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

Submission Title: VLC Proposal for Multiplexing and MAC features
Date Submitted: September 20, 2009
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Re: Response to call for proposals on 25th August, 2009.

Abstract: Multiplexing is needed in VLC mobile-infrastructure systems. This proposal presents methods for both intra-luminary and inter-luminary multiplexing. Additionally, MAC concepts for PDU structure, MAC functional entities, and uplink coordination are presented

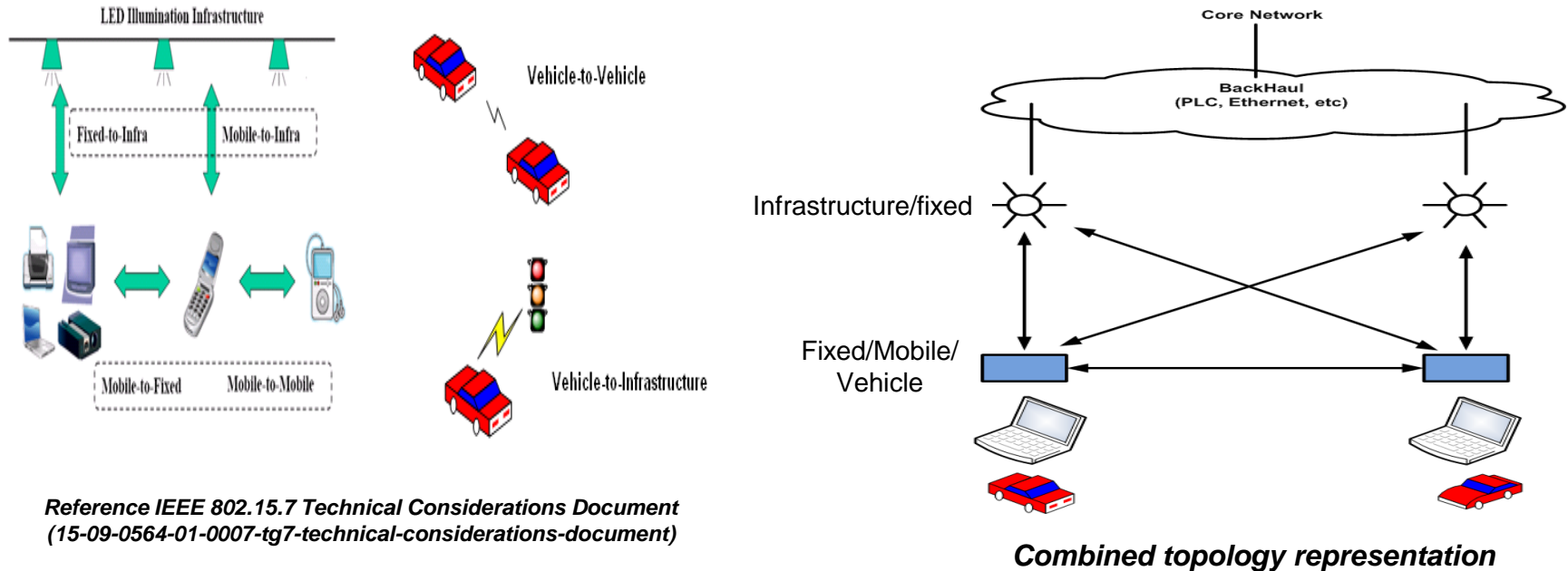**Purpose:**   [Proposal to IEEE 802.15.7 VLC TG]

Proposal for Infrastructure MAC

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Outline

- 802.15.7 Topology
- Multiplexing in Infrastructure Mode: Options
- Inter-Luminary CDMA Spreading Codes
- Intra-Luminary Logical Channels
- Addressing & PDU Format
- Infrastructure Device Discovery
- Infrastructure Uplink considerations

802.15.7: Topology

*Reference IEEE 802.15.7 Technical Considerations Document
(15-09-0564-01-0007-tg7-technical-considerations-document)*

Combined topology representation

- ## Modes:
    - Peer-to-peer
    - Infrastructure
- ## Infrastructure mode multiplexing dimensions:
    - Inter-Luminary: Multiplexing across Luminaries
    - Intra-Luminary: Multiplexing within a single Luminary

