Current Status of IEEE 802.15.7r1 OWC Standardization

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IEEE TG7r1 Standardization Status

IEEE TG7r1 Introduction

IEEE 802.15 WPANTM

15.7 Revision: Short-Range Optical Wireless Communications Task Group (TG 7r1)

Tuesday, 7 July 2015

Overview

IEEE 802.15 has formed a Task Group to write a revision to IEEE 802.15.7-2011 that accommodates infrared and near ultraviolet wavelengths, in addition to visible light, and adds options such as:

- **Optical Camera Communications** which enables scalable data rate, positioning/localization, and message broadcasting, etc. using devices such as the flash, display and image sensor as the transmitting and receiving devices (defined here).
- **LED-ID** which is wireless light ID (Identification) system using various LEDs (defined here).
- **LiFi** which is high-speed, bidirectional, networked and mobile wireless communications using light (defined here).

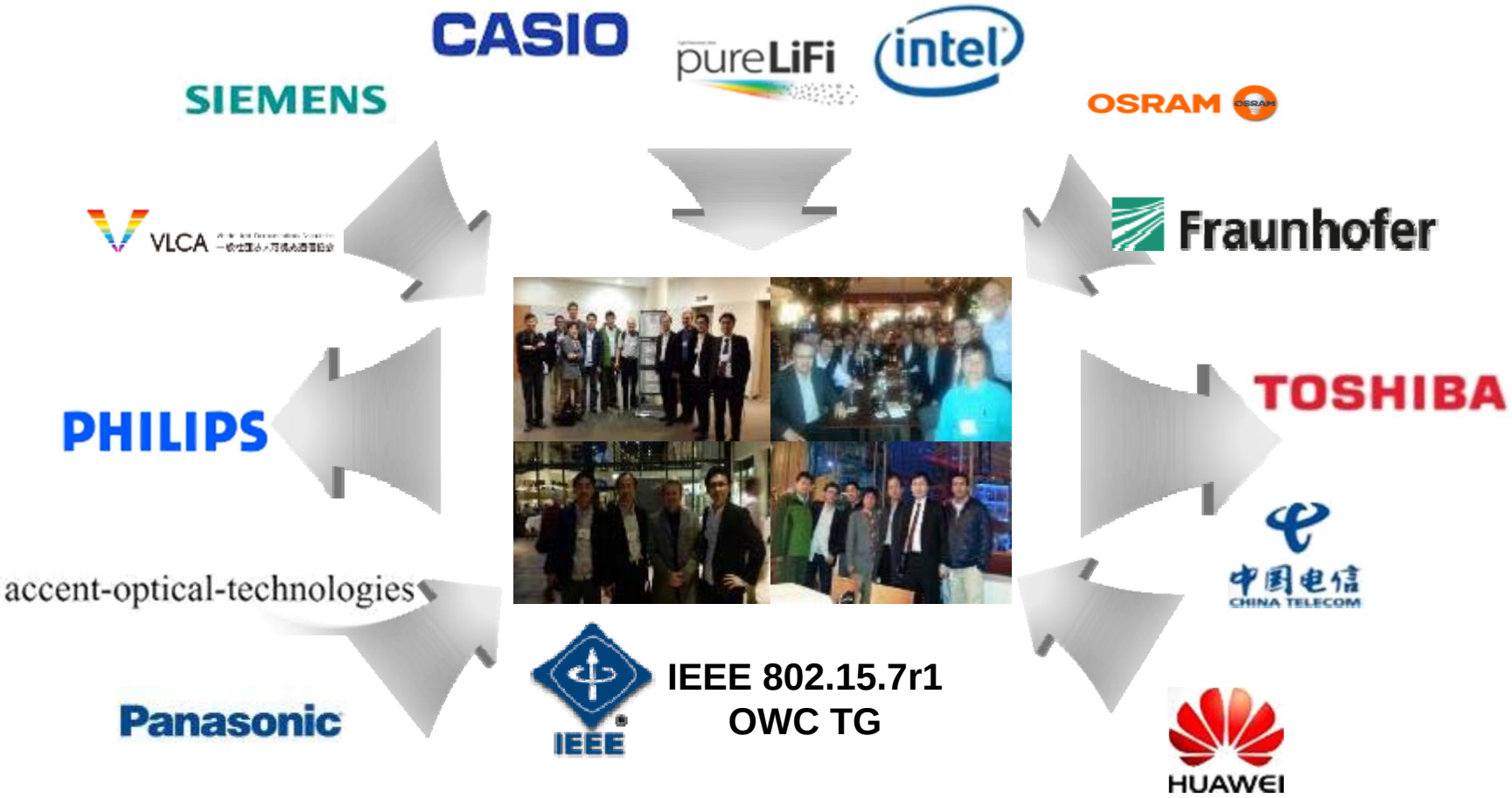
Benefits of OCC Technology

	Bluetooth	WiFi	VLC	OCC
Interference	Yes	Yes	Yes	Less
Security	High	High	Highest due to LOF	Highest due to LOF
Link Setup	Scan-and-Link	Scan-and-Link	LOS Link	Look-to-Link
Protocol	IEEE 802.15.1	IEEE 802.11a and IEEE 802.11b	IEEE 802.15.7	IEEE 802.15.7r1
Frequency band	2.4GHz	2.4, 3.6 and 5 GHz	Visible light (400-800THz)	**Visible light, IR, UV.**
Data transfer rate	800 Kbps	11 Mbps	PHY I: 11.67kbps-266.6 kbps PHY II: 1.25Mbps-96Mbps PHY III: 12Mbps-96Mbps	- Lower than VLC. - Enhance by increasing the number of LEDs, camera's resolution.
Cover range	30m	46m, up to 100m	Near	**Can be extended using Zoom function (up to km)**

