Volume 1, Issue 1, January 2014 ISSN: 2348-8565 (Online)
International Journal of Modern Engineering and Research Technology
Website: http://www.ijmert.org Email: editor.ijmert@gmail.com

Study of Exploration of Optical Wireless Connectivity in Free Space Domain

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Abstract

This paper deals with communication through optics using one of the latest wireless technologies called the Free Space Optics (FSO). FSO may sound new and experimental but in fact it predates optical fiber and has its roots in wartime efforts to develop secure communication systems that did not require cable and could withstand radio jamming. FSO has been around for more than a decade, but it is only recently that interest in this technology has started to grow. Typical gains and losses along the path from the transmitter through the medium, to the receiver are introduced in this paper.

Free-space optics (FSO) is a line-of-sight technology that uses lasers to provide optical bandwidth connections that can send and receive voice, video, and data information on invisible beams of light. Today, FSO technology — the foundation of Cable Free's optical wireless offering — has enabled the development of a new category of products that can transmit voice, data, and video at bandwidths up to 2.5 Gbps at distances up to 4 km, over any protocol. This optical connectivity doesn't require expensive fiber-optic cable or securing spectrum licenses. FSO technology requires light, which can be focused by using either light emitting diodes (LEDs) or light amplification by stimulated emission of radiation (LASER). Light travels through air faster than it does through glass, so it is fair to classify Free Space Optical technology as optical communications at the speed of light.

FSO could also be the solution for high speed residential access. Though this technology sprang into being, its applications are wide and many. It indeed is the technology of the future.

Keywords:*—*FSO , WDM, FCC

I. Introduction

FSO: Optical or Wireless?

Speed of fiber — flexibility of wireless. Optical wireless, based on FSO-technology, is an optical technology that provides the speed of fiber, with the flexibility of wireless. It enables optical transmission at speeds of up to 2.5 Gbps and, in the future, 10 Gbps using WDM. This is not possible with any fixed wireless/RF technology today. Optical wireless also obviates the need to buy expensive spectrum (it requires no FCC or municipal license approvals), which further distinguishes it from fixed wireless technologies. Moreover, its narrow beam transmission is typically two meters versus 20 meters and more for traditional, even newer radio-based technologies such as millimeter-wave radio.

Optical wireless products' similarities with conventional optical solutions enable the seamless integration of access networks with optical core networks and helps to realize the vision of an all-optical network.[1]

FSO is an optical communication n technology that uses light propagating in free space to transmit data for telecommunication or computer networking. "Free space" means air, outer space, vacuum, or something similar. This contrasts with using 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. FSO systems (in space and inside the atmosphere) have developed in response to a growing need for high-speed and tap-proof communication systems.[7] Furthermore, long-haul optical links through the atmosphere suffer from strong fading as a result of index-of-refraction turbulence (IRT) and link blockage by obscuration such as clouds, snow and rain.

II. WORKING PRINCIPLE OF FSO

Free Space Optics (FSO) transmits invisible, eye-safe light beams from one "telescope" to another using low power infrared lasers in the terahertz spectrum. The beams of light in Free Space Optics (FSO) systems are transmitted by laser light focused on highly sensitive photon detector receivers. [2]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. 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. Free Space Optics (FSO) systems can function over distances of several kilometers. As long as there is a clear line of sight between the source and the destination, and enough transmitter power, Free Space Optics (FSO) communication is possible.

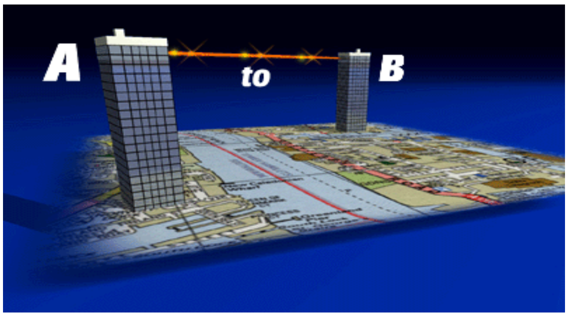

Figure 1. Principle of FSO

2.1 Network Architecture of FSO

A common configuration involves a central hub, or node, positioned on the roof of a high rise building with good lookdown for achieving line of sight to buildings of lesser stature within the coverage area. [4] The hub building can be connected to service provider's backbone via FSO or point-to-point microwave. Transceiver can be located on a rooftop, on a corner of building or indoors behind a window.

