

Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Samsung/ETRI's EFC: HBC PHY proposal]

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Re: [Response to IEEE 802.15.6 Call for Proposals]

Abstract: [PHY proposal for 802.15.6 Requirements]

Purpose: [To be considered in IEEE 802.15.6]

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Proposal Scope

- Data exchange for control, personal health care, entertainment, etc.
 - Periodical data, random bursts, etc.
- Everyday operation environment: home, office, outdoors, etc.
- On-body to On-body (CM3)
 - Devices should be on the body surface or near a person as long as the person can reach and make contact
- Data rate ranges up to 10 Mbps
- Low power consumption

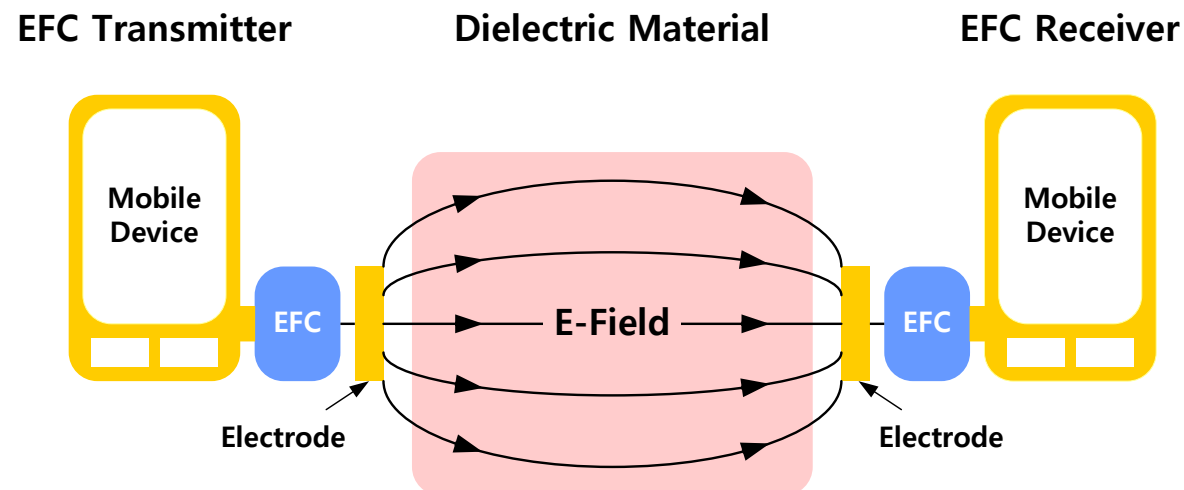
Human Body Communication

- Features of HBC
 - Allows quick and easy connection
 - Intuitive Service, Quick Setup, Easy Use
 - Afford Privacy & Security
 - Utilizes Direct Digital Signaling → FSDT (Frequency Selective Digital Transmission)
 - Easy to Implement
 - Low Power Consumption
 - Small Size



