International Journal of Engineering Research and General Science Volume 3, Issue 1, January-February, 2015
ISSN 2091-2730

A SURVEY ON CHALLENGES IN WDM-PON SYSTEMS

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Abstract— Communication is a process of exchanging information and ideas between users. In today's world communication networks have emerged as a source of empowerment. Optical communication has a dynamic role in providing secure communication. A Wavelength Division Multiplexing-Passive Optical Networks (WDM-PON) generally supports much higher bandwidth in optical communication. This paper involves a survey on the analysis of the performance parameters for WDM-PON systems. A PON network provides upstream and downstream communication through WDM with different wavelengths. Many parameters such as BER, quality factor, power penalty, etc. are analyzed in this survey for WDM-PON system. With this survey the future researchers will get idea about colorless WDM-PON which supports simultaneous transmission of multiple services in optical communication

Keywords— Wavelength division multiplexing (WDM), Passive optical networks (PON), colorless, downstream, upstream, (Bit error rate) BER, power penalty.

INTRODUCTION

The wavelength division multiplexed passive optical network (WDM-PON) is highly used for its large data bandwidth, enhanced security and scalability to support several local subscribers. Still now various techniques have been proposed by researchers in WDM-PON system. A system that involves with transmission of a single service or a number of services is proposed with WDM-PON. Each system operates with different and discrete techniques. Various methods are also employed for providing both upstream and downstream in a WDM-PON. Simultaneous transmission of wireless and wireline services in which one WDM slot is used to carry the downstream signals is proposed for a WDM-PON [1]. In case of wireless signal some particular range of radio wave signals are used. Many techniques that involve the transmission and analysis of Ultra Wideband signal is proposed for a WDM-PON. For this it should be first noted that whether a corresponding signal is compatible with a WDM-PON or not. Thus a UWB over fiber system that is compatible with WDM-PON based on Fabry-Perot laser diode is reported in [2].

A simple approach to realize flexible access of wireline and IR-UWB services was proposed. The performances of both the services were measured in case of different data rates [3]. A WDM-RoF-PON that can achieve wireline and wireless access synchronously was designed. This system is based on the polarization multiplexing (PM) and Carrier-Suppressed Return to Zero Quadrature Differential-Phase-Shift-Keying (CSRZ-QDPSK). It provides source free (Optical Network Units) ONUs [4]. A spectrally sliced ASE (Amplified Spontaneous Emission) injected RSOA (Reflective Semiconductor Optical Amplifier) with 50 GHz channel spacing was investigated. Then a loop back WDM-PON with 100 Gb/s capacity using the spectrally sliced ASE injected RSOA was designed [5]. A WDM/OCDM PON with loop back configuration is designed which is also capable of upstream transmission. This system is proposed as a simple system with the use of short optical pulses. The quality of these short optical pulses are examined for the designed WDM/OCDM PON system and found to be sufficient for 4-chip OCDM encoding at the Optical network units (ONUs) [6].

An analysis and investigation of the performance of receivers of different classes of WDM PON system is proposed. The performance is analyzed using Manchester coding for different receivers using various data rates and various fibre distances at the optical network unit in a 32 user WDM PON and DWDM PON [7]. WDM-PON architecture is demonstrated which provides a high speed point-to-point downlink data and double-broadcast services with a data rate of 1.25 Gb/s. These two services are provided simultaneously by the proposed WDM-PON system [8]. A centralized light source WDM-PON which supports simultaneous transmission of two services is proposed. The two services are point-to-point data and broadcast services with data rates of 10 Gbit/s differential quadrature phase shift keying (DQPSK) as downstream data and superimposed 2.5 Gbit/s inverse return-to zero (IRZ) broadcast service [9]. A WDM-PON system is designed with upstream scenario and the performance of the system is measured by incorporating tunable lasers in the ONUs [10].The performances of the systems are analyzed along with various parameters. Some of the important parameters are BER and power penalties. The remaining part of this article analyzed and examined about concept behind WDM-PON systems, upstream and downstream communication and performance analysis of the different parameters of WDM-PON systems.

