Asian Journal of Research in Computer Science

7(4): 48-58, 2021; Article no.AJRCOS.67395
ISSN: 2581-8260

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

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Authors' contributions

This work was carried out in collaboration among all authors. Authors FQK and SRM prepared the detailed review of previous works related to optical fiber communications. Both authors HID and MAMS wrote the first draft of the manuscript. In addition, authors ZNR, DAH and KHS managed the analyses and discussion parts of the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJRCOS/2021/v7i430188
Editor(s):
(1) Dr. Young Lee, Texas A&M University-Kingsville, USA.
(2) Dr. R. Gayathri, Anna University, India.
(3) Dr.Shivanand S.Gornale, Rani Channamma University, India.
Reviewers:
(1) Jian Peng, Kunming University of Science and Technology, China.
(2) Satish Kumar Alaria, Arya Institute of Engineering & Technology, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/67395

Review Article

Received 08 February 2021
Accepted 16 April 2021
Published 20 April 2021

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

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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 OICI 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].

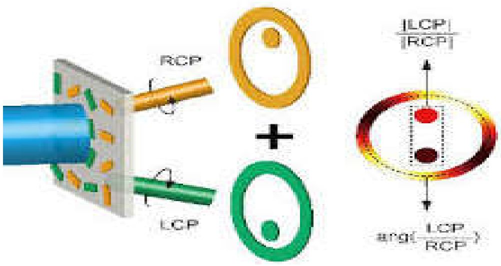

Fig. 1. Optical Devices Directly Measure Polarization [13]

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:

i) The transmitter creates the optical signal by an electrical signal.
ii) The second step involves ensuring the signal's safety from distortion by sending the signal along with the fiber.
iii) The third step consists of the receiving of the transmitted optical signal.
iv)

The last step involves converting the optical signal into an electrical form.

2.3 Advantage of Optical Fiber Communication

i) Huge possible bandwidth: the metallic cables have less potential transmission BW than the optical carrier frequency.
ii) The small weight and size: a small diameter is one of the optical fiber characteristics.
iii) 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.
iv) 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.

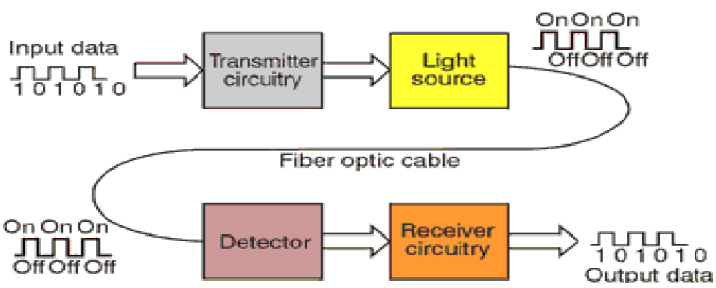

Fig. 2. Communication Systems of Fiber Optic

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

Fibber 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.

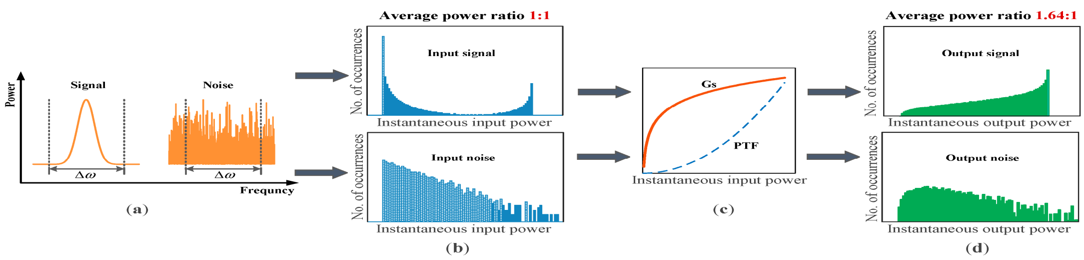

Fig. 3. The nonlinear transfer process of the signal pulse and amplified spontaneous emission [20]

