Survey on Optical technologies used for Communication

[1,5]Shivmanmeet Singh, [2]Harmandeep Kaur, [3,5]Lakhveer Singh, [4,5]Rehan Dhir [6]Ajay Vasishth

[1]*Department of Electronics and Communication Engineering, Guru Nanak Dev Engineering College, Ludhiana, India*

[2]*Department of Computer Application, Guru Nanak Dev Engineering College, Ludhiana, India*

[3]*Department of Mechanical and Production Engineering, Guru Nanak Dev Engineering College, Ludhiana, India*

[4]*Department of Mechanical Engineering, Guru Nanak Dev Engineering College, Ludhiana, India*

[5]*Center for Multifaceted Learning, Guru Nanak Dev Engineering College, Ludhiana, India*

[6]*Department of Physics, Chandigarh University, Mohali, India*

Email:, shivmanmeet@gmail.com, harmandeepkaur156@gmail.com, lakhveerbathinda@gmail.com, rehan2000.rd@gmail.com, ajay.e8023@cumail.in

Abstract.

Future high data rate fifth Generation mobile networks services will need more frequency transmission, which is now inadequate to do so. A potential answer to the radio frequency spectrum dilemma is optical wireless communication as it can be used on an extremely broad range of unregulated spectrum. In the last ten years, it has drawn increasing scientific attention from all around the globe for both outdoor and indoor applications. OWC offloads applications from radio frequency networks that generate a lot of data. Through OWC, a 100 Gigabit per second data rate has already been demonstrated. Both indoor and outdoor services are available, and communication ranges from a few nm to more than 10,000 km. In this work, optical wireless technologies are reviewed and given a technical overview. We review the most important technologies for comprehending OWC and provide cutting-edge standards. Clarifying the distinctions between many prospective related current radio frequency technologies is the main contribution of this research.

Keywords. Internet of Things (IoT), Electric (E), magnetic (M), and electromagnetic (EM).

1. INTRODUCTION

The latest work in mobility communication is 5G communication. With the superior system capacity, huge interconnections, lowest energy consumption, ultra-high security and exceptionally high experience quality [1]–[6], it will provide novel services. It can be anticipated that 5G communication would use densely branched heterogeneous networks, with a 1000-fold increase in mobile data volume per area and a 100-fold increase the number of wireless devices connected, compared to the number of current wireless networks [1]. Radio frequency (RF) is now an extensively utilised technology in many wireless applications but the spectrum is not enough to support the IoT paradigm and the rising need for 5G wireless bandwidth. It is anticipated that existing wireless technologies will not be able to capture the enormous connectivity requirement of future mobile data traffic because the electromagnetic spectrum, which has advantageous communication properties below 10 GHz, has almost been exhausted by current wireless technologies [12]. In addition, the band (below 10 Gigahertz) includes restrictions such as a band with narrow spectrum, laws governing the usage of the spectrum, and intense RF interference from neighbouring access points. As a result, for wireless communication connection, researchers are exploring new complementing spectrum, such as mm and nm waves [11]. The electromagnetic spectrum's RF band spans a range of frequencies from 3 Kilohertz to 300 Gigahertz. Local and international authorities have severe regulations on the usage of this band. Most of the time, only a few operators, such as point to point television broadcasters, microwave connections and cellular phone companies, are granted full licences for RF sub-bands. Future high density, high-capacity networks are predicted to be developed using the optical spectrum, which is seen as a potential option. Using the optical spectrum, wireless connection is called OWC (OWC). It can provide quality services both indoors and outside. However, OWC systems struggle because of their susceptibility to obstruction blocking and their low transmitted power. Thus, the cohabitation of OWC and RF systems may provide a practical answer to the enormous needs of the impending 5th Generation mobile networks and beyond communication systems.

2. OVERVIEW

2.1. What do OWC Technologies consist of?

Using directed visible light (VL), ultraviolet (UV) or infrared (IR) spectrum as the propagation medium, optical transmission is referred to as OWC. OWC systems that use this band are often referred to as visible light communication systems. VLC can provide lighting and location all at once. IR, UV, and VL frequencies are used for satellite to earth systems. Line of sighting process and non-sighting process is used for optical communication lines thereafter possible working using UV communication.

2.2 Platforms for OWC Applications

Applications for OWC span a broad spectrum [12]. Number of settings where OWC may be used, including business, healthcare, railroad stations, transportation, residences, workplaces, malls, underwater environments, and space.

