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Method and Modelling for Allocating Wavelength in WDM Passive Optical Networks

Vikas Chhabra, Monika Dhiman

***Abstract*— To circumvent issue of Rayleigh noise reduction in wavelength-division-multiplexed passive optical network (WDM-PON), we provide an insight into the source of Rayleigh noise, and confirm that suppression of carrier Rayleigh backscattering (RB) should be the primary target in the design of Rayleigh noise-resilient upstream receiver module. It propose and demonstrate an effectively scheme suppress the carrier RB in carrier-distributed WDM-PONs. This paper studies alternative network architecture with dynamic wavelength allocation to provide a scalable optical architecture with a guaranteed QoS in the presence of dynamic and bursty traffic loads. In this research work, the issue of connection provisions and performance analysis in WDM network ensuring the quality of service requirement of the connection requests from the client in the network in optical networks. While designing WDM system is explored, it considers the physical layer impairments incurred by non-ideal optical transmission media that accumulates along the optical path. For very high transmission speed, dispersion developed a considerable degradation factor and in this work concentrated on the effects of dispersion on fiber design parameters such as bandwidth, delay and bit rate. The dependence of carrier RB suppression on DI's extinction ratio (ER) and optical carrier's line width is also theoretically analysed. In this article, we present a delay-constrained admission control mechanism and adapt this scheme to our previously proposed bandwidth allocation technique. The main relations between different parameters of optical network unit (ONU) are also studied.**

***Index Terms*— Passive Optical Networks, WDM-PON, Wavelength Allocation, Rayleigh Scattering Parameters.**

I. INTRODUCTION

Foreseeing the rapidly growing demand for multimedia services and the trend of service convergence, the wavelength-division-multiplexed (WDM) passive optical network (WDM-PON) is a promising technology to provide next-generation broadband access that requires large dedicated symmetric bandwidth and upgrading flexibility. An optical network is a type of data communication network built with optical fiber technology. It utilizes optical fiber cables as primary communication medium for converting data as light pulses between sender and receiver nodes. Wavelength division multiplexing (WDM) technology is a strong candidate for next generation high performance networks because it provides large bandwidth, low bit error rate, low control requirements and low cost. WDM knowledge has provided tremendous bandwidth for optical fibers by allowing simultaneous transmission of traffic on many non-overlapping channels (wavelengths) in an optical fiber [1].

In a wavelength-routed WDM system, end users communicate with one another via all-optical WDM channels, which are referred to as light paths [2]. A passive optical network (PON) is a point-to-multipoint, fiber to premises system architecture in which unpowered optical splitters are used to enable a single optical fiber to serve multiple premises, typically 16-128. A PON consists of optical line terminal (OLT) at the service provider's central office and a number of optical network units (ONUs) near end users. Passive optical network (PON) has advantages in high bandwidth capacity, also low operation and maintenance rate, and has been measured as a promising access network solution and widely deployed [3]. Various PONs, e.g., Ethernet PON (EPON) and Gigabit-capable PON (GPON), use time division multiplexing (TDM) technique to enable multiple users to share a common wavelength bandwidth resource in PON, and they are called as TDM PONs. WDM technology enables network operators to continuously increase the capacity of their networks. Undoubtedly, WDM will continue the key technology to satisfy the ever increasing demand for more bandwidth within the next years [3].

In multi-hop network design, the selection of a proper logical topology is followed by the wavelength assignment process. The simplest scheme for wavelength assignment assigns one wavelength channel to each of the logical links. An alternative scheme that requires a smaller number of wavelengths and transmitters is the assignment of one wavelength channel per end-node. If number of wavelength channels in the network is smaller than the number of end-nodes, these schemes will fail. The carrier RB light towards OLT, with a fine spectrum, can be effectively suppressed by an optical notch filter. While carrier regeneration decreases number of wavelengths, the signal quality of carrier must be considered because it becomes slightly worse after regeneration. If signal quality becomes unacceptable after several regenerations, its wavelength should not be reprocessed anymore in order to eliminate communication fault. i.e, the allowable number of carrier regenerations per wavelength should not be exceeded [6].

The paper is organized as follows. In section II, we discuss related work with the wavelength allocation scheme. In Section III, It describes the types of PON. Section IV describes the proposed system architecture and analyse the different parameters of Rayleigh scattering in impairing the upstream signal. Section V reports the effectiveness of the proposed scheme and also describes the results of scheme.

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Vikas Chhabra, ECE Department, Galaxy Global Inst. of Engg, Kurukshetra University, Ambala, Haryana.

