Available online at www.sciencedirect.com

ScienceDirect

IFAC Papers Online CONFERENCE PAPER ARCHIVE

IFAC-PapersOnLine 48-4 (2015) 234–239

Security issues in visible light communication systems

Grzegorz Blinowski*

** Institute of Computer Science, Warsaw University of Technology, Nowowiejska 15/19, 00-665 Warszawa; Poland (Tel: 0048222347184; e-mail: g.blinowski@ii.pw.edu.pl).*

Abstract: Visible light communication (VLC) has been recently proposed as an alternative standard to radio-based wireless networks. Because of its physical characteristics, and in line with the slogan "what you see is what you send", VLC is considered a secure communication method. In this work we focus on security aspects of VLC communication, starting from basic physical characteristics of the communication channel. We analyze the risks of signal jamming, data snooping and modification. We also discuss MAC-level security mechanisms as defined in the IEEE 802.15.7 standard.

Keywords: Wireless networks, visible light communication, wireless network security, industrial wireless standards, IEEE 802.15.7

1. INTRODUCTION

Solid-state lighting is a rapidly developing field. White-light (and tri-color) LEDs are more energy efficient, and have better reliability than traditional incandescent and fluorescent light sources. Visible light communication (VLC) is a wireless optical communication technology through which baseband signals are modulated on the light emitted by an LED - Nakagawa (2007), Kraemer (2009), Elgala (2011), Hranilovic (2013), Tsiatmas (2014). The decreasing cost and hence rapid adaptation of LED-based light make VLC a promising communication technique and a significant alternative to radio-based wireless communication such as Wi-Fi, Bluetooth and others. An important adoption factor in favor of VLC is the increasing "pollution" of the radio spectrum. Radio wireless devices, ranging from IEEE 802.3 (Wi-Fi) compatible equipment, PAN (personal area network) devices, to child monitors, generate interference and clog up the available spectrum. VLC data transmission networks (sometimes referred to as "Li-Fi") provide an attractive alternative to traditional wireless techniques, since:

- they are interface-orthogonal to cellular, Wi-Fi, Bluetooth and other radio-frequency based networks,
- light does not penetrate solid objects,
- light can be easily directed through optics,
- most indoor, and a significant percentage of outdoor, environments are illuminated.

One of the features in which VLC techniques are considered superior to traditional radio-based communication is security – the directivity and high obstacle impermeability of optical signals are considered to provide a secure way to transmit data within a closed indoor environment, making the data difficult to intercept from outside. The common slogan summarizing VLC security features is: "What you see is what you send" - WYSIWYS (Conti (2008)).

Since history likes to repeat itself - a common mistake in the development of novel communications techniques was to neglect or downplay the security issues: such was the case with the internet protocol suite (both on the network and, application layer), fiber-optics based networks, and more recently – radio-based wireless networks. Currently the VLC industry seems to be on the same path again: the indubitable "pro-security" physical characteristics of visual light communication have directed the developers' focus away from security issues.

In this paper we address the classic security triad of: confidentiality, authenticity and integrity in VLC communications. As far as VLC standards are concerned, we will refer to the IEEE Standard 802.15.7 (IEEE (2011)); however, our discussion should also be relevant to other proposed VLC techniques not covered by the current IEEE norm.

The structure of this paper is as follows: In the remaining part of this section we will discuss the VLC channel structure and properties, as well as most important practical applications of VLC. In section 2 we discuss security risk in various aspects of in-door VLC communication. In section 3 we further analyze security risks at the physical and MAC layer - especially with respect to IEEE 802.15.7 standard. The work is summarized in section 4.

1.1 The VLC Data-Link

A VLC data-link consists of: the transmitter, the propagation channel and the receiver. Their properties are as follows:

Transmitter – There are two types of white-light LEDs used in solid-state lightning: 1) red-green-blue (RGB) emitters; 2) blue-LED on yellow-light emitting phosphorus layer ("single-chip"). *The VLC transmitter* may use both types, but the second type is more popular in illumination due to its energy efficiency and lower complexity (when compared to RGB

10.1016/j.ifacol.2015.07.039

emitters). Different types and form factors of LED are employed in various environments: high power LEDs or LED arrays are the choice for typical in-door illumination purposes, while low-power devices are used in smart-phones and other mobile appliances. Single-chip LEDs driven by a single modulation source achieve a bandwidth of approx. 2.5 MHz for the white and 14 MHz for the blue component (O'Brien (2008a)) (the slow response of yellow phosphorus to blue light modulation limits its spectral component bandwidth to 2MHz, hence the yellow component is filtered-out at the receiver and only the blue component is detected). Data throughput of up to 40 Mb/s has been demonstrated in a single-emitter–single-receiver scenario – Grubor (2007). With techniques such as simple analogue equalization on the receiving side, a transfer rate of 100 Mb/s was achieved (Le Minh (2008)). High data rates exceeding 100 Mb/s are also attainable with multiple-subcarrier modulation techniques such as OFDM. With arrays of separately driven light sources and OFDM, a data throughput of up to 1Gbit/s was demonstrated, techniques similar to radio frequency MIMO are used in such a case – see Helmi (2013).

