IEEE P802.15

**Wireless Personal Area Networks**

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| Title | Text proposal of both MAC and PHY for PAC operating in synchronous mode (doc) |
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| Re: | In response to call for proposals to TG8 |
| Abstract | This document is a text proposal describing the proposed PHY and MAC for PAC operating in synchronous mode |
| Purpose | This document provides the framework from which the draft PAC specification will be developed. The document provides an outline of each the functional blocks that will be a part of the final specification. The document is intended to reflect the working consensus of the group on the broad outline for the draft specification. As such it is expected to begin with minimal detail reflecting agreement on specific techniques and highlighting areas on which agreement is still required. It may also begin with an incomplete feature list with additional features added as they are justified. The document will evolve over time until it includes sufficient detail on all the functional blocks and their inter-dependencies so that work can begin on the draft specification itself. |
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# Overview

The 802.15.8 specification shall be developed according to the P802.15.8 Peer Aware Communication (PAC) project authorization request (PAR), document number 15-12-0063r2 and Five Criteria (5c), document number 15-12-0064r1, which were approved by the IEEE-SA in March of 2012.

# Definitions

# Abbreviations and acronyms

BCI Burst Control Indicator

BU Blocking Unit

CAR Consecutive Allocation Request

DS-REQ Distributed Scheduling – Request

DS-RSP Distributed Scheduling – Response

GI Guard Interval

IS Interference Sensing

PD PAC Device

PID Peering Identifier

Peering-REQ Peering-Request

Peering-RSP Peering-Response

RU Resource Unit

SIV Service Information Version

SP Scheduling Priority

SRI Scheduling Request Indicator

# General descriptions

This clause provides the basic framework of PDs. The framework serves as a guideline in developing the functionalities of PDs and their interactions specified in detail in the subsequent clauses.

## Concepts and architecture

IEEE 802.15.8 supports fixed and sectionized frame structure.

IEEE 802.15.8 frame consists of synchronization, discovery, peering, and data region.

IEEE 802.15.8 supports coexistence with heterogeneous device.

IEEE 802.15.8 supports fully distributed synchronization.

IEEE 802.15.8 supports both device discovery and service discovery in the broadcasting manner and the query-based manner.

IEEE 802.15.8 supports peering procedure consists of monitoring of local peering status and exchange of peering signalling through randomly selected resource.

IEEE 802.15.8 supports contention-free multiple access with orthogonal requests and priority-based fully distributed scheduling.

## Topology

## Reference model

# MAC layer

## MPDU structure

## Multiple access

The multiple access scheme of IEEE 802.15.8 is contention-free multiple access with orthogonal requests. Contention-free multiple access consists of exchanging DS-REQ (Distributed Scheduling – Request) and DS-RSP (Distributed Scheduling – Response) between the peered PDs.

Once peering is over, available data channels used are assigned to the peered PDs by data channel mapping. In the assigned data channel, resources for request and response signals are determined by SP(Scheduling Priority) mapping.

For a PD trying to send DS-REQ, it shall sense the air medium to check to see if interferences are produced from heterogeneous devices. If the air medium is determined to have no interference, the PD may transit DS-REQ.

The PD shall transmit SRI(Scheduling Request Indicator) before transmitting DS-REQ. After the transmission of SRI, the PD shall transmit DS-REQ in the scheduling interval to request resource allocation in the data interval for data transmission. The other peered PD shall transmit DS-RSP in the scheduling interval in a response to the received DS-REQ signal. The information delivered by the exchange of DS-REQ and DS-RSP is used by the distributed scheduling algorithm.

## Synchronization procedure

IEEE 802.15.8 follows a synchronization procedure in the distributed manner. A PD shall perform a synchronization procedure before performing a discovery procedure. A PD shall search the start of frame and ultraframe in sequence. A PD shall transmit or receive the synchronization signal for distributed synchronization.

## Discovery procedure

IEEE 802.15.8 follows a periodic discovery operation based on the broadcasting manner. The discovery operation consists of transmission of a PD’s discovery signal and reception of other PD’s discovery signals for a period. A PD transmits own discovery signal through a selected discovery RU and receives other PD’s discovery signals through the remained discovery RUs in the discovery region.

The period of discovery resource is an ultraframe. The selection of discovery RU is performed on the basis of the resource structure of discovery. After monitoring the utilization of discovery RUs during multiple periods before selecting a discovery RU, a PD selects a discovery RU which is unused (or least congested) from each PD’s perspective. The collision between PDs because of using the same resource is resolved by the following procedure. At the arbitrarily selected time, a PD receives the signals without transmitting own discovery signal through a selected discovery RU. It is to determine whether there are signals transmitted by other PDs. If a collision is detected, a PD performs the discovery RU reselection and transmits own discovery signal periodically through newly selected discovery RU.