Monika Dhiman, Asst. Professor, Ambala College of Engg. & Applied Research/ ECE Department, Kurukshetra University, Ambala, Haryana .

The various relations between different parameters are examined. Finally, conclusion is given in Section VI.

II. RELATED WORK

In literature, several proposed Rayleigh noise reduction in wavelength-division-multiplexed passive optical network (WDM-PON). Then they propose and demonstrate a novel scheme to effectively suppress the carrier RB in carrier-distributed WDM-PONs. By simply replacing upstream modulation format of conventional on-off keying with differential phase-shift keying (DPSK), the system tolerance to carrier RB is substantially enhanced by 19 dB, as carrier RB can be considerably rejected by the notch filter-like destructive port of the delay-interferometer at the optical line terminal, which is used instantaneously to demodulate the upstream DPSK signal. As no thoughtful spectral up-shifting is required in this scheme, neither other modulator nor complicated modulation/demodulation circuit is needed at ONU/OLT. In terms of optical notch filter used to reduce RB light, the standard DI used in the future scheme is also more favourable than the non-standard filters [2].

Authors propose and demonstrate a novel colourless optical transmitter based on all-optical wavelength conversion using a reflective semiconductor optical amplifier for upstream transmission in wavelength -division- multiplexed passive optical systems. The proposed colourless optical transmitter for the optical network unit is composed of an electro-absorption modulated laser, a photosensitive coupler, and an RSOA. Through cross-gain modulation in RSOA, the upstream data from the EML pump light are imposed onto a continuous-wave probe light provided from the central office. An optical delay interferometer at CO tailors the chirp of the upstream signal to improve the bandwidth of the system and dispersion tolerance. The proposed optical transmitter is based on the fast gain recovery of the RSOA governed by carrier-carrier scattering and carrier-phonon relations. End-to-end real-time optical orthogonal frequency-division multiple-access (OOFDMA) passive optical networks (PONs) with adaptive dynamic bandwidth allocation (DBA) and colourless optical network units (ONUs) are experimentally established, for the first time.

Next generation Passive Optical Network (PON) technology has been evolving to consolidate the metro and access networks in order to offer enhanced capacity, high split ratio and compact deployment cost per subscriber. However, transmission of signals to long distances up to 100km leads to increased propagation delay whereas high split ratio may lead to long cycle times resulting in large queue occupancies and long packet delays. In this article, they current a delay-constrained admission control mechanism and adapt this scheme to our previously proposed bandwidth allocation technique. This paper investigates problem of dynamic wave length allocation and fairness control in WDM optical networks. An f network topology, with a two-hop path network, is studied for mainly three classes of traffic. Each class corresponds to a source & destination pair. For each class call inter-arrival & holding times remain studied. The objective is to find a wavelength allocation policy to maximize the weighted sum of users of all the three programs. In a conventional WR network, an entire wavelength is assigned to a given connection. This can lead to lower channel utilization when individual sessions do not need the entire channel bandwidth [7].

III. TYPES OF PON

A PON system uses the passive splitter that takes one input and splits it to "broadcast" signals to many users.

A. Broadband Passive Optical Network

For many network operators, an optical access network is the ultimate target for the delivery of fixed broadband services. The BPON is accepted as a cost-effective fibre to the home solution well-suited to the future needs of broadband services. A major feature of the BPON is that 32 customers can be concentrated on a single fibre to the central office using a simple passive optical splitter. Since optical splitter requires no electrical power, it removes a major cost and maintenance element in today’s digital loop carrier systems. The BPON supports a bit rate of 622 or 155 Mbit/s in the downstream and upstream direction, which is shared by the users through time division multiplexing. Broadband passive optical network standards are based on the G.983 series of ITU-T Recommendations that specify ATM as the transport and signalling protocol. By improving the optical budget on the BPON fibre, up to 128 or 256 homes could be “passed” by a single high split. Up to 64 of these homes could be connected, which is the maximum number of ONUs (Optical Network Unit) that can be identified by a G.983.1 compliant system. In preparation for higher service penetrations, optical splitter in the outside network would be limited to 8, 16 or 32-way split. Since exchange carriers have an extensive embedded ATM switching infrastructure, these carriers are using BPON technology to deploy the fiber-to-the-premises networks. By improving the optical budget on the BPON fibre, up to 128 or 256 homes could be “passed” by a single high split. . In preparation for higher service penetrations, optical splitter in the outside network would be limited to 8, 16 or 32-way split.

