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| Title | **Proposed Contribution to ITU-R WP 1A: *Comment on Working Document towards a PRELIMINARY Draft New Report ITU-R SM.[Visible-Light]*** | |
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| Re: | ITU-R WP 1A | |
| Abstract | This document proposes an attachment to a proposed contribution to ITU-R Working Party 1A (IEEE 802.18-17-0075). | |
| Purpose | For attachment to the proposal in IEEE 802.18-17-0075. | |
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|  | **Radiocommunication Study Groups** | |  |
| **INTERNATIONAL TELECOMMUNICATION UNION** | |  | |
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| Source: Document 1A/TEMP/42 (edited)  Subject: Question [ITU-R 238/1](http://www.itu.int/pub/R-QUE-SG01.238), Report on ‘Visible Light’ | | **Annex 17 to Document 1A/144** | |
| **12 December 2016** | |
| **English only** | |
| {DRAFT} Proposed updates by IEEE  Annex 17 to Working Party 1A Chairman’s Report | | | |
| Working Document towards a PRELIMINARY Draft New  Report ITU-R SM.[Visible-Light] | | | |
| Visible Light for Broadband Communications | | | |

# 1 Introduction

*[Editor´s note: Section should contain the reasons for the development of the Report and make a reference to the Question, adopted by the Radio Assembly 2015].*

# 2 Different aspects of visible light communication

*[Editor´s note: Section 2 could deal with the different aspects of visible light, such as free-space optical communication systems for long distance communications as opposed to visible light for short distances. This is intended to provide background information.]*

## 2.1 Description of visible light

Visible Light Communications (VLC) use the visible spectrum (wavelengths between 390 and 750 nm) and can provide wireless communications using illumination and display elements.

## 2.2 Different aspects and use of visible light

From the ancient times to the 19th century, all VLC communication systems were relying on the human eye as the receiver. The invention of the Photophone by Alexander Graham Bell and Charles Sumner Tainter changed the nature of VLC communications. They used the fact that selenium resistance varies with respect to light intensity and used this property by connecting it to a phone receiver in order to send audio signals. Many improvements have been achieved on these systems until the 1950s, however most of the materials used for detection have higher sensitivity to infra-red radiations, hence precluding visible light to be used as a transmission medium. The introduction of light-emitting diodes (LED) created a new interest for the use of visible light communications. More specifically, the introduction of GaN LEDs [1] and white light-emitting phosphors [2] provided visible light sources, which can be modulated at higher speeds, without sacrificing their main illuminating role. In 2004, the first high-speed communication demonstrations with LEDs were made in Japan, using photodiodes. On the other hand, the proliferation of cellular phones with cameras, enabled them to be used as VLC receivers. Researchers started using LCD screens and other display elements as transmitters. One of the first standardization bodies to work on a VLC standard was the Visible Light Communications Consortium (VLCC) of Japan. They expanded the irDA standard for infrared communications to the visible light spectrum in 2008.

The IEEE 802.15 Working Group completed, in 2011, IEEE Std 802.15.7-2011 on “Short-Range Wireless Optical Communication Using Visible Light” [3] A project to revise IEEE Std 802.15.7-2011 was authorized in December 2014 and is currently active [7]. It intends to develop a standard for optically transparent media using light wavelengths from 10,000 nm to 190 nm. Additionally, the IEEE 802.15.13 Task Group began developing, in March 2017, a project on “Multi-Gigabit per Second Optical Wireless Communications (OWC) with Ranges up to 200 meters”. [8]

The IEEE 802.11 Working Group initiated, in late 2016, a Topic Interest Group (TIG) on Light Communication [9], aiming to determine the technical and economic opportunity presented by using the light medium for wireless communications.

# 3 Visible light and broadband

*[Editor´s Note: Section 3 could deal with the possibilities of broadband use via visible light, the efficiency gains of the use of visible light for broadband communications in terms of their use of the spectrum the description of the possible applications/services benefiting from visible light]*

## 3.1 Possibilities of broadband use via visible light

## 3.2 Efficiency gains of the use of visible light for broadband communications

## 3.3 Use of the spectrum

Optical Wireless Communications (OWC), also known as Light Communications (LC), has the potential to ease congestion in the lower radio frequency (RF) spectrum bands since light can be used as an additional spectrum resource for broadband communications.

## 3.4 Possible applications/services benefiting from visible light

Possible visible light communication services can be classified into three groups:

– Image sensor communications (ISC).