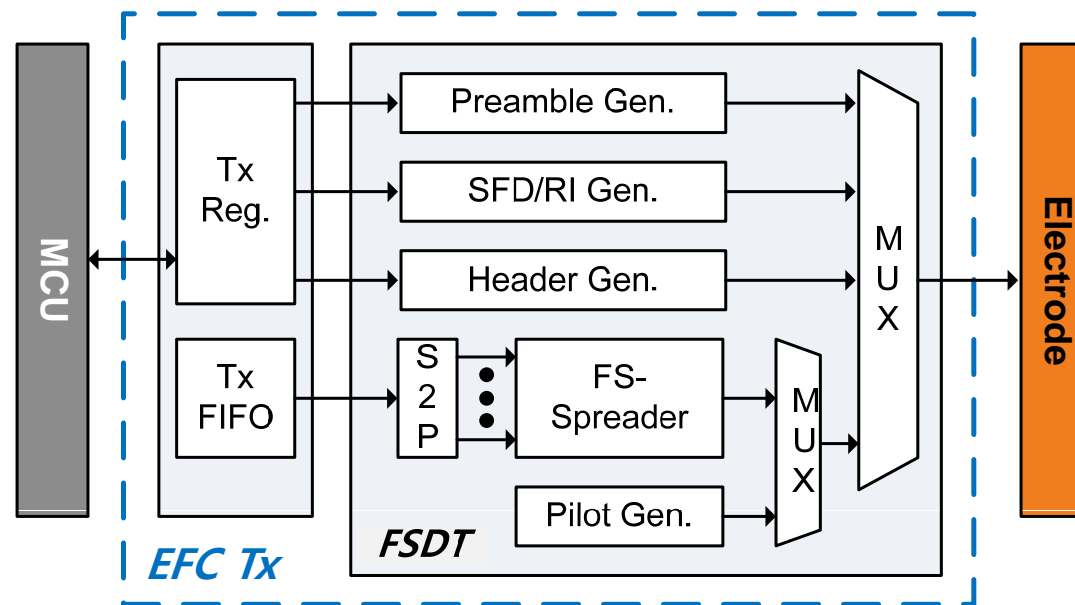
Electric Field Communication

- Properties of EFC
 - Data transmitted by inducing electric-field and capacitive coupling on dielectric material
 - Human body has about 300~500 times better permittivity than air
 - Facilitates FSDT and enables HBC
 - No Antenna, less complex
 - Extremely low power consumption



System Block Diagram

- Data Modulation: FS-Spreader (Orthogonal Code + FSC)
- Scalable Data rate: Up to 10 Mbps



FS : Frequency Selective
FSC : Frequency Shift Code

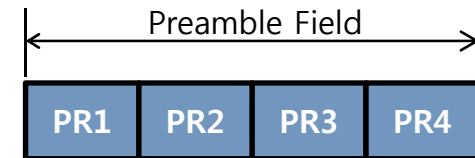
Packet Structure

- Consists of Preamble (PR), SFD (Start Frame Delimiter), and payload
- In a PHY payload (PSDU), MAC header, MAC payload, and FCS (Frame Check Sequence) are included
- PHY payload size: < 1 K octets

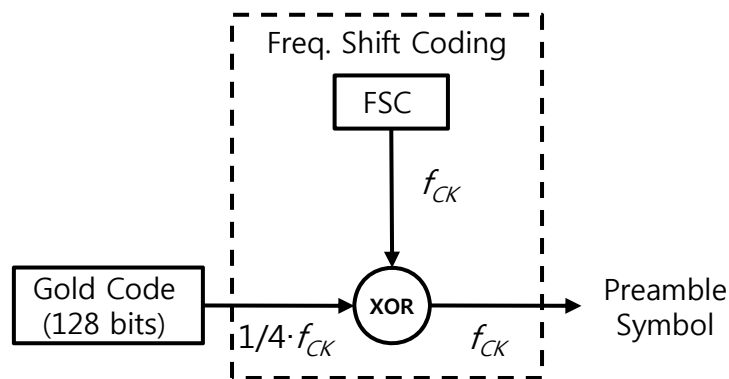


Signal Generation (1/4)

- Preamble
 - Preamble symbol repeated 4 times
 - 1 preamble length: 128-bit Gold sequence \times FSC
 - FSC: Frequency Shift Code
 - Repeated [0 1]
 - Operation freq. = f_{CK}



1 Preamble Symbol Generation



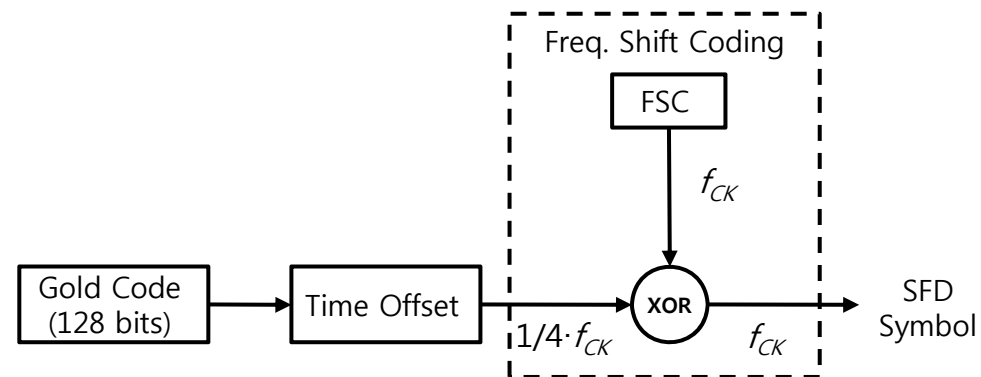
Preamble length

Preamble Symbol Generation	Preamble 1 Symbol Length	Preamble Length \times 4
128-bit Gold code \times FSC 4-chip	512 chip	2048 chip

