VISIBLE LIGHT COMMUNICATION (VLC)

Abstract

Visible light communication (VLC) is an emerging technology which deploy light to transfer data. Because of fast growing population of mobile users, wireless communication based on radio frequency (RF) faced a series spectrum shortage problem. Today world experiencing revolution of access technology called" anywhere, anytime" and people are looking for greener technology as well as removable.[3] in this project we do study about Physical layer of VLC by introducing this technology, advantages, applications and describing VLC channel modelling and OFDM modulation technology.

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Introduction

While the radio spectrum is limited, the demand for wireless data transmission keeps increasing. As we see in figure 1, according to global mobile data traffic forecast by ITU. Overall mobile data traffic is estimated to grow at an annual rate of around 55%.

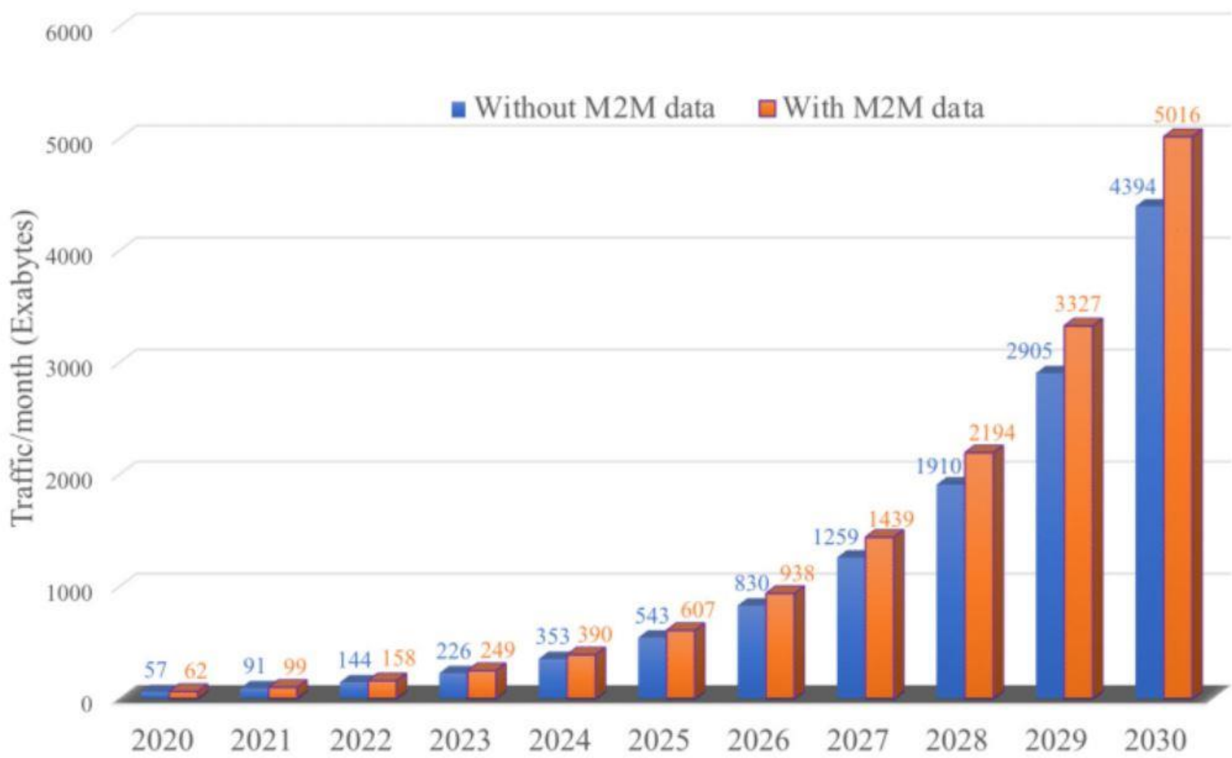


Figure 1, ITU forecast, traffic increase [4]

So visible light communication (VLC) has been proposed as an alternative means of wireless communication.

VLC uses the visible light bandwidth in general electromagnetic spectrum. In compare with total frequency bandwidth in RF spectrum (roughly 300GHz), the frequency bandwidth for VLC is around (300THz). [2]

