International Journal of Engineering, Management, Humanities and Social Sciences Paradigms (IJEMHS)
(Vol. 02, Issue 01, December 2013)
ISSN: 2347 - 601X
www.ijemhs.com

Development in the Field of Optical Fiber Communication Systems: A Review

Pulkit Berwal

Electronics and Communication Department
pulkit.berwal123@gmail.com

Abstract

This paper presents a review of the latest research and development in the field of optical fiber communication system. Remarkable developments are observed over the past decade. Wide-bandwidth signal transmission with low latency is emerging as a key requirement in a number of applications, including the development of future exaflopscale supercomputers, financial algorithmic trading and cloud computing. Optical fibers provide unsurpassed transmission bandwidth, Optical fiber is now the transmission medium of' choice for long distance and high bit rate transmission in telecommunications networks.

Keywords: *Applications, bandwidth, fiber optic, multiplexing, transmission and telecommunications networks.*

1. Introduction

Now we are in the twenty first century, the era of ‘Information technology’ [1-6]. There is no doubt that information technology has had an exponential growth through the modern telecommunication systems. Particularly, optical fiber communication plays a vital role in the development of high quality and high-speed telecommunication systems. Today, optical fibers are not only used in telecommunication links but also used in the Internet and local area networks (LAN) to achieve high signaling rates. The Optical fiber communications have changed our lives in many ways over the last four decades there is no doubt that low-loss optical transmission fibers have been critical to the enormous success of optical communications technology. There is no doubt that low loss optical transmission fibers have been critical to the enormous success of optical communications technology. In the telecommunication sector, the so-called passive optical network was proposed for the already envisioned fiber-to-the-home (FTTH) network. This network relied heavily on the use of passive optical splitters. These splitters were fabricated from standard single-mode fibers (SMFs). Although FTTH, at a large scale, did not occur until decades later, research into the use of components for telecommunications applications continued. The commercial introduction of the fiber optic amplifier in the early 1990s revolutionized optical fiber transmissions. With amplification, optical signals could travel hundreds of kilometres without regeneration [1].

The performance of any communication system is ultimately limited by the signal-to-noise ratio (SNR) of the received signal and available bandwidth. This limitation cans be stated more formally by using the concept of *channel capacity* introduced within the framework of information theory [2]. Optical underwater Communication is an effective alternative to current underwater technology especially in some particular environments such as shallow, coastal and fresh inland water where the use of this approach is useful to overcome all the shortcomings related to the use of acoustic communication and to allow a wide adoption of underwater monitoring systems [3]. Both the transmission capacity and flexibility in optical network design can significantly be improved using wavelength division multiplexing (WDM) systems [4]. Due to economic advantages, maturing technology, and high information capacity, single-mode fiber- optic transmission media will be embedded in future telecommunications networks. A desirable feature for these future optical networks would be the ability to process information directly in the optical domain for purposes of multiplexing, demultiplexing, filtering, amplification, and correlation. Optical signal processing would be advantageous because potentially it can be much faster than electrical signal photon-electron-photon conversions. Several new classes of optical networks are now emerging [5]. For example, code-division multiple access (CDMA) networks using optical signal processing techniques were recently introduced [6]-[13]. The optical fibers, widespread and commonly used in telecommunications, are the transmission medium that have been recently considered as very attractive to build links for T/Transfer [14], offering much better performance compared with the satellite links. This is because of unsurpassed propagation symmetry in both directions that is displayed by the optical fibers. A number of projects are devoted to applying the optical fibers to transmit either the light modulated by the electrical signals from an atomic clock [15]–[20] or a highly coherent optical carrier generated by the optical standard [21]–

[23].Throughout the world, serious efforts are undertaken to setup the fiber-optic networks on an international scale dedicated to comparison of distant clocks and dissemination of the T/Signals. The paper is organized as follows. Section II deals with Evolution of Fiber Optics. Section III, describes Optical fiber. Section IV Presents Review of Development in Fiber Optic Communication and finally the Conclusions and Discussion are given in section V.

