A Survey of Optical Fiber Communications: Challenges and Processing Time Influences

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ABSTRACT

Optical fibers are utilized widely for data transmission systems because of their capacity to carry extensive information and dielectric nature. Network architectures utilizing multiple wavelengths per optical fiber are used in central, metropolitan, or broad-area applications to link thousands of users with a vast range of transmission speeds and capacities. A powerful feature of an optical communication link is sending several wavelengths through the 1300-to-1600-nm range of a fibre simultaneously. The technology of integrating several wavelengths onto a similar fiber is called wavelength division multiplexing (WDM). The principle of WDM utilized in concurrence with optical amplifiers has an outcome in communication links that permit rapid communications among users in the world's countries. This paper presents an overview of the challenges of fibre optic...
communication. This paper offers an outline of the areas to be the most relevant for the future advancement of optical communications. The invention of integrated optics and modern optical fibers takes place in the field of optical equipment and components.

Keywords: Optical fiber; communications; challenges; FSO.

1. INTRODUCTION

The optic fiber communication system is an essential infrastructure for the networks of worldwide broadband [1]. The optical fibers provide massive and unique transmission bandwidth with negligible latency. It is now the most choices transmission medium for transmitting for long-distance [2]. The thrust behind the broad famous and utilization of fiber optic communications is some of the preferred aspects such us high and quick expanding buyer and business interest for the limited transmission of media [3,4]. The main building block in the telecommunication infrastructure is the fiber optic; its features make it ideal for gigabit transmission [5]. High data rate demand is increasing globally; thus, the researchers try to find various techniques to provide the gigabit capacity [6,7]. The optical communication networks have several classes [8]. For example, the code division multiple access networks recently introduced using optical signal technique [9]. A precise analysis of the OICl physical layer's security factors is presented by LI [10].

In this paper, a comprehensive review is performed for the latest and most efficient approaches that researchers have conducted in the past years about optical fiber communication challenges. Reliability and solutions of optical fiber communication and Optical fiber transmission network need higher open and cooperative requirements. Also, the details about their methods, such as using me optical devices, datasets, and the findings achieved, are summarized. Besides, we highlighted the most commonly used approaches and the highest accuracy methods achieved.

The research issue in this paper is that optically connected connections can meet physical limitations, the so-called "fiber wall" from a single optical fiber. It is anticipated that developments will hit the point that the bandwidth of the optical connection with a single optical fiber is no longer increased in systems of normal single-mode optical fiber that will enable increasing transmitting capacity due to rapid technological research. Because of this "fiber wall" crash, scientific activities are all the more needed to create future solutions. The modern networking approaches include coherent communications, multidimensional modulation and multiplexing technologies, along with the use of optical signal processing, in order to achieve the objectives. In the future, modern optical networking will enable adaptable wavelength, bandwidth and modulation formats, from high-performance fiber links in the backbone to wideband users connectivity in our homes.

The key goal of this study (i.e. its contribution) is to declare in future the implementation of optical fiber communications networks. This means vast quantities of data can be transferred using the easiest and inexpensive devices with low energy consumption.

The remaining paper's organization is as follows: Section II contains a theory of optical fiber communications challenges and devices; Section III gives a related work on optical fiber communications challenges; Section IV is the last section which concludes the research work.

2. BACKGROUND THEORY

2.1 Optical Devices

The optical communication field development goes into the integrated optic direction known as planar lightwave circuits (PLCs) [11]. The integration becomes an important tool that helps reduce the production costs of the optical devices and limit the impact on the environment concerning the carbon-footprint emissions amount that results from the electricity uses and increase the functionality of telecommunications networks. Optical circuit development implies that a cheaper monolithic solution will replace the current hybrid solutions [12].

