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PHY/MAC Protocol Design for Low Rate OWC

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Abstract:- **The semiconductor technology advancements in smart devices and LED technologies enables most viable short range optical wireless communication (OWC) in response to the increasing RF capacity demand on unlicensed visible light spectrum. The OWC designed to operate the data rate from tens of b/s to hundreds of Mb/s, but the PHY/MAC packet format in standards uses the same no of bits for transmission in all data rates which adds data overheads on OWC system operates in tens of b/s and increase the system response time too high in real-time scenario. This paper propose the forbidden PHY/ MAC frame configuration over-the-air to eliminate the data overheads and to reduce the response time on low data rate OWC system. The proposed low rate OWC PHY/MAC design considered to integrate with photo detector (PD) or optical camera communication (OCC) on existing network IP stack in the context of wireless networking. In this research deliberate on key challenges involved in PHY/MAC protocol design and optical wireless networking to design the next generation wireless technologies using visible light.**

Index terms **– OWC, VLC, PHY, MAC, NETWORK LAYER, IEEE802.15.7, Low Rate, LED, PD, OCC**

I. INTRODUCTION

The OWC technology provided with illumination variation on LED devices is characterized by high range of spectral efficiency, unlicensed wide range of bandwidth with high security and dual-use nature as light source and transmission medium. This short range wireless communication fulfill the RF wireless traffic demand. There are few recent days standards discuss about OWC standardization, say IEEE, VLCC, etc. The visible light communication (VLC) consortium (VLCC) standard for VLC was initiated by the Japan and discusses data transmission using visible light. The IEEE standard IEEE802.15.7 and IEEE802.15.7m describes the PHY/MAC protocol standard for VLC and OWC on personal area networks, localization, and illumination control.

The visible light based short range wireless communication system design have receiving strong recommendation from the system designers of the next generation of wireless networks [1] and the potential VLC's usages, development challenges, system installation challenges and market conditions are described in [2].

The 802.15.7 IEEE standard developed [3] for short-range optical wireless communication using visible light. The initial IEEE standard for VLC species three PHY layers with varying data rate from 11:67 kb/s to 96 Mb/s. The present IEEE OWC standard 802.15.7m defines three more PHY layers in addition with data rate from tens of b/s to hundreds of Mb/s.

The most used VLC receiver uses the PD receivers, in [4] and a reverse-biased LED is used as a receiver to implement a bidirectional communication. The software defined communication radio using 802.15.7 protocol is shown in [5] and has been exploited in [6] to introduce a communication network. The PHY/MAC design to enable internet infrastructure connectivity on VLC is described in [7].

This research focusing on PHY/MAC limitations on low rate optical wireless communication mode and challenges to integrate with network connectivity over owc based wireless infrastructure. In OWC system, LED acts as physical media to interface with networking platform and add-on software framework for Medium Access Control (MAC) and Physical Layer (PHY) layer protocols interface with IP stack for designed application connectivity. In this proposed approach, the low rate OWC PHY/MAC header configuration information not aired as those information are aired in high data rate OWC system to reduce the data overload and system response time. This proposed approach applicable to use in PD and Camera based receiver design.

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The OWC network interface is described in clause II. The MAC and PHY design for low rate OWC is described in clause III and IV. The clause V describes the PHY/MAC design considerations and analysis. The conclusions for proposed approach is finally drawn in clause VI.

II. OPTICAL WIRELESS COMMUNICATION

The OWC works on visible lights wavelengths also accommodates the additional wavelengths of infrared and near ultraviolet, and this categories VLC into three sub division as OCC, LED-ID, and LiFi.

