

IEEE Standard for
Local and metropolitan area networks—

Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)

Amendment 6: TV White Space Between 54 MHz and 862 MHz Physical Layer

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

IEEE
3 Park Avenue
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USA

IEEE Std 802.15.4m™-2014
(Amendment to
IEEE Std 802.15.4™-2011
as amended by IEEE Std 802.15.4e™-2012,
IEEE Std 802.15.4f™-2012,
IEEE Std 802.15.4g™-2012,
IEEE Std 802.15.4j™-2013,
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Approved 27 March 2014

IEEE-SA Standards Board

Abstract: In this amendment to IEEE Std 802.15.4™-2011, outdoor low-data-rate, wireless, television white space (TVWS) network requirements are addressed. Alternate physical layers (PHYs) are defined as well as only the medium access control (MAC) modifications needed to support their implementation.

Keywords: ad hoc network, IEEE 802.15.4™, IEEE 802.15.4m™, low data rate, low power, LR-WPAN, mobility, PAN, personal area network, radio frequency, RF, short range, TV white space, wireless, wireless personal area network, WPAN

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Clinton C. Powell, *Task Group 4m Co-editor*
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Alina Liru Lu, *Task Group 4m Co-Secretary*
Kunal Shah, *Task Group 4m Co-Secretary*

Soo-Young Chang, Benjamin A. Rolfe, Cristina Seibert, *Coexistence Assurance Contributing Editors*

Jon Adams
Moshaddique Ameen
Arthur Astrin
Tuncer Baykas
Monique Brown
Kiran Bynam
Edgar Callaway
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Radhakrishna Canchi
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David Evans
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Ryuhei Funada
Matthew Gillmore
Elad Gottlib
Jussi Haapola
Shinsuke Hara
Marco Hernandez
Jin-Meng Ho
Iwao Hosako
David Howard
Jung-Hwan Hwang
Tetsushi Ikegami
Takuya Inoko
Young-Ae Jeon
Wuncheol Jeong

Steven Jillings
Sunggeun Jin
Matthew Johnson
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Akifumi Kasamatsu
Shuzo Kato
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Tao Xing
Ping Ping Xu
Yang Yang
Kaoru Yokoo
Chanho Yoon
Eldad Zeira
Mu Zhao
Ming-Tuo Zhou
Chunhui Zhu

Major contributions were received from the following individuals:

Soo-Young Chang	Byounghak Kim	Shigenobu Sasaki
Sangsung Choi	Jaehwan Kim	Cristina Seibert
Yutaro Fukaishi	Fumihide Kojima	Kunal Shah
Ryuhei Funada	Sangjae Lee	Chang Sub Shin
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Introduction

This introduction is not part of IEEE Std 802.15.4m-2014, IEEE Standard for Local and metropolitan area networks—Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)—Amendment 6: TV White Space Between 54 MHz and 862 MHz Physical Layer.

This amendment specifies alternate physical layers (PHYs) in addition to those of IEEE Std 802.15.4-2011. In addition to the new PHYs, the amendment also defines the medium access control (MAC) modifications needed to support their implementation.

The alternate PHYs support principally outdoor, low-data-rate, wireless, TV white space (TVWS) network applications under multiple regulatory domains. The TVWS PHYs are as follows:

- Frequency Shift Keying (TVWS-FSK) PHY
- Orthogonal Frequency Division Multiplexing (TVWS-OFDM) PHY
- Narrow Band Orthogonal Frequency Division Multiplexing (TVWS-NB-OFDM) PHY

The TVWS PHYs support multiple data rates in bands ranging from 54 MHz to 862 MHz.

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2. Normative references

Insert the following new references alphabetically into Clause 2:

IEEE Std 802[®], IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture.^{2,3}

IETF RFC 6225, Dynamic Host Configuration Protocol Options for Coordinate-Based Location Configuration Information, Internet Engineering Task Force.⁴

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3. Definitions, acronyms, and abbreviations

3.1 Definitions

Insert the following new definitions alphabetically into 3.1:

dependent device: A device that operates without direct Internet access to a database and depends on another device for channel availability information.

independent device: A device that has direct access to the television white space (TVWS) database via the Internet.

super personal area network (PAN) coordinator: The PAN coordinator of a television white space (TVWS) multichannel cluster tree PAN (TMCTP), which has access to the TVWS geolocation database and provides synchronization services for the TMCTP.

television white space (TVWS) channel: Spectrum unit allocation as defined by the television bands channel availability database.

television white space (TVWS) multichannel cluster tree personal area network (PAN) (TMCTP): A PAN operating in a TVWS band employing a super PAN coordinator to form a multichannel cluster tree topology.

television white space (TVWS) multichannel cluster tree personal area network (PAN) (TMCTP) child (TMCTP-child) PAN coordinator: A logical child device that is responsible for maintaining synchronization with its TMCTP-parent device in the TMCTP while it operates as the coordinator of a PAN.

television white space (TVWS) multichannel cluster tree personal area network (PAN) (TMCTP) parent (TMCTP-parent) PAN coordinator: A logical parent device that is responsible for providing synchronization services to its TMCTP-child devices in the TMCTP while it operates as the coordinator of a PAN.

3.2 Acronyms and abbreviations

Insert the following new abbreviations alphabetically into 3.2:

BOP	beacon only period
DA	device announcement
DBS	dedicated beacon slot
GDB	geolocation database
SPC	super PAN coordinator
TMCTP	TVWS multichannel cluster tree PAN
TVWS	television white space
TVWSPS	television white space power saving

4. General description

4.2 Components of the IEEE 802.15.4 WPAN

Insert the following new paragraph at the end of 4.2:

A TVWS multichannel cluster tree PAN (TMCTP) includes at least one FFD, which operates as both the PAN coordinator and the super PAN coordinator (SPC). The SPC communicates with other PAN coordinators on their dedicated channels during the beacon only period (BOP), as described in 5.1.1.1.3.

4.3 Network topologies

4.3.2 Peer-to-peer network formation

Insert the following new paragraph (including Figure 2a) at the end of 4.3.2:

A TMCTP is a form of cluster tree network where the SPC is the overall PAN coordinator providing synchronization services to other PAN coordinators in the cluster. The SPC also has access to the geolocation database (GDB) server to provide TVWS channel availability information to other PAN coordinators. Each PAN coordinator may use a different channel allocated by the SPC. An example is shown in Figure 2a. In the TMCTP, collisions between clusters can be reduced because each cluster uses its own channel; in addition, the coverage area is increased through the TMCTP parent-child structure. Each TMCTP-parent PAN coordinator, including the SPC, communicates with its TMCTP-child PAN coordinators during the CAP or CFP of the TMCTP-parent PAN coordinator superframe and receives beacon frames of its TMCTP-child PAN coordinators on a dedicated channel during the dedicated beacon slots (DBS) assigned to them in the BOP, as shown with an asterisk (*) in Figure 2a.

