**IEEE P802.15**

**Wireless Personal Area Networks**

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| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) | |
| Title | Text proposal for Pulsed Modulation PHY | |
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| Abstract | [Proposal for pulsed modulation PHY in 802.15.13] | |
| Purpose | [Inform TG13 about most recent work.] | |
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1. **Pulsed Modulation PHY**

The Pulsed Modulation PHY enables moderate data rate from 1 Mbit/s up to few 100 Mbit/s. The main approach is to achieve higher data rates by increasing the optical clock rate but keep the spectral efficiency low. Therefore PAM modulation with variable data rates as defined in Table 1. Controlled by higher layers, the PM PHY includes means to adapt the data rate to varying channel conditions i) by varying the optical clock rates and ii) by varying the modulation and coding scheme. In Table 1, only i) is considered.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Opt. clock rate /MHz** | **Tseq/ns** | **TCP/ns** | **Nseq/optical clock cycles** | **NCP/optical clock cycles** | **MCS** | **Data rate/Mbit/s** |
| 3.125 | 5120 | 160/320 | 16 | 1/2 | 2-PAM  8B10B  RS(255,248) | 2,4 |
| 6.25 | 32 | 2/4 | 4,7 |
| 12.5 | 64 | 4/8 | 9,4 |
| 25 | 128 | 8/16 | 19 |
| 50 | 256 | 16/32 | 38 |
| 100 | 512 | 32/64 | 75 |
| 200 | 1024 | 64/128 | 150 |

**Table 1 Numerology for Pulsed Modulation PHY**

* 1. **PPDU format**

Preamble

Channel estimation

SHR

PHY header

HCS

Optional Fields

PHR

PSDU

PHY payload

**Figure 1 PPDU format for Pulsed Modulation PHY**

The PM PHY uses the PPDU format shown in Figure 1. It consists of a synchronization header (SHR), physical layer header (PHR) and PHY payload (PSDU). Fields are specified in the following sub-clauses.

**1.2 Transmission**

**1.2.1 Synchronization Header (SHR)**

**1.2.1.1 Preamble**

The Preamble enables Schmidl-Cox autocorrelation [1] to achieve time synchronization [2, 3, 4] using a correlation window size of 192. As a base sequence **A**64, a specific pseudo-noise sequence of length 64 is used, see Appendix 1).

In the preamble, the base sequence **A**64 is repeated six times yielding a total sequence length of 384. Each base sequence is multiplied with positive or negative sign as given below which is known to create a sharper peak after the autocorrelation [2, 3, 4].

The total preamble reads **P**384 = [**A**64 **A**64 **- A**64 **A**64 **- A**64 **- A**64].

**1.2.1.2 Channel estimation**

The channel estimation sequence enables block-wise frequency-domain equalization (FDE). The block consists of two parts, a base sequence and a cyclic prefix (CP). Measured in time units, the duration of the base sequence Tseq and the length of the cyclic prefix TCP are maintained, independent of the optical clock rate. The overhead for FDE is always constant at 6/12 %, if the short/long CP is used, respectively. Also without FDE, the CP is transmitted. The consistent block duration enables mixed operation of links with different optical clock rates in the same superframe. When the optical clock rate is increased, the number of optical clock cycles for the sequence and for the CP, i.e. Nseq and NCP, respectively, increase proportionally, see Table 1. As channel estimation sequences, a specific pseudo-noise sequence **A**N given in Appendix 1) of length N=2k (k=5…11) is used, depending on the optical clock rate, so that N=Nseq (see **Table 1).**

**1.2.2 Physical Layer Header (PHR)**

**1.2.2.1 PHY header**

The PHY header contains frame type (Probe or Data) and the length of the PSDU. The PHY header defines the fields given in Table 2.

|  |  |  |  |
| --- | --- | --- | --- |
| **Field** | **Octet** | **Bits** | **Description** |
| FT | 0 | [7:0] | Frame type |
| PSDU\_length | 1-2 | [15:0] | Length of PSDU in optical clock cycles |

**Table 2 PHY header**

FT defines the frame types

FT=0 Data frame (used in MAC e.g. for Data, RTS, CTS, ACK, Feedback, etc.)

