**IEEE P802.15**

**Wireless Personal Area Networks**

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| Title | **TBD items related synchronization** | |
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| Re: |  | |
| Abstract | Resolves TBD items related ty synchronization procedure. | |
| Purpose | Discussion and approval. | |
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***Note***

This document resolves TBD items, mostly related to synchronization procedure.

The suggested text changes are based on PAC draft 0.18.0. Black texts represent existing texts in the draft, red texts with strike through represent deleted texts, and texts in blue are added texts.

New proposed text changes proposed in revision 1 are in green.

**<<<<< Beginning of proposed text changes >>>>>**

1. Overview
2. Normative references
3. Definitions
4. General description
5. MAC protocol
   1. MAC functional description
   2. MAC frame formats
      1. Device addresses
      2. General MAC frame format
      3. Format of individual frame types
      4. Information Elements (IEs)
      5. Transmission, reception, and acknowledgment
         1. Transmission
         2. Reception and rejection

Each PD may choose whether the MAC sublayer is to enable its receiver during idle mode. During these idle mode, the MAC sublayer shall still service transceiver task requests from the next higher layer. A transceiver task shall be defined as a transmission request with acknowledgment reception, if required, or a reception request. On completion of each transceiver task, the MAC sublayer shall request that the PHY enables or disables its receiver, depending on the values of *macRxOn*.

Due to the nature of radio communications, a PD with its receiver enabled will be able to receive and decode transmissions from all PDs complying with this standard that are currently operating on the same channel and are in its radio communications range, along with interference from other sources. The MAC sublayer shall, therefore, be able to filter incoming frames and present only the frames that are of interest to the upper layers.

For the first level of filtering, the MAC sublayer shall discard all received frames that do not contain a correct value in their Frame Check Sequence (FCS) field in the MFR, as described in ~~TBD~~5.2.2.9. The FCS field shall be verified on reception by recalculating the purported FCS over the MHR and MAC payload of the received frame and by subsequently comparing this value with the received FCS field. The FCS field of the received frame shall be considered to be correct if these values are the same and incorrect otherwise.

The second level of filtering shall be dependent on whether the MAC sublayer is currently operating in promiscuous mode. In promiscuous mode, the MAC sublayer shall pass all frames received after the first filter directly to the upper layers without applying any more filtering or processing. The MAC sublayer shall be in promiscuous mode if *macPromiscuousMode* is set to TRUE.

If the MAC sublayer is not in promiscuous mode (i.e., *macPromiscuousMode* is set to FALSE), it shall accept only frames that satisfy all of the following third-level filtering requirements:

* The Frame Type field shall not contain a reserved frame type.
* The Frame Version field shall not contain a reserved value.
* If a destination PAC?? identifier is included in the frame, it shall match macPACId or shall be the broadcast PAC identifier.
* 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 *macExtendedAddress*.
* .
* If only source addressing fields are included in a data or MAC command frame, the frame shall be accepted only if the PD is in broadcasting.
* If the service type field is included in a data or MAC command frame, the frame shall be accepted only if the service type matches *macServiceType* (programmed by/from higher layer)*.*

If any of the third-level filtering requirements are not satisfied, the MAC sublayer shall discard the incoming frame without processing it further. If all of the third-level filtering requirements are satisfied, the frame shall be considered valid and processed further. For valid frames, if the Frame Type field indicates a data or MAC command frame and the Acknowledgment Request (AR) field is set to request an acknowledgment, the MAC sublayer shall send an acknowledgment frame. Prior to the transmission of the acknowledgment frame, the sequence number included in the received data or MAC command frame shall be copied into the Sequence Number field of the acknowledgment frame. This step will allow the transaction originator to know that it has received the appropriate acknowledgment frame.

The PD shall process the frame using the incoming frame security procedure described in TBD.

If the status from the incoming frame security procedure is not SUCCESS, the MLME shall issue the corresponding confirm or MLME-COMM-STATUS.indication primitive with the status parameter set to the status from the incoming frame security procedure, indicating the error, and with the security-related parameters set to the corresponding parameters returned by the unsecuring process.

If the valid frame is a data frame, the MAC sublayer shall pass the frame to the next higher layer. This is achieved by issuing the MCPS-DATA.indication primitive containing the frame information. The security- related parameters of the MCPS-DATA.indication primitive shall be set to the corresponding parameters returned by the unsecuring process.

If the valid frame is a MAC command frame, it shall be processed by the MAC sublayer accordingly, and a corresponding confirm or indication primitive may be sent to the next higher layer. The security-related parameters of the corresponding confirm or indication primitive shall be set to the corresponding parameters returned by the unsecuring process.