B. Ethernet Passive Optical Network

Data traffic is increasing at an unprecedented rate. Sustainable data growth rate of over 100% per year has been observed since 1991. There were periods when a combination of economic and technological factors resulted in even larger growth rates, e.g., 1000% increase per year in 1995 and 1996. Ethernet PON (EPON) is a PON-based network that carries data traffic encapsulated in Ethernet frames (defined in IEEE 802.3 standard). It uses a standard 8b/10b line coding (8 user bits encoded as 10 line bits) and operates at standard Ethernet speed. Since this method encapsulates and transports data in Ethernet frames, it is easy to carry IP packets over an Ethernet link. This scheme thus simplifies the interoperability of metro and wide area network assets with installed Ethernet LANs compared to the use of BPON technology. Ethernet has become a universally accepted standard, with over 300 million port deployments worldwide, offers staggering economies of scale. High-speed Gigabit Ethernet deployment is widely accelerating and 10 Gigabit Ethernet products are becoming available.

Ethernet, which is easy to scale and manage, is winning new grounds in MAN & WAN. Considering the fact that 95% of LANs use Ethernet, which clears that ATM PON may not be the best choice to interconnect two Ethernet networks. One EFM option uses an EPON architecture that follows the standard PON layout, which has one main feeder line going to an optical splitter. Up to 32 distribution branches leave the splitter and interface to ONTs. The IEEE 802.3 standard defines two basic configurations for an Ethernet network. In one configuration, it can be organized over a shared medium using the Carrier Sense Multiple Access with Collision Detection protocol. In another configuration, stations may be connected through a switch using full-duplex point-to-point links. The Properties of EPON are such that it cannot be considered either a shared medium or a point-to-point network; rather, it is a combination of both. In downstream direction, Ethernet frames conveyed by OLT pass through a *1: N* passive splitter and reach each ONU. N is typically between 4 and 64. This behaviour is similar to a shared network. Because Ethernet is broadcast by nature, in the downstream direction (from network to user), it fits perfectly with Ethernet PON architecture: packets are broadcast by the OLT and extracted by their destination ONU based on the media-access control address. In the upstream direction, due to the directional properties of a passive optical combiner, data frames from ONU will only reach the OLT, and no other ONUs.

C. Gigabit Passive Optical Network

The growing demand for higher speeds in the access network spawned the idea of developing a PON with capabilities beyond those of the BPON and EPON architectures. A major aim of this idea was to develop a versatile PON with a frame format that could transmit variable-length packets efficiently at gigabit per second rates. The FSAN group started such an effort in April 2001. The result was the ITU-T recommendation series G.984.1 through G.984.4 for a gigabit *PON.*

The GPON standard is defined in the International Telecommunication Union Telecommunication Standardization Sector (ITU-T) G.984.x series of Recommendations sponsored by the full service access network (FSAN). Several upstream and downstream rates up to 2.48832 Gb/s are specified in the standard. Here we consider the 1.24416 Gb/s upstream rate to make it comparable with EPON. The GPON protocol is based on the standard 125 µs (~19,440 bytes at 1.24416 Gb/s) periodicity used in the telecommunications industry. This periodicity provides certain efficiency advantages over EPON, as messages (control, buffer report, and grant messages) can efficiently be integrated into the header of each 125 µs frame.

Within GPON each Ethernet frame or frame fragment is encapsulated in a general encapsulation method (GEM) frame including a 5-byte GEM header. The network layout for a GPON follows that of a standard PON concept. It also retains much of the same functionality characteristic of BPON and EPON schemes, such as DBA and the use of operations, administration, and maintenance (OAM) messages.

IV. PROPOSED SYSTEM ARCHITECTURE AND RAYLEIGH PARAMETERS

A. *System Architecture*

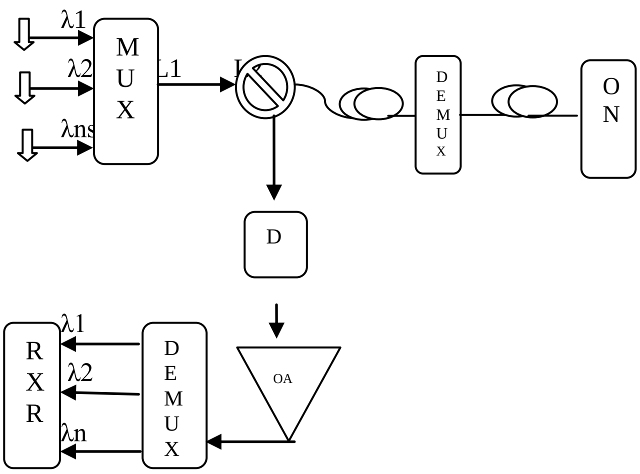

Fig 1: Proposed system architecture to suppress Rayleigh sound. OA: optical amp, D: delay-interferometer, MUX: Multi-plexer, DEMUX: De-multiplexer, ON: Optical network Unit.