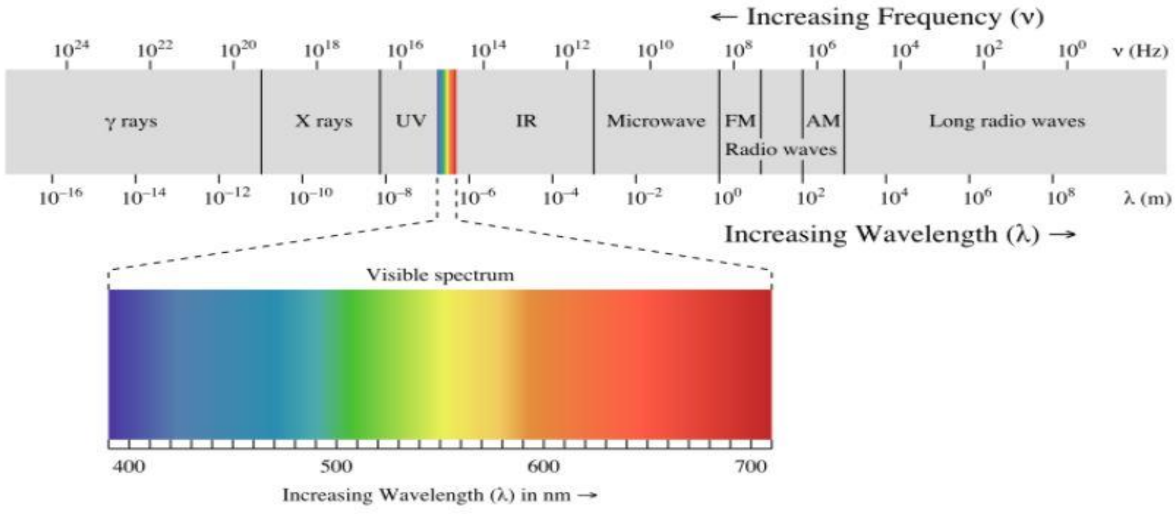


Figure2. Visible light spectrum [2]

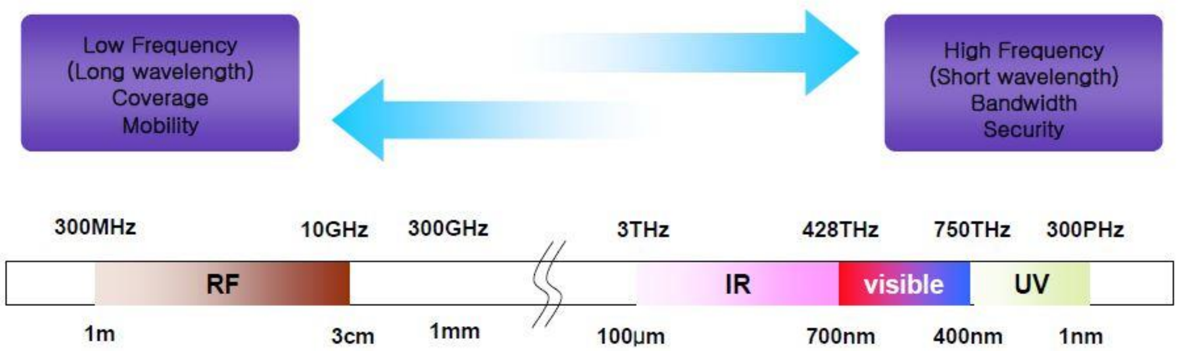


Figure 3, VLC and RF bandwidth [4]

VLC spectrum is basically visible light waves so use of VLC bandwidth does not need authorization and spectrum usage fees. This technology supports high data rate optical communications and facilitates the bandwidth reuse. Another advantage of this kind of communication is security is much securer than RF communications. Because Transmission medium is visible light, which cannot penetrate walls and other non-transparent objects in an indoor environment, so its transmission is limited in the line of sight (LOS)., and it is much more difficult for eavesdroppers to intercept communication content without being noticed by the senders in the same room.[2,3]

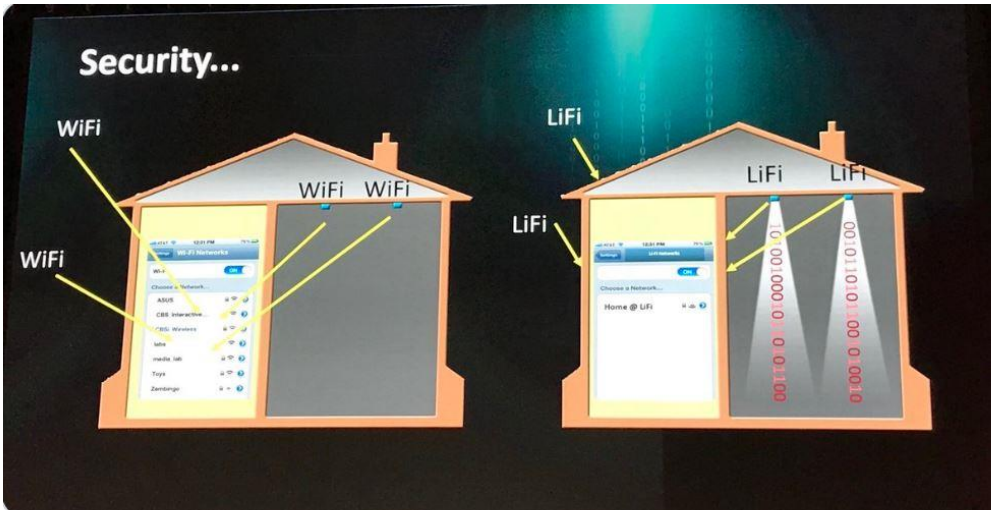


Figure 4, security in WiFi and LiFi [4]

Three is no electromagnetic pollution as long as VLC uses florescent or LED, since this fast flashing light to transmit information can not seen by the human eyes. So, it is type of green wireless communication that can operate without radiation damage to the human body. [2, 4]