802.15.7: Options for Multiplexing in Infrastructure Mode

- <u>Inter-Luminary</u>
  - CDMA
  - Subcarrier or FDM
  - ✘ Spatial (e.g., image sensor) – too complex for first release
- <u>Intra-Luminary – Downlink only</u>
  - MAC Multiplexing
    - MAC header
  - ✘ PHY channel multiplexing
    - CDMA
    - OFDMA
    - Wavelength (color)
- <u>Options for uplink:</u>
  - ✘ TDD, CSMA
  - ✘ Space (e.g., image sensor)
 - Uplink on another RAT
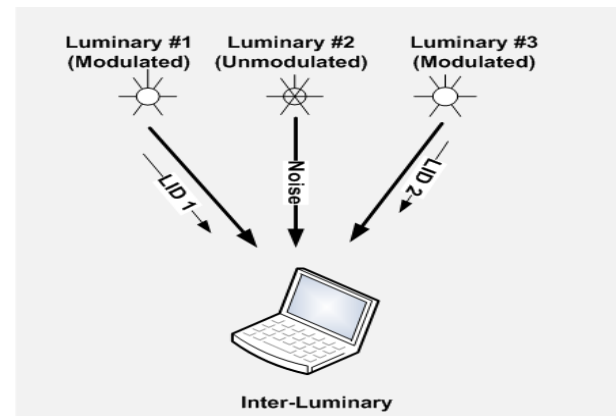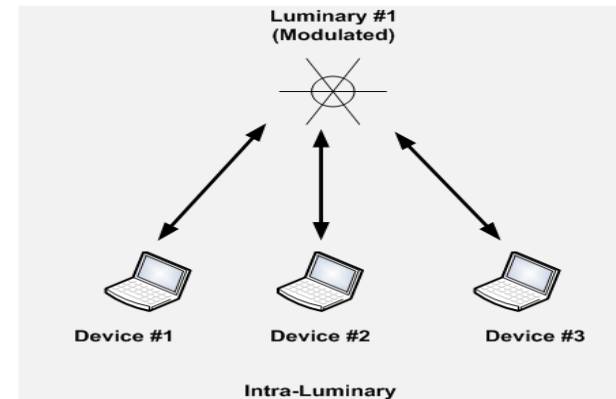
Proposal:
1. Inter-Luminary CDMA or sub-carrier frequency modulation
2. Intra-Luminary MAC multiplexing
3. Uplink on another RAT
4. Use Color bands for PHY aggregation, not multiplexing
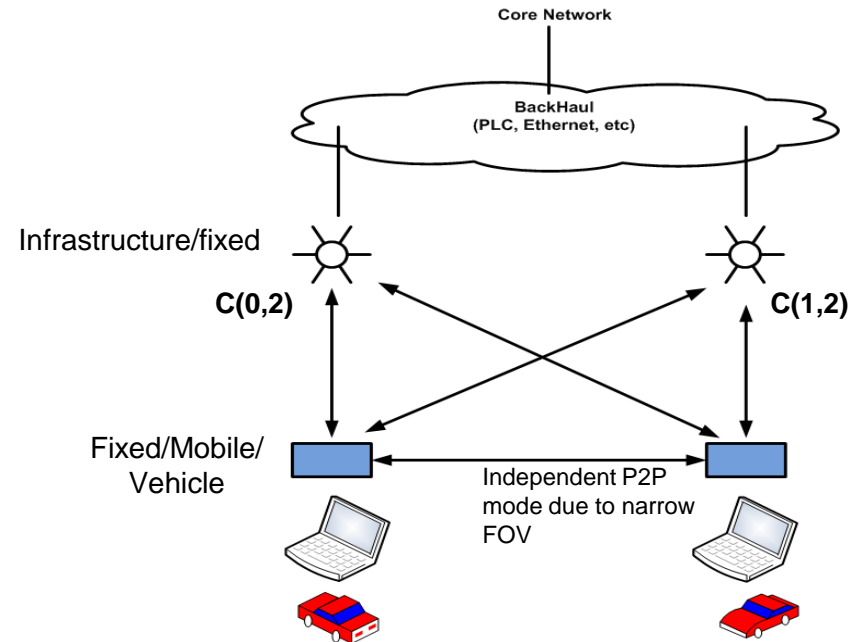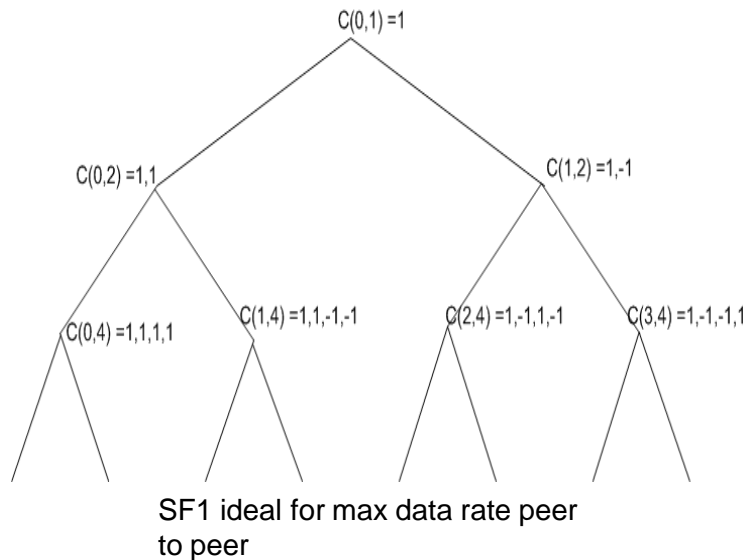
Comparison of Modulation Schemes