Fig. 1 shows the proposed architecture of a WDM-PON. As downstream plus upstream signals are transmitted over different wavelength bands in the carrier-distributed WDM-PON, RB from upstream signal will not affect with the downstream signal, and vice versa. Passive optical systems have high bandwidth Point-to-Multipoint optical fiber network based on the Asynchronous Transfer Mode (ATM), Ethernet or TDM. PONs relies on light waves for data transfer. Only passive components are used such as optical fiber, splices and circulators etc. PONs reduces the fiber deployment in both the local exchange office and local loop. The PON is an access network based on optical fiber [11]. It is designed to provide virtually unlimited bandwidth to subscriber. The multi-wavelength optical carriers for upstream transmission are generated by continuous-wave (CW) lasers as centralized light sources, and then multiplexed through an AWG. After transmission in a feeder fiber with a length of L1, optical carriers are wavelength routed toward different ONUs, by another AWG at the remote node (RN). The length of the distribution fiber (between RN and ONU) is L2. At ONU, CW light is first amplified and then modulated driven by differentially pre-coded upstream data, before being sent back to OLT. Due to DI’s periodic frequency response, all upstream channels could be simultaneously demodulated by a common DI at the OLT. Note that only destructive port of the DI can be used for upstream demodulation and carrier RB suppression simultaneously due to its notch filter-like frequency response [4].

B. Components Used

1. Transponders

Transponder is the basic element for transmission and reception of optical signal from the channel. A transponder is generally characterized by the maximum bit rate it can handle with and the maximum distance the optical pulse can travel without degradation. Transponders convert an optical signal from one wavelength to an optical pulse with another

wavelength. Another important function of transponder device is the conversion of broadband signal to a signal associated with specific wavelength by optical to electrical to optical conversion.
For detection purposes, it uses photo-detector. This photo-detector generates an electrical current proportional to the incident optical power. Photo-detectors are made of semiconductor materials. Photons incident on a semiconductor are absorbed by electrons in the valence band. As a result, these electrons acquire higher energy and are excited into the conduction band, leaving behind a hole in valence band. When an outer voltage is applied to the semiconductor, these electron-hole pairs give rise to an electrical current, termed the photocurrent.

2. Wavelength Cross Connect

Wavelength cross connect is a switching device whose function is to switch or connect any wavelength from the input port to any one of the out port in the fiber. The functioning is completely in optical domain. An OXC with N input and N output ports capable of handling W wavelengths per port can be thought as W independent N×N optical switches. The polarization-independent Acoustic optical tunable filters (AOTF) can be used as a two input, two-output dynamic wavelength cross connect.

3. Couplers

A passive optical network employs a passive (not requiring any power) device to split optical signal (power) from one fiber into several fibers and reciprocally, to combine the optical signals from multiple fibers into one. This device is an optical coupler. In simplest form, an optical coupler consists of two fibers fused together. Signal power received on input port is split between both output ports. The splitting ratio of splitter can be controlled by the length of the fused region and therefore is a constant parameter. A directional coupler is used to combine and split signals in an optical network.

4. Circulators

A circulator is similar to isolator, except that it has multiple ports, typically three or four. In 3-port circulator, an input signal on port 1 is sent out on port 2, a signal on port 2 is sent out on port 3, plus an input signal on port 3 is sent out on port 1. Circulators are useful to construct optical add/drop elements. Circulators operate on the same principles as isolators.

5. Multiplexers

Optical Add-Drop multiplexer is a device which is capable to add or drop one or more wavelengths from the existing WDM system. There are three important domains for an OADM- optical multiplexer, de multiplexer and a method to reconfigure the path between multiplexer and de multiplexer. Demultiplexers and multiplexers can be cascaded to realize static wavelength cross connects. . The device routes signals from an input port to an output port based on the wavelength.