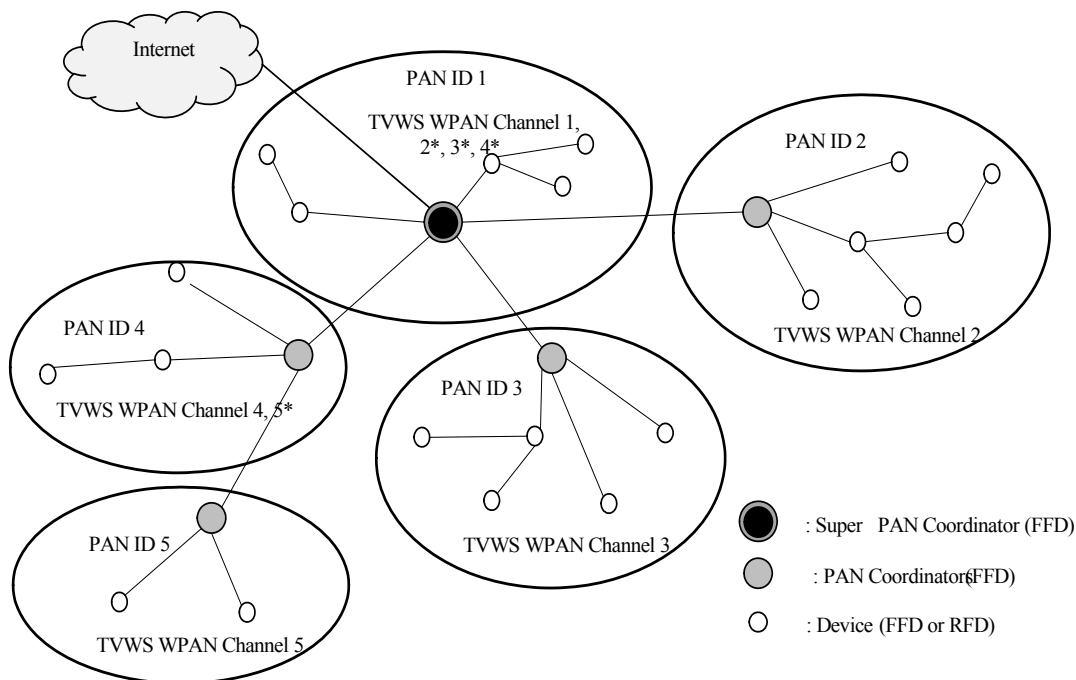


Figure 2a—Example of TVWS multichannel cluster tree PAN

4.5 Functional overview

4.5.1 Superframe structure

Insert the following new subclause (4.5.1.5, including Figure 5ba) after 4.5.1.4:

4.5.1.5 Superframe extension for TVWS multichannel cluster tree PAN (TMCTP)

TVWS allows the optional use of a superframe structure in a TMCTP that is extended by the addition of a BOP to the active portion of the superframe. The format of the TMCTP superframe is defined by the SPC which sends an enhanced beacon containing a TMCTP Specification IE, as in 5.2.4.35. The TMCTP superframe is bounded by network beacons sent by the SPC. The active portion of the TMCTP superframe is composed of a beacon, a CAP, a CFP, and a BOP. An example of a TMCTP superframe including a BOP is illustrated in Figure 5ba. The BOP is composed of one or more DBSs. A DBS is used to communicate beacons between a TMCTP-parent PAN coordinator and one of its TMCTP-child PAN coordinator(s). More information on the TMCTP superframe structure can be found in 5.1.1.8.

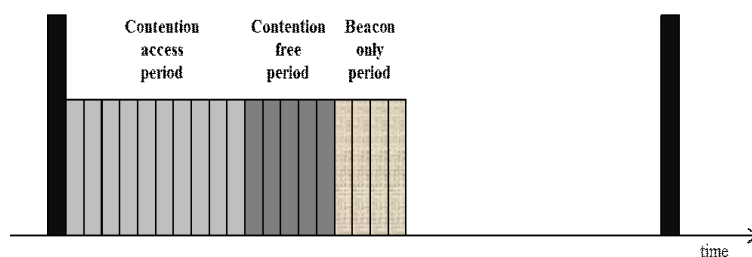


Figure 5ba—TMCTP superframe extension

4.5.2 Data transfer model

4.5.2.3 Peer-to-peer data transfers

Insert the following text as the second paragraph of 4.5.2.3:

For effective peer-to-peer data transfer (unicast), a MAC-layer destination address is needed at a source device. A device announcement (DA) as described in 5.1.6.7 can be used for exchanging 16-bit short or 64-bit extended addresses among devices within radio communication range.

4.5.5 Power consumption considerations

Insert the following new subclause (4.5.5.3) after 4.5.5.2:

4.5.5.3 TVWS low-energy mechanisms

Energy efficiency is an important feature in most of the applications in IEEE 802.15.4 systems. In the TVWS band, besides meeting the application demands on low energy consumption, devices are also required to be able to meet TVWS regulatory requirements.

For TVWS, a low energy mechanism that is capable of reducing energy consumption and at the same time holds the characteristics to be compliant to regulatory requirements is specified.

Insert the following new subclause (4.5.7) after 4.5.6:

4.5.7 Overview of TVWS operation

This clause provides an overview of operation of IEEE 802.15.4 devices in TVWS bands.

TVWS operation defined in this standard differs from that with the use of other license exempt and licensed band, in that there is an additional requirement to determine which TVWS frequency allocations are available for use at a given time and geographic location. Devices have access to TVWS channel availability information, such as via the Internet to a database, for determination of available TVWS spectrum. Access of a TVWS channel based on sensing alone is not assumed for TVWS, but is not excluded either.

An independent device is a device that has access to the TVWS database via the Internet. A dependent device is one that has no connection to the database and so must depend upon another device to acquire channel availability information.

Because relevant regulations may vary from region to region, this standard provides methods that may be used to meet the requirements of regional regulations without any specific direction on how those requirements may be met.

5. MAC protocol

5.1 MAC functional description

5.1.1 Channel access

5.1.1.1 Superframe structure

Insert the following new paragraph after the first paragraph of 5.1.1.1:

When operating as a TMCTP, the superframe includes the beacon only period as described in 5.1.1.1.3, and the structure of the superframe is described in 5.1.1.8.

Insert the following new subclause (5.1.1.1.3) after 5.1.1.1.2:

5.1.1.1.3 Beacon only period (BOP)

When present, the BOP shall follow the CAP and CFP, if the CFP is present. When there is no CFP, the BOP shall follow the CAP. The CAP and CFP comprise the first 16 slots of the superframe as described in 5.1.1.8, and the BOP shall commence on the slot boundary immediately following. The BOP shall complete before the end of the active portion of the superframe. The BOP duration depends on the number of DBSs one of which is allocated to each TMCTP-child PAN coordinator. All DBSs shall be located within the BOP and occupy contiguous slots. The BOP, therefore, grows or shrinks depending on the total length of all of the combined DBSs. Multiple base slots in the BOP can be allocated to a DBS according to the length of the beacon to be sent by the TMCTP-child coordinator which will occupy the DBS.

CSMA is not used for beacon transmissions in the BOP. A TMCTP-child PAN coordinator transmitting in the BOP shall ensure that its beacon transmission is complete within one IFS period before the end of its DBS. The IFS period is described in 5.1.1.3.