Properties	CDMA	Subcarrier Modulation
Multiple Access	Yes	Yes
Scalability	Additional scrambling codes allows number of transmitters to exceed number of orthogonal codes	Number of transmitters limited by number of subcarriers
Support for binary LED Level (OOK)	Yes if each transmitter uses a single code	No. If square waves are used, harmonics would interfere with other subcarriers

CDMA-based Visible Light Modulation
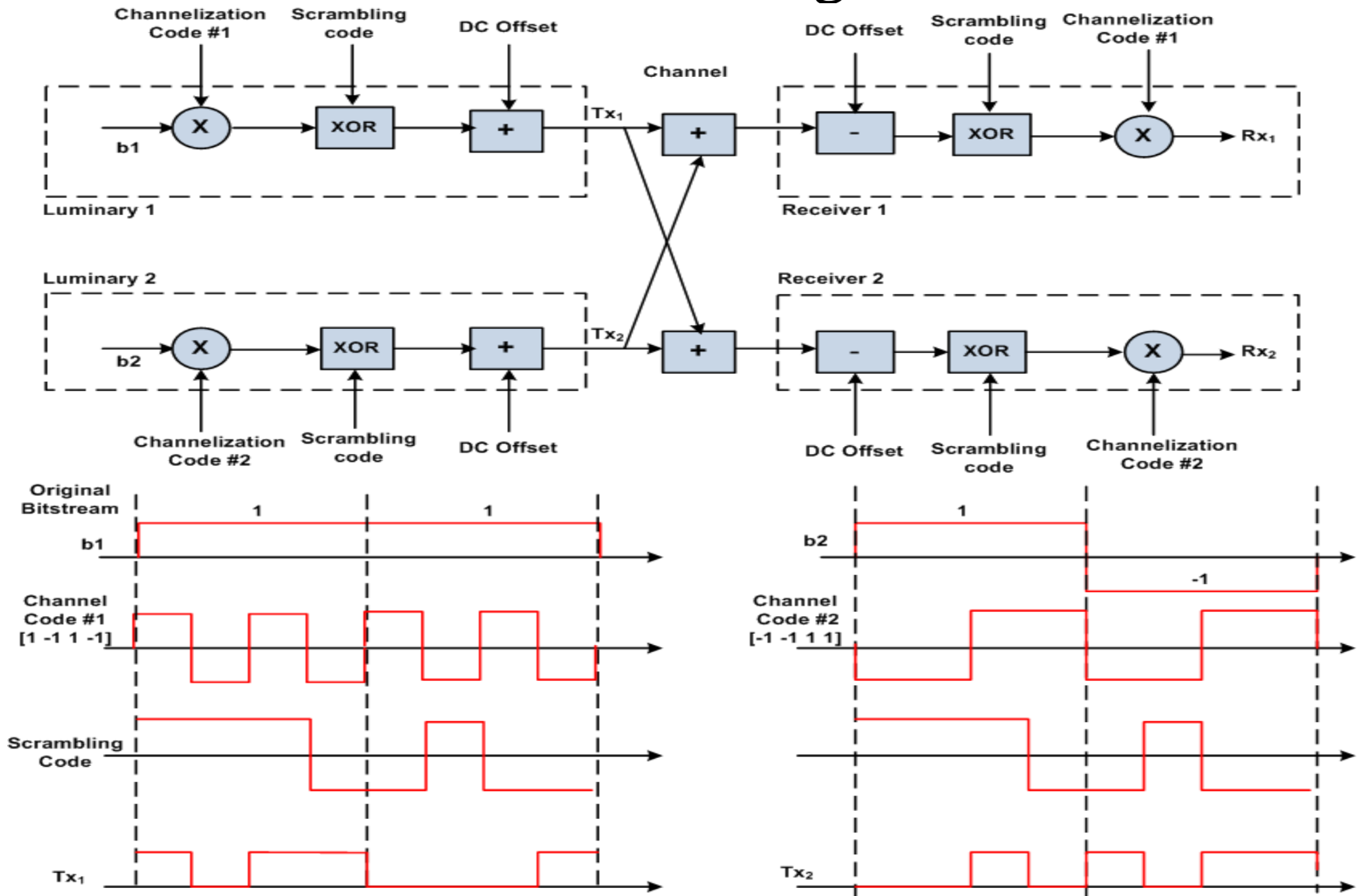
Inter-Luminary CDMA spreading Codes

C(n,k), n=Channel No., k=spreading factor based on system reuse factor, per color band

