IEEE P802.15
Wireless Personal Area Networks

Project	IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)
Title	**NICT Impulse Radio Ultra-Wideband PHY Proposal to IEEE 802.15.8 (text)**
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Re:	TG8 Call for Proposals (CFP) (15-13-0069-05-0008)
Abstract	This is the text of the NICT Impulse Radio Ultra-Wideband PHY proposal to IEEE 80215.8.
Purpose	This document provides the details of the NICT IR-UWB PHY proposal to IEEE 802.15.8
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1. Table of Contents

1. 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.

2. Definitions

3. Abbreviations and acronyms

PD PAC Device

4. 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

Topology

Reference model

5. MAC layer

MPDU structure

Multiple access

e.g. Contention-based access, Contention-free access

Synchronization procedure

Discovery procedure

Peering procedure

Scheduling

QoS

Interference management

Transmit power control

Multicast

Broadcast

Multi-hop operation

Relative positioning

Power management

Security

Coexistence

Higher layer interaction

6. Physical layer

Channelization

1.1.1. Operating frequency bands

We are using higher UWB band of 6 – 10.25 GHz as specified in "Technical Guidance for 802.15.8 Proposals." We are proposing a single channel in upper UWB band for the system to maximize allowed Tx power level. Channel location and bandwidth are determined by regulation at a given Geo.

1.1.2.

2.

Duplex schemes

Multiplex schemes

(e.g. CDMA, OFDMA)

Frame structure

2.1.1. Discovery frame structure

2.1.2. Data frame structure

Modulation and coding scheme (MCS)

2.1.3. Pulse shape and duration

We do not define a specific pulse shape in order to allow different low-complexity pulse generators. Furthermore, operating bands are not defined will be different at different Geos.
Pulse shape is constrained
In spectrum by the local regulations.
In duration by the Duty Cycle (DC) of no more than DC=1/32=3.1%.

2.1.4. Packet structure

SHR	PHR	PPDU

Fig. 1: **Packet structure.**

As Fig, 1. shows, packet consists of SHR – Synchronization Header, PHR – PHY Header and PPDU – Physical Layer Protocol Data Unit.

2.1.5. SHR Structure

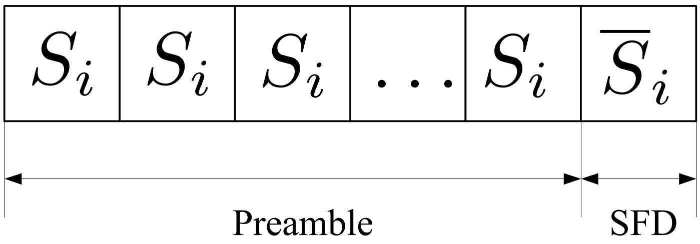

Fig. 2. **SHR structure.**

Preamble consists of M=8 times repetition of the sequence S_i. S_i is one of the Gold sequences of length 31. Since set of Gold sequences of length 31 has 33 sequences, there are 33 virtual channels available per physical channel. Gold sequences of length 31 have relatively short length with good circular autocorrelation properties.

Sync. Frame Delimiter (SFD) represents inversion of S_i used in the preamble.

2.1.6. Symbol structure

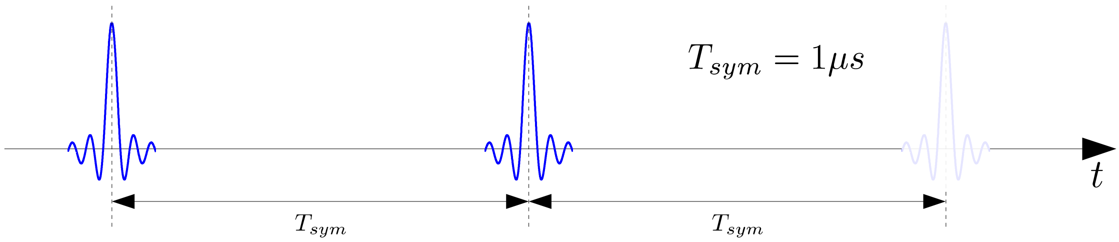

Fig. 3. **Symbol structure**

Symbol structure is shown in Fig. 3. The whole packet, is transmitted using the same symbol structure regardless of the data rate used with On-Off Keying (OOK) modulation. For $k \in \{\mathrm{PR}, \mathrm{SFD}, \mathrm{PSDU}\}$, where k is the symbol index, the same symbol duration of $T_{sym} = 1024\,\mathrm{ns}$ is used. Transmitted pulse waveform is denoted $w(t)$. Hence, transmitted signal for the k-th transmitted symbol is

$$a_k(t) = b_k \exp(j\varphi_k) w(t - kT_{sym}), \tag{1}$$

where $b_k \in \{0, 1\}$ is transmitted bit and $\varphi_k \in \{0, \pi\}$ is pseudo-random sequence used in $k \in \mathrm{PSDU}$ to flatten the spectrum of the transmitted signal, while for $k \in \{\mathrm{PR}, \mathrm{SFD}\}$ $\varphi_k = 0$ is set. Pseudo-random sequence used is the same Gold sequence used in PR and SFD for $b_k \in \{0, 1\}$.