Hybrid integrated circuits and their current technology in the single enclosure combine various integrated circuits or discrete components, which perform certain electrical and optical functions [14].
Modern research aims to integrate light sources, modulators, transmitters, and signal processing elements *(and vice versa; detectors, demodulators, and receivers)*. The field of optical devices is developing, and this leads to the development of Free-Space Optics (FSO), Micro-Electro-Mechanical Systems (MEMS), photonic crystals, gratings, plasmonic circuits, ring resonators, and devices [15].

### 2.2 Fiber Optic Communication principles

Fiber-optic communication is how digital information is transmitted between two points by light waves via optical fiber [16]. Data sent by computer and internet networks are digital in their type, which is called digital information. The optical fiber consists of dielectric waveguide cylinders made from silicon dioxide materials. To transform electrical signals into optical signals, an optical transmitter which used via optical fiber [17]. The cable comprises several optical fiber packages, an optical receiver to reconvert the received optical signal back to the original transmitted electrical signal, and optical amplifiers to boost the optical signal's power. Fig. (1) shows the fiber optic communication system in a simplified representation [2]. Surface Plasma Resonance (SPR) is one of the most promising optical techniques in various areas. SPR technology was first applied to sensors in 1983. Several SPR sensing structures have been identified since then for both chemical and biochemical sensing [12]. SPR technology induces electron density oscillations (called a plasma wave barrier, the SPW) on the metal-dielectric interface with a transverse magnetic or p-polarised light [18].

The basic steps in the communication of fiber optic process are:

1. The transmitter creates the optical signal by an electrical signal.
2. The second step involves ensuring the signal's safety from distortion by sending the signal along with the fiber.
3. The third step consists of the receiving of the transmitted optical signal.
4. The last step involves converting the optical signal into an electrical form.

### 2.3 Advantage of Optical Fiber Communication

1. Huge possible bandwidth: the metallic cables have less potential transmission BW than the optical carrier frequency.
2. The small weight and size: a small diameter is one of the optical fiber characteristics.
3. Isolation of electrical: the fabrication of optical fiber is either from a plastic polymer or glass. These are electrical insulators, and it does not exhibit earth loop or interface problems; this is unlike their metallic counterpart.
4. The security of signal: The high degree of protection of the signals is achieved because the optical fiber's light does not radiate significantly.

The loss transmission is low: The optical fiber technological developments have resulted in the optical cables in the last years.
2.4 Disadvantage of Optical Fiber Communication

i) The high installation cost.
ii) The high cost of the interfaces and connectors between the fiber optics despite the fiber optic's low cost.
iii) The repairing and maintenance process is done in the fiber optic by sophisticated and specialized tools [19].

2.5 Some of Fiber Optic Communication Future Trends

2.5.1 Developments in optical transmitter and receiver technology

Achieving a high transmission quality is essential in fiber-optic communications for the optical signals’ distorted waveform and low signal-to-noise ratio during transmission.

Developing the optical transceivers is the research concerns to adopt new and advanced modulation technology. Optical Signal to Noise Ratio (OSNR) tolerance and chromatic dispersion will be effective for “ultra-long-haul” communication systems besides better error correction codes.

2.5.2 Whole optical communication networks

Fiber optics communications are envisioned in the optical domain for supporting the whole-optical communication network’s rising. All the signals in such networks will be processed in the optical domain, but they will manipulate electrical forms externally [21]. When the data rate increases, there will not be a need for replacing the electronic, which is the benefit of whole-optical networks, since all the operations of routing and signal processing will occur in the optical domain [2].

2.5.3 Some review related to fiber optic communication developments

Fiber-optic networking and information transmission networks are witnessing rapid technological change [23]. As a result, this section displays future works related to the discussion of fiber optic communications challenges.

Fig. 3. The nonlinear transfer process of the signal pulse and amplified spontaneous emission [20]

Fig. 4. Schematic of an optical communication network [22]
Paper [24] represents optical communication technologies, theoretical studies, and experimental field trials using the optical intersatellite. Then, orbit-to-ground links are operable [25,26]. Finally, terminals are lightweight and compacted. Researchers in [27] presented a review of optical fibers biosensors applications and mentioned the biosensors’ trends in actual samples. In [28], the optimization and characteristics of the flexible transducers are represented. In [29], the fiber optic sensors developments based on immobilized nitrophenol are represented. Research [30] presented the optical affinity sensor. Researchers in [31] present the fiber-based wavelength division multiplexed data transmission first experimental demonstration.