Change the first paragraph of 5.1.1.3 as indicated:

5.1.1.3 Interframe spacing (IFS)

The MAC sublayer needs a finite amount of time to process data received by the PHY. To allow for this, two successive frames transmitted from a device shall be separated by at least an IFS period; if the first transmission requires an acknowledgment, the separation between the acknowledgment frame and the second transmission shall be at least ~~an~~ the IFS period or aTurnaroundTime, whichever is greater. The length of the IFS period is dependent on the size of the frame that has just been transmitted. Frames (i.e., MPDUs) of up to *aMaxSIFSFrameSize* shall be followed by a short interframe space (SIFS) period of a duration of at least *macSIFSPeriod*. Frames (i.e., MPDUs) with lengths greater than *aMaxSIFSFrameSize* shall be followed by a long interframe spacing (LIFS) period of a duration of at least *macLIFSPeriod*. These concepts are illustrated in Figure 10.

Replace Figure 10 with the following figure:

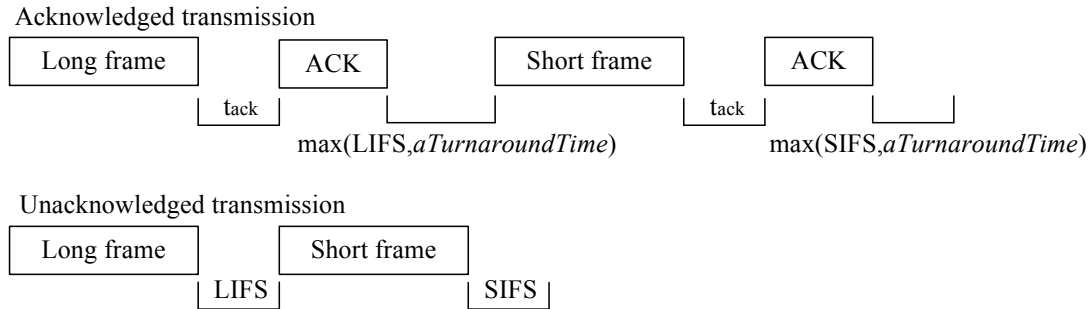


Figure 10—IFS

5.1.1.7 LE functional description

Insert the following list item at the end of the dashed list in 5.1.1.7:

- *macTvwPsEnabled*

Insert the following new subclause (5.1.1.8, including Figure 11i) after 5.1.1.7.4:

5.1.1.8 Superframe use for TMCTP operation

The TMCTP superframe is an extension of the basic superframe defined in 5.1.1.1. The active portion of the TMCTP superframe is composed of four parts, which is illustrated in Figure 5ba.

- The beacon, as described in 5.2.2.1, which is used to set the timing allocations and to communicate management information for the PAN.
- The CAP, as described in 5.1.1.1.1, which is used to communicate command frames and/or data.
- The CFP, as described in 5.1.1.1.2, which is composed of GTSS. No transmissions within the CFP shall use a CSMA-CA mechanism to access the channel.
- The BOP, as described in 5.1.1.1.3, which is composed of one or more DBSs. A DBS is used to communicate beacons between a TMCTP-parent PAN coordinator (including the SPC) and one of its TMCTP-child PAN coordinator(s) in a TMCTP.

The SD and BI of the TMCTP superframe are the same as described in 5.1.1.1. The MAC PIB attribute *macTmctpExtendedOrder* describes the extended length of the active portion of the superframe. The value of *macTmctpExtendedOrder* and the extended duration, ED, are related as follows:

$$\begin{aligned} \text{ED} &= a\text{BaseSuperframeDuration} \times 2^{\text{macTmctpExtendedOrder}} \\ &= a\text{BaseSlotDuration} \times a\text{NumSuperframeSlots} \times 2^{\text{macTmctpExtendedOrder}} \end{aligned}$$

for

$$0 \leq \text{macTmctpExtendedOrder} \leq (\text{macBeaconOrder} - \text{macSuperframeOrder}) \leq \text{macBeaconOrder} \leq 14$$

The ED of each TMCTP superframe shall be divided into $aNumSuperframeSlots \times 2^{macTmctpExtendedOrder}$ equally spaced slots of duration $aBaseSlotDuration$ in a BOP. The BOP consists of multiple DBSs. Each DBS is composed of one or more base slots, which are $aBaseSlotDuration$ in length. The total duration of the active portion of each TMCTP superframe consists of the base superframe duration, SD, and the extended duration for the BOP, ED:

$ESD = SD + ED$

An example of a TMCTP superframe structure is shown in Figure 11i, according to various values of the *macBeaconOrder* (BO), the *macSuperframeOrder* (SO), and the *macTmctpExtendedOrder* (EO).

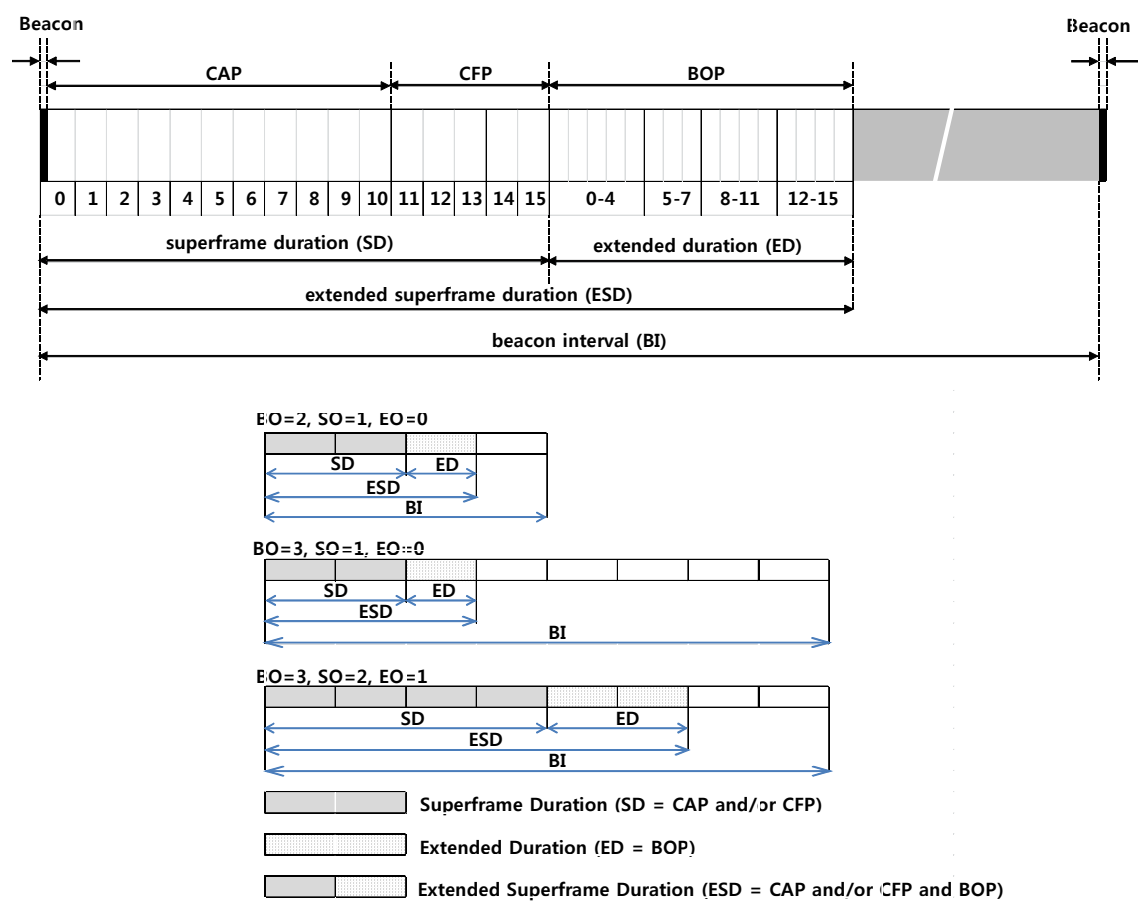


Figure 11i—An example of the TMCTP superframe structure

5.1.6 Transmission, reception, and acknowledgment

5.1.6.2 Reception and rejection

Change the fourth list item after the sixth paragraph of 5.1.6.2 as indicated:

