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

Submission Title: Initial proposal O-QPSK PHY for Long Range

Date Submitted: July 16, 2024

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Abstract: Overview of proposed resolutions

Purpose: Discussion

Introduction:

- A Long Range PHY is proposed that is suitable for low-cost implementation
- Reusing a big part of the O-QPSK 2.4 GHz PHY [1]
- Compatible with existing channel plans in Wi-SUN
- Meeting the sensitivity requirement as stated in the PAR

[1] IEEE 802.15.4-2020 - clause 12

Why O-QPSK:

- Compatible with existing Wi-SUN channel plans and channel spacings
  - Use same channel hopping and channel access schemes as the legacy FSK PHYs
- Spreading helps with frequency offset tolerance.
  - E.g. FSK, at mod-index = 1, at 10 kbps:
    - Limits frequency tolerance to 5 kHz → 5 ppm
  - E.g. O-QPSK at 10 kbps with SF = 8:
    - Limits frequency tolerance of 25 ppm
- Supports low-cost implementation
  - SUN O-QPSK is not associated with low-cost devices
    - High development cost + additional chip area (chip whitening, 4x higher SF)
- Proven and wide-spread O-QPSK DSSS technology
  - Already used by several standards like Zigbee and Thread
  - > 1 Billion devices deployed
  - Supported by several device manufactures

Reusing the O-QPSK (1):

- Use same symbol-to-chip mapping as the O-QPSK PHY for 2.4 GHz. See clause 12.2.5:

Table 12-1—Symbol-to-chip mapping for the 2450 MHz and 2380 MHz bands

Data symbol	Chip values (c_0 c_1 … c_{30} c_{31})
0	1 1 0 1 1 0 0 1 1 1 1 0 0 0 0 1 1 0 1 0 1 0 0 1 0 0 0 1 0 1 1 1 0
1	1 1 1 0 1 1 0 1 1 0 0 1 1 1 0 0 0 0 1 1 0 1 0 1 0 0 1 0 0 0 1 0
2	0 0 1 0 1 1 1 0 1 1 0 1 1 0 0 1 1 1 0 0 0 0 1 1 0 1 0 1 0 0 1 0
3	0 0 1 0 0 0 1 0 1 1 1 0 1 1 0 1 1 0 0 1 1 1 0 0 0 0 1 1 0 1 0 1
4	0 1 0 1 0 0 1 0 0 0 1 0 1 1 1 0 1 1 0 1 1 0 0 1 1 1 0 0 0 0 1 1
5	0 0 1 1 0 1 0 1 0 0 1 0 0 0 1 0 1 1 1 0 1 1 0 1 1 0 0 1 1 1 0 0
6	1 1 0 0 0 0 1 1 0 1 0 1 0 0 1 0 0 0 1 0 1 1 1 0 1 1 0 1 1 0 0 1
7	1 0 0 1 1 1 0 0 0 0 1 1 0 1 0 1 0 0 1 0 0 0 1 0 1 1 1 0 1 1 0 1
8	1 0 0 0 1 1 0 0 1 0 0 1 0 1 1 0 0 0 0 0 0 1 1 1 0 1 1 1 1 0 1 1
9	1 0 1 1 1 0 0 0 1 1 0 0 1 0 0 1 0 1 1 0 0 0 0 0 0 1 1 1 0 1 1 1
10	0 1 1 1 1 0 1 1 1 0 0 0 1 1 0 0 1 0 0 1 0 1 1 0 0 0 0 0 0 1 1 1
11	0 1 1 1 0 1 1 1 1 0 1 1 1 0 0 0 1 1 0 0 1 0 0 1 0 1 1 0 0 0 0 0
12	0 0 0 0 0 1 1 1 0 1 1 1 1 0 1 1 1 0 0 0 1 1 0 0 1 0 0 1 0 1 1 0
13	0 1 1 0 0 0 0 0 0 1 1 1 0 1 1 1 1 0 1 1 1 0 0 0 1 1 0 0 1 0 0 1
14	1 0 0 1 0 1 1 0 0 0 0 0 0 0 1 1 1 0 1 1 1 1 0 1 1 1 0 0 0 1 1 0 0
15	1 1 0 0 1 0 0 1 0 1 1 0 0 0 0 0 0 0 1 1 1 0 1 1 1 1 0 1 1 1 0 0 0

Reusing the O-QPSK (2):

- Use same preamble and SFD:

12.1.2 SHR field format

12.1.2.1 General

The SHR field shall be formatted as illustrated in Figure 12-2.

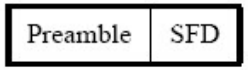

Figure 12-2—Format of the SHR

12.1.2.2 Preamble field

The length of the Preamble field for the O-QPSK PHYs shall be 8 symbols (i.e., 4 octets), and the bits in the Preamble field shall be binary zeros.

12.1.2.3 SFD field

The SFD is a field indicating the end of the SHR and the start of the packet data. The SFD shall be formatted as illustrated in Figure 12-3.

Bits: 0	1	2	3	4	5	6	7
1	1	1	0	0	1	0	1

Figure 12-3—Format of the SFD field

Channel spacing and chip rate:

- For example, at 100 kcps (data rate 12.5 kbps)
  - Channel spacing of 200 kHz is appropriate
- 200 kHz channels are defined in:
  - 802.15.4 (clause 19.5, Table 19-14)
  - Wi-SUN PHY TPS

What could be different, compared to O-QPSK PHY:

- Lower chip rate
  - Standard O-QPSK 2.4 GHz PHY: 2Mcps for 250 kbps data rate
  - Example Long-Range PHY: 100 kcps for 12.5 kHz data rate
- PHR copied from SUN-FSK
  - May support Mode-Switch PHR so that the O-QPSK PHY can be used as base-PHY
  - It may be desirable to have the PHY with the longest range as base PHY
- FCS copied from SUN-FSK
  - Either 16 or 32 bit, signaled in PHR
- FEC (optional)
  - Note that FEC prolongs packet duration → higher probability of collisions.

Sensitivity:

- Better than -120 dBm @ 10 kbps

Thank you!