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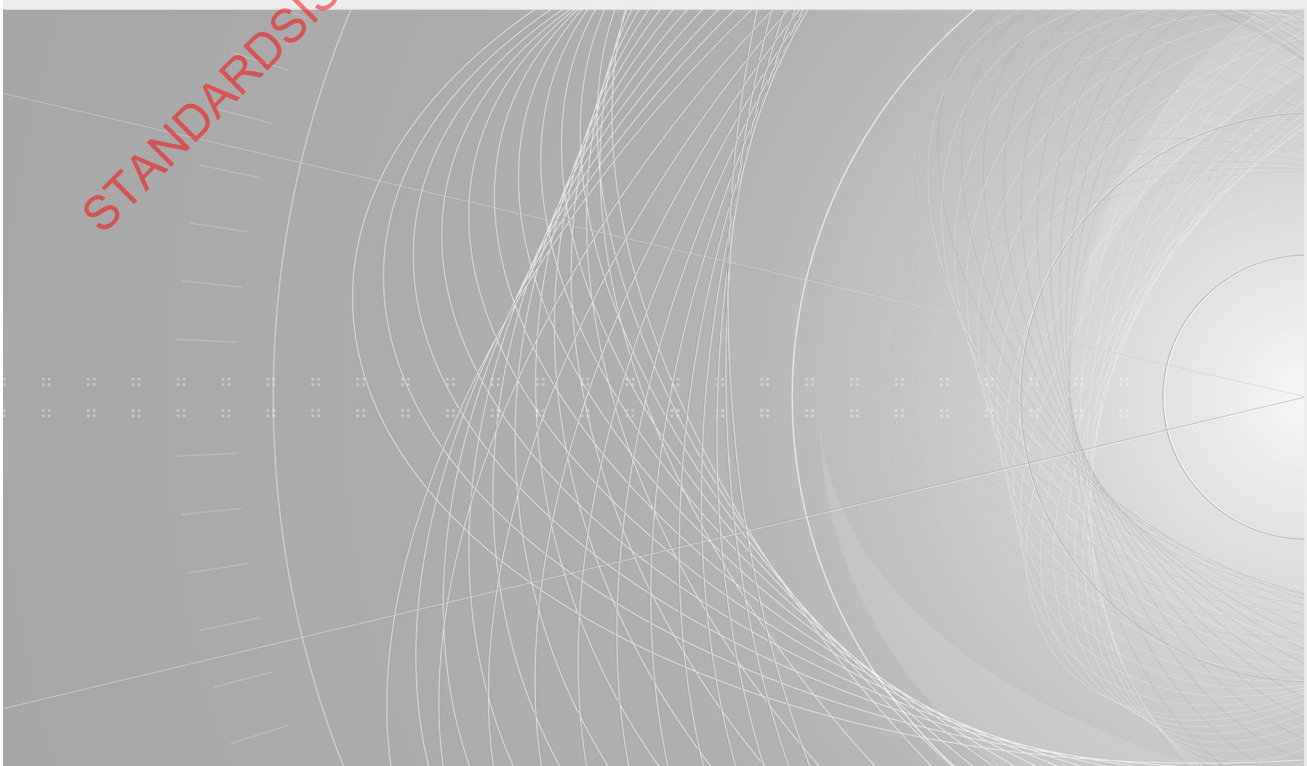
INTERNATIONAL STANDARD

Information technology – Wireless beacon-enabled energy efficient mesh network (WiBEEM) for wireless home network services – Part 3: NWK layer



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Information technology – Wireless beacon-enabled energy efficient mesh network (WiBEEM) for wireless home network services – Part 3: NWK layer

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INFORMATION TECHNOLOGY – WIRELESS BEACON-ENABLED ENERGY EFFICIENT MESH NETWORK (WIBEEM) FOR WIRELESS HOME NETWORK SERVICES –

Part 3: NWK layer

FOREWORD

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The list of all currently available parts of the ISO/IEC 29145 series, under the general title *Information technology – Wireless beacon-enabled energy efficient mesh network (WiBEEM) for wireless home network services*, can be found on the IEC web site.

This International Standard has been approved by vote of the member bodies, and the voting results may be obtained from the address given on the second title page.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

INTRODUCTION

This International Standard specifies the WiBEEM (Wireless Beacon-enabled Energy Efficient Mesh network) protocol, which provides low-power-consuming mesh network functions by enabling the “beacon mode operation”. WiBEEM is based on the IEEE 802.15.4 standard with additional upper layer protocols and a specific usage of the MAC layer protocol. Through the novel use of beacons, WiBEEM technology achieves longer battery life, larger network support, quicker response, enhanced mobility and dynamic reconfiguration of the network topology compared with other protocols such as ZigBee.

In the beacon mode, beacon information propagates over the entire mesh network nodes during the BOP (Beacon-Only Period) of the superframe structure without any beacon conflicts by utilising a smart beacon scheduling technique in the BOP. It also provides location information about moving devices without spending extra time running a positioning and locating algorithm by using RSSI (Received Signal Strength Indication). These features allow the WiBEEM protocol to be widely used for wireless home network services in the ubiquitous network era.

One of the key features of the WiBEEM protocol is that it has a special time interval called BOP (Beacon-Only Period) in the superframe structure that allows more than two beacons to be transmitted. This unique time period is located at the beginning of the Superframe. Because the BOP does not use the CSMA/CA mechanism, the network will not work properly in the beacon mode unless an appropriate algorithm is applied. This algorithm needs to manage and control multiple beacons in a single superframe. The solution is the Beacon Scheduling method applied in the BOP to avoid collisions among beacons, providing synchronisation among all the nodes of the entire mesh network.