- If a short destination address is included in the frame, it shall match either *macShortAddress* or the broadcast address. Otherwise, if an extended destination address is included in the frame, it shall match either *macExtendedAddress* or, if *macGroupRxMode* is set to TRUE, an EUI-64 group address, as defined in IEEE Std 802.

5.1.6.4 Use of acknowledgments and retransmissions

Change 5.1.6.4 as indicated:

A data or MAC command frame shall be sent with the AR field set appropriately for the frame. A beacon or acknowledgment frame shall always be sent with the AR field set to indicate no acknowledgment requested. Similarly, any frame that is broadcast or has a group address as the extended destination address, as defined in IEEE Std 802. shall be sent with its AR field set to indicate no acknowledgment requested.

5.1.6.4.2 Acknowledgment

Change the third paragraph of 5.1.6.4.2 as indicated:

The transmission of an acknowledgment frame in a nonbeacon-enabled PAN or in the CFP shall commence t_{ack} after the reception of the last symbol of the data or MAC command frame. The transmission of an acknowledgment frame in the CAP shall commence either t_{ack} after the reception of the last symbol of the data or MAC command frame or at a backoff period boundary. In the latter case, the transmission of an acknowledgment frame shall commence between t_{ack} and $(t_{ack} + aUnitBackoffPeriod)$ after the reception of the last symbol of the data or MAC command frame. The value of t_{ack} is 1 ms for the SUN PHYs, and LECIM PHYs, and TVWS PHYs. The value of t_{ack} is equal to $macSIFSPeriod$ for all other PHYs.

Insert the following sentence at the end of the last paragraph (“When in TSCH mode, ... to macTsAckWait.”) of 5.1.6.4.2:

For TVWS RDEVs, the enhanced acknowledgment frame shall include the Timestamp Difference IE as defined in 5.2.4.34.2 if the RNG field of the PHR is set to 1 in the frame being acknowledged.

Insert the following new subclause (5.1.6.7, including Figure 29a) after 5.1.6.6:

5.1.6.7 Device announcement

To facilitate data transfer effectively between two or more peer devices, a device announces its address and its neighbors' addresses to its neighbor devices by broadcasting beacons with a Device Announcement IE (DA IE) (5.2.4.36).

A device shall broadcast a beacon frame with a DA IE upon receiving a MLME-DA.request primitive (6.2.24.1) from the next higher layer. It may also broadcast beacons with a DA IE at other times. After transmitting a beacon with the DA IE requested by an MLME-DA.request, the device shall send an MLME-DA.confirm, as described in 6.2.24.2, to the next higher layer.

Upon receiving a beacon frame with a DA IE, a device shall indicate the address of the transmitting device and the addresses list in the DA IE to its next higher layer using the MLME-DA.indication primitive (6.2.24.3). A device may check whether or not its address is known at the transmitting device by tracking the received beacon frames with a DA IE. If not, the device may broadcast a beacon with a DA IE to announce its address at the appropriate time.

The message sequence chart for a broadcast beacon with a DA IE to announce the address of a device and its neighbors' addresses is illustrated in Figure 29a.

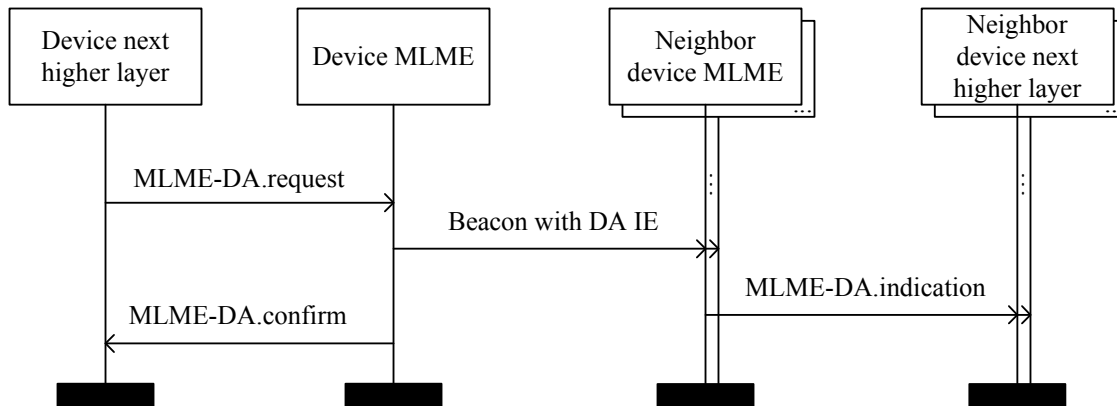


Figure 29a—Message sequence chart for broadcast beacon with DA IE upon receiving MLME-DA.request primitive

5.1.8 Ranging

5.1.8.4 The ranging exchange

Change the fourth paragraph of 5.1.8.4 as indicated:

For the UWB PHY, in all of these timestamp reports, the timestamp itself shall consist of the 12 octets defined for the timestamp report in 14.7.1, 14.7.2, and 14.7.3. Use of nonzero timestamp reports is limited to RDEVs. Only devices that have *phyRanging* set to TRUE shall return a nonzero timestamp report to a next higher layer.

Insert the following new paragraph at the end of 5.1.8.4:

For TVWS RDEVs, the Timestamp IE and the Timestamp Difference IE are provided for exchanging timing information between TVWS RDEVs to support the ranging feature.

Insert the following new subclauses (5.1.14 and 5.1.15, including Figure 34x to Figure 34aa) after 5.1.13:

5.1.14 Starting and maintaining TVWS multichannel cluster tree PANs (TMCTP)

This subclause specifies the procedures for TMCTP formation.

Figure 34x shows an example with a suggested message sequence for TMCTP formation between the SPC, which is the TMCTP-parent PAN coordinator, and a TMCTP-child PAN Coordinator. The example is explained as follows:

In step A, the SPC obtains the list of available TVWS channels from the GDB through the Internet. The protocol used to access the GDB over the Internet is outside the scope of this standard. Alternatively, the SPC may obtain the list of available TVWS channels from another device. The SPC maps the TVWS channels to corresponding PHY channels, selects one of the available PHY channels, and transmits its beacon through that channel. The TMCTP-child PAN coordinator completes the scan procedure over all PHY channels.