FT=1 Probe frame

FT>1 Reserved

The PSDU length scales from 0 up to *aMaxPHYFrameSize.*

**1.2.2.2 HCS**

The HCS uses CRC-16 as defined in Annex C. The HCS bits shall be processed in the transmitter order. The registers shall be initialized to all ones.

**1.2.2.3 Optional fields**

Presence and structure of optional fields depend on the FT defined in the beginning of the PHY header.

If **FT=0** (data frame), optional fields provide descriptors for the modulation and coding scheme (MCS) used, for implicit reference sequences (IRS) and the IRS themselves. IRS enable measurements of the effective channel matrix including the effect of the precoder for single or parallel data streams. The effective channel matrix allows demodulation of data and higher layer control information.

|  |  |  |  |
| --- | --- | --- | --- |
| **Field** | **Octet** | **Bits** | **Description** |
| MCS\_vector | 3-6 | [31:0] | Modulation and Coding Vector for PSDU |
| IRS\_type | 13-14 | [15:0] | Type of IRS |
| NIRS | 15 | [7:0] | Number of IRS |
| IRS | t.b.d | t.b.d. | Block of IRS |

**Table 3 Optional fields for FT=0.**

The MCS\_vector defines the used modulation and coding schemes, being a number for single-stream transmission and a vector for spatial multiplexing with per-stream MCS adaptation. The MCS vector definition is t.b.d..

The most significant bit of the IRS type defines the use of time- or frequency-domain IRS. Time-domain IRS typically apply for transmission without FDE at lower optical clock rates and for single-stream transmission. Frequency-domain IRS enable transmission at higher optical clock rates when using FDE. Moreover, they simplify orthogonal transmission and detection of IRS for multiple streams.

If **FT=1** (probe frame), optional fields provide a time reference, descriptors for explicit reference sequences (ERS) and the ERS themselves. ERS enable measurement of the direct channel matrix from individual transmitters to individual receivers. The most important role of a probe frame is the beacon sent at the beginning of a superframe.

|  |  |  |  |
| --- | --- | --- | --- |
| **Field** | **Octet** | **Bits** | **Description** |
| Time\_stamp | 9-12 | [31:0] | Start of probe frame, 10 ns time resolution |
| ERS\_type | 13-14 | [15:0] | Type of ERS |
| NERS | 15 | [7:0] | Number of ERS |
| ERS | t.b.d | t.b.d. | Block of ERS |

**Table 3 Optional fields for FT=1.**

The most significant bit of the ERS type defines the use of time- or frequency-domain ERS. Time-domain ERS typically apply for transmission without FDE at lower optical clock rates and when using a single transmitter. Frequency-domain ERS enable transmission at higher optical clock rates when using FDE. Moreover, they simplify orthogonal transmission and detection of ERS for multiple transmitters.

IRS and ERS are constructed following the same basic principles.

**1.2.2.3.1. Time-domain RS**

The time-domain RS for the ith data stream/transmitter in case of IRS/ERS, respectively, is constructed by bit-wise logical XOR operation of the base sequence **A**N given in the Appendix 1), where N=Nseq according to the numerology in Tabl*e* 1, and the ith row of the NxN Hadamard matrix **H**k obtained as follows



where N=2k. Note that the sequence in the first row of **H**k contains a sequence with all ones so that the base sequence is reproduced for the first stream/transmitter. All pairs of sequences in **H**k are mutually orthogonal, when they are multiplied bit-wise and results are summed up from j=1…N. The XOR operation with **A**N does not change orthogonality of sequences but it improves their auto- and cross-correlation significantly in case of multi-path effects [5, 6].

