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

Submission Title: VLC Dimming Proposal
Date Submitted: September 20, 2009
Source: Samian Kaur, Weimin Liu, Douglas Castor [InterDigital Communications, LLC]
Address: 781 Third Ave, King of Prussia, PA 19406
Voice:[610-878-7800], FAX: [610-878-7841], E-Mail:[Samian.Kaur;Weimin.Liu;Douglas.Castor@interdigital.com]

Re: Response to call for proposals on 25th August, 2009

Abstract: This proposal describes a method for dimming controlled by the VLC MAC and supported by VLC PHY transmission structure

Purpose: Proposal to IEEE 802.15.7 VLC TG

Proposal for Dimming

Samian Kaur, Weimin Liu, Douglas Castor
InterDigital Communications,
781 Third Avenue,
King of Prussia, PA, USA

Background

- Support for Dimming is essential
  - PAR scope includes “compatibility with visible-light infrastructures”
  - TCD (15-09-0564-00-0007), Section 18: Lighting Dimming
    - The infrastructure link should support dimming control, albeit possibly at reduced performance levels. It is possible that popular LED dimming options such as PWM could have an impact on communication [13].
  - Mobile-to-infrastructure VLC systems used ubiquitously with illumination is a significant prospective market

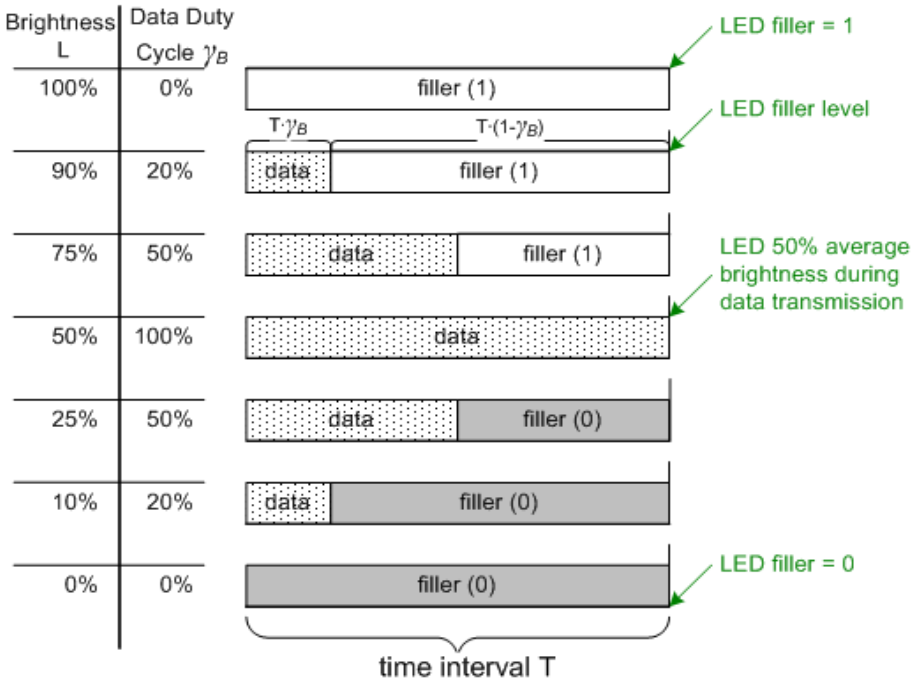
- Two approaches to dimming LED illumination
  - Reduce current flowing through LEDs. Not desired due to:
    - Low energy efficiency in drivers (critical factor for lighting infrastructure)
    - Color change
  - Pulse width modulation (PWM), LEDs on and off to reduce average brightness.
    - LED operations are binary
    - Average brightness is determined by the LEDs’ peak brightness and the proportion of the time they are turned on

Objectives for Dimming with VLC

- Reduce complexity by integrating light control with VLC
  - VLC provides solution for dimming rather than rely on coexistence with numerous lighting industry solutions
  - Better communication system solutions if timing due to dimming pulses are predictable
- Achieve maximum data rate given the brightness
  - MAC control of dimming allows maximized data rate
  - Maximum data rate occurs at 50% brightness (with OOK), assuming randomized data through scrambling
  - Avoid zero throughput with “Provisional brightness” defined for maximum and minimum (0.1%) illumination
- Comply with Flicker requirements
  - Requirement from VLC Regulation Document 802.15-09-0202-02-0007
    - “Even though low-bit-rate transmission or bunching data, the modulation frequency of VLC MUST be higher than CFF (critical fusion frequency) threshold.”