The receiver collects and concentrates the incoming light on a photo-detecting element. Both imaging and non-imaging receivers may be used. Generated photocurrent is amplified and fed to the D/A circuitry. With current technology achieving sufficient photo-detector sensitivity, the required bandwidth is not a problem (the transmitter and channel loss and dispersion are the major bandwidth limiting factors). Currently in devices such as smartphones, tablets, etc., low cost photodiodes or typical optical sensors are used as photodetectors for the VLC channel. As these devices work in an Intensity Modulation/Direct Detection (IM/DD) regime, the photodetector produces a signal proportional to the intensity (not the amplitude) of the incident wave: the detector works as a squarer.

The propagation channel in the case of indoor environments communication may be characterized by six different link configurations, as originally defined by Kahn and Barry (1997) for IR links. *The propagation* channel requires a direct or indirect line-of-sight (LOS) between the transmitter and the receiver. The degree of directionality is a second factor determining the channel type which is dependent on the source beam-angle and detector field of view (FOV). All possible channel configurations are show in figure 1. The most common link types used by VLC are:

- (a) directed-LOS – mainly for short range (<1m) mobile-mobile and fixed-mobile communication and also for infrastructure uplink communications
- (e) non-directed LOS – mainly for infrastructure downlink
- (f) non-directed NLOS (dispersed) – mainly for infrastructure downlink

In general, in all of the above cases, the propagation channel is formed by a number of line-of-sight paths from the transmitter to the receiver, and a diffuse channel is formed by the light from the source reflecting off multiple surfaces. The combination of the directed and the diffuse channel determine the overall power received; hence the Signal to Noise Ratio (SNR)) and, in consequence, the bandwidth of the channel.

In outdoor environments, directed or dispersed LOS is used; in this case light from other sources, both artificial and natural, must be taken into account.

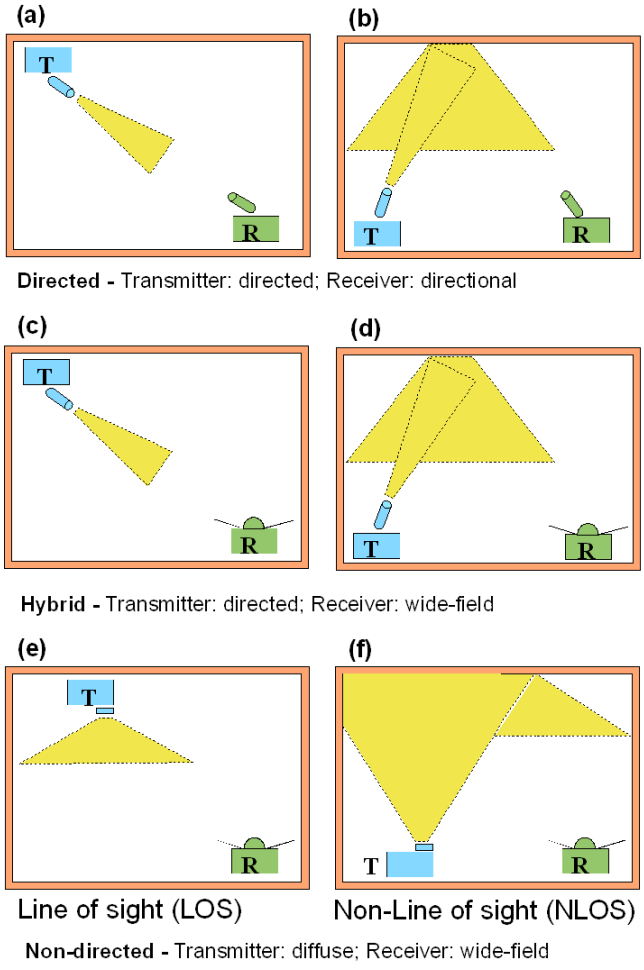

Fig 1. Classification of links according to LOS/NLOS (line-of-sight) and directionality of transmitter and receiver.

1.2 Applications of VLC

VLC was proposed both for in-door and out-door applications – see Samsung (2008) and Elgala (2011). In-door applications include a range of communication facilities provided today by Wi-Fi networks, Bluetooth and Personal Area Networks (PAN). Indoor VLC applications range from: office communication – Rahaim (2011), multimedia conferencing – Chen (2014), peer-to-peer data exchange, data broadcasting – especially multimedia such as home-audio and video streams, see Javaudin (2008), Langer (2008), O'Brien (2008b, 2009) to positioning – Yoshino (2008), Ren (2014) Because of their physical characteristics, VLC systems permit very close spacing between nodes, providing higher data density which results in increased network capacity.

Currently available commercial systems focus mainly on data broadcasting, and include solutions for museums, shopping centers, exhibition centers, airports and train stations as well