operations in the network. It is used for service discovery to describe node power features to external inquiring devices.
:Config_Simple_Descriptors	Contents of the Simple Descriptor(s) for each active endpoint for this device (see sub-clause 1.3.3.6).	The :Config_Simple_Descriptors are created when the application is first loaded and are treated as “read-only”. The Simple Descriptor are used for service discovery to describe interfacing features to external inquiring devices.

:Config_NWK_Mode_and_Params	Consists of the following fields: Channel List – The list of channels to be scanned when using NLME-NETWORK-DISCOVERY. Protocol Version – Used in NLME-NETWORK-FORMATION and NLME-JOIN (Chapter 2). Stack Profile – Used in NLME-NETWORK-FORMATION and NLME-JOIN (Chapter 2). Beacon Order – Used in NLME-NETWORK-FORMATION (Chapter 2). Superframe Order – Used in NLME-NETORK-FORMATION (Chapter 2). BatteryLifeExtension – TRUE or FALSE (sub-clause 2.3.3) Security Setting – Used in NLME-NETWORK-FORMATION (sub-clause 2.3.3)	The :Config_Node_Descriptor contains a field describing this devices Logical Device Type. That information plus the specific logic employed in this devices ZDO permits the device application to use the parameters in :Config_NWK_Mode_and_Params to form or join a network consistent with the applications supported on the device.
:Config_NWK_Scan_Attempts	Integer value representing the number of scan attempts to make before the NWK layer decides which ZigBee coordinator or router to associate with (see sub-clause 1.5.5.4).[a] This attribute has default value of 5 and valid values between 1 and 255.	The :Config_NWK_Scan_Attempts is employed within ZDO to call the NLME-NETWORK-DISCOVERY.request primitive the indicated number of times (for routers and end devices).

:Config_NWK_Time_btwn_Scans	Integer value representing the time duration (in seconds) between each NWK discovery attempt described by :Config_NWK_Scan_Attempts (see subclause 1.5.5.4). This attrubue has a default value of 1 (second) and valid values between 1 and 255 (seconds).	The :Config_NWK_Time_btwn_Scans is employed within ZDO to provide a time duration between the NLME-NETWORK-DISCOVERY.request attempts.
:Config_Complex_Descriptor	Contents of the (optional) Complex Descriptor for this device (see subclause 1.3.3.7).	The :Config_Complex_Descriptor is either created when the application is first loaded or initialized with a commissioning tool prior to when the device begins operations in the network. It is used for service discovery to describe extended device features for external inquiring devices.
:Config_User_Descriptor	Contents of the (optional) User Descriptor for this device (see subclause 1.3.3.8).	The :Config_User_Descriptor is either created when the application is first loaded or initialized with a commissioning tool prior to when the device begins operations in the network. It is used for service discovery to provide a descriptive character string for this device to external inquiring devices.
:Config_Max_Bind	A constant which describes the maximum number of binding entries permitted if this device is a ZigBee Coordinator or ZigBee Router.	The :Config_Max_Bind is a maximum number of supported Binding Table entries for this device.
:Config_Master_Key	Master Key used if security is enabled for this device (see Chapter 3).	The :Config_Master_Key is either present when the application is first loaded or initialized with a commissioning tool prior to when the device begins operations in the network. It is used for security operations on the device if security is supported and enabled.
:Config_EndDev_Bind_Timeout	Timeout value in seconds employed in End Device Binding (see subclause 1.4.3.2).	The :Config_EndDev_Bind_Timeout is employed only on ZigBee Coordinators and used to determine whether end device bind requests have been received within the timeout window.

:Config_Permit_Join_Duration	Permit Join Duration value set by the NLME-PERMIT-JOINING.request primitive (see Chapter 2).	The default value for :Config_Permit_Join_Duration is 0x00, however, this value can be established differently according to the needs of the profile.
:Config_NWK_Security_Level	Security level of the network (see Chapter 2).	This attribute is used only on the trust center and is used to set the level of security on the network.
:Config_NWK_Secure_All_Frames	If all network frames should be secured (see Chapter 2).	This attribute is used only on the trust center and is used to determine if network layer security shall be applied to all frames in the network.
:Config_NWK_Leave_removeChildren	Sets the policy as to whether child devices are to be removed if the device is asked to leave the network via NLME-LEAVE (see Chapter 2).	The policy for setting this parameter is found in the Stack Profile employed.[b]
:Config_NWK_BroadcastDeliveryTime	See Table 132.	The value for this configuration attribute is established in the Stack Profile.[c]
:Config_NWK_TransactionPersistenceTime	See Table 132. This attribute is mandatory for the ZigBee coordinator and ZigBee routers and not used for ZigBee End Devices.	The value for this configuration attribute is established in the Stack Profile.[d]

[a]CCB Comment #171
[b]CCB Comment #107
[c]CCB Comment #269
[d]CCB Comment #252

Chapter 2 Network Specification

2.1 NWK layer status values

Network (NWK) layer confirmation primitives often include a parameter that reports on the status of the request to which the confirmation applies. Values for NWK layer status parameters appear in Table 96.

Table 96 NWK layer status values

Name	Value	Description
SUCCESS	0x00	A request has been executed successfully.
INVALID_PARAMETER	0xc1	An invalid or out-of-range parameter has been passed to a primitive from the next higher layer.
INVALID_REQUEST	0xc2	The next higher layer has issued a request that is invalid or cannot be executed given the current state of the NWK layer.
NOT_PERMITTED	0xc3	An NLME-JOIN.request has been disallowed.
STARTUP_FAILURE	0xc4	An NLME-NETWORK-FORMATION.request has failed to start a network.
ALREADY_PRESENT	0xc5	A device with the address supplied to the NLME-DIRECT-JOIN.request is already present in the neighbor table of the device on which the NLME-DIRECT-JOIN.request was issued.
SYNC_FAILURE	0xc6	Used to indicate that an NLME-SYNC.request has failed at the MAC layer.
TABLE_FULL	0xc7	An NLME-JOIN-DIRECTLY.request has failed because there is no more room in the neighbor table.
UNKNOWN_DEVICE	0xc8	An NLME-LEAVE.request has failed because the device addressed in the parameter list is not in the neighbor table of the issuing device.
UNSUPPORTED_ATTRIBUTE	0xc9	An NLME-GET.request or NLME-SET.request has been issued with an unknown attribute identifier.
NO_NETWORKS	0xca	An NLME-JOIN.request has been issued in an environment where no networks are detectable.[a]
LEAVE_UNCONFIRMED	0xcb	A device failed to confirm its departure from the network.[b]
MAX_FRM_CNTR	0xcc	Security processing has been attempted on an outgoing frame, and has failed because the frame counter has reached its maximum value.[c]
NO_KEY	0xcd	Security processing has been attempted on an outgoing frame, and has failed because no key was available with which to process it.[d]
BAD_CCM_OUTPUT	0xce	Security processing has been attempted on an outgoing frame, and has failed because security engine produced erroneous output.[e]

[a]CCB Comment #105

[b]CCB Comment #107
[c]CCB Comment #159
[d]Ibid
[e]Ibid

2.2 General description

2.2.1 Network (NWK) layer overview

The network layer is required to provide functionality to ensure correct operation of the IEEE 802.15.4-2003 MAC sub-layer and to provide a suitable service interface to the application layer. To interface with the application layer, the network layer conceptually includes two service entities that provide the necessary functionality. These service entities are the data service and the management service. The NWK layer data entity (NLDE) provides the data transmission service via its associated SAP, the NLDE-SAP, and the NWK layer management entity (NLME) provides the management service via its associated SAP, the NLME-SAP. The NLME utilizes the NLDE to achieve some of its management tasks and it also maintains a database of managed objects known as the network information base (NIB).

2.2.1.1 Network layer data entity (NLDE)

The NLDE shall provide a data service to allow an application to transport application protocol data units (APDU) between two or more devices. The devices themselves must be located on the same network.

The NLDE will provide the following services:

— **Generation of the Network level PDU (NPDU).** The NLDE shall be capable of generating an NPDU from an application support sub-layer PDU through the addition of an appropriate protocol header.

— **Topology specific routing.** The NLDE shall be able to transmit an NPDU to an appropriate device that is either the final destination of the communication or the next step towards the final destination in the communication chain.

2.2.1.2 Network layer management entity (NLME)

The NLME shall provide a management service to allow an application to interact with the stack.

The NLME shall provide the following services:

— **Configuring a new device.** The ability to sufficiently configure the stack for operation as required. Configuration options include beginning operation as a ZigBee coordinator or joining an existing network.

— **Starting a network.** The ability to establish a new network.

— **Joining and leaving a network**. The ability to join or leave a network as well as the ability for a ZigBee coordinator or ZigBee router to request that a device leave the network.

— **Addressing**. The ability of ZigBee coordinators and routers to assign addresses to devices joining the network.

— **Neighbor discovery**. The ability to discover, record and report information pertaining to the one-hop neighbors of a device

— **Route discovery**. The ability to discover and record paths through the network whereby messages may be efficiently routed.

— **Reception control.** The ability for a device to control when the receiver is activated and for how long, enabling MAC sub-layer synchronization or direct reception.

2.3 Service specification

Figure 31 depicts the components and interfaces of the NWK layer.

The NWK layer provides two services, accessed through two service access points (SAPs). These are the NWK data service, accessed through the NWK layer data entity SAP (NLDE-SAP) and the NWK management service, access though the NWK layer management entity SAP (NLME-SAP). These two services provide the interface between the application and the MAC sub-layer, via the MCPS-SAP and MLME-SAP interfaces (see [B1]). In addition to these external interfaces, there is also an implicit interface between the NLME and the NLDE that allows the NLME to use the NWK data service.

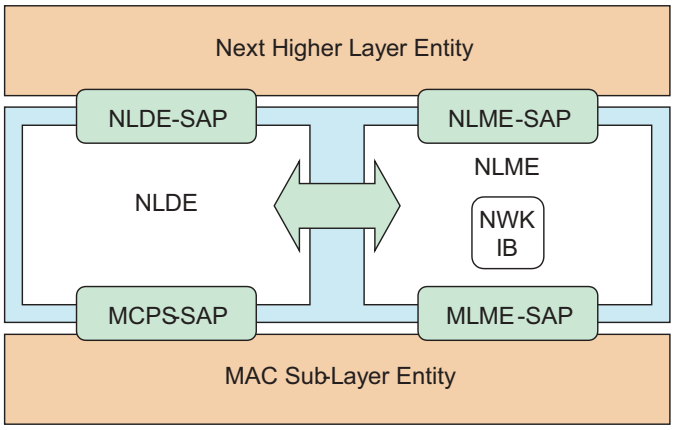


Figure 31 The NWK layer reference model

2.3.1 NWK data service

The NWK layer data entity SAP (NLDE-SAP) supports the transport of application protocol data units (APDUs) between peer application entities. Table 97 lists the primitives supported by the NLDE-SAP. Each of these primitives will be discussed in the following sub-clauses.