2. Evolution of Fiber Optics

To guide light in a waveguide, initially metallic and non-metallic wave guides were fabricated. But they have enormous losses. So they were not suitable for telecommunication. Tyndall discovered that through optical fibers, light could be transmitted by the phenomenon of total internal reflection. During 1950s, the optical fibers with large diameters of about 1 or 2 millimetre were used in endoscopes to see the inner parts of the human body. Optical fibers can provide a much more reliable and versatile optical channel than the atmosphere, Kao and Hockham published a paper about the optical fiber communication system in 1966. But the fibers produced an enormous loss of 1000 dB/km. But in the atmosphere, there is a loss of few dB/km. Immediately Kao and his fellow workers realized that these high losses were a result of impurities in the fiber material. Using a pure silica fiber these losses were reduced to 20 dB/km in 1970 by Kapron, Keck and Maurer. At this attenuation loss, repeater spacing for optical fiber links become comparable to those of copper cable systems. Thus the optical fiber communication system became an engineering reality. The research phase of fiber-optic communication systems started around 1975. The first generation of light wave systems operated near 0.8 μm and used GaAs semiconductor lasers. After several field trials during the period 1977–79, such systems became available commercially in 1980 [24]. They operated at a bit rate of 45 Mb/sand allowed repeater spacing of up to 10 km. The larger repeater spacing compared with 1-km spacing of coaxial systems was an important motivation for system designers because it decreased the installation and maintenance costs associated with each repeater. The second-generation of fiber-optic communication systems became available in the early 1980s,but the bit rate of early systems was limited to below 100 Mb/s because of dispersion in multimode fibers [25]. This limitation was overcome by the use of *single-mode* fibers. A laboratory experiment in 1981 demonstrated transmission at 2 Gb/s over 44 km of single-mode fiber [15]. The introduction of commercial systems soon followed. By1987, second-generation light wave systems, operating at bit rates of up to 1.7 Gb/s with a repeater spacing of about 50 km, were commercially available. Third-generation light wave systems operating at 2.5 Gb/s became available commercially in 1990. Such systems are capable of operating at a bit rate of up to 10 Gb/s [26]. The best performance is achieved using dispersion shifted fibers in combination with lasers oscillating in a single longitudinal mode. A drawback of third-generation 1.55-μm systems is that the signal is regenerated periodically by using electronic repeaters spaced apart typically by 60–70 km. The fourth generation of light wave systems makes use of *optical amplification* for increasing the repeater spacing and of *wavelength division multiplexing* (WDM) for increasing the bit rate. By 1996, not only transmission over 11,300 km at a bit rate of 5 Gb/s had been demonstrated by using actual submarine cables [27], but commercial transatlantic and transpacific cable systems also became available. The fifth generation of fiber-optic communication systems is concerned with extending the wavelength range over which a WDM system can operate simultaneously. The conventional wavelength window, known as the C band, covers the wavelength range 1.53–1.57μm. It is being extended on both the long- and short-wavelength sides, resulting in the L and S bands, respectively. The Raman amplification technique can be used for signals in all three wavelength bands. Moreover, a new kind of fiber, known as the *dry fiber* has been developed with the property that fiber losses are small over the entire wavelength region extending from 1.30 to 1.65 μm [28].

3. Optical Fiber

Optical fiber cable use smooth, hair thin strands of glass or plastic to transmit data as a pulse of light and the cable is about the diameter of a human hair. [2] A fiber optic cable is made up of three main sections. They are the core, cladding, and buffer. This is show in Figure 1. The core is at the middle of the cable and it is made up of silica. It functions as the light transmitting section of the fiber and act as a boundary layer for the cable. Next is the cladding. The cladding is made up of pure silica and it act like a guide for the light waves to travel down the cable. This component is very important because light moves in waves and will shoot out of the core if this component is not present. This cladding will eventually reflect back into the core. As for buffer, it is at the middle of these three layers. It is made up of acrylic polymer. This buffer layer protects cladding and core against ultraviolet light and gives the cable rigidity.

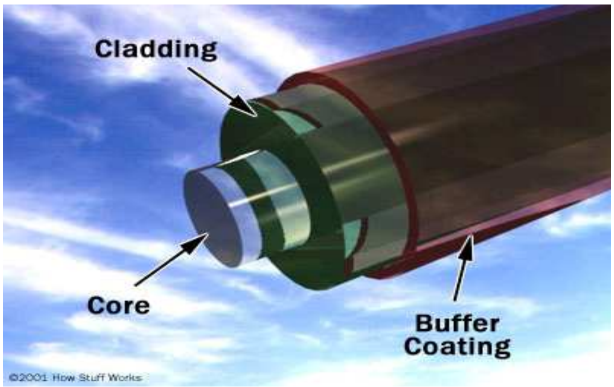

Figure 1: Three main sections of fiber optic cable.