6. Optical Amplifiers

An optical amplifier is a device which amplifies the optical signal directly without optical to electrical conversion i.e., all functions occurs in optical domain. In optical fiber, the light pulse itself is amplified. Optical amplifiers provide high gain and low noise for the optical signal; it has importance in the overall bandwidth provided by WDM system. Optical amplifiers offer several advantages over regenerators. On one hand, regenerators are specific to the bit rate and modulation format used by the communication system. On the other hand, optical amplifiers are insensitive to the bit rate or signal formats. Thus a system using optical amplifiers can be more easily upgraded. Thus a system using optical amplifiers can be more easily upgraded, for example, to a higher bit rate, without replacing the amplifiers. In contrast, in a system using regenerators, such an upgrade would require all the regenerators to be replaced. Furthermore, optical amplifiers have fairly large gain bandwidths. Thus optical amplifiers have become essential components in high-performance optical communication systems.

7. Interferometers

An interferometer is a device that makes use of two interfering paths of different lengths to resolve different wavelengths. Mach interferometers are typically constructed in integrated optics and consist of two 3 dB directional couplers interconnected through two paths of differing lengths. Mach Zehnder interferometers are useful as both filters and demultiplexers. Even though there are better technologies for making narrow band filters, for example, dielectric multi-cavity thin-film filters, MZI are still useful in realizing wide band filters. Narrow band interferometers filters are fabricated by cascading a number of stages.

8. Switches

Optical switches are used in optical networks for a variety of applications. The different applications require different switching times and number of switch ports. One application of optical switches is in the provisioning of light paths. In this application, switches are used inside wavelength cross-connects to reconfigure them to support new light paths. Switches are also important components in high-speed optical packet-switched networks. In these networks, the switches are used to switch signals on a packet-by packet basis.

For this application, the switching time must be much smaller than packet duration, and large switches will be needed. Yet another use for switches is as external modulators to turn on and off the data in front of a laser source. In this case, switching time must be a small fraction of the bit duration. The extinction ratio of an on-off switch is the ratio of the output power in the on state to the output power in off state. This ratio should be as large as possible. The insertion loss of a switch is the fraction of power (usually expressed in decibels) that is lost because of the presence of the switch and must be as small as possible. The switch needs to have a readout capability wherein its current state can be monitored. This is important to verify that the right connections are made through the switch.

C. Rayleigh Parameters

Rayleigh scattering named after the British physicist Lord Rayleigh, is elastic scattering of light or other electromagnetic radiation by particles much smaller than the wavelength of light. After the Rayleigh scattering the state of material remains unchanged, hence this rayleigh scattering is also said to be a parametric process. These particles may be individual atoms or molecule. It can occur when light travels through transparent solids and liquids, but it is most prominently seen in gases. Rayleigh scattering results from electric polarizability of particles. The oscillating electric field of a light wave acts on the charges within a particle, causing them to move at same frequency.

Rayleigh crosstalk is induced by the beating between the upstream signal and the in-band RB noise towards the OLT. Two types of RB exist: carrier RB and signal RB. The carrier RB arises from the CW carrier delivered to ONU, whereas the signal RB is the back reflection of the upstream signal, which is further amplified and modulated at ONU before transmitting to the OLT, along with the upstream signal. By calculating the power ratio between two types of RB, we can find out their different contributions in the upstream Rayleigh noise [5].

We first calculate the power of carrier RB. The mean intensity of the carrier RB produced in the feeder fiber is given by [12]:

$$Pcb1 = \frac{Pc}{R1} \quad (1)$$

Where Pc is the power of optical carrier incident to the feeder fiber, and R1 is RB-induced return loss of the feeder fiber that is given by equation (2):

$$R1 = \frac{2}{S(1-e^{-2\alpha pL1})} \quad (2)$$

With S, αp being the recapture factor, and fiber attenuation factor in units of km respectively. Now, mean intensity of the carrier RB generated in the distribution fiber is given by equation (3):

$$Pcb2 = \frac{Pc}{(\alpha 1 \alpha A)^2 R2} \quad (3)$$

Where α1, αA are the insertion loss of the feeder fiber and the AWG at RN in linear scale, respectively, and is RB induced return loss of the distribution fiber. Now, α1 and R2 are given by equation (4) & (5):

$$\alpha 1 = e^{\alpha pL1} \quad (4)$$

$$R2 = \frac{2}{S(1-e^{-2\alpha pL2})} \quad (5)$$

Similarly, we can calculate the power of signal RB at port 2 of the OLT optical circulator. The mean intensity of the signal RB generated in the feeder fiber is given by equation (6):

$$Psb1 = \frac{Pc * Gonu^2}{R1 * \alpha 1^2 (\alpha A * \alpha 2)^4} \quad (6)$$

With *α2* and *Gonu* being the insertion loss of the distribution fiber and the ONU gain, respectively. The ONU gain is defined as the power ratio between the output and the input signals at ONU. *α2* is further given by equation (7):

