Optical Wireless Communication

Submitted By

Sufian Ahmad 04-BSc-Engg-17

BSc Electrical Engineering

Session : 2017-2021

Department of Electrical Engineering

Government College University , Lahore

Optical Wireless Communication

Submitted to

Mam Amna Ehsan

May 24,2021

By

Sufian Ahmad

This proposed paper will Discuss the basic introduction of Optical wireless communication.We will see the impact of this new technology in our future life.We will discuss the challenges that we are facing in implanting this new technology and discuss the application of it.

ABSTRACT

In past few years the higher data rate is essential for the developing countries to meet the users demand.The congestion of radio frequency (RF) spectrum (3kHz-300GHz) will limit the growth of future wireless system so we need the new wireless technology which meet the challenges of the future.Optical wireless communication is the solution of bandwidth problems.In this proposed paper we will discuss the about the optical wireless technology.We explain the challenges that we are facing regarding optical wireless communication.We will see the different modulation techniques,Sources of optical and other parameters of optical wireless technology.At last we will discuss the applications of optical wireless technology.And see the future trends regarding this technology.

Keywords : Optical Wireless Communication(OWC) ,Challenges in OWC, Applications of OWC ,Visible light communication

Table of Contents

SECTION IV

SECTION V

SECTION VI

SECTION VII

LISTS OF FIGURES

LIST OF TABLES

LISTS OF ABBERVIATIONS

OWC	Optical Wireless Communication
LED	Light Emitting Diode
LD	Laser Diode
RF	Radio Frequency
VLC	Visible Light Communication
OCC	Optical Camera Communication
FSO	Free Space Optical
IM	Intensity Modulation
DD	Direct Detection
PAM	Pulse Amplitude Modulation
PPM	Pulse Position Modulation
PIM	Pulse Interval Modulation
OOK	On-Off Keying
OFDM	Orthogonal Frequency Division Multiplexing
MCM	MultiCarrier Modulation
WDM	Wavelength Division Modulation
VCSEDs	Vertical Cavity Surface Emitting Diode
OLED	Organic Light Emitting Diode
LoS	Line Of Sight
FFT	Fast Fourier Transform
IFFT	Inverse Fourier Transform
MIMO	Multiple Input Multiple Output
TDMA	Time Division Multiple Access
FDMA	Frequency Division Multiple Access
CDMA	Code Division Multiple Access
NOMA	Non-orthogonal Multiple Access
UOWC	Under water Wireless Communication
UWSN	Underwater Sensor Network
AUVs	Automonous Underwater Vehicles
RCVs	Remotely Controlled Vehicles
PD	Photo Detector
WBAN	Wireless Body Area Network
EMG	Electromyogram
EEG	Electroencephalogram
ECG	Electrocardiogram
EMI	Electromagnetic Interference
UWB	Ultra wide Band
LEO	Low Earth Orbit
GEO	Geostationary Orbit

Section I

1 : Introduction

Radio communication have the limitation due to limited channel capacity and transmission rate.while the demand for the higher data rate is increased by every year.So different techniques was used to get better use of radio spectrum.But that was not enough.According to Cisco, mobile Internet traffic over this half of the decade (2016-2021) is expected to increase by 27 times. Given this expectation of dramatically growing demand for data rates, the quest is already underway for alternative spectrum bands beyond radio waves. The latter are bands currently used and planned for near future systems, such as 5G cellular systems.So new technologies are arrived and now replacing the RF.In this technologies the optical wireless communication is one of them for indoor usage.Optical Wireless communication (OWC) provides the higher data rate and it is remained for research for almost three decades.In the OWC system a modulated beam of the infrared,visible or ultra-violet light is transmitted through the atmosphere , by an optical wireless transmitter.Optical wireless communication used the light emitting diodes(LED), or laser diodes (LD) to transmit the light.OWC system are able to transmit video,data and voice at the data rates up to 25Gbps in the indoor system.
In recent years, there has been a significantly increasing interest from academia and industry in optical wireless communication (OWC) technologies. There is also now a wide range of OWC technologies, as a result of the many use cases they can serve.

1.1 : Optical Wireless Communication Technologies

The main OWC technologies are
(i) free space optical (FSO) communications
(ii) visible light communications (VLC)
(iii) optical camera communications (OCC)
(iv) wireless networking with light, which is also referred to as LiFi.
FSO communication is the closest functionally to optical fibre communications as it provides static wireless point-to-point communications over relatively large distances of up to tens of Kilo metre. FSO systems primarily use the infrared spectrum. With the advent of the blue light emitting diode (LED) which led to the development of the bright white LED, visible light communication (VLC) emerged. The first VLC application which used white LEDs was for wireless audio signal transmission .In a similar way to how white high brightness LEDs have led to VLC, the digital camera in smart phones has led to OCC, because it is possible to use this sensor to detect information encoded in flickering light.

1.2 : Features of Optical Wireless Communication

Optical wireless communication have better features as compared to to radio frequency(RF).Some features are given below

* Rapid deployment
* Low start up and operational cost

* Higher bandwidth
* The nature of light gives the OWC systems are immunity against interference caused by the adjacent channels in neighbouring rooms.which may increased the capacity .
* OWC system also offer better security at the physical layer.And we know light did not penetrate which reduced the need for data encryption.

1.3 : Electromagnetic Spectrum

There are certain wavelength that are suitable for the communication in optical wireless spectrum.And it is range between 780-950 nm .And this is best range for wide field of view communication.
Some ranges for particular light is given below
* 1 mm to 750 nm for infrared
* 780 nm to 380 nm for Visible light
* 10nm to 400nm for Ultraviolet Light

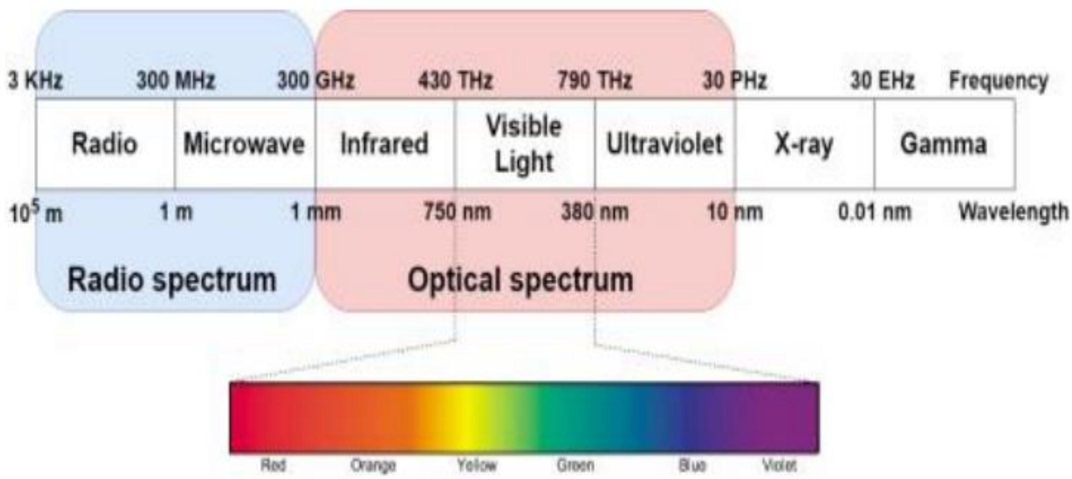

Fig 1 : The Electromagnetic Spectrum

1.4 : Drawback of Optical Wireless Communication

The drawback of the optical wireless communication is given below :

* In a indoor system optical wireless access points ,in different rooms ,have to be connected via a wired backbone as light cannot penetrate walls.
* Optical signals also suffer from attenuation due to multipath propagation, reflections and signal spread.
* The signal at the receiver can include the shot noise .
* The transmitted power is limited due to eye and skin safety regulations.

* OWC systems require a receiver with a photo sensitive detector with large area to collect the maximum optical signal possible, and this leads to an increase in the capacitance of the Photo detector, consequently the available receiver bandwidth decreases.

1.5 : Comparison of Radio and Optical and wireless Systems

Table 1 compares Radio and OW systems. To place OWC in the communications scene

Property	Radio System	OW System
Bandwidth Regulated	YES	NO
Security	Low	High
RF Electromagnetic interference	YES	NO
Passes through walls	YES	NO
Technology Cost	High	Low
Beam Directionality	Low	Medium
Available bandwidth	Low	Very high
Transmitted Power	Restricted (Interference)	Restricted (Eye safety and interference)
Noise Sources	Other Users and Systems	Sun light and Ambient Light
Power consumption	Medium	Relatively low
Multipath Fading	YES	NO

Table 01 : Comparison of Optical Wireless System with Radio system

OWC systems can provide high data rates beyond 10 Gbps .However, there are many challenges to implement OW systems. For instance, fog, rain and dust reduce data rates and coverage area of free space optics (FSO) outdoor systems, while multipath propagation, receiver noise and interference tend to limit the capacity of indoor OWC systems. .