Figure 2. Architecture of FSO

III. ADVANTAGES OF FSO

There are many advantages to free space optic. Among these are the lower costs associated with the system. There are no fiber optic cables to lay, no expensive rooftop installations required, and no security upgrades necessary. In addition, the system upgrades are generally made quite easily and no RF license is required. Another advantage of free space optical communication is that it is incredibly fast. These systems can currently transmit a large amount of data, 1.25 GB per second. In the future it is expected that this will increase to a whopping 10 GB per second. This speed is due to the fact that the signals can be transmitted through the air faster than they can be transmitted through fiber optic cables. The signals are sent from one wireless unit to another in a direct line through the atmosphere. Yet another benefit of free space optics is that there is no interference of the signal by radio frequencies. This means fewer disruptions to the information flow.[3]

3.1 Technological Advantages Of FSO

1. FSO is protocol independent and transmits any higher-layer protocol including Ethernet,SDH,ATM and TCP/IP.
2. FSO is unaffected by (EMI) Electro-Magnetic interference.This is a great advantage when compared with Radio Frequency systems,which definitely suffer from EMI.
3. Since FSO transceiver can transmit and receive through glass windows,it is possible to mount Free Space Optical systems inside buildings,reducing the need to compete for roof space.
4. FSO technology is highly secured as laser beam generated by FSO systems are narrow and invisible, making them harder to find and even harder to intercept and crack as well as data can be transmitted over an encrypted connection adding to the degree of security available in FSO network transmission.
5. There is no need to dig trenches to lay cable,the permits associated with digging up streets,disrupting traffic and installation normally is complete in a few days.

IV. Applications of FSO

Free-Space Optics has several applications in Telecom Networks where an optical gap exists between the network core and the network edge. FSO delivers cost-effective optical connectivity and faster returns on investment for enterprises and service providers. The number of FSO uses in Telecom Networks and beyond continues to grow as high-bandwidth demands and the need for economically viable optical solutions outpace the deployment of fiber-optic cable. FSO has moved from niche to mainstream:

Telecom Network Extensions: FSO can be deployed to extend an existing metro ring or to connect new networks. These links generally do not reach the ultimate end user, but are more an application for the core of the network.

Enterprise: The Flexibility of FSO allows it to be deployed in many enterprise applications such as LAN to LAN connectivity, Storage Area Networks, and intra-campus connections.

Last-mile connectivity: These are the links that reach the end user. They can deployed in point-to-point, point-to-multipoint, ring or mesh connections. Fiber deployment in urban areas could cost $300,000-$700,000 given the costs involved in digging tunnels and obtaining rights-of-way. By contrast, a short FSO link of 155 Mbps might cost only $15,000-$18,000.

Fiber Complement: FSO may also be deployed as a redundant link to back up fiber. Most operators deploying fiber for business applications connect two fibers to secure a reliable service plus backup in the event of outage. Instead of deploying two fiber links, operators could opt to deploy an FSO system as the redundant link.

Access: FSO can also be deployed in access applications such as gigabit Ethernet access. Service providers can use FSO to provide high capacity links to businesses.

Backhaul: FSO can be used for backhaul such as LMDS or cellular backhaul as well as gigabit Ethernet "off-net" to transport network backhaul.

With the advent of VOIP (Voice Over IP), videoconferencing and streaming, new high bandwidth applications,bandwidth requirements for all aspects of the network are constantly increasing Technologically much less challenging are data links between metropolitan buildings (LAN-to-LAN connections), where a free-space data link over distances of hundreds of meters or even over a few kilometers can be much simple and cost-effective to install than any kind of cable,FSO can be used in highspeed links that connect end -users with Internet service providers or other networks[8]. It can also be used to bypass local -loop systems to provide businesses with high-speed connections. FSO can be also used to provide instant service to fiber-optic customers while their fiber infrastructure is being laid. FSO can be used to carry cellular telephone traffic from antenna towers back to facilities wired into the public switched telephone network. It is possible to transmit tens of M bit/s or more over many thousands of kilometers, using moderate laser average powers of the order of a few watts. One can also transmit data between a more remote spacecraft and a station on or near earth. If the spacecraft has a pulsed laser source and an optical telescope of moderate size targeting the receiver it can greatly expand the transmission capacity to hundreds of k bit/s or even several Mbit/s[5]

4.1. Typically scenarios for use are:

- LAN-to-LAN connections on campuses at Fast Ethernet or Gigabit Ethernet speeds
- LAN-to-LAN connections in a cit, a metropolitan area network
- To cross a public road or other barriers which the sender and receiver do not own
- Speedy service delivery of high-bandwidth access to optical fiber networks
- Converged Voice-Data-Connection
- Temporary network installation (for events or other purposes)
- Reestablish high-speed connection quickly (disaster recover)
- As an alternative or upgrade add-on to existing wireless technologies
- As a safety add-on for important fiber connections (redundancy)

V. FSO CHALLENGES

Optical wireless systems are not without challenges. The fundamental limitation of free space optical communications arises from the environment through which it propagates.Although relatively unaffected by rain and snow,free space optical communication systems can be severely affected by fog and atmospheric turbulence. The main design challenges in free space optical communications are as follows:

