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

Submission Title: [Channel Page/Number Proposal]
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Re: [Proposal for expansion of channel page to support 4g PHY modes and the extended channel requirements]

Abstract: [Updated proposal for how to handle channel pages/numbers for the 802.15.4g PHY modes. This proposal is based on proposals submitted by Larry Taylor and Daniel Popa]

Purpose: [This document summarizes the approach used to define channels for the 802.15.4g PHY modes. This proposal has been reviewed by the FSK Channel Page/Number subgroup and is used to support the draft text submitted in document #: 802-15-10-xxxx-00]

Channel Bands Update

Focus of the Update

- The general form of the Channel Band Descriptor provides a very powerful generic PHY description mechanism
- Channel page 7 enumerates the standard defined PHY modes
- Channel page 8 enumerates the PHY modes defined using the Generic PHY mechanism
- Defines a channel numbering scheme for 15.4g operation

Part I – Channel Numbering

Reminder – The Problem

- 802.15.4:
  - To support the existing PHY modes and channels, channels are defined using a combination of Channel Page and Channel Number
  - There can be up to 32 channel pages and for each page, up to 27 channels
  - For each page, 27 bits correspond to a specific PHY mode channel. (Each bit represents a standard defined PHY mode and channel within that mode).
  - The existing definition of a channel fully defines all the parameters of the channel (frequency band, modulation scheme, center frequency, etc.)

Reminder – The Problem (2)

- 15.4g defines PHY modes that cannot fit within the existing channel numbering mechanism:
  - A large number of frequency bands (~20)
  - A large number of PHY Modes (~50)
    - Different data rates, channel separations, modulation schemes, etc
  - There are a much higher number of possible channels due to the addition of frequency hopping modes in the 915 and 2400 MHz bands (over 400 channels in the 2400 MHz band alone)
  - This results in a very large number of distinct channels – far more than can be represented using the 32-bit Channel Page/Channel Number structure

Existing Constraints

- Many MAC Management primitives and MAC Commands use Channel Page and Channel Number parameters
- To maintain consistency with existing 15.4 specifications the extended channel numbering model must retain the Channel Page and Channel Number structure

Overview of Solution

- The Channel Page/Number field cannot represent everything (frequency band, modulation scheme, supported channels, etc) so:
  - Use the Channel Page/Number field to represent everything except for channel numbers.
  - Page 7 and 8 channel numbers are defined differently than channel numbers for other pages (0-6)
  - New PIB attributes will describe the channels when the Channel Page is 7 or 8

15.4g Channel Page Structure

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Page 0					2450 MHz. O-QPSK, 16 Channels																915 MHz. BPSK, 10 Channels										*
:					:																										
:					:																										
Page 6					Reserved					950 MHz. GFSK, 12 Channels											950 MHz, BPSK, 11 Channels									
Page 7					Freq Band					Modulation Scheme	**Standard Defined PHY Modes** Bit map, where each bit corresponds to a particular PHY mode. PHY modes are defined for each Freq Band and Modulation Scheme																				
Page 8					Reserved					Reserved	**Generic PHY Defined PHY Modes** Bit map, where a set bit indicates a Generic PHY mode supported by the device. Each set bit position corresponds to an element in phyGenericPHYDescriptors																				
Pages 9-31					Reserved																										

* 868 MHz. BPSK, 1 Channel

- For Page 7, use three fields to fully define the PHY (everything except supported channels):
  - **Freq Band** – 5 bits to define up to 32 possible frequency bands
  - **Modulation Scheme** – 2 bits to define up to 4 modulation schemes
  - **PHY Mode** – 20 bits to define up to 20 modes for each freq band and modulation scheme
- For Page 8, the PHY is defined by the Generic PHY mechanism. The 20 bits represent elements in the Generic PHY descriptor.
  - Page 8 could also use the Freq Band and Modulation Scheme fields, but there is no reason to do so since these fields are described by the Generic PHY parameters