Signal Generation (2/4)

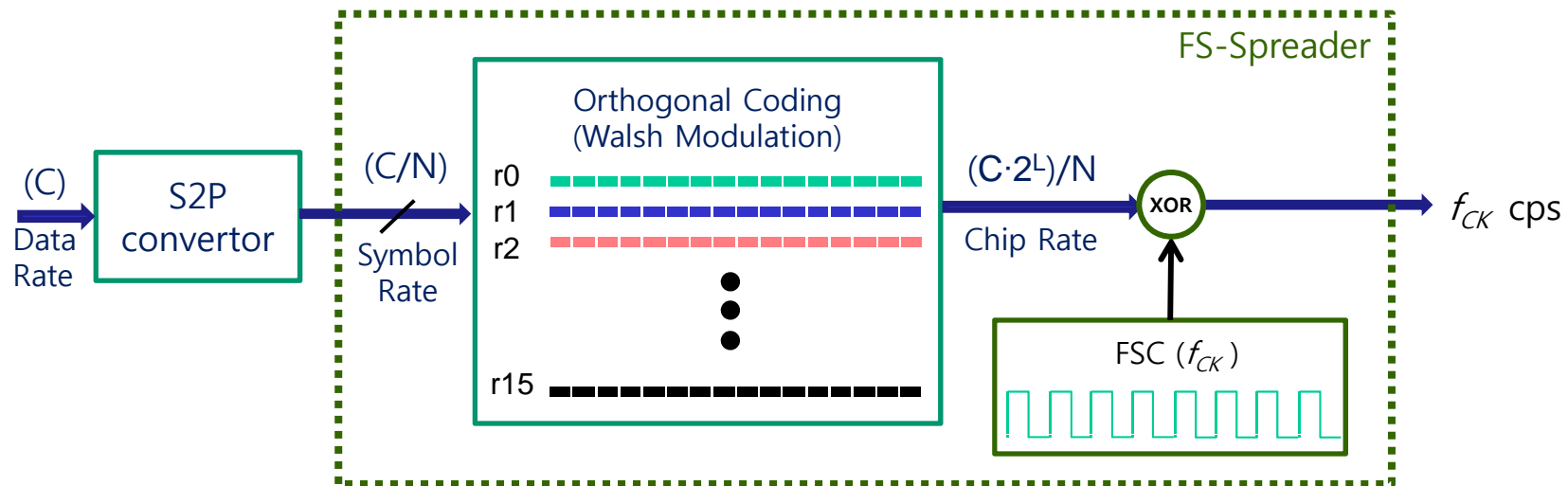
- Start Frame Delimiter (SFD)
 - SFD field : 128-bit Gold sequence \times FSC + time offset(Rate Indicator)
 - FSC: Repeated [0 1]
 - Operation freq. = f_{CK}

SFD Generation



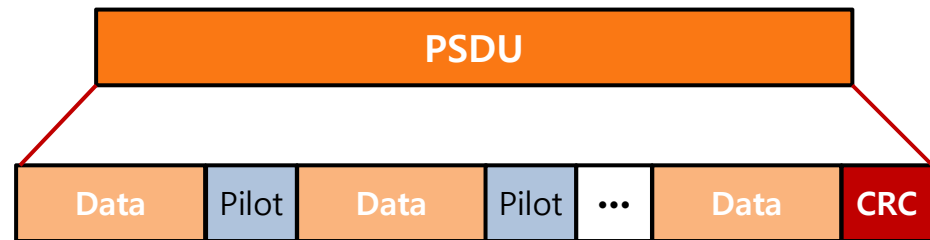
Signal Generation (3/4)