Figure 1. Resource structure of discovery

A PD performs both device discovery and service discovery of other PDs using the insertion of different contents in a discovery signal to be periodically transmitted. Device discovery is performed periodically by a PD for the presence discovery of other PDs. And a device ID of a PD is included in the discovery signal. In addition, service discovery is performed in the query-based manner (using request and response message) to obtain the information related to other PD’s service. And Service information of a PD is included in the discovery signal. A resource for device discovery of a PD is used infrequently for the exchange of request and response messages to obtain the service information of other PD. To support aperiodic service discovery in the query-based manner, a parameter named SIV (Service Information Version) is also included in the discovery signal for device discovery. SIV is used to indicate the change in the service provided by each PD. By providing the parameter related to service information (i.e. SIV) periodically, the exchange of request and response messages is executed only if the information update is required.

Service discovery should be also supported through message transfer in the data region.

### *Resource shuffling*

A resource shuffling is used to vary the configuration of PDs which uses the RUs in a BU. The positions of RUs are shuffled via a specific pattern. A PD calculates the current position of a selected RU using the shuffling pattern and the previous position.

A Shuffling pattern for discovery region is configured using the discovery RUs of entire BUs in a suprerfame. And the shuffling pattern for a discovery region has the form of a square matrix. The value of N is the total number of rows (or columns) in the matrix. And it is the same as the number of RUs in a BU or the number of BUs in a superframe. One shuffling pattern is used for all superframes in an ultraframe. The pattern is changed every ultraframe.



Figure 2. Configuration of shuffling pattern for discovery region





Figure 3. Change of shuffling pattern

## Peering procedure

Peering procedure is to establish a link between a pair of PDs discovered during the discovery procedure.

Peering procedure consists of peering request / response message exchange at Peering- REQ/Peering-RSP interval and the usage check of the entire PIDs at the PID broadcast interval in the peering region of the frame.



Figure 4. Resource structure of peering

After successful peering procedure, a pair of PDs shares a PID to be used for multiple access to the data region. For orthogonal use of PID in distributed communication environment, a PD should notify other PDs of the use of PIDs at the fixed position specified by each PID in the PID broadcast interval.

A PD performs the state check of the entire PIDs before sending a message related to the peering. Based on the PID usage information acquired in the PID broadcast interval, the list of available PIDs (i.e. unused PIDs) is included in the peering request message by the requesting PD. A PD which received the peering request message sends the peering response message including the selected PID. Through these messages, a pair of PDs shares a PID.

A PD selects a Peering-REQ RU at random. A PD which transmits the peering request message waits the reception of the peering response message at the corresponding Peering-RSP RU. If a PD fails to receive the peering response message at the Peering-RSP RU corresponding to the selected Peering-REQ RU, it reselects a Peering-REQ RU and retransmit the peering request message through newly selected Peering-REQ RU.

### *Resource Shuffling*

A resource shuffling is used to vary the configuration of PDs which use the RUs blocked by a specific PD. Shuffling pattern for PID broadcast interval of peering region is configured using the entire RUs of a superfame. One of two patterns (i.e. s(0) and s(1)) is applied to two consecutive superframes and the same pattern is applied at eight times per ultraframe.



Figure 5. Configuration of shuffling pattern for PID broadcast interval



Figure 6. Change of shuffling pattern

## Scheduling

IEEE 802.15.8 supports the priority-based fully distributed scheduling among the contending PDs.

### Resource mapping

After successful peering, the peered PDs share the same orthogonal PID. The orthogonal PID in conjunction with synchronization information such as frame number and superframe number determines available resources for sending DS-REQ/DS-RSP and data transmission of the peered PDs. The determination of available resource for sending DS-REQ/DS-RSP and data transmission of the peered PDs is referred to as resource mapping.

#### Data channel mapping

Data channel is a fundamental unit used for sending DS-REQ/DS-RSP and data transmission occurring in the scheduling interval and the data interval, respectively. The data channel mapping is a function that determines available data channels for the peered PDs based on PID, frame number, and superframe number.

The available data channel index *l* (0 ~ 15) for the peered PDs with PID *p* (0 ~ 127), frame number *n* (0 ~ 9), and superframe number *s* (0~15) is given by

*l* = (floor(*p* / 8) + *s*ⅹ10 + *n*) modulo 16.

(In frame type 0 (*n* = 0), data channels corresponding to *l*=0, 1, 2 are not defined.)

#### SP mapping

SP(scheduling Priority) is the priority in access to the data interval over other contending PDs. SP is also used to determine the resource for both DS-REQ and DS-RSP in the scheduling interval of the data channel assigned by the data channel mapping. SP ranges from 0 to 7 and 7 corresponds to the highest priority.