Page 7 Frequency Bands

Dec Value	Description
0	950 MHz (Japan)
1	400-430 MHz (Japan)
2	863-870 MHz
3	915 MHz
4	2400-2483.5 MHz
5	220-222, US & Can, 12.5 kHz channels
6	450-470 MHz (US FCC Part 90)
7	470-510 MHz (US FCC Part 24)
8	896-901 MHz (US FCC Part 90)
9	901-902 MHz (US FCC Part 24)
10	928-960 MHz (US, Non-contiguous)
11	1427-1452 MHz (US & Canada, Non-contiguous)
12	1492-1518 MHz (US & Canada, Non-contiguous)
13	1605-1625 MHz (US, Non-contiguous)
14	1800-1830 MHz (US & Canada, Non-contiguous)
15	779-787 MHz (China)
16	922 MHz (Korea)
17	TV white spaces
18-31	Reserved

Page 7
Modulation Schemes

Dec Value	Description
0	FSK/GFSK
1	OFDM
2	O-QPSK
3	Reserved

Page 7 Definitions

- Freq Band = 0 = 950 MHz (Japan)
- Modulation Scheme = 0 = (G)FSK
- 3 standard defined PHY modes (bit positions 0, 1, & 2)
- 17 PHY modes undefined and reserved for future use

950 MHz Frequency Band, FSK

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Page					Freq Band					Modulation		Standard Defined PHY Modes																			
0	0	1	1	1	0	0	0	0	0	0	0	Reserved																	1	1	1
Page 7					0 = 950 MHz					0=(G)FSK		Three standard defined PHY modes (bit positions 0-2)																			

Bit Position 0 = 50 kbps, GFSK, Mod Index = 1.0, Channel Spacing = 200/400 kHz (mandatory mode)

Bit Position 1 = 100 kbps, GFSK, Mod Index = 1.0, Channel Spacing = 400 kHz

Bit Position 2 = 200/400 kbps, GFSK/4-GFSK, Mod Index = 1.0/0.33, Channel Spacing = 600 kHz

Bit Positions 3-19 = Reserved

Page 7 Definitions

- Freq Band = 1 = 400-430 MHz (Japan)
- Modulation Scheme = 0 = (G)FSK
- 3 standard defined PHY modes (bit positions 0, 1, & 2)
- 17 PHY modes undefined and reserved for future use

400-430 MHz Frequency Band, FSK

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Page					Freq Band					Modulation		Standard Defined PHY Modes																			
0	0	1	1	1	0	0	0	0	1	0	0	Reserved																	1	1	1
Page 7					1=400-430MHz					0=(G)FSK		Three standard defined PHY modes (bit positions 0-2)																			

Bit Position 0 = 50 kbps, GFSK, Mod Index = 1.0, Channel Spacing = 200/400 kHz (mandatory mode)

Bit Position 1 = 100 kbps, GFSK, Mod Index = 1.0, Channel Spacing = 400 kHz

Bit Position 2 = 200/400 kbps, GFSK/4-GFSK, Mod Index = 1.0/0.33, Channel Spacing = 600 kHz

Bit Positions 3-19 = Reserved

Page 7 Definitions

- Freq Band = 3 = 915 MHz
- Modulation Scheme = 0 = (G)FSK
- 3 standard defined PHY modes (bit positions 0, 1, & 2)
- 17 PHY modes undefined and reserved for future use

915 MHz Frequency Band, FSK

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Page					Freq Band					Modulation		Standard Defined PHY Modes																			
0	0	1	1	1	0	0	0	1	1	0	0	Reserved																	1	1	1
Page 7					3 = 915 MHz					0=(G)FSK		Three standard defined PHY modes (bit positions 0-2)																			

Bit Position 0 = 50 kbps, FSK, Mod Index = 1.0, Channel Spacing = 200 kHz (mandatory mode)

Bit Position 1 = 150 kbps, FSK, Mod Index = 0.5, Channel Spacing = 400 kHz

Bit Position 2 = 200 kbps, GFSK, Mod Index = 0.5, Channel Spacing = 400 kHz

Bit Positions 3-19 = Reserved

Page 7 Definitions

- Freq Band = 4 = 2400-2483.5 MHz
- Modulation Scheme = 0 = (G)FSK
- 3 standard defined PHY modes (bit positions 0, 1, & 2)
- 17 PHY modes undefined and reserved for future use

