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|  | **Radiocommunication Study Groups** | |  |
| **INTERNATIONAL TELECOMMUNICATION UNION** | |  | |
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| **12 December 2016** | |
| **English only** | |
| 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].*

Liesbeth Kruizinga (4/5/2017)

Due to diverse technological developments, like Internet of Things, Smart Grids etc., the radio spectrum becomes more and more busy. In order to make sure that all applications are able to use the scarce radio spectrum, it is necessary to start looking for (innovative) ways for efficient use. It is in this context the ITU-R working group on Spectrum Management initiated the question ITU-R 238/1, adopted by the Radio Assembly in 2015. The intention of this report is not to create spectrum regulation or suggest the creation of such regulation for visible light communications, but to see to how the use of (near) visible light communication can help to ease the congestion in the todays radio spectrum. The development of new technologies, combined with the renewed attention for the use of visible light, could be an interesting combination and possibly one of the solutions for efficient use of the radio spectrum. Nevertheless, in order to be sure, more research regarding Visible Light for Broadband Communications is required. Therefore, the main question in this research is:

*How, and in which way and to what extent can (near) Visible Light Communication (or Optical Wireless Communication) help to ease the congestion in the usage of Radio Frequency spectrum?*  
This leads to the following questions:  
  
- What are the distinctive characteristics (technical and operational) of the use of (near)  
 Visible Light Communication for broadband communications in terms of their use of  
 the spectrum;  
- What are the advantages and disadvantages of the use of (near) Visible Light   
 Communication? (These might include: efficiency, interference, health risks,  
 cybersecurity);   
- What are the new applications associated with visible light used for broadband   
 communications;  
- Are there any barriers for the development of broadband communications in order to   
 move to worldwide implementation of (near) Visible Light Communication (e.g.  
 regulative, cultural, and/or economical);  
- In which way does (near) Visible Light Communication connect to current   
 telecom systems (fixed and mobile)?

# 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.

In the year of 2011, IEEE 802 LMSC published the IEEE Standard 802.15.7 for Short-Range Wireless Optical Communication Using Visible Light [3,4]. Due to the growing interest in visible light communications, in 2014, the IEEE standardization association approved another project authorization request from IEEE 802 to amend the previous standard for a faster, better and more application enabling standard [5]. The group developed use cases and channels models for VLC communications [6].

# 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

## 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 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]*

*Mr René Vroom (5/5/2017)*

* *VLC/OWC technology foreseeably will make use of unregulated spectrum, of (near) visible light frequencies that does not need regulators’ spectrum licensing. It is important however, that the VLC/OWC systems, devices etc. do not impose any health hazards, that they are correctly and safely installed so that they do not produce any EMI.*
* *VLC/OWC systems and devices should (preferably) fit with / be compliant to international standards (i.e. for Europe ETSI), and, as any system and device, should comply to countries’ law and regulations.*

Mr. Les Brown:

* Explanation wavelength versus frequency domain

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

Mr. Volker Jungnickel:

* Increasing spectrum opportunities by combining 60 GHz by Optical wireless: fog and sunlight mitigation

**4.2 Issue 2: Spectrum planning principles**

Mr. Les Brown:

* Interference mitigation: at what level (physical and session layer)
* how to a define a common MAC?

Mr. Ton Koonen:

* is MAC needed? (beam forming)
* power density

Mr. Tuncer Baykas:

* Channel models

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

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

**5.1 Current Standardization activities**

Mr. Tuncer Baykas (Mr. Les Brown)

**5.2 Current ITU-T activities**

Mr. Les Brown (Mr. Tuncer Baykas)

**5.3 Optical components and technology**

Mr. Nico Baken: future proofing of optical devices

*[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.

Mr Ton Koonen:

* eye safety aspects plus references

Mr Volker Jungnickel / Mr. Nico Baken:

* use cases industrial wireless (smart street lights)

Mr. Ton Koonen:

- smart city mapping (city genome)

# 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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[6] M. Uysal, *et al.* “TG7r1 CIRs Channel Model Document for High-rate PD Communications,” Online: <https://mentor.ieee.org/802.15/dcn/15/15-15-0747-00-007a-tg7r1-cirs-channel-model-document-for-high-rate-pd-communications.zip>

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