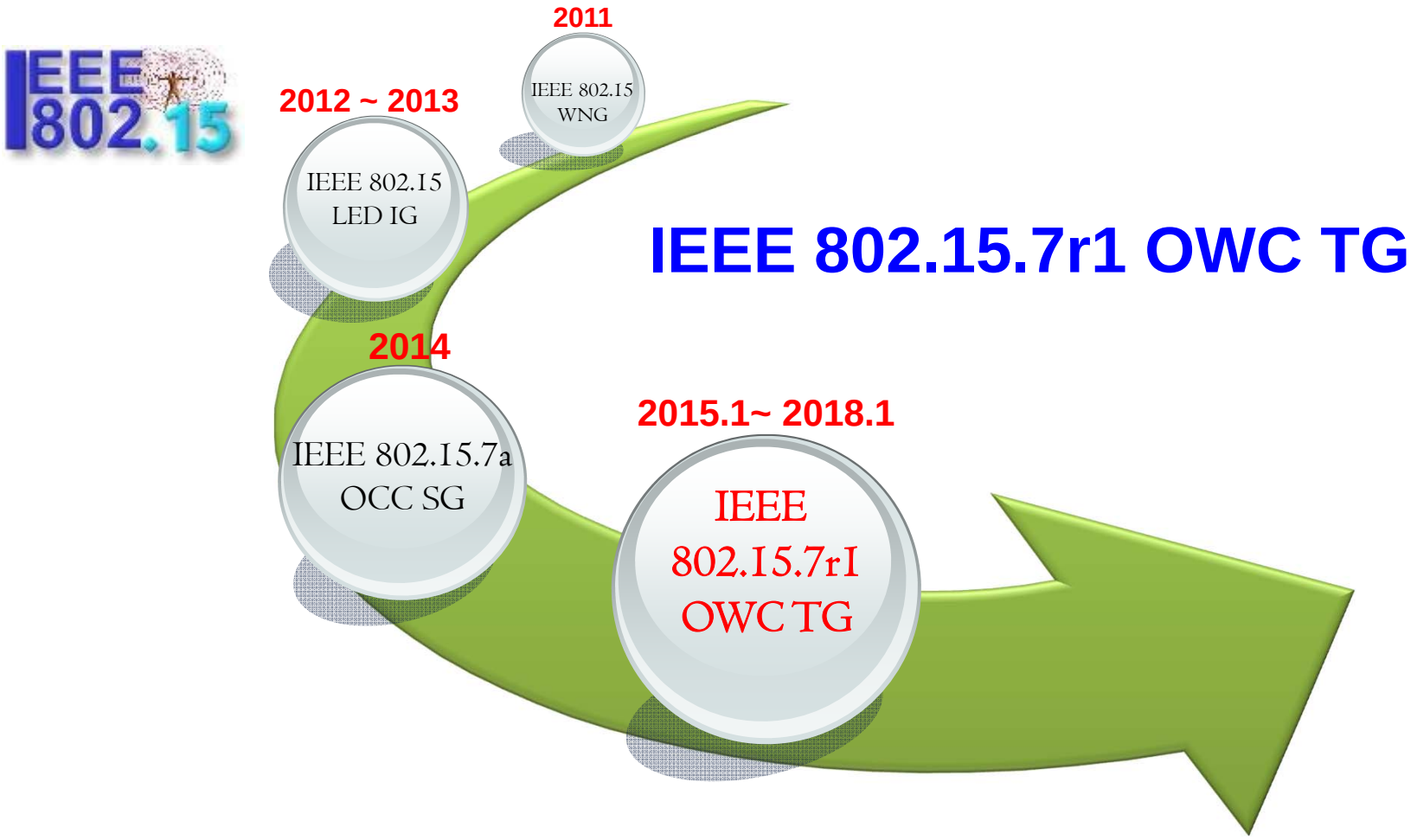
Technical Comparison

	LiFi (High Rate PD Communications)	OCC (Image Sensor Communications)
Receiver	PD	Image Sensor(Camera)
MIMO (multiplexing)	Complex to Implement	Easy to Implement
Diversity	Easy	difficult
Frame Sampling	No	Yes
SNR	Low	High
Interference	High	Low
Decoding technique	Signal Processing from received photo current	Image Processing using gray level or color of pixels
	pureLiFi, Fraunhofer, Fudan University, ETRI	Intel, Casio, Toshiba, China Telecom, Panasonic, Kookmin University, SNUST

TG7r1 Interested Companies



TG7r1 Baseline Schedule



TG7r1 Baseline Schedule

Baseline Schedule of IEEE 802.15.7r1 OWC

CFA : Call for Application
TCD : Technical Consideration Document
CFP : Call for Proposals

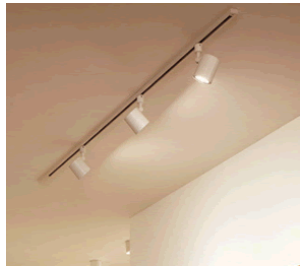
LB : Letter Ballot
SA : Standards Association
SB : Sponsor Ballot

Interested Use Cases in TG7r1

Ceiling light

Flash light

Car light

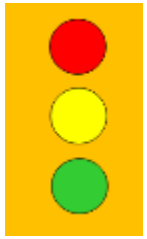


Indirect light

Illuminated signage

Digital signage

Traffic light



Lighthouse

D2D using Digital Signage/LED and Image Sensor is interesting and very promising.

TG7r1 Technology Aspects

OWC Technology Aspects

- **Image Sensor Communications** which enables optical wireless communications using an image sensor as a receiver.
- **High Rate PD Communications** which is high-speed, bidirectional, networked and mobile wireless communications using light with a high speed photodiode receiver.
- **Low Rate PD Communications** which is wireless light ID system using various LEDs with a low speed photodiode receiver.

1- Image Sensor Communications

Applications/Use Case

- A2 IoT (M2M/D2D/ Internet of Light (IoL))
- A3 LBS / Indoor Positioning
- A4 Vehicular Communication
- A5 Underwater Communication
- A6 Power Consumption Control
- A7 Vehicular Positioning
- A8 Seaside Communication
- A9 LED based Tag application
- A10 Point-to-(multi)point / relay communication
- A11 Digital signage

Transmitter

The standard should support the following devices as transmitters for each application.

