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IEEE Standard for Low-Rate Wireless Networks

Amendment 6: Enabling Spectrum Resource Measurement Capability

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

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USA

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(Amendment to
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as amended by IEEE Std 802.15.4n™-2016,
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IEEE Standard for Low-Rate Wireless Networks

Amendment 6: Enabling Spectrum Resource Measurement Capability

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LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 15 February 2018

IEEE-SA Standards Board

Abstract: Definitions of MAC related functions to enable spectrum resource management are addressed in this amendment to IEEE Std 802.15.4™. It specifies the following:

— Spectrum resource measurements and network performance metrics, such as packet error ratio, delay, etc.

— Information elements and data structures to capture these measurements,

— Procedures for collecting and exchanging spectrum resource measurement information with higher layers or other devices.

Keywords: IEEE 802.15.4™, spectrum resource measurement, transmit power control

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Introduction

This introduction is not part of IEEE Std 802.15.4s-2018, IEEE Standard for Low-Rate Wireless Networks—Amendment 6: Enabling Spectrum Resource Measurement Capability.

This amendment to IEEE Std 802.15.4-2015 enhances the functionalities to realize spectrum resource measurement and management for IEEE Std 802.15.4 physical layer (PHY) and medium access control layer (MAC). The standardized management mechanism enables individual PAN devices to coordinate with each other and operate more efficiently where devices are densely deployed in shared license exempt frequency bands and heavy interference could limit the overall performance. To this end, this amendment specifies the framework, PIB attributes, MLME primitives and MAC commands for exchanging information on spectrum resource usage, which includes the following:

— Spectrum resource measurements and network performance metrics.

— Information elements and data structures to capture these measurements.

— Procedures for collecting and exchanging spectrum resource measurement information with higher layers or other devices.

This amendment builds on popularity of IEEE Std 802.15.4-2015 to enhance performance of existing deployment and increases opportunities for applications of IEEE Std 802.15.4-2015 based system in new ways.

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NOTE—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strikethrough~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Deletions and insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE will not be carried over into future editions because the changes will be incorporated into the base standard.

3. Definitions, acronyms, and abbreviations

3.2 Acronyms and abbreviations

Replace definition for TPC with new definition as follows:

TPC transmit power control

Insert the following acronyms alphabetically into 3.2 as follows:

ANPI average noise power indicator

IPI idle power indicator

RCPI received channel power indicator

RSNI received signal noise indicator

SRM spectrum resource measurement

TBPC turbo product code

5. General description

5.7 Functional overview

Insert new sublcause 5.7.7 after 5.7.6 as follows:

5.7.7 Enabling spectrum resource measurement capability

SRM enables devices to gather a variety of data for evaluating radio link performance, which contributes to the selection of the best available PAN for joining and efficient radio spectrum usage for the selected PAN. As shown in Figure 5-10, the device obtains radio link characteristics by local measurements or via exchange of information with other devices via reporting messages all the way to the PAN coordinator. The PAN coordinator is also able to disseminate information to the devices in the PAN, such as the maximum transmit power, by which the receiving devices can set their radio parameters in a unified manner. SRM data is also made available to the upper protocol layers, which is able to use it for controlling the lower layer or their applications.

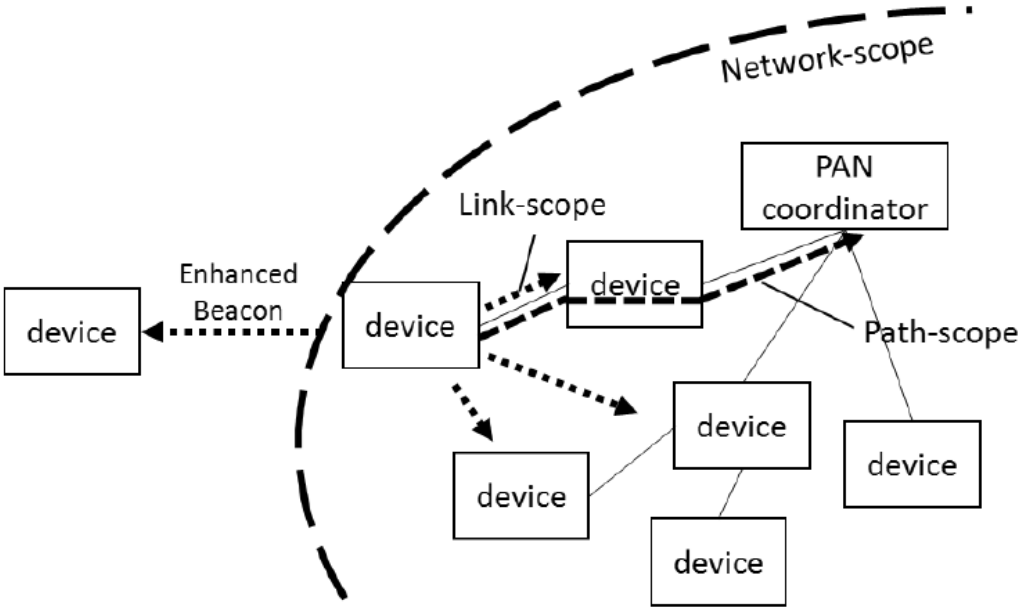


Figure 5-10—Scope-based forwarding control

The measurement of SRM metrics are conducted only when the device is capable of doing it. In the case of LE transmission and reception, for example, even if the requesting device requests the peer device to measure SRM metrics for a specific duration of time, the requested device can do it only when the receiver is enabled.

In the case of TSCH, there are three modes of measurement operation.

— Full measurement: the device conducts the measurement for a specified duration of time regardless of the channel.

— Channel-specific measurement: the device coducts the measurement only when it is on the specifed channel within the hopping sequence. The device puts the measured data together and calculates the performance metrics. The obtained result is the characteristics of the specified channel.

— Link-specific measurement: the device conducts the measurement only when it is on a specific link, which is represented by *macLinkHandle* defined in Table 8-85. The device puts the measure data together and calculates the performance metrics. The obtained result is the characteristics of the specified link.

6. MAC functional descriptions

Insert new subclause 6.17 after 6.16 as follows:

6.17 Spectrum resource measurement (SRM)

SRM specifies the following functions and procedures in order to effectively operate wireless systems that could have heavy interferences within or outside the network:

— Spectrum resource measurements and network performance metrics, such as packet error ratio, delay, etc.
— Information elements and data structures to capture these measurements
— Procedures for collecting and exchanging spectrum resource measurement information with higher layers or other devices and for transmit power control (TPC)

6.17.1 SRM performance metrics

6.17.1.1 Energy detection (ED)

ED capability is included in the fundamental features for PHY technologies as described in 10.2.5. In the case that SRM capabilities is supported, the scaling of ED data shall abide by the following rule.

— The minimum and maximum values of ED are 0x0 and 0xf, respectively.

This range covers twice the range of 40 dB with the accuracy of 6 dB.

6.17.1.2 Percentage of time of failed transmissions

The percentage of time of failed transmissions feature is intended for use by a higher layer, or by a common network manager existing in a multiple wireless network environment, to aid in the estimation of propagation quality of specific links as part of a channel selection algorithm.

The output of the feature is a value for the PIB attribute *macTxFailTime*, which shall be calculated with the following equation:

$$macTxFailTime = \frac{\Sigma\ tx\ fail\ time[j]}{\Sigma\ attempted\ time[i]}$$

macTxFailTime is linearly scaled with 0xff representing 100%.

In this equation, *tx fail time* [*j*] is the time period starting at the first bit of the MPDU and stopping at the end of the last retry time out. The value of *j* is determined by the number of the failed transmissions within the Measurement time as depicted in Figure 6-79, where the first attempt on the left hand side is successful and not counted *as tx fail time* [*j*] and the second attempt on the right hand side is unsuccessful so that it is counted as *tx fail time* [*j*]. Also, *attempted time* [*i*] is the time when the first frame is attempted to be transmitted to the time when either it is successfully transmitted and acknowledged or it is failed to transmit by reaching *macMaxFrameRetries* times. Measurement time is defined as the duration of the requested measurement specified by the SRM Duration in Figure 7-136. By considering only the attempted time within the measurement time, the time between any two consecutive attempts, which is idle, is excluded. The accuracy for the time used in this equation shall be ± 100 μs.

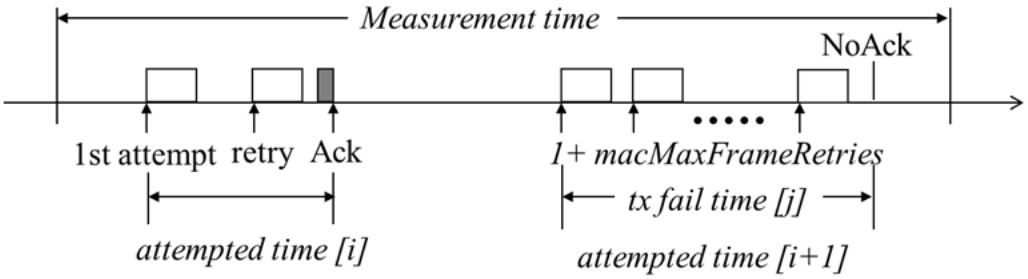


Figure 6-79—maxTxFailTime

6.17.1.3 Percentage of time of deferred transmissions

The percentage of time of deferred transmissions feature is intended for use by a higher layer, or by a common network manager existing in a multiple wireless network environment, to aid in the estimation of congestion with coexisting LR-WPAN, WLAN, or other networks as part of a channel selection algorithm. The output of the feature is a value for the PIB attribute *macDeferredTxTime*, which shall be calculated with the following equation:

$$macDeferredTxTime = \frac{\Sigma\ deferred\ period\ [j]}{\Sigma\ attempted\ time\ [i]}$$

In this equation, *deferred period [j]* is the total duration of all back-off periods of all packets sent during the Measurement Time as depicted in Figure 6-80. Also, *attempted time [i]* is the time when the first frame is attempted to be transmitted to the time when it is successfully transmitted and acknowledged. Measurement time is defined as the duration of the requested measurement specified by the SRM Duration in Figure 7-136. By considering only the attempted time within the measurement time, the time between any two consecutive attempts, which is idle, is excluded. The accuracy for the time used in this equation shall be ± 100 μs.