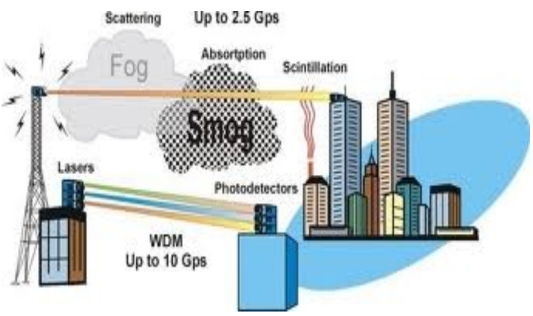

Figure 3. FSO challenges

5.1 Fog

The main challenge is fog. Fog is vapor composed of water droplets, which are only a few hundred microns in diameter but can modify light characteristics or completely hinder the passage of light through a combination of absorption, scattering, and reflection. This can lead to a decrease in the power density of the transmitted beam, decreasing the effective distance of a free space optical link.

5.2 Scintillation

Scintillation is the spatial variation in light intensity caused by atmospheric turbulence. Such turbulence is caused by wind and temperature gradients that create pockets of air with rapidly varying densities and, therefore, fast-changing indices of optical reflection. These air pockets act like lenses with time-varying properties and can lead to sharp increases in the bit-errorrates of free space optical communication systems, particularly in the presence of direct sunlight.

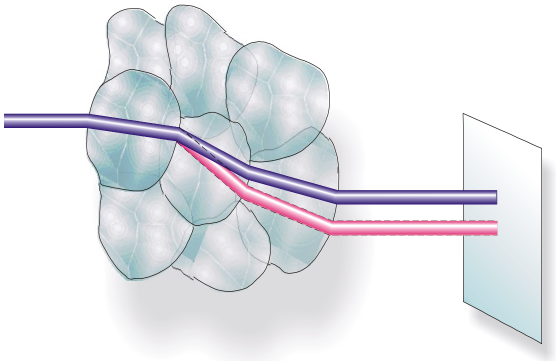

Figure 4. Scintillation

5.3 Beam Wander

Beam wander arises when turbulent wind current (eddies) larger than the diameter of the transmitted optical beam cause a slow, but significant, displacement of the transmitted beam. Beam wander may also be the result of seismic activity that causes a relative displacement between the position of the transmitting laser and receiving photodetector .

5.4 Physical Obstruction

Since light can't penetrate trees,hills or buildings or any physical obstruction.As the clear line of sight is an absolute requirement between the light transmitter and the receiver for FSO so any physical obstruction will completely absorb, deflect, reflect and otherwise render the signal useless.

VI. SOLUTION TO CHALLENGES

These factors cause an attenuated receiver signal and lead to higher bit error rati (BER). To overcome these issues, vendors found some solutions, like multi-beam or multi-path architectures, which use more than one sender and more than one receiver. Some state-of-the-art devices also have larger fade margi (extra power, reserved for rain, smog, fog). To keep an eye-safe environment, good FSO systems have a limited laser power density. Multiple laser beams are used.[6]

Automated power control, and calculated laser beam divergence are used. Pulsed laser beams start out just centimeters wide and can diverge to 1 meter or more over typical link distances—like using a really big bullet to hit a small target. FSO linkheads essentially "talk" to one another, and just as people repeat words in conversation, data can be retransmitted in the event of a temporary beam blockage.

VII. CONCLUSION

The future will require higher and higher bandwidth solutions to meet the needs of corporations and individuals. Cost effective alternatives need to be found to augment the legacy WAN technologies in providing secure, redundant links between corporate resources, the Internet and the telephone company carriers. Free-Space Optics can meet these needs and will be used in an ever-increasing way to provide these solutions in the future. FSO systems offer a viable solution toward building optical connectivity in a cost-effective, quick, and reliable manner in certain situations With its cost effective and high bandwidth qualities. optical wireless operating in the near infrared wavelength range is an alternative transport technology to interconnect high capacity networking segments. Optical wireless communication systems are among the most secure networking transmission technologies It is extremely difficult to intercept the optical wireless light beam carrying networking data because the information is not spread out in space but rather kept in a very narrow cone of light.[4]

Nevertheless, challenges remain. The main problems of FSO links working outdoors in the atmosphere result from attenuation and fluctuation of optical signal at a receiver. To improve reliability, a number of new methods are being applied. For example, a hybrid FSO/ RF system increases link availability by overcoming attenuation effects. RF transmission is affected more by rain and optical transmission is affected more by fog. Further, error protection schemes able to deal with the slow fading typical for FSO links are currently under development. After considering all its advantages and disadvantages it is clear that FSO has good prospects for widespread implementation. FSO technology is ready for utilization as terrestrial links, mobile links and satellite links.

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