Device	Applications/Use cases
Ceiling light / Lighting Source	A2, A3
Flash light	A5, A2
Car light	A4, A7
Indirect light	A1, A4
Illuminated signage with diffused light	A1, A2
Illuminated signage with discrete LEDs	A1, A2
Digital signage (such as LCD)	A1, A2
Traffic light and Intelligent Traffic System (ITS)	A1, A2, A4, A7
Lighthouse	A1, A8
LED Tag	A9, A5, A8, A1
Display / Image patterns	A9, A5, A8, A1

Receiver

The standard will support an optical camera receiver, which has an image sensor that measures the intensity of visible light, IR and/or UV. The standard will support image sensors of global shutter or sequential shutter (such as rolling shutter) with multiple PHY/MAC modes.

Carrier Wavelength

Carrier wavelength will be limited to visible light, IR and UV.

Transfer mode

A PHY/MAC mode of the standard will support at least one of the following transfer modes according to the duplex mode:

- **ID broadcast mode** which repetitively broadcast ID with small overhead of MAC frame for application A1, A2, A3, A4, A5, A7, A9 and A11.
- **Unidirectional data transfer mode** which transmit longer data stream for application A2, A4, A6, A8 and A11.
- **Bidirectional data transfer mode** which enables efficient communication for application A2 and A10.

The standard may provide multiple PHY/MAC modes that allow the efficient use of the available optical bandwidth on a given luminaire.

Dimming Control

- The standard will support dimming control for application A1, A2, A3, A4 and A7.

Power Consumption Control

- The standard should support power consumption control for application A6.

Coexistence with Ambient Light

- The standard will co-exist with ambient light that may be reflected on a surface of a transmitter. In addition, coexistence shall be investigated with the existing IEEE802.15.7-2011 operating modes.

Coexistence with Other Lighting Systems

- The standard will co-exist with other lighting systems. It will enable a receiver to receive a signal from a transmitter even if other lighting systems are captured in the same image frame, which are optically separable from the transmitter.

Simultaneous Communication with Multiple Transmitters

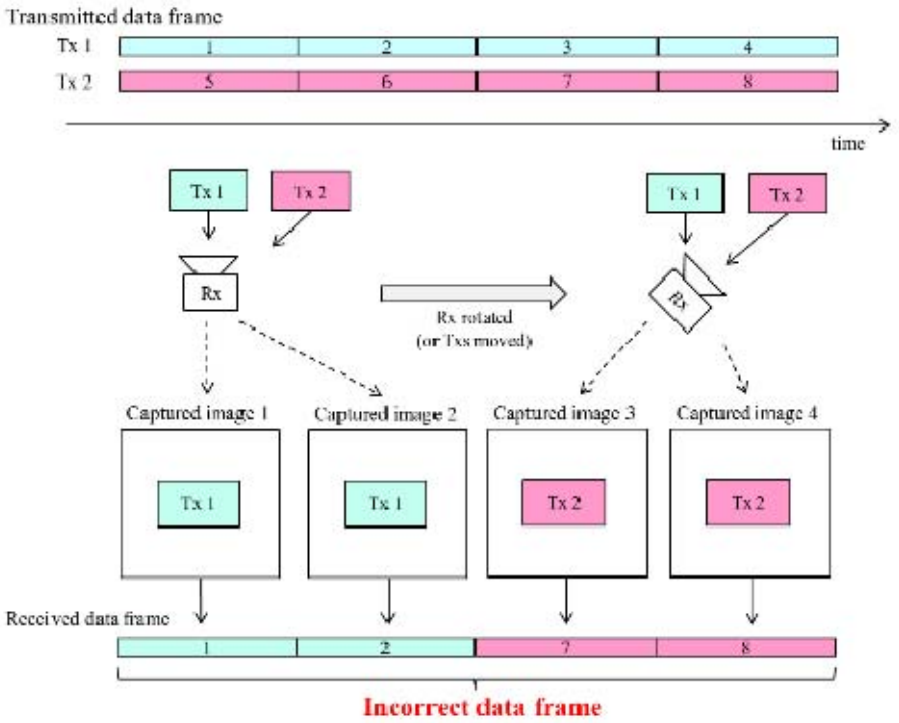
- The standard may support simultaneous communication with multiple coordinated/uncoordinated transmitters, which are separated on a captured image. Simultaneous communication with coordinated transmitters is called Multiple Input/Multiple Output (MIMO) and a MIMO MAC protocol may be incorporated into the standard so the camera enabled receiving device knows how to process the received data.