Table 97 NLDE-SAP Primitives

NLDE-SAP primitive	Request	Confirm	Indication
NLDE-DATA	2.3.1.1	2.3.1.2	2.3.1.3

2.3.1.1 NLDE-DATA.request

This primitive requests the transfer of a data PDU (NSDU) from the local APS sub-layer entity to a single or multiple peer APS sub-layer entities.

2.3.1.1.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLDE-DATA.request	(DstAddr, NsduLength, Nsdu, NsduHandle, Radius[a], DiscoverRoute, SecurityEnable)

[a]CCB Comment #125

Table 98 specifies the parameters for the NLDE-DATA.request primitive.

Table 98 NLDE-DATA.request parameters

Name	Type	Valid range	Description
DstAddr	Network address	0x0000 – 0xffff	The network address of the entity or entities to which the NSDU is being transferred.
NsduLength	Integer	< *aMaxMACFrameSize* - *nwkcMinHeaderOverhead*[a]	The number of octets comprising the NSDU to be transferred.
Nsdu	Set of octets	-	The set of octets comprising the NSDU to be transferred.
NsduHandle	Integer	0x00 – 0xff	The handle associated with the NSDU to be transmitted by the NWK layer entity.
Radius[b]	Unsigned integer	0x00—0xff	The distance, in hops, that a frame will be allowed to travel through the network.[c]
DiscoverRoute	Integer	0x00-0x02	The DiscoverRoute parameter may be used to control route discovery operations for the transit of this frame (see sub-clause 2.7.3.4). 0x00 = suppress route discovery 0x01 = enable route discovery 0x02 = force route discovery[d]
SecurityEnable	Boolean	TRUE or FALSE	The SecurityEnable parameter may be used to enable NWK layer security processing for the current frame. If the security level specified in the NIB is 0, meaning no security, then this parameter will be ignored. Otherwise, a value of TRUE denotes that the security processing specified by the security level will be applied and a value of FALSE denotes that no security processing will be applied.

[a]CCB Comment #366
[b]CCB Comment #125
[c]Ibid
[d]CCB Comment #256

2.3.1.1.2 When generated

This primitive is generated by a local APS sub-layer entity whenever a data PDU (NSDU) is to be transferred to a peer APS sub-layer entity.

2.3.1.1.3 Effect on receipt

On receipt of this primitive on a device that is not currently associated, the NWK layer will issue an NLDE-DATA.confirm primitive with a status of INVALID_REQUEST.

On receipt of this primitive, the NLDE first constructs an NPDU in order to transmit the supplied NSDU. If, during processing, the NLDE issues the NLDE-DATA.confirm primitive prior to transmission of the NSDU, all further processing is aborted. In constructing the new NPDU, the destination address field of the NWK header will be set to the value provided in the DstAddr parameter and the source address field will have the value of the *macShortAddress* attribute in the MAC PIB. The discover route sub-field of frame control field of the NWK header will be set to the value provided in the DiscoverRoute parameter. If a value has been supplied for the Radius parameter, that will be placed in the radius field of the NWK header. If a value is not supplied, then the radius field of the NWK header will be set to twice the value of the *nwkMaxDepth* attribute of the NWK IB. The NWK layer will generate a sequence number for the frame as described in sub-clause 2.7.2.1. The sequence number value shall be inserted into the sequence number field of the NWK header of the frame.[85] Once the NPDU is constructed, the NSDU is routed using the procedure outline in Figure 57 and described in sub-clause 2.7.3.3. When the routing procedure specifies that the NSDU is to be transmitted, this is accomplished by issuing the MCPS-DATA.request primitive with both the SrcAddrMode and DstAddrMode parameters set to 0x02 indicating the use of 16-bit network addresses. The SrcPANId and DstPANId parameters should be set to the current value of macPANId from the MAC PIB. The SrcAddr parameter will be set to the value of macShortAddr from the MAC PIB. The value of the DstAddr parameter is the next hop address determined by the routing procedure. The TxOptions parameter should always be non-zero when bitwise ANDed with the value 0x01, denoting that acknowledged transmission is required. On receipt of the MCPS-DATA.confirm primitive, the NLDE issues the NLDE-DATA.confirm primitive with a status equal to that received from the MAC sub-layer.

If the network-wide security level specified in the NIB has a non-zero value and the SecurityEnable parameter has a value of TRUE then NWK layer security processing will be applied to the frame before transmission as described in clause 3.4. Otherwise no security processing will be performed at the NWK layer for this frame. If security processing is done and it fails for any reason, then the frame is discarded and the NLDE issues the NLDE-DATA.confirm primitive with a status parameter value equal to that returned by the security suite.

2.3.1.2 NLDE-DATA.confirm

This primitive reports the results of a request to transfer a data PDU (NSDU) from a local APS sub-layer entity to a single peer APS sub-layer entity.

2.3.1.2.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLDE-DATA.confirm	(NsduHandle, Status)

[85] CCB Comment #101, 109, 125, 111, 256

Table 99 specifies the parameters for the NLDE-DATA.confirm primitive.

Table 99 NLDE-DATA.confirm parameters

Name	Type	Valid range	Description
NsduHandle	Integer	0x00 – 0xff	The handle associated with the NSDU being confirmed.
Status	Status	INVALID_REQUEST, MAX_FRM_COUNTER, NO_KEY, BAD_CCM_OUTPUT[a] or any status values returned from security suite or the MCPS-DATA.confirm primitive (see [B1]).	The status of the corresponding request.

[a]CCB Comment #159

2.3.1.2.2 When generated

This primitive is generated by the local NLDE in response to the reception of an NLDE-DATA.request primitive.

The Status field will reflect the status of the corresponding request, as described in sub-clause 2.3.1.1.3.

2.3.1.2.3 Effect on receipt

On receipt of this primitive the APS sub-layer of the initiating device is notified of the result of its request to transmit. If the transmission attempt was successful, the status parameter will be set to SUCCESS. Otherwise, the status parameter will indicate the error.

2.3.1.3 NLDE-DATA.indication

This primitive indicates the transfer of a data PDU (NSDU) from the NWK layer to the local APS sub-layer entity.

2.3.1.3.1 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLDE-DATA.indication        (
                            SrcAddress,
                            NsduLength,
                            Nsdu,
                            LinkQuality
                            }
```


Table 100 specifies the parameters for the NLDE-DATA.indication primitive.

Table 100 NLDE-DATA.indication parameters

Name	Type	Valid range	Description
SrcAddress	16-bit Device address	Any valid device address except the broadcast address.	The individual device address from which the NSDU originated.
NsduLength	Integer	< *aMaxMACFrameSize - nwkcMinHeaderOverhead*[a]	The number of octets comprising the NSDU being indicated.
Nsdu	Set of octets	-	The set of octets comprising the NSDU being indicated.
LinkQuality	Integer	0x00 – 0xff	The link quality indication delivered by the MAC on receipt of this frame as a parameter of the MCPS-DATA.indication primtitive (see [B1]).

[a]CCB Comment #336

2.3.1.3.2 When generated

This primitive is generated by the NLDE and issued to the APS sub-layer on receipt of an appropriately addressed data frame from the local MAC sub-layer entity.

2.3.1.3.3 Effect on receipt

On receipt of this primitive the APS sub-layer is notified of the arrival of data at the device.

2.3.1.3.4 NWK management service

The NWK layer management entity SAP (NLME-SAP) allows the transport of management commands between the next higher layer and the NLME. Table 101 summarizes the primitives supported by the NLME through the NLME-SAP interface. See the following sub-clauses for more details on the individual primitives.

Table 101 Summary of the primitives accessed through the NLME-SAP

Name	Request	Indication	Response	Confirm
NLME-NETWORK-DISCOVERY	2.3.2.1			2.3.2.2
NLME-NETWORK-FORMATION	2.3.2.2			2.3.3.2
NLME-PERMIT-JOINING	2.3.6.1	2.3.6.2		2.3.6.3
NLME-START-ROUTER	2.3.5.1			2.3.5.2
NLME-JOIN	2.3.6.1	2.3.6.2		2.3.6.3
NLME-DIRECT-JOIN	2.3.7.1			2.3.7.2
NLME-LEAVE	2.3.8.1	2.3.8.2		2.3.8.3
NLME-RESET	2.3.9.1			2.3.9.2

Table 101 Summary of the primitives accessed through the NLME-SAP

NLME-SYNC	2.3.10.1			2.3.10.2
NLME-GET	2.3.11.1			2.3.11.2
NLME-SET	2.3.11.3			2.3.11.4

2.3.2 Network discovery

The NWK layer management entity SAP (NLME-SAP) supports the discovery of operating networks. The primitives employed in network discovery are the NLME-NETWORK-DISCOVERY primitives.

2.3.2.1 NLME-NETWORK-DISCOVERY.request

This primitive allows the next higher layer to request that the NWK layer discover networks currently operating within the POS.

2.3.2.1.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-NETWORK-DISCOVERY.request	{
	ScanChannels,
	ScanDuration
	}

Table 102 specifies the parameters for the NLME-NETWORK-DISCOVERY.request primitive.

Table 102 NLME-NETWORK-DISCOVERY.request parameters

Name	Type	Valid range	Description
ScanChannels	Bitmap	32 bit field	The five most significant bits (b27,..., b31) are reserved. The 27 least significant bits (b0, b1,... b26) indicate which channels are to be scanned (1 = scan, 0 = do not scan) for each of the 27 valid channels (see [B1]).
ScanDuration	Integer	0x00-0x0e	A value used to calculate the length of time to spend scanning each channel. The time spent scanning each channel is (*aBaseSuperframeDuration* * (2n + 1)) symbols, where n is the value of the ScanDuration parameter. For more information on MAC sub-layer scanning see [B1].

2.3.2.1.2 When generated

This primitive is generated by the next higher layer of a ZigBee device and issued to its NLME to request the discovery of networks operating within the device's personal operating space (POS).

2.3.2.1.3 Effect on receipt

On receipt of this primitive, the NWK will attempt to discover networks operating within the device's POS by scanning over the channels specified in the ScanChannels argument for the period specified in the ScanDuration parameter.

If the device is an IEEE 802.15.4-2003 FFD [B1], then it will perform an active scan. If it is an RFD, it will perform an active scan provided that the device implements active scan. Otherwise it will perform a passive scan using the MLME-SCAN.request primitive. On receipt of the MLME-SCAN.confirm primitive the device's neighbor table (see sub-clause 2.7.1.3.4) is updated to reflect the information returned by the scan and a network descriptor list is assembled and the NLME issues the NLME-NETWORK-DISCOVERY.confirm primitive containing the information about the discovered networks and with a Status parameter value equal to that returned with the MLME-SCAN.confirm.

2.3.2.2 NLME-NETWORK-DISCOVERY.confirm

This primitive reports the results of a network discovery operation.

2.3.2.2.1 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-NETWORK-DISCOVERY.confirm      {
                                    NetworkCount,
                                    NetworkDescriptor,
                                    Status
                                    }
```


Table 103 describes the arguments of the NLME-NETWORK-DISCOVERY.confirm primitive.