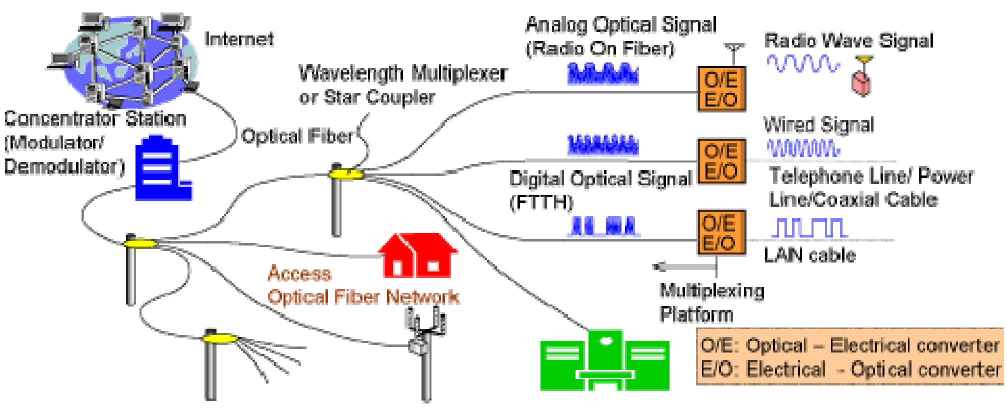

Fig. 4. Schematic of an optical communication network [22]

Paper [24] represents optical communication technologies, theoretical studies, and experimental field trials using the optical inter-satellite. 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 across the several execution units [53]. Each of them is responsible for part of the model. In other words, each PADS is dealing with its local event list; hence it entirely local [54]. However, locally generate events could require sending to remote execution units, which could minimize the run time cost, positively impacting the model's efficiency [55].

3. LITERATURE REVIEW

Batageli, janyani, and Tomažič [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 foreseen 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 canters. 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.

Table 1. Comparison of related work

Author	Challenges	Solutions
Batageli, et al. [12]	Speed, Quality	coherent detection polarization multiplexing, digital processing, and multilevel modulations
Trichili et al. [56]	foreseen 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.
Pfeifle 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 Lugiato-Lefever equation.	Experiment with advanced modulation formats in optical fiber transmission.

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 LTSM network.
Gao et al. [64]	Dispersion, speed	An auto-Bäcklund 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]	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.

REFERENCES

1. Hasan DA, Hussan BK, Zeebaree SR, Ahmed DM, Kareem OS, Sadeeq MA. "The impact of test case generation methods on the software performance: A review." International Journal of Science and Business. 2021;5:33-44,
2. Idachaba F, Ike DU, H Orovwode. "Future trends in fiber optics communication"; 2014.
3. Joshi NK, Bhatt P. "A Technical assessment on fiber optics communication: Latest trends and its application"; 2016.
4. Sadeeq MA, Zeebaree SR, Qashi R, Ahmed SH, Jacksi K. "Internet of things security: A survey." in 2018 International Conference on Advanced Science and Engineering (ICOASE). 2018;162-166.
5. Sharma P, Pardeshi S, Arora RK, Singh M. "A review of the development in the field of fiber optic communication systems." International Journal of Emerging Technology and Advanced Engineering. 2013;3:113-119.
6. Chen M, Mao S, Liu Y. "Big data: A survey." Mobile networks and Applications. 2014;19:171-209,
7. Taleb T. "Toward carrier cloud: Potential, challenges and solutions." IEEE Wireless Communications. 2014;21:80-91.
8. Wang X, Kitayama K-I. "Analysis of beat noise in coherent and incoherent time-spreading OCDMA". Journal of Lightwave Technology. 2004;22:2226.
9. Shake TH. "Confidentiality performance of spectral-phase-encoded optical CDMA."