**1.2.2.3.2. Frequency-domain RS**

The frequency-domain RS for the ith data stream/transmitter in case of IRS/ERS, respectively, is also constructed using the base sequence **A**N given in the Appendix 1), where N=Nseq according to the numerology in Tabl*e* 1. Frequency-domain RSs are defined as a set of NIRS or NERS OFDM symbols [7]. Each stream/antenna in case of IRS/ERS, respectively, is first identified by a specific comb of subcarriers in the frequency domain.

The comb spacing *Δ* is defined by higher layers taking the fundamental relation

*Δ≤Nseq/NCP*

into account. The definition of *Δ* is a matter of higher layer protocols and conveyed to the receiver in the variables ERS\_type and IRS\_type.

There are

*Ncomb*=*Nseq/NCP*

non-zerosignals (tines) in the comb. The base sequence AN where *N=Ncomb* yield an appropriate definition of the tines in the comb which guarantees a low peak-to-average power ratio after applying the IFFT operation.

By using a single OFDM RS, up to Δ streams/transmitters could be identified. This is achieved by an individual cyclic shift of the comb by an integer numbers

Nshift=0…Δ-1

of the subcarriers, which makes the RS oprtogonal in the frequency domain. However, higher layers shall reserve the shift Nshift = Δ-1 for noise estimation at the receiver. Hence, any subset of streams/transmitters is always smaller than Δ-1.

If the number of streams/transmitters is larger than Δ-1, additional OFDM RS are added. Higher layers shall indicate this by variables NIRS/NERS, accordingly. In order to keep RS for multiple subsets of streams/transmitters orthogonal to each other, the whole OFDM RS is multiplied by mth row of the NxN Hadamard matrix **H**k obtained as follows



where N =NIRS/NERS = 2k.

**1.2.2.4 Header encoding and modulation**



**Figure 2 Transmitter structure.**

The transmitter structure in Fig. 1 is used for the header. Header encoding is based on RS(36,24) code as defined below. 8B10B line coding and 2-PAM modulation apply to the header. Note that, for maintaining a constant average light output, both the systematic output of the FEC ( bits) and the redundant part (*k*-*n* bits) should pass through the line encoder.

**1.2.2.3.1 RS(36,24) code**

t.b.d.

**1.2.3 PHY payload**

**1.2.3.1 General**

The transmitter structure in **Figure 2** is used for the payload data. The payload uses RS(255,248) code with code rate 248/255 with 8B10B line code and 2-PAM modulation.

**1.2.3.2 Scrambler**

Scrambling is foreseen in the coordinated topology to ensure that uncoordinated interference is randomized. In other topologies, scrambling is optional. t.b.d.

**1.2.3.3 RS Encoding**

Systematic RS codes are used for the FEC with GF(256), generated by the polynomial *x*4*+x+*1. For the generators of RS(n, k) codes, see Appendix 2) t.b.d..

Codes rates may vary in fixed steps t.b.d..

The Reed-Solomon code may be shortened for the last block if it does not meet the block size requirements. No zero padding is required for the RS code. A shortened RS code is used for frame sizes not matching code word boundaries via the following operation to minimize padding overhead. Using a RS(n,k) encoder, one can get an shortened RS(n-s, k-s) code as follows:

a) Pad the *k-s* input data symbols with *s* zero symbols.

b) Encode using RS(n, k) encoder.

c) Delete the padded zeros (do not transmit them).

d) At the decoder, add the zeros, then decode.

**1.2.3.3.1 RS(255,248) code**

t.b.d.

**1.2.3.4 Interleaver**

t.b.d.

**1.2.3.5 Line Encoder**

In combination with 2-PAM, the line encoder uses 8B10B. Note that, for maintaining a constant average light output, both the systematic output of the FEC ( bits) and the redundant part (*k*-*n* bits) should pass through the line encoder. For the 8B10B encoding, see ANSI/INCITS 373 and Appendix 3) t.b.d.. See also <http://application-notes.digchip.com/056/56-39724.pdf>

4-PAM is only used in conjunction with HCM defined below. In this case no line coding is used.

