**IEEE P802.15**

**Wireless Personal Area Networks**

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***Note to Editor: Black texts represent the existing text in P802.15.8 PAC draft, and the proposed text changes are in blue.***

**3. Definitions**

**3.1 Definitions**

**3.2 Acronyms and abbreviations**

CQI channel quality indicator

CRC cyclic redundancy check

CS carrier sense

CSI channel state information

CSMA/CA carrier sense multiple access with collision avoidance

…

HCS header check sequence

IFFT inverse fast Fourier transform

IFS interframe space

ITU international telecommunications union

LFSR linear feedback shift register

**5. MAC protocol**

**5.1 MAC functional description**

**5.2 MPDU formats**

**5.3 Channel scanning**

**5.4 Synchronization procedure**

**5.5 Discovery**

**5.6 Peering**

**5.6.1 One-to-one peering procedure**

**5.6.2 One-to-one Re-peering procedure**

**5.6.3 One-to-one De-peering procedure**

**5.6.4 Access scheme in Peering Period**

A PD shall transmit management messages for peering, re-peering, and de-peering in Peering Period using *p*-EIED protocol described in 5.7.1. A PD shall maintain and update independent *TM* and *p*basic for Peering Period separate from *TM* and *p*basic for CAP. See 5.7.1 for the detailed description of *p*-EIED.

**5.7 Communication period**

Communication period is utilized for data packet transmission. Communication period comprises Contention Access period (CAP) and Contention-free period (CFP).

Data packet for unicast, multicast, or broadcast can be transmitted during Communication period. Whether all communication types are supported by both CAP and CFP respectively is TBD. Some control packets related to data packet transmission may be transmitted during Communication period (e.g. Control packets for scheduling, group management, etc.)



Figure 28—Communication period

**5.7.1 CAP (Contention Access Period)**

A PD can transmit control or data packet during CAP period using the following access scheme:

The transmission scheme in CAP is random access scheme *p*-EIED, which is based on LBT. ~~Details are TBD. CW is the time window where random access is attempted by a PD.~~ For a PD to transmit, it shall sense the medium to determine if another PD is transmitting. If the medium is not determined to be busy, the transmission may proceed. If the medium is determined to be busy, the PD shall defer until the end of the current transmission. After deferral, or prior to attempting to transmit again immediately after a successful transmission, the PD shall update its persistence level *p*, which will be described in 5.7.1.5..

The *p*-EIED protocol is a fully distributed contention based access scheme designed to provide high efficiency, scalability, and adaptability in an environment where PDs freely move around from one point of attraction to another.

CS shall be performed both through physical and virtual mechanisms. The virtual CS mechanism is achieved by the exchange of RTS and CTS frames prior to the actual data frame. The RTS and CTS frames contain a Duration field that defines the period of time that the medium is to be reserved.

~~There is a condition to determine CW for unicast transmission. Details of the condition to determine CW are TBD. There is a condition to determine CW for multicast or broadcast transmission. Details of the condition to determine CW are TBD.~~

~~Whether transmission of data packet should be completed within current CAP or not is TBD.~~

Data packet can be fragmented for CAP and details of the fragmentation are TBD which may be referred from 802.15.4 or 802.11.

QoS (Quality of Service) is supported for CAP to differentiate traffic types such as urgent traffic, control type of traffic, or etc. Details of QoS control may be referred from 802.15.4 or 802.11.

**5.7.1.1 CS mechanism**

Physical and virtual CS functions are used to determine the state of the medium. When either function indicates a busy medium, the medium shall be considered busy; otherwise, it shall be considered idle.

A physical CS mechanism shall be provided by the PHY. The details of physical CS are provided in the individual PHY specifications. A virtual CS mechanism shall be provided by the MAC. This mechanism is referred to as the NAV. The duration information is also available in the MAC headers of all frames sent during the CAP.

**5.7.1.2 MAC-level acknowledgement**

**~~5.7.1.1 Consideration for Unicast in CAP~~**

A PD which received a unicast message responds with ACK/NACK for reliable transmission. Details for ACK/NACK corresponding to fragmented packet are TBD.

**~~5.7.1.2 Consideration for Multicast in CAP~~**

A PD which received a multicast message does not respond with ACK/NACK. For reliable multicast, ACK/NACK may be required. Details are TBD.

