A Comprehensive Review of Performance Analysis in Wavelength Division Multiplexing MDM-PON System Using Advanced Modulations

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Abstract:Analysis of the performance of a Wave length Division Multiplexing Mode Division Multiplexing-Passive Optical Network system using various advanced modulation techniques. The purpose of this research is to evaluate the system's performance by analyzing various advanced modulation techniques under varying conditions. The findings will shed light on the suitability of various schemes for WDM MDM-PON system and aid in optimizing the system's performance.

Index Terms: WDM, MDM-PON . (key words)

I. INTRODUCTION

The increasing usage of internet applications, including online games, video conferencing, high-definition television, and more, has resulted in a surge in demand for high-capacity optical networks. The current network capacity of 10 Gbit/s fiber to the home (FTTH) is insufficient to meet this growing demand [1]. Passive optical networks have limited support for high data rates, and therefore, the integration of wavelength division multiplexing (WDM) is essential in FTTH networks. PON offers services using various multiplexing techniques, including TDM, WDM, and TDM/WDM combinations. PON-WDM has numerous benefits, such as high-speed access, large bandwidth, large capacity, ease of management, channel independence, format transparency, and network security. Future networks must possess large bandwidth, legacy network compatibility, affordability, flexibility, upgradeability, and manageability. For last-mile connectivity, WDM PON has emerged as a crucial optical network solution. Split-mode multiplexing is used in WDMPON systems to increase system capacity due to its ability to transport high data rates. MDM adds a new dimension to the WDMPON system by introducing another aspect of multiplexing, the standard wavelength size [1]. Passive optical networks (PON) are considered a promising approach for implementing FTTH. PONs offer various services such as peer-to-peer transmission, video on demand (VoD), Internet Protocol TV (IPTV), and more. The Optical Networks division is conducting extensive research on WDM-PON for various applications using different types of modulation formats in OLT. Due to significant advancements in system coverage and data transmission capacity, various WDM PON architectures are being deployed today, which increases the availability of modulation techniques. WDM PON networks offer better performance than TDM PON networks. Manchester coding outperforms RZ and NRZ coding techniques in terms of Min BER, Max Q factor, and Eye Diagram. Graphs show that if central office power consumption is increased, high data rates can be transmitted. The research can be extended to include DWDM PON, CWDM PON, and OCDMA PON architectures, as well as various coding techniques [2]. Mode division multiplexing (MDM) is another multiplexing technique that uses Eigen modes to extend the data transmission range of optical multimode communication systems. MDM employs multi-mode photonic crystal fibres, optical signal processing, and spatial light modulators to provide simultaneous data transmission across multiple spatial modes on a single wavelength. This technique can be used to push optical fibre data transmission capacity beyond the limits of conventional single-mode fibres. Finally, combining wireless and optical communication technologies can provide even faster data transmission rates. A recent study, for example, demonstrated the transmission of four high-speed channels, each with a capacity of 24 Gbps, over a 35 km FSO link using millimetre waves upconverted to 40 GHz. This technology has the potential to provide high-speed wireless connectivity in places where traditional wired connections are impractical.[3]. For the MDM system, the study achieved a data rate of 40 Gbit/s at a wavelength of 1550.12 nm and an MMF length of 1500 m. Mode coupling coefficients, modal delays, and eye graphs were investigated and analysed for various topological loads as performance evaluation parameters.[4].K Singh, M Singh,and others proposed , A free-spatial optical-radio communication link based on orthogonal frequency division multiplexing at 4 × 20 Gbit/s40 GHz, combining modal division multiplexing transmission techniques and hybrid wavelength, proposed in this paper. Four channels, each carrying 20 Gbit/s40 GHz information successfully transmitted using distinct spatial modes (HG01, HG03, LG02 and LG03) within 3000 and 2700 m respectively under rainy weather large and foggy, with acceptable performance using a detection technique involving the use of Srm at the receiving terminal. In addition, an improved detection scheme implementing a square root module after each photodiode at the receiver terminal is proposed to minimize negative performance effects due to the nonlinear characteristics of the photodiodes. The proposed 4×20 Gbit/s40 GHz-based RoFSO link provides a useful foundation for future high-capacity, long-range RoFSO transmission links. In the future, the performance of the proposed link will be further improved by combining optical code division multiple access transmission as well as adaptive optics and digital signal processing techniques at the receiver.[5]. Optical interconnects and logical switches may both have practical uses for the model. The spiral phased HG-ring MDM launch achieves better BER performance at a higher data rate than pure HG mode launches and is tolerant of small misalignments of up to 4 [6]. Over 10 km of fibre length and a 25 Gbps data rate, DRZ modulation outperforms the other encoding schemes, resulting in an acceptable bit error rate (BER) of 10−14[7]. In terms of Bit error rate (BER) at various MMF link lengths, the performance of

various advanced modulations is assessed, including compressed spectrum return to zero (CSRZ), duo-binary return to zero (DRZ), and modified duo-binary return to zero (MDRZ)[8].

Here's how this document is structured. The section II is devoted to simulation software, followed by section III on research gap ad problem formation, section IV design and system setup, and section V on a conclusion.