* + - 1. Extracting pending data from a PD
      2. Use of acknowledgements and retransmissions

A data or MAC command frame shall be sent with the AR field set appropriately for the frame. An acknowledgment frame shall always be sent with the AR field set to indicate no acknowledgment requested. Similarly, any frame that is multicast or broadcast shall be sent with its AR field set appropriately to indicate whether acknowledgment requested or not.

* + - * 1. No acknowledgment

A frame transmitted with its AR field set to indicate no acknowledgment requested, as defined in ~~TBD~~5.2.2.1.4, shall not be acknowledged by its intended recipient. The originating PD shall assume that the transmission of the frame was successful.

The message sequence chart in Figure 23 shows the scenario for transmitting a single frame of data from an originator to a recipient without requiring an acknowledgment.



Figure 23—Successful data transmission without an acknowledgment

* + - * 1. Acknowledgment
        2. Retransmissions
      1. Promiscuous mode
      2. Transmission scenarios
  1. Synchronization procedure

Synchronization procedure includes the following sub-procedures:

1. Initial synchronization procedure
2. Maintaining synchronization procedure
3. Re-synchronization procedure

A PD starts Initial synchronization procedure if the PD does not have its own reference timing, e.g. when the PD is powered on, etc.

After successful Initial synchronization procedure, a PD makes a transition to Maintaining synchronization procedure.

A PD may make a transition to Re-synchronization procedure from Maintaining synchronization procedure according to a triggering condition. Details of the triggering condition are ~~TBD~~in 5.3.2.

* + 1. Initial synchronization procedure

To acquire reference timing, a PD scans for the existing synchronization signals for a ~~TBD scanning periodt~~time period corresponding to five consecutive superframes.

If existing synchronizations are found during the scanning period, and the synchronized condition is met, it derives its own timing from the detected synchronization signal and makes a transition to Maintaining synchronization procedure. ~~The synchronized condition is determined from the fact whether synchronization signals with the same timing are detected during the scanning period.~~The synchronized condition is met if synchronization signals are correctly received in three consecutive superframes after the scanning period.

If synchronization signals are found during the scanning period, but the synchronized condition is not met, a PD follows the procedure described in 5.3.1.1 and 5.3.1.2 until synchronized condition is met with initial timing derived from one of the detected synchronization signals. The synchronized condition is met if synchronization signals are correctly received or transmitted in three consecutive superframes. When the synchronization condition is met, the PD makes a transition to Maintaining synchronization procedure.

If a PD fails to detect any synchronization signal during the scanning period, it starts to transmit synchronization signal with its own timing of arbitrary choice.

* + - 1. Transmission of synchronization signals

The synchronization signals are transmitted in the Synchronization period using random access to avoid collision. The structure of Synchronization period is illustrated in Figure 28. The length of Synchronization period is equivalent to the length of ~~[TBD]~~34 backoff slots, where one backoff slot is equivalent to the length of two OFDM symbols. The PPDU structure of the synchronization signal is illustrated in Figure 65.



Figure 28—Structure of synchronization period

The random access scheme used for transmission of synchronization signal is slotted CSMA/CA (carrier sense multiple access with collision avoidance) with EIED (exponential increase exponential decrease) backoff algorithm. The random access scheme is as follows:

1. Each PD maintains its own CW (contention window).
2. A PD selects an integer *n* randomly drawn from {0, 1, 2, …, CW-1} and sets its backoff counter to the selected random integer *n*, and follows backoff procedure until its backoff counter becomes zero. Then the PD transmits a synchronization signal, and sets its backoff counter to CW-1-*n*, and follows backoff procedure until its backoff counter becomes zero, at which point it goes to Step c).
3. A PD updates its CW and goes to Step b).

The backoff procedure is as follows:

* A PD performs CCA (clean channel accessment), and decreases its backoff counter by 1 at the end of the backoff slot if the channel was idle during the backoff slot.
* A PD performs CCA. If the channel is busy, the PD does not decrease the backoff counter.

The CW is used to regulate the transmission of synchronization signals. PDs update their CW so that the average transmission rate of synchronization signal in the network remains constant regardless of the PD density, and the variation of the CW among PDs is minimized. PDs need to calculate the average inter-arrival time of synchronization signals, and the average CW sizes of other PDs within their communication range from the received synchronization signals according to the following equations once a synchronization signal is received:

TM := βA·TM + (1 - βA)·MIAT

CWoth := W/V

V := βB·V + (1+βB)·CWr

W := βB·W + (1+βB)·(CWr)2

where TM is the average measured inter-arrival time, MIAT is the measured inter-arrival time between the last two synchronization signals received, CWoth is the average CW size of other PDs in communication range calculated from the received synchronization signals, βA and βB satisfy 0≤βA≤1 and 0≤βB≤1, and CWr is the CW size contained in the received synchronization signal. The value of TM, βA and βB are TBD.