For the network layer, the NAA (Next Address Available) mechanism, which is a short address allocation algorithm, has been adopted to provide an efficient way of utilising the complete 16-bit address space. The NAA algorithm does not limit the maximum number of children nodes that a node of a mesh network can have. Since the number of children nodes is unlimited, the NAA mechanism allows the WiBEEM protocol to be used not only for home network services, but also for community services. WiBEEM can be used where high network expandability through efficient use of short address spaces, device mobility and end-to-end QoS are required.

This part of ISO/IEC 29145 specifies the network layer (NWK) of the WiBEEM protocol for wireless home network services that support a low-power-consuming wireless mesh network as well as device mobility and QoS.

INFORMATION TECHNOLOGY – WIRELESS BEACON-ENABLED ENERGY EFFICIENT MESH NETWORK (WIBEEM) FOR WIRELESS HOME NETWORK SERVICES –

Part 3: NWK layer

1 Scope

This part of ISO/IEC 29145 specifies the network layer (NWK) of the WiBEEM (Wireless Beacon-enabled Energy Efficient Mesh network) protocol for wireless home network services that support a low-power-consuming wireless mesh network as well as device mobility and quality of service.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 29145-1:2014, *Information technology – Wireless beacon-enabled energy efficient mesh network (WiBEEM) for wireless home network services – Part 1: PHY layer*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
association
service used to establish the membership of a device in a wireless mesh network

3.1.2
co-ordinator
wireless device configured to provide synchronisation services through the transmission of beacons

Note 1 to entry: If a co-ordinator is the principal controller of a wireless mesh network, it is called the WMC (WiBEEM mesh co-ordinator).

3.1.3
device
entity containing an implementation of the WiBEEM applications, NWK, MAC and physical interface to the wireless medium

3.1.4
frame
data format of aggregated bits from a medium access control (MAC) layer entity transmitted in a specified sequence

3.1.5
packet
format of aggregated bits transmitted in a specified sequence across the physical medium

3.1.6
personal operating space
space of typically about 10 m around a person or an object, no matter whether this person or object is stationary or in motion

3.1.7
protocol data unit
unit of data exchanged between two peer entities

3.1.8
WiBEEM end device
WiBEEM device acting as the leaf device of a mesh network

3.1.9
WiBEEM mesh co-ordinator
WiBEEM device acting as the principal controller of a mesh network

Note 1 to entry: A WiBEEM mesh network has exactly one WiBEEM mesh co-ordinator.

3.1.10
WiBEEM routable co-ordinator
WiBEEM device acting as the router of a mesh network

3.1.11
wireless medium
medium used to implement the transfer of protocol data units (PDUs) between peer physical layer (PHY) entities of a low-rate wireless mesh network

3.2 Abbreviations

The following acronyms and abbreviations are used in this standard and commonly used in other industry publications.

AES	Advanced Encryption Standard
ARQ	Automatic Request-Response
BO	Beacon Order
BOP	Beacon Only Period
BTTSL	Beacon Transmit Time Slot Length
CAP	Contention Access Period
ID	Identifier
MIB	Management Information Base
NAA	Next Address Available
PDU	Protocol Data Unit
PQP	Prioritised QoS Period
QoS	Quality of Service
RAP	Reservation-Based Access Period
WED	WiBEEM End Device
WiBEEM	Wireless Beacon-enabled Energy Efficient Mesh network
WMC	WiBEEM Mesh Co-ordinator

WRC WiBEEM Routable Co-ordinator

3.3 Conventions

All the italicised words used in this standard represent relevant constants defined and stored in the MIB (management information base) of each layer.

4 Conformance

A WiBEEM device that claims conformance to this part of ISO/IEC 29145 shall implement all the primitives that are specified in 6.2. Each WiBEEM device shall be able to act as a WMC, a WRC and a WED. When operating in the role of a WMC it shall act as specified in 5.3.2 of ISO/IEC 29145-1:2014, when operating in the role of a WRC, it shall act as specified in 5.3.3 of ISO/IEC 29145-1:2014, and when operating in the role of a WED, it shall act as specified in 5.3.3 of ISO/IEC 29145-1.

5 Overview of the WiBEEM technology

Clause 5 of ISO/IEC 29145-1:2014 presents an overview of the WiBEEM technology and the functionalities of the WiBEEM devices.

6 NWK layer specifications

6.1 General

This clause specifies the NWK layer of this standard. The NWK layer handles network management, message broker and routing. This clause specifies the services that shall be provided by the WiBEEM NWK layer.

Constants and attributes that are specified and maintained by the MAC layer are written in the text of this clause in italics. Constants have a general prefix of “a”. Attributes have a general prefix of “mac”.

6.2 NWK layer service specifications

6.2.1 Overview

The NWK layer services provide an interface between the NWK layer and the APP layer. The NWK layer provides two services, accessed through two SAPs:

– MAC data service, accessed through the NWK layer data SAP (NLDE-SAP); and

– NWK management service, accessed through the NLME-SAP.

Figure 1 depicts the elements and interfaces of NWK layer.

