**IEEE P802.15**

**Wireless Personal Area Networks**

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| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) |
| Title | Change Proposal for LRP UWB PHY |
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| Abstract | [Change Proposal for LRP UWB PHY in 802.15.4z] |
| Purpose | [Propose options to LRP UWB PHY definition for enhancing spectrum sharing and payload capacity of secure ranging PHY and related MAC changes for 802.15.4z proposes] |
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**Proposed add-ons and new contributions are highlighted in blue.**

**Modifications of the existing standard are highlighted in red.**

19.2 LRP UWB PHY symbol structure

In base mode, a LRP UWB PHY symbol consists of presence/absence of pulses in 1/TCHIP PRF train.

In extended mode, LRP UWB PHY symbol consists of presence/absence of pulses in 1/TCHIP PRF train generated by convolution code with octal generators (5,7,7,7).

In long range mode, LRP UWB PHY symbol consists of Manchester-encoded groups of 64 pulses (32 on, 32 off) in 2/TCHIP PRF train.

In dual-frequency mode, LRP UWB PHY symbol consists of the presence of pulses at either one of the center frequencies defined in Table TBD, transmitted in 2/TCHIP PRF train.

In extended dual-frequency mode, LRP UWB PHY symbol consists of the presence of pulses at either one of the center frequencies defined in TBD, transmitted in 2/TCHIP PRF train and generated by convolution with octal generators (5,7,7,7).

19.2.1 Pulse repetition period (PRP) definition

The pulse repetition period can be modified from its nominal value of 1µs (PRF=1MHz) to provide for some multi-user access interference rejection. Eight different PRP (or PRF) are provided and are identified by the parameter kPRP. To calculate the exact value of the PRP, it is assumed that the nominal chipping period is split into 128 time slots of equivalent duration of 7.8125 ns. The optional PRP are obtained by subtracting kPRP∙7.8125 ns to the nominal chipping period of 1µs, where kPRP = 1..7. The mandatory PRP is defined by kPRP = 0 (see Table below).

***Table [PRF]***

|  |  |  |  |
| --- | --- | --- | --- |
| **PRP/PRF Mode** | **TCHIP [µs]****TDSYM [µs]** | **peak PRF [MHz]** | **comment** |
| kPRP = 0 | 1 | 1 | mandatory mode |
| kPRP = 1 | 0.9921875 | 1.00787401574803… | optional |
| kPRP = 2 | 0.9843750 | 1.01587301587302… | optional |
| kPRP = 3 | 0.9765625 | 1.024 | optional |
| kPRP = 4 | 0.9687500 | 1.03225806451613… | optional |
| kPRP = 5 | 0.9609375 | 1.04065040650407… | optional |
| kPRP = 6 | 0.9531250 | 1.04918032786885… | optional |
| kPRP = 7 | 0.9453125 | 1.05785123966942… | optional |

19.2.2 Base mode LRP UWB PHY symbol structure

[no changes]

19.2.3 Extended mode LRP UWB PHY symbol structure

[no changes]

19.2.4 Long-range mode LRP UWB PHY symbol structure

[no changes]

19.2.5 Dual-frequency LRP UWB PHY symbol structure

[see draft 15-18-0260-00-004z]

19.2.6 Extended dual-frequency LRP UWB PHY symbol structure

[see draft 15-18-0260-00-004z]

19.5 LRP UWB PHY PSDU

19.1.2 One bit per chip PSDU

In base mode the PSDU is encoded as per 19.2.2; in extended mode the PSDU is encoded as per 19.2.3; and in long-range mode the PSDU is encoded as per 19.2.4; in dual-frequency mode the PSDU is encoded as per 19.2.5; in extended dual-frequency mode the PSDU is encoded as per 19.2.6.

19.1.2 Multiple bits per pulse PSDU (EPC mode)

The enhanced payload capacity (EPC) mode is a mode that provides for higher data capacity in the PSDU of the LRP UWB PHY. This mode uses an M-ary PPM modulation scheme during the PSDU portion of the frame. The symbol structure in EPC mode is illustrated in the Figure [EPC]. The symbol time is split into a PPM “active” part (TPPM) and a guard interval (Tguard).



**Figure [EPC] EPC mode LRP UWB PHY structure using M-ary PPM modulation**

Similar to the variable PRF for multi-user, it is assumed that the nominal chipping period of 1 μs is split into 128 time slots of equal duration of 7.8125 ns. The EPC mode supports different configurations that cover peak PSDU data rates from 3 Mb/s to 10 Mb/s.