Section II

2 : Modulation Techniques in optical wireless communication

OWC channels are different from traditional RF channels. This has resulted in different methods of modulation being used. Modulation schemes that fit well in RF channels do not necessarily perform well in the optical domain. There are four criteria that guide the choice of a specific modulation technique for OWC systems.
The first is the average power used (power efficiency) of a given modulation format. This is important in view of eye hazards and power consumption in mobile terminals.
The second criterion is the available channel bandwidth and receiver bandwidth requirements. The third factor is the complexity of the modulation format (and power consumption in portable devices). The last set of factors relate to the physical limitations in the transmitter (i.e. LD or LED) which the modulation format may have to take into account.
Modulation in optical wireless communication is done by two steps which is given below
i : Information is coded as the waveform

ii :These waveform are modulated onto the instantaneous power of the carrier

2.1 : Intensity Modulation and Direct Detection

Intensity modulation (IM) and direct detection (DD) is the preferred transmission technique in OWC systems. IM is achieved by varying the bias current of the LD or the LED. In OWC systems, the transmitted signal must always be positive in intensity. Direct detection is the simplest method that can be used to detect an intensity modulated signal. The photo detector generates a current that is proportional to the incident optical power intensity. A simple description for the IM/DD channel is given as

$$y(t) = Rx(t) \otimes h(t) + Rn(t)$$

where R is the photo detector responsitvity, y(t) is the instantaneous photo current received, t is the absolute time, $\otimes$ denotes convolution, h(t) is the channel impulse response, x(t) is the instantaneous transmitted power and n(t) is the background noise (BN), which is modeled as white Gaussian and is independent of the received signal.

2.2 : Types of Modulation

There are three broad types of modulation that can apply on optical wireless

communication

2.2.1 : Baseband modulation

2.2.2 : Multicarrier modulation

2.2.3 :Multicolor modulation

2.2.1 : Baseband modulation

Baseband modulation techniques are divided into four modulation

i : Pulse Amplitude Modulation (PAM)

ii : Pulse Position Modulation (PPM)

iii : Pulse interval Modulation (PIM)

i : Pulse amplitude modulation(PAM)

PAM is simple technique of modulation which is commonly used in communication.On-Off keying (OOK) is simple type of PAM which is used in optical wireless communication.OOK is easily implantable because in optical wireless communication data is sent by on and off of LED's and LD.In the simplest form ,the presence of the carrier for a specific duration represents a binary one,While its absence for the same duration represents a binary zero.But OOK is not efficient when we compare it with the other modulation .

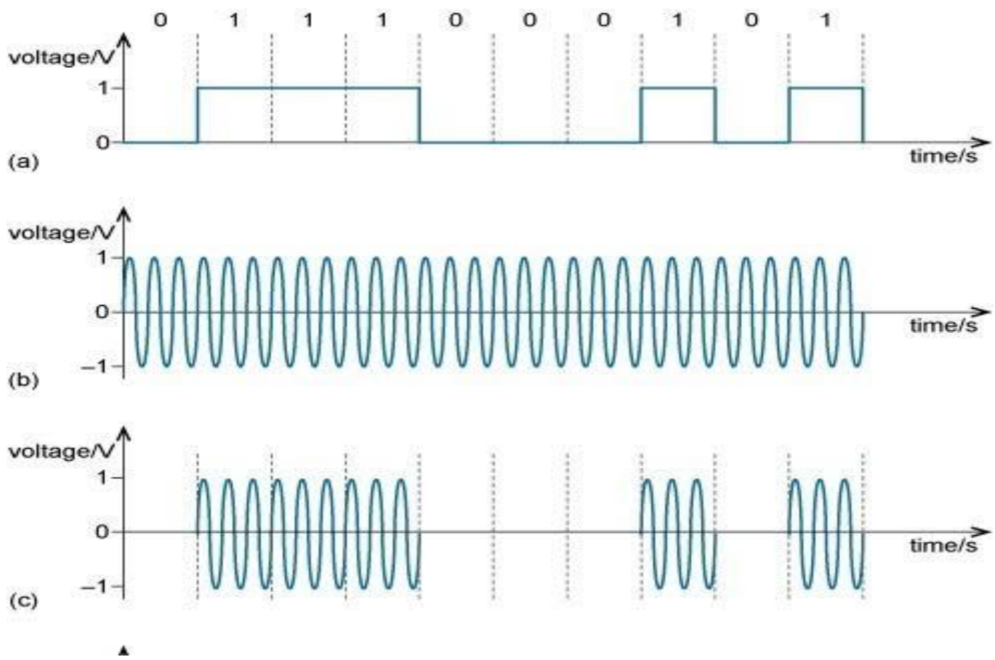

Fig 2 : On-Off Keying Modulation

ii :Pulse position modulation(PPM)

In this technique modulation is done by adjusting the position of pulse according to switch on and off of LED's and LD.It consume less power.In this Technique, each symbol consist of a single pulse of a constant power.This pulse can occupy one slot out of L possible time slots and the rest of the slots are empty.The pulse position carried the encoded information.it is more efficient as compared to PAM.Differential PPM (DPPM) was evaluated in OWC system to increase the achievable data rates. It consumes less power on average when compared to PPM. However, the distortion in the DPPM signal is greater than in the PPM signal .

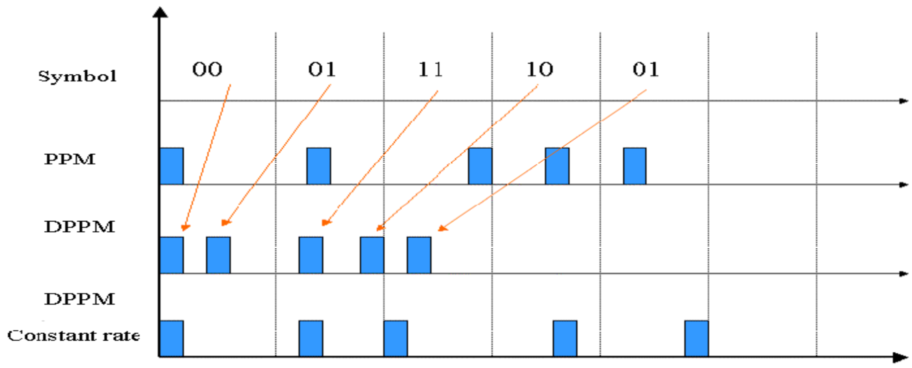

Fig 3 : Pulse Position Modulation

iii :Pulse interval modulation(PIM)

PIM encodes the information by inserting empty slots between two pulses. Its design relies on accurate synchronization which can increase its complexity compared to PPM. Digital pulse interval modulation (DPIM) is a digital version of PIM. The performance is improved in DPIM compared to PPM by removing the redundant frame space in PPM, however errors can propagate from a frame to the next.

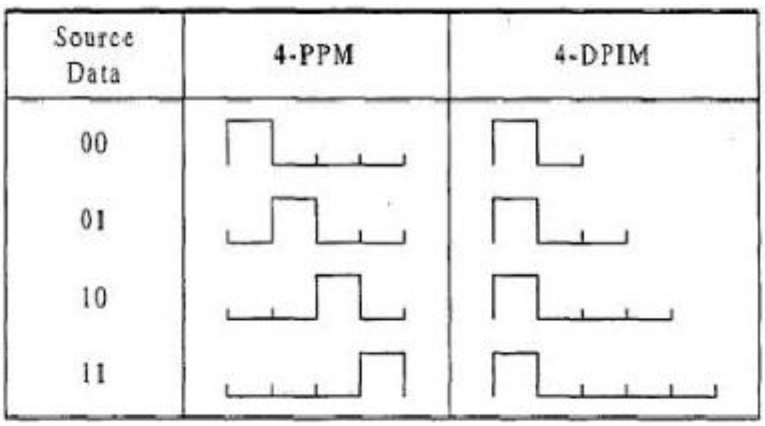

Fig 4 : Comparison of PPM with DPIM

Here we compare the PPM and PIM .We take the 2 bit message signal.so L=4 as L=2^m.So we see that the in PPM the pulse position changed according the information signal and in the PIM the empty slots added between two pulses as the information signal.

2.2.2: Multicarrier Modulation :

Multi carrier modulation is a method of transmitting data by splitting it into several components and ending each of these components over separate carrier signals.the individual carriers have narrow bandwidth ,bu the composite signal can have broad bandwidth.