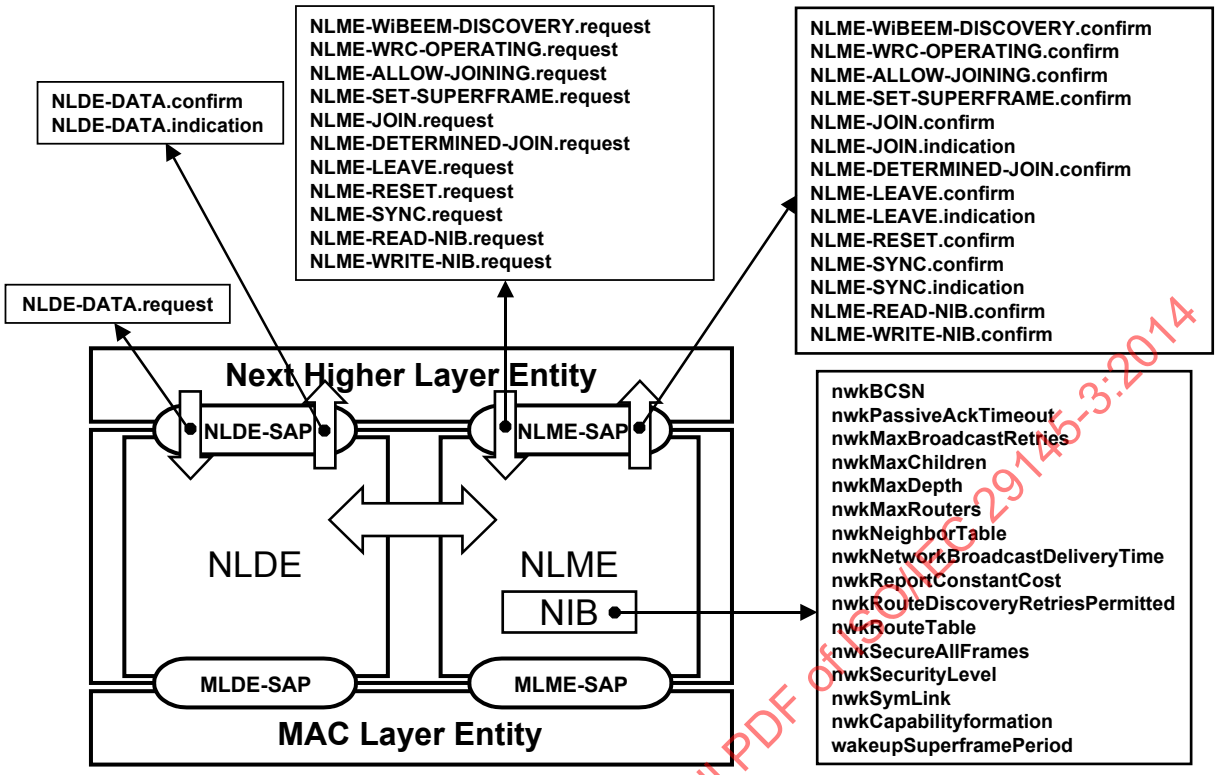

Figure 1 – NWK layer structure

6.2.2 NWK data service

6.2.2.1 Overview

The NWK layer data entity SAP (NLDE-SAP) supports the transport of application protocol data units (APDUs) between peer application entities.

6.2.2.2 NLDE-DATA.request

6.2.2.2.1 Function

This primitive requests the transfer of a data PDU (NSDU) from the local Application layer entity to a single or multiple peer application layer entities.

6.2.2.2.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
DE-DATA.request     (
                    DstAddr,
                    NsduLength,
                    Nsdu,
                    NsduHandle,
                    BroadcastRadius,
                    DiscoverRoute,
                    SecurityEnable
                    )
```

Table 1 specifies the parameters for the NLDE-DATA.request primitive.

Table 1 – NLDE-DATA.request parameters

Name	Type	Valid range	Description
DstAddr	Device address	Specified by the DstAddr	The network address of the entity or entities to which the NSDU is being transferred.
NsduLength	integer	≤nwkcMaxPayloadSize	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 to 0xff	The handle associated with the NSDU to be transmitted by the NWK layer entity.
BroadcastRadius	integer	0x00 to 0xff	The distance, in hops, that a broadcast frame will be allowed to travel through the network.
DiscoverRoute	Boolean	TRUE or FALSE	The DiscoverRoute parameter may be used to enable route discovery operations for the transit of this frame. TRUE = enable route discovery FALSE = disable route discovery
Security enable	Boolean	TRUE or FALSE	The SecurityEnable parameter may be used to enable NWK layer security processing for the current frame.

6.2.2.2.3 When generated

This primitive is generated by a local APS sublayer entity whenever a data PDU (NSDU) is to be transferred to a peer APS sublayer entity.

6.2.2.2.4 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.

6.2.2.3 NLDE-DATA.confirm

6.2.2.3.1 Function

This primitive reports the results of a request to transfer a data PDU (NSDU) from a local APS sublayer entity to a single peer APS sublayer entity.

6.2.2.3.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLDE-DATA.confirm   (
                        NsduHandle,
                        Status
                        )
```

Table 2 specifies the parameters for the NLDE-DATA.confirm primitive.

Table 2 – NLDE-DATA.confirm parameters

Name	Type	Valid range	Description
nsduHandle	Integer	0x00 to 0xff	The handle associated with the NSDU being confirmed.
Status	Enumeration	SUCCESS, TRANSACTION_OVERFLOW, TRANSACTION_EXPIRED, CHANNEL_ACCESS_FAILURE, INVALID_GTS, NO_ACK, UNAVAILABLE_KEY, FRAME_TOO_LONG, FAILED_SECURITY_CHECK, or INVALID_PARAMETER	The status of the corresponding request.

6.2.2.3.3 When generated

This primitive is generated by the local NLDE in response to the reception of an NLDE-DATA.request primitive.

6.2.2.3.4 Effect on receipt

On receipt of this primitive the APS sublayer 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.