$$\alpha 2 = e^{\alpha pL2} \quad (7)$$

The mean intensity of signal RB generated in the distribution fiber is given by equation (8):

$$Psb2 = \frac{Pc * Gonu^2}{R2 * (\alpha 1 * \alpha A * \alpha 2)^2} \quad (8)$$

Algorithm: *Proposed Rayleigh Scattering Parameters*

- *S=0.0016*
- $\alpha_p=0.046$
- *Step 1: For (carrier RB):*
- *Read Length L1 and L2.*
- *Calculate* $(R1=2/S\ (1-e^{-2\alpha pL1})$ *and* $R2=2/S\ (1-e^{-2\alpha pL2}))$.
- *Calculate* $\alpha_1=e^{\alpha pL1}$ *and* $\alpha_2=e^{\alpha pL2}$
- *Then calculate Mean intensity of carrier RB in feeder fiber* $Pcb\_1=Pc/R1$ *and Mean intensity of carrier RB in distribution fiber* $Pcb\_2=Pc/(\alpha_1.\alpha_A)^2 \cdot R2$
- *Step 2: for (signal RB):*
- *Read L1 and L2.*
- *Calculate* $(R1=2/S\ (1-e^{-2\alpha pL}$ *and* $R2=2/S\ (1-e^{-2\alpha pL2}))$
- *Calculate* $\alpha_1=e^{\alpha pL1}$ *and* $\alpha_2=e^{\alpha pL2}$
- *Then calculate Mean intensity of signal RB in feeder fiber* $Psb\_1=P \cdot G^2_{ONU}/R_1.\alpha_1^2(\alpha_A.\alpha_2)^4$ *and (Mean intensity of signal RB in distribution fiber* $Psb\_2 = P_c.G^2_{ONU}/R_2(\alpha_1.\alpha_A.\alpha_2)^2$
- *Step 3: Calculate power ratio between two types of RB:* $P_{cb}/P_{sb}=[(\alpha_1.\alpha_A)^2 \cdot R_2+R1].\alpha_2^4\alpha_A^2/G^2_{ONU}[(\alpha_2.\alpha_A)^2.R_1+R_2]$
- *end*

D.Estimation of Blocking Probability

Blocking probability is simply the ratio of total number of calls blocked to the total number of calls expressed in percentage. Minimum blocking is continually the desired condition for provisioning. A connection requests can be jammed either due to the availability of QoS satisfied path or due to the absence of free light path. Blocking Probability represents in terms of percentage (%). It is represented in terms of Erlangs. The erlang (symbol E) is a dimensionless unit that is used in telephony as a measure of offered load or carried load on service-providing elements such as telephone or telephone switching equipment. It is clear that if the nodes have a smaller transmission radius then the interference constraints on each hop are fewer but the calls hop through many links to reach the destination. This increases the internal load in the system. In contrast, a larger transmission radius reduces the number of hops of a call but increases the interference constraints at each hop. The effect of this trade off on blocking probability is non-trivial and leads to different observations under different node topologies.

Algorithm: Estimation of Blocking Probability

- *m=input('Enter the number of m ');   no. of servers*
- *n=input('Enter the number of n '); % wavelengths*
- *rho=input('Enter the number of rho ');*
- *if ((floor(m) ~= m) || (m < 1))*
- *warning('m is not positive integer');*
- *E=NaN;*
- *return*
- *end*
- *if ((floor(n) ~= n) || (n < 0))*
- *warning('n is not nonnegative integer');*
- *E=NaN;*
- *return*
- *end*
- *if (rho < 0.0)*
- *warning('rho is negative!');*
- *E=NaN;*
- *return*
- *end;*
- *blocking probability is 0.*
- *%*
- *if (m<=n)*
- *E=0;*
- *return*
- *end*
- *E=1;*
    - *for k=1:n,*
    - *E=(rho*(m-k+1)*E)/(k+rho*(m-k+1)*E);*

  end;

E. Relation Between Gain and System Margin

The required gain *Gonu* can be given by equation (9):

$$Gonu = \frac{M \times Pr \times (\alpha 1 \times \alpha A \times \alpha 2)^2 \alpha cir}{Pc} \qquad (9)$$

With *M*, *Pr* and *αcir* being the system margin, the minimum received upstream power and the insertion loss from port 2 to 3 of the circulator respectively. The input power to the feeder fiber is expected to be *Pc=3dBm*. Then, by substituting calculated ONU gain to equation (9), calculate the power ratio between two types of RB for different system reaches, with considering different length ratio between the feeder and distribution fibers.