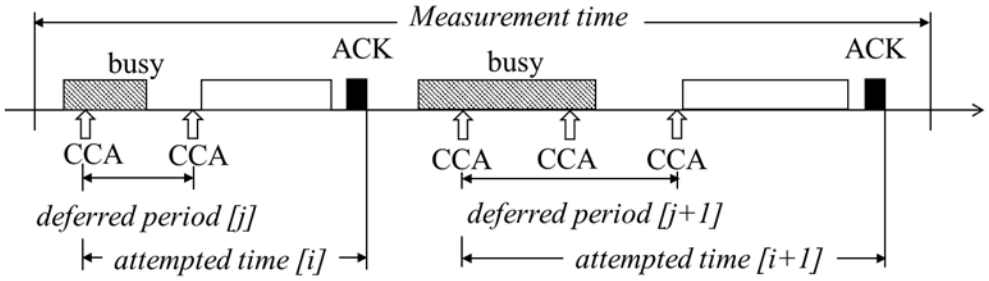


Figure 6-80—*macDeferredTxTime*

6.17.1.4 Retry Histogram

Retry Histogram is intended for use by the next higher layer or a common network manager existing in multiple wireless network environment, in order to optimize the utilization of spectrum resource.

Retry histogram is the histogram of the number of retries for one transmission during the measurement time. The bins range from 0 to macMaxFrameRetries. Retry number=0 means that the transmission is successful without retry. Retry number=macMaxFrameRetries means that the transmission is failed and it is regarded

as the transmission failure. The period of retry attempts is measured as Tx fail time*[j]* as depicted in Figure 6-79.

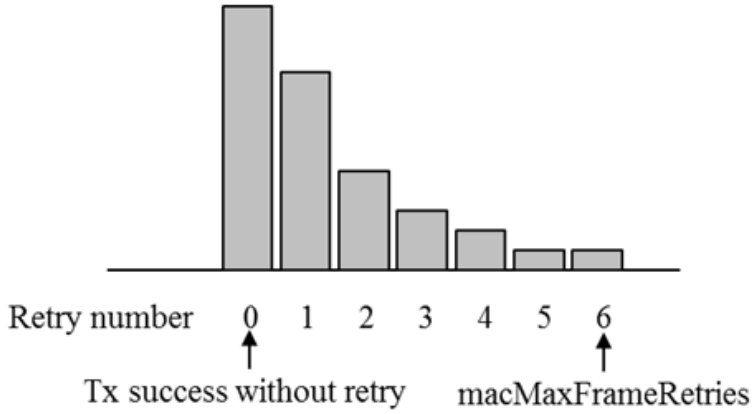


Figure 6-81—Retry Histogram

6.17.1.5 Channel utilization

Channel utilization is intended for use by the next higher layer or a common network manager existing in multiple wireless network environment, in order to optimize the utilization of spectrum resource. Total channel used time for Tx and Rx over the measurement time, linearly scaled with 0xff representing 100 %.

Channel Busy Time is defined as follows:

— Total time of Tx and Rx of all Frames including beacons and ACKs for and from this device.
— CCA time during deferred period is also added.

The accuracy for the time used shall be ± 100 μs.

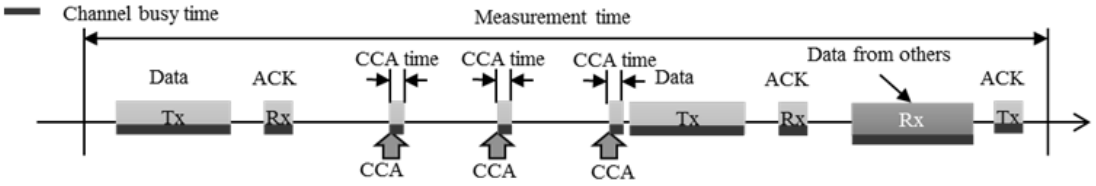


Figure 6-82—Channel utilization

6.17.1.6 Received channel power indicator (RCPI)

The RCPI indicator, which is defined as *macRcpi*; one of the SRM metrics in Table 7-49, is a measure of the received RF power in the selected channel for a received frame. RCPI value shall be equivalent to the received RF power averaged over the duration of the entire received frame. The valid range of values is 0 to 150, and shall be rounded to the nearest integer value in units of dBm. The value shall be interpreted as follows (also depicted in Figure 6-83):

— 0: Power ≤ – 150 dBm
— 1: Power = – 149 dBm
— 2: Power = – 148 dBm

and so on up to

— 150: Power ≥ – 0 dBm
— 151–254: Reserved
— 255: Measurement not available

where

RCPI = Integer [Power in dBm + 150] for 0 dBm > Power > – 150 dBm

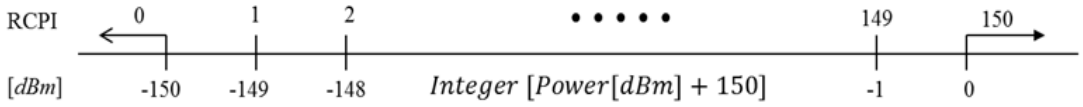


Figure 6-83—Received Channel Power Indicator (RCPI)

6.17.1.7 Received Signal Noise Indicator (RSNI)

Received Signal Noise Indicator is intended for use by the next higher layer or a common network manager existing in multiple wireless network environment, in order to optimize the utilization of spectrum resource.

An indication of the signal to noise plus interference ratio of a received frame, which is defined by the ratio of the received signal power (RCPI-ANPI) to the noise plus interference power (ANPI) as measured on the channel and at the antenna connector used to receive the frame. IPI Density in the specified channel is a function of time over the measurement duration where the channel is idle (CCA indicates idle and no Tx or Rx) as shown in Figure 6-84 and Table 6-5.

$$\text{IPI Density} = Integer\left[\frac{D_{IPI}[\mu s]}{Channel\ Idle\ Time\ [\mu s]} \times 255\right]$$

$$\text{ANPI} = averaged\ IPI\ Density\ values$$

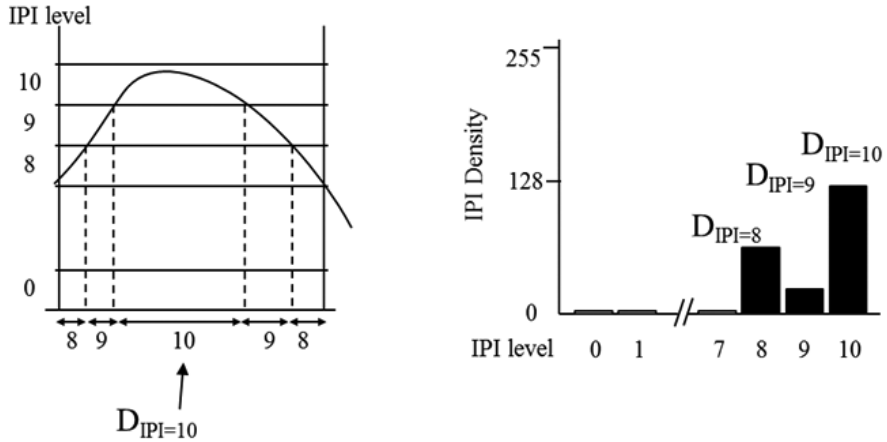


Figure 6-84—IPI Density

ANPI is calculated by averaging IPI Density(D_{IPI}) from IPI=0 to IPI=10.

RSNI shall be defined as $10\times\log_{10}((RCPI_{power}-ANPI_{power})/ANPI_{power})$, where $RCPI_{power}$ and $ANPI_{power}$ indicate power domain values for RCPI and ANPI and not dB domain values. RSNI is rounded to the nearest 0.5 dB and defined over the range from –10 dB to +117 dB. RSNI shall be an 8-bit integer, having the value $RSNI=2\times(RSNI_{dB}+10)$. The value 255 indicates that RSNI is not available.

NOTE—RCPI, ANPI, IPI and RSNI are specified in IEEE Std 802.11™-2016. ANPI and IPI are not a PIB attribute and used only for calculating RSNI. The IPI value should be updated to calculate RSNI as accurately as possible. If the device operates in CCA Mode 4 or CCA capability is not used, the procedure returns with a Status of NON_SUPPORTED.

6.17.1.8 Received signal strength indicator (RSSI)

Received Signal Strength Indicator is intended for use by the next higher layer or a common network manager existing in multiple wireless network environment, in order to assess the utilization of spectrum resource together with RCPI and RSNI.

RSSI is a measure of the RF power received as described below. The RF power level at the input of the transceiver measured during the PHR and is valid after the SFD is detected. The minimum and maximum values are 0x00 and 0xff as shown in Table 8-77 and the values in between should be uniformly distributed.

6.17.1.9 Noise Histogram

Noise Histogram is intended for use by the next higher layer or a common network manager existing in multiple wireless network environment, in order to optimize the utilization of spectrum resource.

The Noise Histogram shall be a histogram of non-IEEE 802.15 noise power in the specified channel defined as a functon of time over the measurement duration when CCA indicates idle and the device is neither transmitting nor receiving a frame. The Noise Histogram Report shall contain the IPI densities, defined in 6.17.1.7, observed in the channel for the IPI levels defined in Table 6-5. If the device operates in CCA Mode 4 or CCA capability is not used, the procedure shall return with a Status of NON_SUPPORTED.

