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

Submission Title: [Need for VLC bandplan]
Date Submitted: [15 October, 2009]
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Re: []

Abstract: [Updating bandplan proposal for supporting channel aggregation]

Purpose: [Contribution to IEEE 802.15.7 VLC TG]

Use of bandplan

It is true that for VLC, we can use the entire visible spectrum for communication

For any (wireless/wired/optical) communication, it can be useful to know which frequency/frequencies are being used for transmission and reception.

- This is needed so that proper transmitters and receivers can be developed that can interoperate and can have good performance

Need for bandplan

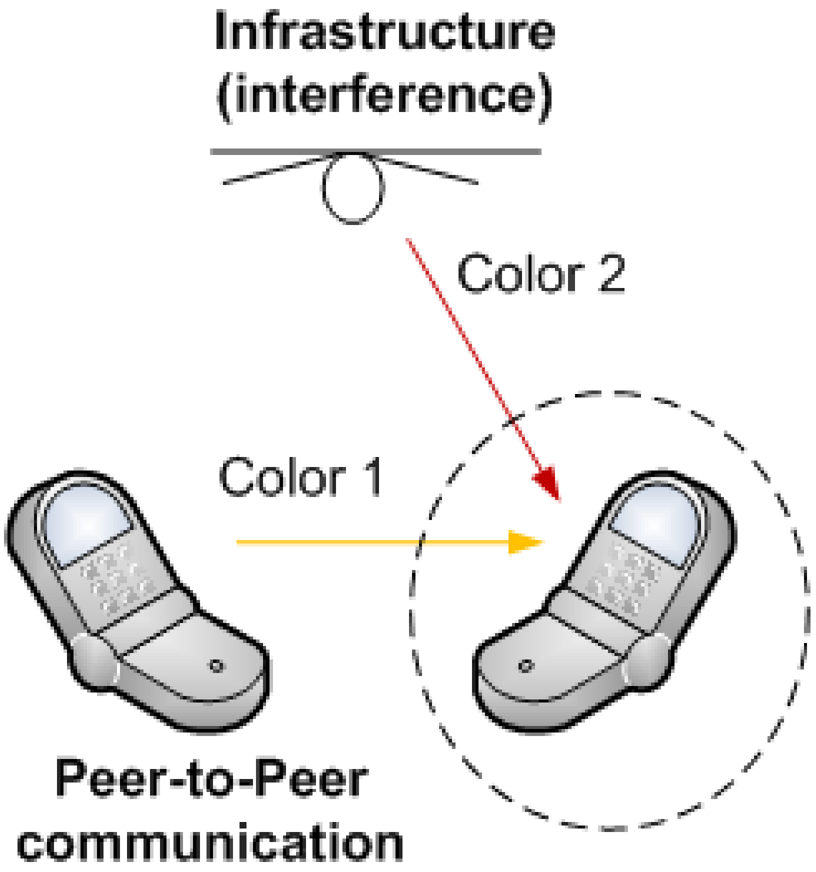
Samsung supports receiving on entire visible spectrum

- For link establishment for bi-directional communication
- For unidirectional broadcasting (IB/VB)

Samsung believes that having a bandplan can provide certain advantages for communication without any complexity

Interference handling

Indicating desired frequency band can help receiver filter unwanted interference, if receiver has multiple PDs/filters



Channel selection for multi-channel support

If a device supports multiple LEDs, one can optimize the link to choose the desired LED (or set of LEDs) for best performance and network capacity