Simultaneous Communication with Multiple Receivers

- The standard may support at least one PHY/MAC layer for simultaneous image sensor communication between multiple coordinated/uncoordinated transmitters and multiple coordinated/uncoordinated receivers.

Data Frame Consistency

- The standard will support a scheme to confirm data frame consistency to avoid incorrect data frame in situations such as described in the following figure.



Nearly point image data source

- The standard will support at least one PHY mode that works when the light source appears as nearly a point source; that is, the light source illuminates only a small number of image pixels.

Identification of modulated light sources

- The standard may support at least one PHY mode that allows identification of modulated light sources at one camera frame rate and then demodulation at a different camera frame rate.

Low overhead repetitive transmission

- The standard will support at least one MAC mode that supports repetitive informational broadcast at very low data rate; that is, the frame format has very little overhead and is optimized for short payloads sent in a repetitive manner.

Image Sensor Compatibility

- The standard will support a PHY mode that is compatible with a variety of cameras with different image sensing sampling rates (read-out time), resolutions and frame rates. Specifically, either constant frame rate or varying frame rate will be supported. And also specifically, either constant resolution or varying resolution will be supported.

Localization

- The standard may provide mechanisms to support positioning algorithms.

2- High Rate PD Communications

Applications/Use Case

The following High Speed Photodiode Receiver applications/use cases were presented in response to TG7r1 Call for Applications.

- B1 Indoor Office/Home Applications: (Conference Rooms, General Offices, Shopping Centres, Airports, Railways, Hospitals, Museums, Aircraft Cabins, Libraries etc.)
- B2 Data Center / Industrial Establishments, Secure Wireless (Personalized Manufacturing Cells, Factories, Hangers, etc.)
- B3 Vehicular Communications (Vehicle-to-vehicle, Vehicle-to-Infrastructure)
- B4 Wireless Backhaul (Small Cell Backhaul, Surveillance Backhaul, LAN Bridging)

Transmitter

The standard shall support the following devices as transmitters for each application.

Device	Applications/Use cases
Ceiling/Street light	B1, B2, B3
Indirect light	B1, B2
Car light	B3
Directed light	B2, B4

Receiver

High speed photodiode

Transfer mode

The standard will support continuous data streaming for all applications with bidirectional functionality as well as short packet transmissions where low latency is required. The standard must provide a PHY mode that allows an efficient use of the available optical bandwidth of a given luminaire for B1 – B4.

The standard must define a range of data rates with minimum supported connectivity of at least 1 Mbps at the PHY SAP. The standard must support at least one PHY mode that supports peak data rates of 10 Gbps at the PHY SAP.

The standard may allow a range of latencies from maximum supported of at most 30 ms to minimum latency of 1 ms.

Dimming Control

The standard will support dimming control for application B1 – B3.

Adaptive Transmission and Multiple User Support

The standard must provide MAC/PHY mechanisms to support adaptive transmission as well as the support of multiple users communicating different data streams from the same light source (multiple access).

Asymmetric Communication

The standard will support asymmetric communication between transmitters and receivers to allow higher data rates in one direction.

Handover and Interference Coordination

The standard will provide mechanisms to support horizontal handover between light sources, allowing the users to maintain a continuous network connection for applications B1 – B3.

The standard may provide efficient mechanisms that can be used to deliver interference coordination techniques by higher layers.

Handover mechanisms may not be required for point-to-point communications.

Localization

The standard may provide mechanisms to support positioning algorithms.

Coexistence with Ambient Light and Other Lighting Systems

The standard will co-exist with ambient lights. This may enable a receiver to communicate with a supported transmitter even in the presence of other modulated lights.