The assigned SP for the peered PDs with data channel index *l* (0 ~ 15) for the peered PDs with PID *p* (0 ~ 127), frame number *n* (0 ~ 9), and superframe number *s* (0~15) is given by



### Resource allocation

In this clause, the PD transmitting DS-REQ is referred to as the originator, and the peered PD of the originator as recipient.

#### Normal allocation

Normal allocation is the fundamental allocation mechanism of IEEE 802.15.8. Normal allocation enables peered PDs to participate in multiple access to the resource for data transmission.

After transmitting SRI, the originator sends DS-REQ using the resource for DS-REQ corresponds to the determined SP. In the blocking unit for DS-REQ, the originator shall transmit blocking signals, before and after the transmission of DS-REQ.



Figure 7. SP relevance to the resources for DS-REQ and DS-RSP

The originator sets Required slots field of DS-REQ payload to the required resource in the data interval in terms of OFDM slots. OFDM slot is a basic unit of data interval and one OFDM slot is 4 OFDM symbols. The required resource shall be the sum of data burst to be transmitted, ACK, and two GIs which is one for GI between data burst and ACK and the other for GI between ACK and the next data burst.



Figure 8. DS-REQ payload format

The recipient shall try to receive the DS-REQ that may be transmitted by the originator. Once the recipient succeeds in decoding the DS-REQ payload, it shall receive all the DS-REQs with higher SP than its own. If the recipient fails to decode the DS-REQ from the originator, it does not need to receive any other DS-REQs. The recipient shall accumulate the value of Required slots field of all the received DS-REQs with higher SP than its own.

The resource for DS-RSP is also determined by SP. The recipient shall transmit DS-RSP using the mapped resource for it in a response to the received DS-REQ from its originator. In the blocking unit for DS-RSP, the recipient shall transmit blocking signals, before and after the transmission of DS-RSP.

The recipient shall set Offset field of DS-RSP payload to the accumulated value of Required slots field of all the received DS-REQs with higher SP than its own. If the Offset field exceeds data interval boundary, recipient shall not send DS-RSP.

Allocated slots field of DS-RSP payload is set to the Required slots field of the DS-REQ received from its originator. If (Offset + Required slots) exceeds data interval boundary, the recipient shall adjust Allocated slots field in order not to exceed the data interval boundary.



Figure 9. DS-RSP payload format

The originator shall try to receive the DS-RSP from its recipient. Once the originator succeeds in decoding the DS-RSP payload, it shall receive all the DS-RSPs with higher SP than its own. If the originator fails to decode the DS-RSP form its recipient, it does not need to receive any other DS-RSPs.

After the successful exchange of DS-REQ and DS-RSP, the originator shall check to see whether its allocated ranging from Offset to (Offset+ Allocated slots) overlaps with resources allocated to other PDs with higher SP than its own. The originator shall utilize the allocated resource for its data transmission only when there is no conflict with other resources for PDs with higher SP than its own. Otherwise, the originator shall not use the allocated resource and stop the normal allocation process.

The originator shall transmit its data burst at Offset. The recipient shall transmit ACK at (Offset + Allocated slots- GI between ACK and the next data burst).

#### Consecutive allocation

Consecutive allocation is an allocation mechanism enabling any PDs performed normal allocation in a data channel to have an opportunity of another normal allocation in the following data channel which is not assigned by the data channel mapping.

The originator trying consecutive allocation in the data channel #(*n*+1) shall set CAR (Consecutive allocation request) bit to 1 when it sends DS-REQ to the recipient in data channel #*n*. Only if the originator succeeds in receiving DS-RSP from the recipient, it can precede consecutive allocation process in data channel #(*n*+1) in addition to the normal allocation in data channel #*n*.

In data channel #(*n*+1), after interference sensing, the originator shall check to see whether there is SRI signal in the scheduling interval. If SRI signal is detected, the originator immediately stops consecutive allocation process. Otherwise, the originator may continue consecutive allocation process, which is same to another normal allocation as an originator in data channel #(*n*+1).

If the recipient receives DS-REQ with CAR bit set to 1 in data channel #n, it shall also check to see whether there is CI signal in data channel #(*n*+1). If CI signal is detected, the recipient immediately stops consecutive allocation process. Otherwise, the recipient shall precede consecutive allocation process, which is same to another normal allocation as a recipient in data channel #(*n*+1).

## QoS

## Interference management

## Transmit power control

## Multicast

## Broadcast

## Multi-hop operation

## Relative positioning

## Power management

## Security

## Coexistence

An interference sensing before transmission, using a blocking signal and low power transmission of the essential control signal at the fixed position without interference sensing is a basic coexistence scheme.