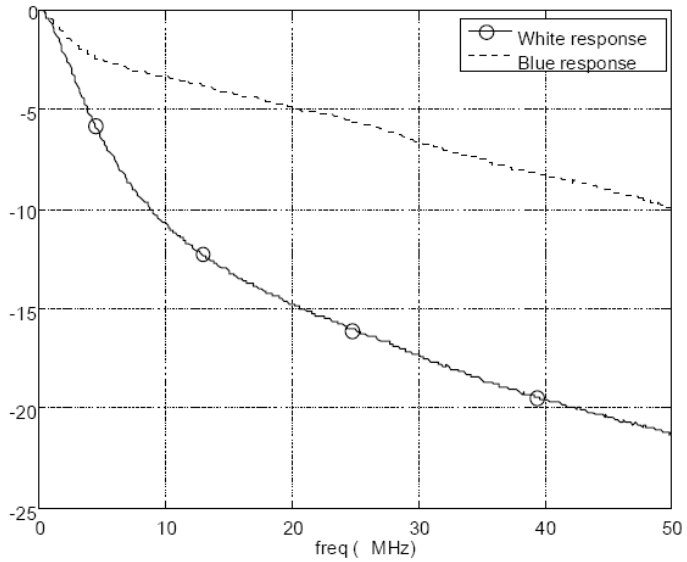
This requires the knowledge of the frequency bands of the different LEDs

Filtering unwanted TX emissions at RX

Yellow phosphor can reduce data rates due to intersymbol interference and a blue filter can help to increase data rates by focusing on blue LED.

- Ref 1 : Visible Light Communications: recent progress and challenges, WWRF 2008
- Ref 2: IEEE 802.15-15-08-0265-03-0vlc

Standard should support use of RX filters for performance improvement by indicating the LED transmission frequency



Source: Ref [1]

FDD mode support

Self-interference between LED and PD due to proximity

- IrDA specifies only half-duplex modes

If a device is transmitting on certain color in FDD mode (for example, visibility pattern during RX/idle mode to maintain visibility), it may not want to be receiving on the same color, if it can distinguish multiple colors with filters (depending on the RX architecture)

Knowing what LED frequency bands are being used for transmission and what LED frequency bands are supported can influence RX's choice for reverse link transmission

Proposed Band Plan

Frequency band (nm)		Spectral width (nm)	Color	Proposed Code
380	450	70	pB	000
450	510	60	B, BG	001
510	560	50	G	010
560	600	40	yG,gY, Y,yO,O	011
600	650	50	rO	100
650	710	60	R	101
710	780	70	R	110
			Reserved	111

Red – popular LED for comm.

- Non-uniform distribution based on CIE diagram
- Human eye most sensitive to green color and visible LEDs are designed to match human eye sensitivity
- Provides support for up to 7 independent and parallel channels

Why ~~not~~ support any frequency in entire visible spectrum?

The standard must specify some way of letting designers know which transmitter and receiver frequency specification they should build their VLC system (a) for best performance and (b) for interoperability

We support all frequencies in the visible spectrum with our bandplan. Proposed bandplan allows use of any type and frequency response of LED/LD.

