Optical Space Communication: An Introduction and Applications

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Abstract: Optical Space communication (OSC) becomes more and more interesting as an alternative to radio frequency communication since last many years. It is an optical communication technology that uses light propagating in free space to wirelessly transmit data for telecommunications or computer networking. "Free space" means air, outer space or vacuum. This avoids the use of solids such as optical fiber cable or an optical transmission line. The technology is useful where the physical connections are impractical due to high costs or other considerations. In this paper the need of OSC is discussed with brief introduction. The paper also includes the applications and advantages of OSC over OFC (Optical Fiber Communication).

I. INTRODUCTION:

As the world wide demand for high speed Internet is increasing rapid advancements in the field of wireless communication is required. The term "wireless system" was referred to RF communication only due to wide scale implementation of RF devices and systems [1]. But since last decade Optical wireless communication has emerged as a solution to costly and constrained (in terms of capacity) RF system. Both are being used according to requirements as both are having their pros and cons. Optical Space Communication is also known as Free space optical communication (FSO). FSO is gaining popularity by offering higher bandwidth and ease of deployment today. FSO is used due to economic advantages also as light travels through air for a very less money. Free Space Optics (FSO) is a line-of-sight technology that uses lasers to provide optical bandwidth connections. Currently, FSO offers a bandwidth up to 2.5 Gbps for voice, data, and video transfers, whereas in RF it's 622 Mbps. [2]. The main commercial limitation for FSO is that light does not propagate very far in dense fog, which occurs a non-negligible amount of the time. It needs to operate at higher power to travel larger distance [3].

Based on direct connectivity between different FSO units this technology becomes relatively simple. in each Free Space Optics (FSO) unit the beams of light are transmitted by laser light focused on highly sensitive photon detector receivers to provide bi –directional/full duplex capability . These receivers are telescopic lenses able to collect the photon stream and transmit digital data containing a mix of Internet messages, video images, radio signals or computer files. Figure 1 shows block diagram for FSO. These transmissions will not experience interference from radio frequencies and this type of communication does not require an RF license.

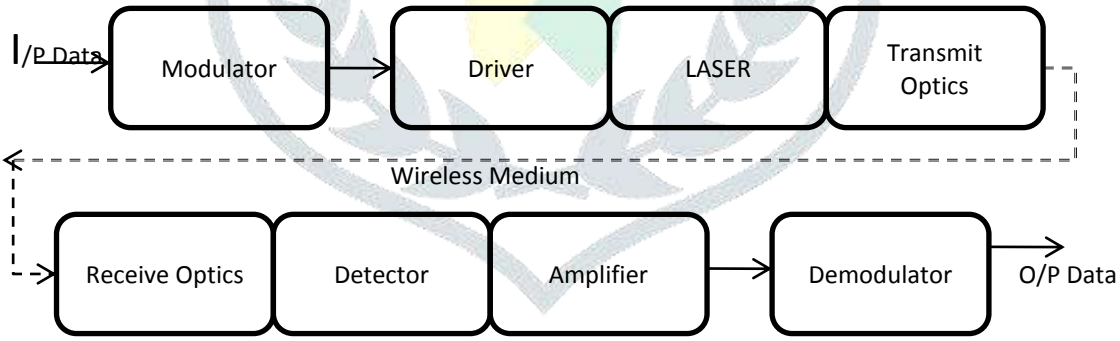

Fig. 1: Block diagram of FSO

Free Space Optics (FSO) communication is possible over distances of several kilometres as long as there is a clear line of sight between the source and the destination. FSO is easily upgradeable, and its open interfaces support equipment from a variety of vendors, which helps service providers to protect their investment in embedded telecommunications infrastructures.

Free Space Optics (FSO) transmits invisible, eye - safe light beams from one "telescope" to other using low power infrared lasers in the terahertz spectrum. Commercially available systems offer capacities in the range of 100 Mbps to 2.5 Gbps, and demonstration systems report data rates as high as 160 Gbps.

II. NEED OF FSO:

The demand for higher bandwidth is increasing exponentially in metro networks is incessant. Pursuit of a range of applications, including metro network extension, enterprise LAN-to-LAN connectivity, wireless backhaul and LMDS supplement has created an imbalance. This imbalance is often referred to as the "last milebottleneck." Service providers are faced with the need to provide services quickly and cost-effectively at a time when capital expenditures are constrained. But the last mile bottleneck is only part of a larger problem. Similar issues exist in other parts of the metro networks. "Connectivity bottleneck" better addresses the core dilemma. The connectivity bottleneck is everywhere in

metro networks. From a technology standpoint, there are several options to address this "connectivity bottleneck," but most don't make economic sense. Firstly, the most obvious choice is fiber-optic cable. Without a doubt, fiber is the most reliable means of providing optical communications. But the digging, delays and associated costs to lay fiber often make it economically prohibitive. Second option is the radio frequency (RF) technology. RF is a mature technology that offers longer ranges than FSO, but RF-based networks require immense capital investments to acquire spectrum license. RF technologies cannot scale and the bandwidth is limited to 622 megabits. The third alternative is wire- and copper-based technologies, (i.e. cable modem, DSL etc.). Although copper infrastructure is available almost everywhere and the percentage of buildings connected to copper is much higher than fiber, it is still not a viable alternative for solving the connectivity bottleneck. The biggest hurdle is bandwidth scalability. Copper technologies may ease some short-term pain, but the bandwidth limitations of 2 megabits to 3 megabits make them a marginal solution, even on a good day. Fourth and finally, the most viable-alternative is FSO. The technology facilitates an optimal solution, bandwidth scalability, speed of deployment (hours versus weeks or months), redeployment and portability, and cost-effectiveness (on average, one-fifth the cost of installing fiber-optic cable). [4]