6.2.2.4 NLDE-DATA.indication

6.2.2.4.1 Function

This primitive indicates the transfer of a data PDU (NSDU) from the NWK layer to the local APS sublayer entity.

6.2.2.4.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLDE-DATA.indication (
                     SrcAddress,
                     NsduLength,
                     Nsdu,
                     LinkQuality
                     )
```

Table 3 specifies the parameters for the NLDE-DATA.indication primitive.

Table 3 – NLDE-DATA.indication parameters

Name	Type	Valid range	Description
SrcAddre	16-bit Device address	Any valid device address Except the broadcast Address	The individual device address from which the NSDU originated.
NsduLength	integer	≤nwkcMaxPayloadSize	The number of octets comprising the NSDU being indicated.
Nsdu	Set of Object	–	The set of octets comprising the NSDU being indicated.
LinkQuality	Integer	0x00 to 0xff	The link quality indication delivered by the MAC on receipt of this frame as a parameter of the MAC-DATA.indication primitive.

6.2.2.4.3 When generated

This primitive is generated by the NLDE and issued to the APS sublayer on receipt of an appropriately addressed data frame from the local MAC sublayer entity.

6.2.2.4.4 Effect on receipt

On receipt of this primitive the APS sublayer is notified of the arrival of data at the device.

6.2.3 NWK management service

6.2.3.1 Overview

The NWK layer management entity SAP (NLME-SAP) allows the transport of management commands between the next higher layer and the NLME. Table 4 summarises the primitives supported by the NLME through the NLME-SAP interface. See the following subclauses for more details on the individual primitives.

Table 4 – Summary of primitives used by NWK layer

Name	Request	Indication	Response	Confirm
NLME-WiBEEM-DISCOVERY	O			O
NLME-WRC-OPERATING	O			O
NLME-ALLOW-JOINING	O			O
NLME-WRITE-NIB-SUPERFRAME	O			O
NLME-JOIN	O	O		O
NLME-DETERMINED-JOIN	O			O
NLME-LEAVE	O	O		O
NLME-RESET	O			O
NLME-SYNC	O	O		O
NLME-READ-NIB	O			O
NLME-WRITE-NIB	O			O

6.2.3.2 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.

6.2.3.3 NLME-WiBEEM-DISCOVERY.request

6.2.3.3.1 Function

This primitive allows the next higher layer to request that the NWK layer discover networks currently operating within the POS.

6.2.3.3.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-WiBEEM-DISCOVERY.request  (
                               ScanChannels,
                               ScanDuration
                               )
```

Table 5 specifies the parameters for the NLME- WiBEEM-DISCOVERY.request primitive.

Table 5 – NLME-NETWORK-DISCOVERY.request parameters

Name	Type	Valid range	Description
ScanChannels	Bitmap	32 bit field	The five most significant bits (b_{27} ,b_{31}) are reserved. The 27 least significant bits (b_0, b_1, ... b_{26}) indicate which channels are to be scanned (1 = scan, 0 = do not scan) for each of the 27 valid channels.
ScanDuration	Integer	0x00 to 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. For more information on MAC subayer scanning.

6.2.3.3.3 When generated

This primitive is generated by the next higher layer of a device and issued to its NLME to request the discovery of networks operating within the device's personal operating space (POS).

6.2.3.3.4 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.

6.2.3.4 NLME-WiBEEM-DISCOVERY.confirm

6.2.3.4.1 Function

This primitive reports the results of a network discovery operation.

6.2.3.4.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-WiBEEM-DISCOVERY.confirm      (
                                   NetworkCount,
                                   NetworkDescriptor,
                                   Status
                                   )
```

Table 6 below describes the arguments of the NLME-WiBEEM-DISCOVERY.confirm primitive.

Table 6 – NLME-WiBEEM-DISCOVERY.confirm paramters

Name	Type	Valid range	Description
NetworkCount	Integer	0x00 to 0xff	Gives the number of networks discovered by the search.
NetworkDescription	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 10 gives a detailed account of the content of each item.
Status	Enumeration	SUCCESS, NO_BEACON, or INVALID_PARAMETER	Result of scan request

Table 7 gives a detailed account of the content of a network descriptor from the NetworkDescriptor parameter.

Table 7 – Network descriptor information fields

Name	Type	Valid range	Description
MeshID	Integer	0x0000 to 0xffff	The 16-bit Mesh Identifier of the discovered network.
LogicalChannel	Integer	Selected from the available logical channels supported by the PHY	The current logical channel occupied by the network.
StackProfile	Integer	0x00 to 0x0f	A WiBEEM stack profile identifier indicating the stack profile in use in the discovered network.
WiBEEMVersion	Integer	0x00 to 0x0f	The version of the WiBEEM protocol in use in the discovered network.
BeaconOrder	Integer	0 to 15	This specifies how often the MAC sublayer beacon is to be transmitted by a given device on the network. For a discussion of MAC sublayer beacon order.
SuperframeOrder	Integer	0-BO or 15	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 sublayer superframe order.
PermitJoining	Boolean	TRUE or FALSE	A value of TRUE indicates that at least one WRC on the network currently permits joining, i.e. its NWK has been issued an NLMEPERMIT-JOINING primitive and the time limit, if given, has not yet expired.
SecurityLevel	Integer	0x00 to 0x07	The security level in use on the discovered network.

6.2.3.4.3 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-WiBEEM-DISCOVERY.request primitive.

6.2.3.4.4 Effect on receipt

On receipt of this primitive, the next higher layer is notified of the results of a network search.

6.2.4 Network formation

6.2.4.1 Overview

This set of primitives defines how the next higher layer of a device can initialise itself as the WMC of a new network.

6.2.4.2 NLME – WRC – OPERATING.request

6.2.4.2.1 Function

This primitive allows the next higher layer to request that the device start a new network with itself as the WMC.

6.2.4.2.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-WRC-OPERATING.request      (
                                ScanChannels,
                                ScanDuration,
                                BeaconOrder,
                                SuperframeOrder,
                                MeshID,
                                BatteryLifeExtension,
                                BTTSL,
                                MaxBeaconTxNumber,
                                Profile ID
                                )
```

Table 8 specifies the parameters for the NLME-WRC-OPERATING.request primitive.