2400-2483.5 MHz Frequency Band, FSK

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Page 7					Freq Band					Modulation		Standard Defined PHY Modes																			
0	0	1	1	1	0	0	1	0	0	0	0	Reserved																	1	1	1
Page 7					4 = 2400 MHz					0=(G)FSK		Three standard defined PHY modes (bit positions 0-2)																			

Bit Position 0 = 50 kbps, FSK, Mod Index = 1.0, Channel Spacing = 200 kHz (mandatory mode)

Bit Position 1 = 150 kbps, FSK, Mod Index = 0.5, Channel Spacing = 400 kHz

Bit Position 2 = 200 kbps, GFSK, Mod Index = 0.5, Channel Spacing = 400 kHz

Bit Positions 3-19 = Reserved

Page 7 Definitions

- Freq Band = 3 = 915 MHz
- Modulation Scheme = 2 = O-QPSK (DSSS)
- 4 standard defined PHY modes (bit positions 0, 1, 2, & 3)
- 16 PHY modes undefined and reserved for future use

915 MHz Frequency Band, O-QPSK

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Page					Freq Band					Modulation		Standard Defined PHY Modes																			
0	0	1	1	1	0	0	0	1	1	1	0	Reserved																1	1	1	1
Page 7					3 = 915 MHz					2 = O-QPSK		Four standard defined PHY modes (bit positions 0-2)																			

Bit Position 0 = Chip rate =1000 kchip/s, 16,1 spreading, Data Rate = 31.25 kbps
Bit Position 1 = Chip rate =1000 kchip/s, 16,4 spreading, Data Rate = 125 kbps
Bit Position 2 = Chip rate = 1000 kchip/s, 8,4 spreading, Data Rate = 250 kbps
Bit Position 3 = Chip rate =1000 kchip/s, no spreading, Data Rate = 500 kbps
Bit Positions 4-19 = Reserved

Page 7 Definitions

- Not all Page 7 definitions are shown in this presentation (but can be easily added by following the previous examples)

Page 8 Definitions

- Page 8 is reserved for PHY modes defined using the Generic PHY mechanism
- Definition of each particular PHY mode is per Generic PHY Descriptors

Channel Pages

- For Channel Pages 7 and 8, the Channel Page is used to define the frequency band, modulation scheme and specific PHY modes available for the frequency band and modulation scheme
- A device can support multiple instances of Channel Pages 7 and 8.
- PHY PIB attributes need to be added to describe the supported SUN Channel Pages (i.e. supported PHY modes) and the current Channel SUN Page (i.e. current PHY mode):
  - ***phyNumSunPageEntriesSupported*** *(new)* – The number of SUN PHY pages (pages 7 and 8) supported by the device
  - ***phySunPageEntriesSupported*** *(new)* – Array of *phyNumSunPagesSupported* rows, where each row is a 32-bit element defining a supported SUN page. The 32-bits are per the page 7 and page 8 “channel page” definitions.
  - ***phyCurrentSunPageEntry*** (*new*)– The specific 32-bit page 7 or 8 definition for the current Sun Page (current frequency band, modulation scheme and PHY mode). This attribute is valid when *phyCurrentPage* equals 7 or 8.

Number of Channels and Channels Supported

- Currently in 802.15.4:
  - The current 15.4 channel bit map in bits 0..26 of the Channel Page indicate which channels are supported
  - Allows a subset of possible channels to be supported
  - Also used for channel scanning
- Add support for 802.15.4g PHY modes (more than 26 channels):
  - The number of channels is frequency band and mode dependent
  - The total number of channels is either standard defined (page 7) or defined by the Generic PHY mechanism (page 8).
  - ***phySunChannelsSupported*** is a bit map identifying the supported channels for the current SUN mode
  - Add a PHY PIB attribute to control the size of ***phySunChannelsSupported.*** ***phyMaxSunChannelSupported*** defines the highest channel number supported and is only used to size the ***phySunChannelsSupported*** array.
  - Size of *phySunChannelsSupported* in octets = *phyMaxNumSunChannelSupported* / 8