C(0,1) =1

C(0,2) =1,1   C(1,2) =1,-1

C(0,4) =1,1,1,1   C(1,4) =1,1,-1,-1   C(2,4) =1,-1,1,-1   C(3,4) =1,-1,-1,1

SF1 ideal for max data rate peer to peer

Core Network

BackHaul
(PLC, Ethernet, etc)

Infrastructure/fixed

C(0,2)   C(1,2)

Fixed/Mobile/
Vehicle   Independent P2P
                           mode due to narrow
                           FOV

- Use Walsh codes
- Variable spreading based on system reuse parameter.
- Orthogonality implies synchronization between luminaries. This is beneficial, but not mandatory

Subcarrier modulation
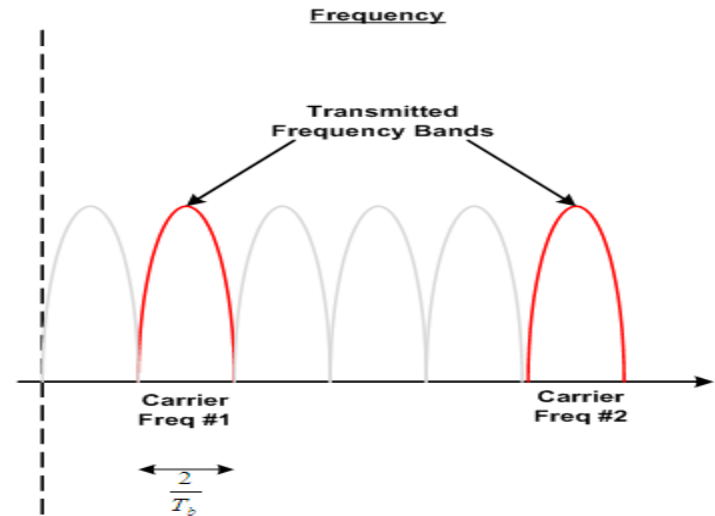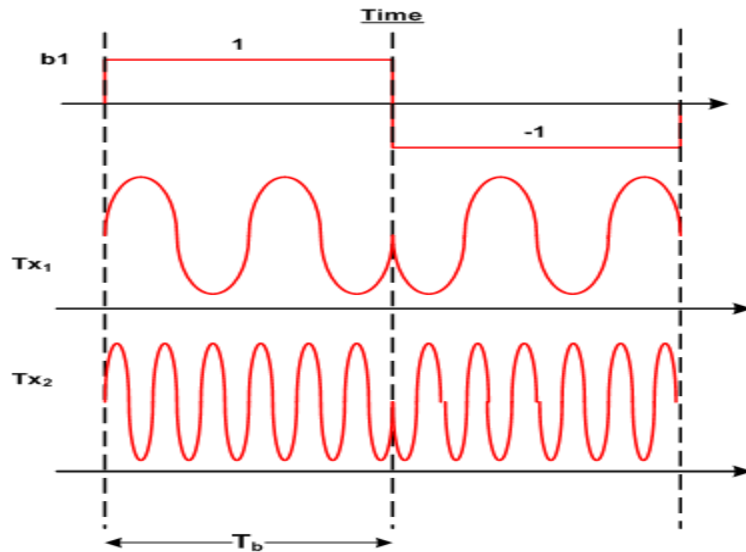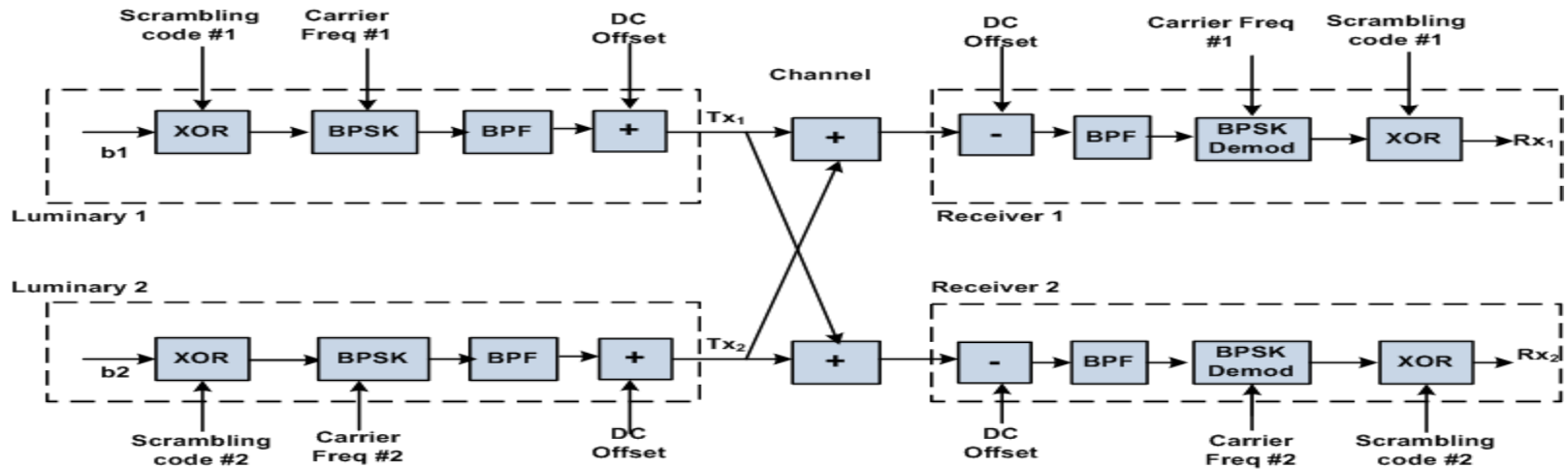
IEEE 802.15.7:Intra-Luminary