Journal of Lightwave Technology. 2005;23:1652.
10. Li X, Yu J, Dong Z, Chi N. "Photonics millimeter-wave generation in the E-band and bidirectional transmission." IEEE Photonics Journal. 2013;5:7900107-7900107.
11. Abdulazeez AM, Zeebaree SR, Sadeeq MA. "Design and implementation of electronic student affairs system." Academic Journal of Nawroz University. 2018;7:66-73,
12. Batagelj B, Janyani V, Tomažič S. "Research challenges in optical communications towards 2020 and beyond." Informacije Midem. 2015;44:177-184.
13. Photonics Views, "Optical Devices Directly Measure Polarization "; 2019.
14. Doerr CR. "Highly integrated monolithic photonic integrated circuits." In optical communication (ECOC 2013), 39th European Conference and Exhibition on. 2013;1.
15. Wu MC, Solgaard O, Ford JE. "Optical MEMS for lightwave communication". Journal of Lightwave Technology. 2006;24:4433-4454.
16. Maulud DH, Zeebaree SR, Jacksi K, Sadeeq MAM, Sharif KH. "State of art for semantic analysis of natural language processing." Qubahan Academic Journal. 2021;1.
17. Sadeeq MM, Abdulkareem NM, Zeebaree SR, Ahmed DM, Sami AS, Zebari RR. "IoT and cloud computing issues, challenges and opportunities: A review." Qubahan Academic Journal. 2021;1:1-7.
18. Gupta BD, Verma RK. "Surface plasmon resonance-based fiber optic sensors: Principle, probe designs, and some applications." Journal of Sensors. 2009;2009.
19. Kwan S. "Principles of optical fibers." Partial Fulfillment of Course Requirement for MatE. 2002;115.
20. Wan F, Wu B, Wen F, Qiu K. "In-band OSNR measurement method for all-optical regenerators in optical domain." Applied Sciences. 2019;9:5438.
21. Sulaiman MA, Sadeeq M, Abdulraheem AS, Abdulla AI. Analyzation study for gamification examination fields. Technol. Rep. Kansai Univ. 2020;62:2319-2328.
22. criepi.
23. Glazov A, Grigor'ev V, Kravtsov V, Mityurev A, Svetlichnyi A, Savkin K, et al. International comparisons of standards in the area of fiber-optic communication and information transmission systems. Measurement Techniques. 2018;60:1064-1070.
24. Sodnik Z, Furch B, Lutz H. Free-space laser communication activities in Europe: SILEX and beyond. LEOS 2006-19th Annual Meeting of the IEEE Lasers and Electro-Optics Society. 2006;78-79.
25. Jono T, Takayama Y, Shiratama K, Mase I, Demelenne B, Sodnik Z, et al. Overview of the inter-orbit and the orbit-to-ground laser communication demonstration by OICETS. in Free-Space Laser Communication Technologies XIX and Atmospheric Propagation of Electromagnetic Waves. 2007;645702.
26. Moll F, Knapek M. Wavelength selection criteria and link availability due to cloud coverage statistics and attenuation affecting satellite, aerial, and downlink scenarios. Free-Space Laser Communications VII. 2007;670916.
27. Llobera A, Wilke R, Büttgenbach S. Optimization of poly (dimethylsiloxane) hollow prisms for optical sensing. Lab on a Chip. 2005;5:506-511.
28. Lucas P, Solis MA, Le Coq D, Juncker C, Riley MR, Collier J, et al. Infrared biosensors using hydrophobic chalcogenide fibers sensitized with live cells. Sensors and Actuators B: Chemical. 2006;119:355-362.
29. Misiakos K, Kakabakos SE, Petrou PS, Ruf HH. A monolithic silicon optoelectronic transducer as a real-time affinity biosensor. Analytical Chemistry. 2004;76:1366-1373.
30. Poletti F, Wheeler NV, Petrovich MN, Baddela N, Fokoua EN, Hayes JR, et al. Towards high-capacity fibre-optic communications at the speed of light in vacuum. Nature Photonics. 2013;7: 279-284,.
31. Zhou J, Chen X, Zhao Z, Li J. Research in security of optic-based information communication architecture for next generation power system applications. 2010 International Conference on Power System Technology. 2010;1-5.
32. Ageed Z, Mahmood MR, Sadeeq M, Abdulrazzaq MB, Dino H. Cloud computing resources impacts on heavy-load parallel processing approaches. IOSR Journal of Computer Engineering (IOSR-JCE). 2020;22:30-41.