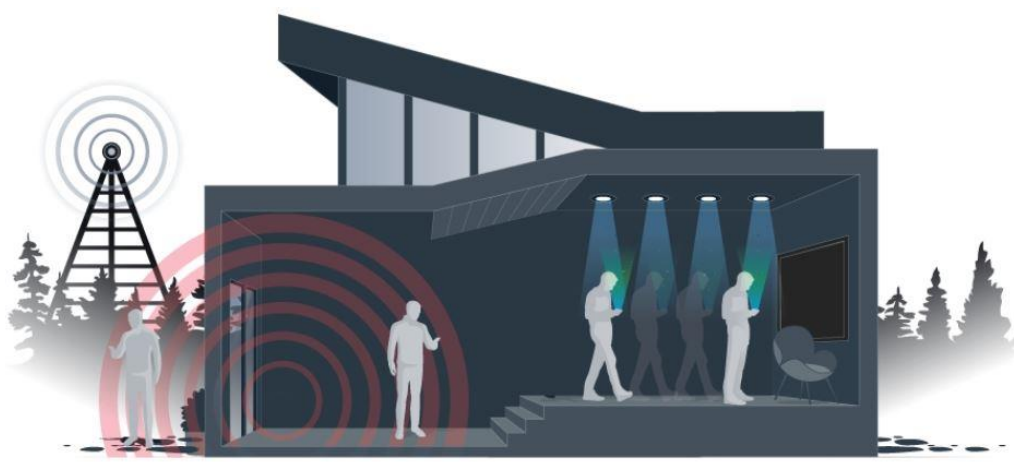
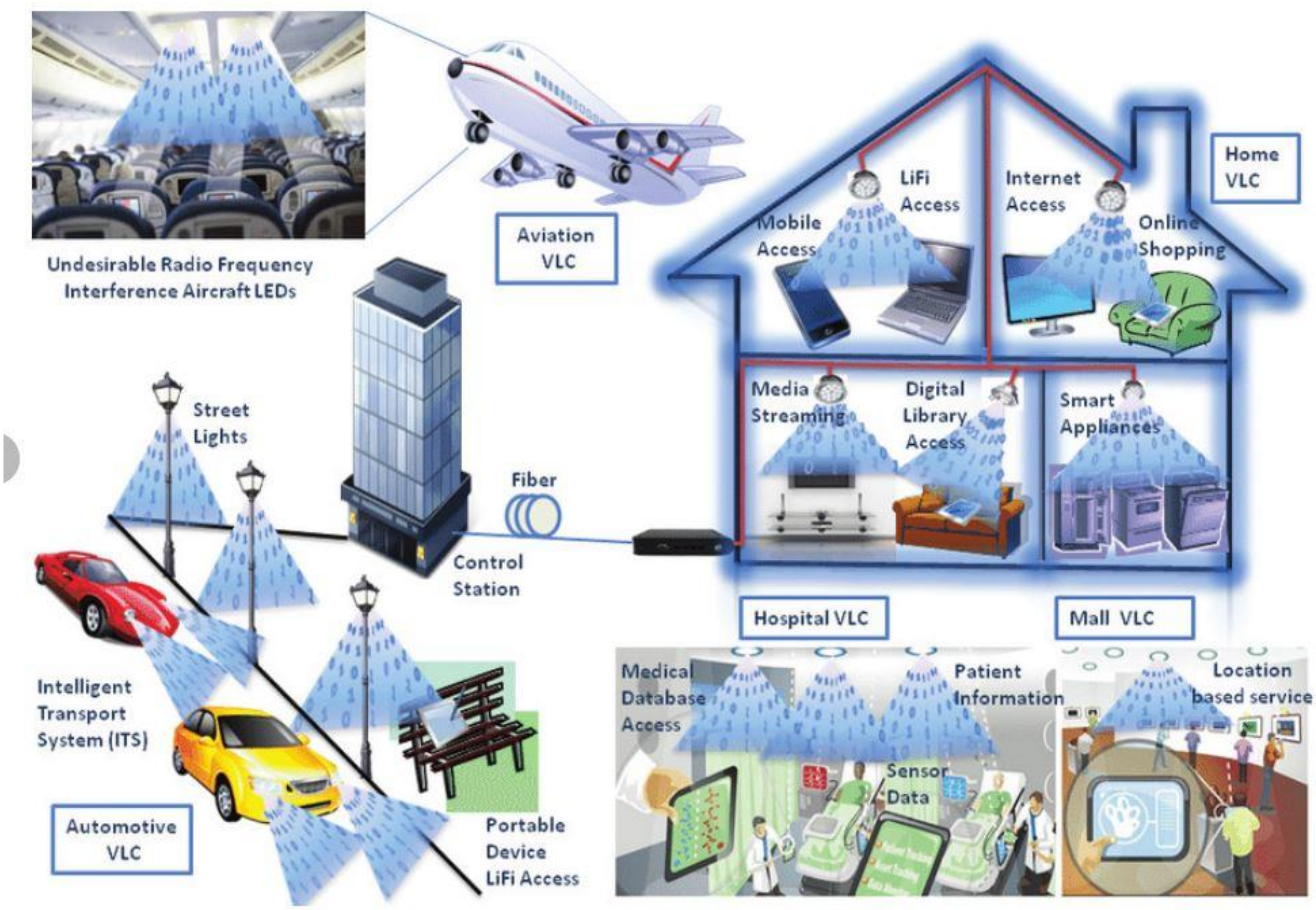


Figure5, electromagnetic waves [4]

Beside integration of lightening and intelligent communication can help human conserve more energy and promote a green lifestyle. [2, 3]

VLC Applications

as shown on figure 6, it is possible to use VLC technology in many widely applications. From intelligent house to intelligent transportation, real time broadcast, identification of traffic information. Since it has no electromagnetic interference can be installed in aircraft, plane or satellite to transfer signal to LED lights of passenger’s seats



Visible light communication applications.