Proposal

- VLC performs dimming
- Desired brightness is controlled by varying the duty cycle (γ_B) of active data transmission within transmission interval, T, with "filler" bits of either "1" or "0" during inactive portion of duty cycle
  - Data are transmitted over repeated time intervals
    - Each time interval T is no more than 5ms
    - The duration of the time interval can be fixed or variable



Aligned with options of prior contributions

- 802.15-09-0557-01-0007 ”Co-existence with Lighting Control” (CSUS/ETRI)
- Aligned with Option 2-1, allowing lighting control performed through VLC MAC Layer

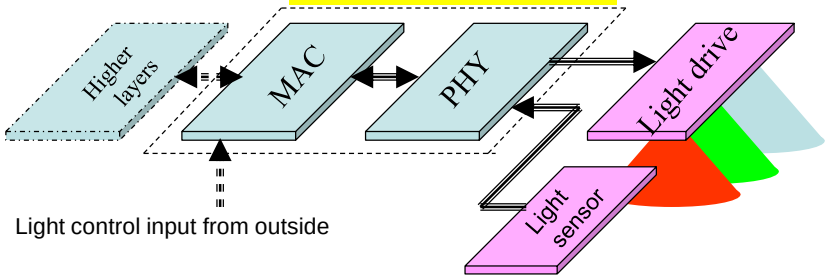
- 802.15.-09-0369-00-0007 “Dimming Considerations for VLC” (Samsung)
- Aligned with “Case C” providing for MAC scheduling based on dimming
- Our proposal adds to “Case C” a transmission structure under MAC scheduled sleep/transmissions

July 2009 doc.: IEEE 802.15-09-0557-01

PROPOSED VLC SYSTEM STRUCTURE 2

Structure 2-1: with light control performed through VLC MAC layer : control through VLC

Covered by 802.15.7 standard

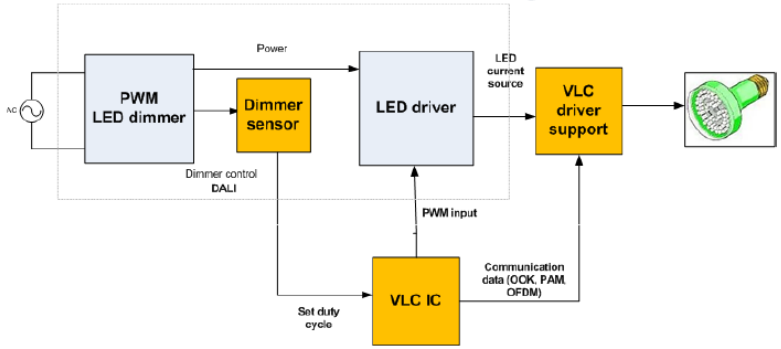


Lighting system is not a part of VLC: a stand-alone lighting system already deployed.