- PHY Header/PSDU Generation
 - 1 symbol : 16-bit \times FSC
 - FSC: Repeated [0 1]
 - Operation freq. = f_{CK}
 - Signal bandwidth depends on data rate (C), symbol conversion rate (1/N), and the length of orthogonal code (2L)



Signal Generation (4/4)

- Pilot sequence use SFD sequence
 - Used to compensate for clock drift
 - Inserted periodically
 - Indicated in PHY header

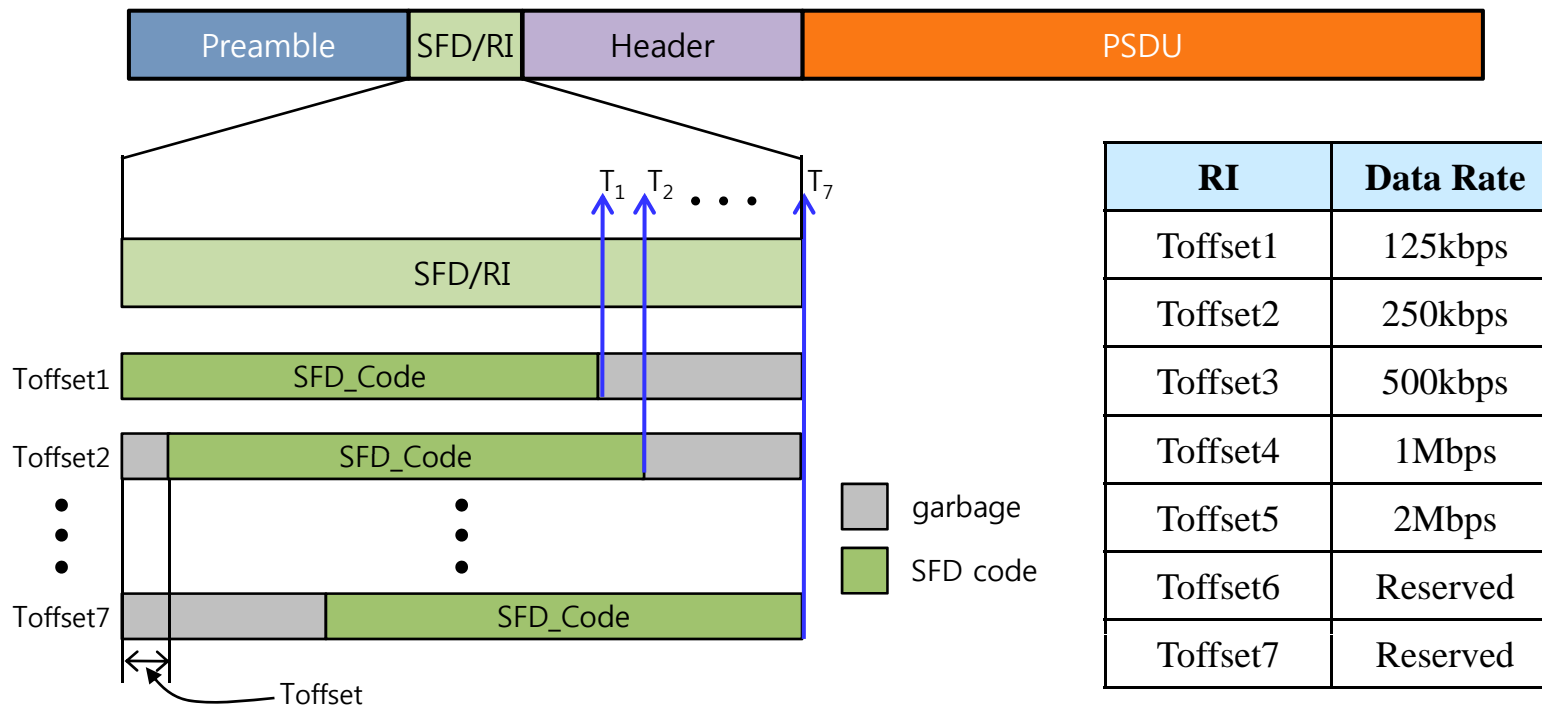


Pilot Info Field [†]	Insertion Period
000	16 byte
001	32byte
010	64 byte
011	128 byte
100	256 byte
101	512 byte
110	No pilot insertion