Table 103 NLME-NETWORK-DISCOVERY.confirm parameters

Name	Type	Valid range	Description
NetworkCount	Integer	0x00—0xff	Gives the number of networks discovered by the search.
NetworkDescriptor	List of network descriptors	The list contains the number of elements given by the NetworkCount parameter.	A list of descriptors, one for each of the networks discovered. Table 104 gives a detailed account of the contents of each item.
Status	Status	Any Status value returned with the MLME-SCAN.confirm primitive.	See [B1].

Table 104 gives a detailed account of the contents of a network descriptor from the NetworkDescriptor parameter.

Table 104 Network descriptor information fields[a]

Name	Type	Valid range	Description
PanID	Integer	0x0000—0x3fff	The 16-bit PAN identifier of the discovered network. The 2 highest-order bits of this parameter are reserved and shall be set to 0.
LogicalChannel	Integer	Selected from the available logical channels supported by the PHY (see [B1]).	The current logical channel occupied by the network.
StackProfile	Integer	0x00 – 0x0f	A ZigBee stack profile identifier indicating the stack profile in use in the discovered network.
ZigBeeVersion	Integer	0x00 – 0x0f	The version of the ZigBee protocol in use in the discovered network.
BeaconOrder	Integer	0x00-0x0f	This specifies how often the MAC sub-layer beacon is to be transmitted by a given device on the network. For a discussion of MAC sub-layer beacon order see [B1].
SuperframeOrder	Integer	0x00-0x0f	For beacon-oriented networks, i.e. beacon order < 15, this specifies the length of the active period of the superframe. For a discussion of MAC sub-layer superframe order see [B1].
PermitJoining	Boolean	TRUE or FALSE	A value of TRUE indicates that at least one ZigBee router on the network currently permits joining, i.e. its NWK has been issued an NLME-PERMIT-JOINING primitive and the time limit, if given, has not yet expired.

[a]CCB Comment #267

2.3.2.2.2 When generated

This primitive is generated by the NLME and issued to its next higher layer on completion of the discovery task initiated by an NLME-NETWORK-DISCOVERY.request primitive.

2.3.2.2.3 Effect on receipt

On receipt of this primitive, the next higher layer is notified of the results of a network search.

2.3.3 Network formation

This set of primitives defines how the next higher layer of a device can initialize itself as the ZigBee coordinator of a new network and subsequently make changes to its superframe configuration[86].

2.3.3.1 NLME-NETWORK-FORMATION.request

This primitive allows the next higher layer to request that the device start a new ZigBee network with itself as the coordinator and subsequently, to make changes to its superframe configuration[87].

2.3.3.1.1 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-NETWORK-FORMATION.request      (
                                    ScanChannels,
                                    ScanDuration,
                                    BeaconOrder,
                                    SuperframeOrder,
                                    PANId,
                                    BatteryLifeExtension
                                    )
```

Table 105 specifies the parameters for the NLME-NETWORK-FORMATION.request primitive.

Table 105 NLME-NETWORK-FORMATION.request parameters

Name	Type	Valid range	Description
ScanChannels	Bitmap	32 bit field	The five most significant bits (b27,..., b31) are reserved. The 27 least significant bits (b0, b1,... b26) indicate which channels are to be scanned in preparation for starting a network (1=scan, 0=do not scan) for each of the 27 valid channels (see [B1]).
ScanDuration	Integer	0x00-0x0e	A value used to calculate the length of time to spend scanning each channel. The time spent scanning each channel is (*aBaseSuperframeDuration* * (2^n + 1)) symbols, where *n* is the value of the ScanDuration parameter [B1].
BeaconOrder	Integer	0x00—0x0f	The beacon order of the network that the higher layers wish to form.

[86]CCB Comment #137
[87]Ibid

Table 105 NLME-NETWORK-FORMATION.request parameters

SuperframeOrder	Integer	0x00—0x0f	The superframe order of the network that the higher layers wish to form.
PANId	Integer	0x0000—0x3fff or NULL	An optional PAN identifier that may be supplied if higher layers wish to establish this network with a predetermined identifier. If PANId is not specified, i.e. a NULL value is given, then the NWK layer will choose a PAN ID. The 2 highest-order bits of this parameter are reserved and shall be set to 0.
BatteryLifeExtension	Boolean	TRUE or FALSE	If this value is TRUE, the NLME will request that the ZigBee coordinator is started supporting battery life extension mode. If this value is FALSE, the NLME will request that the ZigBee coordinator is started without supporting battery life extension mode.

2.3.3.1.2 When generated

This primitive is generated by the next higher layer of a ZigBee coordinator-capable device and issued to its NLME to request the initialization of itself as the ZigBee coordinator of a new network and subsequently, to make changes to its superframe configuration[88].

2.3.3.1.3 Effect on receipt

On receipt of this primitive by a device that is not capable of being a ZigBee coordinator or else already initialized as the ZigBee coordinator[89] of a network, the NLME issues the NLME-NETWORK-FORMATION.confirm primitive with the Status parameter set to INVALID_REQUEST

If the device is to be initialized as a ZigBee coordinator, the NLME requests that the MAC sub-layer first perform an energy detection scan and then an active scan on the specified set of channels. To do this, the NLME issues the MLME-SCAN.request primitive to the MAC sub-layer with the ScanType parameter set to indicate an energy detection scan and then issues the primitive again with the ScanType parameter set to indicate an active scan. After the completion of the active scan, on receipt of the MLME-SCAN.confirm primitive from the MAC sub-layer, the NLME selects a suitable channel. If the next higher layer has specified the PANId parameter, then the NWK layer confirms that the given PAN identifier does not conflict with the PAN identifier of an already established network on the chosen channel. If a conflict is discovered, then another channel will be chosen from the specified set, if possible. If no channel can be chosen such that the given PAN identifier does not conflict with another network on that channel, then the NWK layer issues the NLME-NETWORK-FORMATION.confirm primitive with a status of STARTUP_FAILURE. If the PANId parameter has not been specified, then the NWK layer will pick a PAN identifier that does not conflict with that of any network known to be operating on the chosen channel. Once a suitable channel and PAN identifier are found, the NLME will choose 0x0000 as the 16-bit short MAC address and inform the MAC sub-layer. To do this the NLME issues the MLME-SET.request primitive to the MAC sub-layer to set the MAC PIB attribute *macShortAddress*. If no suitable channel or PAN identifier can be found, the NLME issues the NLME-NETWORK-FORMATION.confirm primitive with the Status parameter set to STARTUP_FAILURE.

[88] CCB Comment #137
[89] Ibid

To initialize a new superframe configuration or modify an existing one[90], the NLME issues the MLME-START.request primitive to the MAC sub-layer. The PANCoordinator parameter of the MLME-START.request primitive is set to TRUE[91]. The BeaconOrder and SuperframeOrder given to the MLME-START.request primitive will be the same as those given to the NLME-NETWORK-FORMATION.request. The CoordRealignment parameter in the MLME-START.request primitive is set to FALSE if the primitive is issued to initialize a new superframe. The CoordRealignment parameter is set to TRUE if the primitive is issued to change any of the PAN configuration attributes.[92] On receipt of the associated MLME-START.confirm primitive, the NLME issues the NLME-NETWORK-FORMATION.confirm primitive to the next higher layer with the status returned from the MLME-START.confirm primitive.

2.3.3.2 NLME-NETWORK-FORMATION.confirm

This primitive reports the results of the request to initialize a ZigBee coordinator in a network.

2.3.3.2.1 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-NETWORK-FORMATION.confirm      (
                                    Status
                                    )
```

Table 106 specifies the parameters for the NLME-NETWORK-FORMATION.confirm primitive.

Table 106 NLME-NETWORK-FORMATION.confirm parameters

Name	Type	Valid range	Description
Status	Status	INVALID_REQUEST, STARTUP_FAILURE or any status value returned from the MLME-START.confirm primitive.	The result of the attempt to initialize a ZigBee coordinator or request a change to the superframe configuration[a].

[a]CCB Comment #137

2.3.3.2.2 When generated

This primitive is generated by the NLME and issued to its next higher layer in response to an NLME-NETWORK-FORMATION.request primitive. This primitive returns a status value of INVALID_REQUEST, STARTUP_FAILURE or any status value returned from the MLME-START.confirm primitive. Conditions under which these values may be returned are described above in sub-clause 2.3.3.1.3.

2.3.3.2.3 Effect on receipt

On receipt of this primitive, the next higher layer is notified of the results of its request to initialize the device as a ZigBee coordinator or request a change to the superframe configuration[93]. If the NLME has been successful, the status parameter will be set to SUCCESS. Otherwise, the status parameter indicates the error.

[90]CCB Comment #137
[91]Ibid
[92]CCB Comment #102, 137
[93]CCB Comment #137

2.3.4 Allowing devices to join

This primitive defines how the next higher layer of a ZigBee coordinator or router can request that devices be permitted to join its network.

2.3.4.1 NLME-PERMIT-JOINING.request

This primitive allows the next higher layer of a ZigBee coordinator or router to set its MAC sub-layer association permit flag for a fixed period during which it may accept devices onto its network.

2.3.4.1.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-PERMIT-JOINING.request	(PermitDuration)

Table 107 specifies the parameters for the NLME-PERMIT-JOINING.request primitive.

Table 107 NLME-PERMIT-JOINING.request parameters

Name	Type	Valid range	Description
PermitDuration	Integer	0x00 – 0xff	The length of time in seconds during which the ZigBee coordinator or router will allow associations. The values 0x00 and 0xff indicate that permission is disabled or enabled, respectively, without a specified time limit.

2.3.4.1.2 When generated

This primitive is generated by the next higher layer of a ZigBee coordinator or router and issued to its NLME whenever it is desired to allow devices to join its network.

2.3.4.1.3 Effect on receipt

It is only permissible that the next higher layer of a ZigBee coordinator or router issue this primitive. On receipt of this primitive by the NWK layer of a ZigBee end device, the NLME-PERMIT-JOINING.confirm primitive returns a status of INVALID_REQUEST.

On receipt of this primitive with the PermitDuration parameter set 0x00, the NLME sets the MAC PIB attribute, *macAssociationPermit*, to FALSE by issuing the MLME-SET.request primitive to the MAC sub-layer. Once the MLME-SET.confirm primitive is received, the NLME issues the NLME-PERMIT-JOINING.confirm primitive with a status equal to that received from the MAC sub-layer.