Fiber optics is a medium for carrying information from one point to another in the form of light. Unlike the copper form of transmission, fiber optics is not electrical in nature. A basic fiber optic system consists of transmitting device that converts an electrical signal into a light signal, an optical fiber cable that carries the light, and a receiver that accepts the light signal and converts it back into an electrical signal. The complexity of a fiber optic system can range from very simple (i.e., local area network) to extremely sophisticated and expensive (i.e., long distance telephone or cable television trucking). For example, the system shown in Figure 1 could be built very inexpensively using a visible LED, plastic fiber, a silicon photo detector, and some simple electronic circuitry.

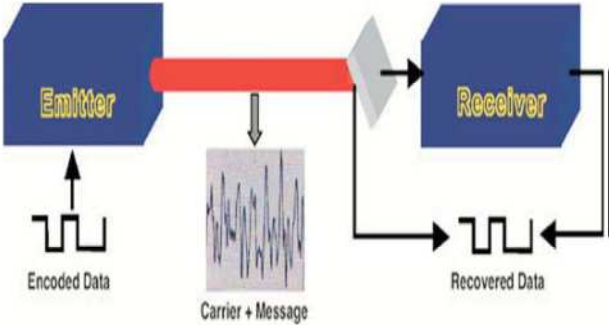

Figure 2: Basic fiber optic communication system [29]

We can categorize the fiber optic communication in two categories:

1. Step Index

a. Single Mode

b. Multimode

2. Guided Index

Step Index:

These types of fibers have sharp boundaries between the core and cladding, with clearly defined indices of refraction. The entire core uses single index of refraction.

Single Mode Step Index:

Single mode fiber has a core diameter of 8 to 9 microns, which only allows one light path or mode.

Multimode Step-Index Fiber:

Multimode fiber has a core diameter of 50 or 62.5 microns (sometimes even larger). It allows several light paths or modes.

This causes modal dispersion – some modes take longer to pass through the fiber than others because they travel a longer distance.

Multimode Graded-Index Fiber

Graded-index refers to the fact that the refractive index of the core gradually decreases farther from the centre of the core. The increased refraction in the centre of the core slows the speed of some light rays, allowing all the light rays to reach the receiving end at approximately the same time, reducing dispersion.

Advantage of Optical Fiber Communication:

a) Enormous potential bandwidth: The optical carrier frequency has a far greater potential transmission BW than metallic cable systems.

b) Small size and weight: Optical fiber has small diameters. Hence, even when such fibers are covered with protective coating they are far smaller and lighter than corresponding copper cables.

c) Electrical Isolation: Optical fibers which are fabricated from glass or sometimes a plastic polymer are electrical insulators and unlike their metallic counterpart, they do not exhibit earth loop or interface problems. This property makes optical fiber transmission ideally suited for communication in electrically hazardous environments as fiber created no arcing or spark hazard at abrasion or short circuits.

d) Signal security: The light from optical fiber does not radiate significantly and therefore they provide a high degree of signal security. This feature is attractive for military, banking and general data transmission i.e. computer networks application.

e) Low transmission loss: The technological developments in optical fiber over last twenty years has resulted in optical cables which exhibits very low attenuation or transmission loss in comparison with best copper conductors.

f) Potential low cost: The glass which provides the optical fiber transmission medium is made from sand. So, in comparison to copper conductors, optical fiber offers the potential for low cost line communication.

Disadvantage of Optical Fiber Communication:

a) It requires a higher initial cost in installation

b) Although the fiber cost is low, the connector and interfacing between the fiber optic costs a lot.

c) Fiber optic requires specialized and sophisticated tools for maintenance and repairing [29]

Attenuation

Attenuation and pulse dispersion represent the two most important characteristics of an optical fiber that determine the information-carrying capacity of a fiber optic communication system. The decrease in signal

strength along a fiber optic waveguide caused by absorption and scattering is known as attenuation.
Attenuation is usually expressed in dB/km.

4. Review of Development in Fiber Optic Communication

Franz Fidler et al. [31] reviewed of technologies, theoretical studies, and experimental field trials for optical communications from and to high-altitude platforms (HAPs). Using lightweight and compact terminals, optical inter satellite links and orbit-to ground links are already operable [32]–[34], the latter suffering from cloud coverage [35], harsh weather conditions, and atmospheric Turbulence [36]. Current research also investigates optical communications from or to highaltitude platforms (HAPs) [37], [38]. HAPs are aircraft or airships situated well above the clouds at typical heights of 17 to 25 km, where the atmospheric impact on a laser beam is less severe than directly above ground [35]. As depicted in Fig. 3, optical links between HAPs, satellites, and ground stations are envisioned to serve as broadband backhaul communication channels if data from various sensors or RF communication terminals onboard the HAP is to be transmitted, or if an HAP works as a data relay station.