Table 8 – NLME-WRC-OPERATING.request parameters

Name	Type	Valid range	Description
ScanChannels	Bitmap	32-bit field	The five most significant bits (b_{27}, ... ,b_{31}) are reserved. The 27 least significant bits (b_0, b_1, ... b_{26}) 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.
ScanDuration	Integer	0 to 14	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.
BeaconOrder	Integer	0 to 15	The beacon order of the network that the higher layers wish to form.
SuperframeOrder	Integer	0 to BO or 15	The superframe order of the network that the higher layers wish to form.
MeshID	Integer	0x0000 to 0xffff	The 16-bit mesh identifier of the discovered network.
BatteryLifeExtension	Boolean	TRUE or FALSE	If this value is TRUE, the NLME will request that the WMC is started supporting battery life extension mode. If this value is FALSE, the NLME will request that the WMC is started without supporting battery life extension mode.
BTTSL	BYTE	0x00 to 0xff	The length of the beacon transmission time slot. This value can be calculated by adding the size of the beacon and the BeaconTxMargin.
MaxBeaconTxNumber	BYTE	0x00 to 0xff	The maximum number of beacons transmitted.
Profile ID	BYTE	0x00 to 0xff	The number that specifies its corresponding application. A different application program is running based on this value.

6.2.4.2.3 When generated

This primitive is generated by the next higher layer of a WMC-capable device and issued to its NLME to request the initialisation of itself as the WMC of a new network.

6.2.4.2.4 Effect on receipt

On receipt of this primitive by a device that is not capable of being a WMC of a network, the NLME issues the NLME-NETWORK-FORMATION.confirm primitive with the status parameter set to INVALID_REQUEST.

6.2.4.3 NLME-WRC-OPERATING.confirm

6.2.4.3.1 Function

This primitive reports the results of the request to initialise a WMC in a network.

6.2.4.3.2 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-NETWORKFORMATION.confirm (
Status
)

Table 9 specifies the parameters for the NLME-NETWORK-FORMATION.confirm primitive.

Table 9 – 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 initialise a WMC.

6.2.4.3.3 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.

6.2.4.3.4 Effect on receipt

On receipt of this primitive, the next higher layer is notified of the results of its request to initialise the device as a WMC. If the NLME has been successful, the status parameter will be set to SUCCESS. Otherwise, the status parameter indicates the error.

6.2.5 Allowing devices to join

6.2.5.1 Overview

This primitive defines how the next higher layer of a WMC or WRC can request that devices be permitted to join its network.

6.2.5.2 NLME-ALLOW-JOINING.request

6.2.5.2.1 Function

This primitive allows the next higher layer of a WMC or WRC to set its MAC sublayer association permit flag for a fixed period during which it may accept devices onto its network.

6.2.5.2.2 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-ALLOW-JOINING.request (
PermitDuration
)

Table 10 specifies the parameters for the NLME-ALLOW-JOINING.request primitive.

Table 10 – NLME-ALLOW-JOINING.request

Name	Type	Valid range	Description
PermitDuration	Integer	0x00 to 0xff	The length of time in seconds during which the WMC or WRC will allow associations. The values 0x00 and 0xff indicate that permission is disabled or enabled, respectively, without a specified time limit.

6.2.5.2.3 When generated

This primitive is generated by the next higher layer of a WMC or WRC and issued to its NLME whenever it is desired to allow devices to join its network.

6.2.5.2.4 Effect on receipt

It is only permissible that the next higher layer of a WMC or WRC issue this primitive. On receipt of this primitive by the NWK layer of a WED, the NLME-PERMIT-JOINING.confirm primitive returns a status of INVALID_REQUEST.

6.2.5.3 NLME-ALLOW-JOINING.confirm

6.2.5.3.1 Function

This primitive allows the next higher layer of a WMC or WRC to be notified of the results of its request to permit the acceptance of devices onto the network.

6.2.5.3.2 Semantics of the service primitive

The semantics of this primitive is as follows:

NLME-ALLOW-JOINING.confirm (
Status
)

Table 11 specifies the parameters for the NLME-ALLOW-JOINING.confirm primitive.

Table 11 – NLME-ALLOW-JOINING.confirm parameters

Name	Type	Valid range	Description
Status	Status	Any status returned from the MLME-SET.confirm primitive	The status of the corresponding request.

6.2.5.3.3 When generated

This primitive is generated by the initiating NLME of a WMC or WRC 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 sublayer or an error code of INVALID_REQUEST.

6.2.5.3.4 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.

6.2.6 Begin as a router

6.2.6.1 Overview

This set of primitives allows a WRC that is newly joined to a network to setup its superframe configuration. It may also be used by a WMC or WRC to reconfigure its superframe.

6.2.6.2 NLME-SET-SUPERFRAME.request

6.2.6.2.1 Function

This primitive allows the next higher layer of a WRC to initialise or change its superframe configuration. It also allows the next higher layer of a WMC to change its superframe configuration.