Figure 6, VLC application [4]

VLC Basic Diagram

Basic VLC block diagram is shown as follow, figure 7.

In this block diagram system divided to three parts, LED transmitter, visible light transmission and LED receiver.

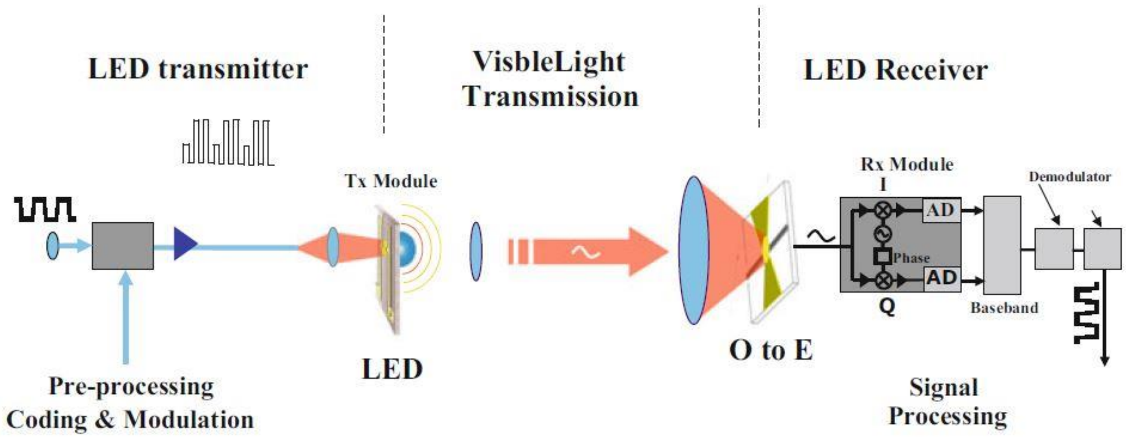


Figure7, Basic VLC block diagram [3]

After pre equalization and coding modulation to improve the response bandwidth of LEDs and help to increase the transmission rate, the original binary bit stream enters the LED's to convert the electrical signals into optical signals. Optical signal which carrying data is transmitted in free space and focused on a photodetector through the lens in front of the receiver. Photodetector converts the received optical signal into electrical signals to recover original transmitted signal after signal processing, demodulation and decoding in receiver. [2,3]

LEDs

Concept of VLC is back to many years ago around 2000 when they started to use light emitting diodes(LED) as a light source, today typically there is two type of LEDs, phosphor LEDs and REG-LED s which can use as light source of white LEDs in visible light communication.[3]

Phosphor LED widely used, it uses blue light to inspire the yellow phosphor to produce white light, they have simple structure lower cost lower modulation complexity, but modulation bandwidth is very low, so spectrum utilization rate is also low. Figure 8

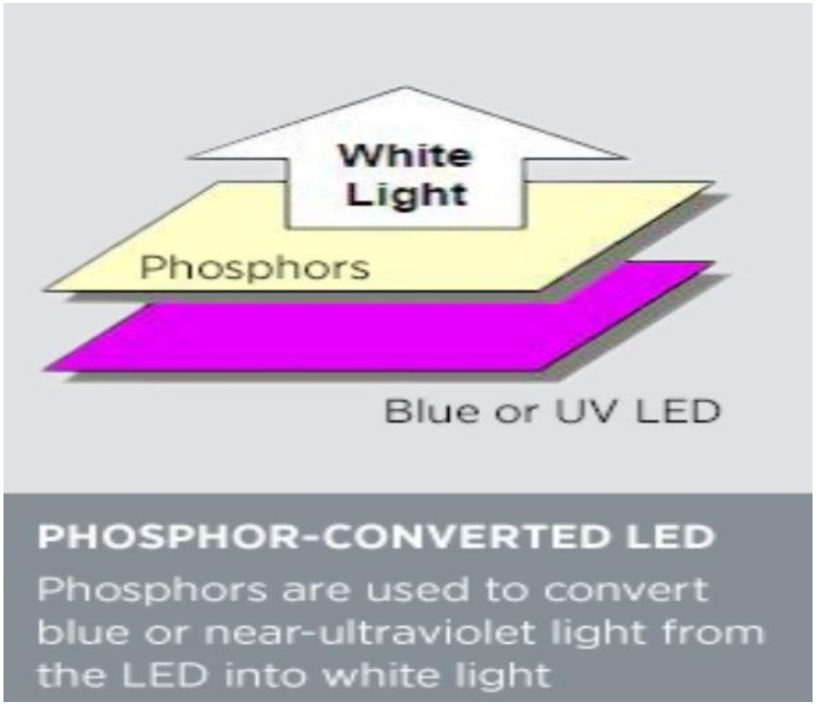


Figure 8, Phosphor LED [3]

Another Type of LED is the RGB- LED, in this type red, green and blue LED chips have been encapsulated to mix the light emitted and make white light, This kind of LED has very high modulation bandwidth, so can use it for high speed signal transmission. But modulation is more complex to control three chips to avoid flickering and maintaining the mixed color stability. Figure 9.