2.6 Processing Time

In particular, the proliferation of network traffic, particularly data transmission traffic caused by the creation of cloud-based and video streaming systems, now makes large backbone networks important [32]. The capability of optical communication system wavelength-division multiplexing (WDM) can be expanded considerably with the use of digital signal processing (DSP) and digital coherent optical communication [33].

Huang et al. [34], A practical and precise fiber delay measurement device has developed. The key idea is to turn the time fiber transmission delay into phase detection and by frequency scanning removing the uncertainty, followed by a data processor to get the result [35].

The fibre-optical fiber sensor based on the time regulated digital optical frequency domain reflectometry has a linear response to long measurement wavelength vibration signals. However, the computational complexity and a large amount of data stream make it difficult to realize online data processing [36].

The series of states of processes and threads during their Life-Cycles (LC) from development as a new process to termination (or even starvation) is critical and must be analyzed to keep track of its traversing [37]. Users have no idea about what happened during program execution. This may be a typical situation for nonprogrammers [38]. However, for programmers, the program’s structure may prevent different complexities for processes states sequence if they knew the actual events for programs [39]. So, they know what is happening immediately for the process and can interfere with its states, the programming approach, and, consequently, the system can be improved [40].

Complex issues with poor reliability and consistency need a long time to be resolved. To fix these drawbacks, studies have broken the problem into separate sections and treated each part separately so that every processing unit can concurrently perform its part of the problem with the others [41].

Modern computer systems are designed according to multiprocessor configurations [42]. Multiple processors enable multiple threads to be executed simultaneously to execute the threads of the same process to be run on different processors simultaneously [43].

The influences of pushing processes in shared memory structures focus on concepts of parallel processing. These effects contribute to overall computing and CPU times. Based on the loading size and number of CPUs, CPU consumption is often calculated differently [44].

Multi-core is one of the most critical processing speed patterns to increase performance [45]. The new manufacturers, therefore, concentrate on multi-core processors (MCP). Improving multitasking computer ability is one of MCP's many advantages [46]. These processors have multiple complete implementing cores instead of one with an individual front-side bus interface. [47].

The parallel execution of numerous threads can significantly increase performance and overall computer systems efficiency [48]. In many computer systems, numerous performance counters are available [49]. For example, performance counters may count the number of threads executing at a given time [50].

In recent days, increasing numbers of Internet and wireless network users have helped accelerate the need for encryption mechanisms and devices to protect user data sharing across an unsecured network [51]. Data security, integrity, and verification may be used due to these features. In internet traffic encryption, symmetrical block chips play an essential role [52].

Parallel and distributed simulation (PADS) depends on the simulation models’ partition
3. LITERATURE REVIEW

Batageli, janyani, and Tomazić [12] claimed that optical communications are evolving. It will be subject to the sophistication and development that helps overcome the created boundaries. The competition for high quality, higher speed, and enormous capacity is in development and meets this development a coherent detection polarization multiplexing, digital processing, and multilevel modulations are needed.

Trichili et al. [56] claimed that the use of spatial mode communication of light is the critical solution to cope with the unforeseen capacity crunch. In particular orbital angular momentum OAMs, spatial multiplexing modes have been demonstrated over FSO links, optical fibers, and underwater communication links.

Kaushal and Laddoum [57] showed that the information business reached higher data rates because of the information technology explosion due to needing to switch from radio frequency to optical domain. To meet the business requirements of higher speed and huge requirements, the free space optical FSO communication is used.

Kedar and Arnon [58] used the adaptive field to reduce the communication degradation by scattering to facilitate multi-user communication through turbulence and appropriate data processing and detector arrays.