2.3. OWC for IoT and 5G

Optical Wireless Communication (OWC) has emerged as a viable solution for enabling high data date trans receiver stations [6] to overcome the problem of distance, speed and time. Furthermore, high-capacity backhaul support for 5th Generation mobile networks and beyond communication systems may be efficiently provided via FSO, LiFi, and VLC. OWC technologies use relatively little power, which is essential for 5G [2].

2.4. Classification by OWC

OWC systems can be broadly divided into five groups based on communication range. Ultra-short range OWC: Communications at the nm/mm level take place in this subcategory of

OWC. Nm distance chip to chip communication is an example of this kind of communication. Medium range OWC: This particular communication range includes outdoor V2X communications and WLANs based on VLC. Long-range OWC: This particular range of communication allows for km-range connections, for instance, between buildings. Ultra-long range OWC. This particular communication range includes linkages between satellites, between satellites and the Earth, between satellites and aircraft, between aircraft and other aircraft, and between aircraft and the ground.

3. TECHNOLOGIES USED

The architecture and operating principles of each optical technology (VLC, OCC, LiFi, FSO and LiDAR) are distinct. Additionally, they could vary in terms of communication medium, sending and receiving systems, and modulation techniques. The fundamental structures of the different OWC technologies. As physical transmitters, several OWC devices employ either LDs or LEDs. Physical receivers are PDs, cameras, or ISs, while communication mediums are IR, VL, or UV spectra. This diagram illustrates how the transmitter, receiver, and communication medium of the different OWC systems vary from one another.

3.1. Communication with Visible Light (VLC)

Over the decade, VLC which is a fragment of OWC, has become an encouraging technology. VLC might be crucial in achieving this goal since IoT makes it possible for several devices to be linked for resource sharing, monitoring, and sensing. Compared to RF-based solutions, VLC technology provides 10,000 times larger bandwidth capacity. Significant prospects for applications in homes, workplaces, vehicles, aircraft, trains, and roadways are offered by VLC based on the VL spectrum. Additionally, it does not hurt anyone.

3.2. Light Fidelity (LiFi)

Light Fidelity falls within the category of nm-wave communication. Light Fidelity and Visible Light Communication differ primarily in that Light Fidelity is a bidirectional communication system, whereas VLCS can be either unidirectional [3] or bidirectional [4], (ii) VLCS can be either unidirectional [3] or bidirectional [4], and (iii) Light Fidelity must provide seamless user mobility, whereas mobility support is not required for Visible Light Communication; and (iv) Visible Light Communication systems can be either unidirectional [3] or bidirectional. Thus, Light Fidelity creates a new tiny at to cell layer inside existing heterogeneous wireless networks since it is a full-featured wireless networking system that facilitates smooth user mobility. In light of this, a Visible Light Communication system will only be considered a Light Fidelity system if it contains Light Fidelity capabilities (such as multiuser communication, point-to-multipoint and multipoint-to-point communications, and seamless user mobility). However, a Light Fidelity system may only be considered a Visible Light Communication system when VL is utilised as a transmission medium.

3.3. Communication using optical cameras (OCC)

We are now quite used to having smart gadgets in our daily lives. Majority of these gadgets have front and/or back facing camera/cameras with Light Emitting Diodes flashes. This enables it to build OWC utilising devices in an easier way where the transceiver pair is a flash and a camera. No more hardware modifications are needed for this approach. OWC implementation employing Light Emitting Diodes, screens or other light sources, it might be considered an Optical Camera Communication system. Additionally, when an Optical Camera Communication system employs VL as the communication medium, it may be regarded as a Visible Light Communication.

3.4. Optical Free Space Communication (FSOC)

A subclass of OWC called FSOC [7]-[9] is often operated utilising the Near Infrared channel. Additionally, it can be controlled utilising the UV and VL spectra. The levels of attenuation are lower while employing IR, however. In FSO, illumination is not necessary. Instead of using LEDs for the transmission, FSO often employs LDs. The inputted source information data must be sent to a distant location. The raw data is first encoded. Prior to modulation, channel coding is an optional step. OOK/PM/OFDM modulation is carried out by the modulator. If necessary, an optical amplifier may be utilised to boost the modulated beams of laser power intensity. Light beam is then gathered and can be refocused using beam forming optics prior to transmission [7]. An LD is often used as an optical source in FSO systems [2]. Some manufacturers further use beam collimators and high-power LEDs. In FSO systems, the optical source should be able to supply relatively power for temperature. The optical filters and lens on the receiver front-end gather and concentrate into receiver. The voltage is then created from the PD output current.