Table 6-5—IPI Definitions for Noise Histogram

IPI Level	IPI Measured Power (dBm)
0	$IPI \leq -110$
1	$-110 < IPI \leq -105$
2	$-105 < IPI \leq -100$
3	$-100 < IPI \leq -95$
4	$-95 < IPI \leq -90$
5	$-90 < IPI \leq -85$
6	$-85 < IPI \leq -80$
7	$-80 < IPI \leq -75$
8	$-75 < IPI \leq -70$
9	$-70 < IPI \leq -65$
10	$-65 < IPI \leq -60$
11	$-60 < IPI \leq -55$
12	$-55 < IPI$

6.17.1.10 Average access delay

Average Access Delay is intended for use by the next higher layer or a common network manager existing in multiple wireless network environment, to aid in the assessment of channel congestion with coexisting LR-WPANs, WLANs, or other networks as part of a channel selection algorithm.

The average medium access delay for transmitted frames is measured from the time the first bit of the MPDU is ready for transmission until the actual frame transmission start time in μs. In the case of TSCH, *macTsTxOffset* can be used calculate Access Delay time. The average access delay is not calculated if there is no frame transmitted in the measurement time (e.g., due to the channel busy).

6.17.1.11 MAC performance metrics specific MAC PIB attributes

If *macSrmEnabled* is TRUE, the attributes of MAC PIB defined in 8.4.2.6 shall follow the following rules.

— The MAC PIB attributes defined in 8.4.2.6 are also used for SRM.

By using these attributes, the packet success rate (PSR) can be calculated as follows:

$$\mathrm{PSR} = 1 - \frac{macTxFailCount}{macTxSuccessCount + macRetryCount + macMultipleRetryCount + macTxFailCount}$$

The PSR is the rate of the successfully received packets indicated by the ACK to the number of transmission attempts including the retries in the total measurement time.

SRM Metric ID is used to indicate which metric the value in this IE represents and several IDs (e.g., *macCounterOctets*) are redefined from MAC Count IDs in Table 7-18. If SRM is supported, SRM Metric ID should be used.

Scope ID is used to indicate in which scope the metric value is valid and each scope has the following meaning and usage.

If the Scope ID is “link,” the value is valid on the link that the sending device is connected to. The received device should not disseminate the information in SRM IEs to other devices.

If the Scope ID is “Path”, the value is valid on the path from the sending device to the PAN coordinator. The received device should send the SRM IEs to the parent device toward the PAN coordinator. The content of the SRM IEs can be modified to reflect its own situation. For example, the device may add the *macAverageAccessDelay* PIB attribute of its own to that in the SRM IE to represent the delay between the sending device and its own device and convey that value to the parent device. By performing the same process at the device on the path to the PAN coordinator, the PAN coordinator can estimate the total delay from the originated device. Note that a delay has additive characteristics, while the frame loss rate has multiplicative characteristics. It depends on the parameter about how to represent the characteristics of the path, which is not specified in the document.

If the Scope ID is “Network,” the value is valid in the entire PAN. The received device should disseminate to all the neighboring device(s) by broadcast if it has not be received before. An example of using this Scope ID is to disseminate the maximum transmit power in this PAN, which is represented by *phyMaxTxPower*.

6.17.2 SRM functionality

When *macSrmEnabled* is set to TRUE in the coordinator and the device, the following SRM functionality shall be supported.

6.17.2.1 Signaling

The SRM IE, as defined 7.4.4.32, is conveyed in either Enhanced Beacon frames (if supported), Multipurpose frames or MAC Command frames. Enhanced Beacon frames are used for the devices that haven't joined the PAN, yet. By receiving such Enhanced Beacon frames with SRM IEs, that device can select the most suitable PAN if multiple ones are available. Once that device has been authorized to join the PAN, SRM IEs can be conveyed on Multipurpose frames or MAC command frames with encryption.

SRM information has the following scope of its validity:

— Link scope: the SRM metric(s) is/are measured on the link that the sending device is connected; thus best represent(s) the characteristics of that link.

— Path scope: the SRM metric(s) is/are measured on the path from the sending device to the PAN coordinator; thus best represent(s) the characteristics of that path. How it is measured is outside the scope of this specification.

— Network scope: the SRM metric(s) is/are measured in the entire PAN that the sending device is joining; thus best represent(s) the characteristics of that PAN. How it is measured is outside the scope of this specification.

6.17.2.2 Transmit power control

Transmit power control (TPC) is one of the effective means of enhancing the performance of WPANs. A careful setting of the operating transmit power by the wireless node offers several benefits; e.g., efficient spatial re-use of the radio spectrum and minimizes interference. At the time of joining the network, the maximum transmit power that the device shall abide by is notified by the adjacent devices that are already in the network via the beacon frame or association response frame. After joining the network, the device can specify the transmit power for the following communication types:

— Broadcast communication (e.g., in the scan process).

— Unicast communication with any device (e.g., when a specific communication quality is required for an individual communication or in order to reduce the interference to other devices).

— Unicast communication with a specific peer device If the TX power is limited for a device in the PAN, where CSMA/CA is employed, it should be limited to the same value for all devices in the PAN to enable the CSMA/CA algorithm to work correctly.

The above transmit power shall not exceed the maximum transmit power. If the TX power is limited for a device in the PAN, where CSMA/CA is employed, it should be limited to the same value for all devices in the PAN to enable the CSMA/CA algorithm to work correctly.

6.17.2.3 SRM Request/Response

SRM Request/Response flows for getting PIB information are depicted in Figure 6-85. The higher layer on the receiver side may be involved as shown in the dotted box if the decision needs to be made by the higher layer, but this is not always the case.

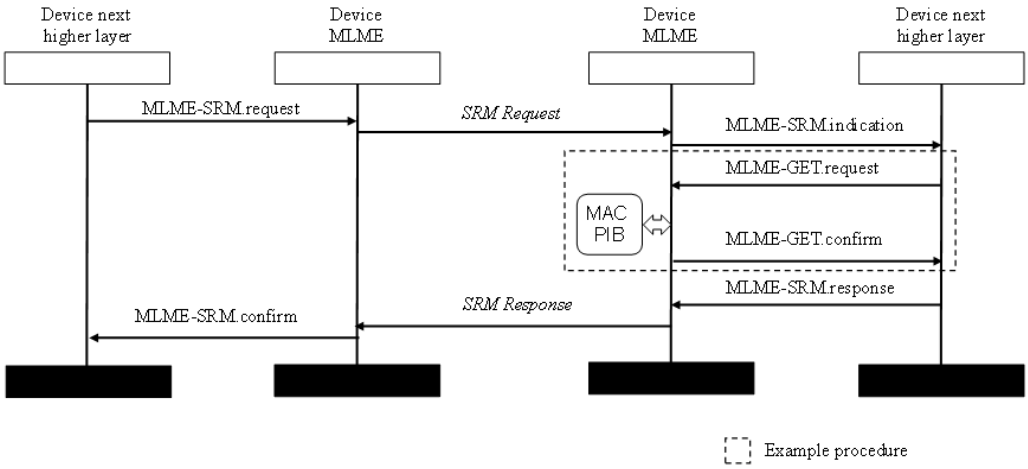
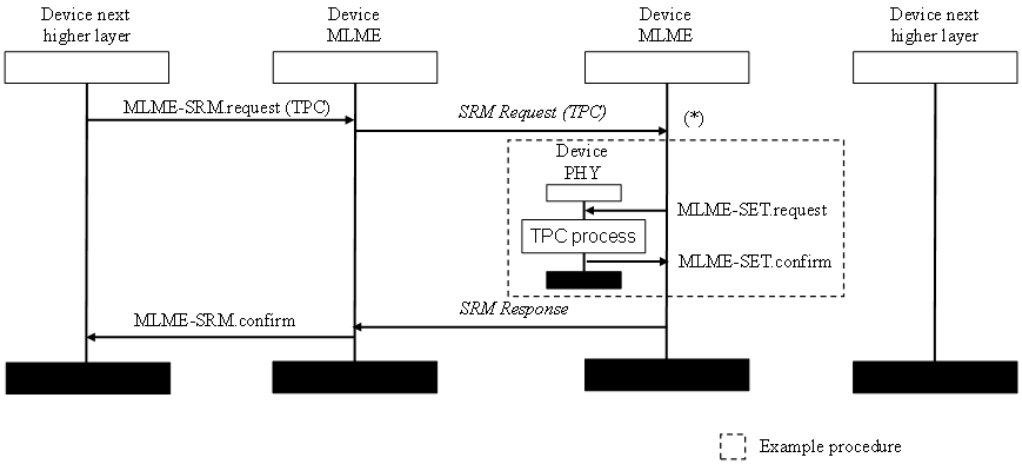


Figure 6-85—SRM Request/Response flows for getting PIB information

SRM Request/Response flows for setting PIB information (e.g., TPC) are depicted in Figure 6-86. The lower layer may be involved as shown in the dotted box if the requested procedure needs to be taken by the lower layer, but this is not always the case.



(*) Depending on the application or use case, it is also possible that the MAC layer of the recipient of SRM Request notifies the higher layer of its reception by MLME-SRM.indication and the higher layer triggers MLME-SET to control the lower layer.

Figure 6-86—SRM Request/Response flows for setting PIB information

6.17.2.4 SRM Report

SRM Report flows are depicted in Figure 6-87. SRM Report command is sent from a device to the PAN coordinator periodically or based on some event.