Lam et al. [59] showed that Datacentre networks use the full range of fiber optic technologies to provide coverage to the long haul in the sense of distance. Intra-Datacentre interconnects characteristics are of utmost importance for rising data centers. Potential technologies to realize next-generation intra-data centre interconnects include improved fiber optic communication infrastructure, lightwave optical transmission, signal modulation to resolve losses, and other means of enhancing high-speed interconnects between data centres.

Temprana et al. [60] showed that the optical carrier stability is essential in cancelling Kerr-induced transformations and that nonlinear wave communication in silica can be significantly reduced if optical carriers have enough mutual coherence. These results suggest that fiber information capability can be substantially improved concerning previous estimates.

Pfeifle et al. [61] proposed an estimate for laser pump intensity jitter and enhanced spontaneous emission noise caused by an erbium-doped fiber amplification using a probabilistic Lugiato-Lefever equation. Experiment with advanced modulation formats in optical fiber transmission. They demonstrate that when noise is taken into account, the prominent comb’s coherence is vastly better than their solitonic or unstable counterparts for almost the same pump power utilizing crystalline whispering-gallery-mode reflectors with centre frequency for a comb generation.

Thomas, Elhajjar, and Hanzo [62] begin by providing a basic overview of a ROF architecture, and then they went into detail about ROF methods of improving system performance. Finally, they went over the ROF techniques that have been built to lower the cost of installing a ROF device.

Yang and He [63] proposed a method based on a long short-term memory (LSTM) network to estimate nonlinear noise power and OSNR induced via fiber nonlinearity at the same time. The LSTM network generates the critical features with an input signal in the frequency domain during the training process.

Gao [64] performed a symbolic computation on a newly proposed simplified higher-order variable-coefficient Hirota formula for particular ultrashort optical pulses promulgating in the nonlinear inhomogeneous fiber. An auto-Backlund transmutation and a family of analytic solutions are designed for the congregation envelope function related to the fibre’s optical-pulse electric domain.

Yang et al. [65] presented a novel C-RoFN framework for MSRO utilizing software-specified networking. To improve radio coverage and meet the QoS constraints, the proposed framework will efficiently leverage radio frequency, BBU processing services, and the optical spectrum.
Milione, Nolan, and Alfano [66] proposed a framework for determining an MMF's theory modes. Their proposed method is the mode-based signal delay system, which expands the MMF of an analogous technique for evaluating the principal conditions of distortion of the single-mode optical fiber.

Karanov et al. [67] used an end-to-end deep neural network to introduce a system of optical fiber communication, which included the entire chain of a transmitter, receiver, and channel model. This method allows for transceiver optimization in the process of single end-to-end. By applying this approach to the system of intensity modulation/direct detection (IM/DD), they demonstrated that bit error rates could be held below the threshold of 6.7% of hard-decision forward error correction (HD-FEC).

Lavery et al. [68] examined the advantages of digital fiber nonlinearity compensation, where digital signal processing is split between the receiver and the transmitter. Implementing the Gaussian noise model shows that splitting the nonlinearity compensation when there are two or more periods is often beneficial.

Zhang et al. [35] proposed and demonstrated a basic nonlinear equalizer based on functional-link of neural networks (FLNN). To address fiber nonlinearity in optical communication transmission systems, they create an FLNN primarily with signals from two polarizations and mapped features as data. The nonlinear probabilistic mapping allows FLNN to operate as a nonlinear network.

4. DISCUSSION AND COMPARISON

Depending on the detailed review of those works focussed on optical fiber communications, it can be concluded that they are working on the solution to the challenges. The most famous challenges can be Speed, Quality, communication degradation, using the full spectrum range of fiber optic, estimating nonlinear noise power, Performance, Dispersion, Improving radio coverage, cost, and QoS.