On receipt of this primitive with the PermitDuration parameter set to 0xff, the NLME sets the MAC PIB attribute, *macAssociationPermit*, to TRUE by issuing the MLME-SET.request primitive to the MAC sub-layer. Once the MLME-SET.confirm primitive is received, the NLME issues the NLME-PERMIT-JOINING.confirm primitive with a status equal to that received from the MAC sub-layer.

On receipt of this primitive with the PermitDuration parameter set to any value other than 0x00 or 0xff, the NLME sets the MAC PIB attribute, *macAssociationPermit*, to TRUE as described above. Following the receipt of the MLME-SET.confirm primitive, the NLME starts a timer to expire after PermitDuration seconds. Once the timer is set, the NLME issues the NLME-PERMIT-JOINING.confirm primitive with a

status equal to that received by the MAC sub-layer. On expiration of the timer, the NLME sets *macAssociationPermit* to FALSE by issuing the MLME-SET.request primitive.

Every NLME-PERMIT-JOINING.request primitive issued by the next higher layer supersedes all previous requests.

2.3.4.2 NLME-PERMIT-JOINING.confirm

This primitive allows the next higher layer of a ZigBee coordinator or router to be notified of the results of its request to permit the acceptance of devices onto the network.

2.3.4.2.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-PERMIT-JOINING.confirm	(Status)

Table 108 specifies the parameters for the NLME-PERMIT-JOINING.confirm primitive.

Table 108 NLME-PERMIT-JOINING.confirm parameters

Name	Type	Valid range	Description
Status	Status	INVALID_REQUEST or any status returned from the MLME-SET.confirm primitive (see [B1]).	The status of the corresponding request.

2.3.4.2.2 When generated

This primitive is generated by the initiating NLME of a ZigBee coordinator or router and issued to its next higher layer in response to an NLME-PERMIT-JOINING.request. The status parameter either indicates the status received from the MAC sub-layer or an error code of INVALID_REQUEST. The reasons for these status values are described in sub-clause 2.3.4.1.

2.3.4.2.3 Effect on receipt

On receipt of this primitive, the next higher layer of the initiating device is notified of the results of its request to permit devices to join the network.

2.3.5 Begin as a router

This set of primitives allows a ZigBee router that is newly joined to a network to setup its superframe configuration. It may also be used by a ZigBee router[94] to reconfigure its superframe.

2.3.5.1 NLME-START-ROUTER.request

This primitive allows the next higher layer of a ZigBee router to initialize or change its superframe configuration.[95]

[94]CCB Comment #137
[95]Ibid

2.3.5.1.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-START-ROUTER.request	(BeaconOrder, SuperframeOrder, BatteryLifeExtension)

Table 109 specifies the parameters for NLME-START-ROUTER.request.

Table 109 NLME-START-ROUTER.request parameters

Name	Type	Valid range	Description
BeaconOrder	Integer	0x00—0x0f	The beacon order of the network that the higher layers wish to form.
SuperframeOrder	Integer	0x00—0x0f	The superframe order of the network that the higher layers wish to form.
BatteryLifeExtension	Boolean	TRUE or FALSE	If this value is TRUE, the NLME will request that the ZigBee router[a] is started supporting battery life extension mode. If this value is FALSE, the NLME will request that the ZigBee router[b] is started without supporting battery life extension mode.

[a]CCB Comment #137
[b]Ibid

2.3.5.1.2 When generated

This primitive is generated by the next higher layer of a new device and issued to its NLME to request the initialization of itself as a ZigBee router. It may also be issued to the NLME of a device that is already operating as a ZigBee router[96] to adjust the configuration of its superframe.

2.3.5.1.3 Effect on receipt

On receipt of this primitive by a device that is not already joined to a ZigBee network as a router, the NLME issues the NLME-START-ROUTER.confirm primitive with the Status parameter set to INVALID_REQUEST.

To initialize a new superframe configuration or to reconfigure an already existing one, the NLME issues the MLME-START.request primitive to the MAC sub-layer. The CoordRealignment parameter in the MLME-START.request primitive is set to FALSE if the primitive is issued to initialize a new superframe. The CoordRealignment parameter is set to TRUE if the primitive is issued to change any of the PAN configuration attributes.

On receipt of the associated MLME-START.confirm primitive, the NLME issues the NLME-START-ROUTER.confirm primitive to the next higher layer with the status returned from the MLME-START.confirm primitive. If, and only if, the status returned from the MLME-START.confirm primitive is SUCCESS, the device may then begin to engage in the activities expected of a ZigBee router including the routing of data frames, route discovery, route repair and the accepting of requests to join the network from other devices. Otherwise the device is expressly forbidden to engage in these activities.[97]

[96]CCB Comment #137

2.3.5.2 NLME-START-ROUTER.confirm

This primitive reports the results of the request to initialize or change the superframe configuration of a ZigBee router.[98]

2.3.5.2.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-START-ROUTER.confirm	(Status)

Table 110 specifies the parameters for NLME-START-ROUTER.confirm.

Table 110 NLME-START-ROUTER.confirm parameters

Name	Type	Valid range	Description
Status	Status	INVALID_REQUEST or any status value returned from the MLME-START.confirm primitive.	The result of the attempt to initialize a ZigBee router[a].

[a]CCB Comment #137

2.3.5.2.2 When generated

This primitive is generated by the NLME and issued to its next higher layer in response to an NLME-START-ROUTER.request primitive. This primitive returns a status value of INVALID_REQUEST or any status value returned from the MLME-START.confirm primitive. Conditions under which these values may be returned are described above in sub-clause 2.3.5.1.3.

2.3.5.2.3 Effect on receipt

On receipt of this primitive, the next higher layer is notified of the results of its request to initialize or change the superframe configuration of a ZigBee router[99]. If the NLME has been successful, the status parameter will be set to SUCCESS. Otherwise, the status parameter indicates the error.

2.3.6 Joining a network

This set of primitives defines how the next higher layer of a device can:

— request to join a network through association.

— request to join a network directly.

— request to re-join a network if orphaned.

2.3.6.1 NLME-JOIN.request

This primitive allows the next higher layer to request to join a network either through association or directly or to re-join a network if orphaned.

[97]CCB Comment #193
[98]CCB Comment #137
[99]CCB Ibid

2.3.6.1.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-JOIN.request	(PANId, JoinAsRouter, RejoinNetwork, ScanChannels, ScanDuration, PowerSource, RxOnWhenIdle, MACSecurity)

Table 111 specifies the parameters for the NLME-JOIN.request primitive.

Table 111 NLME-JOIN.request parameters

Name	Type	Valid range	Description
PANId	Integer	0x0000—0x3fff	The PAN identifier of the network to attempt to join or re-join. The 2 highest-order bits of this parameter are reserved and shall be set to 0
JoinAsRouter	Boolean	TRUE or FALSE	The parameter is TRUE if the device is attempting to join the network in the capacity of a ZigBee router. It is FALSE otherwise. The parameter is valid in requests to join through association and ignored in requests to join directly or to re-join through orphaning.
RejoinNetwork	Boolean	TRUE or FALSE	The parameter is TRUE if the device is joining directly or rejoining the network using the orphaning procedure. The parameter is FALSE if the device is requesting to join a network through association.
ScanChannels	Bitmap	32 bit field	The five most significant bits (b27,..., b31) are reserved. The 27 least significant bits (b0, b1,... b26) indicate which channels are to be scanned (1=scan, 0=do not scan) for each of the 27 valid channels (see [B1]). This parameter is ignored for requests to join through association.
ScanDuration	Integer	0x00-0x0e	A value used to calculate the length of time to spend scanning each channel. The time spent scanning each channel is (*aBaseSuperframeDuration* * (2^n + 1)) symbols, where *n* is the value of the ScanDuration parameter [B1].

Table 111 NLME-JOIN.request parameters

PowerSource	Integer	0x00 – 0x01	This parameter becomes a part of the CapabilityInformation parameter passed to the MLME-ASSOCIATE.request primitive that is generated as the result of a successful executing of a NWK join. The values are: 0x01 = Mains-powered device. 0x00 = other power source. (see [B1]).
RxOnWhenIdle	Integer	0x00 – 0x01	This parameter indicates whether the device can be expected to receive packets over the air during idle portions of the CAP[a]. The values are: 0x01 = The receiver is enabled when the device is idle. 0x00 = The receiver may be disabled when the device is idle. RxOnWhenIdle shall have a value of 0x01 for ZigBee coordinators and ZigBee routers operating in a non-beacon-oriented network.
MACSecurity	Integer	0x00 – 0x01	This parameter becomes a part of the CapabilityInformation parameter passed to the MLME-ASSOCIATE.request primitive that is generated as the result of a successful executing of a NWK join. The values are: 0x01 = MAC security enabled. 0x00 = MAC security disabled (see [B1]).

[a]CCB Comment #138

2.3.6.1.2 When generated

The next higher layer of a device generates this primitive to request to join a new network using the MAC sub-layer association procedure, to join a new network directly using the MAC sub-layer orphaning procedure or to locate and re-join a network after being orphaned.

2.3.6.1.3 Effect on receipt

On receipt of this primitive by a device that is currently joined to a network, the NLME issues an NLME-JOIN-confirm primitive with the status parameter set to INVALID_REQUEST.

On receipt of this primitive by a device that is not currently joined to a network, the device attempts to join the network specified by the PANId parameter.

If the RejoinNetwork parameter is FALSE, the NLME issues an MLME-ASSOCIATE.request with its CoordAddress parameter set to the address of a router in its neighbor table for which following conditions are true:

1) The router belongs to the network identified by the PANId parameter.
2) The router is open to join requests.
3) The link quality for frames received from this device is such that a link cost of at most 3 is produced when calculated as described in sub-clause 2.7.3.1.

If a device exists in the neighbor table for which these conditions are true, the LogicalChannel parameter of the MLME-ASSOCIATE.request primitive is set to that found in the neighbor table entry corresponding to the coordinator address of the potential parent. The bit-fields of the CapabilityInformation parameter shall have the values shown in Table 112 and the capability information assembled here shall be stored as the value of the *nwkCapabilityInformation* NIB attribute (see Table 132). If more than one device meets the requirements outlined above then the joining device shall select the parent with the smallest tree depth.

Table 112 CapabilityInformation bit-fields

Bit	Name	Description
0	Alternate PAN coordinator	This field will always have a value of 0 in implementations of this specification.
1	Device type	This field will have a value of 1 if the joining device is a ZigBee router and the JoinAsRouter parameter[a] has a value of TRUE. It will have a value of 0 if the device is a ZigBee end device or else a router-capable device that is joining as an end device.
2	Power source	This field shall be set to the value of lowest-order bit of the PowerSource parameter passed to the NLME-JOIN-request primitive. The values are: 0x01 = Mains-powered device. 0x00 = other power source.
3	Receiver on when idle	This field shall be set to the value of the lowest-order bit of the RxOnWhenIdle parameter passed to the NLME-JOIN.request primitive. 0x01 = The receiver is enabled when the device is idle. 0x00 = The receiver may be disabled when the device is idle.