Then based on equation (9) we can calculate the maximum system margin and the required optimal ONU gain for different system reaches. Thus, an attractive feature of proposed scheme is that all ONU's with similar length ratios can be set to a fixed gain even for a large change in system reach.

F. Estimation Of Bit Error Rate

With the increasing use of high speed serial links in commercial systems, the use of the term bit error rate (BER) is becoming more common place in the serializer- deserializer community. Even though the basic concept of BER is generally easy to grasp, there appears to be much confusion regarding the utility of BER as a system parameter and the elements affecting BER.The bit error rate is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is unit-less performance measure, generally expressed as a percentage. The bit error probability p_e is expectation value of BER. The BER can be considered as an approximate estimate of the bit error probability (BER). This estimate is accurate for a long time interval and a high number of bit errors.

G.Estimation of Delay

For delay computation for fiber link we have to consider the pulse spreading due to various types of dispersion in fiber. The time interruption introduced in optical fiber due to chromatic dispersion can be calculated as equation (10):

$$Tcd = \lambda \times D \times L \qquad (10)$$

Where *D* is the dispersion coefficient and *λ* is the wavelength assigned for the link with length *L*. So, delay completely depends on wavelength assignment value and it provides better performance than related work [10].

A framework is provided for evaluation of packet delay distribution in an optical circuit-switched network. The framework is based on fluid traffic model, packet queueing at edge routers, & circuit-switched transmission between edge routers. Packets are assigned to buffers acc. to their destination, delay constraint, physical route & wavelength. At every choice epoch, a subset of buffers is allocated to end-to-end circuits for transmission (Txn), where circuit holding times are based on limited and exhaustive circuit allocation policies. To ensure computational tractability, framework approximates the evolution of each buffer independently.

V. RESULTS AND DISCUSSION

A. *Simulation Environment Tool*

MATLAB (as shown in fig 2) is the high-performance language for technical computing. It integrates computing, visualization, and programming in the easy-to-use environment where problems & solutions are expressed in familiar mathematical notation. Typical uses include Math & computation Algorithm development Data acquisition Modeling, simulation, & prototyping Data analysis, exploration, & visualization Scientific & engineering graphics Application development, including graphical user interface (GUI) building. Although MATLAB is intended primarily for numerical computing, another toolbox uses the MuPAD symbolic engine that allowing access to symbolic computing capabilities. An extra package Simulink, adds graphical multi-domain simulation & Model-Based Design for dynamic & embedded systems [13].

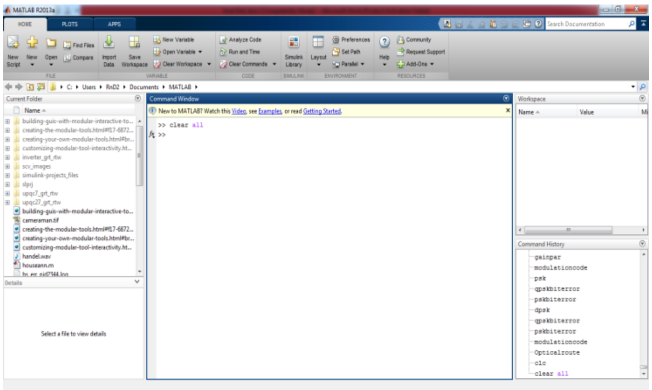

Fig 2: MATLAB Tool

B. *Graphical User Interface*

In computing graphical user interface (GUI) is a type of user interface that allows users to interact with electronic devices using images rather than text command. GUIs can be used in computers, hand-held devices such as MP3, portable media players or gaming devices, household appliances, office, & industry equipment. A GUI represents information and actions available to a user through graphical icons & visual indicators such as secondary (sec) notation, as opposed to text based interfaces, typed command labels and text navigation. These actions are usually performed through direct manipulation of graphical elements. MATLAB apps are self-contained MATLAB programs with GUI front ends that automate a task or calculation. The Graphic User Interface (GUI) typically contains controls such as menus, toolbars, buttons & sliders. Many MATLAB components, such as Curve Fitting Toolbox, Signal Processing Toolbox (DSP), and Control System Toolbox, include applications with custom user interfaces. A GUI uses a combination of technologies and devices to provide a platform that the user can interact with, for tasks of gathering & producing information as shown in fig 3[14].