6.2.6.2.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-SET-SUPERFRAME.request (
                                    BeaconOrder,
                                    SuperframeOrder,
                                    BatteryLifeExtension
                                    )
```

Table 12 specifies the parameters for NLME-SET-SUPERFRAME.request.

Table 12 – NLME-SET-SUPERFRAME.request parameters

Name	Type	Valid range	Description
BeaconOrder	Integer	0 to 15	The beacon order of the network that the higher layers wish to form.
SuperframeOrder	Integer	0 to BO or 15	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 WMC is started supporting battery life extension mode. If this value is FALSE, the NLME will request that the WMC is started without supporting battery life extension mode.

6.2.6.2.3 When generated

This primitive is generated by the next higher layer of a new device and issued to its NLME to request the initialisation of itself as a WRC. It may also be issued to the NLME of a device that is already operating as a WMC or WRC to adjust the configuration of its superframe.

6.2.6.2.4 Effect on receipt

On receipt of this primitive by a device that is not already joined to a network as a WRC, the NLME issues the NLME-START-ROUTER.confirm primitive with the Status parameter set to INVALID_REQUEST.

To initialise a new superframe configuration or to reconfigure an already existing one, the NLME issues the MLME-START.request primitive to the MAC sublayer. The CoordRealignment parameter in the MLME-START.request primitive is set to FALSE if the

primitive is issued to initialise a new superframe. The CoordRealignment parameter is set to TRUE if the primitive is issued to change any of the PAN configuration attributes.

6.2.6.3 NLME-SET-SUPERFRAME.confirm

6.2.6.3.1 Function

This primitive reports the results of the request to initialise or change the superframe configuration of a WRC. If the device is a WMC, then the primitive reports the results of the request to change the superframe configuration.

6.2.6.3.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-SET-SUPERFRAME.confirm   (
                                Status
                              )
```

Table 13 specifies the parameters for NLME-SET-SUPERFRAME.confirm.

Table 13 – NLME-SET-SUPERFRAME.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 initialise a WMC.

6.2.6.3.3 When generated

This primitive is generated by the NLME and issued to its next higher layer in response to an NLME-SET-SUPERFRAME.request primitive. This primitive returns a status value of INVALID_REQUEST or any status value returned from the MLME-START.confirm primitive.

6.2.6.3.4 Effect on receipt

On receipt of this primitive, the next higher layer is notified of the results of its request to initialise or change the superframe configuration of a WRC or to change the superframe configuration of a WMC. If the NLME has been successful, the status parameter will be set to SUCCESS. Otherwise, the status parameter indicates the error.

6.2.7 Joining a network

6.2.7.1 Overview

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.

6.2.7.2 NLME-JOIN.request

6.2.7.2.1 Function

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.

6.2.7.2.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-JOIN.request   (
                        MeshId,
                        JoinAsRouter,
                        RejoinNetwork,
                        ScanChannels,
                        ScanDuration,
                        PowerSource,
                        RxOnWhenIdle
                        )
```

Table 14 specifies the parameters for the NLME-JOIN.request primitive.

Table 14 – NLME-JOIN.request parameters

Name	Type	Valid range	Description
MeshID	Integer	0x0000 to 0xffff	Network 16-bit mesh ID
JoinAsRouter	Boolean	TRUE or FALSE	The parameter is TRUE if the device is attempting to join the network in the capacity of a WRC. 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 (b_{27}, ... ,b_{31}) are reserved. The 27 least significant bits (b_0, b_1, ... b_{26}) indicate which channels are to be scanned (1 = scan, 0 = do not scan) for each of the 27 valid channels. This parameter is ignored for requests to join through association.
ScanDuration	Integer	0 to 14	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.
PowerSource	Integer	0x00 to 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.
RxOnWhenIdle	Integer	0x00 to 0x01	This parameter indicates whether the device can be expected to receive packets over the air during idle portions of the active portion of its superframe. The values are: 0x01 = The receiver is enabled when the device is idle. 0x00 = The receiver may be disabled when the device is idle.

6.2.7.2.3 When generated

The next higher layer of a device generates this primitive to request to join a new network using the MAC sublayer association procedure, to join a new network directly using the MAC sublayer orphaning procedure or to locate and re-join a network after being orphaned.

6.2.7.2.4 Effect on receipt

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 MeshId parameter.

6.2.7.3 NLME-JOIN.indication

6.2.7.3.1 Function

This primitive allows the next higher layer of a WMC or WRC to be notified when a new device has successfully joined its network by association.

6.2.7.3.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-JOIN.indication (
                    ShortAddress,
                    ExtendedAddress,
                    CapabilityInformation
                    )
```

Table 15 specifies the parameters for the NLME-JOIN.indication primitive.

Table 15 – NLME-JOIN.indication parameters

Name	Type	Valid range	Description
ShortAddress	Network address	0x0000 to 0xffff	The network address of an entity that has been added to the network.
ExtendedAddress	64-bit IEEE address	64-bit, IEEE address	The 64-bit IEEE address of an entity that has been added to the network.
CapabilityInformation	Bitmap	–	Specifies the operational capabilities of the joining device.

6.2.7.3.3 When generated

This primitive is generated by the NLME of a WMC or WRC and issued to its next higher layer on successfully adding a new device to the network using the MAC association procedure.

6.2.7.3.4 Effect on receipt

On receipt of this primitive, the next higher layer of a WMC or WRC is notified that a new device has joined its network.