– Low rate photodiode receiver communications (LR-PC).

– High rate photodiode receiver communications (HR-PC).

In regards to the definition of low rate and high rate, the throughput threshold data rate is 1 Mbps as measured at the physical layer output of the receiver. Throughputs less than 1 Mbps rate are considered low rate and higher than 1 Mbps are considered high rate.

Image sensor communications

ISC enable optical wireless communications using an image sensor as a receiver, which exists in many consumer devices such as cameras, cell phones and tablets. The main applications of IMC are:

– Marketing/Public Information Systems.

– Internet of Things.

– Location-Based Services / Indoor Positioning.

– Vehicular Communications.

– LED based tag applications.

– Point-to-(multi)point / relay/ communications.

– Digital signage.

The requirements to be observed by the ISC can be listed as: dimming control, power consumption control, coexistence with ambient light, coexistence with other lighting systems, simultaneous communication with multiple transmitters and multiple receivers (MIMO), nearly point image data source, identification of modulated light sources, low overhead repetitive transmission, image sensor compatibility and localization.

For MIMO communications, a MIMO MAC protocol may be incorporated so that the camera enabled receiving device knows how to process the received data. ISC should support communication when the light source appears as nearly a point source; i.e., the light source illuminates only a small number of image pixels.

Low rate photodiode communications

Low rate photodiode receiver communications require LEDs as transmitters and low speed photodiodes as receivers. The main applications are:

– Point-to-(multi)point communications

– Digital signage

– Internet of Things

– LOS Authentication

– Identification based services.

LR-PC is mainly for the LED Tags and the Smart Phone Flash lights as transmitters. It may provide mechanisms to support handover between LED light sources, allowing the users to maintain a continuous network connection.

LR-PC may provide mechanisms that can be used to develop and deliver interference coordination techniques by higher layers and may support link recovery mechanisms to maintain connection in unreliable channels and reduce connectivity delays.

High rate photodiode communications

The use of high rate photodiode receivers will enable high-speed, bidirectional, networked and mobile wireless communications. The main applications of this mode are:

– Indoor office/home applications: (conference rooms, shopping centers, museums, etc.)

– Data centers / industrial establishments, secure wireless (manufacturing cells, factories, etc.)

– Vehicular communications.

– Wireless backhauling (small cell backhauling, surveillance backhauling, LAN bridging).

In HR-PC, continuous data streaming for all applications should be supported with bidirectional functionality as well as short packet transmissions where low latency is required. Mechanisms to support adaptive transmission as well as multiple users communicating with different data streams from the same light source (multiple access) should be included.

# 4 Spectrum management aspects relevant to visible light

*[Editor´s note: Section 4 could deal with the implementation/use of visible light in term of spectrum management activities]*

Light communications are subject to substantially different propagation characteristics relative to frequencies in the radio frequency spectrum. As a result, the potential for interference is small, and light communications need not be managed by spectrum regulators. IEEE 802 believes that light communications operations should be classified as license-exempt and not subject to exclusive licensing. Adherence to the relevant local health and safety regulations regarding human eye safety and sensitivity is essential. Devices using LC or OWC should adhere to any local regulations regarding spurious RF emissions and should avoid causing interference in other RF spectrum bands.

**4.1 Issue 1: Spectrum opportunities and spectrum allocation**

**4.2 Issue 2: Spectrum planning principles**

**4.3 Issue 3: International and regional harmonization**

# 5 Technical and operational characteristics of short distance broadband communication via visible light

*[Editor´s note: Section 5 should cover the new applications]*

# 6 Other relevant aspects (user needs, socio-economic aspects) for decisions on visible light

*[Editor´s note: Section 6 could cover relevant non-spectrum management aspects as proposed]*

Regarding eye safety, the modulated light that can be seen by the human eye shall be safe in regards to the frequency and intensity of light (e.g., IEC 60825-1:2014) and the modulated light will not stimulate sickness, such as photosensitive epilepsy.

# 7 Conclusions

[This includes descriptions on suitable methodologies for the use of visible light]

*[Editor´s note: Section 7 could refer to national projects which could be described in detail in an annex]*

Annexes on information received on national or regional scientific projects and developments and experiences in spectrum management of visible light and best practices [if any].

References

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[9] <http://www.ieee802.org/11/Reports/lctig\_update.htm>

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