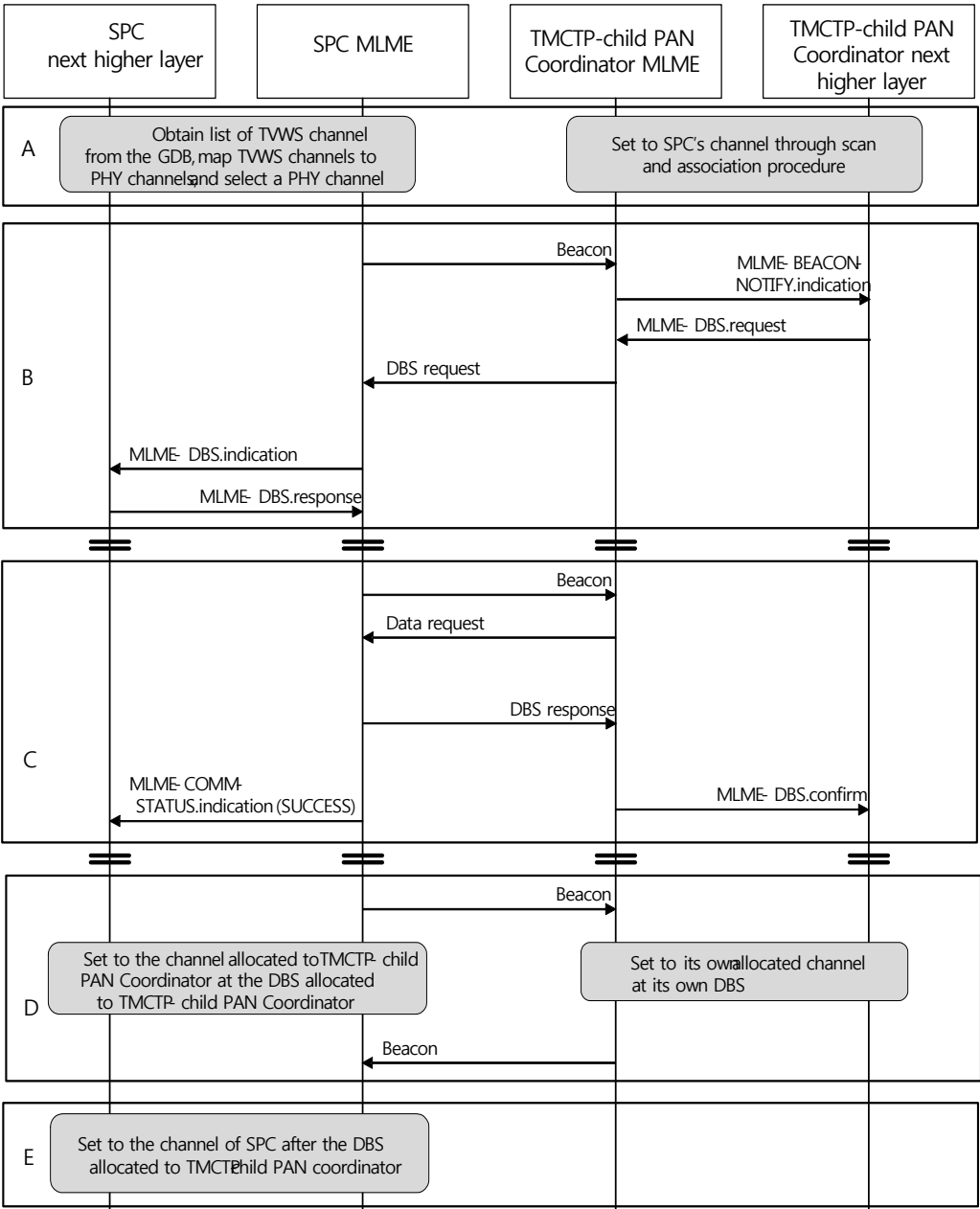


Figure 34x—Example message sequence chart between SPC and TMCTP-child PAN coordinator

In Step B, the SPC transmits an enhanced beacon containing a TMCTP Extended Superframe Specification IE as described in 5.2.4.35. Upon successful reception of the beacon from the SPC, the TMCTP-child PAN coordinator may request a DBS allocation or a DBS deallocation by sending a DBS request frame, as described in 5.3.14, to the SPC. Upon receiving the DBS request, the SPC will allocate or deallocate a DBS slot and a channel and generate a DBS response frame, as described in 5.3.15, to report the slot and the channel allocated or deallocated. The SPC can generate the DBS response frame for the deallocation without the request of the TMCTP-child PAN coordinator.

In Step C, the SPC indicates pending data for the TMCTP-child PAN coordinator in its beacon. The TMCTP-child PAN coordinator sends the data request command frame. Upon receiving the data request, the SPC replies with the DBS response generated in Step B. The SPC then sends its own beacon frame.

In Step D, the SPC switches to the channel allocated to the TMCTP-child PAN coordinator and listens for the beacon frame from the TMCTP-child PAN coordinator. If the SPC does not receive a beacon frame from the TMCTP-child PAN coordinator within three BIs, the SPC switches to the SPC channel and sends a DBS response frame to the TMCTP-child PAN coordinator in next superframe of the SPC.

In Step E, upon receiving the beacon frame during the slot allocated to the TMCTP-child PAN coordinator on the channel allocated to the TMCTP-child PAN coordinator, the SPC switches to its own dedicated channel.

During the CAP of the SPC, each TMCTP-child PAN coordinator sends a DBS request to the SPC and receives a DBS response from the SPC. The SPC switches to the channel allocated to the TMCTP-child PAN coordinator before the DBS slot time allocated to the TMCTP-child PAN coordinator. Each TMCTP-child PAN coordinator forms an independent PAN by transmitting its beacon during the allocated DBS slot.

Figure 34y provides another example for TMCTP formation between two PAN coordinators, where one is the TMCTP-parent PAN coordinator and the other is a TMCTP-child PAN Coordinator.

In Step A, the TMCTP-child PAN coordinator performs a scan procedure and waits for the beacon of the TMCTP-parent PAN coordinator.

In Step B, the TMCTP-parent PAN coordinator sends an enhanced beacon containing a TMCTP Specification IE, as in 5.2.4.35. Upon successful reception of the beacon from the TMCTP-parent PAN coordinator, the TMCTP-child PAN coordinator requests a channel and a slot by using the DBS request sent to the TMCTP-parent PAN coordinator. Upon receiving the DBS request, the TMCTP-parent PAN coordinator either directly generates the DBS response frame reporting the slot and the channel allocated or deallocated, or sends the DBS Request Command Frame to the SPC and then receives the DBS Response Command Frame from the SPC. The TMCTP-parent PAN coordinator may generate the DBS response frame for the deallocation without a request of the TMCTP-child PAN coordinator.

In Step C, the TMCTP-parent PAN coordinator sends a beacon. The TMCTP-parent PAN coordinator switches to the channel allocated to the TMCTP-child PAN coordinator and receives the beacon frame from the TMCTP-child PAN coordinator.

In Step D, upon receiving the beacon frame during the slot allocated to the TMCTP-child PAN coordinator on the channel allocated to the TMCTP-child PAN coordinator, the TMCTP-parent PAN coordinator switches to its own dedicated channel.