Proposed Band Plan
(based on CIE diagram)

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 – can consider expansion to more channels

- Multi-band (color) support provides for PHY layer channel aggregation.
- Not efficient to use for infrastructure mode channel multiplexing
  - Unused colors from each luminary would cause interference.
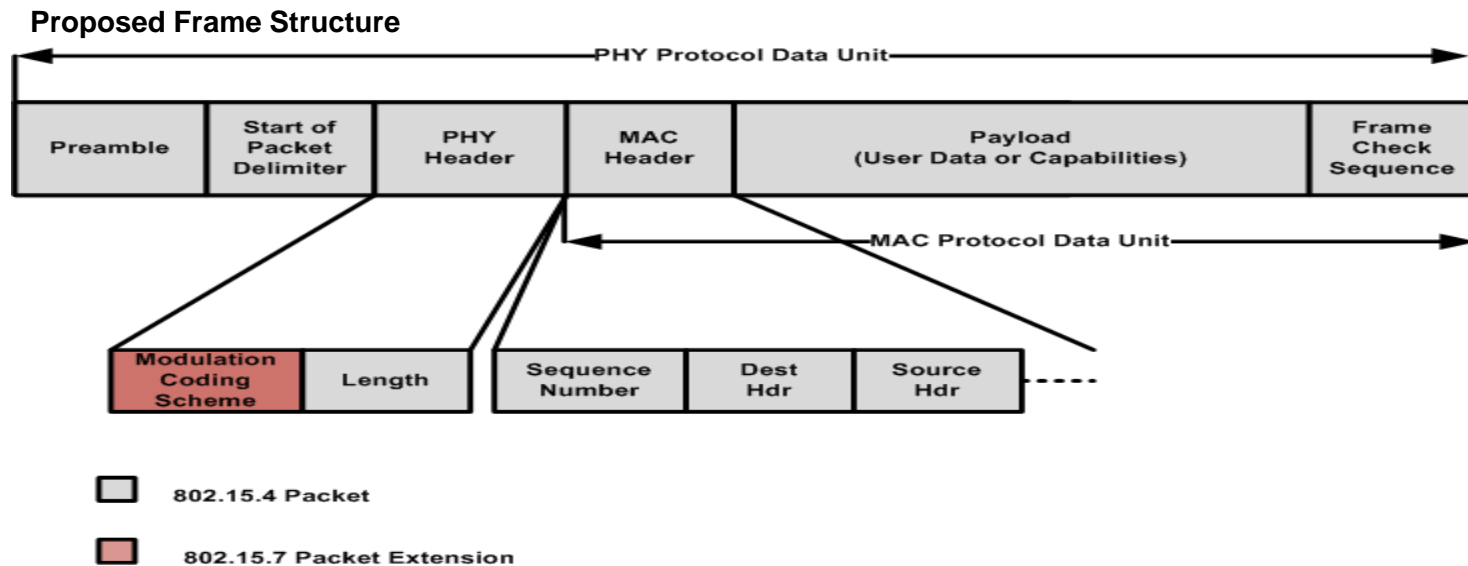
802.15.7: MAC Multiplexing
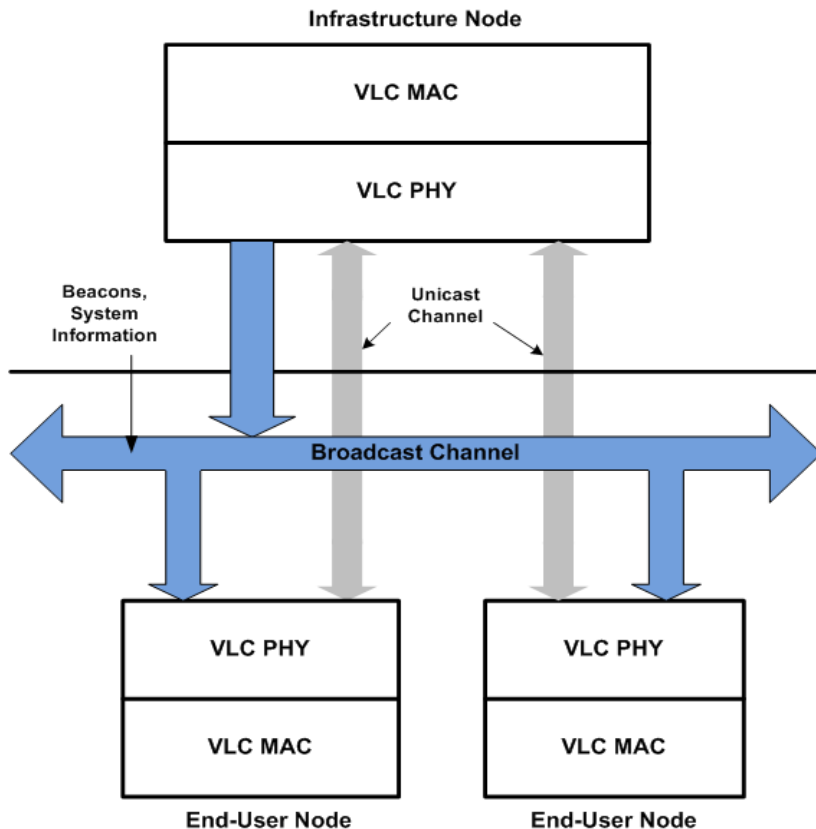
- ## MAC multiplexing
  - ### PDU Types
    - Control: System Information (Unacknowledged)
    - Data:
      - Unacknowledged and acknowledged