Modified based on feedback from F2F

Supporting any frequency in bandplan by channel aggregation and guard channels

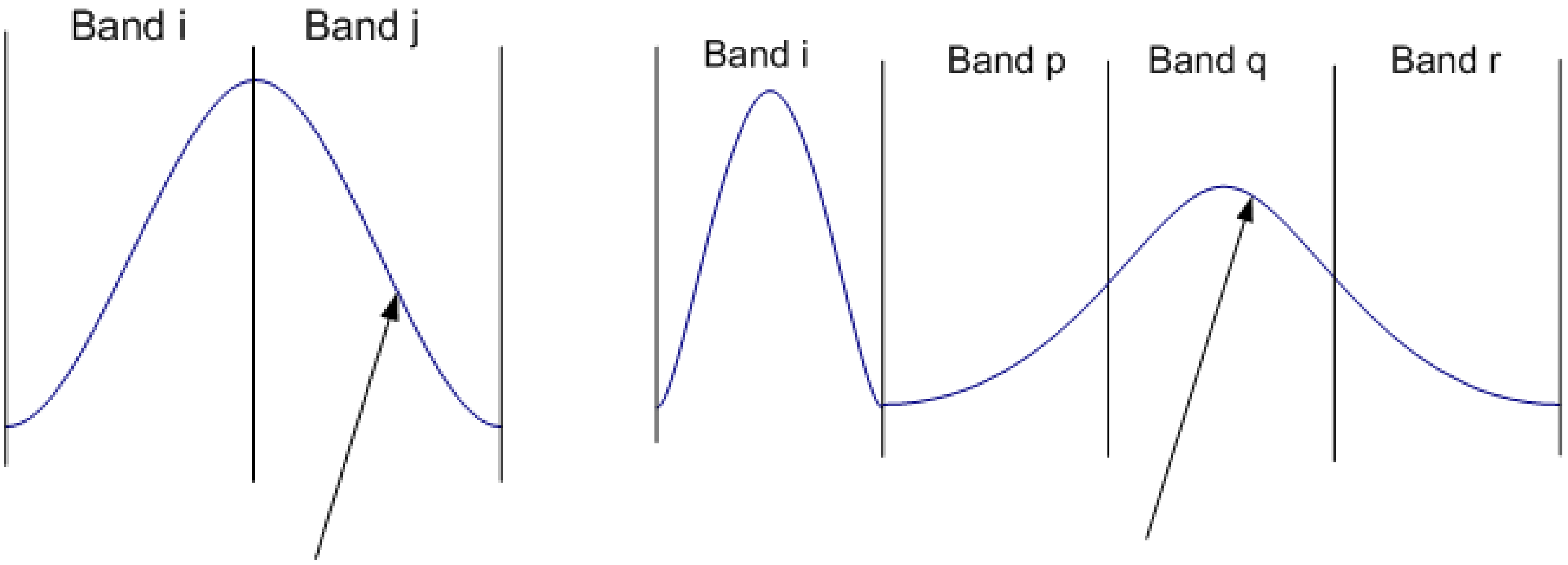
If there is a LED that spans across a band, such as a blue LED that spans two bands, the two bands can be merged and indicated as an aggregate channel

- Similar to ‘channel bonding’ in 802.11n

If there is a LED that leaks into other bands (white LED with yellow phosphor) whose information can be discarded, the leakage band can be indicated as the guard channel

These concepts are provided in the information capabilities in the MAC and do not impact PHY or the illumination

Example of channel aggregation vs. guard channels



Intentional transmission
Indicate merged band in
MAC capabilities
(Channel aggregation)

Unintentional transmission
Indicate guard band(s) in
MAC capabilities,
depending on leakage
amount
(Guard Channel)

Bitmap : indication channel aggregation

Same format as bitmap proposed for guard channels

Done on a per LED type (band characteristics)

- Aggregation and guard bitmap for every LED color (frequency band) at TX

Bit position 'm' set to 1 for band 'm'

Aggregation bitmap also includes band usage for current LED type, no need for separate field indication for channel band support

Example of bit-map use

Example 1: I = 1, J = 2

- aggregation bitmap = 0110000 (7–bit number for 7 channels, bands 1 and 2 are aggregated BLUE LED)
- Guard bitmap = 0000000

Example 2: I = 1, P = 3, Q=4, R =5

- Aggregation bitmap = 0100000 (transmission on only 1 band – this is a BLUE LED)
- Guard bitmap = 0001110 (assuming leakage in bands 3, 4 and 5 exceed a certain threshold, YELLOW leakage)

Optimization possible by merging aggregation and guard bitmaps and have single bitmap (for all LED types supported by device)

- not shown - simple, one time communication during capabilities exchange using the MAC

Byte-alignment for MAC, unused bits set to reserved for future use

Logistics for channel aggregation/multi-color transmission

If multiple bands are aggregated or multiple LEDs are transmitting simultaneously

- the same data must be sent on all LEDs during the preamble or header for link establishment since it is not known what the receiver capabilities are
- the PHY header should indicate lowest frequency band number
- the preamble cover sequence belonging to the lowest frequency band number should be used

Bandplan usage is flexible

If certain receiving devices do not wish to use the bandplan information, they can choose to ignore this information.