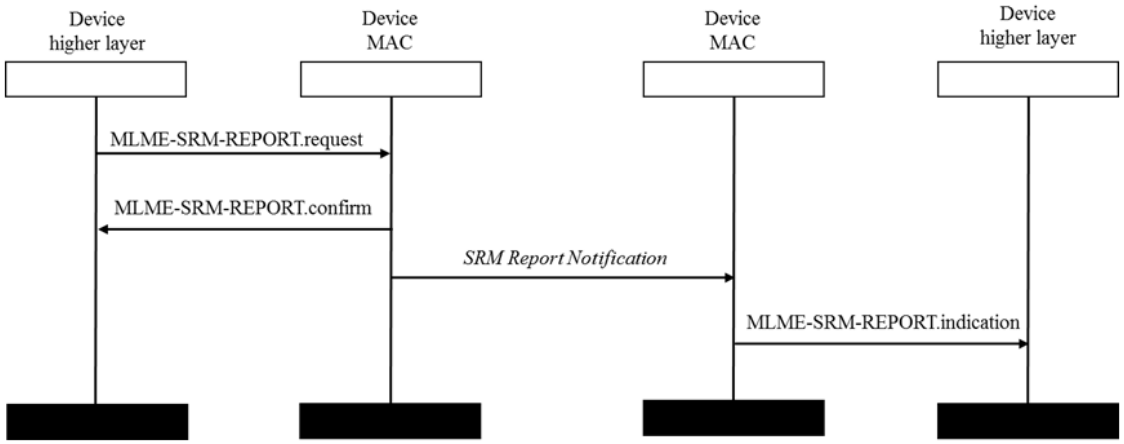


Figure 6-87—SRM Report flow

6.17.2.5 SRM Information

SRM Information flows are depicted in Figure 6-88. SRM Information Notification can be sent by the Enhanced Beacon, MAC command or multipurpose frame, which is specified by the higher layer. If AckedConfirm described in Figure 8-82 is set to TRUE in MLME-SRM-INFORMATION.request primitive, MLME-SRM-INFORMATION.confirm is returned when the SRM Information notification is acknowledged. If AckedConfirm is set to FALSE, MLME-SRM-INFORMATION.confirm is returned immediately after the SRM Information Notification is successfully transmitted.

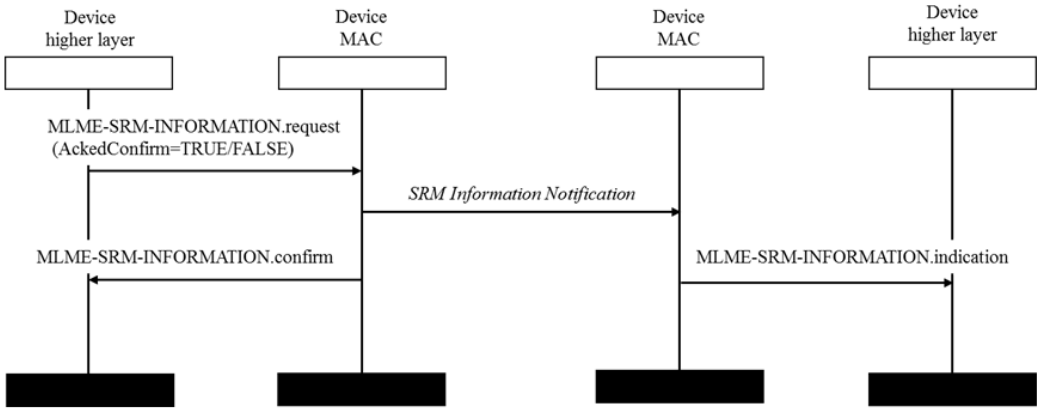


Figure 6-88—SRM information flow with waiting for acknowledgement

6.17.2.6 MAC performance metrics specific MAC PIB attributes

In the case that SRM capabilities is supported, the attributes of MAC PIB defined in 8.4.2.6 shall follow the following rules.

— 10 metric specific MAC PIB attributes are defined in 8.4.2.6. These attributes are reused for SRM.

— By using these attributes, the packet success rate can be calculated as follows:

$$\text{Packet Success Rate} = 1 - \frac{macTxFailCount}{macTxSuccessCount + macRetryCount + macMultipleRetryCount + macTxFailCount}$$

7. MAC frame formats

7.4 IEs

7.4.4 Nested IEs

7.4.4.1 Format of Nested IE

Add the following item to the end of Table 7-19 (the entire table is not shown as indicated):

Table 7-19—Sub-ID allocation for short format

Sub-ID value	Name	Enhanced Beacon	Enhanced ACK	Data	Multipurpose	MAC command	Format subclause	Use description	Used by	Created by
0x46	SRM IE	X			X	X	7.4.4.32	6.17	UL	UL

Insert the following new subclause 7.4.4.32 after 7.4.4.31 as follows:

7.4.4.32 SRM IE

The SRM IE field shall be formatted as illustrated in Figure 7-102, which should be inserted in Table 7-19, "Sub ID allocation for short format." Format of SRM Metric ID and Scope ID are defined in Table 7-20 and Table 7-21, respectively. Type and range for the Content field shall be defined in corresponding attribute in Table 8-106.

Bits: 0–5	6-7	Octet: 0-126
SRM Metric ID	Scope ID	Content

Figure 7-102—SRM Metric ID

Table 7-20—Format of SRM Metric ID

Attribute name	SRM Metric ID b5 b4 b3 b2 b1 b0
macED	000000
MacTxFailTime	000001
macTxDeferredTime	000010
macRetryHistogram	000011
macChannelUtilization	000100
macRcpi	000101
macRsni	000110
macRssi	000111
macNoiseHistogram	001000
macFrameErrorCount	001001
macCounterOctets	001010
macRetryCount	001011
macMultipleRetryCount	001100
macTxFailCount	001101
macTxSuccessCount	001110
macFcsErrorCount	001111
macSecurityFailure	010000
macDuplicateFrameCount	010001
macRxSuccessCount	010010
macNackCount	010011
macDeferredTxCount	010100
macAverageBufferUtilization	010101
macMaximumBufferUtilization	010110
macTxFragmentCount	010111
macRxFragmentCount	011000
macTxMulticastCount	011001
macRxMulticastCount	011010
macAverageAccessDelay	011011
macChannelPage	011100
macChannelNumber	011101
macRxAddrMode	011110
macRxDeviceAddress	011111
Reserved	100000-111111

Table 7-21—Format of Scope ID

Measured range	Scope ID b1 b0
Link	00
Path	01
Network	10
Reserved	11

7.4.4.33 Scope-based Performance Metric

In the case that SRM capabilities are supported, the scope-based performance metric may be used to acquire the radio spectrum resource usage information from more than 1 hop area specified by the Scope information.

— Use case for Scope-based Performance Metric is depicted in Figure 7-103.
— How path-scope and network scope performance is calculated is outside the scope of the specification.

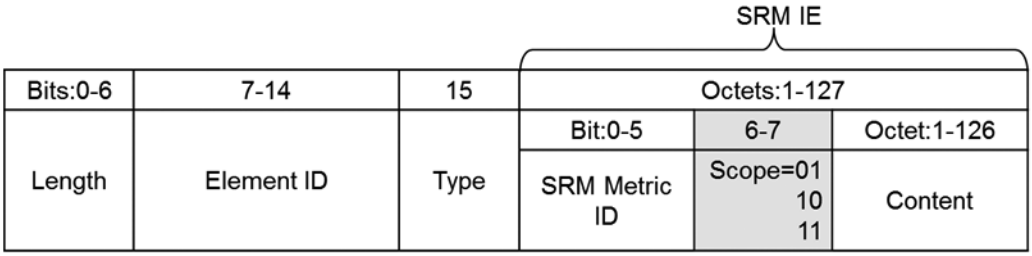


Figure 7-103—Scope-based Performance Metric

7.4.4.34 Example of Signal quality related IEs

In the case that SRM capabilities is supported, the SRM measurement shall be carried by IEs as following:

— When multiple channels are used, the channel on which the measurement is executed needs to be specified
— Device address for which the measurement is executed may also be needed to be specified

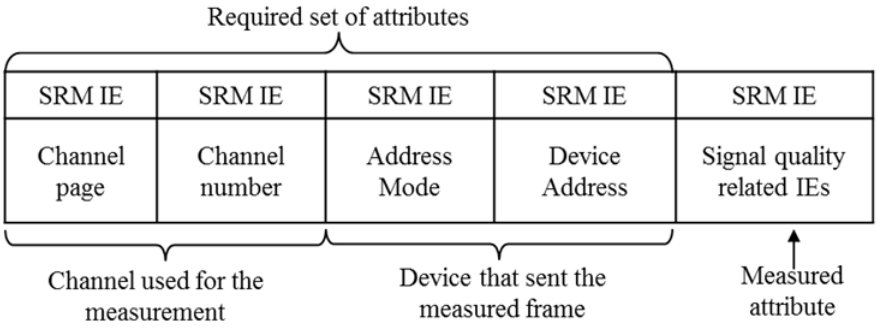


Figure 7-104—Example of Signal quality related IEs

The following attributes in Table 7-48 can be applied for this rule.

Table 7-48—Signal quality related attributes

Attribute
macEd
macRcpi
macRsni
macRssi
macNoiseHistogram

7.5 MAC commands

7.5.1 Command ID field

Add the following items at the end of Table 7-49 (the entire table is not shown):

Table 7-49—MAC commands

Command ID	Command name	RFD		Subclause
		TX	RX	
0x23	SRM Request command			7.5.27
0x24	SRM Response command			7.5.28
0x25	SRM Report command			7.5.29
0x26	SRM Information command			7.5.30

Insert the following new subclause 7.5.27 after 7.5.26 as follows:

7.5.27 SRM Request command

If the device is assigned a short address, the Source Addressing Mode field of the Frame Control field shall be set to indicate short addressing; otherwise, it shall be set to indicate extended addressing.