### Interference sensing

If interference from heterogeneous devices is sensed during IS, the PD shall give up the transmission. In consideration of the WiFi, interference sensing should be performed at least 16us.



Figure 10. an example scenario of interference sensing

### Blocking signal

To prevent resource occupancy of heterogeneous devices, the blocking signal can be transmitted by PDs. One or more subcarriers can be allocated for transmission of the blocking signal.



Figure 11. Conflict avoidance using the blocking

PDs can transmit the blocking signal, before data transmission (Forward Blocking) and after data transmission (Backward Blocking). A blocking concept is applied to the transmission of the control signal (Discovery, Peering, Scheduling). The size of blocking unit is the size of the resources that PDs want to reserve prior to heterogeneous devices.

### Low power transmission

To guarantee the presence of essential control signals at the fixed position, PDs can use any resource whenever PDs need it with the sufficiently low power. For reliability of the transmitted signal, time domain repetition can be applied.



Figure 12. Low power and repeated transmission

## Higher layer interaction

# Physical layer

## Channelization

### Operating frequency bands

PAC shall operate in unlicensed/licensed bands.

## Duplex schemes

PAC shall use TDD duplex scheme.

## Multiplex schemes

(e.g. CDMA, OFDMA)

PAC shall use TDMA/OFDM scheme.

## Frame structure

The ultraframe has a fixed length and appears repeatedly. Ultraframe, superframe, frame has a hierarchical structure.



Figure 13. Hierarchical structure of ultraframe

Every frame consists of a synchronization region, a discovery region, a peering region and a data region. The type of a frame can be the frame type 0 of the frame type 1 according to the configuration. The frame type 0 consists of a synchronization region, a discovery region, a peering region and a data region. Frame type 1 consists of a synchronization region and a data region. The frame type 0 is used if the frame number is 0 and the frame type 1 is used otherwise.

### Synchronization region

The synchronization region is located at the head of a frame. The synchronization signal for the distributed synchronization is sent in the synchronization region. A PD transmits the synchronization signal without interference sensing but the synchronization signal is transmitted by low power for coexistence with heterogeneous devices. The synchronization signal is transmitted repeatedly for reliability. There are two kinds of synchronization signals. One is used at the synchronization region of the first frame in an ultraframe and another is used at other frame.



Figure 14. Synchronization region

### Discovery region

In the discovery region, a discovery signal is transmitted. The discovery region consists of multiple discovery RUs, ISs and GIs. The discovery RU consists of a preamble signal and a discovery signal. The Forward Blocking scheme is used for coexistence. The discovery region consists of 8 blocking unit and one blocking unit consists of 8 discovery RUs. The IS interval is present in front of every blocking unit.



Figure 15. Discovery region

### Peering region

The peering region consists of the Peering-REQ/RSP interval and the PID broadcast interval. The Peering-REQ/ RSP interval consists of multiple PID-REQ RUs, PID-RSP RUs, ISs and GIs. The Peering-REQ RU consists of a preamble signal and a Peering-REQ signal. The Peering-RSP RU consists of a preamble signal and a Peering-RSP signal. Forward & Backward Blocking scheme is applied at Peering-REQ blocking unit, and Forward Blocking scheme is applied at Peering-RSP blocking unit. Four Peering-REQ blocking units and four Peering-RSP blocking units exist in the Peering-REQ/RSP interval. A Peering-REQ blocking unit has four Peering-REQ RUs and a Peering-RSP blocking unit has four Peering-RSP RUs.

In the PID broadcast interval, multiple PID broadcast RUs mapped to PID exist. Forward Blocking scheme is used.



Figure 16. Peering region

### Data region

The data region is comprised of multiple data channels with a fixed size. In case of frame type 0, the data region has 13 data channels because 3 data channels (0~2) are used for the control such as Discovery and Peering. In case of frame type 1, data region has 16 data channels.

A data channel consists of a scheduling interval and a data interval. The scheduling interval consists of DS-REQ RUs, DS-RSP RUs, IS, GIs, and SRI. In case of the DS-REQ RU and the DS-RSP RU, a preamble signal is followed by a DS-REQ signal and a DS-RSP signal, respectively. Forward and Backward Blocking schemes are utilized in both DS-REQ and DS-RSP blocking units. The data interval consists of GIs and multiple pairs of data burst and ACK. The data burst consists of a preamble signal, a BCI (Burst Control Indicator) signal, and a data signal. The BCI signal is used to indicate the modulation order, the code rate, and the length of data signal. ACK consists of a preamble signal and a ACK signal. The number of data bursts and each burst size are determined by the distributed scheduling.



Figure 17. Data region

## Modulation and coding scheme (MCS)

### Data rates

## Multiple antennas