In addition, coexistence shall be investigated with the existing IEEE802.15.7-2011 operating modes.

Simultaneous Communication with Multiple Transmitters

The standard may support multiple coordinated/uncoordinated transmitters, which is referred to as multiple-input multiple-output (MIMO) communications. It may support cooperative signal processing among multiple transmitters with negligible impact on latency.

The standard will support efficient and reliable feedback and control channels. These may be used for adaptive transmission, multiple user support, MIMO support, cooperative signal processing or other features.

Waveform

The standard will employ at least one PHY mode that uses variable current modulation.

Metric Reporting

The standard may provide internal metrics via an open interface. This information may be used to support cooperative signal processing, vertical handover and link aggregation with other wireless transmission techniques.

For this purpose, the High Rate PD Communications may report the following metrics with minimized overhead and low latency:

Information about instantaneous metrics such as SINR and detailed channel state information.

Information about recent history of the metrics such as temporal characteristics, signal blocking, frequency of signal losses.

3- Low Rate PD Communications

Applications/Use Case

The following Low Speed Photodiode Receiver applications/use cases were presented in response to TG7r1 Call for Applications.

- C1 Underwater/Seaside Communication [8]
- C2 Point-to-(multi)point / communication [5, 8, 9]
- C3 Digital signage [5, 8, 17]
- C4 D2D/IoT [5, 9]
- C5 LOS Authentication [5, 17]
- C6 Identification based service [20, 21]

Transmitter

The standard should support the LED Tags, Smart Phone Flash lights, Lighting source, etc. for various applications.

Device	Applications/Use cases
Smart Device Flash light	C2, C4,
Lighting source	C1, C3,C5,C6

Receiver

The standard will support Low Speed Photodiode Receiver. It measures intensity of visible light, IR and/or near UV, as receiver.

Carrier Wavelength

Carrier wavelength will be limited to visible light, IR and near UV frequency band.

Transfer mode

The standard may provide multiple PHY/MAC modes that allow the optimal use of the available optical bandwidth on a given luminaire for C1 – C6.

D2D/IoT data transmission and Relay mode with ID information with PHY/ MAC frame for applications C2, C3, C4, C5 and C6.
Uni/Bi-directional data transfer mode for applications C1 – C6..

In regards to the definition of low speed and high speed, the throughput threshold data rate is 1 Mbps as measured at the PHY SAP. Throughput less than 1 Mbps rate at the PHY SAP is considered low rate and higher than 1 Mbps at the PHY SAP is considered high rate.

Dimming Control

The standard will support dimming control for all of applications

Handover, Link Recovery and Interference Coordination

The standard may provide mechanisms to support handover between LED light sources, allowing the users to maintain a continuous network connection.

The standard may provide mechanisms that can be used to develop and deliver interference coordination techniques by higher layers.

The standard may support link recovery mechanism to maintain connection in unreliable channel for reducing the connection delay.

Localization

The standard may provide mechanisms to support indoor positioning algorithms.

Coexistence with Ambient Light

The standard will co-exist with ambient light that may be reflected on a surface of a transmitter. In addition, coexistence shall be investigated with the existing IEEE802.15.7-2011 operating modes.

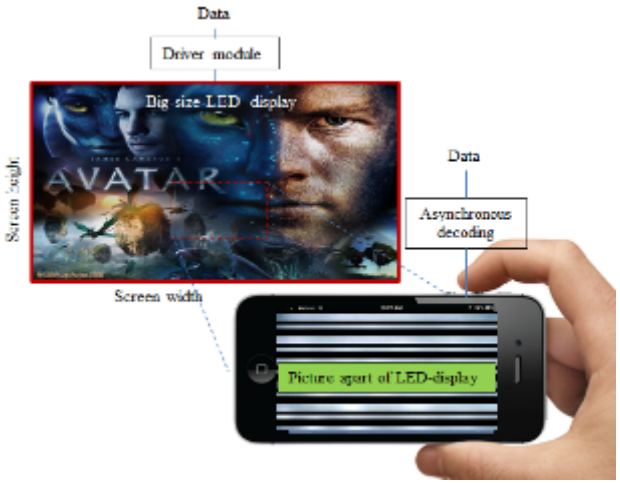
Coexistence with Other Lighting Systems

The standard will co-exist with other lighting systems.