WDM-RoF PON systems

A wavelength division multiplexing–passive optical networking (WDM-PON) architecture that is compatible with 60 GHz Radio-over-Fiber (RoF) systems is designed. This system is capable of providing both wireless and wired services simultaneously. Each wireless/wire-line channel is placed in one WDM slot to carry a 2.5 Gb/s Orthogonal Frequency Division Multiplexing (OFDM) signal. The downstream wavelengths of the wireless and wire-line channels and reused for uplink by an on–off-keying modulation format signal. In this paper, the design for wireless and wireline channels is independent. Because of this the layouts of wireless or wire-line channels are flexible for different applications. From the analysis results it is noted that the power penalty for both 2.5 Gb/s wire-line downstream and 2.5 Gb/s wireless downstream are less than 0.5 dB. This performance exists for BER of 1×10^{-4} for 20 km

transmission. The power penalty is less than 1 dB for BER of 1×10^{-4} for 50 km transmission. It is also analyzed that the wireless upstream power penalty is less than 0.4 and 0.7 dB at a BER of 10^{-9} over 20 and 50 km of SMF, respectively. The power penalty for wire-line upstream is less than 0.2 and 0.4 dB at a BER of 10^{-9} over 20 and 50 km SMF, respectively.

Compatibility of UWB in WDM-PON:

A novel approach to check the compatibility of ultra-wideband (UWB) over fiber system with wavelength-division-multiplexing passive optical network architecture is demonstrated. This method is designed with a key device which is a Fabry–Pérot laser diode (FP-LD). The FP-LD is made to operate as an active optical filter. In order to generate the UWB signal, the phase modulation is converted to intensity-modulation. This is achieved by locating the optical carrier of a phase-modulated injection optical signal at one slope of the filter response. The generated UWB signal has a power spectrum that meets the FCC-specified spectral mask. Experimental evaluations are made with measured eye diagrams and bit-error rates. Transmission is carried by a 20-Km single-mode fiber. Two cases were examined. Error free operation is achieved while placing the FP-LD in the remote site and the in the center office. The power penalty for the transmission is less than 3.2 dB. This approach is used for applications in future wired/wireless converged optical access networks.

WDM-PON-Compatible System for distribution of two different services

A novel and simple scheme for realizing flexible access for gigabit wireline and impulse radio ultra wideband (IR-UWB) wireless services for IR-UWB-over fiber based on multi-subcarrier up conversion has been proposed and experimentally demonstrated. Multi-carrier up conversion and reshaping of the baseband signals is used to create the UWB signals. This method of generation provides very simple UWB generation and efficiently improves access flexibility. Experimental demonstration of the proposed system was carried with the performances of 2.0-Gb/s data in both baseband and UWB formats. Performances are also measured after transmission of the signal by a 46-km single mode fiber and further 0.5-m wireless for UWB data. The system's flexibility is confirmed by investigating the performance of the system at different data rates. Performances are measured for data rates including 1.0 and 1.6 Gb/s. The compatibility of the system is confirmed with the existing Wavelength division multiplexing (WDM)-Passive optical networks (PON) systems because of the optical wavelength independency and data-rate flexibility of UWB signal generation.

WDM-RoF-PON for wireless and wireline access

A wavelength-division multiplexed radio-over-fiber passive optical network (WDM-RoF- PON) based on polarization multiplexing (PM) and carrier suppressed return-to-zero quadrature differential phase- shift keying (CSRZ-QDPSK) is designed. This design can achieve wire-line and wireless access synchronously. The bandwidth utilization is improved by the system because of the use of PM and QDPSK modulation. This approach provides a key new feature which contains a source-free optical network units (ONUs) including wireless access and upstream communication. The WDM-PON system is colorless because the ONU saves the laser source. This happens by the use of a Reflective Semiconductor Optical Amplifier (RSOA) and the reuse of the downstream light source. It is found that the networking has some credible transmission properties through the analysis results. The properties include wireless access and fiber transmission. It also has a large coverage area. From this analysis it is noted that the narrow laser bandwidth and steady frequency and phase of the subcarrier signal are the key technologies to achieve a better property of access networking.