**1.2.3.6. Pulse Amplitude Mapping**

The PAM mapper is using 2 or 4 levels. For 2 levels, each input bit is mapped in one symbol. The symbols are mapped to levels as {0, 1} to {0, 1}. With 4 levels, two consecutive bits are combined in a symbol. The symbols are mapped to levels as {00, 01, 10, 11} to {0, . , 1}.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Modulation | Level | FEC RS(n,k) | Line code | HCM | Optical Clock Rates/MHz | Data Rate/Mbps |
| PAM | 2 | (255, 248) | 8B10B | (1,1) | 200/2N with N=0…7 | see Table 1 |
| (36,24) |
| 2 | 1B1B | (7,8) |
| 4 | (15,16) |

**1.2.3.7. HCM Mapping**

Hadamard Coded Modulation (HCM) is a bit to symbol mapper that is applied on the signal after PAM, and removes the need for line coding. In this block, as shown in Figure 180, a block of (where is a power of two) data symbols are inserted into a fast Walsh-Hadamard transform (FWHT). As described in [Ref A], the HCM signal is generated from the data sequence as , where is the binary Hadamard matrix of order [Ref B], and is the complement of . The components of are assumed to be -ary pulse amplitude modulated (PAM), where o for .

As shown in [Ref A], the DC part of HCM signals can be reduced without losing any information, making HCM more average power efficient. Let the first component of () be set to zero and only codewords of the Hadamard matrix be modulated, as proposed in [Ref A]. In this scheme, the average transmitted power is reduced by sending () instead of , An example of DC reduction is shown in Figure 181. The reduced DC level is per HCM symbol and its value can be different for each symbol. This makes the transmitted signals orthogonal to DC bias at a overhead cost on data-rate. The overhead for different ’s are listed in Table 145.