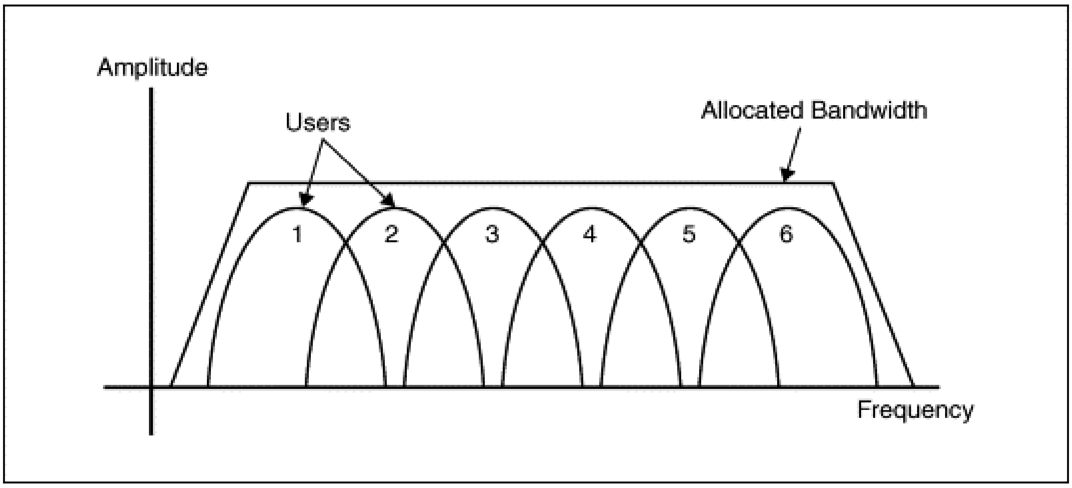

Fig 5 : Multicarrier Modulation

From above fig 5 we see that Multicarrier modulation operates by dividing the data stream to be transmitted into a number of lower data rate data streams. Each of the lower data rate streams is then used to modulate an individual carrier.When the overall transmission is received, the receiver has to then re-assembles the overall data stream from those received on the individual carriers.The history of multicarrier modulation can said to have been started by military users. The first MCM were military HF radio links in the late 1950s and early 1960s.Originally the concept of MCM required the use of several channels that were separated from each other by the use of steep sided filters of they were close spaced. In this way, interference from the different channels could be eliminated.However, multicarrier modulation systems first became widely used with the introduction of broadcasting systems such as DAB digital radio and DVB,

2.2.2.1:Orthogonal Frequency Division Multiplexing

Digital Video Broadcasting which used OFDM, orthogonal frequency division multiplexing. OFDM used processing power within the receiver and orthogonality between the carriers to ensure no interference was present.Orthogonal frequency division multiplexing (OFDM) is the form of multicarrier modulation .OFDM is possibly the most widely used form of multicarrier modulation. It uses multiple closely spaced carriers(as shown in fig 6) and as a result of their orthogonality, mutual interference between them is avoided.

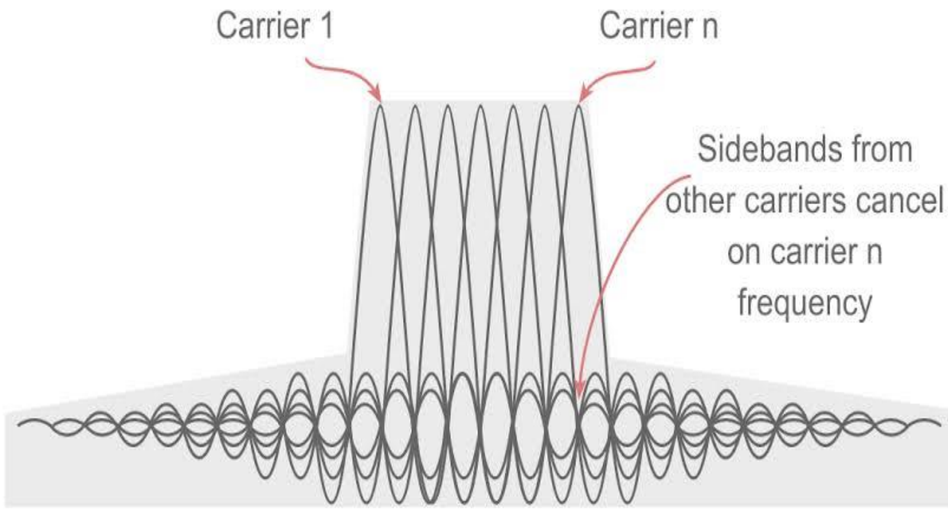

Fig 6 : Closely Spaced Multiple Carrier in OFDM

Orthogonal frequency division multiplexing (OFDM) was applied in indoor OWC systems to achieve high data rates over a noisy channel and to reduce ISI. The system, however, did not achieve a high SNR. The main disadvantages of OFDM are the sensitivity to frequency offset and phase noise as well as the high peak to average power ratio (PAR) . In general, the use of complex modulation leads to an improvement in the performance of the OWC systems, such as mitigating the ISI effect and increasing the data rates. However, these modulation techniques require a complex transceiver.

2.2.3 :Multicolor Modulation

Multicolor modulation has recently been considered to provide high data rates or multiple access for users. White light can be generated from red, green and blue (RGB) type LEDs which means data can be transferred through each color or wavelength. Wavelength division multiplexing (WDM) is the multiplexing used here.

2.2.3.1 : Wavelength Division Multiplexing

Wavelength division multiplexing (WDM) is a technique of multiplexing multiple optical carrier signals through a single optical fiber channel by varying the wavelengths of laser lights. WDM allows communication in both the directions in the fiber cable.In WDM, the optical signals from different sources or (transponders) are combined by a multiplexer, which is essentially an optical combiner. They are combined so that their wavelengths are different.The combined signal is transmitted via a single optical fiber strand. At the receiving end, a demultiplexer splits the incoming beam into its components and each of the beams is send to the corresponding receivers.

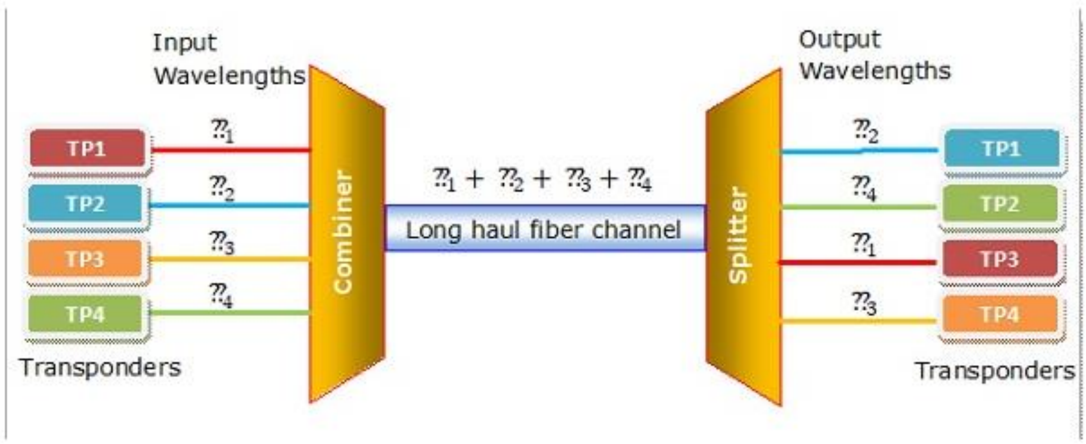

Fig 7 : Wavelength Division Multiplexing

2.2.3.2 : Types of WDM

Based upon the wavelength, WDM can be divided into two categories :

i : Course WDM (CWDM)

CWDM generally operates with 8 channels where the spacing between the channels is 20 nm (nanometers) apart. It consumes less energy than DWDM and is less expensive. However, the capacity of the links, as well as the distance supported, is lesser.

ii :Dense WDM (DWDM)

In DWDM, the number of multiplexed channels much larger than CWDM. It is either 40 at 100GHz spacing or 80 with 50GHz spacing. Due to this, they can transmit the huge quantity of data through a single fiber link. DWDM is generally applied in core networks of telecommunications and cable networks. It is also used in cloud data centers for their IaaS services.

Section III

3 : Main Challenges in Optical wireless communication

In the following, we will briefly introduce some of the key challenges in all the different research areas.

3.1 : Devices and components

While the optical spectrum is three orders of magnitude larger than the entire RF spectrum (figure 8).