[†] in PHY Header

Rate Indicator (1/2)

- RI uses SFD to indicate data rate: 7 classes
 - Both PHY header and PSDU transmitted at the same data rate
 - Provides throughput efficiency, especially for high data rates



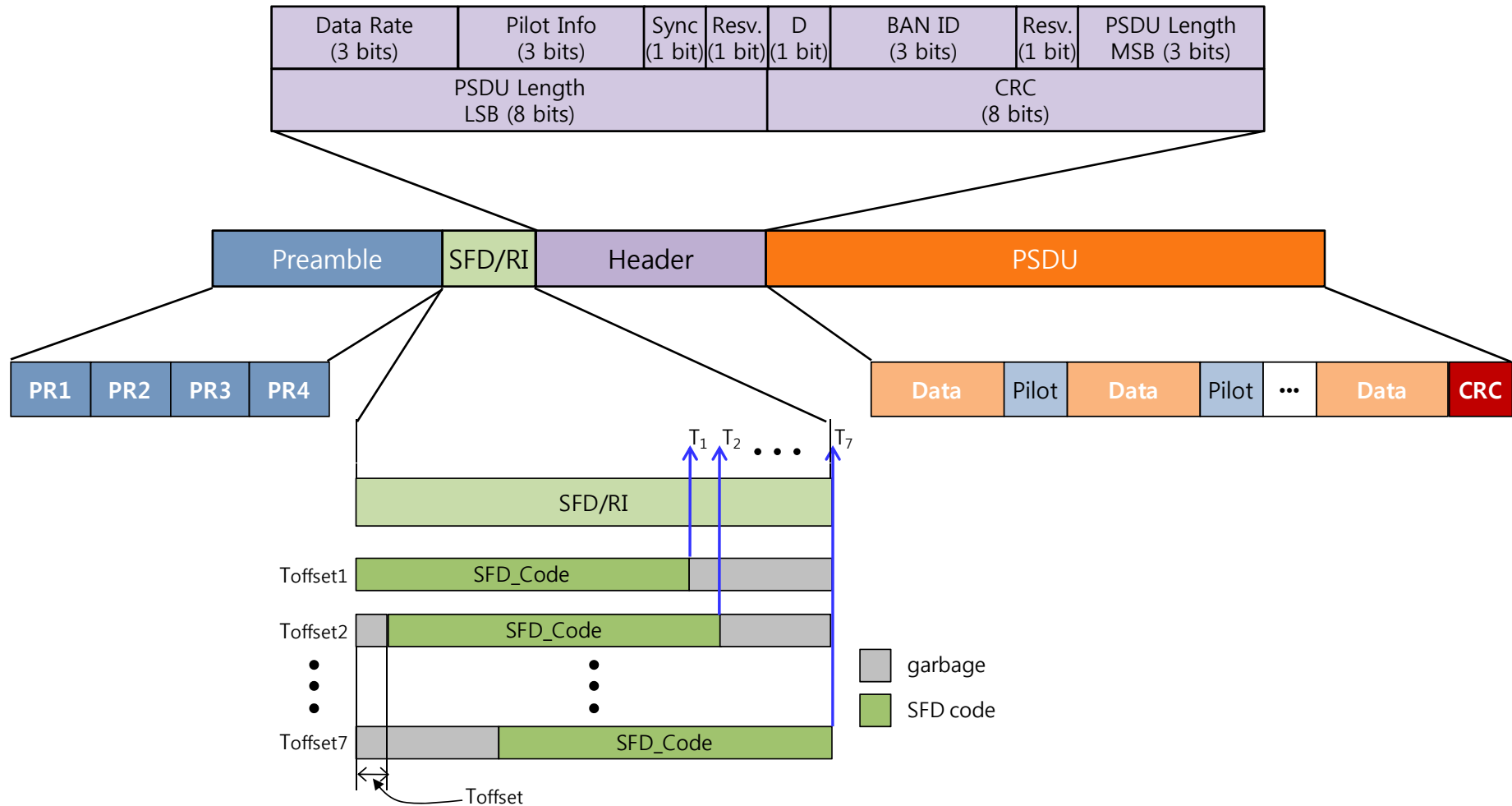
Rate Indicator (2/2)