III. APPLICATIONS, ADVANTAGES AND DISADVANTAGES

Free-Space Optics has many applications in communication because it serves as the best last mile option between the network core and the network edge: [4]

a) For RF communication service providers require licence to use spectrum whereas FSO doesn't need any licence.
b) To provide cost effective last mile access is always a challenge for service providers, FSO can be utilised to solve such problems by implementing with other networks. As the implementation of FSO is very easy, it is the best choice for interconnecting different LANs to connect buildings [5] .
c) FSO is a good solution to provide backup link [5].
d) It can be used for extension of fiber rings of metropolitan area , completion of SONET rings [5].
e) FSo can be used in cellular network to increase the speed of transmission between antenna tower and PSTN
f) As FSO is secure and easy to deploy with minimum planning, it is highly suitable for military use.
g) It provides high speed point to point and point to multipoint links [6].
h) As FSO is secure, easy and quick to deploy suitable for military applications [7].

ADVANTAGES:

a) FSO provides better speed than broadband networks.
b) It requires very low initial budget [5].
c) Very easy to deploy and take s30 minutes to install at normal places.
d) No need to acquire spectrum licence or frequency reuse concepts [8] .
e) It is very secure and power efficient system.
f) Immunity to Electromagnetic interference [9].
g) Provides high bandwidth.
h) As the medium is air, transmission is at the speed of light [10].
i) Lower BER and high SNR
j) Allows two way flow of information

DISADVANTAGES/LIMITATIONS: As the signal travels through the air, some environmental challenges and limitations are inevitable. Fig. 1 shows effect of different atmospheric conditions over FSO.

a) High maintenance cost as compared to OFC
b) Preferable for point to point communication only.
c) Expensive optical transmitter and receivers.
d) Transmission rate is weather dependent
e) Physical obstructions like tall buildings can block a single beam, as FSO requires line of sight (LOS) for transmission
f) The photons power is absorbed by water molecules in terrestrial atmosphere which cause attenuation.
g) Atmospheric turbulence causes fluctuations in the density of air and it changes the air refractive index which causes problem for transmission.
h) Rain, fog, smoke, cloud, snow also attenuates the optical signal, which is the major disadvantage of FSO [11].
i) Safety against the lasers used for transmission, and high voltages within the laser systems and their power supplies is a major concern. Exposure to laser beams causes much more harm to the eyes than any other part of the human body. Standards have been set for laser safety and performance. Light Pointe's FSO systems comply with these standards [4].

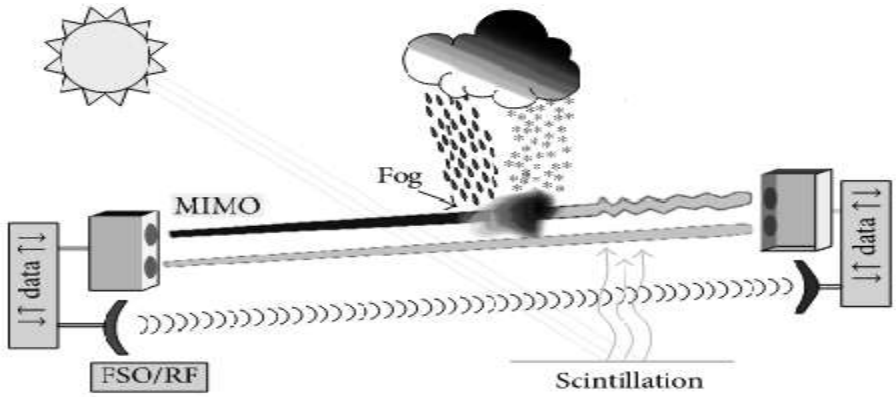

Fig. 2: Atmospheric effects on FSO system [1].

IV. WORKING OF FSO:

Since last decade there has been massive expansion in FSO due to tremendous technology advancement in opto-electronics devices. FSO transmits voice, video, and data in form of optical signal using air as the medium, so the main difference between OFC and FSO is the medium. It requires connectivity between FSO based optical transceiver units with a transmitter and a receiver to provide full duplex connectivity. FSO system uses high power optical LASER as a source and a telescope to transmit light through air to receiving end telescope. At receiver side telescope is connected to high sensitivity optical receiver via optical fiber cable. The transmitter and receiver should be in line of sight of each other.

V. COMPARISON OF FSO , OFC AND RF:

FSO system has several advantages over OFC and RF communication. Table 1 shows comparison between FSO, OFC and RF for various parameters.

Table 1: Comparison of FSO over OFC and RF [3]

Parameter	FSO	Fiber	RF
Cost	Less	Moderate	High
Security	Moderate	High	High
Installation	Easy	Difficult	Easy
Latency	Less	Moderate	High
Distance	Last mile solution	Long	Long/Short
Transmission Speed	Gbps	Gbps	Mbps
Spectrum Licence	Not Required	Required	Required
Noise/Interferance	Weather	Atmospheric conditions	Electromagnetic Interference

VI. CONCLUSION:

The use of light is a simple concept similar to optical transmissions using fiber-optic cables; the only difference is the medium. Light travels through air faster than it does through glass, so it is fair to classify FSO technology as optical communications at the speed of light. In this paper importance of FSO communication is presented. light travels through air for a very less money. Hence, FSO is used due to economic advantages. The technology is useful where the physical connections are impractical due to high costs or other considerations. FSO provides licence free secured communication at Lower BER over the long range communications. light does not propagate very far in dense fog, which occurs a non-negligible amount of the time, which is the main limitation of FSO communication.

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