6.2.7.4 NLME-JOIN.confirm

6.2.7.4.1 Function

This primitive allows the next higher layer to be notified of the results of its request to join a network.

6.2.7.4.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-JOIN.confirm  (
                    MeshId,
                    Status
                    )
```

Table 16 specifies the parameters for the NLME-JOIN.confirm primitive.

Table 16 – NLME-JOIN.confirm parameters

Name	Type	Valid range	Description
MeshID	Integer	0x0000 to 0xffff	The mesh 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 or any status value returned from the MLME-ASSOCIATE.confirm primitive or the MLMESCAN.confirm primitive.	The status of the corresponding request.

6.2.7.4.3 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 or any status value returned from either the MLME-ASSOCIATE.confirm primitive or the MLME-SCAN.confirm primitive.

6.2.7.4.4 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 sublayer association procedure, to join directly using the MAC sublayer orphaning procedure or to re-join a network once it has been orphaned.

6.2.8 Joining a device directly to a network

6.2.8.1 Overview

This set of primitives defines how the next higher layer of a WMC or WRC can request to directly join another device to its network.

6.2.8.2 NLME-DETERMINED-JOIN.request

6.2.8.2.1 Function

This primitive allows the next higher layer of a WMC or WRC to request to directly join another device to its network.

6.2.8.2.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-DETERMINED-JOIN.request   (
                                 DeviceAddress,
                                 CapabilityInformation
                                 )
```

Table 17 specifies the parameters for the NLME-DETERMINED-JOIN.request primitive.

Table 17 – NLME-DETERMINED-JOIN.request parameters

Name	Type	Valid range	Description
DeviceAddress	64-bit IEEE address	64-bit, IEEE address	The IEEE address of the device to be directly joined.
CapabilityInformation	Bitmap	–	The operating capabilities of the device being directly joined.

Table 18 illustrates the formatting of the CapabilityInformation parameter.

Table 18 – Capability information parameter format

Bits:0	1	2	3	4-5	6	7
Alternative mesh co-ordinator	Device type	Power source	Receive on when idle	Reserved	Security capability	Reserved

6.2.8.2.3 When generated

The next higher layer of a WMC or WRC generates this primitive to add a new device directly to its network. This process is completed without any over the air transmissions.

6.2.8.2.4 Effect on receipt

On receipt of this primitive, the NLME will attempt to add the device specified by the DeviceAddress parameter to its neighbour table. The CapabilityInformation parameter will contain a description of the device being joined. The alternate WMC bit is set to 0 in WiBEEM v1.0. The device type bit is set to 1 if the device is a WRC 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 to secure operation or to 0 otherwise.

6.2.8.3 NLME-DETERMINDE-JOIN.confirm

6.2.8.3.1 Function

This primitive allows the next higher layer of a WMC or WRC to be notified of the results of its request to directly join another device to its network.

6.2.8.3.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
LME- DETERMINED-JOIN.confirm   (
                                 DeviceAddress,
                                 Status
                                 )
```

Table 19 specifies the parameters for the NLME-DIRECT-JOIN.confirm primitive.

Table 19 – NLME-DETERMINED-JOIN.confirm parameters

Name	Type	Valid range	Description
DeviceAddress	64-bit IEEE address	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.

6.2.8.3.3 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.

6.2.8.3.4 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.

6.2.9 Leaving a network

6.2.9.1 Overview

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.

6.2.9.2 NLME-LEAVE.request

6.2.9.2.1 Function

This primitive allows the next higher layer to request that it or another device leaves the network.

6.2.9.2.2 Semantics of the service primitive

This semantics of this primitive is as follows:

```
LME-LEAVE.request (
                    DeviceAddress
                    )
```

Table 20 specifies the parameters for the NLME-LEAVE.request primitive.

Table 20 – NLME-LEAVE.request parameters

Name	Type	Valid range	Description
DeviceAddress	Device address	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.

6.2.9.2.3 When generated

The next higher layer of a device generates this primitive to request to leave the network. The next higher layer of a WMC or WRC may also generate this primitive to remove a device from the network.

6.2.9.2.4 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 and with the DeviceAddress parameter equal to NULL, the NLME issues the MLME-DISASSOCIATE.request primitive to the MAC sub-layer.

6.2.9.3 NLME-LEAVE.indication

6.2.9.3.1 Function

This primitive allows the next higher layer of a device to be notified if that device has been removed from the network by its parent

6.2.9.3.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-LEAVE.indication (
                        DeviceAddress
                        )
```

Table 21 specifies the parameters for the NLME-LEAVE.indication primitive.

Table 21 – NLME-LEAVE.indication parameters

Name	Type	Valid range	Description
DeviceAddress	Device address	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.

6.2.9.3.3 When generated

This primitive is generated by the NLME of a WMC or WRC 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 WRC or WED and issued to its next higher layer to indicate that it has been successfully removed from the network by its associated WRC or WMC. This primitive is issued whenever the NLME received the MLME-DISASSOCIATE.indication primitive and for no other reason.

6.2.9.3.4 Effect on receipt

On receipt of this primitive, the next higher layer of a WMC or WRC 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 WRC or WED is informed that it has been removed from the network by its associated WRC or WMC.

6.2.9.4 NLME-LEAVE.confirm

6.2.9.4.1 Function

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.