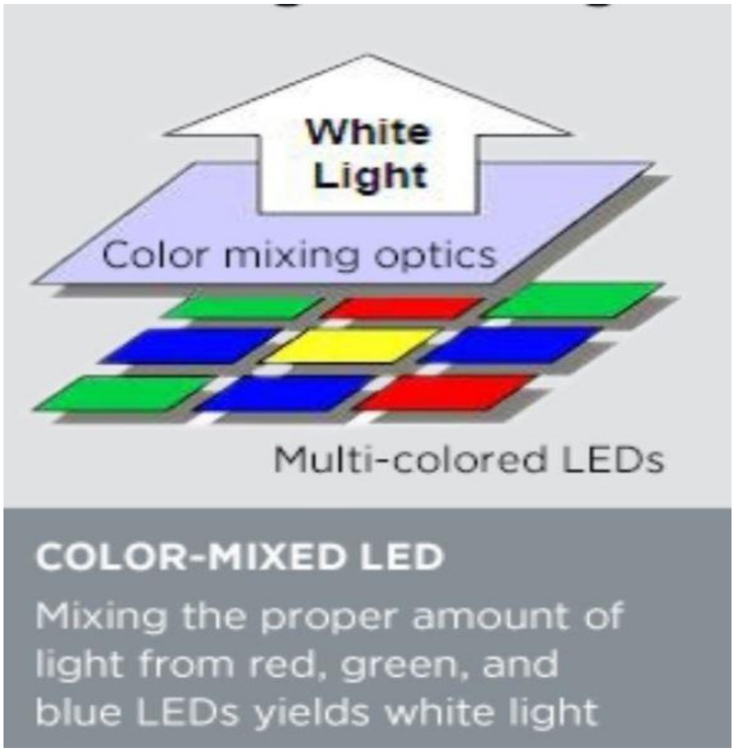


Figure 9, RGB- LEDs [3]

It is important to chose proper LEDs as transmitter and receiver in VLC system as a key to achieve the appropriate performance. Several parameters like type of LED, bandwidth, power and color have a direct impact on the performance.[3]

VLC Channel Modelling

Very first step for efficient and reliable VLC system designing is considering channel modelling. For modelling we need to know characteristic of visible light source, features of receivers, impulse response of the channel, room models and LED models and reflection characteristics of environment. [1,3]

First, we are going to introduce channel links, three important parameters of VLC channel, RMS, Path loss and bandwidth. then compare three different configurations to analyse impact of different number of transmitters, their location in room and materials in network response.

VLC Links

In general, there are two different type of VLC links, Point to point link and Diffusing link.

point-to-point links, transceivers communicate with each other through a bunch of narrow beams, it requires no obstacles exist between the transceivers, and beams should be pointed to the right directions. So, link setup is important to reduce interferences to the receiver and lower signal attenuation, also achieve high data rate transmission. Figure 6. point to pint link is base on Line of sight (LOS) therefore it is very sensitive to blocking and shadow effects. [1, 3]

Diffusing link, signal radiates based on a wide angle, like radio frequency (RF) links. so, a diffusing link does not have radiation orientation and shading issues that exist in point to-point links, benefits is receiver in this kind of link can have small mobility.

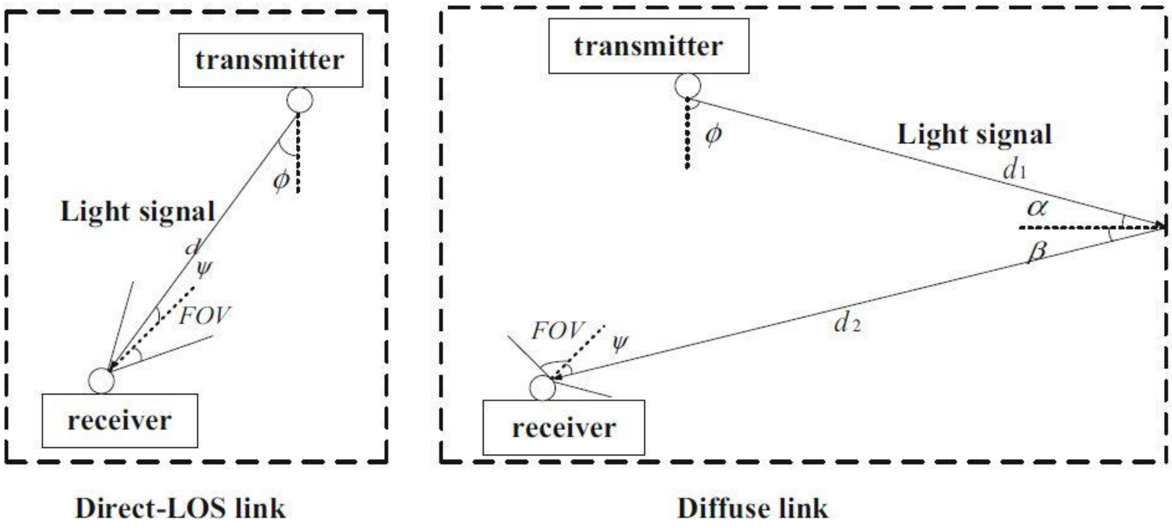


Figure 10, VLC Links,[3]