A PD updates its CW once it receives a synchronization signal using the rule described in Table 19. Target inter-arrival time TT is a pre-determined value determined to maximize the probability of successfully receiving at least one synchronization signal in each Synchronization period. The value of TT is [TBD].

Table 19—CW update rule

|  |  |  |  |
| --- | --- | --- | --- |
|  | CW < CWoth / r | CWoth / r < CW < r CWoth | r CWoth < CW |
| TM < TT | CW := 4CW | CW := √2 CW | CW := CW / √2 |
| TT < TM | CW := √2 CW | CW := CW / √2 | CW := CW / 4 |

Figure 29 is a flow chart illustrating the random access procedure for transmission of synchronization signals.



Figure 29—Random access procedure for transmission of synchronization signals

* + - 1. Adjustment of reference timing

All PDs maintain a synchronization timer whose phase **ϕ** varies from 0o to 360o. The value of the phase **ϕ** at the beginning of each superframe is 0o, and the value of the phase **ϕ** at the end of each superframe is 360o. Each PD transmits a synchronization signal when the phase **ϕ** of its synchronization timer reaches 360o using the random access procedure described in 5.3.1.1. The relationship between the superframe and synchronization timer is illustrated in Figure 30.



Figure 30—The relationship between Superframe and the phase of a synchronization timer.

When a PD receives a synchronization signal, it adjusts its reference timing by changing the phase **ϕ** of its synchronization timer based on the reference timing obtained from the received synchronization signal. The rule for a PD to update its phase **ϕ** of its synchronization timer is as follows:

* If the phase **ϕ** of its synchronization timer is smaller than 180o, then the PD does not change its reference timing
* If the phase **ϕ** of its synchronization timer is greater than 180o, then the PD adjusts its reference timing by changing the phase value to 360o.

~~An optional alternative mechanism that can be used to update the phase of synchronization timer is illustrated in Figure 31. The convex curve~~ *~~f~~*~~(~~**~~ϕ~~**~~) illustrated in Figure 2 is given by~~

*~~f~~*~~(~~**~~ϕ~~**~~)~~*~~=~~*~~(~~*~~1/b~~*~~)~~~~ln(~~*~~1 +~~* ~~[~~*~~e~~~~b~~~~-1~~*~~]~~**~~ϕ~~**~~)~~

~~where the parameter~~ *~~b~~* ~~determines the degree of curvature of~~ *~~f~~*~~(~~**~~ϕ~~**~~). If the phase of the synchronization timer of a PD is~~ **~~ϕ~~**~~1~~ ~~when a synchronization signal is received by the PD, the PD updates the phase of its synchronization time to~~ **~~ϕ~~**~~2~~ ~~given by the following equation.~~