6.2.9.4.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-LEAVE.confirm (
                        DeviceAddress,
                        Status
                        )
```

Table 22 specifies the parameters for the NLME-LEAVE.confirm primitive.

Table 22 – NLME-LEAVE.confirm parameters

Name	Type	Valid range	Description
DeviceAddress	Device address	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	INVALID_REQUEST, UNKNOWN_DEVICE or any status value returned from MLME-DISASSOCIATE.confirm primitive.	The status of the corresponding request.

6.2.9.4.3 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 any status value returned from the MLME-DISASSOCIATE.confirm primitive.

6.2.9.4.4 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.

6.2.10 Resetting a device

6.2.10.1 Overview

This set of primitives defines how the next higher layer of a device can request that the NWK layer is reset.

6.2.10.2 NLME-RESET.request

6.2.10.2.1 Function

This primitive allows the next higher layer to request that the NWK layer performs a reset operation.

6.2.10.2.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-RESET.request (
                    )
```

This primitive has no parameters.

6.2.10.2.3 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.

6.2.10.2.4 Effect on receipt

On receipt of this primitive, the NLME issues the MLME-RESET.request primitive to the MAC sublayer with the SetDefaultMIB parameter set to TRUE.

6.2.10.3 NLME-RESET.confirm

6.2.10.3.1 Function

This primitive allows the next higher layer to be notified of the results of its request to reset the NWK layer.

6.2.10.3.2 Semantics of the service primitive

The semantics for this primitive are as follows:

```
NLME-RESET.confirm    (
                      Status
                      )
```

Table 23 specifies the parameters for this primitive.

Table 23 – NLME-RESET.confirm parameters

Name	Type	Valid range	Description
Status	Status	Any status value returned from the MLME-RESET.confirm primitive	The result of the reset operation.

6.2.10.3.3 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.

6.2.10.3.4 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.

6.2.10.4 Network layer reset message sequence chart

Figure 2 illustrates the sequence of messages necessary for resetting the NWK layer.

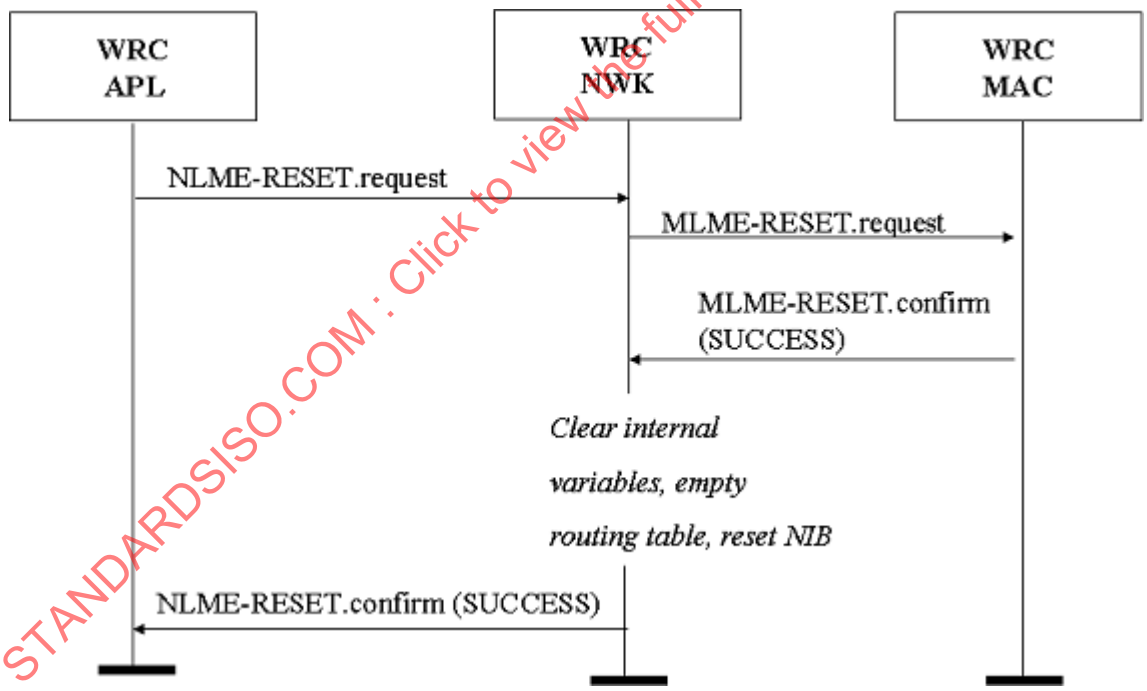

Figure 2 – Message sequence chart for resetting the network layer

6.2.11 Receiver synchronisation

6.2.11.1 Overview

This set of primitives defines how the next higher layer of a device can synchronise with a WMC or WRC and extract pending data from it.

6.2.11.2 NLME-SYNC.request

6.2.11.2.1 Function

This primitive allows the next higher layer to synchronise or extract data from its WMC or WRC.

6.2.11.2.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-SYNC.request       (
                        Track
                        )
```

Table 24 specifies the parameters for this primitive.

Table 24 – NLME-SYNC.request parameters

Name	Type	Valid range	Description
Track	Boolean	TRUE or FALSE	Whether the synchronisation should be maintained for future beacons or not.

6.2.11.2.3 When generated

This primitive is generated whenever the next higher layer wishes to achieve synchronisation or check for pending data at its WMC or WRC.

6.2.11.2.4 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 sublayer. On receipt of the corresponding MLME-POLL.confirm primitive, the NLME issues the NLME-SYNC.confirm primitive with the status parameter set to 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 sublayer 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.

6.2.11.3 NLME-SYNC.indication

6.2.11.3.1 Function

This primitive allows the next higher layer to be notified of the loss of synchronisation at the MAC sublayer.

6.2.11.3.2 Semantics of the service primitive

The semantics of this primitive is as follows:

```
NLME-SYNC.indication ( )
```