Table 112 CapabilityInformation bit-fields

4 – 5	Reserved	This field will always have a value of 0 in implementations of this specification.
6	Security capability	This field shall be set to the value of lowest-order bit of the MACSecurity parameter passed to the NLME-JOIN-request primitive. The values are: 0x01 = MAC security enabled. 0x00 = MAC security disabled.
7	Allocate address	This field will always have a value of 1 in implementations of this specification, indicating that the joining device must be issued a 16-bit short address.

[a]CCB Comment #118

If no device exists in the neighbor table for which the conditions are true, then the NWK layer will issue an NLME-JOIN.confirm with the Status parameter set to NOT_PERMITTED. Otherwise, the NLME issues the NLME-JOIN.confirm with the Status parameter set to the status parameter value returned from the MLME-ASSOCIATE.confirm primitive.

If the RejoinNetwork parameter is FALSE and the JoinAsRouter parameter is set to TRUE, the device will function as a ZigBee router in the network. If the JoinAsRouter parameter is FALSE, then it will join as an end device and not participate in routing.

If a device that is not joined to a network receives this primitive and the RejoinNetwork parameter is equal to TRUE, then it issues an MLME-SCAN.request with the ScanType parameter set to indicate an orphan scan and the scan duration set to the value provided by the ScanDuration parameter. Upon receipt of the MLME-SCAN.confirm primitive, the NLME issues the NLME-JOIN.confirm with the Status parameter set to NO_NETWORKS, if the device was unable to find a network to join, or else to the status parameter value returned from by scan.[100]

2.3.6.2 NLME-JOIN.indication

This primitive allows the next higher layer of a ZigBee coordinator or ZigBee router to be notified when a new device has successfully joined its network by association.

2.3.6.2.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-JOIN.indication	(ShortAddress, ExtendedAddress, CapabilityInformation SecureJoin[a])

[a]CCB Comment #203

[100]CCB Comment #105

Table 113 specifies the parameters for the NLME-JOIN.indication primitive.

Table 113 NLME-JOIN.indication parameters

Name	Type	Valid range	Description
ShortAddress	Network address	0x0000 – 0xffff	The network address of an entity that has been added to the network.
ExtendedAddress	64-bit IEEE address	Any 64-bit, IEEE address.	The 64-bit IEEE address of an entity that has been added to the network.
CapabilityInformation	Bitmap	See [B1].	Specifies the operational capabilities of the joining device.
SecureJoin	Boolean	TRUE or FALSE	This parameter will be TRUE if the underlying MAC association was performed in a secure manner and FALSE otherwise.[a]

[a]CCB Comment #203

2.3.6.2.2 When generated

This primitive is generated by the NLME of a ZigBee coordinator or router and issued to its next higher layer on successfully adding a new device to the network using the MAC association procedure. An association attempt initiates this primitive following the reception by the NLME of the MLME-ASSOCIATE.indication primitive, the subsequent acceptance of the new device as a network member and the issuance of the MLME-ASSOCIATION.response primitive.

2.3.6.2.3 Effect on receipt

On receipt of this primitive, the next higher layer of a ZigBee coordinator or ZigBee router is notified that a new device has joined its network.

2.3.6.3 NLME-JOIN.confirm

This primitive allows the next higher layer to be notified of the results of its request to join a network.

2.3.6.3.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-JOIN.confirm	(PANId, Status)

Table 114 specifies the parameters for the NLME-JOIN.confirm primitive.

Table 114 NLME-JOIN.confirm parameters

Name	Type	Valid range	Description
PANId	Integer	0x0000—0x3fff	The PAN identifier from the NLME-JOIN.request to which this is a confirmation. The 2 highest-order bits of this parameter are reserved and should be set to 0.
Status	Status	INVALID_REQUEST, NOT_PERMITTED, NO_NETWORKS[a] or any status value returned from the MLME-ASSOCIATE.confirm primitive or the MLME-SCAN.confirm primitive.	The status of the corresponding request.

[a]CCB Comment #105

2.3.6.3.2 When generated

This primitive is generated by the initiating NLME and issued to its next higher layer in response to an NLME-JOIN.request primitive. If the request was successful, the status parameter indicates a successful join attempt. Otherwise, the status parameter indicates an error code of INVALID_REQUEST, NOT_PERMITTED, NO_NETWORKS[101] or any status value returned from either the MLME-ASSOCIATE.confirm primitive or the MLME-SCAN.confirm primitive. The reasons for these status values are fully described in sub-clause 2.3.6.1.3.

2.3.6.3.3 Effect on receipt

On receipt of this primitive, the next higher layer of the initiating device is notified of the results of its request to join a network using the MAC sub-layer association procedure, to join directly using the MAC sub-layer orphaning procedure or to re-join a network once it has been orphaned.

2.3.7 Joining a device directly to a network

This set of primitives defines how the next higher layer of a ZigBee coordinator or router can request to directly join another device to its network.

2.3.7.1 NLME-DIRECT-JOIN.request

This primitive allows the next higher layer of a ZigBee coordinator or router to request to directly join another device to its network.

[101]CCB Comment #105

2.3.7.1.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-DIRECT-JOIN.request	(DeviceAddress, CapabilityInformation)

Table 115 specifies the parameters for the NLME-DIRECT-JOIN.request primitive.

Table 115 NLME-DIRECT-JOIN.request parameters

Name	Type	Valid range	Description
DeviceAddress	64-bit IEEE address	Any 64-bit, IEEE address.	The IEEE address of the device to be directly joined.
CapabilityInformation	Bitmap	See Table 112.	The operating capabilities of the device being directly joined.

Figure 32 illustrates the formatting of the CapabilityInformation parameter.

bits: 0	1	2	3	4-5	6	7
Alternate PAN coordi-nator	Device type	Power source	Receiver on when idle	Reserved	Security capability	Reserved

Figure 32 Capability Information parameter format

2.3.7.1.2 When generated

The next higher layer of a ZigBee coordinator or router generates this primitive to add a new device directly to its network. This process is completed without any over the air transmissions.

2.3.7.1.3 Effect on receipt

On receipt of this primitive, the NLME will attempt to add the device specified by the DeviceAddress parameter to its neighbor table. The CapabilityInformation parameter will contain a description of the device being joined. The alternate PAN coordinator bit is set to 0 in devices implementing this specification. The device type bit is set to 1 if the device is a ZigBee router or to 0 if it is an end device. The power source bit is set to 1 if the device is receiving power from the alternating current mains or to 0 otherwise. The receiver on when idle bit is set to 1 if the device does not disable its receiver during idle periods or to 0 otherwise. The security capability bit is set to 1 if the device is capable of secure operation or to 0 otherwise.

If the NLME successfully adds the device to its neighbor table, the NLME issues the NLME-DIRECT-JOIN.confirm primitive with a status of SUCCESS. If the NLME finds that the requested device is already present in its neighbor tables, the NLME issues the NLME-DIRECT-JOIN.confirm primitive with a status of ALREADY_PRESENT. If no capacity is available to add a new device to the device list, the NLME issues the NLME-DIRECT-JOIN.confirm primitive with a status of TABLE_FULL.

2.3.7.2 NLME-DIRECT-JOIN.confirm

This primitive allows the next higher layer of a ZigBee coordinator or router to be notified of the results of its request to directly join another device to its network.

2.3.7.2.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-DIRECT-JOIN.confirm	(DeviceAddress, Status)

Table 116 specifies the parameters for the NLME-DIRECT-JOIN.confirm primitive.

Table 116 NLME-DIRECT-JOIN.confirm parameters

Name	Type	Valid range	Description
DeviceAddress	64-bit IEEE address	Any 64-bit, IEEE address	The 64-bit IEEE address in the request to which this is a confirmation.
Status	Status	SUCCESS, ALREADY_PRESENT, TABLE_FULL	The status of the corresponding request.

2.3.7.2.2 When generated

This primitive is generated by the initiating NLME and issued to its next higher layer in response to an NLME-DIRECT-JOIN.request primitive. If the request was successful, the status parameter indicates a successful join attempt. Otherwise, the status parameter indicates an error code of ALREADY_PRESENT or TABLE_FULL. The reasons for these status values are fully described in sub-clause 2.3.7.1.3.

2.3.7.2.3 Effect on receipt

On receipt of this primitive, the next higher layer of the initiating device is notified of the results of its request to directly join another device to a network.

2.3.8 Leaving a network

This set of primitives defines how the next higher layer of a device can request to leave or request that another device leaves a network. This set of primitives also defines how the next higher layer of a ZigBee coordinator device can be notified of a successful attempt by a device to leave its network.

2.3.8.1 NLME-LEAVE.request

This primitive allows the next higher layer to request that it or another device leaves the network.

2.3.8.1.1 Semantics of the service primitive

This semantics of this primitive is as follows:

NLME-LEAVE.request	(DeviceAddress RemoveChildren[a] MACSecurityEnable[b])

[a]CCB Comment #107
[b]CCB Comment #297

Table 117 specifies the parameters for the NLME-LEAVE.request primitive.

Table 117 NLME-LEAVE.request parameters

Name	Type	Valid range	Description
DeviceAddress	Device address	Any 64-bit, IEEE address	The 64-bit IEEE address of the entity to be removed from the network or NULL if the device removes itself from the network.
RemoveChildren	Boolean	TRUE or FALSE	This parameter has a value of TRUE if the device being asked to leave the network is also being asked to remove its child devices, if any. Otherwise it has a value of FALSE.[a]
MACSecurityEnable	Boolean	TRUE or FALSE	If, as a result of the receipt of an NLME-LEAVE.request primitive, the NWK layer opts to issue an MLME-DISASSOCIATE.request primitive to the MAC layer as described in sub-clause 2.7.1.7.1, this parameter allows higher-layer control of the MAC layer SecurityEnable parameter (see [B1]). In effect, this parameter act as an override for the SecurityEnable parameter of the MAC layer primitive. If the NWK layer, as implemented, would normally request that security be applied to the outgoing disassociation notification command frame then a TRUE value for this parameter allows the required security processing to go forward and a FALSE value suppresses it. If the NWK layer, as implemented, would not normally request security processing for the outgoing disassociate notification command frame then the value of this parameter is ignored.[b]

[a]CCB Comment #107
[b]CCB Comment #297

2.3.8.1.2 When generated

The next higher layer of a device generates this primitive to request to leave the network. The next higher layer of a ZigBee coordinator or router may also generate this primitive to remove a device from the network.

2.3.8.1.3 Effect on receipt

On receipt of this primitive by the NLME of a device that is not currently joined to a network, the NLME issues the NLME-LEAVE.confirm primitive with a status of INVALID_REQUEST.