If the device knows the short address of the destination device, the Destination Addressing Mode shall be set to indicate short addressing; otherwise, it shall be set to indicate extended addressing.

The Frame Pending field shall be set to zero. The AR field shall be set to one. The Frame Version field shall be set to two.

The Source PAN ID field shall contain the value of *macPanId*, and the Source Address shall field contain the value of *macShortAddress* or *macExtendedAddress* according to the Source Addressing Mode field.

The Destination PAN ID field shall contain the value of *macPanId*, and the Destination Address field shall contain the value of the short address or the extended address of the destination device according to the Destination Addressing Mode field.

The SRM Request command Content field shall be formatted as illustrated in Figure 7-135.

Bits:0-5	6-7	Octets:1	variable
SRM Metric ID	Scope ID	SRM Token	Measurement Information

Figure 7-135—SRM Request command Content field format

The SRM Metric ID and the Scope ID shall be formatted as described in Table 7-49 and Table 7-50, respectively.

The SRM Token shall be set to a nonzero number that is unique among SRM Request frames. If the SrmHandle defined in Figure 8-75 is provided via MLME-SRM.request primitive, the SRM Token shall use this value.

The Measurement Information field shall be formatted as illustrated in Figure 7-136.

Bits:0	1	2	3	4	5-15	Octets:0/4	0/2	0/1	0/1	0/2
Start Time Present	SRM Duration Present	Channel Page Present	Channel Number Present	Link Handle Present	Reserved	Start Time	SRM Duration	Channel Page	Channel Number	Link Handle

Figure 7-136—Measurement Information field format

The Start Time Present shall be set to one if the Start Time is present and shall be set to zero if the Start Time is not present.

The SRM Duration Present shall be set to one if the SRM Duration is present and shall be set to zero if the SRM Duration is not present.

The Channel Page Present shall be set to one if the Channel Page is present and shall be set to zero if the Channel Page is not present.

The Channel Number Present shall be set to one if the Channel Number is present and shall be set to zero if the Channel Number is not present.

The Start Time, which shall be formatted as described in Table 7-96, indicates the time in at which the measurement to get started. The actual start time may be aligned with the start time of the closest time slot. The unit of a time slot equals to 1 μs.

The SRM Duration in units of time slots indicates the duration during which the measurement to be performed. The unit of a time slot equals to 1 μs.

The Channel Page indicates the channel page on which the measurement is to be performed.

The Channel Number indicates the channel number on which the measurement is to be performed.

The Link Handle, which is described in Table 8-85, indicates the link on with the measurement to be performed.

7.5.28 SRM Response command

If the device is assigned a short address, the Source Addressing Mode field of the Frame Control field shall be set to indicate short addressing; otherwise, it shall be set to indicate extended addressing.

If the device knows the short address of the destination device, the Destination Addressing Mode shall be set to indicate short addressing; otherwise, it shall be set to indicate extended addressing.

The Frame Pending field shall be set to zero. The AR field shall be set to one. The Frame Version field shall be set to two.

The Source PAN ID field shall contain the value of *macPanId*, and the Source Address shall field contain the value of *macShortAddress* or *macExtendedAddress* according to the Source Addressing Mode field.

The Destination PAN ID field shall contain the value of *macPanId*, and the Destination Address field shall contain the short address or the extended address of the destination device according to the Destination Addressing Mode field.

The SRM Response command Content field shall be formatted as illustrated in Figure 7-137.

Bits:0-5	**6-7**	**Octets:1**	**1**	**Octets: variable**	**4**
SRM Metric ID	Scope ID	SRM Token	Status	Measured Device Information	Attribute Value

Figure 7-137—SRM Response command Content field format

The SRM Metric ID and the Scope ID shall be formatted as described in Table 7-49 and Table 7-50, respectively.

The SRM Token field shall be set to SRM Token in the corresponding SRM Request element.

The Status field shall be formatted as illustrated in Figure 7-138.

Status (b0 b1 b2 b3)	Description
0000	Success
0001	Not Supported
0010	Rejected
0011-1111	Reserved

Figure 7-138—Status field format

The Measured Device Information field shall be formatted as illustrated in Figure 7-139.

Bits:0-1	2-7	Octets:2/8
Address Mode	Reserved	Device Address

Figure 7-139—Content Information field format

The Address Mode field, which shall be set to one of the values given in Table 7-3, indicates the address mode of the device that conducted the measurement.

The Device Address field, which shall be set to the short address or extended address according to the Address Mode field, indicates the address of the device that conducted the measurement.

The Attribute Value field contains the PIB attribute value defined in Table 8-95.

7.5.29 SRM Report command

If the device is assigned a short address, the Source Addressing Mode field of the Frame Control field shall be set to indicate short addressing; otherwise, it shall be set to indicate extended addressing.

If the short address of the destination device is available, the Destination Addressing Mode shall be set to indicate short addressing; otherwise, it shall be set to indicate extended addressing.

The Frame Pending field shall be set to zero. The AR field shall be set to one. The Frame Version field shall be set to two.

The Source PAN ID field shall contain the value of *macPanId*, and the Source Address shall field contain the value of *macShortAddress* or *macExtendedAddress* according to the Source Addressing Mode field.

The Destination PAN ID field shall contain the value of *macPanId*, and the Destination Address field shall contain the short address or the extended address of the destination device according to the Destination Addressing Mode field.

The SRM Report command Content field shall be formatted as illustrated in Figure 7-140.

Bits:0-5	6-7	Octets:1	variable	4
SRM Metric ID	Scope ID	SRM Token	Measurement information	Attribute Value

Figure 7-140—SRM Report command Content field format

The SRM Metric ID and the Scope ID shall be formatted as described in Table 7-49 and Table 7-50, respectively.

The SRM Token field shall be set to the SRM Token in the corresponding the SRM Request element. If the SrmHandle defined in Figure 8-82 is provided via MLME-SRM-REPORT.request primitive. If the SRM Report element is being sent autonomously, then the SRM Token is set to 0.

The Measurement Information field shall be formatted as illustrated in Figure 7-136.

The Attribute Value field contains the PIB attribute value defined in Table 8-106.

7.5.30 SRM Information command

If the device is assigned a short address, the Source Addressing Mode field of the Frame Control field shall be set to indicate short addressing; otherwise, it shall be set to indicate extended addressing.

If the device knows the short address of the destination device, the Destination Addressing Mode shall be set to indicate short addressing; otherwise, it shall be set to indicate extended addressing.

The Frame Pending field shall be set to zero. The AR field shall be set to one. The Frame Version field shall be set to two.

The Source PAN ID field shall contain the value of *macPanId*, and the Source Address shall field contain the value of *macShortAddress* or *macExtendedAddress* according to the Source Addressing Mode field.

The Destination PAN ID field shall contain the value of *macPanId*, and the Destination Address field shall contain the short address or the extended address of the destination device according to the Destination Addressing Mode field.

The SRM Information command Content field shall be formatted as illustrated in Figure 7-141.

Bit:0-5	6-7	Octet:1	variable	4
SRM Metric ID	Scope ID	SRM Token	Measurement information	Attribute Value

Figure 7-141—SRM Information command Content field format

The SRM Metric ID and the Scope ID shall be formatted as described in Figure 7-20 and Table 7-21, respectively.

The SRM Token field shall be set to the SRM Token in the corresponding the SRM Request element. If the SrmHandle defined in Table 8-82 is provided via MLME-SRM-INFORMATION.request primitive. If the SRM Information is being sent autonomously, then the SRM Token is set to 0.

The Measurement Information field shall be formatted as illustrated in Figure 7-136.

The Attribute Value field contains the PIB attribute value defined in Figure 8-106.

8. MAC services

8.2 MAC management services

8.2.1 Primitives supported by the MLME-SAP interface

Add the following items to the end of Table 8-1 (the entire table is not shown):

Table 8-1—Summary of the primitives accessed through the MLME-SAP

Name	Request	Indication	Response	Confirm
MLME-SRM	8.2.26.1*	8.2.26.2*●	8.2.26.3*●	8.2.26.4*
MLME-SRM-REPORT	8.2.27.1*	8.2.27.2*●		8.2.27.3*
MLME-SRM-INFORMATION	8.2.28.1*	8.2.28.2*●		8.2.28.3*

Insert the following new subclauses 8.2.26, 8.2.27, and 8.2.28 after 8.2.25:

8.2.26 Primitives for SRM

These primitives are used by a device when PIB attribute *macSRMcapable* set to TRUE.

8.2.26.1 MLME-SRM.request

The MLME-SRM.request primitive is used by a device to request that a device start collecting SRM information.

The semantics of this primitive are as follows:

```
MLME-SRM.request        (
                        SrmHandle
                        DeviceAddrMode,
                        DeviceAddress,
                        PayloadIeList,
                        SrmMetricId,
                        ScopeId,
                        StartTime,
                        Duration,
                        ChannelPage,
                        ChannelNumber,
                        LinkHandle,
                        SecurityLevel,
                        KeyIdMode,
                        KeySource,
                        KeyIndex
                        )
```

The primitive parameters are defined in Table 8-75.