A loop-back WDM-PON system

A successful demonstration of loop-back wavelength division multiplexing passive optical network (WDM-PON) with a 100 Gb⁄s (80 × 1.25 Gb⁄s) capacity using a spectrally sliced amplified spontaneous emission (ASE) injected reflective semiconductor optical amplifier (RSOA) is proposed. An investigation of the 1.25 Gb⁄s operation of a spectrally sliced ASE injected RSOA with 50 GHz channel spacing is carried here. Three methods were used to alleviate the system performance degradation which is caused by relative intensity noise (RIN) deterioration. First the injection current is adjusted into the RSOA properly in order to mitigate post-filtering induced RIN degradation. Then the dispersion management method is employed to improve the Chromatic Dispersion-induced intensity noise degradation for spectrally sliced light. Finally, an optical receiver is adopted with an optimized decision threshold level. This is done to detect a modulated signal with a relatively large intensity noise component. By these methods, complete operation of error free upstream and downstream transmissions were obtained in the loop back WDM-PON.

In order to realize the WDM-PON with a large capacity (~100 Gb⁄s), transmission experiments were performed over 20 km of SMF with 80 WDM channels at 1.25 Gb⁄s. The transmission impairments, like dispersion penalty and back-reflection induced penalty are also examined for a 1.25 Gb⁄s bidirectional WDM-PON that is based on an RSOA with 50 GHz channel spacing. Error-free transmission for almost all WDM channels within a 1.5 dB power penalty is achieved in the downstream transmission experiments. Similarly, error free transmission performance for all upstream WDM channels is also accomplished. The power penalty arising from the variations of power injected into the RSOA at the ONU and from variations in the downstream extinction ratio (ER) was approximately 3dB. It is concluded that there is no problem in transmitting a spectrally sliced ASE at a 1.25 Gb⁄s line rate in a loop-back WDM-PON based on an RSOA with a 50 GHz channel spacing and in future the capacity of this system could be expanded to up to 100 Gb⁄s (80 × 1.25 Gb⁄s).

WDM/OCDM-PON system with loop-back configuration

Design of a 2WDM/4OCDM-PON was successfully demonstrated using a remotely supplied short optical pulse source. The design is proposed in loop-back configuration. This system is designed without the use of any high cost devices. An investigation of loop-back transmission of short optical pulses for OCDM in upstream transmission was done in this paper. This makes the Optical network units (ONUs) simple. The short optical pulses of two gain switching laser diodes (GS-LDs) which has a repetition rate of 1.25 GHz is generated in the OLT and is amplified by the remotely pumped EDFA. The amplified short pluses after passing the AWG and splitter at the remote node (RN) are transmitted to the ONUs.

The pulse sources are individually injected into the reflective semiconductor optical amplifiers (RSOAs) at the ONUs. Along with these pulse sources the injected short pulses at the RSOAs were amplified and intensity modulated with upstream data at 1.25 Gb⁄s. The quality of these short optical pulses was supplied through a 23 km single-mode fiber (SMF), and this is sufficient for 4-chipOCDM encoding at the ONUs. And for this system, error-free transmission of the signals at a BER of $<10^{-9}$ was achieved. By the analysis results the power penalties were examined for one interfering channel and three interfering channels. It was found that the power penalties are about 0.8 dB with only one interfering channel and around 2 dB with three interfering channels.

Performance analysis of different receivers for a WDM-PON

Performance analysis and investigation of receivers for different classes of WDM PON system was carried out in this paper. Two different photo receivers were taken for the analysis. One is the PIN receiver and the other is the Avalanche Photo Detectors (APD) receiver. These two different receivers were taken with various data rates and various fibre distances at the optical network unit (ONU). The performance is analyzed using Manchester coding. The analysis is carried on for a 32 user WDM PON and DWDM PON. The results are analyzed using the parameters BER, Qfactor and Eye Pattern. It is found that at higher distance, in PIN receiver the BER value is significantly very less as compared to that of APD receiver. It is also noted that as the distance is increased to 150 Km the BER value for PIN is even less than the minimum required BER value. And at less distances i.e., distances less than 60 Km range there is not much difference between PIN and APD BER values. In terms of data carrying capacity per user the performance gain is found to be around 2.5 Gbps. This is achieved if the APD receivers are used in the receiver side downstream direction.

WDM-PON with different services and source free ONUs

In this paper, a novel WDM-PON architecture is experimentally demonstrated with simultaneous provision of high speed point-to-point downlink data and double-broadcast services. These services are provided with a data rate of 1.25-Gb/s. It is proposed that the double broadcast services could be overlaid over high-speed point-to-point downlink data in a WDM-PON with source-free optical network units (ONUs). A set of single-drive Mach- Zehnder modulators (MZMs) are driven in the optical line terminal (OLT) by downlink point-to-point data to generate a differential phase-shift keying (DPSK) format. Here a dual-parallel MZM (DPMZM) is used as a double broadcast services transmitter. The downlink DPSK signals which are obtained from different wavelengths are multiplexed.