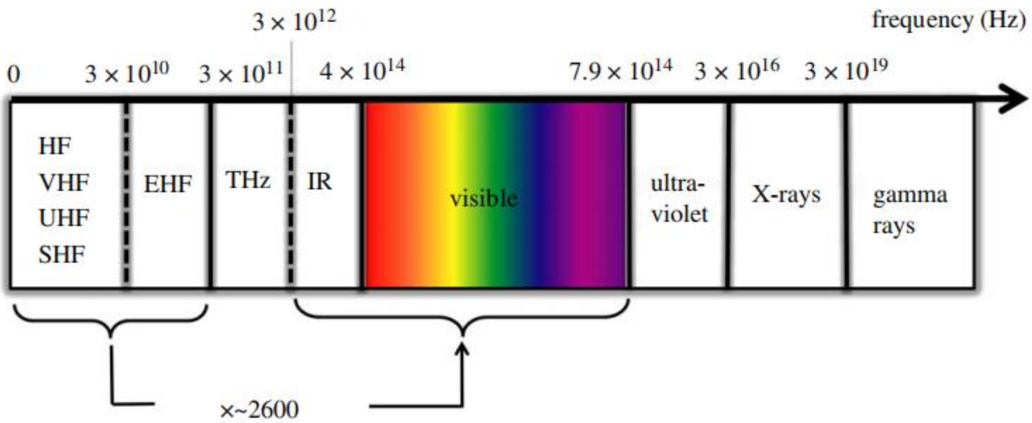

Fig 8 : The entire electromagnetic spectrum

3.1.1 : Limitation in wireless transmission

There are fundamental limitations that currently prevent us from being able to fully understand this huge amount of wireless transmission resource especially when using LEDs as transmitters.This is because the bandwidth of typical LED devices is limited to 10 s and 100 s of MHz . This limits the data speeds of single LEDs, typically to below 10 Gbps . However, to overcome this limitation, it is possible to use multiple devices of similar bandwidth, but at a different emission spectrum, which is referred to as wavelength division multiplexing (WDM). it was shown that four standard off-the-shelf LEDs have yielded an aggregate data rate of 15.7 Gbps despite the partial overlap of their emission spectra. An optimum use of WDM would require sub-nanometre spectral emission masks and high device bandwidth. The required device bandwidth can be approximated as follows:

$$B_{\text{device}} \approx c\frac{\Delta\lambda}{\lambda^2},$$

where *c* is the speed of light in vacuum, λ is the emission spectrum of the light source assuming a rectangular spectrum mask, and λ is the centre wavelength .

3.1.2 : Device bandwidth as function of emission spectrum

We plot this above equation as a function of the centre wavelength of the emission spectrum in fig (9) .From figure 9 it can be seen that a red light source (600 nm) with an emission spectrum of 0.45 nm would require a device bandwidth in excess of 350 GHz.

First, it is clearly not possible to achieve such a narrow emission spectrum with current LEDs, and second, it is practically difficult to achieve a transmit device bandwidth of 350 GHz with current technology .let alone achieving detectors that have a bandwidth of 350 GHz. Overcoming the device limitations is an area of active research. Unlike point-to-point communication, such as in FSO, wireless networking systems have to provide simultaneous wireless connections to a potentially very large number of end users in indoor environments. There is, therefore, an additional challenge (in addition to device bandwidth) which is related to link margins and receiver sensitivity due to the small detector size on the one hand, and the widely spread optical power on the other hand. In the short- to medium-term, laser-based lighting may offer the next step towards higher device bandwidths while providing high optical output power to enhance the link data rate performance and maintaining eye-safety requirements.

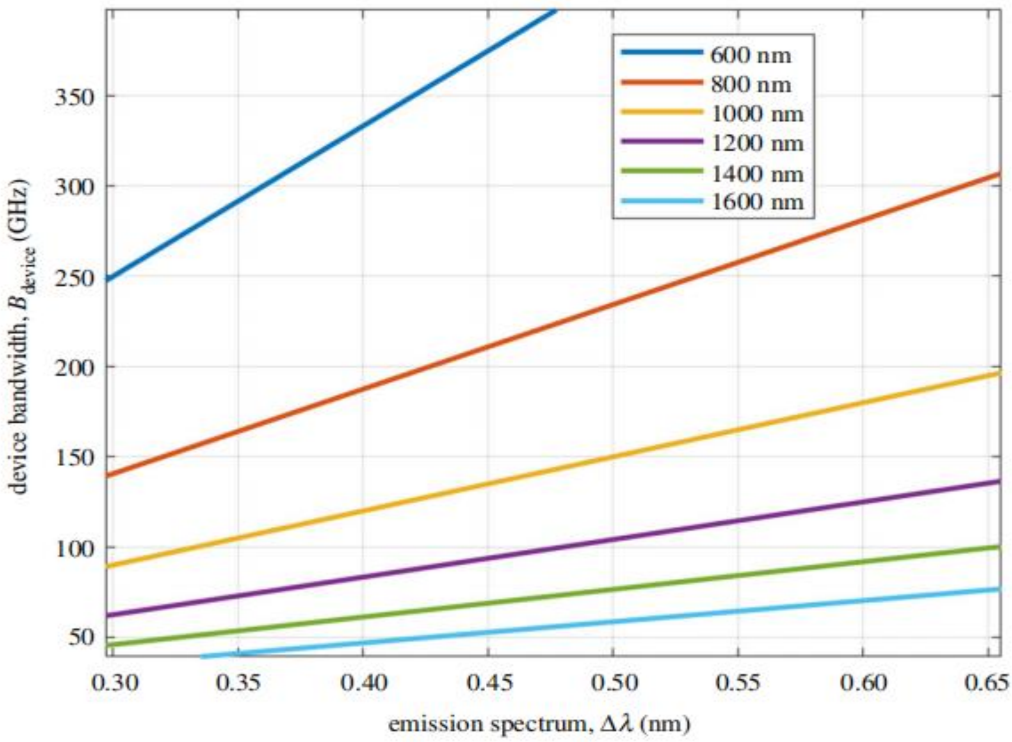

Fig 9 : Required device bandwidth as function of emission spectrum

3.1.3 : Choice of Optical Transmitter

The major limitation of these devices is the low optical output power, but arrays of micro LEDs can be used to overcome this limitation.Various laser devices such as vertical-cavity surface-emitting lasers (VCSELs) operating in the infrared spectrum have also been used to build high-speed OWC links.Although inorganic semi-conductor devices have primarily been used as optical transmitter and receiver devices, organic semiconductors exhibit properties which make them ideal candidates for optical devices in VLC systems. In particular, their flexibility can be used to bend them around edges which can be helpful to increase connectivity when the device is randomly oriented. While it has been shown that it is possible to achieve gigabit per second links using organic LEDs (OLEDs).

it has also been demonstrated that organic photo voltaic cells can be used as high-speed data detectors.OWC systems primarily use intensity modulation/direct detection (IM/DD). The information is encoded in changes of the light intensity. For the decoding of the information, a square-law detector is used typically, a photo diode (PD).

3.2 : Optical front end system

The optical front-end can be divided into the transmitter part and the receiver part. Because the objective is to build bi-directional communication links, both parts have to be integrated into a single transceiver unit. Sufficient decoupling of the received and transmitted signals is important and various duplexing techniques can be used. Trade-offs to consider in the design of the duplexing techniques are bandwidth, latency and data rate.The optical system of the transmitter has to ensure that eye-safety standards are met while achieving quality of service requirements. This can be challenging when the transmitter is a point source. It is, therefore, often desirable to convert the point source into an extended source which changes eye-safety conditions.

3.2.1: Challenges in Mobile networking

One of the key challenges in mobile networking is that the mobile terminal randomly changes orientation. Moreover, the link between the mobile terminal and the fixed access point can be obstructed. In a system that heavily relies on line-of-sight (LoS) link conditions, this becomes a critical challenge. A possible solution to this challenge is to provide link diversity by means of multiple simultaneously active transmitters whose position and possibly orientation is different.

3.2.2 : Challenges at the Receiver Antenna

At the receiver, the challenge is to capture enough photons to ensure correct detection of the transmitted information. Ideally, the receiver would have a large area to allow the system to collect a large number of photons. However, a large-area detector typically has a low bandwidth because the large area results in a detector that has a high capacitance. Therefore, often concentrators are used. The maximum concentration gain is governed by

$$G_{\max} = \frac{n^2}{\sin^2(\theta)},$$

where n is the refractive index of the concentrator material and θ is its half-angle. As seen from above equation if a large gain is desired, the half-angle has to be small.The ideal receiver optical sub-system

(i) is flat

(ii) uses small detectors

(iii) allows for a half-angle close to 90° to avoid strict alignment.

3.2.3 : Bandwidth Enhancements

Moreover, there has been very interesting research on ultra-low impedance trans impedance amplifiers which lead to significant bandwidth enhancements . This is because the dominating time constant which determines the device bandwidth is a product of capacitance and resistance. Ensuring a low resistance is therefore a promising direction to reduce the time constant and increase the bandwidth.
There has also been a lot of work on angular diversity receivers to overcome link obstruction and alignment issues.