**~~5.7.1.3 Consideration for Broadcast in CAP~~**

A PD which received a broadcast message does not respond with ACK/NACK.

**5.7.1.3 IFS for CAP**

The time interval between frames is called the IFS. Three different IFSs are defined.

a) SIFS short interframe space

b) DIFS DCF interframe space

c) EIFS extended interframe space

The IFS timings are defined as time gaps on the medium, and the IFS timings are fixed for each PHY.

**5.7.1.3.1 SIFS**

The SIFS shall be used prior to transmission of an ACK frame, a CTS frame, and the second or subsequent MPDU of a fragment burst. The SIFS is the time from the end of the last symbol of the previous frame to the beginning of the first symbol of the preamble of the subsequent frame as seen at the air interface.

An IEEE 802.15.8 implementation shall not allow the space between frames that are defined to be separated by a SIFS time, as measured on the medium, to vary from the nominal SIFS value by more than ±10% of SIFS for the PHY in use.

**5.7.1.3.2 DIFS**

The DIFS shall be used by PDs operating under *p*-EIED to transmit data frames (MPDUs) and management frames (MMPDUs). A PD using *p*-EIED shall be allowed to contend to transmit if its CS mechanism determines that the medium is idle for DIFS after a correctly received frame.

**5.7.1.3.3 EIFS**

The EIFS shall be used by PDs operating under *p*-EIED before transmission, when it determines that the medium is idle following reception of an erroneous frame.

**5.7.1.4 Basic access**

Basic access refers to the core mechanism a PD uses to determine whether it may transmit. In general, a PD may transmit a pending MPDU when it is operating under *p*-EIED access method, when the PD determines that the medium is idle for greater than or equal to a DIFS period, or an EIFS period if the immediately preceding medium-busy event was caused by detection of a frame that was not received at this PD correctly. If, under these conditions, the medium is determined by the CS mechanism to be busy when a PD desires to transmit a frame, the backoff procedure described in 5.7.1.6 shall be followed. The basic access mechanism is illustrated in Figure XXX.



Figure XXX—Basic access method

**5.7.1.5 Backoff procedure for *p*-EIED**

This subclause describes backoff procedure that is to be invoked when *p*-EIED is used. The behavior of *p*-EIED is governed by four parameters: persistence level *p*, the average persistence level of neighboring PDs *p*avg, measured average inter-arrival time *TM*, and target inter-arrival time *TT*.

a) The persistent level *p* is used to regulate the transmission of data frames. PDs update their persistence level *p* so that the average transmission rate in the network remains constant regardless of the PD density, and the variation of *p* among PDs minimized. If channel becomes idle, after DIFS period, a PD attempts to transmit a data frame in each backoff slot with probability *p*.

b) The average persistence level of neighboring PDs *p*avg is used to provide fairness among PDs.

c) Each PD measures the average inter-arrival time *TM*, where *inter-arrival time* is defined as the number of consecutive idle slots between transmissions. *TM* represents the channel condition, i.e., the contention, and is highly correlated with the average packet transmission rate in the network. *TM* as a measure of channel condition can be used even when unicast messages are mixed with broadcast and multicast messages that are not acknowledged by an ACK.

d) *TT* is the target inter-arrival time optimized for predetermined packet length *l*basic. If *TM* is smaller than *TT*, a PD increases its persistence level *p* to make *TM* converge to the value of *TT*. On the other hand, if *TM* is larger than *TT*, a PD decreases its persistence level *p*.

When a PD receives a packet, it updates *TM* and *p*avg. *TM* is updated by the following equation:

*TM* := β · *TM* + (1 - β) ·*TS*,

where *TS* is the measured inter-arrival time between the last two packets, and 0 < β < 1. The value of *p*avg is updated by the following equation:

*p*avg := *Q* / *R*,

where

*Q* := β · *Q* + (1 - β) · (1/ γ*r* ),

*R* := β · R + (1 - β) · 1/( γ*r* *pr* ),

*pr* is the persistence level contained in the packet received last, γ*r* is a scaling factor, and 0 < β < 1. The value of β is up to implementation. The scaling factor γ*r* is defined as

$γ\_{r}=\left(\frac{l\_{r}}{l\_{basic}}\right)^{-\frac{1}{2}}$,

where *lr* is the length corresponding to the length of payload plus EIFS in case of basic access, and the length of RTS packet plus EIFS in case of access mechanism with RTS/CTS handshaking.