The OCC enables the applications like positioning/localization, and message broadcasting, etc. with scalable data rate support using devices like flash, display as a transmitting device and image sensor as receiving device. The LED-ID is light based ID (Identification) system using different LEDs. The LiFi is a bidirectional high-speed, networked wireless communications using lighting devices.The optical wireless personal area network device comprises of a physical layer (PHY) and a medium access control (MAC) layer. The PHY layer contains the light transceiver along with required low-level control mechanism. The MAC layer used to provide the access to the physical channel for all types of transfers with device specific control and configurations. The proposed VLC network interface to enable internet connectivity on OWC based infrastructure is shown in figure 1. The OWC network interface includes the MAC/PHY layer to interface visible light based network infrastructure on TCP/IP stack based intranet/internet generalized connectivity model.

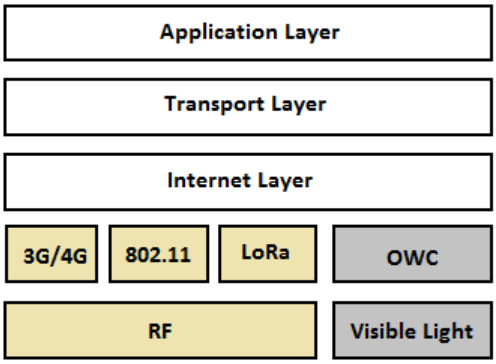

Figure 1: OWC Network Interface

III. LOW RATE OWC MAC DESIGN

The IEEE 802.15.7m MAC layer designed for OWC communication as shown in figure 2. The MAC layer is responsible to configures and control required access to the physical layer, generating network beacons if the device is a coordinator, synchronizing to network, supporting visibility and dimming, flickering mitigation and device security to provide a reliable link between two peers with mobility in the networks.

Octets: 2	1	0/2	0/2/8	0/2	0/2/8	0/5/6/10/14	variable	2
Frame Control	Sequence Number	Destination OWPAN Identifier	Destination Address	Source OWPAN Identifier	Source Address	Auxiliary Security Header	Frame Payload	FCS
		Addressing fields						
MHR							MSDU	MFR

Figure 2: MAC Frame Format

The MAC frame format integrated low data rate OWC system data transfer which works on tens of b/s adds data overheads. This data overheads increase the response time more than 5 secs and increase complexity on the system integration. To eliminate low data rate OWC system limitations, this paper propose not to transfer the MAC frame configuration over-the-air instead of that MAC frame configuration be done via the MAC physical-layer personal-area-network information base (PIB).

IV. LOW RATE OWC PHY DESIGN

The OWC PHY layer frame format defines the LED illumination dimming, LED flicker mitigation, and modulation scheme used to transfer data, etc. The OWC PHY is adaptive to different modulation schemes like OOK, PPM, VPPM, Offset-VPWM, etc. The OWC physical-layer data unit (PPDU) frame structure is illustrated in Figure 3.

Preamble	PHY header	HCS	Optional fields	PSDU
SHR	PHR			PHY payload

Figure 3: PPDU Frame Format

The PHY preamble field is used to obtain optical clock synchronization with an incoming message in OWC system. The PSDU field has a variable data

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length and carries the data on the PHY frame and the FCS is appended if the PSDU has a non-zero byte payload.

The PHY frame format integrated low data rate OWC system data transfer which works on tens of b/s adds data overheads. This data overheads increase the response time and increase complexity on the system integration. To eliminate low data rate OWC system limitations, this paper propose not to transfer the PHY frame configuration over-the-air instead of that PHY frame configuration be done via the PHY PIB.

V. PHY/MAC DESIGN CONSIDERATIONS AND ANALYSIS

This paper propose to use of over-the-air PHY/MAC frame configuration is forbidden for low rate OWC system. The over-the-air is not proposed for low rate OWC is due to the fact that unlike traditional wireless LAN/PAN, the data rates associated with low rate PD or OCC are such that the configuration overhead cannot be tolerated in real-time system response. The proposed approach anticipated that PHY/MAC configuration will be with application layer "APPS" that are specifically loaded to support a particular PD or OCC PHY mode as PHY/MAC PIB attributes. The PHY/MAC PIB is not transmitted and these attributes is written by the device management entity and is read by the PHY/MAC layer in the application.The OWC MAC PIB attributes added based on requirement to manage the MAC sublayer of a device. The sample OWC MAC PIB are illustrated in Table 1.