On receipt of this primitive by the NLME of a device that is currently joined to a network, with the DeviceAddress parameter equal to NULL and the RemoveChildren parameter equal to FALSE, the NLME will remove the device itself from the network using the procedure described in sub-clause 2.7.1.7.1. Following this, the NLME will clear its routing table and issue an MLME-RESET.request primitive to the MAC sub-layer. If the NLME receives an MLME-RESET.confirm primitive with the Status parameter set to anything other than SUCCESS, the NLME may choose to re-issue the reset request. The NLME will also set the relationship field of the neighbor table entry corresponding to its former parent to 0x03, indicating no

relationship. If the NLME-LEAVE.request primitive is received with the DeviceAddress parameter equal to NULL and the RemoveChildren parameter equal to TRUE, then the NLME will attempt to remove the device's children, as described in sub-clause 2.7.1.7.2, before removing itself. Each time the removal of a child is completed, the NLME will issue the NLME-LEAVE.confirm with the DeviceAddress parameter equal to the 64-bit IEEE address of the device just removed and the Status parameter equal to SUCCESS if the removal was successful, or LEAVE_UNCONFIRMED if the removal failed for any reason. It will also set the relationship field of the corresponding neighbor table entry to 0x03, indicating no relationship. After attempting to remove all of its children, the NLME will remove the device itself as described above.[102]

On receipt of this primitive by a ZigBee coordinator or ZigBee router and with the DeviceAddress parameter not equal to NULL, the NLME determines whether the specified device exists in its neighbor tables. If the requested device does not exist, the NLME issues the NLME-LEAVE.confirm primitive with a status of UNKNOWN_DEVICE. If the requested device exists, the NLME will attempt to remove it from the network using the procedure described in sub-clause 2.7.1.7.2. If the RemoveChildren parameter is equal to TRUE then the device will be requested to remove its children as well. Following the removal, the NLME will issue the NLME-LEAVE.confirm primitive with the DeviceAddress equal to the 64-bit IEEE address of the removed device and the Status parameter equal to SUCCESS if the removal was successful and LEAVE_UNCONFIRMED otherwise. Then the relationship field for the neighbor table entry corresponding to the removed device will then be set to 0x03, indicating no relationship.[103]

2.3.8.2 NLME-LEAVE.indication

This primitive allows the next higher layer of a ZigBee device to be notified if that device has been removed from the network by its parent. It also allows the next higher layer on a ZigBee router or ZigBee coordinator to be informed if one of its associated devices has left the network by disassociation.

2.3.8.2.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-LEAVE.indication	(DeviceAddress)

Table 118 specifies the parameters for the NLME-LEAVE.indication primitive.

Table 118 NLME-LEAVE.indication parameters

Name	Type	Valid range	Description
DeviceAddress	64-bit IEEE address	Any 64-bit, IEEE address	The 64-bit IEEE address of an entity that has removed itself from the network or NULL in the case that the device issuing the primitive has been removed from the network by its parent.

2.3.8.2.2 When generated

This primitive is generated by the NLME of a ZigBee coordinator or ZigBee router and issued to its next higher layer on the successful exit of one of that device’s associated children from the network. It is also generated by the NLME of a ZigBee router or end device and issued to its next higher layer to indicate that it has been successfully removed from the network by its associated router or ZigBee coordinator.[104]

[102]CCB Comment #107
[103]CCB Comment #107

2.3.8.2.3 Effect on receipt

On receipt of this primitive, the next higher layer of a ZigBee coordinator or ZigBee router is notified that a device that was formerly associated with it has left the network. The primitive can also indicate that the next higher layer of a ZigBee router or end device is informed that it has been removed from the network by its associated ZigBee router or ZigBee coordinator.

2.3.8.3 NLME-LEAVE.confirm

This primitive allows the next higher layer to be notified of the results of its request for itself or another device to leave the network.

2.3.8.3.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-LEAVE.confirm	(DeviceAddress, Status)

Table 119 specifies the parameters for the NLME-LEAVE.confirm primitive.

Table 119 NLME-LEAVE.confirm parameters

Name	Type	Valid range	Description
DeviceAddress	64-bit IEEE address	Any 64-bit, IEEE address.	The 64-bit IEEE address in the request to which this is a confirmation or null if the device requested to remove itself from the network.
Status	Status	SUCCESS, INVALID_REQUEST, UNKNOWN_DEVICE or LEAVE_UNCONFIRMED.[a]	The status of the corresponding request.

[a]CCB Comment #107

2.3.8.3.2 When generated

This primitive is generated by the initiating NLME and issued to its next higher layer in response to an NLME-LEAVE.request primitive. If the request was successful, the status parameter indicates a successful leave attempt. Otherwise, the status parameter indicates an error code of INVALID_REQUEST, UNKNOWN_DEVICE or LEAVE_UNCONFIRMED[105]. The reasons for these status values are fully described in sub-clause 2.3.8.1.3.

2.3.8.3.3 Effect on receipt

On receipt of this primitive, the next higher layer of the initiating device is notified of the results of its request for itself or another device to leave the network.

2.3.9 Resetting a device

This set of primitives defines how the next higher layer of a device can request that the NWK layer is reset.

[104]Ibid
[105]CCB Comment #107

2.3.9.1 NLME-RESET.request

This primitive allows the next higher layer to request that the NWK layer performs a reset operation.

2.3.9.1.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-RESET.request	( )

This primitive has no parameters.

2.3.9.1.2 When generated

This primitive is generated by the next higher layer and issued to its NLME to request the reset of the NWK layer to its initial condition.

2.3.9.1.3 Effect on receipt

On receipt of this primitive, the NLME issues the MLME-RESET.request primitive to the MAC sub-layer with the SetDefaultPIB parameter set to TRUE. On receipt of the corresponding MLME-RESET.confirm primitive, the NWK layer resets itself by clearing all internal variables and route discovery table entries and by setting all NIB attributes to their default values. Once the NWK layer is reset, the NLME issues the NLME-RESET.confirm with the Status parameter set to SUCCESS if the MAC sub-layer was successfully reset or DISABLE_TRX_FAILURE otherwise.

If this primitive is issued to the NLME of a device that is currently joined to a network, any required leave attempts using the NLME-LEAVE.request primitive should be made a-priori at the discretion of the next higher layer.

2.3.9.2 NLME-RESET.confirm

This primitive allows the next higher layer to be notified of the results of its request to reset the NWK layer.

2.3.9.2.1 Semantics of the service primitive

The semantics for this primitive are as follows:

NLME-RESET.confirm	(Status)

Table 120 specifies the parameters for this primitive.

Table 120 NLME-RESET.confirm parameters

Name	Type	Valid range	Description
Status	Status	Any status value returned from the MLME-RESET.confirm primitive (see [B1]).	The result of the reset operation.

2.3.9.2.2 When generated

This primitive is generated by the NLME and issued to its next higher layer in response to an NLME-RESET.request primitive. If the request was successful, the status parameter indicates a successful reset attempt. Otherwise, the status parameter indicates an error code of DISABLE_TRX_FAILURE. The reasons for these status values are fully described in sub-clause 2.3.9.1.3.

2.3.9.2.3 Effect on receipt

On receipt of this primitive, the next higher layer is notified of the results of its request to reset the NWK layer.

2.3.9.3 Network layer reset message sequence chart

Figure 33 illustrates the sequence of messages necessary for resetting the NWK layer.

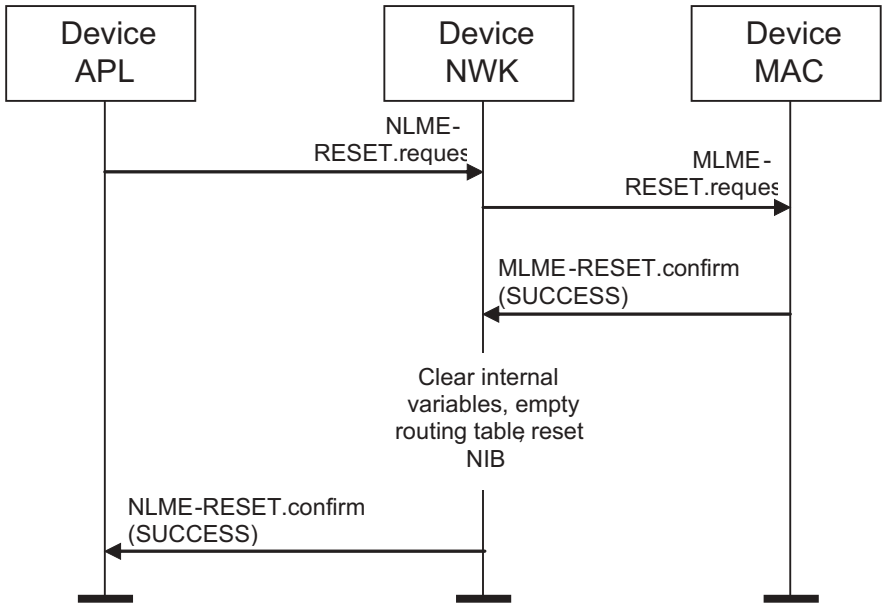


Figure 33 Message sequence chart for resetting the network layer

2.3.10 Receiver synchronization

This set of primitives defines how the next higher layer of a device can synchronize with a ZigBee coordinator or router and extract pending data from it.

2.3.10.1 NLME-SYNC.request

This primitive allows the next higher layer to synchronize or extract data from its ZigBee coordinator or router.

2.3.10.1.1 Semantics of the Service Primitive

The semantics of this primitive is as follows:

NLME-SYNC.request	(Track)

Table 121 specifies the parameters for this primitive.

Table 121 NLME-SYNC.request parameters

Name	Type	Valid Range	Description
Track	Boolean	TRUE or FALSE	Whether the synchronization should be maintained for future beacons or not.

2.3.10.1.2 When generated

This primitive is generated whenever the next higher layer wishes to achieve synchronization or check for pending data at its ZigBee coordinator or router.

2.3.10.1.3 Effect on receipt

If the TRACK parameter is set to FALSE and the device is operating on a non-beacon enabled network, the NLME issues the MLME-POLL.request primitive to the MAC sub-layer. On receipt of the corresponding MLME-POLL.confirm primitive, the NLME issues the NLME-SYNC.confirm primitive with the Status parameter set SUCCESS if the MAC primitive was successful, or SYNC_FAILURE otherwise.

If the TRACK parameter is set to FALSE and the device is operating on a beacon enabled network, the NLME first sets the *macAutoRequest* PIB attribute in the MAC sub-layer to TRUE by issuing the MLME-SET.request primitive. It then issues the MLME-SYNC.request primitive with the TrackBeacon parameter set to FALSE. The NLME then issues the NLME-SYNC.confirm primitive with the Status parameter set to SUCCESS.

If the TRACK parameter is set to TRUE and the device is operating on a non-beacon enabled network, the NLME will issue the NLME-SYNC.confirm primitive with a status parameter set to INVALID_PARAMETER.