3.3 : Channel Models :

An important system element is the optical free-space propagation channel. The optimum design of the transceiver depends on the optical channel characteristics. Since objects act as reflectors, an impulse sent by the transmitter arrives at the receiver via multiple delayed paths. This is referred to as multipath propagation. Multipath propagation causes inter-symbol interference. This means that a transmitted symbol is corrupted by n previous symbols. This effect has to be eliminated by means of digital equalization, or has to be avoided by a proper selection of transmission techniques. Moreover, there may not always be a LoS channel. The receiver has to be able to cope with the situation that there are only reflections.

It is, therefore, important to get a comprehensive understanding of

(i) the power included in the reflected paths (in addition to the power received on the LOS path)

(ii) the temporal spread of the reflected signals.

Furthermore, the reflectivity of the materials used indoors is wavelength-dependent. A full understanding of the wavelength dependent reflectance and absorption of objects and materials in typical deployment scenarios such as homes, offices and manufacturing plants is paramount to the development of OWC networks.
In this issue, we have a contribution by Miramirkhani & Uysal who have been at the forefront of the development of channel models for OWC systems. The same group has provided reference channel models to the IEEE 802.11bb standardization group. This standard is the first that defines wireless light-based networking systems.

3.4 : Data Transmission Techniques :

Although IM/DD is the major transmission technique used in OWC, it is possible to use coherent transmission at the cost of increased transceiver complexity. Recently, there has been an increasing number of works on coherent OWC systems. This is a direction that this field may also take in the future.

3.4.1 : On-Off Keying Technique

The most basic data transmission technique for IM/DD systems is on-off keying (OOK). OOK,however, severely limits the spectrum efficiency since in every transmission step or channel use only one bit is transmitted. Because the system is limited by the device bandwidth, this results in a hugely sub optimum use of the available bandwidth. However, OOK benefits from implementation simplicity and it is also robust to device non linearities. In addition, OOK severely suffers from inter-symbol interference when it is deployed at high data rates. It is desirable to use data transmission techniques that are more spectrum efficient, i.e. transmit multiple bits per channel use while increasing the robustness to multipath propagation.

3.4.2 :Enhancement in data rate by OFDM

One such technique is orthogonal frequency division multiplexing (OFDM) which sends data symbols simultaneously on orthogonal sub channels. This is achieved by using the inverse fast Fourier transformation(IFFT) at the transmitter and the fast Fourier transformation (FFT) at the receiver. The parallel transmission means that the OFDM symbol is much longer than the maximum multipath delay.

Therefore, a single-tap equalizer can be deployed. Also, every sub channel can carry a complex data symbol out of an alphabet of M total symbols where every symbol carries log2(M) bits.However, since the OFDM symbol is bi-polar, the signal needs to be subjected to a direct current (DC) bias before exposing the signal to the light transmitter, which operates solely in the first quadrant and thus cannot accept negative signals. This measure has a negative impact on the energy efficiency as the DC bias power is wasted unless it is used for other purposes such as illumination. However, while illumination might be desirable if an access point is combined with an illumination device, it is certainly undesirable in a mobile device such as a smartphone. Therefore, new digital modulation techniques have been developed based on multi-stream, or layered data transmission in conjunction with superposition modulation and iterative detection.

3.4.3 : Multiple input multiple-output (MIMO) techniques

Due to the bandwidth limitation of the devices, it is paramount to consider other dimensions for data encoding in particular, the spatial dimension and the wavelength dimension. Multipleinput multiple-output (MIMO) techniques harness the spatial dimension.Multiple input multiple output technology uses multiple antennas to make use of reflected signals to provide gains in channel robustness and throughput.

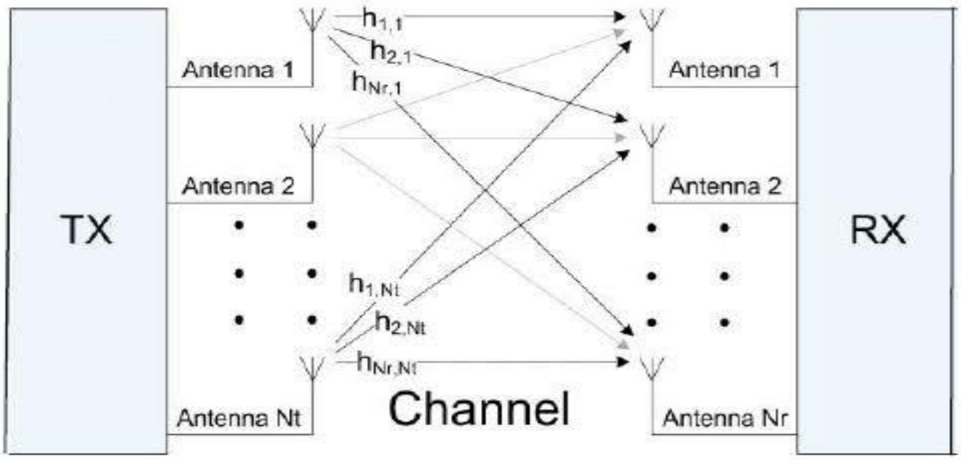

Fig 10 : Multiple Input Multiple output system

There are two fundamental techniques in OWC systems:
(i) imaging MIMO
(ii) non-imaging MIMO
Imaging MIMO is very intolerant to movement and is thus more suitable for FSO-type systems while non-imaging MIMO can be used in mobile applications. However, it is usually not guaranteed that the MIMO channel matrix is always full rank, which is a necessity to fully benefit from maximum spatial multiplexing gains. In addition, MIMO systems suffer from inter-channel interference or cross-talk. Iterative interference cancellation techniques can be used to mitigate this effect, but these techniques require significant computational processing power.
A MIMO technique which has attracted large interest in academia and industry is spatial modulation . Spatial modulation completely avoids inter-channel interference and hence results in low computationally complexity MIMO decoding techniques.

3.5 : Medium Access Protocol

In OWC wireless networks, the simultaneous support of many mobile terminals from a single access point (e.g. a light in the ceiling) is essential. These mobile terminals may have different service requirements. For example, in a manufacturing plant, the transmission delay may be more important than the peak data rate. It is, therefore, important to first develop optimum multiuser access techniques which avoid multiuser interference and achieve high spectrum efficiency. Ideally, the sum data rate of an access point is greater when supporting many users as compared to a single-user scenario.

3.5.1 : Types of Multiple Access Schemes

Several multiple access (MA) schemes have been studied for use in OWC systems. Some of the MA schemes that have been used in RF systems are also used in OWC systems. These include time division multiple access (TDMA), frequency division multiple access (FDMA), code division multiple access (CDMA),non-orthogonal multiple access (NOMA).

3.5.1.1 : TDMA and FDMA

TDMA for multi-user OWC systems was proposed and investigated in. It is also sometimes used for preventing collisions where other MA schemes may fail, such as situations where two transmitters have the same distance to the receiver . A controller can share time between the transmitters in a medium access control (MAC) protocol, which may also allow uneven time splitting between trasnceivers. The throughput of TDMA schemes decreases if the number of users increases. As a result the system cost may rise due to the need for synchronization between transmitters.FDMA is a scheme that can support multiple access based on orthogonal frequency bands.

3.5.1.2 : Code Division Multiple Access (CDMA)

CDMA is a non-orthogonal multiple access scheme which can offer high spectral efficiency compared to OFDMA and TDMA. Each user in CDMA uses a special code to provide simultaneous transmission and reception. The special code used by each user is typically an optical code.CSK is another technique that was proposed in conjunction with CDMA. It can provide 3dB gain for each user compared to OOK. Techniques were proposed based on CDMA to provide interference-free links, but in small areas while other approaches were reported to increase the achievable data rates and number of users.

3.5.1.3 : non-orthogonal multiple access (NOMA).

NOMA is also called power domain multiple access. NOMA differs from other multiple access techniques which provide orthogonal access for multiple users either in frequency, time, code or phase. Each user in NOMA can use the same band at the same time. Thus, the power level can be used to help distinguish users. In addition, the transmitter in NOMA applies superposition coding to simplify the operation at the receiver. As a result, channels are separated at the receiver for both uplink and downlink users. NOMA was also studied in some recent work as a means to support multiple users at high data rates.

3.6 : Interference mitigation and mobility support

A wireless network is characterized by many access points which are spatially distributed. Every access point covers a certain area. If a mobile device enters the coverage zone of an access point, the system performs a handover from the access point to which the mobile was previously connected to the new access point. This process needs to be fast enough to ensure uninterrupted wireless service provision. If the coverage of an access point is small, the requirement of a fast handover becomes particularly important.

3.6.1 : Advantages of Small Cell

The key advantage of optical wireless networking is that very small cells can be generated where a cell is defined by the coverage area of an access point.

This is a very important advantage because the same transmission resource can be reused many more times when compared to large area cells. This principle of cell shrinkage is the main reason in RF communication for the improvements in data rates delivered to smart phones during the last decade.