2.1.7. Channel coding and data rates

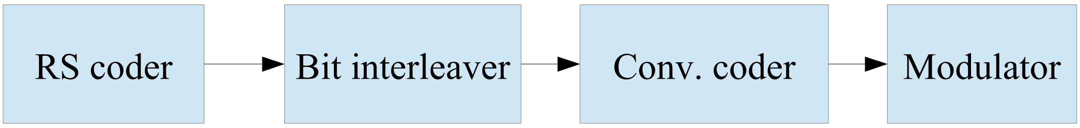

Fig. 4.: **Concatenated coding scheme used.**

Coding is concatenation of outer Reed-Solomon RS6(63,55) codes and inner convolutional codes. Different data rates have different convolutional coding as in Table 1.

Data rate (Kbps)	54.56	109.12	218.25	436.51	873.02
Conv. coding rate	1/4	1/4	1/4	1/2	1/1
Chips per symbol	4	2	1	1	1

Table 1.: **Data rates used with convolutional coding rates and number of chips per symbol.**

Table 2. provides detailed specification of the convolutional codes used. Bit interleaver used is algebraic bit interleaver specified in the UWB PHY of the IEEE 802.15.6-2012 standard for Body Area Networks.

Conv. coding rate	½	¼
Constrained length	3	4
Generators in octal	5 7	13 15 15 17
Free distance	8	13

Table 2.: **Convolutional codes used.**

2.1.8. Symmetrical double-sided two-way ranging

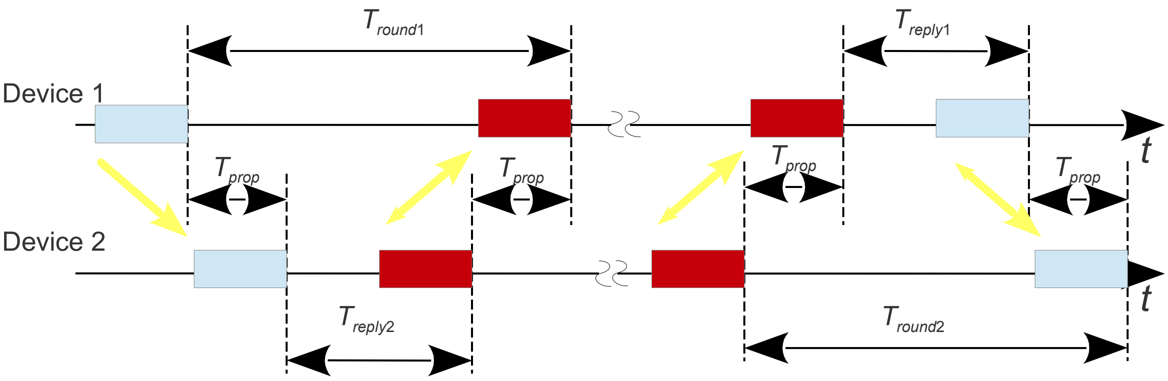

Fig. 4. **Principle of symmetrical double-sided two-way ranging.**

As Fig. 4. shows, symmetrical double-sided two-way ranging is achieved by measuring two round trip times: round trip time from device 1 to device 2 denoted T_{round1} and round trip time from device 2 to device 1 denoted T_{round2}.

T_{prop} denotes propagation time that is being estimated, while T_{reply1} and T_{reply2} represent reply times of device 1 and 2 respectively. Hence, T_{prop} estimate is calculated as follows

$$\hat{T}_{prop} = \frac{1}{4}\left(T_{round1} - T_{reply1} + T_{round2} - T_{reply2}\right). \tag{2}$$

If relative errors of timing at device 1 and 2 are denoted e_1 and e_2 it follows that

$$T_{round1} = T_{round} \times (1 + e_1) \tag{3}$$

$$T_{round2} = T_{round} \times (1 + e_2) \tag{4}$$

$$T_{reply1} = T_{reply} \times (1 + e_1) \tag{5}$$

$$T_{reply2} = T_{reply} \times (1 + e_2) \tag{6}$$

Thus error of T_{prop} estimation is:

$$\hat{T}_{prop} = T_{prop}\left(1 + \frac{e_1 + e_2}{2}\right) \tag{7}$$

Hence, relative error of the range estimation is also in the same order of magnitude as e_1 and e_2, which for crystal oscillators is usually around 20 ppm.

1.1.1.

Multiple antennas