3.5. Light Detection and Ranging (LiDAR)

Light Detection and Ranging (LiDAR) is an appealing optical remote sensing technique which helps to determine a target's range and/or other details about it [2], [3]. NIR and VL are often used by LiDAR to image things. The laser installed on an aeroplane, for instance, can be utilised to map topography with a resolution of 300 mm or greater. In order to construct points for 3D mapping, beams of laser are employed to find the characteristics of dispersed light. Similar technologies and concepts are used by LiDAR and RADAR to track the positions and motions of objects, respectively. Each technology functions differently, and each has a different set of applications that it is best suited for. Both technologies employ the energy reflected off the things they are aiming at to infer different information about those items. In contrast to RADAR, LiDAR employs optical light as its source of energy rather than microwaves. The energy in the form of optical light is sent from a transmitter as a signal in both LiDAR and RADAR. An item reflects a little of the energy of the original signal when it gets affected by the transmitted signal. The receiver at the site of the source of energy subsequently receives this reflected energy, which is then used to obtain the object's distance, size and other properties. Additionally, most of these things that can be accurately measured and found using RADAR and LiDAR range are size and makeup.

4. UNRESOLVED PROBLEMS AND PROSPECTIVE RESEARCH LINES

4.1. Hybrid Network Architecture

In particular, optical wireless is a strong contender for delicate applications where RF interference must be minimised. A hybrid network may be useful for load balancing, improving link stability, providing wireless access in far-off locations (such as deep space, ocean and earth conditions), and therefore reducing interference. The researchers were drawn to this problem because of this. Switching from one communication method to another in an adaptable and seamless manner is a key difficulty for hybrid systems.

4.2. High data rate optical backhaul

High capacity backhaul networks are a critical problem for 5G and beyond communications [3]. An interesting area for investigation is optical wireless networks, such as VLC or FSO, which can act as a nice addition to the current wired and wireless backhaul communication.

4.3. UV communication via NLOS and Inter Cell Interference (ICI)

UV communication, a key characteristic of the UV band, allows for high-data-rate NLOS communication. Future study should focus on a thorough evaluation and utilisation of trans receiver geometrical configuration needs. ICI is a concern for dense validation of LED's for LiFi/VLC small cell/attocell design. The optical spectrum may be extended beyond the UV band, which has several advantages thanks to powerful and reasonably priced sources.

4.4. Wireless optical communication underwater

As several applications for oil pipe inquiry, and off-shore investigation have been presented, underwater wireless optical communication has recently gained a lot of interest. Many underwater communication applications need long-distance, fast connectivity.

4.5. Mobility with ease and in vehicle communication

OWC systems are necessary for providing the user mobility. At best, LiFi currently offers seamless connectivity [11]. Thus, researchers are trying to validate vertical handovers [4] in hybrid networks [1]. To maintain smooth connections, it is crucial to have a handover mechanism. This is a difficult problem that has to be thoroughly researched. There is thus a tonne of room to improve air loss mitigation in OWC systems. IEEE 802.11p employs an unlicensed RF spectrum and is also called Wireless Access in Vehicular Environments (WAVE). The OWC system may potentially be used for traffic control.

4.6. OWC for positioning and in drone application

High precision, licence-free operation, lack of electromagnetic interference, affordable frontends, etc., are the main reasons of attention of LED positioning [10]. Also, might be the next big thing in transportation. Numerous problems, including accurate location and dependable drone communication, will emerge from its large-scale deployment. Due to the shortcomings of RF-based technologies, OWC might be a useful supplementary strategy to resolve these problems.

4.7. Red, Green and Blue (RGB) LED-based OCC

[5], [8] OCC employing Red, Green and Blue LEDs and colour cameras (or IS) is a potential method for successful parallel (∥) visible light communications. Numerous scientists are focusing on RGB LEDs to create effective communication technologies.

5. CONCLUSION

The rapid surge in demand for wireless bandwidth for 5th Generation mobile networks and future communications cannot be met by the present RF technology. Visible, infrared and ultraviolet sub-bands of the exceptionally broad optical spectrum may be exploited for wireless networking to enable 5G and IoT. The issues brought on by a lack of spectrum for RF-based wireless communication will be solved by using optical bands in addition to RF. Many applications that presently rely on RF communication are being converted to OWC by researchers. Healthcare, industry, places of public meeting, stadiums, homes, workplaces, transits, retail markets and malls, underwater communication, and space will all significantly benefit from optical wireless technology. We have showcased a broad overview of upcoming OWC technologies in this survey report. To ensure a brighter future, optical wireless technologies are undoubtedly promising. In the coming time, 5G and beyond heterogeneous wireless networks, we anticipate that OWC systems will play a significant complementary role to RF-based technologies, and we believe that this comparative assessment will be a critical asset for further research in these areas.

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