If the TRACK parameter is set to TRUE and the device is operating on a beacon enabled network, the NLME first sets the *macAutoRequest* PIB attribute in the MAC sub-layer to TRUE by issuing the MLME-SET.request primitive. It then issues the MLME-SYNC.request primitive with the TrackBeacon parameter set to TRUE. The NLME then issues the NLME-SYNC.confirm primitive with the Status parameter set to SUCCESS.

2.3.10.2 NLME-SYNC.indication

This primitive allows the next higher layer to be notified of the loss of synchronization at the MAC sub-layer.

2.3.10.2.1 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-SYNC.indication	( )

This primitive has no parameters.

2.3.10.2.2 When generated

This primitive is generated following a loss of synchronization notification from the MAC sub-layer via the MLME-SYNC-LOSS.indication primitive with a LossReason of BEACON_LOST. This follows a prior NLME-SYNC.request primitive being issued to the NLME.

2.3.10.2.3 Effect on receipt

The next higher layer is notified of the loss of synchronization with the beacon.

2.3.10.3 NLME-SYNC.confirm

This primitive allows the next higher layer to be notified of the results of its request to synchronize or extract data from its ZigBee coordinator or router.

2.3.10.3.1 Semantics of the Service Primitive

The semantics of this primitive is as follows:

NLME-SYNC.confirm	(Status)

Table 122 specifies the parameters for this primitive.

Table 122 NLME-SYNC.confirm parameters

Name	Type	Valid Range	Description
Status	Status	SUCCESS, SYNC_FAILURE, INVALID_PARAMETER	The result of the request to synchronize with the ZigBee coordinator or router.

2.3.10.3.2 When generated

This primitive is generated by the initiating NLME and issued to its next higher layer in response to an NLME-SYNC.request primitive. If the request was successful, the status parameter indicates a successful state change attempt. Otherwise, the status parameter indicates an error code of SYNC_FAILURE. The reasons for these status values are fully described in sub-clause 2.3.10.1.3.

2.3.10.3.3 Effect on receipt

On receipt of this primitive, the next higher layer is notified of the results of its request to synchronize or extract data from its ZigBee coordinator or router. If the NLME has been successful, the Status parameter will be set to SUCCESS. Otherwise, the Status parameter indicates the error.

2.3.10.4 Message sequence charts for synchronizing with a coordinator

Figure 34 and Figure 35 illustrate the sequence of messages necessary for a device to successfully synchronize with a ZigBee coordinator. Figure 34 illustrates the case for a non-beaconing network, and Figure 35 illustrates the case for a beaconing network.

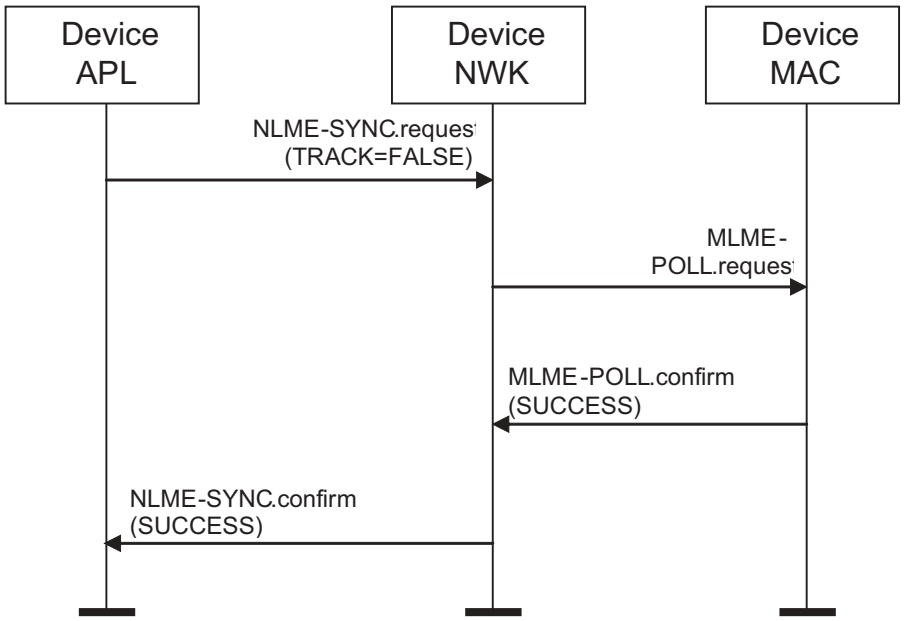


Figure 34 Message sequence chart for synchronizing in a non-beaconing network

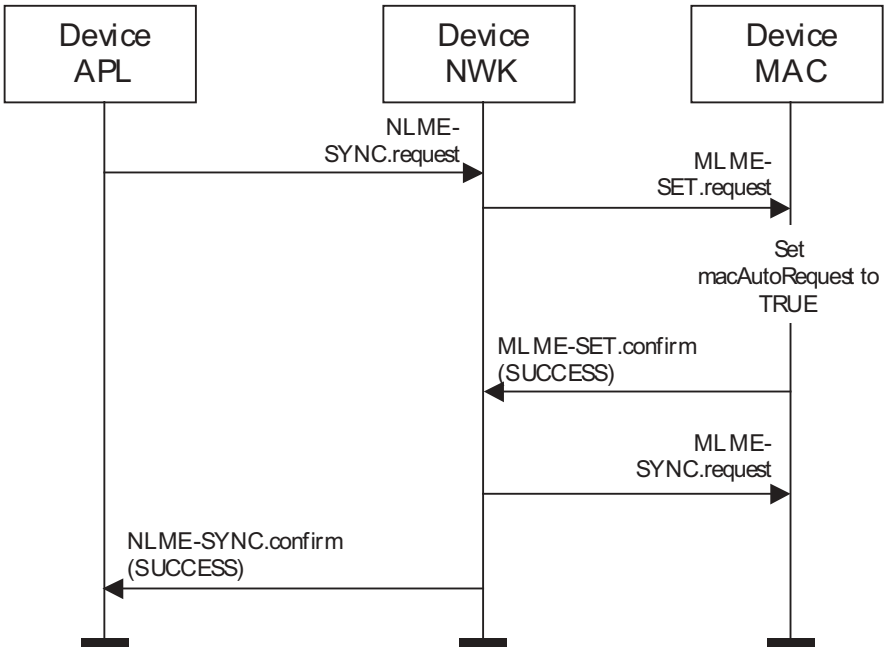


Figure 35 Message sequence chart for synchronizing in a beacon-enabled network

2.3.11 Information base maintenance

This set of primitives defines how the next higher layer of a device can read and write attributes in the NIB.

2.3.11.1 NLME-GET.request

This primitive allows the next higher layer to read the value of an attribute from the NIB.

2.3.11.1.1 Semantics of the Service Primitive

The semantics of this primitive is as follows:

NLME-GET.request	(NIBAttribute)

Table 123 specifies the parameters for this primitive.

Table 123 NLME-GET.request parameters

Name	Type	Valid Range	Description
NIBAttribute	Integer	See Table 132	The identifier of the NIB attribute to read.

2.3.11.1.2 When Generated

This primitive is generated by the next higher layer and issued to its NLME in order to read an attribute from the NIB.

2.3.11.1.3 Effect on Receipt

On receipt of this primitive, the NLME attempts to retrieve the requested NIB attribute from its database. If the identifier of the NIB attribute is not found in the database, the NLME issues the NLME-GET.confirm primitive with a status of UNSUPPORTED_ATTRIBUTE.

If the requested NIB attribute is successfully retrieved, the NLME issues the NLME-GET.confirm primitive with a status of SUCCESS and the NIB attribute identifier and value.

2.3.11.2 NLME-GET.confirm

This primitive reports the results of an attempt to read the value of an attribute from the NIB.

2.3.11.2.1 Semantics of the Service Primitive

The semantics of this primitive is as follows:

NLME-GET.confirm	(Status, NIBAttribute, NIBAttributeLength, NIBAttributeValue)

Table 124 specifies the parameters for this primitive.

Table 124 NLME-GET.confirm parameters

Name	Type	Valid Range	Description
Status	Enumeration	SUCCESS or UNSUPPORTED_ATTRIBUTE	The results of the request to read a NIB attribute value.
NIBAttribute	Integer	See Table 132	The identifier of the NIB attribute that was read.
NIBAttributeLength	Integer	0x0000 – 0xffff	The length, in octets, of the attribute value being returned.
NIBAttributeValue	Various	Attribute Specific (see Table 132)	The value of the NIB attribute that was read.

2.3.11.2.2 When Generated

This primitive is generated by the NLME and issued to its next higher layer in response to an NLME-GET.request primitive. This primitive returns a status of SUCCESS, indicating that the request to read a NIB attribute was successful, or an error code of UNSUPPORTED_ATTRIBUTE. The reasons for these status values are fully described in sub-clause 2.3.11.1.3.

2.3.11.2.3 Effect on Receipt

On receipt of this primitive, the next higher layer is notified of the results of its request to read a NIB attribute. If the request to read a NIB attribute was successful, the Status parameter will be set to SUCCESS. Otherwise, the status parameter indicates the error.

2.3.11.3 NLME-SET.request

This primitive allows the next higher layer to write the value of an attribute into the NIB.

2.3.11.3.1 Semantics of the Service Primitive

The semantics of this primitive is as follows:

```
NLME-SET.request        (
                        NIBAttribute,
                        NIBAttributeLength,
                        NIBAttributeValue
                        )
```

Table 125 specifies the parameters for this primitive.

Table 125 NLME-SET.request parameters

Name	Type	Valid Range	Description
NIBAttribute	Integer	See Table 132	The identifier of the NIB attribute to be written.
NIBAttribute-Length	Integer	0x0000 – 0xffff	The length, in octets, of the attribute value being set.
NIBAttributeValue	Various	Attribute Specific (see Table 132)	The value of the NIB attribute that should be written.

2.3.11.3.2 When Generated

This primitive is to be generated by the next higher layer and issued to its NLME in order to write the value of an attribute in the NIB.

2.3.11.3.3 Effect on Receipt

On receipt of this primitive the NLME attempts to write the given value to the indicated NIB attribute in its database. If the NIBAttribute parameter specifies an attribute that is not found in the database, the NLME issues the NLME-SET.confirm primitive with a status of UNSUPPORTED_ATTRIBUTE. If the NIBAttributeValue parameter specifies a value that is out of the valid range for the given attribute, the NLME issues the NLME-SET.confirm primitive with a status of INVALID_PARAMETER.

If the requested NIB attribute is successfully written, the NLME issues the NLME-SET.confirm primitive with a status of SUCCESS.

2.3.11.4 NLME-SET.confirm

This primitive reports the results of an attempt to write a value to a NIB attribute.

2.3.11.4.1 Semantics of the Service Primitive

The semantics of this primitive is as follows:

NLME-SET.confirm	(Status, NIBAttribute)

Table 126 specifies the parameters for this primitive.