33. Maeda H, Saito K, Kawahara H, Seki T, Sasai T, Hamaoka F. High spectral efficiency real-time 500-Gb/s/carrier long-haul transmission over field-installed fibers. Journal of Lightwave Technology; 2020.
34. Huang X, Yin F, Li J, Dai Y, Zhou Y, Xu K. Time delay measurement in optical fibers based on phase detection. 2018 IEEE 3rd Optoelectronics Global Conference (OGC). 2018;130-134.
35. Rashid ZN, Zebari SR, Sharif KH, Jacksi K. Distributed cloud computing and distributed parallel computing: A review. 2018 International Conference on Advanced Science and Engineering (ICOASE). 2018;167-172.
36. Xia X, Liu Q, Chen D, He Z. Real-time data processing algorithm for phase-demodulation distributed fiber-optic vibration sensor with signal-to-noise ratio over 30 dB. 2017 16th International Conference on Optical Communications and Networks (ICOCN). 2017;1-3.
37. Abdulla AI, Abdulraheem AS, Salih AA, Sadeeq MA, Ahmed AJ, Ferzor BM, et al. Internet of Things and Smart Home Security. Technol. Rep. Kansai Univ. 2020;62:2465-2476.
38. Sadeeq M, Abdulla AI, Abdulraheem AS, Ageed ZS. Impact of electronic commerce on enterprise business. Technol. Rep. Kansai Univ. 2020;62:2365-2378.
39. Abdulraheem AS, Salih AA, Abdulla AI, Sadeeq MA, Salim NO, Abdullah H, et al. Home automation system based on IoT; 2020.
40. Zebari S. A new approach for process monitoring. Polytechnic Journal, Technical Education-Erbil; 2011.
41. Zebari SR, Yaseen NO. Effects of parallel processing implementation on balanced load-division depending on distributed memory systems. J. Univ. Anbar Pure Sci. 2011;5:50-56.
42. Zeebaree S, Zebari RR, Jacksi K. Performance analysis of IIS10. 0 and Apache2 Cluster-based Web Servers under SYN DDoS Attack. TEST Engineering & Management. 2020;83:5854-5863.
43. Zebari SR, Yowakib AS. Improved approach for unbalanced load-division operations implementation on hybrid parallel processing systems. Science Journal of University of Zakho. 2013;1:832-848.
44. Zeebaree S, Jacksi K. Effects of processes forcing on CPU and total execution-time using multiprocessor shared memory system. Int. J. Comput. Eng. Res. Trends. 2015;2:275-279.
45. Rashid ZN, Sharif KH, Zeebaree S. Client/Servers clustering effects on CPU execution-time, CPU usage and CPU Idle depending on activities of Parallel-Processing-Technique operations. Int. J. Sci. Technol. Res. 2018;7:106-111.
46. Alzakholi O, Shukur H, Zebari R, Abas S, Sadeeq M. Comparison among cloud technologies and cloud performance. Journal of Applied Science and Technology Trends. 2020;1:40-47.
47. Zeebaree S, Haji LM, Rashid I, Zebari RR, Ahmed OM, Jacksi K, et al. Multicomputer multicore system influence on maximum multi-processes execution time. TEST Engineering & Management. 2020;83:14921-14931.
48. Rashid ZN, Zeebaree SR, Sengur A. Novel remote parallel processing code-breaker system via cloud computing. TRKU. 2020;62(04).
49. Sallow AB, Sadeeq M, Zebari RR, Abdulrazzaq MB, Mahmood MR, Shukur HM, et al. An investigation for mobile malware behavioral and detection techniques based on android platform. IOSR Journal of Computer Engineering (IOSR-JCE). 2020;22:14-20.
50. Dino HI, Zeebaree SR, Salih AA, Zebari RR, Ageed ZS, Shukur HM, et al. "Impact of Process Execution and Physical Memory-Spaces on OS Performance"; 2020.
51. Ageed ZS, Ibrahim RK, Sadeeq MA. "Unified Ontology Implementation of Cloud Computing for Distributed Systems". Current Journal of Applied Science and Technology. 2020;82-97.
52. Yazdeen AA, Zeebaree SR, Sadeeq MM, Kak SF, Ahmed OM, Zebari RR. "FPGA implementations for data encryption and decryption via concurrent and parallel computation: A review," Qubahan Academic Journal. 2021;1:8-16.
53. Salih AA, Zeebaree SR, Abdulraheem AS, Zebari RR, Sadeeq MA, Ahmed OM. "Evolution of mobile wireless communication to 5g revolution". Technology Reports of Kansai University. 2020;62:2139-2151.
54. Zeebaree SSR, Ameen S, Sadeeq M. "Social media networks security threats,

