IEEE P802.15

Wireless Personal Area Networks

Project	IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)
Title	**Merits of the ULP-GFSK PHY**
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Re:	Merits of ULP-GFSK
Abstract	This document describes the merits of the ULP-GFSK PHY as specified in 802.15.4q.
Purpose	To provide direction towards a low power PHY specification for the IEEE802.15.4 standard
Notice	
Release	

Merits of the ULP-GFSK PHY as specified in 802.15.4q

The ULP-GFSK PHY was designed with low-power as priority. There are several essentials specified by the ULP-GFSK PHY that will significantly prolong the battery life time. This document summarize these essentials.

Options for higher data rate

Higher data rate capabilities in IEEE 802.15.4q reduces the on-air time which saves energy. The highest rate specified in the 4q draft is 1 Mbps which is 2.5 times higher than available in the SUN-FSK PHY. The added advantage is a lower interference footprint resulting in fewer collisions and retransmissions.

Rate Switch

The Rate Switch is signaled in the PHR by the Rate Switch bit. When enabled the Rate Switch is seamless between PHR in 2GFSK and PSDU in 4GFSK. The modulation indices of the 2GFSK and 4GFSK modulation types are specified such that the outer deviation is identical and hence the modulation bandwidth is close to identical. The seamlessness, simplicity and ease of implementation makes the Rate Switch feature unique. Nodes communicating with sufficient link budget can use the Rate Switch to reduce the on time in both transmitting node as well as the receive node and save energy on both sides of the link.

Overhead Reduction

IEEE 802.15.4q is energy efficient as it utilizes shorter preambles and PHY header. Consequently, 15.4q is more energy efficient than PHY 802.15.4f, 802.15.4g and 802.15.4k. As an example: transmission of 4 data Bytes, followed by a short ack. In MR-FSK this will take 23 Bytes (PANID and short addresses) for the data transfer and 13 Bytes for the short ack. Using the ULP-GFSK PHY both data transfer and short ACK are reduced by 3 Bytes = 20% saving. These savings are in addition to afore mentioned savings.

Asymmetric Link Networks

The ULP-GFSK PHY introduces the Asymmetric Link Networks (ALN) which has great potential to save energy in all end nodes of a star network by alleviating their transmit and receive requirements.

An Asymmetric Link Network (ALN) may be formed in a star network. A device being part of an ALN will have a different MCS for transmit compared to its receive MCS. The formation of an ALN may be particularly useful when the central coordinator device employs a higher receive sensitive and transmit power compared to the end node devices in the network. In an ALN the coordinator is preferably a mains powered device which may leverage its excess in sensitivity and transmit power to alleviate these requirements in the end node devices. Lowering the requirements for transmit power and receive sensitivity helps to prolong battery life. In addition, the slightly higher cost of the coordinator allows all the end node devices to be low cost which helps to reduce the overall cost of the network.

As an example the coordinator device may use a coherent receiver optimized for MCS-6 (500 kbps at modulation index 0.5) with FEC capability. Given a proper receiver design and using FEC combined with the differential pre-coding and GMSK may improve the receive sensitivity by up to 8 dB (see document 15-14-0072-00-004q-Joint ULP-GFSK PHY layer proposal). The improved sensitivity in the coordinator allows the end nodes to operate with a lower transmit power.

To continue the example, the end node devices may be equipped with a non-coherent FSK receiver optimized for MCS-4 (500 kbps at modulation index 0.72) without FEC decoding capability but with FEC encoding capability. The higher transmit power of the coordinator permits the end devices to operate with less sensitivity which allows for a current reduction in their receiver components such as LNA and demodulator and absence of FEC decoding. The FEC encoding involves low complexity and its power consumption is insignificant. Notice in link budget calculation below how the noise figure and transmit power are relaxed in the end nodes while maintaining a balanced link budget.

Link budget example of Asymmetric Link Network			
		uplink	downlink
TX	Over-the-air data rate [kSymbols/s]	1000	500
	Distance [m]	30	30
	TX antenna gain [dBi]	**-5**	0
	Center frequency [MHz]	868	868
	Transmit power [dBm]	-5	+5
Channel	Path loss [dB] (PL exponent 2.7)	71	71
RX	RX antenna gain [dBi]	0	-5
	Received signal strength [dBm]	-86	-71
	Receiver noise figure [dB]	5	**10**
	Min. Eb/N0 @1% PER [dB]	3.2	12.1
	Implementation loss [dB]	2	2
	RX sensitivity [dBm]	-103.8	-92.9
	Link margin [dB]	**22.8**	**21.9**

Uplink the transmit power can be reduced, as differential encoding and FEC reduce the signal energy necessary for successful decoding. On the downlink the concentrator device makes up for the missing differential encoding and FEC in the end node by an increased transmit power.

In an ALN the link budget in the uplink direction is characterized by a relatively low transmit power and high receive sensitivity while in downlink direction that is reversed so that the link budget in both directions is balanced.

Wideband Digital Modulation

MCS-4 may be used for wideband digital modulation according to FCC part 15.247 which allows for transmit power in excess of -1.23 dBm without requiring frequency hopping. The elimination of the overhead related to frequency hopping saves energy. In addition the data rate of MCS-4 is relatively high which allows for short on-air times which saves energy as well.