Identification of Transmitter

The standard will support a scheme to identify transmitters' ID information. A receiver can trace a transmitter identification (ID) using Low Speed Photodiode Receiver system.

Kookmin University's Contributions

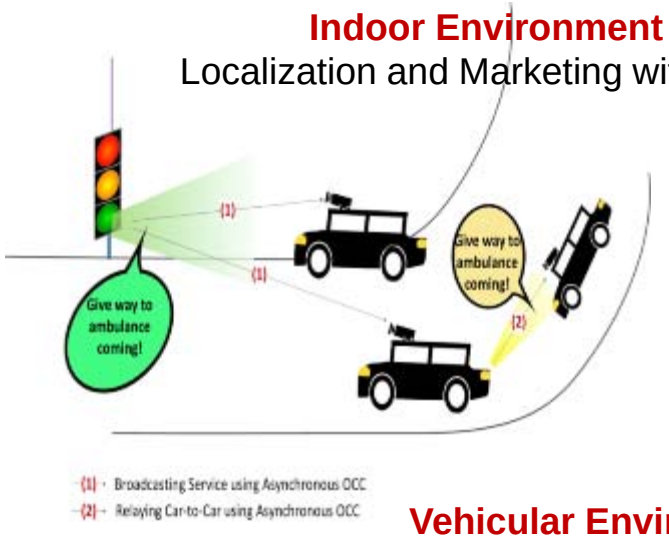


Indoor Environment

Localization and Marketing with OCC

Outdoor Environment

Digital Signage



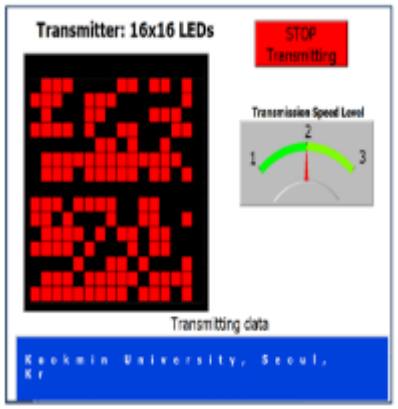
Vehicular Environment

V2V/V2X

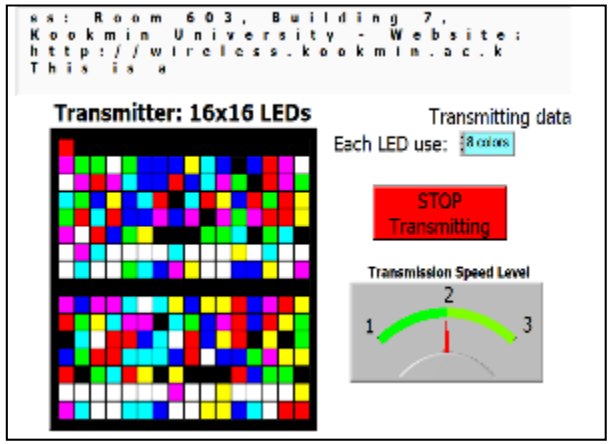
Seaside Environment

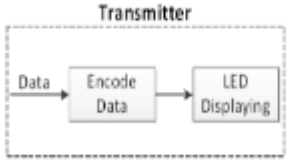
Lighthouse-to-Ship/Ship-to-Ship

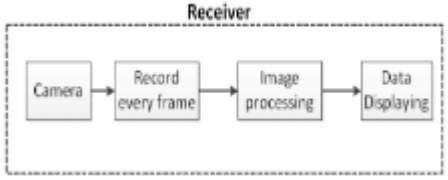
OCC Transmitter



OCC Receiver







User Interface of Transmitter & Receiver

- 16x16 R-G-B LEDs to enhance data rate (three-times increased in compared to OOK single color-system)
- Ability of switching transmission speed and number of encoding colors
- Operating under presence of varying viewing angle (perspective distortion)

Scenario of Light house-to-ship using OCC

Unidirectional OCC

High power LED to blink data at far distance

Data

Driver module

Lighthouse LED

Rolling shutter camera with Zoom module

Data

Asynchronous decoding

Zoom module

Far-distance of transmission required. Asynchronous communication scheme is needed.