During CAP of the TMCTP-parent PAN coordinator, which has a relay capability or a channel allocation capability, each TMCTP-child PAN coordinator sends a DBS request to the TMCTP-parent PAN coordinator and receives the DBS response from the TMCTP-parent PAN coordinator. The TMCTP-parent PAN coordinator switches to the channel allocated to the TMCTP-child PAN coordinator during the DBS slot allocated to each TMCTP-child PAN coordinator. Each TMCTP-child PAN coordinator manages its own WPAN by transmitting a beacon during the allocated DBS slot time.

Figure 34z shows an example of the multichannel allocation for the network topology as presented in Figure 2a. In this case, the SPC operates on the dedicated channel, which is Channel 1 in this figure, and switches to the dedicated channels of TMCTP-child PAN coordinators 2, 3, and 4 during their DBSs. Similarly TMCTP-child PAN coordinator 4 operates on the dedicated channel, which is Channel 4, and switches to the dedicated channel of TMCTP-child PAN coordinator 5 during its DBS to communicate with TMCTP-child PAN coordinator 5.

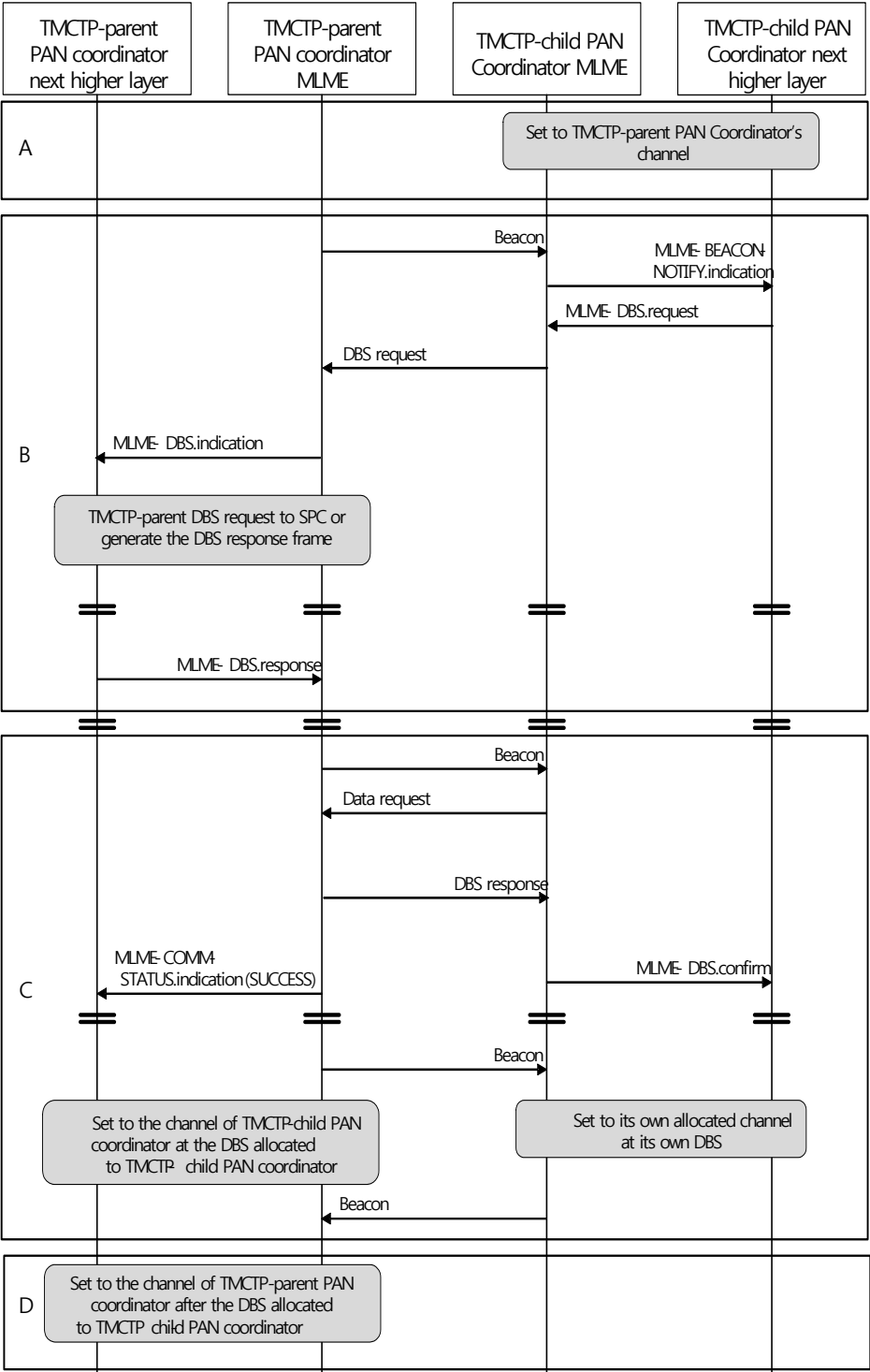


Figure 34y—Example message sequence chart between TMCTP PAN coordinators

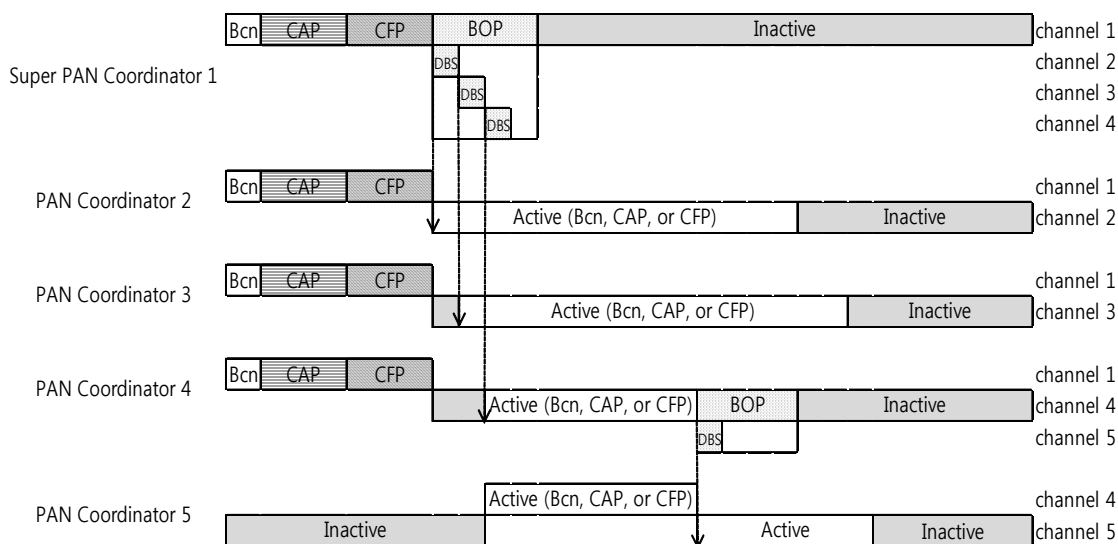


Figure 34z—Example TMCTP BOP allocation

5.1.15 TVWS power saving (TVWSPS)

This subclause defines a scalable and symmetrical power saving model for a wide range of LR-WPAN applications operating in TVWS. The TVWS power saving mechanism is activated when *macTvwsPsEnabled* is set to TRUE. The power saving mechanism is indicated by the MLME-BEACON-NOTIFY.indication primitive as described in 6.2.4.1 and MCPS-DATA.indication primitive as described in 6.3.