- Does not add implementation complexity

Back-up material from previous revision

Why not support large number of frequency bands?

LED is a popular optical light source choice for VLC

The LED spectral width can vary from 10 nm to 100 nm, depending on LED characteristics

It will be very difficult to make optical filters and LEDs if we make the number of bands very large

Large number of choices will make design choices for VLC very complex

Hence, the number of frequency bands supported must not be too large

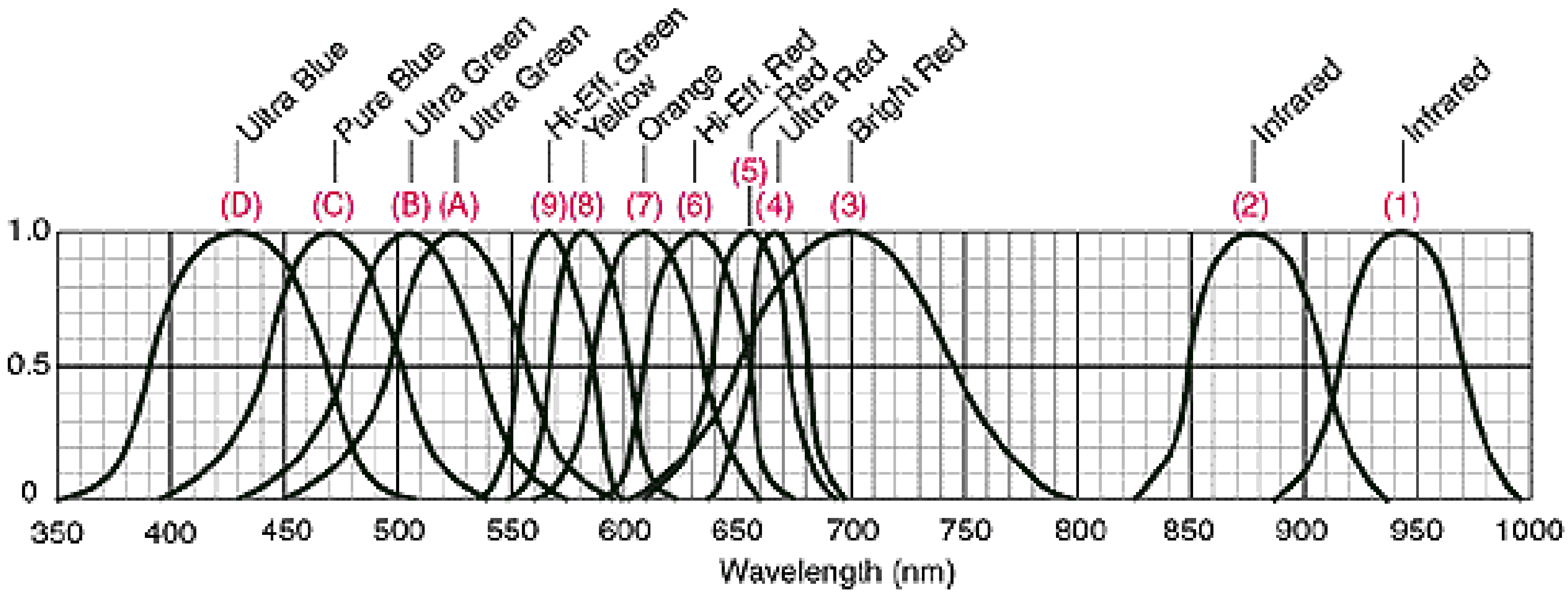
Why not support few number of frequency bands?

We need to support multiple frequency bands to support multiple simultaneous bands of operation and for co-existence.

Traffic lights for example, may want to support transmissions on R, G and Y colors. Some white LEDs may want to support R, G, B colors. Some mobile phones support purple colors.

We would like to have as many colors as possible while making sure optical sources and receivers can be specified and we can distinguish between them without creating interference.

Typical LED spectral widths



Source: http://www.theledlight.com/technical3.html