Submission Slide 12 S.-Y. Chang, CSUS, Myunghee Son, et al., ETRI

May 2009 doc. : IEEE 802.15-09-0369-00-0007

Case (B,C) – no dimming override



(B) PHY layer data rate with OOK can be set using dimmer sensor output

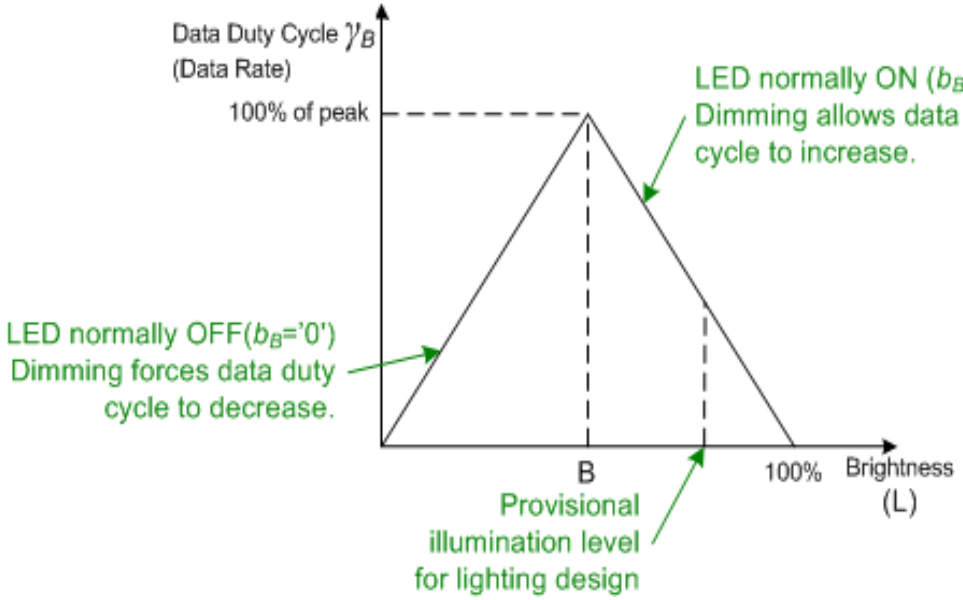
- Lower dimmer settings can cause lower data rate selection in the PHY

(C) MAC schedules sleep/transmissions with duty cycle set by dimmer sensor

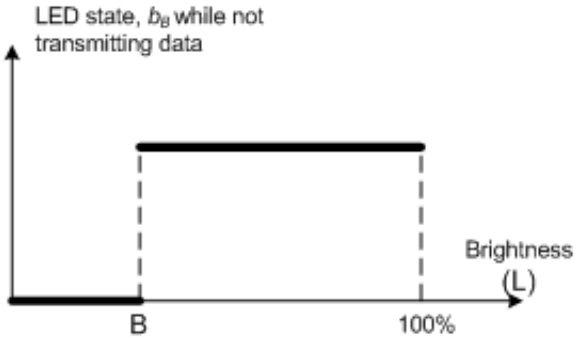
Submission 23 Samsung Electronics

Data duty cycle and LED states – general case

- For any given desired brightness level *L*, expressed as the proportion of the highest brightness level possible, can determine
  - the duty cycle of data transmission γ_B
  - the state the LED b_B for the remaining duration can be determined.
- *L*: the average brightness of illumination