../../UVA%20-%20HCM%20(JSAC)/Main/HCM-TCOM/HCM-Transmitter.pdf

Figure 180. HCM encoder structure

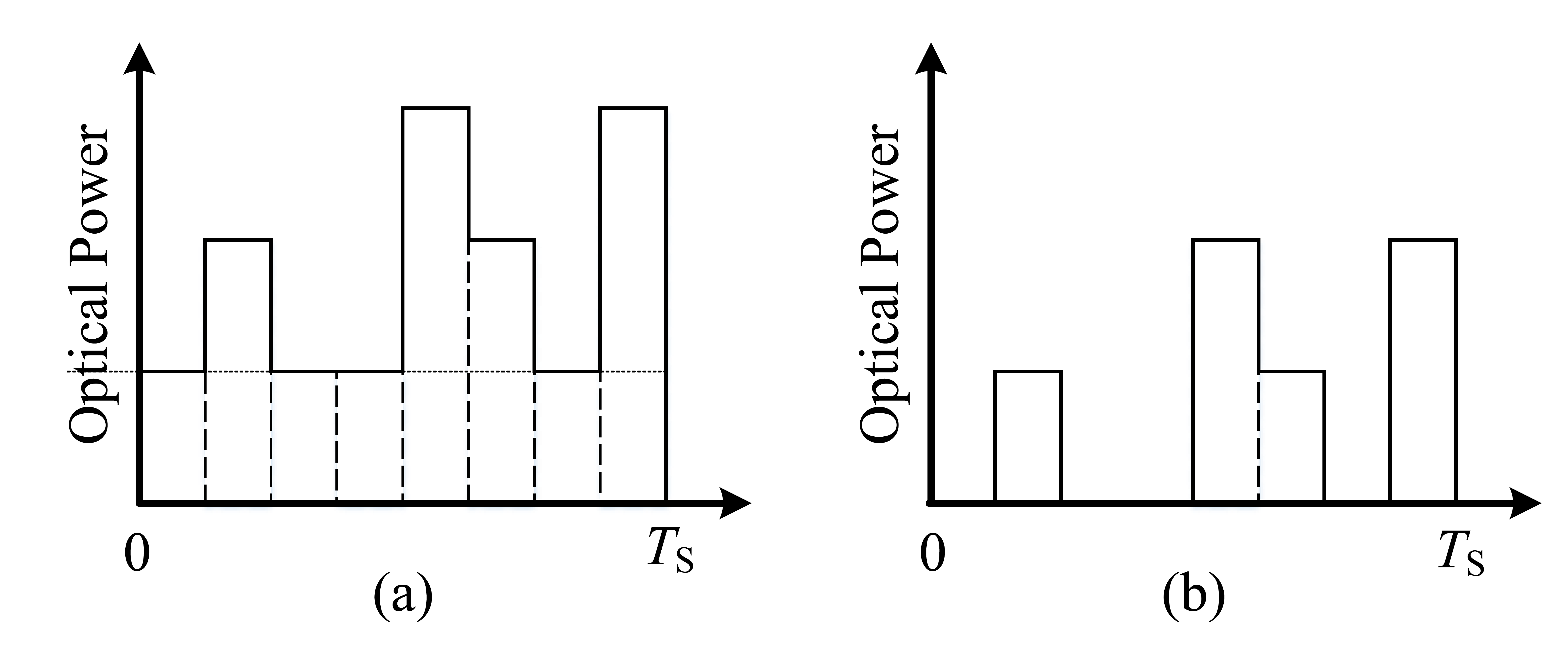


Figure 181. (a) An HCM signal, and (b) its corresponding DC reduced signal.

|  |  |
| --- | --- |
| Size of Hadamard Matrix ( | Data-rate overhead |
| 4 | 25% |
| 8 | 12.5% |
| 16 | 6.25% |
| 32 | 3.125% |

Table 145. Over-head of HCM for different ’s

At the receiver, the decoder is realized by an inverse FWHT (IFWHT) as shown in Figure 182.

../../UVA%20-%20HCM%20(JSAC)/Main/HCM-TCOM/HCM-Receiver.pdf

Figure 182. HCM decoder structure

**1.2.3.8. MIMO transmission**

t.b.d.

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**Appendix**

1. **Pseudo-noise sequences A**N

The following base sequences are the first from two mother sequences of length N=2k with k=1…11 usually used to form a set of Gold sequences. A ‘1’ is added to keep the sequence balanced.

**A**2 = [-1 1]

**A**4 = [-1 1 -1 1]

**A**8 = [-1 -1 1 -1 1 1 -1 1 ]

**A**16 = [-1 -1 -1 1 -1 1 -1 -1 1 1 -1 1 1 1 -1 1]

**A**32 = [ -1 -1 -1 -1 1 1-1 -1 1 -1 1 1 -1 1 1 1 1 -1 1 -1 1 -1 -1 -1 1 -1 -1 1 1 1 -1 1]

**A**64 = [ -1 -1 -1 -1 -1 1 -1 1 -1 1 -1 -1 1 1 -1 -1 1 -1 -1 -1 1 -1 -1 1 -1 1 1 -1 1 1 -1 -1 -1 1 1 1 -1 1 -1 -1 -1 -1 1 1 -1 1 -1 1 1 1 -1 -1 1 1 1 1 -1 1 1 1 1 1 -1 1]

**A**128 = [ -1 -1 -1 -1 -1 -1 1 1 1 -1 -1 -1 1 -1 -1 1 1 1 -1 1 -1 1 1 -1 1 -1 -1 -1 -1 -1 1 -1 1 -1 1 -1 1 1 1 1 -1 1 -1 -1 1 -1 -1 -1 -1 1 1 -1 -1 -1 1 1 -1 1 -1 1 -1 -1 1 1 -1 -1 1 1 1 1 1 -1 -1 1 -1 -1 1 -1 1 -1 -1 -1 1 -1 1 1 1 -1 -1 1 1 -1 1 1 1 -1 1 1 1 1 1 1 -1 1 1 -1 1 1 -1 -1 1 -1 1 1 -1 -1 -1 -1 1 -1 -1 -1 1 1 1 1 -1 1]