However, there is a limit to the continued reduction of cell sizes. This limit is due to increased interference. If access points are spaced too closely together, the transmitted signals overlap (interfere) significantly. This interference enhances the noise and thus reduces the signalto-noise ratio, sometimes to levels where it is impossible to maintain an error-free communication link.

3.6.2: Benefits of OWC over RF in Small Cells

The benefit of optical wireless networking in comparison with RF wireless networking is that the limit, where interference becomes dominant, is significantly lower. This means much smaller cells can be generated while interference is kept at low levels. This is because it is much easier to spatially control light waves compared with radio waves. Microwaves, for example, pass through opaque walls. By contrast, light waves are completely blocked by opaque objects. Also, it is possible to confine the coverage by using simple lenses in an optical subsystem. Nonetheless,
due to multipath propagation and random orientation of mobile devices, there is still interference present in optical wireless networks.

3.7 : Networking And protocol

Lastly, the vision is that optical wireless networks will be seamlessly integrated with existing RF wireless networks . This is seen as an evolutionary process since there are many different RF wireless networking technologies such as 4th generation (4G), 5th generation (5G) cellular networks as well as WiFi. Interoperability between these networks is enabled through the concept of heterogeneous networks. Optical wireless networks will be another such networking technology which is expected to be seamlessly integrated. However, this requires dynamic network management algorithms. SDN is one such dynamic network management technology which is based on the principles of network virtualization and the establishment of separate
control planes and data planes. Optical wireless networks need to be designed to support these paradigms, and hence it is necessary to develop bespoke SDN agents which act as brokers (hypervisors) between specific optical wireless networking properties and general transport mechanisms and application specifific requirements.

These SDN agents will translate these generic requirements via the control plane into network configurations and they will cooperate to ensure that at any time the optimum connectivity to a mobile terminal is provided. For example, an optical wireless SDN agent cooperates with a WiFi agent to ensure that data flows are managed optimally. This, for example, could mean that particular users are served by a WiFi network and by an optical wireless network simultaneously by means of multipath TCP. Here the network directs the specific data flows based on the characteristics of the respective communication links (RF and optical).

Section IV

4: Advantages and disadvantages of Optical wireless communication

4.1 : Advantages of OWC

The advantages are given below

Advantages	Discussion
Low Power Consumption	Less Energy requirements and cost saving
No strict law	Free License Operation
Huge Bandwidth	Good for higher speed application
Unregulated Spectrum	Allow virtually Unlimited use of spectrum by individuals networks
Optoelectronic Technology	Inexpensive components and little power consumption
Reusability	Use some Communication equipment and wavelength by near systems

Table 2 : Advantages of Optical Wireless Communication

4.2 : Disadvantage of OWC

The Disadvantages are given below

Disadvantages	Discussion
Blockage for optical transmitted signals	Leads to design challenge
Low Power Source	Requires High sensitive receivers
Alignment	Leads to more operation Condition
Signal scattering	Leads to multipath problems
Light interference	Affect the system performance negatively

Table 3 : Disadvantages of Optical Wireless Communication

Section V

5 : Applications of Optical wireless communication

Some of the key applications of the optical wireless communication are given below

- Video Surveillance and monitoring
- Broadcasting
- Enterprise/Campus Connectivity
- Wearable interaction
- Backhaul for cellular Systems
- Satellite Communication networks
- Quantum Cryptography
- Indoor low cast communication
- Redundant link and disaster recovery

5 .1 : Underwater optical wireless communications

The underwater wireless communications are a process of transmitting data in unguided water environments via wireless carriers such as acoustic wave, RF wave, and optical wave. Compared to the RF or acoustic alternatives, UOWC offers higher data rate and transmission bandwidth. Basically, the UOWC uses optical wave as wireless carrier for an unguided data transmission.

The UOWC systems are applicable in disaster precaution, offshore exploration, environmental monitoring, as well as military operations. Nevertheless, UOWC systems are susceptible to absorption and scattering which are normally created by the underwater channels. These conditions lead to severe attenuation of optical wave and eventually hindered the system performance.

Different viable techniques have been presented in the literature to attend to the associated technical challenges of a UOWC. One of such is an underwater wireless sensor network (UWSN).

5.1.1 : OWC Suitable in Underwater

The outstanding technical merits of UOWC are the lowest link delay, highest communication security, highest transmission rate, and lowest implementation costs compared to other methods. The comparative high-speed benefit of UOWC makes it a promising candidate for real-time applications like underwater video transmission. In UOWC systems, LOS configuration is normally employed in the transmission. This helps in preventing eavesdroppers, and hence improves communication security. Besides, UOWC is the most cost-effective and energy efficient means of underwater wireless communication. This can be attributed to the comparatively small, low-energy consuming, and low-cost optical transceivers which are normally employed.

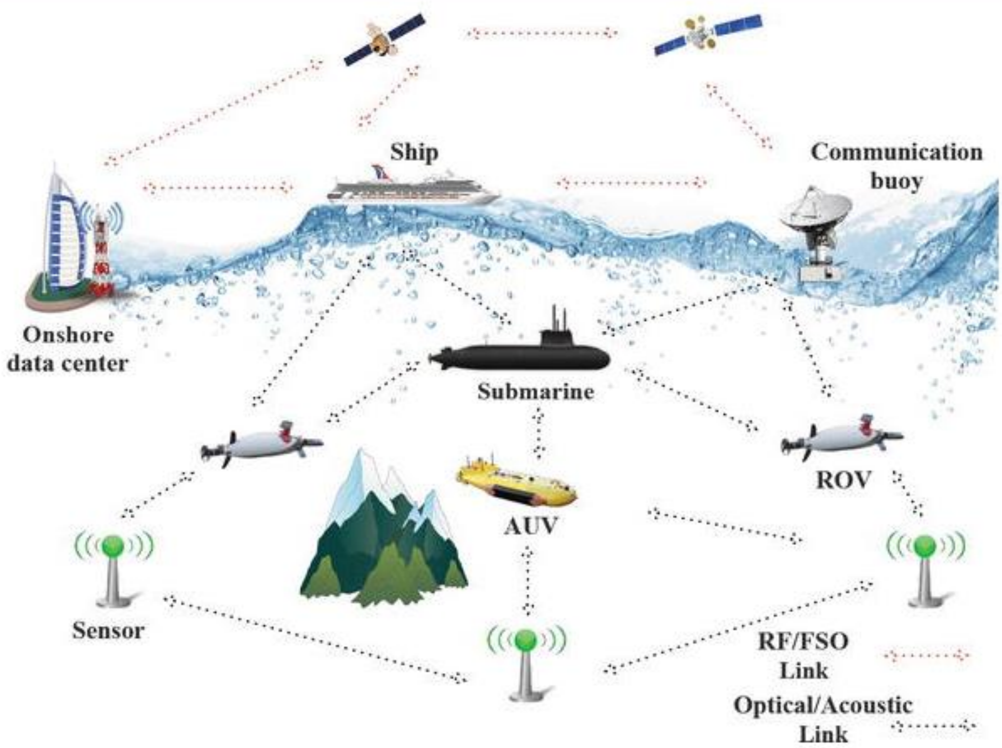

Fig 11 :Underwater Optical Wireless Communication

5.1.2 : Demonstration of OWC in Underwater

The major entities in the UWSN are distributed nodes such as relay buoys, seabed sensors, autonomous underwater vehicles (AUVs), and remotely operated underwater vehicles (ROVs). The network entities are capable of performing tasks like processing, sensing, and communication in order to sustain collaborative monitoring of the underwater environment. The acquired data by the sensors that are located at the seabed are transmitted through acoustic/optical links to the AUVs and ROVs which in turn relay the signal to the ships, communication buoys, and other underwater vehicles. Furthermore, the onshore data center that is above the sea surface then processes the data and communicates with the satellite and the ships via RF/FSO links .

5.2 : Visible light communication system

The current enhancement of LED chip design with swift nanosecond-switching times and extensive deployment of LEDs for energy efficiency paves the way for visible light communication (VLC) system. So, the VLC system has become an attractive technology for addressing challenges such as energy efficiency, bandwidth limitation, electromagnetic radiation, and safety in wireless communications. The VLC system operates in the wavelength range of ~390–750 nm. Figure 11 shows VLC system implementation.

5.2.1 : Advantages of Using VLC over RF in Indoor Application

The concurrent support for communication and illumination by the VLC offers the following advantages over the RF communications.