The optimal target inter-arrival time *TT* can be obtained to maximize channel utilization *U*(*p*), which is defined by

$U(p)=\frac{P\_{succ}}{P\_{idle}T\_{slot}+P\_{succ}T\_{succ}+P\_{coll}T\_{coll}}$,

where $P\_{succ}=Np\left(1-p\right)^{N-1}$, $P\_{coll}=1-P\_{succ}-P\_{idle}$, $P\_{idle}=\left(1-p\right)^{N}$, *T*slot is the length of a backoff slot, *T*succ is the duration the channel is used by a successful transmission, and *T*coll is the duration the channel is wasted by an unsuccessful transmission. *T*succ and *T*coll are determined by *l*basic and the protocol overhead defined as follows:

$$T\_{succ}=\left\{\begin{matrix}l\_{basic}+SIFS+ACK+DIFS, (basic access mechanism)\\RTS+SIFS+CTS+SIFS+l\_{basic}+SIFS+ACK+DIFS, (RTS/CRS mechnaism)\end{matrix}\right.$$

$$T\_{coll}=\left\{\begin{matrix}l\_{basic}+EIFS, (basic access mechanism)\\RTS+EIFS, (RTS/CRS mechnaism)\end{matrix}\right.$$

Maximizing channel utilization is equivalent to minimizing the cost of collision *C*(*p*), where

$C(p)=\frac{P\_{idle}T\_{slot}+P\_{coll}T\_{coll}}{P\_{succ}}$.

The objective of IEEE 802.15.8 is to provide a fully distributed scalable peer aware communications standard, and thus *p*-EIED is optimized for network environment with high density of PDs. Thus the target inter-arrival time *TT* that minimizes *C*(*p*) can be obtained numerically for asymptotically large *N*. For CAP, when *l*basic = 1.367 msec, the target inter-arrival time is given as

*TT* = 8.55362.

The same parameter *TT* will be used in an environment with low PD density, in which case a graceful performance degradation is expected. Each PD maintains its own persistence level *p*basic, and updates *p*basic every time a packet is received using the rule described in Table XXX. *p*basic is the persistence level if the cost of collision is *l*basic.

**Table XXX—*p*basic update rule**

|  |  |  |  |
| --- | --- | --- | --- |
|  | *p*basic < *p*avg / √2 | *p*avg / √2 ≤ *p*basic < √2 *p*avg | √2 *p*avg ≤ *p*basic |
| TM ≤ TT | *p*basic := *p*basic | *p*basic := *p*basic / √2 | *p*basic := *p*basic / 2 |
| TT < TM | *p*basic := 2 *p*basic | *p*basic := √2 *p*basic  | *p*basic := *p*basic |

Since the cost of collision is different from *l*basic, the actual persistence level *p* that a PD uses to transmit a packet needs to be calculated for *p*basic as follows:

$p=\frac{p\_{basic}}{\sqrt{T\_{coll}/l\_{basic}}}$.

**5.7.1.6 Access with RTS/CTS**

TBD

**5.7.2 CFP (Contention Free Period)**

CFP comprises Scheduling Request period, Scheduling Response period, and Resource slots (RSs). Only a PD with Link ID shall exchange Scheduling Request and Scheduling Response messages. Link ID is determined during peering and re-peering procedure. Data packet from higher layer can be fragmented into multiple MPDUs. The channel quality may be measured during preamble and CQI (Channel Quality Indicator) feedback. MCS selection and making a MPDU are performed based on channel quality.

Scheduling Request message represents Link ID, Resource Slot Star Index, and Resource Slot Length.



Resource Slot Start Index is selected within the maximum number of RSs for initial scheduling. Resource Slot Length is selected for initial scheduling within maximum available length which is pre-determined as TBD value. The Resource Slot Start Index and the Resource Slot Length is adjusted for next scheduling based on collected resource information from Scheduling Response messages. Resource Slot Start Index and Resource Slot Length are determined for initial and consecutive scheduling period according to predetermined TBD rule.

***End of the proposed text.***