Important channel parameters

To study channel responses three important parameters defined as follow:

Root mean square delay spread (RMS)

Because of multipath propagation received optical signal is subject to delay spread. When a transmitter sends a vey narrow optical pulse signal, there are many different propagation paths and the path lengths are not the same, so the times that transmitted signal reaches a receiver along different propagation paths are varying.[2]RMS delay can calculated by having impulse response and average delay time as follow.

$$\tau_{RMS} = \sqrt{\frac{\int_{-\infty}^{\infty}(t-\tau_0)^2 h^2(t)dt}{\int_{-\infty}^{\infty} h^2(t)dt}} \qquad (2)$$

$$\tau_0 = \frac{\int_{-\infty}^{\infty} t \cdot h^2(t)dt}{\int_{-\infty}^{\infty} h^2(t)dt}$$

Path Loss

Path loss is introduced by the propagation between a transmitter and a receiver. It is related to channel link design. Diffuse link has the higher path loss than line of sight.[2] calculated as follow

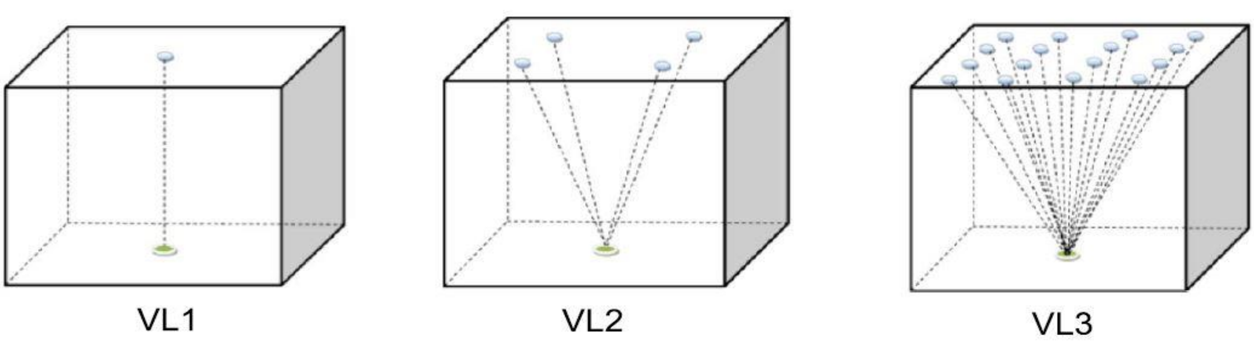
$$L_{light} = -10\log_{10} H(0)$$
$$L_{electric} = 10\log_{10} H^2(0) \qquad (2)$$

3- dB Bandwidth

3-dB bandwidth is defined as the difference between the upper and lower 3dB points. In VLC modelling RMS and bandwidth should be considered together.

Effect of Multi- Transmitter deployment

In this example assume three different situation VL1: empty rectangular room with single transmitter located at the center of the ceiling and single receiver located at the center of the floor.VL2: empty rectangular room with four transmitters located at the ceiling and single receiver located at the center of the floor. VL3: empty rectangular room with 16 transmitters located at the ceiling and single receiver at the center of the floor.[1]



Configuration with multiple light sources.

Figure 11, multiple transmitter and single receiver. [1]

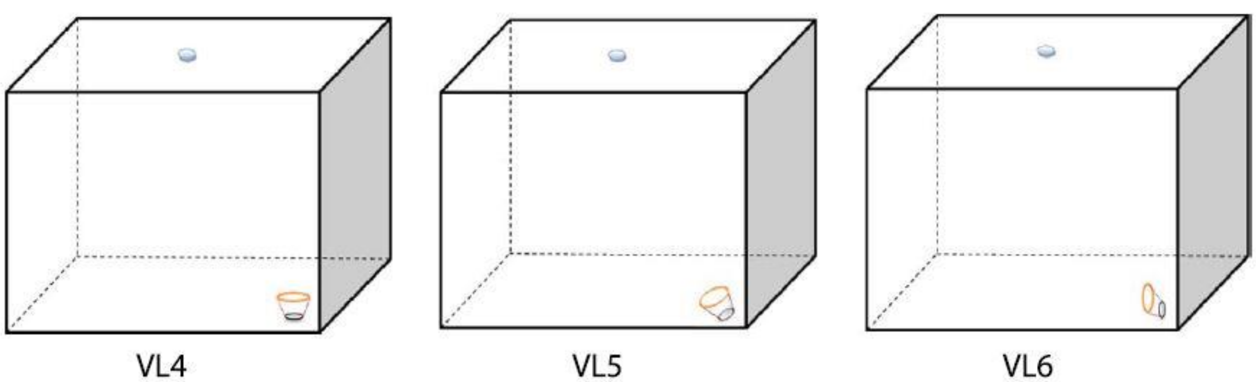
[1] Channel parameters for different numbers of transmitters

Channel Parameters / Config.	τ_0 (ns)	τ_{RMS} (ns)	H_0
VL1	15.22	10.55	5.90×10^{-6}
VL2	19.92	10.60	3.02×10^{-6}
VL3	20.26	10.95	2.58×10^{-6}

We see by increasing the number of transmitters, channel DC gain decreases and RMS delay increases. Because more scattering received from multiple sources.[1]

Effect of position/rotation of receiver

In this example we three different rotated receiver have been considered. VL4: empty rectangular room with single transmitter located at the center of the ceiling and single receiver looking upwards located at the corner of the floor. VL5: empty rectangular room with single transmitter at the center of the ceiling and single receiver with 45 degrees rotation the corner of the floor. VL6: same condition with single receiver 90 degrees rotation located at the corner of the floor.[1]



. Configuration with various rotations of receiver.

