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A Conclusive Survey of High Speed Bidirectional Hybrid Optical Wireless Network

Sidharath[1], Love Kumar[2], Anurag Sharma[3]
[1](*Department of Electronics and Communication Engineering, DAV Institute of Engineering and Technology)*
[2](*Department of Electronics and Communication Engineering, DAV Institute of Engineering and Technology)*
[3](*Department of Electronics and Communication Engineering, CT Institute of Technology and Research)*

Abstract: The fastest growing areas in telecom are broadband services and networks. The explosion of the internet coupled with new video centric services has increased the demand for high bandwidth in access networks. Fiber to the home, based on a Wavelength Division Multiplexing Passive Optical Network (WDM-PON) due to its high bandwidth, cost sharing of Infrastructure and absence of active components, is considered as a good solution to this demand. With the rapid progression of broadband wireless communications, FSO has emerged as a promising technology to provide high data transmission rates over short distances at places where Optical fibers cannot be reached. WDM technique started a revolution in optical communication network due to the fact that capacity of system can be increased simply by increasing the number of channels and tightening the channel spacing without using more than one FSO link. So, WDM approach can be applied in FSO systems to maximize bandwidth usage but in a cheaper way. WDM over FSO communication system has become very efficient communication system in wireless communication system due to its high data rate, security, and minimum bit error rate (BER) [7]. WDM-PON/FSO is a next generation to the deployment of FSO based access network which can provide high bandwidth [1].This Hybrid Optical network can take the advantage of both optical access networks and FSO technologies to create a promising flexible gigabit-bandwidth-capable solution for next generation mobile backhaul networks.

Keywords: BER, FSO, WDM, WDM-PON/FSO, WDM-PON,

1. Introduction

The rapid expansion of high-speed internet market and data communications has accelerated the demand for broadband access. Broadband services and networks are among the fastest growing areas in telecom. The demand for greater bandwidth in access networks is already fuelling a similar growth in all remaining part of the networks and will continue to do so even more [1]. There is a compelling need to deliver new services to a wide number of users over a unique platform while achieving convergence (a network for all the services), flexibility (a network for every situation) and lowering overall costs (low investment and maintenance cost)[17]. The only sensible way to reduce the costs of ownership while delivering high bandwidth services is to use a very simple network, capable to fully exploit the benefit of the optical technology and fiber based networks [2]. Fiber to the home, based on a passive optical network (PON), has been extensively investigated due to its high bandwidth, cost sharing of infrastructure, and absence of active components [4]. Historically, the maximum transmission length of a PON has been considered to be 20 km. Gigabit PONs are being widely deployed in response to the exploding demand for high bandwidth. Services such as IP high-definition video delivery, voice-over-IP (VoIP), social networking and cloud computing will push the demand for bandwidth even beyond what is achievable with today's gigabit PONs [4]. However, these types of optical access networks which typically serve 32 customers over reaches ranging from 20 km to 60 km (in the case of reach extended PONs) may not be the ultimate solution for network operators which seek to radically reduce the cost of supplying broadband services[18]. In next generation, the wide-area broadband access networks are required to offer high-speed connection services between the central office (CO) and Remote Nodes (RNs) [20]. The wavelength division multiplexed passive optical network (WDM-PON) is the new promising solution for PON implementation. In comparison with today's widely used time division multiplexed PON (TDM-PON), WDM-PON offers higher bandwidth per user, higher security, and longer optical network reach [4].

2. Literature Review

In the recent decade, a great deal of scientific researches and studies have been performed on High Speed Bidirectional Hybrid Optical Wireless Network.

Parkash S. et al. [1] demonstrated 40 GB/s, 8 channel Dense Wavelength Division Multiplexing (DWDM) over free space optical (FSO) communication system. Each channel transmitted 5 GB/s data rate in downstream separated by 0.8 nm (100 GHz) channel spacing with 1.8 GHz filter bandwidth. This system

effectively transmitted high data rate with very low BER over 4000 mtr with RZ modulation. Sharp increase in BER occurs if data rate and distance increase up to 10 GB/s and 5000 mtr.

Nguyen et al. [2] analyzed the performance of TWDM-PON/ FSO-hybrid backhaul downlink and concluded that TWDM-PON/FSO-combined system can take the advantages of both optical access networks and FSO technologies to create a promising flexible gigabit-bandwidth-capable solution for next generation mobile backhaul networks.

Kurbatska I. et al. [3] compares performance of different modulation formats for 16-channel (WDM-PON) with transmission speed of 10 Gbit/s per channel. Non return to zero (NRZ), return to zero (RZ), carrier suppressed RZ (CSRZ), duo-binary (DB), NRZ differential phase shift keying (NRZ DPSK), RZ-DPSK and CSRZ-DPSK formats are compared to evaluate their performance for the network topology. It is showed that DB and CSRZ-DPSK formats yield better performance.

Kurbatska I. et al. [4] presented a view to investigate the influence of laser output power, length of dispersion compensating fiber (DCF) and application of erbium-doped fiber amplifiers (EDFA), as well as impact of optical components configuration on received signal quality [4].

Parkash S. et al. [5] presented a demonstration of a high speed 15x48GB/s wavelength division multiplexing passive optical network (WDM-PON) in downstream with 20km fiber length. A link design for 1:48 optical splitter is used as Passive Optical Network (PON) element which creates communication between OLT to different end users. Sharp increase in BER occurred if data rate is increased up to 20 GB/s.

Parkash S. et al. [6] enhanced the performance of 32 channels & 20 Gbps capacity WDM-PON network in downstream by using DFE and FFE techniques over a distance of 40 km using Single mode Fiber. Sharp increase in BER occurs if data rate is increased upto 25 Gbps.