Digital Signage with Lighthouse

Camera Receiver with Zoom

Lighthouse LED Demo

100m Demonstration of OCC

Call for TG7r1 Proposals

IEEE P802.15
Wireless Personal Area Networks

Project	IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)
Title	TG7r1 Call for Proposals (CFP)
Date Submitted	September, 2015
Source	Yeong Min Jang (Kookmin University), Hideki Aoyama (Panasonic), Rick Roberts (Intel), Yu Zeng (China Telecom)

TG7r1 Call for Proposals

The *IEEE 802.15.7 Revision: Short-Range Optical Wireless Communications* Task Group (TG7r1) is issuing a *Call for Proposals* (CFP) for the development of the IEEE 802.15.7r1 standard. The scope of these proposals is strictly limited to those described in the Project Authorization Request (PAR) and Criteria for Standards Development (CSD); both of which were approved by the IEEE-SA in December of 2014.

Proposals are solicited for a standard compliant with the PAR for TG7r1. For technical requirements, see the latest revision of the *Technical Consideration Document* (TCD) [1]. Partial proposals and merged proposals are encouraged. In addition, it is recommended that proposers refer to the IEEE Patent Policy. Proposers must submit their proposal in two steps.

1) First, complete the Intent for Proposal form [2]. The form must be submitted no later than November 01, 2015 (23:59 UTC) by sending a notification email to the following:
The Chair, Yeong Min Jang (yjang@kookmin.ac.kr),
Vice-chair, Hideki Aoyama (aoyama.hideki@jp.panasonic.com),
Vice-chair, Rick Roberts (richard.d.roberts@intel.com),
Vice-chair, Yu Zeng (zengyu@ctbri.com.cn), and
TG7r1 email reflector (stds-802-15-7a@listserv.ieee.org).
Presentations of the Intent for Proposal documents and discussions are scheduled for the November 2015 IEEE 802.15 session, held Nov. 8-13, 2015, in Dallas, USA.

2) Second, submit the proposal no later than January 10, 2016 (23:59 UTC) by following the directions that will be sent by the TG7r1 chairman. Presentations of proposals and discussion will start during the January 2016 IEEE 802.15 session, held Jan. 17-22, 2016, Atlanta, USA.

Proposals addressing the Image Sensor and Low Rate PD communication clauses of the TCD [1] are not required to evaluate against a specific channel model.

Proposals dealing with PHY algorithms for High-rate PD Communications must use the channel impulse responses (CIR) provided in the latest version of the *TG7r1 Channel Model Document* [3,4] for the specific scenario that they intend to address in their proposal [see footnote]. The exact CIRs are provided in the latest version of *TG7r1 CIRs Channel Model Document for High-rate PD Communications* [3,5].

All proposers should state their analysis assumptions and be willing to provide additional analysis as requested by the committee.

All questions should be sent to the TG7r1 Chair, Prof. Yeong Min Jang (yjang@kookmin.ac.kr) ; and cc to Vice Chairs, Hideki Aoyama (aoyama.hideki@jp.panasonic.com), Rick Roberts (richard.d.roberts@intel.com), Yu Zeng (zengyu@ctbri.com.cn).

Conclusion

Conclusion

- Technical Consideration Document for TG7r1 aims to provide three main sections including OCC (Image Sensor Communications), LiFi (High Rate PD Communications) and LED-ID (Low Rate PD Communications).
- ISC will be the new paradigm in the next generation indoor or outdoor wireless communication.
- ISC can bring promising applications and services to Digital Signage, IoT/M2M, and V2V.
- **Should submit the Call for Intent (by Nov. 1, 2015)**


Thank
You!