- ## Logical Channels
  - Broadcast (for control)
  - Unicast (for data)
  - Multicast (for data)
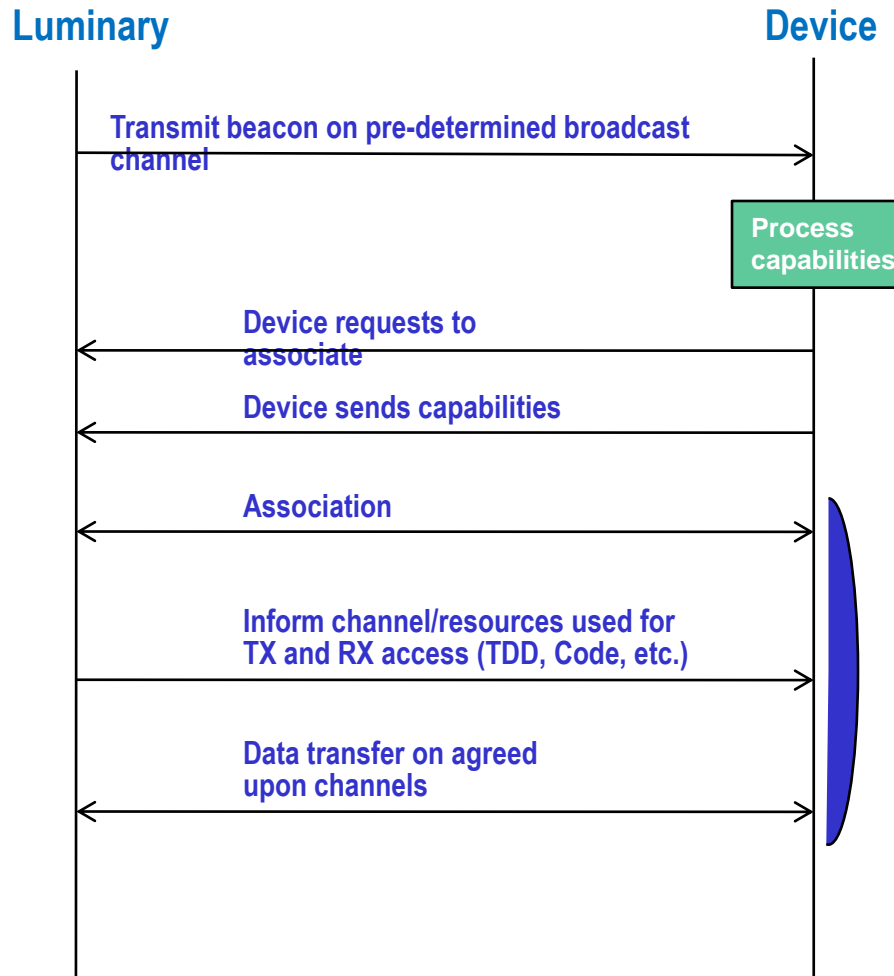
Infrastructure MAC and UE MAC
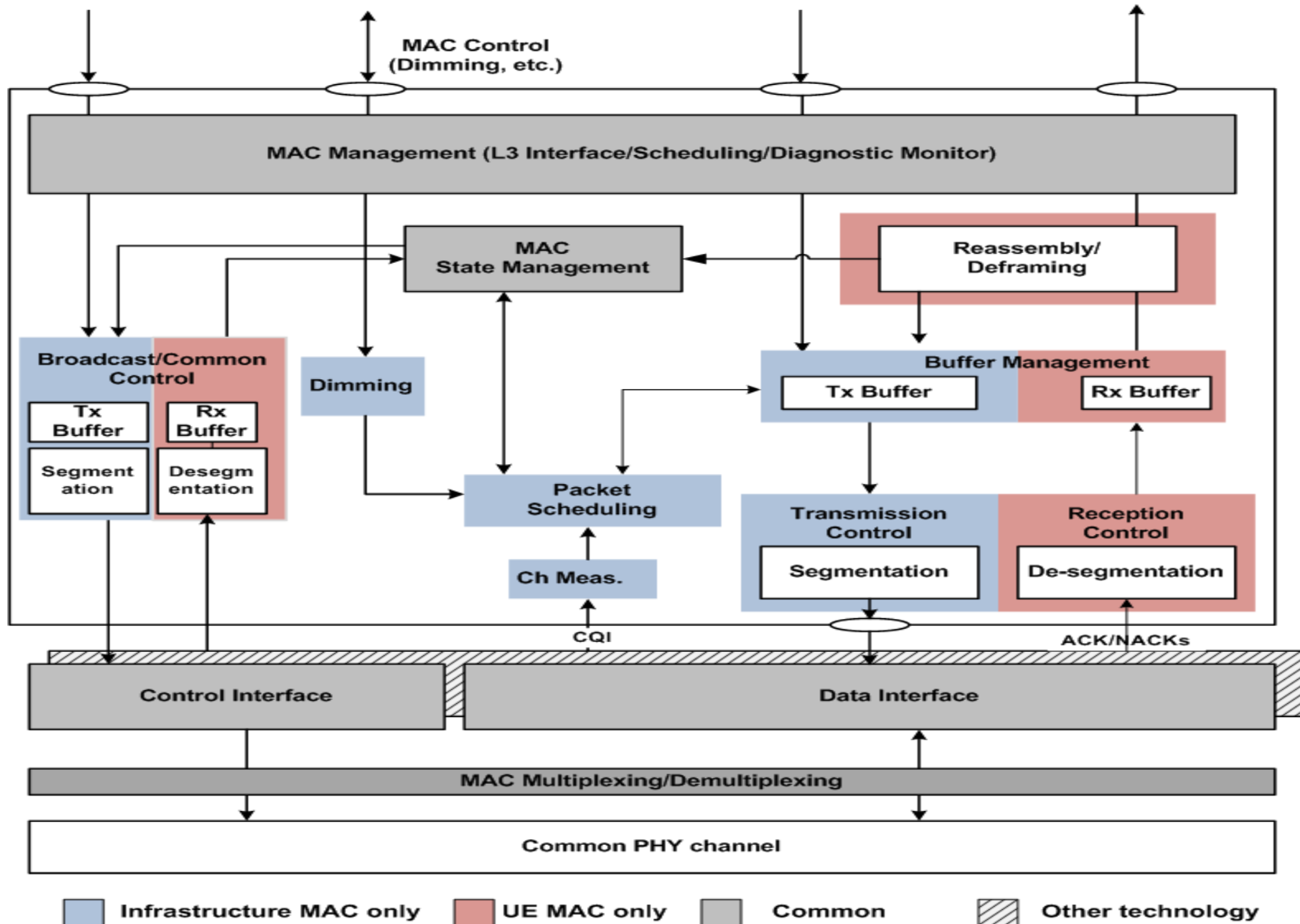
802.15.7: MAC PDU