These modes are defined by:

1) the order of the PPM scheme (i.e. the number of bit per pulses);

2) the time shift dtPPM of the PPM scheme (2 options: 15.625 ns or 7.8125 ns);

3) the length of the symbol (TDSYM). The eight EPC configurations are described in the table [PPM].

**Table [PPM] PSDU options for Enhanced Payload Capacity (EPC) mode with nominal symbol durations of 1 μs (base and extended modes) and 2 μs (dual-frequency and extended dual-frequency modes) .**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EPC mode** | **PPM****order****(bits/pls)** | **PPM****modulation****type** | **max. pulse****offset (TPPM)** | **TDSYM = 1 μs****(base & extended)** | **TDSYM = 0.5 μs****(dual-freq. and ext. dual-freq.)** |
| Tguard | PSDUdata rate | Tguard | PSDUdata rate |
| **mode “A”**dtPPM=1μs∙(1/128)=15.625 ns | 3 | 8-PPM | 8∙dtPPM =125 ns | 875 ns | 3 Mb/s | 375 ns | 6 Mb/s |
| 4 | 16-PPM | 16∙dtPPM =250 ns | 750 ns | 3 Mb/s | 250 ns | 8 Mb/s |
| **mode “B”**dtPPM=1μs∙(1/128)=7.8125 ns | 4 | 16-PPM | 16∙dtPPM =125 ns | 875 ns | 4 Mb/s | 375 ns | 8 Mb/s |
| 5 | 32-PPM | 32∙dtPPM =250 ns | 750 ns | 5 Mb/s | 250 ns | 10 Mb/s |

When using base and extended modes, the multi-user feature described in section x.x.x can be used jointly with PPM PSDU schemes defined for EPC. In that case, TDSYM is chosen among the value listed in table [PRF] and is used as a base value to calculate guard times. The example below computes the resulting guard time when using kPRP = 7 in EPC mode “A” 16-PPM (TDSYM,nom = 1 μs):

Tguard = TDSYM,nom – kPRP ∙ (TDSYM,nom / 128) - 16∙dtPPM = 1 μs – 7∙ 7.8125 ns – 16 ∙ 15.625 = 695.3125 ns

19.9 LRP UWB Scan Mode and Round-Trip Time-of-Flight

19.9.1 Description

For certain applications using two-way time-of-flight with multiple nodes, LRP UWB PHY can be configured to perform ranging without re-transmitting each time the PPDU of the initiator. In this mode, the initiator is only broadcasting its TX PPDU once and is then listening to the multiple nodes during successive time slots.

In a first implementation of this mode; the first responder returns its answer to the initiator immediately after the return time (trt). The following responders are waiting during an idle period (tWTX) before sending back their PPDU to the initiator. The wait time of the Nth responder is defined as:

tWTX,N=(N-1)∙(tPPDU+2∙tTOF,max+tg)

where

tWTX,N is wait time at the Nth responder to transmit back its answer;

tPPDU is the duration of the PPDU frame;

tTOF,max is the maximum one-way time-of-flight of the signal;

tg is a guard interval expressed as a multiple of nominal symbol period TDSYM.

An example of sequential scan mode is given in the Figure below.



***Figure [SCANa] Two-way time-of-flight using sequential scan mode with one initiator and N responders***

In a second implementation of the scan mode, the responders are sending back frames almost simultaneously. LRP UWB PHY with its low PRF allows interleaving multiple responses while minimizing the interference from simultaneous transmissions. Two mechanisms can be employed in this simultaneous scan mode: 1) inserting a time delay t∆n on the transmitted frame of the nth responder and 2) using a different PRF per responder. An example of simultaneous scan mode is given in Figure [SCANb]. An initiator device with the a priori knowledge of the time delay and the expected PRF wil be able to track these multiple frames with a minimum error rate.



***Figure [SCANb] Two-way time-of-flight using simultaneous scan mode with one initiator and N responders***

19.9.2 Rx-to-Tx Return Time

LRP UWB device capable of Round-Trip Time-of-Flight measurement (defined by the PHY PIB attribute *phyRttof* in Table 10-2) shall implement a **fixed** Rx-to-Tx return time of 16μs (16 chip periods in Base Mode and Extended Modes, 32 chip periods in dual-frequency, Extended dual-frequency and Long Range modes).

19.9.3 Tx-to-Rx return time

LRP UWB device capable of Round-Trip Time-of-Flight measurement (defined by the PHY PIB attribute phyRttof in Table 10-2) shall implement a Tx-to-Rx turnaround time **of at most** 16μs (16 chip periods in Base Mode and Extended Modes, 32 chip periods in dual-frequency, Extended dual-frequency and Long Range modes).