Fig 12 : Visible light system Implementation

i : Huge bandwidth

It exhibit almost unlimited and unlicensed bandwidth which approximately ranges from 380 to 780 nm. Therefore, VLC has 350 THz that can support multi-gigabit-per-second data rates with LED arrays in a multiple-input multiple-output (MIMO) configuration . This makes VLC a good alternative to the indoor IR that operates at 780–950 nm for the access technologies.

ii: Low power consumption

VLC provides both communication and lighting, giving Gbps data rates with only unsophisticated LEDs and photo detectors (PDs) that consume low power compared to costly RF alternatives that demand high power consumption for sampling, processing, and transmitting Gbps data .

iii:Low cost

The required optical components such as LEDs and photodetectors are inexpensive, compact, lightweight, amenable to dense integration, and have very long lifespan. Moreover, with large unlicensed optical spectrum as well as much lower power-per-bit cost compared to the RF communications, VLC is relatively cheaper.

iv:No health concerns

VLC does not generate radiation that leads to public health concern. Besides, it lowers the carbon dioxide emission owing to the little extra power consumption for communication purposes .

v:Ubiquitous computing

Due to the fact that there are various luminous devices like traffic signs, commercial displays, indoor/outdoor lamps, TVs, car headlights/taillights, and so on being used everywhere, VLC can be employed for a wide range of network connectivity.

vi:Inherent security
VLC offers comparatively higher security due to the fact that it is highly intricate for a network intruder that is outside to pick up the signal.

5.3 : Wireless body area network (WBAN)

Wireless body area network (WBAN) is a system that comprises a set of miniaturized low-power, lightweight sensor nodes, which form wireless sensor networks (WSNs). Figure 11 shows a WBAN system for medical monitoring. With the help of the sensor nodes, WBANs have emerged as an attractive alternative to the conventional wired medical network. Also, there has been noteworthy increase in the WBAN systems because of the IEEE 802.15.6 standard that regulates their commercial applications.

Furthermore, there is an obligation on 2.36–2.40-GHz frequency band as a medical-only WBAN band by the Federal Communications Commission (FCC). The restriction is purposely for service provisions for the indoor health-care facilities as well as for supporting the patients health-care information and management.
Furthermore, the constraint is also to guarantee high quality of service for the health information transmission.

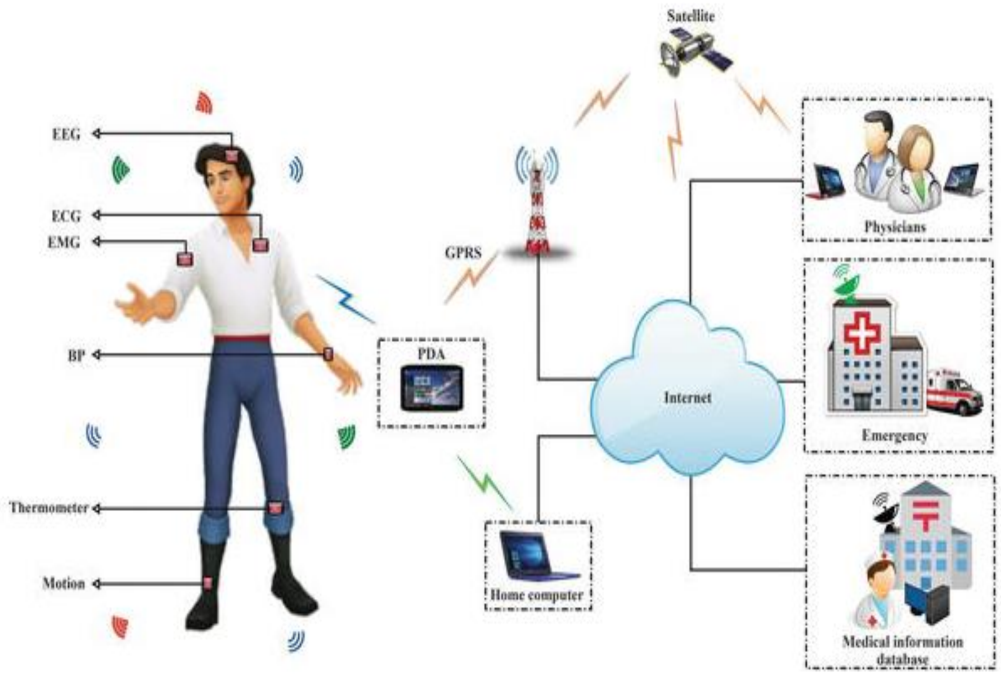

Fig 13 : Wireless body area Network (WBAN)

5.3.1 : Demonstration Of Optical technology in WBAN

The distributed sensors in the WBAN can be implanted in or on the human body in order to monitor physiological parameters in real time.

The implanted sensors that are wirelessly connected to the outside network through a central unit collect different vital health information. The monitored physiological data include electromyogram (EMG), electroencephalogram (EEG), electrocardiogram (ECG), temperature, heart rate, blood pressure (BP), and glucose level .
The ZigBee, Bluetooth, as well as the current Bluetooth Low Energy (BLE) are contending for market share of wireless health devices. Their major appealing advantages are low power consumption and the added mobility.

5.3.2 : Security Issue in WBAN

Health devices that employ these technologies are operating in the industrial, scientific, and medical (ISM) radio bands. High emissions from these devices can create electromagnetic interference (EMI) and eventually disrupt communication. Similarly, there are security issues concerning data transmission for patient monitoring which are susceptible to hacking.
Furthermore, it should be noted that the existing WBANs that use ultra-wide band (UWB) transmissions are RF based. However, their implementation in the hospitals and medical facilities where RF-based system deployment is restricted or prohibited can be challenging. This is due to the potential effects of EMI from various RF transceivers on medical devices. The EMI effects can lead to medical equipment malfunction. Also, RF wave propagation on and/or in the human body is highly complex to examine. Consequently, to address these challenges OWC can be employed as an alternative solution .

5.3.3 : Medical Equipment without Cables

The ECG signal and patient information can be transmitted concurrently with the help of VLC technology. Moreover, certain medical equipment like the one for the cardiac stress test (or cardiac diagnostic test) can be improved on by incorporating LEDs on the sensor units. This implementation will help in minimizing the large amount of cables (e.g., electrodes) that are normally required. Besides, VLC employment is greener (green communication and networking), safer, more secure in RF-restricted/prohibited hospitals and medical facilities . Furthermore, it is worth noting that the current advancements in the organic LED (OLED) technology enable the integration of VLC transceivers into wearable gadgets and clothing.

5.4 : Optical Space Communication

An effective communication links between satellites enable better flexibility, extended coverage, and improved connectivity to be achieved in satellite systems. This is applicable in interorbit links between satellites in low earth orbit (LEO) and geostationary orbit (GEO). Furthermore, intersatellite links between satellites in the same GEO or LEO orbit are other scenarios for application. Also, the satellite system connectivity can be enhanced by exploiting the free-space links between satellites. This will result in an improved capacity for telecommunication systems. Moreover, the capability to relay data from the earth observation satellite to the ground through a GEO relay satellite enables real-time data flow and minimizes the number of ground stations required for service delivery in the system.

5.4.1 :Requirements for Space optical Communication

Generally, the space link implementation can be realized at microwave, millimetric, and optical frequencies. Also, all technologies require the communication beam that emanates from the transmitting terminal to be pointed toward the receiving terminal with sufficient accuracy. This is necessary in order to meet the required link power budget.

An architecture that depicts ground-to-satellite optical links that are connected to satellite network and then satellite-to-ground optical links is illustrated in Figure 12.

optical space-based communication offers high-data rate, large capacity, minimized interference risk with other communication systems, and efficient utilization of frequency resources .