Aditi et al. [7] presented a view to overcome the losses due to attenuation & analyzed the laser power in FSO system by changing the power level. The performance is compared with that of system with constant power. The results revealed that for higher attenuation, there is no significant decrease in link distance if power is reduced from 40dBm to 10 dBm.

Chaudhary S. et al. [8] evaluated (WDM) wavelength division multiplexing approach on free space optical (FSO) transmission systems. Eight independent channels having capacity of 1.56 Gbps each are transmitted over FSO link having a span of 15km. Furthermore, the performance of proposed FSO-WDM system is also evaluated on the effect of varying the beam divergence and results are reported in terms of SNR, BER and eye diagrams.

Khalighi M. et al. [9] presented a view of FSO communication systems & described FSO channel models and transmitter/ receiver structures. It also focused on system design and research activities to approach theoretical limits of FSO channels.

Boroon M. et al. [10] evaluated a new multi-wavelength erbium doped fiber laser (EDFL) and its effectiveness in FSO communication. 8 channels of 1.25 Gbps each are extracted from EDFL and sent to through a single FSO channel. Reliability of signal is investigated over a link range of 1.4 Km**.**

He J. et al. [11] presented a view of the recent researches in optical communications, focused on the topics of modulation, switching, add-drop multiplexer, coding schemes, detection schemes, orthogonal frequency-division multiplexing, free space optics, and optics in data center networks and encouraged further research in this area & the deployment of new technologies in production networks.

Henninger H et al. [12] reviewed the concepts related to the challenges a system designer has to consider while implementing an FSO system. Typical gains and losses along the path from the transmitter through the medium to the receiver are introduced in this article.

Sharma V et al. [13] presented a demonstration of fading resistant FSO system using a simulated test-bed employing FSO link with acceptable SNR and BER with the highest stream rate of 2.5 Gbps under the impact of diverse weather conditions.

Fadhila H. et al. [14] evaluated the quality of data transmission using Wavelength Division Multiplexing (WDM). The results of these analyses are to develop a system of quality-free space optics for a high data rate transmission.

Wang P. et al. [15] presented a view that the aperture effects averaging on each decision threshold in weak to strong turbulences in FSO are studied and compared. This work is helpful in the design of the receivers in FSO communication systems.

Jia Z. et al. [16] analyzed the BER performance for hybrid FSO/RF systems operating over atmospheric attenuation channels and concluded that BER is decreased in the adverse weather conditions and with the increase in distance.

As concluded form the literature survey, authors demonstrated a 40 Gbps, 8 channel Dense Wavelength Division Multiplexing (DWDM) over free space optical (FSO) communication system in downstream direction only (Uni-directional). Each channel transmitted 5 Gbps data rate in downstream separated by 0.8 nm (100 GHz) channel spacing[21]. This system effectively transmitted high data rate with very low BER over 4000 mtrs with RZ modulation. In this system, there is sharp increase in BER , if data rate and distance are increased up to 10 Gbps for each channel and 5000mtr.

3. Conclusion and Review

Table1: Conclusion of Literature Survey

S. No	Title of Paper	Authors	Bit Rate	Type of Network	Modulation Technique Used	Conclusion
1	Performance Investigation of CRZ Modulation Format in GEPON Fiber to the Home (FTTH) Network at 2.5G/bits for 200 ONU's	Parkash S. et al.	2.5 Gbps	Gigabit Ethernet Passive Optical Network (GEPON) FTTH network	CRZ Modulation	As the number of user's increases beyond 200 users the BER comes to unacceptable level and if further increase data rate of system say 5Gbps, then we observes a sharp increase in BER.
2	Performance Enhancement of WDM-PON FTTH Network by Using Decision Feedback and Feed forward Equalizations.	Parkash S. et al.	32 Channel 20Gbps	WDM-PON Network	NRZ	The designed system in this paper is capable of high speed data rate transmission 20*32Gbps
3	Performance Analysis of Gigabit-capable Mobile Backhaul Networks Exploiting TWDM-PON and FSO Technologies	Nguyen et al.	Flexible	TWDM-PON/FSO		The numerical results demonstrated that the combination of TWDM-PON and FSO can provide a flexible and gigabit-bandwidth-capable solution for next generation mobile backhaul networks.
4	Performance Comparison of Modulation Formats for 10 Gbit/s WDM-PON Systems	Kurbatska I. et al.	10 Gbps	16 Channel WDM-PON	NRZ,RZ, CSRZ, DB, NRZ-DPSK, RZ-DPSK	Among the investigated and compared NRZ, RZ, CSRZ, DB, NRZ-DPSK, RZ-DPSK and CSRZ-DPSK formats the best performance for investigated WDM-PON system is yield by DB and CSRZ-DPSK
5	40-Gb/s Downstream and 10-Gb/s Upstream Long-reach WDM-PON Employing Remotely Pumped EDFA and Self Wavelength Managed Tunable Transmitter	Wang et al.	40-Gb/s Downstream and 10-Gb/s Upstream	WDM-PON	DQPSK downstream using MZ Modulator and 10-Gb/s OOK upstream using optical beat noise-based self wavelength managed tunable transmitter	Experimental results show the effectiveness of the optical beat noise-based automatic wavelength control method and the long-reach WDM-PON scheme has a good BERs performance even the transmission distance extended to more than 40-km SSMF.

4. Future Work

High speed bi-directional WDM-PON/FSO Network with 8 channels, 40 Gbps each in downstream direction and 10 Gbps each in upstream direction will be implemented. Then performance of the system will be optimized by varying different parameters like Bit rate, Beam divergence, Attenuation etc. As the system has been analyzed for RZ modulation format there is a scope to analyze it under other modulation formats like CRZ, OQPSK and DPSK etc. This system has a scope to enhance the distance from 4000 mtrs. The system will be further optimized to make it long reach.

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