II. Simulation Software

Opti-System is a software program designed and developed by Opti wave that enables users to model and simulate complex optical communication systems. It is a system-level simulator that provides a hierarchical definition of components and systems, making it easy to design, test, and optimize various types of optical links in the physical layer. It also offers a robust simulation environment that enables users to evaluate the performance of their optical communication systems under different operating conditions and scenarios. Opti-System is a powerful tool that is widely used in the field of optical communication engineering, enabling researchers and engineers to design and optimize complex optical communication systems with high accuracy and reliability, leading to more efficient and effective communication networks

III. Research Gaps

The unpredictable augmentation of the needs of rapid communication and massive bandwidth hunger direct researchers to employ fiber optic in the access networks in place of copper cables. In order to use massive bandwidth of fiber optic cables, a promising and pioneering access technique is passive optical networks which benefit user with large bandwidth. To cater high speed, WDM-PON and TDM-PON network are extensively used. But these systems have their own limitations such as WDM needs equal number of lasers as the channels which increase the expenditure on the system. Also suffers from wavelength crosstalk and degradation of performance occurs. On the other hand, in TDM-PON, interference is negligible but due to time latency and time gap, synchronization is issue at receiver which degrades the performance of the system. Thus, the use of mode division in passive optical networks, open up the new path of research in PONs.

Problem Formulation

Problems encountered in the PON systems are listed as:

Multimode fiber is used in reported work MDM-PON system but distance of only 1 km was covered. Long reach distances are required to serve the distant location-based users. In reported work, CSRZ, DRZ, MDRZ and NRZ modulations were investigated. However, more spectrally efficient modulation is required to improve the performance of the PON system.

IV. Methodology of Proposed System

1**. Problem Statement:** The purpose of this research is to address bandwidth constraints in existing optical communication networks and propose an economical and high-speed capacity enhancement technique based on an MDM-PON system. The study also focuses on improving the performance of the MDM-PON system by employing differential phase shift keying at 25 Gbps over a MMF link length.

2. **Research Design:** The research takes a simulation-based approach, modelling and simulating the proposed MDM-PON system with the Opti System software. The system employs LG modes such as LG12, LG15, LG18, LG111, and LG114 for MDM transmission and a VCSEL laser to reduce overall system costs. In terms of BER and Q factor, the study also compares various modulation schemes, including NRZ, CSRZ, DRZ, MDRZ, and the proposed DPSK.

3.Data Collection: The study's data is derived from the simulation results generated by the Opti System software. The system components, such as LG modes, VCSEL laser, MDM coupler, optical circulator, photodetector, and receiver, are included in the simulation parameters. The simulation also accounts for dispersion, attenuation, and noise in the MMF link.

4. Data Analysis: The simulation results are analyzed using statistical and graphical methods to evaluate the performance of the proposed MDM-PON system and the different modulation schemes. The key performance metrics analyzed include BER and Q factor.

5. Results and Conclusion: This study compared the performance of the proposed MDM-PON system using DPSK modulation with other modulation schemes, including CSRZ, DRZ, MDRZ, and NRZ. Simulation results show that the proposed DPSK modulation scheme outperforms the other modulation schemes in terms of BER and Q factor, demonstrating that DPSK modulation is a promising technique for improving the performance of PON systems. The study concludes that the proposed MDM-PON system using DPSK modulation is an economical and high-speed technique for capacity enhancement in existing PON systems without the need for re-deployment. These findings suggest that DPSK modulation should be considered for future research to improve the performance of PON systems.

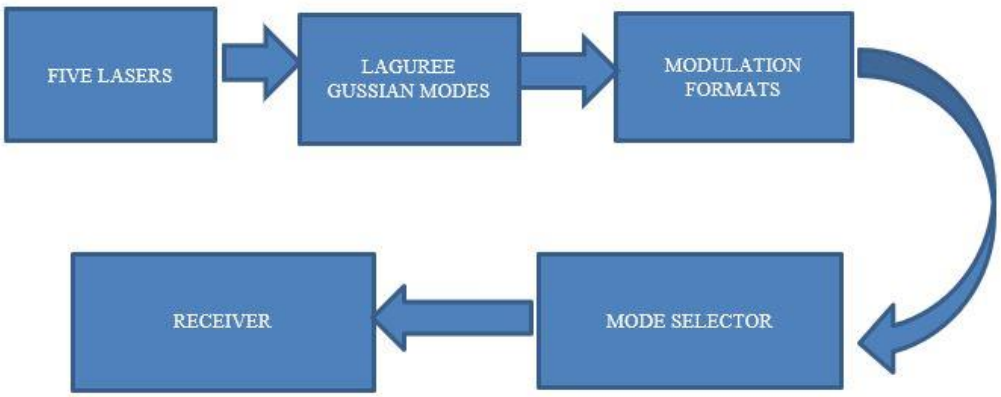

Figure1: - Depicts a proposed a MDM-PON system with modulation formats

V. CONCLUSION

The study's goal is to address the need for a more efficient and cost-effective mode division multiplexing passive optical network system that can cover longer distances and perform better. In an MDM-PON system, the proposed solution employs differential phase shift keying and Laguerre Gaussian modes. The study will employ Opti System software to simulate and evaluate the performance of the proposed system, as well as compare it to previously reported systems. The study will contribute to the growing body of research on passive optical networks and mode division multiplexing by developing and testing a new MDM-PON system. The study's findings will shed light on the feasibility and efficacy of employing DPSK and LG modes in MDM-PON systems, potentially leading to the development of more efficient and cost-effective fiber-optic networks.

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