**A**256 = [ -1 -1 -1 -1 -1 -1 -1 1 1 -1 1 1 1 1 -1 1 -1 1 1 -1 -1 -1 -1 -1 1 -1 1 -1 1 -1 1 -1 -1 -1 1 1 1 1 1 -1 -1 1 1 1 -1 1 -1 1 -1 -1 1 1 -1 -1 1 1 -1 1 -1 -1 -1 -1 -1 -1 1 -1 -1 -1 -1 1 1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 1 -1 1 -1 1 -1 1 1 -1 1 -1 1 1 1 -1 1 1 -1 1 -1 -1 1 -1 1 1 1 -1 -1 1 1 -1 -1 -1 1 1 -1 -1 -1 -1 1 1 1 -1 -1 1 -1 -1 1 1 1 1 -1 1 1 1 -1 1 -1 -1 -1 1 -1 1 -1 -1 -1 -1 1 -1 -1 1 -1 -1 -1 -1 -1 1 1 1 1 -1 -1 1 -1 1 1 -1 -1 1 -1 1 -1 -1 1 -1 -1 1 -1 1 -1 1 1 1 1 1 -1 1 1 -1 -1 -1 1 -1 -1 1 1 -1 1 1 -1 1 1 -1 -1 1 1 1 1 1 1 -1 -1 -1 1 -1 1 1 -1 1 1 1 -1 -1 -1 1 1 1 -1 1 1 1 1 1 1 1 -1 1 -1 -1 1 1 1 -1 -1 -1 -1 1 -1 1 1 1 1 -1 1]

**A**512 = [ -1 -1 -1 -1 -1 -1 -1 -1 1 1 1 1 -1 -1 -1 -1 1 -1 -1 -1 1 1 1 1 -1 1 -1 -1 1 1 -1 -1 1 -1 -1 1 -1 -1 -1 -1 1 -1 1 1 1 1 -1 -1 -1 1 1 -1 -1 1 1 1 1 -1 1 1 -1 1 1 1 -1 1 -1 1 -1 -1 -1 1 -1 1 -1 -1 -1 -1 1 1 -1 1 1 -1 1 -1 -1 -1 1 1 -1 -1 -1 1 1 1 1 1 1 -1 -1 -1 1 -1 -1 -1 1 -1 1 1 -1 -1 -1 -1 1 -1 1 -1 1 1 -1 1 -1 1 1 1 1 1 1 -1 1 -1 1 -1 1 -1 1 -1 -1 -1 -1 -1 1 -1 1 -1 -1 1 -1 1 1 1 1 1 -1 -1 1 -1 -1 -1 1 -1 -1 1 -1 -1 1 -1 1 -1 -1 1 1 1 1 1 -1 1 -1 -1 -1 1 -1 -1 -1 -1 -1 1 1 1 -1 -1 -1 -1 1 1 -1 -1 1 -1 1 1 -1 -1 1 -1 1 -1 -1 -1 1 1 1 -1 -1 1 -1 1 1 1 -1 1 -1 -1 -1 -1 -1 -1 -1 1 -1 1 1 -1 1 -1 -1 1 1 1 -1 1 -1 1 1 -1 -1 1 1 1 -1 -1 1 1 1 1 1 1 1 -1 -1 1 1 -1 -1 1 1 -1 1 -1 1 -1 -1 1 1 -1 1 1 -1 -1 -1 -1 -1 -1 1 -1 -1 1 -1 1 1 -1 1 1 -1 1 1 -1 -1 1 -1 -1 -1 -1 -1 -1 1 1 -1 1 -1 -1 1 -1 1 -1 1 1 1 1 -1 1 -1 1 1 1 -1 1 1 -1 -1 -1 1 -1 -1 1 1 -1 1 -1 -1 -1 -1 1 -1 -1 1 1 1 1 -1 -1 1 -1 1 -1 1 -1 1 1 -1 -1 -1 1 1 -1 1 1 1 1 -1 -1 1 1 1 -1 1 1 1 1 -1 1 1 1 1 1 1 1 1 -1 1 1 1 -1 1 1 1 -1 -1 1 1 -1 1 1 1 -1 -1 -1 1 -1 1 -1 1 -1 -1 1 -1 -1 1 1 1 -1 -1 -1 1 1 1 -1 1 1 -1 1 -1 1 -1 1 1 1 -1 -1 1 -1 -1 1 1 -1 -1 -1 -1 -1 1 1 -1 -1 -1 -1 1 1 1 -1 1 -1 -1 1 -1 -1 -1 1 1 -1 1 -1 1 1 -1 1 1 1 1 1 -1 1 1 -1 -1 1 1 -1 -1 -1 1 -1 1 1 1 -1 -1 -1 -1 -1 1 -1 -1 -1 -1 1 1 1 1 1 -1 1]