A TVWS device may be either an initiating device or a responding device. A responding device switches on its receiver during periodic listening periods *macTvwsPsListeningInterval* apart, each with listening duration *macTvwsPsListeningDuration*. In between listening periods, the responding device may be in sleep mode with the receiver disabled. To poll the responding device, an initiating device transmits frames containing a TVWS Power Saving (TVWSPS) IE (see 5.2.4.30) followed by a channel listening period (sufficiently long to receive an ACK frame from the responding device) at *macTvwsPsPollingInterval*, for total duration *macTvwsPsPollingDuration* or until receiving an acknowledgment frame, whichever occurs first. The total duration of the frame containing the TVWSPS IE and the channel listening period following the frame transmission may be shorter than *macTvwsPsPollingInterval*.

To increase the likelihood of detection, the value of *macTvwsPsPollingInterval* should be less than or equal to *macTvwsPsListeningDuration*, and the value of *macTvwsPsPollingDuration* should be more than or equal to *macTvwsPsListeningInterval*. The TVWSPS IE may be included in an enhanced beacon, data, or multi-purpose frame.

An initiating or responding device indicates the Rendezvous Time as the starting of the data transaction (e.g. ad-hoc listening period), as set by *macTvwsPsRendezvousTime*, and the Data Transaction Duration as the expected duration to complete the data transaction, as set by *macTvwsPsTransDuration*.

Upon receiving a frame with a TVWSPS IE, the responding device shall enable an ad hoc listening period to receive the data from the initiating device at the Rendezvous Time indicated in the received TVWS IE, or transmits the data requested by the initiating device at the indicated Rendezvous Time.

Two cases of the TVWSPS protocol are illustrated in Figure 34aa. In the first example, initiating device 1 has pending data to transmit to the responding device. In the second example, initiating device 2 is requesting data from the responding device.

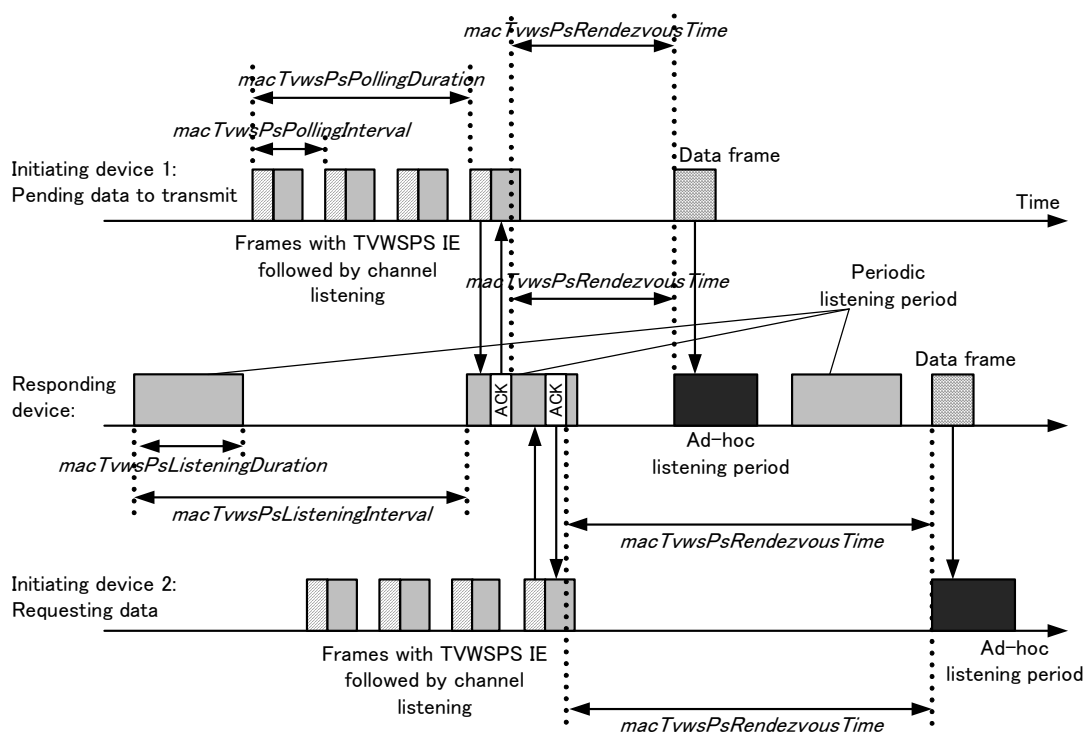


Figure 34aa—TVWS power saving mechanism

5.2 MAC frame formats

5.2.1 General MAC frame format

5.2.1.9 FCS field

Change the end of the first paragraph of 5.2.1.9 as indicated:

Only devices compliant with one or more of the SUN and TVWS PHYs shall implement the 4-octet FCS; for these devices, the default FCS length shall be 4 octets.

5.2.2 Format of individual frame types**5.2.2.1 Beacon frame format****5.2.2.1.1a Information elements field**

Insert the following new row into Table 3b:

Table 3b—EBR IEs per enabled attribute

Attribute Request Identifier	PIB attribute	IE type	IEs to include
5	<i>macDAenabled</i>	Header	Device Announcement (5.2.4.36)

5.2.4 Information element**5.2.4.2 Header information elements**

Insert the following new row into Table 4b:

Table 4b—Element IDs, Header IEs

Element ID	Content length	Name	Description
0x19	variable	DA	Defined in 5.2.4.36

5.2.4.5 MLME information elements

Insert the following new rows into Table 4d, and change the reserved row as indicated:

Table 4d—Sub-ID allocation for short format

Sub-ID value	Content length	Name	Description
0x2a	13	TVWSPS IE	Description of parameters for TVWS power saving mechanism, as defined in 5.2.4.30
0x2b	9	TVWS PHY Operating Mode Description IE	Description of a specific TVWS PHY operating mode, as defined in 5.2.4.31
0x2c	variable	TVWS Device Capabilities IE	Description of TVWS PHY-specific device capabilities, as defined in 5.2.4.32
0x2d	1	TVWS Device Category IE	Description of the device regulatory category, as defined in 5.2.4.33.1
0x2e	variable	TVWS Device Identification IE	Description of the device assigned identification, as defined in 5.2.4.33.2

Table 4d—Sub-ID allocation for short format (continued)

Sub-ID value	Content length	Name	Description
0x2f	variable	TVWS Device Location IE	Description of location of device, as defined in 5.2.4.33.3
0x30	variable	TVWS Channel Information Query Request/Response IE	Description of the query request and response protocol for channel information, as defined in 5.2.4.33.4
0x31	variable	TVWS Channel Information Source Description IE	Description of channel information source for channel enabling, as defined in 5.2.4.33.5
0x32	variable	Channel Timing Management IE	Description of the information for management in timing schedule for channel, as defined in 5.2.4.33.6
0x33	4	Timestamp IE	TX timestamp information as described in 5.2.4.34.1
0x34	4	Timestamp Difference IE	Timing difference for ranging support, as described in 5.2.4.34.2
0x35	variable	TMCTP Specification IE	Description of information for TMCTP protocols, as defined in 5.2.4.35
0x36–0x3f	—	Reserved	—

Insert the following new subclauses (5.2.4.30 to 5.2.4.36, including Figure 48aee to Figure 48aaw and Table 4z to Table 4an) after 5.2.4.29.2:

5.2.4.30 TVWS Power Saving (TVWSPS) IE

The TVWSPS IE is used by a device to initiate a TVWSPS transaction. The content of the IE shall be formatted as shown in Figure 48aee.