**~~ϕ~~**~~2~~ ~~=~~ *~~f~~*~~-1~~~~(max(~~*~~f~~*~~(~~**~~ϕ~~**~~1~~~~) + ε,1))~~

~~ε is a predetermined value which satisfies 0<ε<1. A larger ε represents a stronger coupling between the transmitter and receiver of the synchronization signal, and causes a larger update of the phase of the synchronization timer of the receiver. The values of b and ε are [TBD].~~

~~~~

~~Figure 31—Optional phase update mechanism using concave curve~~ *~~f~~*~~(ϕ)~~

* + 1. Maintaining synchronization procedure

A PD maintains its own timing reference based on measurement of synchronization signals. Maintaining Synchronization procedure includes at least fine adjustment of timing reference and triggering of Re-~~S~~synchronization procedure.

If condition for Re-~~S~~synchronization is not met, it adjusts its own timing based on the detected synchronization signal during Synchronization period(s).

If condition for Re-~~S~~synchronization is met, it makes a transition to Re-~~S~~synchronization procedure. ~~TBD: details of condition for Re-synchronization.~~Re-~~S~~synchronization condition is met if synchronization signal is not received in five consecutive superframes.

Maintaining synchronization is also responsible for merging two PAC networks when two PAC networks meet. Two PAC networks meet when one or more PDs in one PAC network can communicate with one or more PDs in another PAC network directly or through a multi-hop relay route. Two PAC networks can meet each other when the PAC networks move, or any obstacle separating the two PAC networks is removed. When two PAC networks meet, the PAC networks are merged or synchronized by making the PDs in the two PAC networks have the same reference timing.



Figure 32—Two PAC networks out of synchronization.

Figure 32 illustrates two out of synchronization PAC networks, where the reference timing of network 1 is ahead of the reference timing of network 2. Maintaining synchronization procedure that merges the two PAC networks in Figure 32 is as follows:

* A PD in network 1 detects network 2 when it receives a synchronization signal transmitted by a PD in network 2. Similarly, A PD in network 2 detects network 1 when it receives a synchronization signal transmitted by a PD in network 1.
* When a PD detects a PAC network that it does not belong to, the PD notifies the fact to other PDs in the PAC network that it belongs to using an indicator embedded in a synchronization signal in the next opportunity to transmit a synchronization signal. ~~[~~The details of the indication mechanism are ~~TBD~~defined in 9.1.5.1.~~]~~ After the detection, the PD maintains its normal operation in the Synchronization period, but stops all transmissions in Discovery period, Peering period, and Data communication period and operate in receive mode.
* A PD which has detected a PAC network that it does not belong to, the PD decides whether it will remain in the current network by maintaining its own reference timing, or I will move to detected network by stopping transmission of synchronization signals in the Synchronization period in the current network and transmitting synchronization signals in the Synchronization period of the detected network using random access procedure.
* After a PD moves from one PAC network to another, the PD maintain normal operation in the Synchronization period, but operate in receive mode in Discovery period, Peering period, and Communication period of the PAC network it moved to, until it decides merge of the two PAC networks has been completed.
* ~~A PD decides merge on~~Merge of two PAC networks is complete if it does not hear synchronization signal from ~~another network~~ PDs with different reference timing at least ~~for [TBD]~~in five consecutive superframes.
* A PD in sleep mode wakes up and operates in received mode in the entire superframe when it receives an indicator embedded in synchronization signals it received.

When a PD detects another PAC network, it decides whether it will stay in the network it currently belongs to or move to the detected PAC network using the relative timing between the two PAC networks as follows:

* In Figure 32, if T1 is smaller than T2, PDs in network 2 move to network 1, and PDs in network 1 stay in network 1.
* In Figure 32, if T1 is greater than T1, PDs in network 1 move to network 2, and PDs in network 2 stay in network 2.
  + 1. Re-synchronization procedure

If the condition for Re-synchronization is met, a PD enters Re-synchronization procedure. The Re-synchronization procedure is identical to Initial synchronization procedure, except that a PD uses its own timing as an initial timing. The condition for Re-synchronization is defined in 5.3.2. ~~A PD scans for the existing synchronization signals for a TBD scanning period. If a synchronized condition is met, it makes a transition to Maintaining synchronization period. The synchronized condition is determined from the fact whether a synchronization signal or multiple synchronization signals with the same timing is/are detected during the scanning period.~~

~~If the synchronized condition is not met, the PD adjusts its own reference timing based on detected synchronization signals.~~

* 1. Discovery
  2. Peering
  3. Communication period
  4. MAC commands

1. MAC services
2. General PHY requirements
3. PHY services
4. PHY
   1. Low Mobility PHY specification
      1. Operating frequency range
      2. Channel assignments
      3. Duplex schemes
      4. Multiplexing schemes
      5. PPDU format for low mobility PHY
         1. Short Training Field (STF)

The time-domain structure of STF is illustrated in Figure 67.



Figure 67 – Time-domain structure of STF

The STF is used for carrier sensing, AGC, packet detection, partial fine time/frequency synchronization. The length of STF is equivalent to 2 OFDM symbols. What is transmitted is signaled using the STF pattern as shown below:

* Set (D,D,D,D,D), where each “D” in the figure represents one time-domain repetition, is configured in the beginning of the Preamble for ~~each of the sync slot,~~ RTS, CTS, ACK, and discovery/peering indication subslot. Set (D,D,D,D,D) is also used for synchronization signal in initial synchronization procedure, maintaining synchronization procedure, and re-synchronization procedure.
* Set (D,D,D,D,-D) is configured in the beginning of the Preamble for data packet. Set (D,D,D,D,-D) is also used in the Preamble for synchronization signal to indicate that a PAC network with different reference timing is detected. Specifically, a PD switches to STF pattern (D, D, D, D, -D) when a PAC network with different reference timing is detected, and switches back to STF patterm (D, D, D, D, D) when the merge procedure described in 5.3.2 is complete.

Specifically, the discovery indication subslot comprises the STF pattern (D,D,D,D,D) alone. If we perform carrier sensing (CS) based on single auto-correlation method with length-64 (corresponding to three Ds), CS performance can be improved by 6 dB compared to single auto-correlation method with length-16. CS capability is pivotal to reduce the hidden node problem that is well known.

Sub-clauses 9.1.5.1.1 through 9.1.5.1.3 specify the frequency-domain and time-domain signals of STF.

**<<<<< End of proposed text changes >>>>>**