Table 8-75—MLME-SRM.request parameters

Name	Type	Valid range	Description
SrmHandle	Integer	0x00–0xff	An identifier that can be used to refer to the particular primitive transaction; used to match a confirm primitive with the corresponding request.
DeviceAddrMode	Enumeration	SHORT, EXTENDED	The addressing mode of the device being instructed to execute SRM operation.
DeviceAddress	Short address or extended address	As specified by the DeviceAddrMode Parameter	The address of the device being instructed to execute SRM operation.
PayloadIeList	Set of payload IEs as described in 7.4.3	—	The SRM-related payload IEs, excluding Termination IEs, that were included in the frame. If empty, then no payload IEs were included.
SrmMetricId	Integer	0x00-0x3F	The SRM Metric ID as defined in 7.5.30.
ScopeId	Enumeration	LINK, PATH, NETWORK	The scope of the SRM operation as defined in 7.5.30.
StartTime	Unsigned Integer	0x00000000–0xffffffff	The time at which the requested measurement should be started.

Table 8-75—MLME-SRM.request parameters *(continued)*

Duration	Integer	0x0000–0xffff	The duration over that the requested measurement should be measured.
ChannelPage	Integer	Any valid channel page	The channel page on which the measurement to be executed.
ChannelNumber	Integer	Any valid Channel number	The channel number on which the measurement to be executed.
LinkHandle	Integer	0x0000–0xffff	The identifier of Link specified by *macLinkHandle* in Table 8-85. If Link is not used, it shall be set to 0xffff.
SecurityLevel	Integer	As defined in Table 8-77.	As defined in Table 8-77.
KeyIdMode	Integer	As defined in Table 8-77.	As defined in Table 8-77.
KeySource	Set of octets	As defined in Table 8-77.	As defined in Table 8-77.
KeyIndex	Integer	As defined in Table 8-77.	As defined in Table 8-77.

8.2.26.2 MLME-SRM.indication

This MLME-SRM.indication primitives is generate by the MLME and issued to the next higher layer on receipt of a SRM request command.

The semantics of this primitive are as follows:

```
MLME-SRM.indication (
                    SrmHandle
                    DeviceAddrMode,
                    DeviceAddress,
                    PayloadIeList,
                    StartTime,
                    Duration,
                    ChannelPage,
                    ChannelNumber,
                    LinkHandle,
                    SecurityLevel,
                    KeyIdMode,
                    KeySource,
                    KeyIndex
                    )
```

MLME-SRM.indication parameters are the same as MLME-SRM.request parameters.

The primitive parameters are defined in Table 8-76.

Table 8-76—MLME-SRM.indication parameters

Name	Type	Valid range	Description
SrmHandle	Integer	0x00–0xff	An identifier that can be used to refer to the particular primitive transaction; used to match an indication primitive with the corresponding response.
DeviceAddrMode	Enumeration	SHORT, EXTENDED	The addressing mode of the device requesting to execute SRM operation.
DeviceAddress	Short address or extended address	As specified by the DeviceAddrMode Parameter	The address of the device requesting to execute SRM operation.
PayloadIeList	Set of payload IEs as described in 7.4.3	—	The payloade IEs, excluding Termination IEs, that were included in the frame. If empty, then no payloadIEs were included.
StartTime	Unsigned Integer	0x00000000–0xffffffff	The time at which the requested measurement should be started.
Duration	Integer	0x0000–0xffff	The duration over which the requested measurement should be measured.
ChannelPage	Integer	Any valid channel page	The channel page on which the measurement to be executed.
ChannelNumber	Integer	Any valid Channel number	The channel number on which the measurement to be executed.
LinkHandle	Integer	0x0000–0xffff	The identifier of Link specified by *macLinkHandle* in Table 8-85. If Link is not used, it shall be set to 0xffff.
SecurityLevel	Integer	As defined in Table 8-77.	As defined in Table 8-77.
KeyIdMode	Integer	As defined in Table 8-77.	As defined in Table 8-77.
KeySource	Set of octets	As defined in Table 8-77.	As defined in Table 8-77.
KeyIndex	Integer	As defined in Table 8-77.	As defined in Table 8-77.

8.2.26.3 MLME-SRM.response

This MLME-SRM.response primitives is used to initiate a response to an MLME-SRM.indication primitive.

The semantics of this primitive are as follows:

```
MLME-SRM.response       (
                        SrmHandle
                        DeviceAddrMode,
                        DeviceAddress,
                        PayloadIeList,
                        MeasuredDeviceAddrMode,
                        MeasuredDeviceAddress,
                        Status,
                        SecurityLevel,
                        KeyIdMode,
                        KeySource,
                        KeyIndex
                        )
```

The primitive parameters are defined in Table 8-77.

Table 8-77—MLME-SRM.response parameters

Name	Type	Valid range	Description
SrmHandle	Integer	0x00–0xff	An identifier that can be used to refer to the particular primitive transaction; used to match an indication primitive with the corresponding response.
DeviceAddress	Short address or extended Address	As specified by the DeviceAddrMode Parameter	The address of the device requesting to execute SRM operation.
PayloadIeList	Set of payload IEs as described in 7.4.3	—	The SRM-related payload IEs, excluding Termination IEs, that were included in the frame. If empty, then no payload IEs were included.
MeasuredDevice AddrMode	Enumeration	SHORT, EXTENDED	The addressing mode of the device, for which the measurement was executed.
MeasuredDevice Address	Short address or extended address	As specified by the DeviceAddrMode Parameter	The address of the device, for which the measurement was executed.
Status	Enumeration	SUCCESS, NON_SUPPORTED, REJECTED	The status of the SRM attempt.
SecurityLevel	Integer	As defined in Table 8-77.	As defined in Table 8-77.
KeyIdMode	Integer	As defined in Table 8-77.	As defined in Table 8-77.
KeySource	Set of octets	As defined in Table 8-77.	As defined in Table 8-77.
KeyIndex	Integer	As defined in Table 8-77.	As defined in Table 8-77.

8.2.26.4 MLME-SRM.confirm

The MLME-SRM.confirm primitives reports the results of the MLME-SRM.request.

The semantics of this primitive are as follows:

```
MLME-SRM.confirm        (
                        SrmHandle,
                        DeviceAddrMode,
                        DeviceAddress,
                        MeasuredDeviceAddrMode,
                        MeasuredDeviceAddress,
                        Status
                        )
```

The primitive parameters are defined in Table 8-78.

Table 8-78—MLME-SRM.confirm parameters

Name	Type	Valid range	Description
SrmHandle	Integer	0x00–0xff	An identifier that can be used to refer to the particular primitive transaction; used to match a confirm primitive with the corresponding request.
DeviceAddrMode	Enumeration	SHORT, EXTENDED	The addressing mode of the device being instructed to execute SRM operation.
DeviceAddress	Short address or extended address	As specified by the DeviceAddrMode Parameter	The address of the device being instructed to execute SRM operation.
MeasuredDeviceAddrMode	Enumeration	SHORT, EXTENDED	The addressing mode of the device, for which the measurement was executed.
MeasuredDeviceAddress	Short address or extended address	As specified by the DeviceAddrMode Parameter	The address of the device, for which the measurement was executed.
Status	Enumeration	SUCCESS, NON_SUPPORTED, REJECTED	The status of the SRM attempt.

8.2.27 MLME-SRM-REPORT

8.2.27.1 MLME-SRM-REPORT.request

The semantics of this primitive are as follows:

```
MLME-SRM-REPORT.request     (
                            SrmHandle,
                            DeviceAddrMode,
                            DeviceAddress,
                            PayloadIeList,
                            SrmMetricId,
                            ScopeId,
                            StartTime,
                            Duration,
                            ChannelPage,
                            ChannelNumber,
                            SecurityLevel,
                            KeyIdMode,
                            KeySource,
                            KeyIndex
                            )
```

The primitive parameters are defined in Table 8-79.

Table 8-79—MLME-SRM-REPORT.request parameters

Name	Type	Valid range	Description
SrmHandle	Integer	0x00–0xff	An identifier that can be used to refer to the particular primitive transaction; used to match a confirm primitive with the corresponding request.
DeviceAddrMode	Enumeration	SHORT, EXTENDED	The addressing mode of the device, to which SRM report is transferred.
DeviceAddress	Short address or extended address	As specified by the DeviceAddrMode Parameter	The address of the device, to which SRM report is transferred.
PayloadIeList	Set of payload IEs as described in 7.4.3	—	The SRM-related payload IEs, excluding Termination IEs, that were included in the frame.
SrmMetricId	Integer	0x00–0x3F	The SrmMetricId as defined in 7.5.30. .
ScopeId	Enumeration	LINK, PATH, NETWORK	The scope of the SRM operation as defined in 7.5.30. .
StartTime	Unsigned Integer	0x00000000–0xffffffff	The time at which the requested measurement should be started.

Table 79—MLME-SRM-REPORT.request parameters *(continued)*

Duration	Integer	0x0000–0xffff	The duration over which the requested measurement should be measured.
ChannelPage	Integer	Any valid channel page	The channel page on which the measurement to be executed.
ChannelNumber	Integer	Any valid Channel number	The channel number on which the measurement to be executed.
SecurityLevel	Integer	As defined in Table 8-77.	As defined in Table 8-77.
KeyIdMode	Integer	As defined in Table 8-77.	As defined in Table 8-77.
KeySource	Set of octets	As defined Table 8-77.	As defined in Table 8-77.
KeyIndex	Integer	As defined in Table 8-77.	As defined in Table 8-77.

8.2.27.2 MLME-SRM-REPORT.indication

The MLME-SRM-REPORT.indication primitive is used to send IEs contained in a MAC Command frame,

Enh-ACK frame or Multipurpose frame.

The semantics of this primitive are as follows:

```
MLME-SRM-REPORT.indication      (
                                DeviceAddrMode,
                                DeviceAddress,
                                PayloadIeList,
                                SrmMetricId,
                                ScopeId,
                                StartTime,
                                Duration,
                                ChannelPage,
                                ChannelNumber,
                                SecurityLevel,
                                KeyIdMode,
                                KeySource,
                                KeyIndex
                                )
```

MLME-SRM-REPORT.indication parameters are the same as MLME-SRM-REPORT.request parameters except for RequreConfirm.