Table 1: MAC PIB Attribute Definitions

Attribute	Identifier	Type	Range	Description
macSourceOWPANIdentifier	0x101	Unsigned	2 octets	
macSourceAddress	0x102	Unsigned	2 or 8 octets	
macAcknowledgeField	0x103	Unsigned	variable length	
macFramePayload	0x104	Unsigned	variable length	
macFCS	0x105	Unsigned	2 octets	
macFrameVersion		3 bit	000-111	This attribute specifies the OCC MAC frame version. 000: IEEE Std 802.15.7-2011 001: IEEE Std 802.15.7-201x OCC 010-111: Reserved
macOccFrameType		3 bit	000-111	This attribute specifies the OCC MAC frame. 000: Unidirectional Information Broadcasting (IB) frame 001: Light-ID frame 010: Bidirectional data transfer (D2D mode) 011-111: Reserved
macOccSecurityEnable		Boolean	T/F	This is to configure security mode. FALSE: Security disable (all the OCC broadcasting modes) TRUE: Security enable

The low rate OWC PHY PIB attributes comprises with the required configuration options to manage the OWC device. All these attributes can be assigned to the receiver through the optional field during the APPS initialization. The supported sample PHY PIB attributes are illustrated in Table 2.

Table 2: PHY PIB Attribute Definitions

Attribute	Identifier	Type	Range	Description
phyCurrentChannel	0x00	Integer	0–6	The wavelength used for all following transmissions and receptions
phyCCAMode	0x01	Octet	enumerated	b0=CCA mode 1 b1=CCA mode 2 b2=CCA mode 3 b3–b7=reserved
phyDim	0x02	Integer	0–1000	0 is 0% or no visibility and 1000 is 100% visibility (full brightness).
*phyFrequencyLabeling**	0x03		Frequency ration = 1.5	Indicates the PSDU carries the frequencies that will be used for the data frame later on. * This PIB attribute is explicitly defined for future extensibility. For now, only aFrequencyLabelingRatio can control the frequency ratio of the Frequency Labeling field.
phyUseSplitterSymbol	0x04		Frequency ratio = 0.83	Indicates the the PSDU carries the flag to toggle whether the device is going to use SSs or not.
phySplitterFrequency	0x05		Frequency ratio = 0.71	Indicates the PSDU carries the splitter frequency. If the SS is already in used, it will use the original phySplitterFrequency until next cycle.

All the PHY/MAC PIB attributes are labelled as specific functional name as the application. For an example, frequency ratio, using aPreambleFrequency as the baseline in PHY attributes. If one would like to extend the PIB attribute table, do not overlap the ratio with previously defined since it will seriously interfere with the interpretation of all subsequent data symbols.

The phyOccApplicationSpecificMode is used to specify the PHY mode for a given geolocation such as the APP associated with a particular store, The information is provided by an out-of-band channel (i.e. RF) and is provided by the particular store prior usage (i.e. by downloading the stores OCC APP).

Advances being made are relatively specific, to encode and transmit data as fast as possible. To use OWC in existing internet infrastructure still requires some research in the areas of PHY/MAC protocol or routing layers. This reduces overall system overheads and provides the operating condition as application demands.

VI. CONCLUSION

This paper presented the design of the low rate OWC PHY/MAC for visible light based network connectivity using PD or CamCom based optical wireless receiver on existing network infrastructure. This approach shows that the OWC based TCP/IP protocol stack integration can achieve appropriate network connectivity with visible light based communication model with low complexity and low power consumption. This proposed PHY/MAC design is both transparent which means that can accept any input from upper or lower layers and it can provide expected output as defined in OSI TCP/IP standard. However, the proposed PHY/MAC protocol, in essence, is designed for single omni-directional transceiver, and there are obvious flaws with 802.15.7 on OWC link.

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