Hence, many solutions were presented to overcome all these challenges. Some researchers worked on coherent detection polarization multiplexing, digital processing, and multilevel modulations. Simultaneously, others worked on photonic integrated circuits, improved fiber optic communication infrastructure, lightwave optical transmission, signal modulation to resolve losses. However, another trend was generating the critical features with the frequency domain of an input signal during the training process using the LTSM network. The researcher’s orientation was also working on Proposing and testing in simulations a training technique that produces flexible and robust transceivers that enable secure transmission over a wide range of connection dispersions without reconfiguration.

| Author          | Challenges                              | Solutions                                                                 |
|-----------------|-----------------------------------------|---------------------------------------------------------------------------|
| Batageli, et al. [12] | Speed, Quality                          | coherent detection polarization multiplexing, digital processing, and multilevel modulations |
| Trichilì et al. [56]    | foresee capacity crunch                  | spatial mode communication of light                                        |
| Kaushal et al. [57]  | meeting the business requirements        | free-space optical FSO communication is used                              |
| Kedar et al. [58]     | reducing the communication degradation   | adaptive field                                                            |
| Lam et al. [59]       | Datacentre networks using the full spectrum range of fiber optic technologies | photonic integrated circuits, improved fiber optic communication infrastructure, lightwave optical transmission, signal modulation to resolve losses |
| Temprana et al. [60]  | cancelling Kerr-induced transformations  | Fiber information capability can be substantially improved concerning previous estimates. |
| Pfieffe et al. [61]   | Proposing an estimate for laser pump intensity jitter and enhanced spontaneous emission noise caused by an erbium-doped fiber amplification using a probabilistic Lugnieto-Lefever equation. | Experiment with advanced modulation formats in optical fiber transmission. |
Table

| Author               | Challenges                                  | Solutions                                                                 |
|----------------------|---------------------------------------------|---------------------------------------------------------------------------|
| Thomas et al. [62]   | Performance and cost                        | Providing the most prominent factors of the ROF architecture.             |
| Yang et al. [63]     | Estimating nonlinear noise power and OSNR induced via fiber nonlinearity. | It generates the critical features with the frequency domain of an input signal during the training process using the LSTM network. |
| Gao et al. [64]      | Dispersion, speed                           | An auto-Bäcklund trasnmutation and a family of analytic solutions are designed for the congregation envelope function related to the fibre's optical-pulse electric domain. |
| Yang et al. [65]     | They are improving radio coverage and meeting the QoS constraints. | It is efficiently leveraging radio frequency, BBU processing services, and the optical spectrum. |
| Milione et al. [32]  | We are determining an MMF's theory modes.   | We are evaluating the principal conditions of distortion of the single-mode optical fiber. |
| Karanov et al. [67]  | demonstrating the first step towards end-to-end deep learning-based optical fiber communication system optimization. | In simulations, proposing and testing a training technique that produces flexible and robust transceivers enables secure transmission over a wide range of connection dispersions without reconfiguration. |
| Lavery et al. [68]   | Examining the advantages of digital fiber nonlinearity compensation | Showing that splitting the nonlinearity compensation when there are two or more periods is often beneficial using the Gaussian noise model's implementation. |
| Zhang et al. [69]    | proposed and demonstrating a basic nonlinear equalizer based on functional-link of neural networks (FLNN). | Creating an FLNN mostly with the signals from two polarizations and mapped features as input to counter fiber nonlinearity in optical communication transmission systems. |

5. CONCLUSION
The main research challenges for optical communication technology are presented in this paper. In the last decade, the fiber-optic networking market has expanded exponentially in size and scope. A new field should be designed and built to aid in developing higher data speeds and intelligent switching techniques. An intelligent network can respond to traffic patterns rapidly and be profitable in every sense of the term. As in the past, optical communications are required to be encouraged to maintain their unrivalled pace. Optical communications will also evolve and become more sophisticated, allowing them to break through new barriers. Indeed, the race for faster speeds, better efficiency, and vast capability continues to drive significant advancement in the field of optical communications.

COMPETING INTERESTS
Authors have declared that no competing interests exist.

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