- May also use the traditional method using Data Rate Field (DRF) in PHY header
 - One method selected during initial handshaking of two devices
 - Master device selects the desired method
 - During handshaking, DRF method is used to indicate the data rate

DRF [†]	Data Rate
000	125kbps
001	250kbps
010	500kbps
011	1Mbps
100	2Mbps
101	Reserved
110	Reserved
111	Reserved

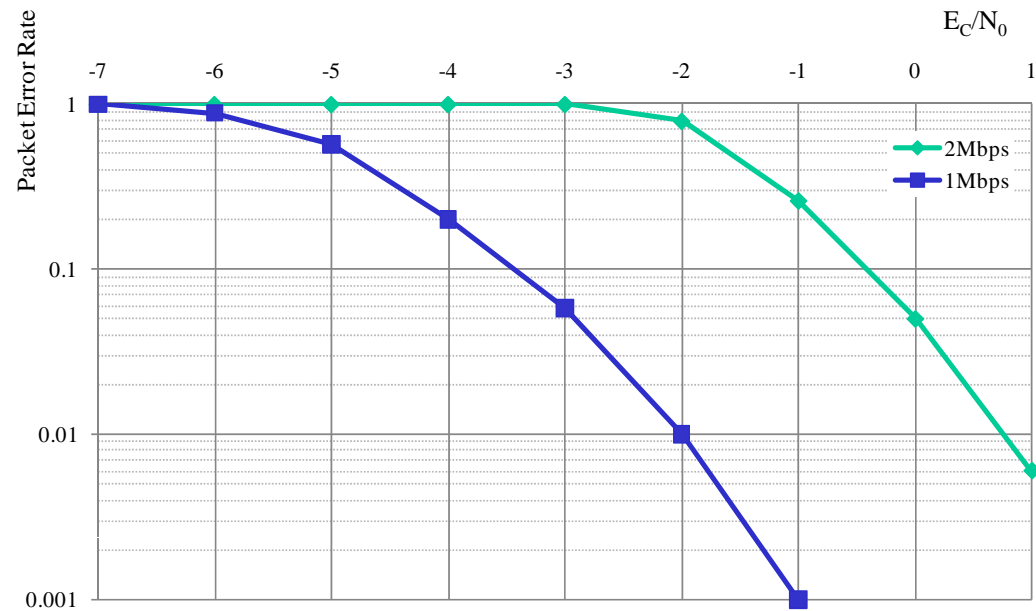
[†] in PHY Header

Packet format



Simulated AWGN Performance

- AWGN channel
- Simulated in MATLAB in case of two samples per chip
- Symbol sync. & frame sync. operations are considered
- 1 & 2 Mbps with 1Koctets payload



Link Budget

Parameter	Symbol	Value	Unit
Data Rate	R	2	Mb/s
Average Tx Power ⁽¹⁾	P_{TX}	-16	dBm
Path Loss ⁽²⁾	P_L	54	dB
Average Rx Power ($P_{RX}=P_{TX}-P_L$)	P_{RX}	-70	dBm
Rx Noise Figure	NF	9	dB
Average Noise Power per bit ($P_N = -174 + 10\log_{10}(R) + NF$)	P_N	-102	dBm
Minimum required E_b/N_o for BER= 10^{-6}	$E_b/N_o _{req}$	7	dB
Implementation Loss	I_L	3	dB
Link Margin ($LM = P_{RX} - P_N - E_b/N_o _{req} - I_L$)	LM	22	dB
Minimum Rx Sensitivity Level ($S_{RX} = P_{RX} - LM$)	S_{RX}	-92	dBm

(1) Voltage-mode transmission

(2) Sec. 8.2.2. Body surface to body surface CM3 (Scenario S4 & S5) for 5-50 MHz
 “Channel Model for Body Area Network (BAN)” [IEEE 802.15-08-0780-09-0006]

Low Power Architecture

- Transmitter
 - Implemented with only digital circuits and share one electrode with receiver
- Receiver
 - No need for blocks related to RF carrier signals such as mixer or VCO
- MAC protocol
 - Merged proposal being prepared

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