Current Channel

- The current channel is determined by *phyCurrentChannel*:
  - The current definition of *phyCurrentChannel* supports a range of 0-26. Range needs to be extended to at least 0-420 to support SUN PHY modes
  - For a channel to be the current channel, the corresponding bit position in *phyChannelsSupported* must be set to 1 (if the channel is from channel page 0-6) or the corresponding bit position in *phySunChannelsSupported* must be set to 1 (if the channel is from channel page 7 or 8)

Summary of PHY PIB Attributes

- **New PHY PIB Attributes**
  - *phyNumSunPageEntriesSupported*
    - Number of SUN page (Channel pages 7 and 8) entries supported by the device
  - *phySunPageEntriesSupported*
    - Array of *phyNumSunPageEntriesSupported* rows, where each “row” is a 32-bit field per the page 7 or page 8 definition.
  - *phyCurrentSunPageEntry*
    - A 32-bit field defining the current Sun PHY mode. The definition of the 32-bit field is per the page 7 or page 8 definition, but only one bit in the 20-bit PHY MODE field will be set. The set bit indicates the standard defined mode (page 7) or the Generic PHY Id (page 8). *phyCurrentSunPageEtnry* is valid if *phyCurrentPage* is equal to 7 or 8.
  - *phyMaxSunChannelSupported*
    - Value is the highest channel number supported by the device and is used to size *phySunChannelsSupported*. Only valid if *phyCurrentPage* equals 7 or 8
  - *phySunChannelsSupported*
    - Channel bit map identifying which channels may be used when *phyCurrentPage* = 7 or 8. The size of *phySunChannelsSupported* = *phyMaxSunChannel* / 8.
- **Modified PHY PIB Attributes**
  - *phyCurrentChannel*
    - Requires amended definition since range will be >27 for some SUN frequency bands. Propose new valid range of 0-511
- **Existing PHY PIB Attributes**
  - *phyCurrentPage*
    - A value between 0 and 31
  - *phyChannelsSupported*
    - An R x 32-bit array used to define the channels supported for channel pages 0-6

Channel Pages Example

A device that supports the 802.15.4d GFSK PHY (all channels), the 802.15.4g FSK PHY mode for the 915 MHz band (mandatory mode and one optional mode), the 802.15.4g FSK PHY mode for the 950 MHz band (all standard defined mandatory and optional modes), the O-QPSK (DSSS) PHY modes for the 915 MHz band (all standard defined modes), and 1 generic PHY defined mode would have the following values for the PIB attributes:

Scenario #1 – Current mode = 915 MHz GFSK (802.15.4g), data rate = 200 kbps

- *phyNumSunPageEntriesSupported = 4*
- *phySunPageEntriesSupported*

0 0 1 1 1	0 0 0 1 1	0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1
Page 7	3 = 915 MHz	0=(G)FSK	**915 MHz, FSK, mandatory mode and one optional mode supported**
0 0 1 1 1	0 0 0 0 0	0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1
Page 7	0 = 950 MHz	0=(G)FSK	**950 MHz, FSK, all 3 standard defined modes supported**
0 0 1 1 1	0 0 0 1 1	1 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1
Page 7	3 = 915 MHz	2 = O-	**915 MHz, O-QPSK, all 4 standard defined modes supported**
0 1 0 0 0	0 0 0 0 0	0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1
Page 8	reserved	reserved	**1 Generic PHY Defined PHY mode supported**