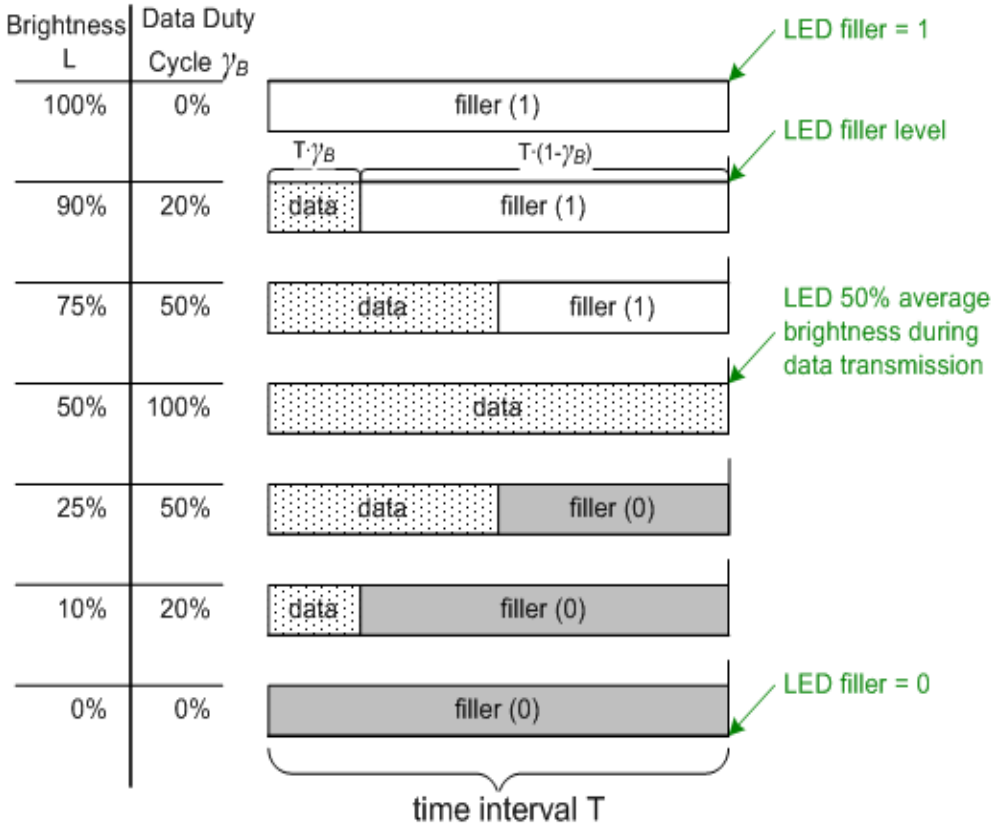


B=0.5 as shown



Modulation	Average Brightness Level, B
OOK	0.5
Manchester	0.5
4-PPM	0.25

Formulae



Data transmission duty cycle:

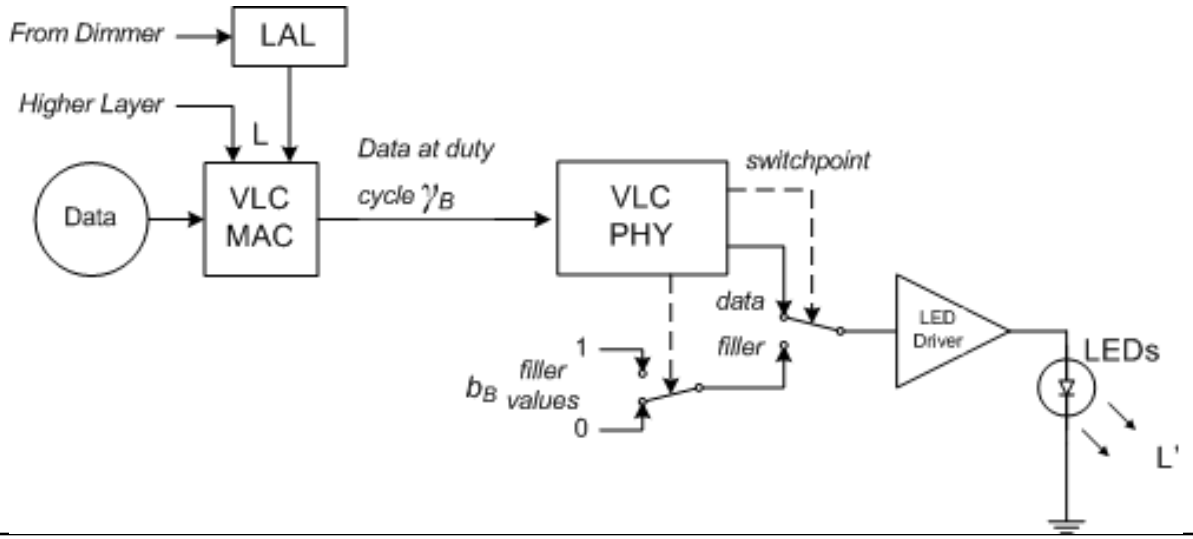
$$\gamma_B = \begin{cases} \dfrac{L}{B}, & L < B \\ \dfrac{1}{1-B}(1-L), & L \geq B \end{cases} \quad (1)$$

LED state while not transmitting data:

$$b_B = \begin{cases} 0, & L < B \\ 1, & L \geq B \end{cases} \quad (2)$$

Block Diagram

- The VLC Dimmer
  - Lighting infrastructure provides illumination level, L
    - Through higher layer <-> MAC interface
    - Or through LAL
  - MAC functions
    - Selects transmission PDU size to maximize data at given brightness
    - Decides whether ‘filler bits’ are “1” or “0” based on Equation (2)
    - Decides whether to send data PDU or dummy PDU with ‘filler’ bits
  - PHY functions
    - Controls timing of switchpoint between data and ‘filler’



Thank You!