The primitive parameters are defined in Table 8-80.

Table 8-80—MLME-SRM-REPORT.indication parameters

Name	Type	Valid range	Description
DeviceAddrMode	Enumeration	SHORT, EXTENDED	The addressing mode of the device that sent the request and where the response is sent back.
DeviceAddress	Short address or extended address	As specified by the DeviceAddrMode Parameter	The address of the device that sent the request and where the response is sent back.
PayloadIeList	Set of payload IEs as described in 7.4.3	—	The SRM-related payload IEs, excluding Termination IEs, that were included in the frame.
SrmMetricId	Integer	0x00–0x3F	The SrmMetricId as defined in 7.5.30.
ScopeId	Enumeration	LINK, PATH, NETWORK	The scope of the SRM operation as defined in 7.5.30.
StartTime	Unsigned Integer	0x00000000–0xffffffff	The time at which the requested measurement should be started.
Duration	Integer	0x0000–0xffff	The duration over which the requested measurement should be measured.
ChannelPage	Integer	Any valid channel page	The channel page on which the measurement to be executed.
ChannelNumber	Integer	Any valid Channel number	The channel number on which the measurement to be executed.
SecurityLevel	Integer	As defined in Table 8-77.	As defined in Table 8-77.
KeyIdMode	Integer	As defined in Table 8-77.	As defined in Table 8-77.
KeySource	Set of octets	As defined in Table 8-77.	As defined in Table 8-77.
KeyIndex	Integer	As defined in Table 8-77.	As defined in Table 8-77.

8.2.27.3 MLME-SRM-REPORT.confirm

The semantics of this primitive are as follows:

```
MLME-SRM-REPORT.confirm     (
                            SrmHandle
                            Status
                            )
```

The primitive parameters are defined in Table 8-81.

Table 8-81—MLME-SRM-REPORT.confirm parameters

Name	Type	Valid range	Description
SrmHandle	Integer	0x00–0xff	An identifier that can be used to refer to the particular primitive transaction; used to match a confirm primitive with the corresponding request.
Status	Enumeration	SUCCESS, FAILURE	The result of the attempt to send MLME-SRM-REPORT.confirm.

8.2.28 MLME-SRM-INFORMATION

8.2.28.1 MLME-SRM-INFORMATION.request

The semantics of this primitive are as follows:

```
MLME-SRM-INFORMATION.request (
                                SrmHandle,
                                DeviceAddrMode,
                                DeviceAddress,
                                PayloadIeList,
                                SrmMetricId,
                                ScopeId,
                                StartTime,
                                Duration,
                                ChannelPage,
                                ChannelNumber,
                                SignalMethod,
                                AckedConfirm,
                                SecurityLevel,
                                KeyIdMode,
                                KeySource,
                                KeyIndex
                                )
```

The primitive parameters are defined in Table 8-82.

Table 8-82—MLME-SRM-INFORMATION.request parameters

Name	Type	Valid range	Description
SrmHandle	Integer	0x00–0xff	An identifier that can be used to refer to the particular primitive transaction; used to match a confirm primitive with the corresponding request.
DeviceAddrMode	Enumeration	SHORT, EXTENDED	The addressing mode of the device, to which SRM report is transferred.
DeviceAddress	Short address or extended address	As specified by the DeviceAddrMode Parameter	The address of the device, to which SRM report is transferred.
PayloadIeList	Set of payload IEs as described in 7.4.3	___	The SRM-related payload IEs, excluding Termination IEs, that were included in the frame.
SrmMetricId	Integer	0x00-0x3F	The SrmMetricId as defined in 7.5.30.
ScopeId	Enumeration	LINK, PATH, NETWORK	The scope of the SRM operation as defined in 7.5.30.
StartTime	Unsigned Integer	0x00000000-0xffffffff	The time at which the requested measurement should be started.
Duration	Integer	0x0000-0xffff	The duration over which the requested measurement should be measured.
ChannelPage	Integer	Any valid channel page	The channel page on which the measurement to be executed.
ChannelNumber	Integer	Any valid Channel number	The channel number on which the measurement to be executed.
SignalMethod	Enumeration	USE_BEACON, USE_CMD, USE_MP	The method to be used to signal intended primitive among the Enhanced Beacon, MAC command or multipurpose frame.
AckedConfirm	Boolean	TRUE, FALSE	Set to TRUE if Acknowledgment is required for MLME-SRM-INFORMATION.confirm.
SecurityLevel	Integer	As defined in Table 8-77.	As defined in Table 8-77.
KeyIdMode	Integer	As defined in Table 8-77.	As defined in Table 8-77.
KeySource	Set of octets	As defined in Table 8-77.	As defined in Table 8-77.
KeyIndex	Integer	As defined in Table 8-77.	As defined in Table 8-77.

8.2.28.2 MLME-SRM-INFORMATION.indication

The semantics of this primitive are as follows:

```
MLME-SRM- INFORMATION.indication(
                                    DeviceAddrMode,
                                    DeviceAddress,
                                    PayloadIeList,
                                    SecurityLevel,
                                    KeyIdMode,
                                    KeySource,
                                    KeyIndex
                                    )
```

The primitive parameters are defined in Table 8-83.

Table 8-83—MLME-SRM-INFORMATION.indication parameters

Name	Type	Valid range	Description
DeviceAddrMode	Enumeration	SHORT, EXTENDED	The addressing mode of the device, to which SRM report is transferred.
DeviceAddress	Short address or extended address	As specified by the DeviceAddrMode Parameter.	The address of the device, to which SRM report is transferred.
PayloadIeList	Set of payload IEs as described in 7.4.3	—	The SRM-related payload IEs, excluding Termination IEs, that were included in the frame.
SecurityLevel	Integer	As defined in Table 8-77.	As defined in Table 8-77.
KeyIdMode	Integer	As defined in Table 8-77.	As defined in Table 8-77.
KeySource	Set of octets	As defined in Table 8-77.	As defined in Table 8-77.
KeyIndex	Integer	As defined in Table 8-77.	As defined in Table 8-77.

8.2.28.3 MLME-SRM-INFORMATION.confirm

The semantics of this primitive are as follows:

```
MLME-SRM-INFORMATION.confirm    (
                                SrmHandle
                                Status
                                )
```

The primitive parameters are defined in Table 8-84.

If the SignalMethod parameter in the request primitive is USE_BEACON and the device is a PAN coordinator in a beacon-enabled PAN that is not using enhanced beacon frames, the MLME-SRM-INFORMATION.confirm primitive shall return a Status of UNSUPPORTED_FEATURE.

Table 8-84—MLME-SRM-INFORMATION.confirm parameter

Name	Type	Valid range	Description
SrmHandle	Integer	0x00–0xff	An identifier that can be used to refer to the particular primitive transaction; used to match a confirm primitive with the corresponding request.
Status	Enumeration	SUCCESS, FAILURE, UNSUPPORTED_FEATURE	The result of the attempt to send MLME-SRM-INFORMATION.confirm.

8.4 MAC constants and PIB attributes

8.4.2 MAC PIB attributes

8.4.2.1 General MAC PIB attributes for functional organization

Add the following rows to the Table 8-93 (the entire table is not shown) as follows:

Table 8-93—General MAC PIB attributes for functional organization

Attribute	Type	Range	Description	Default
macSrmCapable	Boolean	TRUE FALSE	If TRUE, the device is capable of functionality specific to SRM	—
macSrmEnabled	Boolean	TRUE FALSE	If TRUE, the device is using functionality specific to SRM	—

Add the following new subclauses 8.4.2.9 after 8.4.2.8 as follows:

8.4.2.9 SRM specific MAC PIB attributes

Table 8-106 contains the PIB values for SRM.

Table 8-106—SRM specific MAC PIB attribute

Attribute	Type	Range	Description	Default
macEd	Integer	0x00–0xff	The received signal power within the bandwidth of the channel as defined 10.2.5. Refer to 6.17.1.1.	—
macTxFailTime	Integer	0x00–0xff	Percentage of the total transmission attempt time of failed transmissions after all retries with no ACK over the measurement time, linearly scaled with 0xff representing 100 %. Refer to 6.17.1.2.	—