**A**1024 = [-1 -1 -1 -1 -1 -1 -1 -1 -1 1 1 1 -1 -1 -1 1 1 1 -1 1 1 -1 -1 -1 1 -1 -1 1 1 -1 1 -1 1 -1 -1 -1 1 -1 -1 -1 -1 1 -1 1 -1 1 1 1 -1 -1 -1 -1 1 -1 1 1 -1 1 -1 1 -1 1 1 1 1 1 -1 1 -1 -1 -1 -1 -1 -1 -1 -1 1 -1 1 -1 1 -1 1 -1 1 -1 -1 -1 -1 1 -1 1 1 1 1 -1 -1 -1 1 -1 1 1 -1 1 1 1 -1 -1 1 1 -1 1 -1 -1 1 -1 1 -1 -1 1 1 -1 -1 -1 -1 1 -1 1 -1 -1 1 1 1 -1 -1 1 1 -1 -1 -1 -1 -1 -1 1 1 -1 1 -1 1 -1 1 -1 1 1 -1 -1 1 1 -1 -1 1 1 -1 1 -1 1 1 -1 -1 -1 -1 -1 1 -1 1 1 -1 -1 -1 1 1 1 1 -1 1 1 1 -1 -1 1 -1 -1 1 1 -1 1 1 1 -1 1 -1 1 1 -1 -1 1 -1 -1 -1 -1 1 -1 -1 -1 1 -1 1 -1 1 -1 -1 -1 1 1 -1 -1 1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 1 -1 -1 -1 1 -1 1 -1 1 1 -1 -1 -1 1 -1 1 1 1 1 1 -1 -1 -1 -1 1 -1 -1 1 -1 -1 -1 1 1 1 1 -1 -1 1 1 1 -1 1 1 -1 1 -1 1 1 -1 1 -1 -1 1 1 -1 -1 1 -1 1 1 1 -1 1 1 1 -1 1 -1 -1 1 -1 1 1 -1 1 -1 -1 -1 1 -1 1 1 -1 -1 1 1 1 -1 1 -1 -1 1 1 1 1 1 1 -1 1 -1 1 1 -1 1 1 -1 1 -1 -1 -1 -1 -1 1 -1 -1 -1 -1 1 1 1 -1 -1 1 1 1 -1 -1 1 -1 -1 -1 1 -1 -1 1 1 1 1 -1 -1 -1 -1 1 1 -1 1 1 -1 -1 -1 1 1 -1 1 -1 -1 1 1 1 -1 1 1 1 1 -1 -1 1 -1 -1 -1 -1 -1 -1 -1 1 1 -1 -1 -1 1 1 1 -1 -1 1 -1 1 -1 1 1 -1 1 -1 1 1 1 1 -1 1 1 1 1 -1 1 1 -1 1 -1 -1 1 -1 -1 -1 -1 -1 1 -1 1 -1 -1 -1 1 1 1 -1 1 -1 -1 -1 1 1 -1 1 1 1 1 -1 -1 -1 -1 -1 1 -1 -1 1 -1 1 -1 1 -1 1 1 1 -1 1 -1 -1 -1 -1 1 -1 -1 1 1 -1 -1 -1 1 1 -1 -1 -1 -1 -1 1 1 1 1 1 -1 -1 -1 1 1 -1 1 1 -1 1 -1 1 -1 -1 1 1 -1 1 -1 -1 -1 -1 1 1 -1 1 -1 -1 -1 1 1 1 1 1 -1 1 -1 1 -1 -1 1 -1 -1 1 1 -1 -1 1 1 1 1 -1 -1 1 -1 1 -1 -1 1 -1 -1 -1 1 -1 1 1 1 -1 1 -1 1 -1 -1 -1 -1 -1 -1 1 -1 1 1 1 -1 -1 -1 1 1 -1 -1 1 -1 -1 -1 1 1 -1 1 -1 1 1 1 -1 -1 1 -1 1 1 1 1 1 1 -1 -1 1 1 -1 1 1 -1 1 1 1 -1 1 1 1 1 1 -1 1 1 -1 -1 1 -1 -1 1 -1 1 1 -1 -1 -1 -1 1 1 -1 -1 1 -1 1 -1 1 -1 -1 1 1 1 1 -1 1 -1 -1 -1 1 -1 -1 1 -1 1 1 1 -1 -1 1 1 1 1 -1 1 1 -1 -1 -1 -1 -1 -1 -1 1 -1 -1 -1 1 1 1 -1 -1 -1 -1 1 1 1 1 1 1 -1 -1 -1 1 -1 -1 1 -1 -1 1 1 1 -1 1 -1 1 1 1 -1 1 1 -1 -1 1 1 -1 1 1 1 1 1 -1 -1 1 -1 1 1 -1 1 1 -1 -1 -1 -1 1 -1 -1 -1 -1 -1 1 1 1 -1 1 -1 1 -1 1 -1 -1 1 -1 1 1 1 1 -1 1 -1 1 1 1 1 1 1 1 -1 1 -1 -1 1 -1 -1 1 -1 -1 -1 -1 1 1 -1 -1 -1 -1 1 1 1 -1 1 1 1 -1 -1 -1 -1 -1 -1 1 -1 -1 1 1 1 -1 -1 -1 1 -1 1 -1 -1 1 -1 1 -1 1 1 1 1 -1 -1 1 1 -1 -1 1 -1 -1 1 1 1 1 1 -1 -1 1 1 1 1 1 1 1 1 -1 -1 1 -1 -1 1 -1 -1 1 -1 1 -1 -1 -1 1 -1 1 -1 -1 -1 -1 1 1 1 1 -1 1 -1 1 -1 1 1 -1 1 1 1 1 -1 1 -1 -1 1 1 -1 1 1 -1 -1 1 1 1 1 1 -1 1 1 1 -1 1 1 -1 1 1 1 1 1 1 -1 1 1 1 1 1 1 1 1 1 -1 1 1 -1 1 1 -1 1 1 -1 -1 1 -1 1 1 -1 -1 1 -1 1 -1 -1 -1 -1 -1 1 1 -1 -1 1 1 1 -1 -1 -1 -1 -1 1 1 -1 1 1 1 -1 -1 -1 1 -1 -1 -1 -1 -1 -1 1 1 1 1 -1 -1 -1 1 1 1 1 1 1 1 -1 1 ]

1. **Generators of RS(n, k)**

t.b.d.

1. **8B10B encoding**

t.b.d.

Beacon fields moved to MAC layer

|  |  |  |  |
| --- | --- | --- | --- |
| **Field** | **Octet** | **Bits** | **Description** |
| OWPAN ID | 1 | [7:0] | OWPAN ID |
| SID | 2-3 | [15:0] | Source ID |
| DID | 4-5 | [15:0] | Destination ID |
| OWPAN name | 22-53 | [255:0] | Character-based ID of OWPAN |
| CAP duration after beacon | 13-16 | [31:0] | Duration of CAP in SF, 10 ns resolution |
| BPOS | 11-12 | [15:0] | Beacon slot in each frame, 10 ns resolution |