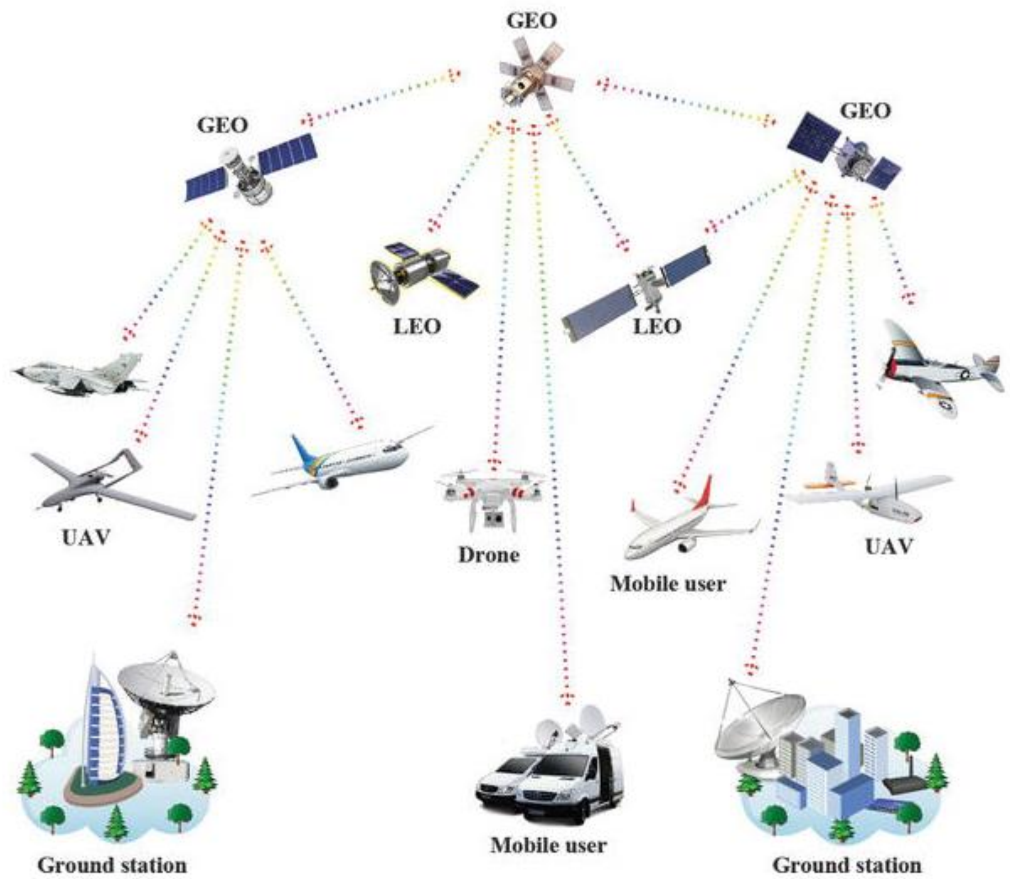

Fig 14 : Optical Space Communication

5.4.2 : Challenges in Space Optical Communication

Consequently, the uplink/downlink transmissions suffer from losses such as atmospheric scintillation, beam divergence, absorption, scattering, misalignment, cloud blockage, background noise and angle-of-arrival fluctuations.

Furthermore, the intersatellite FSO links are insusceptible to weather conditions due to the fact that the satellite orbits are at a considerable distance over the atmosphere.

5.5 : Terrestrial free-space optical (FSO) communications

There have been much more research effort in terrestrial FSO partly because of some successful field trials and commercial deployments. Figure 12 shows a scenario for FSO system deployment as a universal platform for a nippy as well as an efficient ubiquitous wireless service provision for the future broadband access networks. The significant attentions being attracted by the FSO systems are primarily due to their inherent advantages such as cost-effectiveness, lower power consumption (high-energy-efficiency-green communication), ease of deployment, higher bandwidth/capacity, more compact/low-mass equipment, reduced time-to-market, immunity to EMI, high degree of security against eavesdropping, license-free operation, as well as better protection against interference, compared with the traditional RF communication systems.

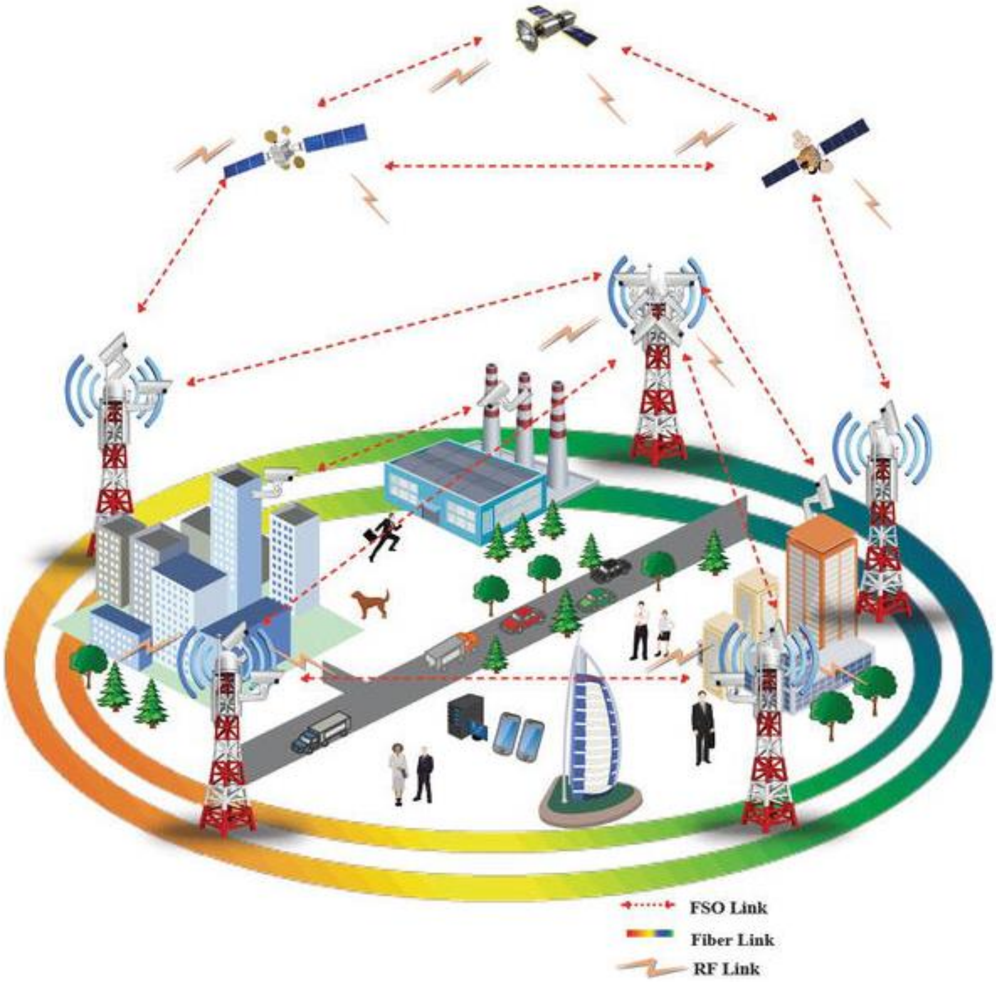

Fig 15 : Terrestrial free-space optical (FSO) communication System

5.5.1 : Feature of Terrestrial free-space optical (FSO) communication System

These salient features make FSO communication systems very appealing for a variety of applications in disaster recovery, radio astronomy, remote-sensing/surveillance/monitoring, metropolitan area network extension, high-definition TV transmission, sharing of medical imaging in real time, and fronthaul and backhaul for wireless cellular networks. Moreover, apart from being used for establishing terrestrial links, they are applicable for launching high-speed interplanetary space links such as intersatellite/deep space and ground-to-satellite/satellite-to-ground links.

In spite of the advantages of FSO communication and diverse application, its extensive use is hindered by some challenges in real-life scenarios. For instance, the FSO links are susceptible to scattering caused by adverse weather conditions like snow, rain, and fog . Moreover, building sway caused by factors such as thermal expansion, wind loads, and weak earthquakes also impairs the FSO link performance.

The system performance is impeded as a result of atmospheric effects which cause loss of spatial coherence, beam spreading, and temporal irradiance fluctuation known as scintillation or fading.

Section VI

6 : Conclusion

In this proposed paper we take the briefly view of the optical wireless communication technology.We see the features of this technology and why we prefer it over the RF technology.In the next decade we will see the implementation of this technology in our daily lives.The optical wireless communication will not only connect the people's it will also provide benefits in other aspects of life like Health monitoring,Path maping etc.In this paper I provide the briefly application of optical wireless technology.And discuss its principle of working.Different modulation techniques are used in this technology like baseband,multicarrier and multicolor modulations which we discuss it in this paper.

The key challenges that we are facing in this optical wireless technology are also discussed in this proposed paper .We also provide some solutions for handling these challenges.there are different application of this technology in different areas of life .We discuss it briefly.We also see the advantages and disadvantages of this technology.So we concluded that optical wireless communication is upcoming giant industry that will changes the way of human living without wires.

Section VII

7 : References

[1] "Optical Wireless Communication Systems, A Survey "

Osama Alsulami,Ahmed Taha Hussein, Mohammed T. Alresheedi and Jaafar M. H. Elmirghani School of Electronic and Electrical Engineering, University of Leeds, LS2 9JT, United Kingdom and Department of Electrical Engineering, King Saud University, Riyadh, Kingdom of Saudi Arabia , 20 January 2019

[2] " Optical wireless communications and potential applications in space"

Dominic O'Brien,Department of Engineering Science ,University of Oxford Parks Road, Oxford OX1 3PJ United Kingdom ,12 october 2019

[3] "Optical wireless communication"

Harald Haas,Jaafar Elmirghani and Ian White

School of Engineering, LiFi Research and Development Centre,

Institute for Digital Communications, University of Edinburgh,

Edinburgh EH9 3JL, UK ,17 juanuary 2020

[4] "Challenges and Opportunities of Optical Wireless Communication Technologies" By Isiaka Alimi, Ali Shahpari, Artur Sousa, Ricardo Ferreira, Paulo Monteiro and António Teixeira, Published date August 9th 2020