- Preamble:
  – For receiver timing and synchronization
- 802.15.7 Header
  – Destination Header & Source Header follow 802.15 format
  – Coding Scheme & Length used by PHY for packet decoding.
- Payload
  - For Beacon, payload is capabilities information, etc.
  - For Data Packet, payload is user PDU.
- Optional Frame Check Sequence.

Proposed Frame Structure

802.15.7: Device Discovery

Luminary   **Device**

Transmit beacon on pre-determined broadcast channel

Process capabilities

Device requests to associate

Device sends capabilities

Association

Inform channel/resources used for TX and RX access (TDD, Code, etc.)

Data transfer on agreed upon channels

System Information

– Beacon: Periodic message sent by Infrastructure node (luminary)
– Capabilities:
  • PHY capabilities:
  • MAC capabilities: Uni-directional traffic support, Bi-directional traffic support, P2P support, P2MP support, Dimming support, Visibility support [IEEE 802.15-09-0549-00-0007]

Device discovery and association:

1. New Device enters Luminary domain and starts receiving on configured channel (code).
2. At periodic intervals, luminary sends beacon with capabilities on broadcast channel.
3. Device receiving beacon makes decision based on capabilities.
4. Device associates with Luminary with capabilities match.

Infrastructure Uplink Considerations

- ## OMEGA's hybrid wireless optics
  - VLC: 100 Mbps, broadcast => Simplex
  - IR: 1Gbps hotspot => Uplink
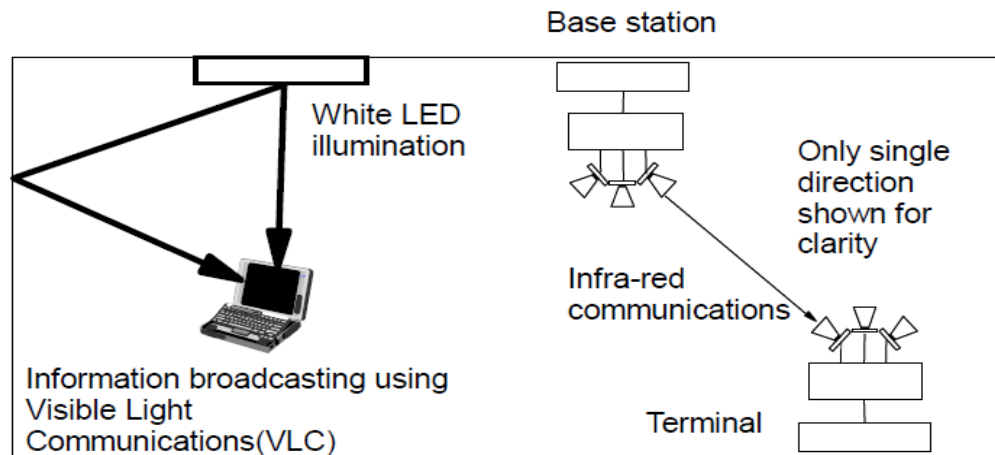
Reference: IEEE 802.15-09-0123-00-0007

Infrastructure Uplink on a different RAT

- ## Needs adaptation layer support in MAC
  - Management Component
    - Availability, QoS mapping, etc.
    - Control/Data multiplexing options, configurations, etc.
  - Data Component
    - Translation, packet adaptation
    - Timing, etc..
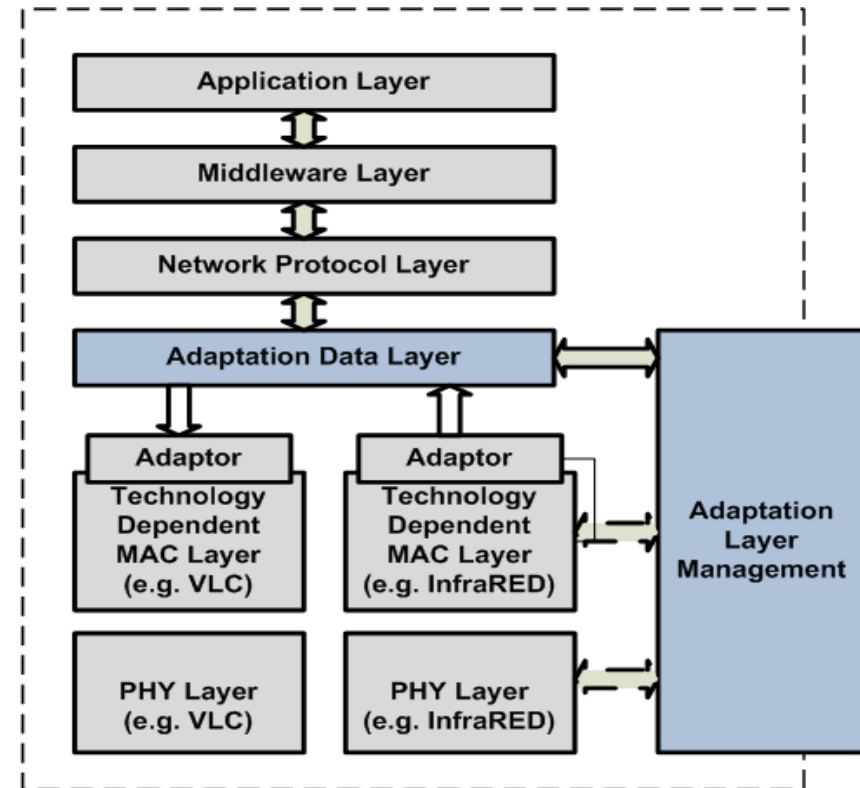
Proposal: Agree that 802.15.7 will support adapter layer that will allow uplink on another access technology.

The end