The multiplexed signals are then fed to the DPMZM. The broadcast service-1 is optical carrier suppression (OCS) format, while the broadcast service-2 is an inverse return-to-zero (IRZ) format. The broadcast service-2 i.e., the DPSK/IRZ signals are split into three parts, first part is made to be detected by an IRZ receiver. This recovers the broadcast service-2. The second part is detected by a DPSK receiver, which retrieves the downlink data and the third part is re-modulated by the upstream amplitude shift keying (ASK). At each Optical network unit (ONU), the optical signals are separated with the help of an optical filter after transmission. The broadcast service-1 is retrieved after detecting the filtered OCS signals. After 25-km transmission of the signals the power penalties of less than 1.5 dB are obtained. The proposed WDM-PON system is found to provide significant improvement on both implement cost and system reliability.

A simple and cost-effective WDM-PON

This paper deals with the performance analysis of centralized light source WDM-PON. This system supports simultaneous transmission of two different services i.e., point-to-point data and broadcast services. Both downstream and upstream operations are carried out by this system. The downstream operation involves a data rate of 10 Gbit/s differential quadrature phase shift keying (DQPSK) and superimposed 2.5 Gbit/s inverse return-tozero (IRZ) broadcast service which are simultaneously transmitted from optical line terminal (OLT) in downstream channels without pulse carving and EDFA amplification. The upstream operation at optical network unit (ONU) involves a data rate of 2.5 Gbit/s on-off keying (OOK) signal using re-modulation of downstream signal power. Additional laser is not used at (ONU).

The performance of such WDM-PON is examined by transmitting both the signals through a 20 km single mode fiber (SMF). It is found that both the downstream and upstream transmission of the different signals with different data rates can be successfully achieved for a distance of 20 km. It is also noted that the system provides improved transmission power penalties and receiver sensitivity which is made clear from the transmission performance analysis in which the eye diagrams has clear and wide eye-openings. Because of this a simple and cost-effective WDM-PON could be implemented in future.

WDM-PON with tunable lasers in ONUs

Design of WDM-PON with tunable lasers in the ONU is proposed in this paper. The tunable lasers are mainly focused for upstream data transmission. These lasers are potential upstream optical light generators and are considered as a promising solution for next-generation broad-band optical access. More traffic could be admissible with broader tuning ranges of the lasers. But this requires sophisticated technology which is of high cost. Thus an optimal tradeoff between the admissible traffic and the cost must be achieved. For this the relationship between tuning ranges of the lasers and admissible traffic of the networks is investigated. By this investigation lasers with proper tuning ranges for the upstream data transmission could be selected and the appropriate WDM PON is designed. Two issues under three scenarios were addressed and focused for this.

The two issues are: how the largest traffic is admitted by proper selection of lasers, and how the given upstream traffic is admitted by using lasers with tuning ranges as narrow as possible. The three scenarios are: the availability of full-range tunable and wavelength-specific lasers, the availability of limited-range tunable lasers, and the lasers with specific tuning ranges are given exactly. In this paper it is given that in the first scenario some full-range tunable lasers are replaced with wavelength-specific lasers. And this is done without decreasing the admissible traffic. In the second scenario the admissible traffic is maximized by selecting lasers with proper tuning ranges. In the third scenario the given rate can be admitted by allocating lasers to ONUs. The ideas in each scenario provide steps to design cost-effective WDM-PON.

CONCLUSION

This research provides a survey on various WDM-PON designs with downstream operation and some designs with upstream operation along with the downstream. Each design has distinct and different techniques for transmitting a single signal or multiple signals. The performances of each design are noted in this survey. The performances are examined and analyzed by the parameters like power penalty, BER and some other simulation results. With the help of this survey, the researchers can implement WDM-PON with simultaneous upstream and downstream operation for both wireless and wireline data. In case of wireless data millimeter wave, Impulse radio Ultra wideband and some other signals can be used for analysis based on the requirement of the research and the performance of the system can be measured by analyzing the parameters like power penalty, BER and receiver sensitivity.

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