Figure 12, Different rotation in receiver.[1]

[1] Channel parameters for different rotations of detector

Config. \ Channel Parameters	T_{tr} (ns)	τ_0 (ns)	τ_{RMS} (ns)	H_0
VL4	49	26.18	11.59	1.09×10^{-6}
VL5	52	26.62	12.04	1.35×10^{-6}
VL6	51	26.34	12.97	1.17×10^{-6}

We see by rotating the detector towards the source channel DC gain increases. Also by comparing this table with last example we see by moving detector to the corner, RMS delay increases because in this case more scattering power from corner sides receive.[1]

Effect of objects in the environment

Two different configuration have been considered to evaluate the effect of objects e.g furniture. In the room transmitter is located at the corner of ceiling and receiver is located at the center of floor. VL7: rectangular room with chair, desk, and desk lamp. VL8: rectangular room with chair, desk, desk lamp, laptop, library and cage.[1]

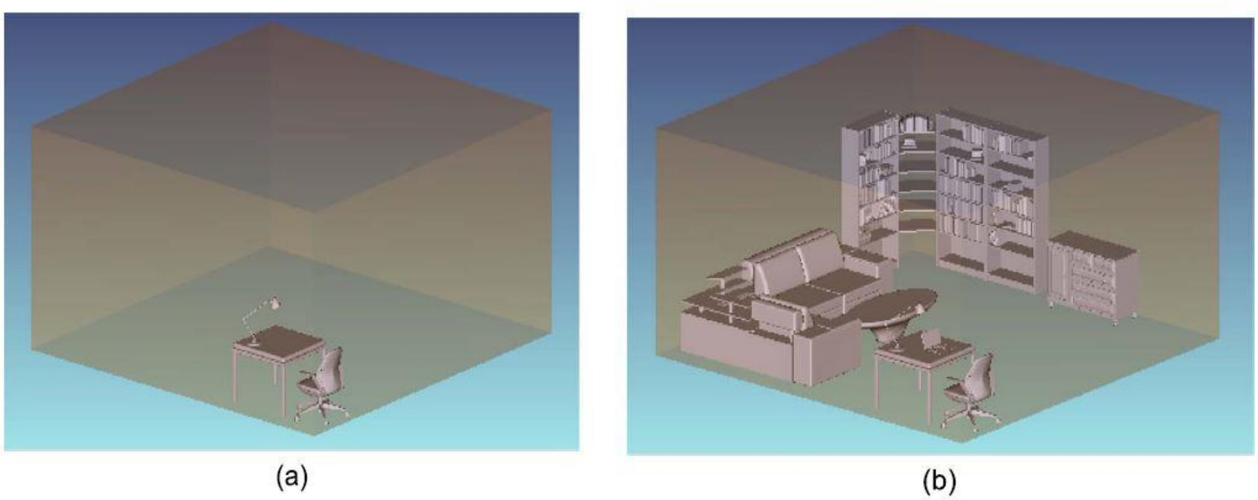


Figure 13, Different number of furniture in rooms.[1]

[1]

Channel parameters for empty room versus furnished room

Config. \ Channel Parameters	T_{tr} (ns)	τ_0 (ns)	τ_{RMS} (ns)	H_0
VL7	41	15.10	10.41	5.91×10^{-6}
VL8	37	13.08	7.80	5.58×10^{-6}

In this example can see effect of coating materials. With furniture RMS delay and channel DC gain decreases. [1]

Orthogonal frequency division multiplexing (OFDM) modulation

In visible light communication, LED modulation bandwidth is limited. In order to improve the VLC system transmission data rate , selecting the appropriate modulation format is very important way to expand the modulation bandwidth.

OFDM modulation technology widely used in visible light communications since it is an efficient and one of the multicarrier modulations, can effectively resist multipath interference to have reliable signal at receiver and frequency selective fading. some advantage of this modulation are resisting multipath interference, high spectral efficiency, Maximum bit rate and strong anti-fading capacity.[3]