- *phyCurrentSunPageEntry*

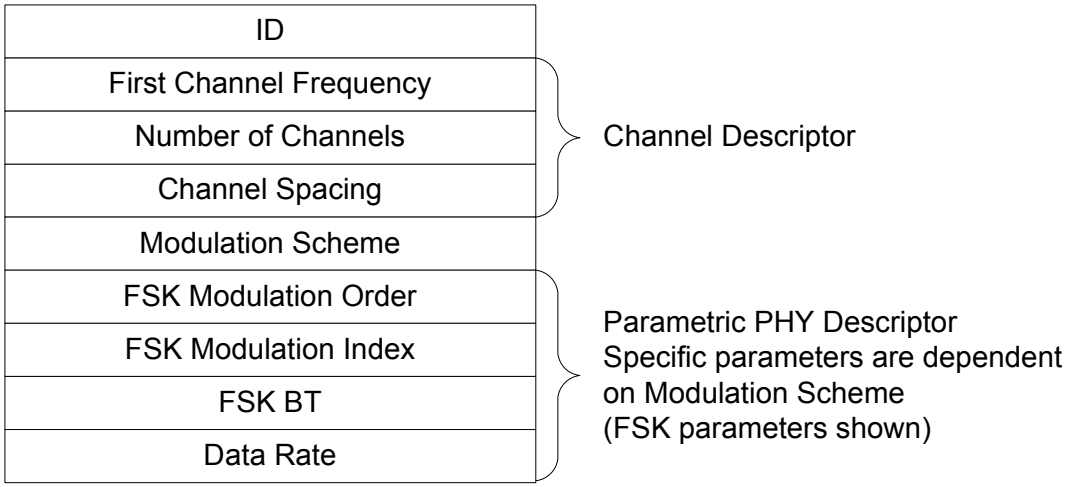
0 0 1 1 1	0 0 0 1 1	0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0
Page 7	3 = 915 MHz	0=(G)FSK	**915 MHz, GFSK, 200 kbps optional modesupported**

- *phyNumSunChannelsSupported = 64*
- *phySunChannelsSupported = a 64/8 = 8 octet array with a bit set for each supported channel.*
- *phyCurrentChannel = a unique value between 0 and (phyNumSunChannels-1)*
- *phyCurrentPage = 7*
- *phyChannelsSupported (lists channels in pages 0-6 supported by the device, R x 32-bit array, R = 1)*

31 30 29 28 27	26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
Page	Supported Channels
0 0 1 1 0	0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0

Generic PHY

Generic PHY Descriptor



- Generic PHY Descriptors are only used for Channel Page 8
- Channel Descriptor part is based on the band agnostic representation
- Parametric PHY part is dependent on Modulation Scheme
  - Parameters for FSK PHY are shown
  - Generic PHY is primarily targeted for FSK modulation schemes. Do other modulation schemes want the same flexibility?

PHY PIB Attributes

- Add PHY PIB attribute *phyNumGenericPHYDescriptors*
- Add PHY PIB attribute *phyGenericPHYDescriptors*
  - Array of *phyNumGenericPHYDescriptors* elements each one containing a Generic PHY Descriptor
  - Elements are uniquely identified by ID in the local system
  - The ID corresponds to a bit position (0-19) in the “channel” page.

Mode Switch Support

Mode Switch PPDU

- Flag in the PHY Header identifies a frame PPDU variant for Mode Switching
- The Frame needs a parameter to identify the operating mode of the subsequent PPDU
- The canonical name serves as this parameter

Canonical Name (1)

- The canonical name is the Channel Page/Number field
- Frequency band and Modulation Scheme are the same for Channel Pages 7 & 8
- Support for PHY mode switching across frequency bands is not required
- Channel Page 7 PHY Mode
  - PHY Mode is the standard defined PHY mode (0-19)
- Channel Page 8 PHY Mode
  - PHY Mode is the element number (Id) of the Generic PHY Descriptor

Canonical Name (2)

- The canonical name is therefore the same as the 32-bit Channel Page/Number field:
  - Channel Page : Freq : Modulation Scheme : PHY Mode Index
  - An encoding with less than 16 bits is possible

	Page	Freq Band	Mod Scheme	Mode
Full representation	5 bits	5 bits	2 bits	20 bits
Shortened form	1 bit *	0 bits	2 bits	5 bits
	* Only need to select page 7 or 8			

- NOTE – Mode is the integer value of the specific bit position (0-19) per the page 7 and page 8 definitions. Bit positions are either standard defined (page 7) or correspond to the Generic PHY Id (page 8)
- It may be sufficient to not include the channel number when specifying a mode change (channel number is the same before and after the mode change).

Questions?