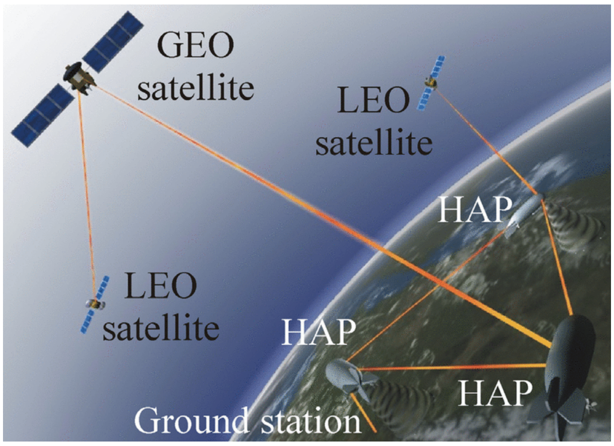

Fig. 3. Laser communication scenarios from HAPs

5. Applications of Wireless Sensor Network

5.1 Structural Health Monitoring

Smart Structures Sensors embedded into machines and structures enable condition-based maintenance of these assets. Typically, structures or machines are inspected at regular time intervals, and components may be repaired or replaced based on their hours in service, rather than on their working conditions. This method is expensive if the components are in good working order, and in some cases, scheduled maintenance will not protect the asset if it was damaged in between the inspection intervals. Wireless sensing will allow assets to be inspected when the sensors indicate that there may be a problem, reducing the cost of maintenance and preventing catastrophic failure in the event that damage is detected. In some cases, wireless sensing applications demand the elimination of not only lead wires, but the elimination of batteries as well, due to the inherent nature of the machine, structure, or materials under test. These applications include sensors mounted on continuously rotating parts, within concrete and composite materials [5], and within medical implants

5.2. Industrial Automation

In addition to being expensive, lead wires can be constraining, especially when moving parts are involved. The use of wireless sensors allows for rapid installation of sensing equipment and allows access to locations that would not be practical if cables were attached. An example of such an application on a production line is shown. In this application, typically ten or more sensors are used to measure gaps where rubber seals are to be placed. Previously, the use of wired sensors was too cumbersome to be implemented in a production line environment. The use of wireless sensors in this application is enabling, allowing a measurement to be made that was not previously practical. Other applications include energy control systems, security, wind turbine, health monitoring, environmental monitoring, location-based services for logistics, and health care.

5.3. Civil Structure Monitoring

One of the most recent applications of today's smarter, energy-aware sensor networks is structural health monitoring of large civil structures, such as the Ben Franklin Bridge (Figure 22.6.2), which spans the Delaware River, linking Philadelphia and Camden, N.J [9,10]. The bridge carries automobile, train and pedestrian traffic. Bridge officials wanted to monitor the strains on the structure as high-speed commuter trains crossed over the bridge. A star network of ten strain sensors were deployed on the tracks of the commuter rail train. The wireless sensing nodes were packaged in environmentally sealed NEMA rated enclosures. The strain gauges were also suitably sealed from the environment and were spot welded to the surface of the bridge steel support structure. Transmission range of the sensors on this star network was approximately 100 meters.

6. Future Development

Most important aspect of WSN is security and the efficiency by vital deployment of batteries. The wireless sensor network product specially in industries will not get acceptance unless there is full proof security to the network. Most of the WSN protocols taking an account of security issues into account. Therefore a proper full proof security protocol must b designed by keeping in mind all the performance and the security issues for the secure WSN. The most general and versatile deployments of wireless sensing networks demand that batteries be deployed. Future work is being performed on systems that exploit piezoelectric materials to harvest ambient strain energy for energy storage in capacitors and/or rechargeable batteries. By combining smart, energy saving electronics with advanced thin film battery chemistries that permit infinite recharge cycles, these systems could provide a long term, maintenance free, wireless monitoring solution.

7. Conclusion

WSN is very wide area for research. Further studies can be done in any topic like protocols, dead node detection and prevention. Currently proposed routing protocols for WSNs are insecure but vital. Link layer encryption and authentication mechanisms provide reasonable defense for mote-class outsider attacks. Cryptography is inefficient in preventing against laptop-class and insider attacks. Remains an open problem for additional research and development. The existing infrastructure is already resource- starved due to Communication bandwidth, Power and Computational power. So still there is need of developing more and more sensor networks which overcome these limitations.

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