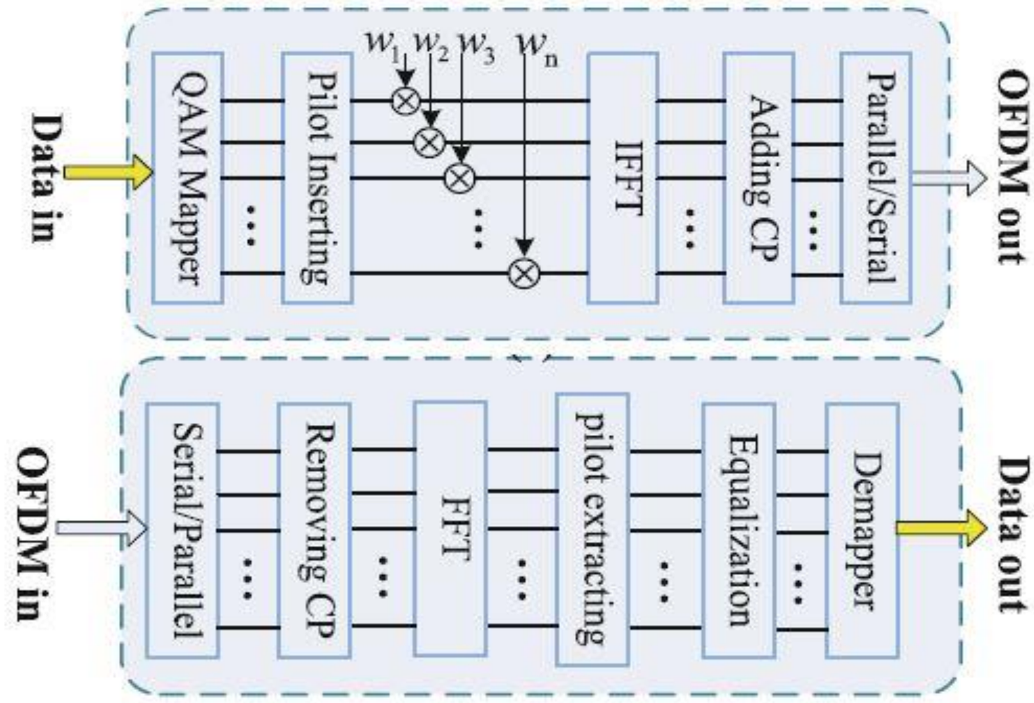


Figure 14, OFDM Algorithm [3]

As shown in figure 12, transmitter contains QAM mapping to transform from serial to parallel, IDFT, add cyclic Prefixes (CP) and transform from parallel to serial. first Channel divided into several orthogonal subchannels, parallel symbol is transformed by the IDFT into a set of N different subcarriers after adding a cyclic prefix, this cyclic prefix uses to avoid the time delay generated by multipath interference. OFDM signals is generated. receiving process is reverse to that transmitter.[3]

Conclusion

VLC is a new wireless optical communication that combine light and communication to serve as a supplement of wireless systems at least in short range coverage. Next generation will use white sources extremely and broadband interest to access high speed communication, more secure and greener technology give good development opportunity to continue study about VLC and use it alternatively.

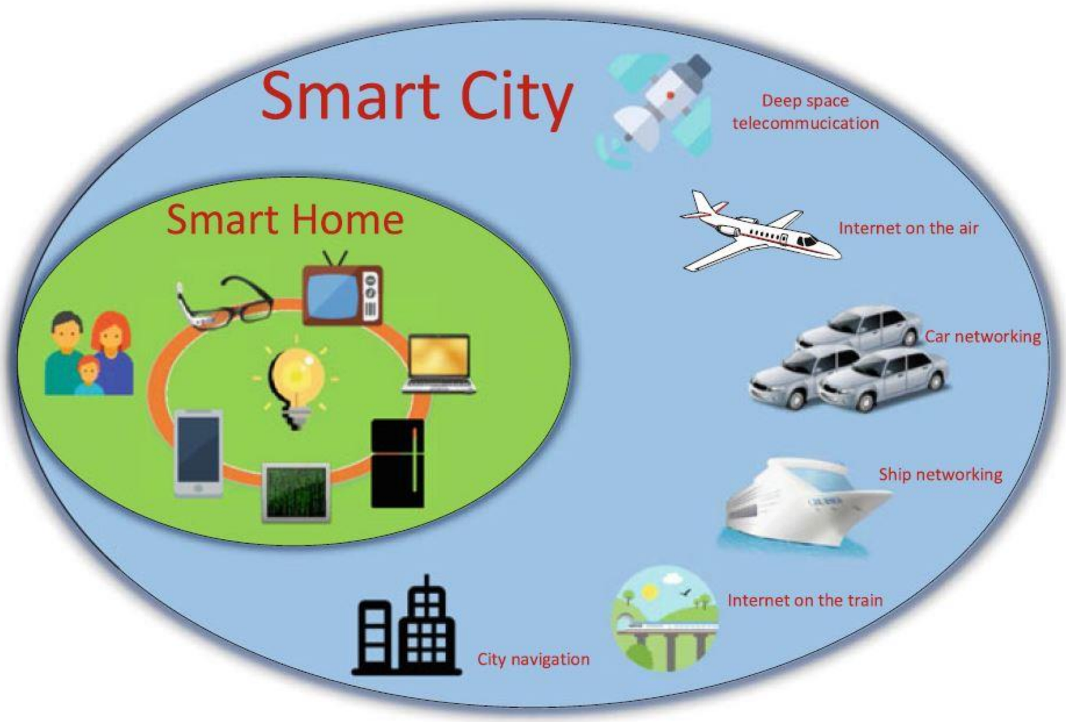


Figure 15, Future proposed optical communication [3]

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