Octets: 1	4	3	3	2
PS Control	Periodic Listening Interval	Periodic Listening Duration	Rendezvous Time	Data Transaction Duration

Figure 48aee—TVWSPS IE

The PS Control field indicates the types of operation intended by the source device. A value of 0 indicates the announcement of a responding device’s Periodic Listening Interval and Periodic Listening Duration and that only the Periodic Listening Interval field and Periodic Listening Duration field are valid. A value of 1 indicates that an initiating device has pending data to be transmitted to the responding device. When value 1 is set, only the Rendezvous Time field and Data Transaction Duration field are valid. A value of 2 indicates that an initiating device is requesting data from the responding device. When value 2 is set, only the Rendezvous Time field and Data Transaction Duration field are valid. All other values are reserved.

The Periodic Listening Interval field is the time between the start of a periodic listening period and the start of the subsequent periodic listening period (see 5.1.15) in milliseconds, with a range as given in Table 52. When generated, this field shall be set to the value of *macTvwsPsListeningInterval*.

The Periodic Listening Duration field is the time between the start and the end of a periodic listening period, in milliseconds, with a range given in Table 52. When generated, this field shall be set to the value of *macTvwsPsListeningDuration*.

The Rendezvous Time field is the time in milliseconds between the end of the acknowledgment frame sent by a responding device or received by an initiating device and the start of the data transaction between the two devices. When generated, the value of this field is set to *macPSRendezvousTime*, with a valid range given in Table 52.

The Data Transaction Duration field is the time needed to complete the transaction between the initiating and responding devices. When generated, this field is set to the value of *macTvwsPsTransDuration*, with a valid range given in Table 52. A value of 0 indicates that the field shall be ignored.

5.2.4.31 TVWS PHY Operating Mode Description IE

The TVWS PHY Operating Mode Description IE is used with the PHY Parameter Change IE (5.2.4.23) to signal dynamically a change in operating channel, band or other PHY operating parameters when the resulting change will be to a configuration defined by the operating TVWS PHY. The TVWS PHY Operating Mode Description IE is an MLME IE as defined in 5.2.4.5. The content field shall be formatted as shown in Figure 48aaf.

Octets: 9
TVWS PHY Operating Mode Description

Figure 48aaf—TVWS PHY Operating Mode Description IE

The TVWS PHY Operating Mode Description field shall be encoded as shown in Table 4z. The specific parameters are encoded depending on the PHY type indicated.

Table 4z—TVWS PHY Operating Mode Description field

Bit number	Description	
0:7	Band ID. The band ID described in Table 4ab.	
8:15	PHY Channel ID. The channel identification for the 802.15.4 TVWS PHY channel as defined in 8.1.2.9.	
16:17	PHY Type Selector: 0 = TVWS-FSK PHY (20.1) 1 = TVWS-OFDM PHY (20.2)s 2 = TVWS-NB-OFDM PHY (20.3) 3 = Reserved	
18:31 for TVWS-FSK Operating Parameters: when PHY Type Selector is set to 0		
	18	FEC 0 = not enabled 1 = enabled
	19:20	FEC Scheme 0 = the first FEC scheme as defined in 20.1.2.2 1 = the second FEC scheme as defined in 20.1.2.2 2 = the third FEC scheme defined as defined in 20.1.2.2 NOTE: This field is reserved if FEC is not enabled.
	21	Interleaving 0 = not enabled 1 = enabled NOTE: This field is reserved if FEC is not enabled or the FEC Scheme field value is not 1.
	22	Spreading 0 = not enabled 1 = enabled
	23	Data Whitening 0 = not enabled 1 = enabled
	24–26	TVWS-FSK Mode as in Table 201
	27	Modulation index option: When TVWS-FSK Mode field value = 1, 2 or 3: 0 = modulation index is 0.5 1 = modulation index is 1.0 When TVWS-FSK Mode field value = 4 or 5, reserved.
	28	SFD Length 0 = 16-bit SFD 1 = 24-bit SFD
	29:31	Reserved

Table 4z—TVWS PHY Operating Mode Description field (continued)

Bit number	Description	
18:31 for TVWS-OFDM Operating Parameters: when PHY Type selector is set to 1		
	18:19	Modulation 0 = BPSK, 1 = QPSK, 2 = 16-QAM, 3 =Reserved
	20:22	MCS Mode 0–5 as given in Table 205 6–7 Reserved
	23:31	Reserved
18:31 for NB-OFDM Operating Parameters: when PHY Type selector is set to 2		
	18:21	MCS Mode 0–8 as given in Table 214 9–15 Reserved
	22	Channel aggregation 0 = not enabled 1 = enabled
	23:31	Reserved
32:71		TVWS Available Frequency Range as described in Figure 48aaq; only present when Band ID field value is <= 5

5.2.4.32 TVWS Device Capabilities IE

The TVWS Device Capabilities IE declares the TVWS capabilities supported by a device. The presence of this IE in a transmitted frame indicates that the device supports operation of a TVWS PHY defined in this standard. The IE content shall be as shown in Figure 48aag.

Octets: 1	3	3	variable
TVWS PHY Type	Supported Bands	TVWS Supported PHY Features	TVWS Supported Channels

Figure 48aag—TVWS Device Capabilities IE

The TVWS PHY Type field indicates the PHY type being described in the IE. This field shall be set to one of the non-reserved values shown in Table 4aa.

Table 4aa—TVWS PHY Type field

Value	Description
0	TVWS-FSK
1	TVWS-OFDM
2	TVWS-NB-OFDM
3–255	Reserved

The Supported Bands field is a bitmap indicating the bands supported by the device. A value of one indicates that the band is supported, and zero indicates the band is not supported. The supported bands shall be encoded as shown in Table 4ab. The device shall indicate only those bands that are implemented and defined for the indicated PHY type. The use of the bands defined in Table 4ab facilitates communication to be maintained when a band becomes unavailable, using the same PHY/MAC capabilities.

Table 4ab—Supported Bands field

Bit number	Band ID
0	TVWS Band USA
1	TVWS Band UK
2	TVWS Band Japan
3	TVWS Band Canada
4	TVWS Band Korea
5	TVWS Band EU
6	450–470 MHz
7	470–510 MHz
8	779–787 MHz
9	863–870 MHz
10	896–901 MHz
11	901–902 MHz
12	902–928 MHz
13	917–923.5 MHz
14	928–960 MHz
15	920–928 MHz
16	950–958 MHz
17	2400–2483.5 MHz
18–23	Reserved