Table 126 NLME-SET.confirm parameters

Name	Type	Valid Range	Description
Status	Enumeration	SUCCESS, INVALID_PARAMETER or UNSUPPORTED_ATTRIBUTE	The result of the request to write the NIB Attribute.
NIBAttribute	Integer	See Table 132	The identifier of the NIB attribute that was written.

2.3.11.4.2 When Generated

This primitive is generated by the NLME and issued to its next higher layer in response to an NLME-SET.request primitive. This primitive returns a status of either SUCCESS, indicating that the requested value was written to the indicated NIB attribute, or an error code of INVALID_PARAMETER or UNSUPPORTED_ATTRIBUTE. The reasons for these status values are fully described in sub-clause 2.3.11.3.3.

2.3.11.4.3 Effect on Receipt

On receipt of this primitive, the next higher layer is notified of the results of its request to write the value of a NIB attribute. If the requested value was written to the indicated NIB attribute, the Status parameter will be set to SUCCESS. Otherwise, the Status parameter indicates the error.

2.4 Frame formats

This sub-clause specifies the format of the NWK frame (NPDU). Each NWK frame consists of the following basic components:

— A NWK header, which comprises frame control, addressing and sequencing information.

— A NWK payload, of variable length, which contains information specific to the frame type.

The frames in the NWK layer are described as a sequence of fields in a specific order. All frame formats in this sub-clause are depicted in the order in which they are transmitted by the MAC sub-layer, from left to right, where the leftmost bit is transmitted first in time. Bits within each field are numbered from 0 (leftmost and least significant) to k-1 (rightmost and most significant), where the length of the field is k bits. Fields that are longer than a single octet are sent to the MAC sub-layer in the order from the octet containing the lowest numbered bits to the octet containing the highest numbered bits.

2.4.1 General NPDU frame format

The NWK frame format is composed of a NWK header and a NWK payload. The fields of the NWK header appear in a fixed order, however, the addressing and sequencing fields may not be included in all frames. The general NWK frame shall be formatted as illustrated in Figure 36.

<table>
<tr><th>Octets: 2</th><th>2</th><th>2</th><th>1</th><th>1</th><th>Variable</th></tr>
<tr><td rowspan="2">Frame Control</td><td>Destination Address</td><td>Source Address</td><td>Radius[a]</td><td>Sequence Number[b]</td><td>Frame Payload</td></tr>
<tr><td colspan="3">Routing Fields</td><td></td></tr>
<tr><td colspan="4">NWK Header</td><td>NWK Payload</td></tr>
</table>

[a]CCB Comment #125
[b]CCB Comment #111

Figure 36 General NWK frame format

2.4.1.1 Frame control Field

The frame control field is 16-bits in length and contains information defining the frame type, addressing and sequencing fields and other control flags. The frame control field shall be formatted as illustrated in Figure 37.

Bits: 0-1	2-5	6-7[a]	8	9	10-15
Frame type	Protocol version	Discover route	Reserved	Security	Reserved

[a]CCB Comment #56

Figure 37 Frame control field

2.4.1.1.1 Frame type sub-field

The frame type sub-field is two bits in length and shall be set to one of the non-reserved values listed in Table 127.

Table 127 Values of the frame type sub-field

Frame type value b_1 b_0	Frame type name
00	Data
01	NWK command
10 – 11	Reserved

2.4.1.1.2 Protocol version sub-field

The protocol version sub-field is four bits in length and shall be set to a number reflecting the ZigBee NWK protocol version in use. The protocol version in use on a particular device shall be made available as the value of the NWK constant *nwkcProtocolVersion*, and shall have the value of 0x01 for all implementations based on this specification draft version.

2.4.1.1.3 Discover route sub-field

The DiscoverRoute parameter may be used to control route discovery operations for the transit of this frame (see sub-clause 2.7.3.4).[106].

Table 128 Values of the discover route sub-field[a]

Discover route field value b7 b6	Field meaning
0x00	Suppress route discovery
0x01	Enable route discovery
0x02	Force route discovery
0x03	Reserved

[a]CCB Comment #256

2.4.1.1.4 Security sub-field

The security sub-field shall have a value of 1 if and only if the frame is to have NWK security operations enabled. If security for this frame is implemented at another layer or disabled entirely, it shall have a value of 0.

2.4.1.2 Destination address field

The destination address field shall always be present. It shall be 2 octets in length and shall hold the 16-bit network address of the destination device or the broadcast address (0xffff). Note that the network address of a device shall always be the same as its IEEE 802.15.4-2003 MAC short address.

[106]CCB Comment #256

2.4.1.3 Source address field

The source address field shall always be present. It will always be 2 octets in length and shall hold the network address of the source device of the frame. Note that the network address of a device shall always be the same as its IEEE 802.15.4-2003 MAC short address.

2.4.1.4 Radius field[107]

The radius field shall always be present. It will be one octet in length and specifies the range of a radius transmission. The field shall be decremented by 1 by each receiving device.[108]

2.4.1.5 Sequence number field[109]

The sequence number field is present in every frame and is 1 octet in length. The sequence number value will be incremented by 1 with each new transmitted frame and the values of the source address field and the sequence number field of a frame, taken as a pair, may be used to uniquely identify a frame within the constraints imposed by the sequence number's 1-octet range. For more detail on the use of the sequence number field see sub-clause 2.7.2.[110]

2.4.1.6 Frame payload field

The frame payload field has a variable length and contains information specific to individual frame types.

2.4.2 Format of individual frame types

There are two defined NWK frame types: data and NWK command. Each of these frame types is discussed in the following sub-clauses.

2.4.2.1 Data frame format

The data frame shall be formatted as illustrated in Figure 38.

Octets: 2	See Figure 36	Variable
Frame control	Routing fields	Data payload
NWK header		NWK payload

Figure 38 Data frame format

The order of the fields of the data frame shall conform to the order of the general NWK frame format as illustrated in Figure 36.

2.4.2.1.1 Data frame NWK header field

The NWK header field of a data frame shall contain the frame control field and an appropriate combination of routing fields as required.

In the frame control field, the frame type sub-field shall contain the value that indicates a data frame, as shown in Table 127. All other sub-fields shall be set according to the intended use of the data frame.

[107] CCB Comment #125
[108] Ibid
[109] CCB Comment #111
[110] CCB Comment #111, 113, 114

The routing fields shall contain an appropriate combination of address and broadcast fields, depending on the settings in the frame control field (see Figure 37).

2.4.2.1.2 Data payload field

The data payload field of a data frame shall contain the sequence of octets, which the next higher layer has requested the NWK layer to transmit.

2.4.2.2 NWK command frame format

The NWK command frame shall be formatted as illustrated in Figure 39.

Octets: 2	See Figure 36	1	Variable
Frame control	Routing fields	NWK command identifier	NWK command payload
NWK header		NWK payload	

Figure 39 NWK command frame format

The order of the fields of the NWK command frame shall conform to the order of the general NWK frame as illustrated in Figure 36.

2.4.2.2.1 NWK command frame NWK header field

The NWK header field of a NWK command frame shall contain the frame control field and an appropriate combination of routing fields as required.

In the frame control field, the frame type sub-field shall contain the value that indicates a NWK command frame, as shown in Table 127. All other sub-fields shall be set according to the intended use of the NWK command frame.

The routing fields shall contain an appropriate combination of address and broadcast fields, depending on the settings in the frame control field.

2.4.2.2.2 NWK command identifier field

The NWK command identifier field indicates the NWK command being used. This field shall be set to one of the non-reserved values listed in Table 129.

2.4.2.2.3 NWK command payload field

The NWK command payload field of a NWK command frame shall contain the NWK command itself.

2.5 Command frames

The command frames defined by the NWK layer are listed in Table 129. The following sub-clauses detail how the NLME shall construct the individual commands for transmission.

Table 129 NWK command frames

Command frame identifier	Command name	Reference
0x01	Route request	2.5.1

Table 129 NWK command frames

0x02	Route reply	2.5.2
0x03	Route Error	2.5.3
0x04[a]	Leave	2.5.4
0x00, 0x05[b]—0xff	Reserved	—

[a]CCB Comment #107
[b]Ibid

2.5.1 Route request command

The route request command allows a device to request that other devices within radio range engage in a search for a particular destination device and establish state within the network that will allow messages to be routed to that destination more easily and economically in the future. The payload of a route request command shall be formatted as illustrated in Figure 40.

Octets: 1	1	1	2	1
Command frame identifier (see Table 129)	Command options	Route request identifier	Destination address	Path cost
NWK payload				

Figure 40 Route request command frame format

2.5.1.1 MAC data service requirements

In order to transmit this command using the MAC data service, specified in [B1], the following information shall be included in the MAC frame header.

The destination PAN identifier shall be set to the PAN identifier of the device sending the route request command. The destination address must be set to the broadcast address of 0xffff.

The source MAC address and PAN identifier shall be set to the address and PAN identifier of the device sending the route request command, which may or may not be the device from which the command originated.

The frame control field shall be set to specify that the frame is a MAC data frame with MAC security disabled, since any secured frame originating from the NWK layer shall use NWK layer security. Because the frame is broadcast, no acknowledgment request shall be specified. The addressing mode and intra-PAN flags shall be set to support the addressing fields described here.

2.5.1.2 NWK header fields

In order to send the route request command frame, the source address field in the NWK header shall be set to the address of the originating device.

The destination address in the NWK header shall be set to the broadcast address.

2.5.1.3 NWK payload fields

The NWK frame payload contains a command identifier field, a command options field, the route request identifier field, the address of the intended destination, and an up-to-date summation of the path cost.

The command frame identify shall contain the value indicating a route request command frame.

2.5.1.3.1 Command options field

The format of the 8-bit command options field is shown in Figure 41.

Bit: 0—6	7
Reserved	Route repair

Figure 41 Route request command options field

The route repair sub-field is a single-bit field. It shall have a value of 1 if and only if the route request command frame is being generated as part of a route repair operation for mesh network topology (see sub-clause 2.7.3.5.1).

2.5.1.3.2 Route request identifier

The route request identifier is an 8-bit sequence number for route requests and is incremented by one every time the NWK layer on a particular device issues a route request.

2.5.1.3.3 Destination address

The destination address shall be 2 octets in length and represents the intended destination of the route request command frame.

2.5.1.3.4 Path cost

The path cost field is 8 bits in length and is used to accumulate routing cost information as a route request command frame moves through the network (see sub-clause 2.7.3.4.2).

2.5.2 Route reply command

The route reply command allows the specified destination device of a route request command to inform the originator of the route request that the request has been received. It also allows ZigBee routers along the path taken by the route request to establish state information that will enable frames sent from the source device to the destination device to travel more efficiently. The payload of the route reply command shall be formatted as illustrated in Figure 42.

Octets: 1	1	1	2	2	1
Command frame identifier (see Table 129)	Command options	Route request identifier	Originator address	Responder address	Path cost
NWK payload					

Figure 42 Route reply command format