Table 106—SRM specific MAC PIB attribute *(continued)*

macTxDeferredTime	Integer	0x00–0xff	Percentage of the total back-off period after first CCA over the measurement time, linearly scaled with 0xff representing 100 %. Refer to 6.17.1.3.	—
macRetryHistogram	Integer	0–100	Histogram of the number of retries for one transmission during the measurement time. Refer to 6.17.1.4.	—
macChannelUtilization	Integer	—	Total channel used time for Tx and Rx and the occupied time for the other devices. Refer to 6.17.1.5.	—
macRcpi	Integer	0x00–0xff	The total channel power (signal, noise, and interference) of a received frame measured on the channel and at the antenna connector used to receive the frame. Refer to 6.17.1.6.	—
macRsni	Integer	0x00–0xff	The signal to noise plus interference ratio of a received frame, which is defined by the ratio of the received signal power to the noise plus interference power as measured on the channel and at the antenna connector used to receive the frame. Refer to 6.17.1.7.	—
macRssi	Integer	0x00–0xff	The RF power level at the input of the transceiver. Refer to 6.17.1.8.	—
macNoiseHistogram	Integer	—	Power histogram measurement of non-IEEE 802.15 noise power. Refer to 6.17.1.9.	—
macFrameErrorCount	Integer	$0–2^{8\times macCounterOctets}–1$	The number of received frames that were discarded due to any error except for FCS error (complementary to *macFcsErrorCount* in 8.4.2.6).	—
macCounterOctets	Integer	As defined in 8.4.2.6	See 8.4.2.6 (existing metric).	—
macRetryCount	Integer	As defined in 8.4.2.6	See 8.4.2.6 (existing metric).	—
macMultipleRetryCount	Integer	As defined in 8.4.2.6	See 8.4.2.6 (existing metric).	—
macTxFailCount	Integer	As defined in 8.4.2.6	See 8.4.2.6 (existing metric).	—
macTxSuccessCount	Integer	As defined in 8.4.2.6	See 8.4.2.6 (existing metric).	—
macFcsErrorCount	Integer	As defined in 8.4.2.6	See 8.4.2.6 (existing metric).	—
macSecurityFailure	Integer	As defined in 8.4.2.6	See 8.4.2.6 (existing metric).	—
macDuplicateFrameCount	Integer	As defined in 8.4.2.6	See 8.4.2.6 (existing metric).	—
macRxSuccessCount	Integer	As defined in 8.4.2.6	See 8.4.2.6 (existing metric).	—
macNackCount	Integer	As defined in 8.4.2.6	See 8.4.2.6 (existing metric).	—
macDeferredTxCount	Integer	$0–2^{8\times macCounterOctets}–1$	The number of times the CSMA-CA algorithm was required to backoff as described in 6.2.3.	—
macAverageBufferUtilization	Integer	0–100	The average percentage of the used buffer space in Tx queue.	—
macMaximumBufferUtilization	Integer	0–100	The maximum percentage of the used buffer space in Tx queue.	—
macAverageAccessDelay	Integer	$0–2^{8\times macCounterOctets}–1$	The average medium access delay for transmitted frames measured from the time the MPDU is ready for transmission until the actual frame transmission start time. Refer to 6.17.1.10.	—
macChannelPage	Integer	Any valid channel page	Channel page for measurement.	—

Table 106—SRM specific MAC PIB attribute *(continued)*

macChannelNumber	Integer	Any valid channel number	Channel number for measurement.	—
macRxAddrMode	Enumeration	SHORT, EXTENDED	Address mode of the received frame that is used for measurement.	
macRxDeviceAddress	As specified by the macRxAddrMode Parameter		Source address of the received frame that is used for measurement.	
macSRMmeasurementMode	Integer	0x00-0x02	In the case of TSCH, the following modes can be applied; otherwise the full measurement (0x00) is applied. Full measurement (0x00) : the measurement is conducted wherever the channel is hopped. Channel-specific measurement (0x01) : the measurement is conducted only on the specified channel. Link-specific measurement (0x02) : the measurement is conducted only on the specified Link.	

10. General PHY requirements

10.1 General requirements and definitions

10.1.5 Transmit power

Change the first paragraph in 10.1.5 as follows:

A compliant device shall have its nominal transmit power level ~~indicated by its~~ that is allowed in the network and the currently configured upper bound based on that level indicated by the PHY parameters, *phyMaxTxPower and phyTxPower*, respectively as defined in 11.3.

11. PHY services

11.3 PHY PIB attributes

Change and insert new rows into Table 11-2 (the entire is not shown) as shown:

Table 11-2—PHY PIB attributes

Attribute	Type	Range	Description
phyTxPower	Signed integer	—	Currently configured upper-bound level of the ~~The~~ transmit power of the device that shall be equal or less than *phyMaxTxPower* in dBm.
phyNomTxPower	Signed integer	—	Nominal transmit power level allowed on a network

Table 11-2—PHY PIB attributes *(continued)*

Attribute	Type	Range	Description
phyCapableTxPower	Signed integer	—	Device capable maximum transmission power.
phyBroadcastTxPower	Signed integer	—	Transmit power in dBm while broadcasting. This value is managed by an upper layer but shall be lower or equal to *phyTxPower*.
phyUnicastTxPower	Signed integer	—	Transmit power in dBm while sending a unicast. This value is managed by an upper later but shall be lower or equal to *phyTxPower*.
phyPeersTxPower	List of parameters as defined in Table 11-4	—	List of exceptions to the *phyUnicastTxPower* while transmitting to specific peer devices.
phyMinSnr	Signed integer	—	Minimum SNR in dB.
phyMinLinkMargin	Signed integer	—	Minimum Link Margin in dB.

Insert new Table 11-4 after Table 11-3 as follows:

Table 11-4—Parameter of phyPeersTxPower

Attribute	Type	Range	Description
deviceAddrMode	Enumeration	SHORT_ADDRESS, EXTENDED_ADDRESS	—
deviceAddress	As specified by the deviceAddrMode Parameter	—	Address of the peer device.
TxPower	Signed integer	—	The value to be placed in the *phyTxPower* PIB Attribute when the device is transmitting to the device with the address deviceAddress.

22. Sun O-QPSK

22.3 Modulation and coding for SUN O-QPSK

22.3.10 MDSSS bit-to-chip mapping

Change the acronym TPC to TBPC in eight places in this subclause, including one place in Figure 22-13 as follows:

First paragraph:

The functional block diagram in Figure 22-13 is provided as a reference for specifying the MDSSS. Each bit in the PSDU shall be processed through the turbo product code (~~TPC~~ TBPC) encoding and multiplexing module. For the horizontal code of the ~~TPC~~ TBPC, 3 bits are encoded into n bits with the [n, 3] Hadamard code for n = 4, 8, 16, and 32. The [4, 3] single parity check encoder is employed as the vertical code of the ~~TPC~~ TBPC.

In Figure 22-13 as follows:

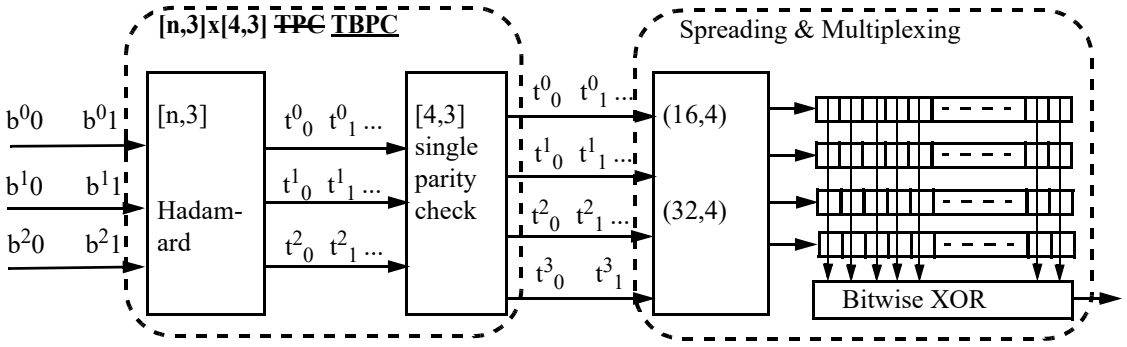


Figure 22-13—MDSSS signal flow

First paragraph immediately after Table 22-17 as follows:

For the horizontal coding of the ~~TPC~~ TBPC, the three parallel bit streams (b^x0, b^x1, b^x2: x = 0, 1, 2) are converted to the three parallel n-bit streams (t^x_0, t^x_1, t^x_2,..., t^x_{n-1}) through the [n, 3] Hadamard encoder. An [n, 3] Hadamard codeword set is given by $[h_0;h_1;h_2;h_3;\overline{h}_3;\overline{h}_2;\overline{h}_1;\overline{h}_0]$, where h_i is the ith row of the $n \times n$ Hadamard matrix and $\overline{h}_i$ is the bitwise inversion of h_i.

First paragraph immediately after Table 22-18 as follows:

For the vertical coding of the ~~TPC~~ TBPC, the single parity check encoder adds one n-bit parity stream (t^3_x, x = 0,1,...,n – 1) to the original three parallel n-bit streams (t^0_x, t^1_x, t^2_x). For instance, if n equals four, the single parity check encoder converts the three parallel 4-bit streams to four parallel 4-bit streams as shown:

Third paragraph after Table 22-18 as follows:

As a result of [4,3] horizontal and [4,3] vertical coding with a parity bit per octet, the PSDU bit stream is transformed into a $[4, 3] \times [4, 3]$ ~~TPC~~ TBPC codeword matrix, forming (4×4) 2-dimensional data, as shown in Figure 22-14.

Sentence immediately after 22-14 as follows:

For n = 8, 16, and 32, the ~~TPC~~ TBPC can be generated by the serial concatenations of T_{unit}.

Annex D

(informative)

Protocol implementation conformance statement (PICS) proforma

D.7 PICS proforma tables

D.7.3 Major capabilities for the MAC sublayer

Add the following rows to Table D.6, Table D.7, and Table D.8 (the entire tables are not shown):

D.7.3.1 MAC sublayer functions

Table D.6—MAC sublayer functions

Item number	Item description	Reference	Status	Support		
				N/A	Yes	No
MLF26a	Spectrum Resource Measurement (SRM)	6.17	O			

D.7.3.2 MAC frames

Table D.7—MAC frames

Item number	Item description	Reference	Transmitter		Receiver	
			Status	Support N/A Yes No	Status	Support N/A Yes No
MF4.26a	SRM Request	7.5.27	MLF26A:M		MLF26A:M	
MF4.26b	SRM Response	7.5.28	MLF26a:M		MLF26a:M	
MF4.26c	SRM Report	7.5.29	MLF26a:M		MLF26a:M	
MF4.26d	SRM Information	7.5.30	MLF26a:M		MLF26a:M	

D.7.3.3 MAC IEs

Table D.8—MAC IEs

Item number	Item description	Reference	Transmitter		Receiver	
			Status	Support N/A Yes No	Status	Support N/A Yes No
MIE2.16a	SRM Metric IE	7.4.4.32	MLF26a:M		MLF26a:M	

Consensus

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