risks and recommendation: A case study in the kurdistan region". International Journal of Innovation, Creativity and Change. 2020;13:349-365.

55. Shukur H, Zeebaree SR, Ahmed AJ, Zebari RR, Ahmed O, B. Tahir SA, et al. "A state of art survey for concurrent computation and clustering of parallel computing for distributed systems" . Journal of Applied Science and Technology Trends. 2020;1:148-154.
56. Trichili A, Park K-H, Zghal M, Ooi B., Alouini M-S. "Communicating using spatial mode multiplexing: Potentials, challenges and perspectives." IEEE Communications Surveys and Tutorials. 2019;21:3175-3203.
57. Kaushal H, Kaddoum G. "Optical communication in space: Challenges and mitigation techniques." IEEE Communications Surveys and Tutorials. 2016;19:57-96.
58. Kedar D, Arnon S. "Urban optical wireless communication networks: The main challenges and possible solutions." IEEE Communications Magazine. 2004;42:S2-S7.
59. Lam CF, Liu H, Koley B, Zhao X, Kamalov V, Gill V. "Fiber optic communication technologies: What's needed for datacenter network operations." IEEE Communications Magazine. 2010;48:32-39.
60. Temprana E, Myslivets E, Kuo B-P, Liu L, Ataie V, N. Alic, et al. "Overcoming Kerr-induced capacity limit in optical fiber transmission." Science. 2015;348:1445-1448.
61. Pfeifle J, Coillet A, Henriet R, Saleh K, Schindler P, Weimann C, et al. "Optimally coherent Kerr combs generated with crystalline whispering gallery mode resonators for ultrahigh capacity fiber communications." Physical Review Letters. 2015;114:093902.
62. Thomas VA, El-Hajjar M, Hanzo L. "Performance improvement and cost reduction techniques for radio over fiber communications." IEEE Communications Surveys and Tutorials. 2015;17:627-670.
63. Wang Z, Yang A, Guo P, He P. "OSNR and nonlinear noise power estimation for optical fiber communication systems using LSTM based deep learning technique." Optics Express. 2018;26:21346-21357.
64. Gao X-Y. "Looking at a nonlinear inhomogeneous optical fiber through the generalized higher-order variable-coefficient Hirota equation." Applied Mathematics Letters. 2017;73:143-149.
65. Yang H, Zhang J, Ji Y, Lee Y. "C-RoFN: Multi-stratum resources optimization for cloud-based radio over optical fiber networks." IEEE Communications Magazine. 2016;54:118-125.
66. Milione G, Nolan DA, Alfano RR. "Determining principal modes in a multimode optical fiber using the mode dependent signal delay method." JOSA B. 2015;32:143-149.
67. Karanov B, Chagnon M, Thouin F, Eriksson TA, Bülow H, Lavery D, et al., "End-to-end deep learning of optical fiber communications." Journal of Lightwave Technology. 2018:36:4843-4855.
68. Lavery D, Ives D, Liga G, Alvarado A, Savory SJ, Bayvel P. "The benefit of split nonlinearity compensation for single channel optical fiber communications." In 2016 IEEE Photonics Conference (IPC); 2016;799-802.
69. Zhang J, Lei P, Hu S, Zhu M, Yu Z, Xu B, et al. "Functional-link neural network for nonlinear equalizer in coherent optical fiber communications." IEEE Access. 2019;7:149900-149907.

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