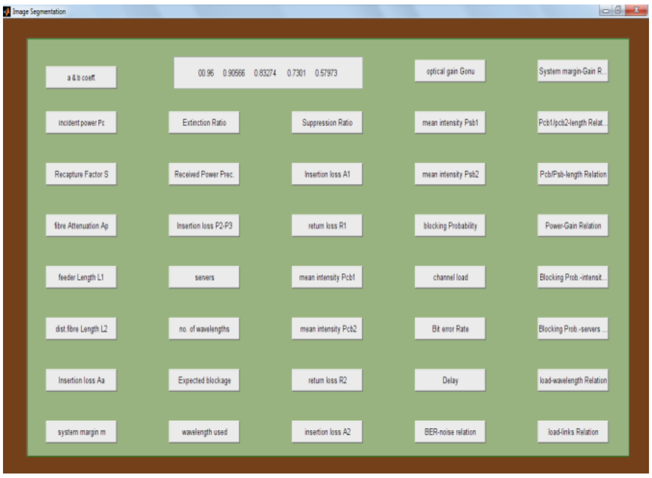

Fig 3: Graphical User Interface Window

C. *Estimation of Power Ratio*

The power ratio between Pcb1 and Pcb2 can be derived via dividing (1) by (3) or via dividing Pcb/Psb. Note that Fig. 4 is independent of ONU gain and all types of RB powers are calculated at port 2 of the OLT optical circulator. An interesting point is that while the carrier RB generated in the feeder fiber is dominant, signal RB generated in a short distribution fiber may be comparable with or even larger than that generated in a long feeder fiber [13].

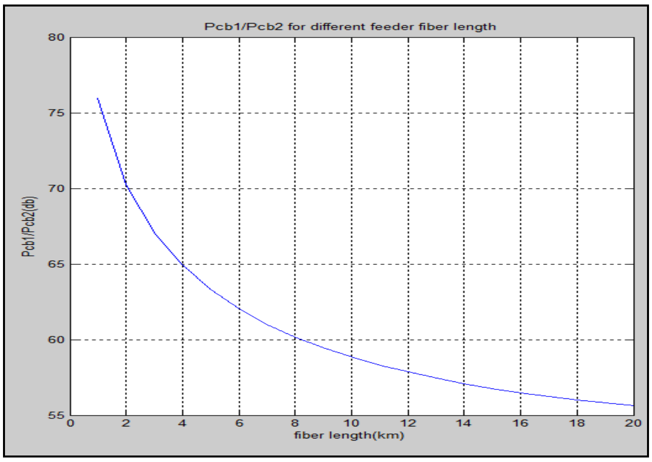

Fig 4: Pcb1/Pcb2 for Different Feeder and Distribution Fiber Lengths for 60-km and 40-km Feeder Fibers respectively.

D. *The Effect of DI's Extinction Ratio*

We have demonstrated that DI's destructive port can effectively suppress carrier RB, due to its notch filter-like frequency response. Here we will further study dependence of carrier RB suppression on DI's ER and optical carrier's line width.

Let ER denote the extinction ratio of DI, coefficients a and b should fulfil the following conditions (11) and (12):

$$0 < a + b \le 1 \qquad (11)$$

$$ER = \frac{a+b}{a-b} \qquad (12)$$

For an ideal DI, $(a+b=1)$. In practice, $(a+b)$ is smaller than 1 due to various reasons, such as unequal coupling ratios of two couplers in the DI and polarization misalignment. Nevertheless, $(a+b)$ should be close to 1 for common cases. Due to this ER, it offers better carrier suppression ratio [8].

E. *Blocking Probability-Servers Relation*

Blocking probability is the probability in which connection was not established due to insufficient transmission of data. Blocking Criteria was used when the design of system was based on the fraction of calls blocked. If all the devices were occupied, demand of service was initiated and blocking occurred. For a system designed on a loss basis, a suitable Grade of Service was considered in which the percentage of calls lost, were recovered. This happened due to unavailability of equipment at the instant of call request. Assume *TNCR (m, n, s, d)* is the total number of connection requested for a source (*s*) and destination (*d*), *TNCB (m, n, s, d)* is the total number of connection blocked, then the blocking probability *BP (m, n, s, d)* can be defined as equation (13):

$$B.P = \frac{TNCB}{TNCR} \qquad (13)$$

Here we have done the analysis by calculating the probability of blocking after establishing light path connections for a number of connection requests. Blocking probability is simply ratio of total number of calls blocked to the total number of calls expressed in percentage. Minimum blocking is always desired condition for provisioning. A connection demands can be blocked either due to the availability of QoS satisfied path or due to the absence of free light path [9].

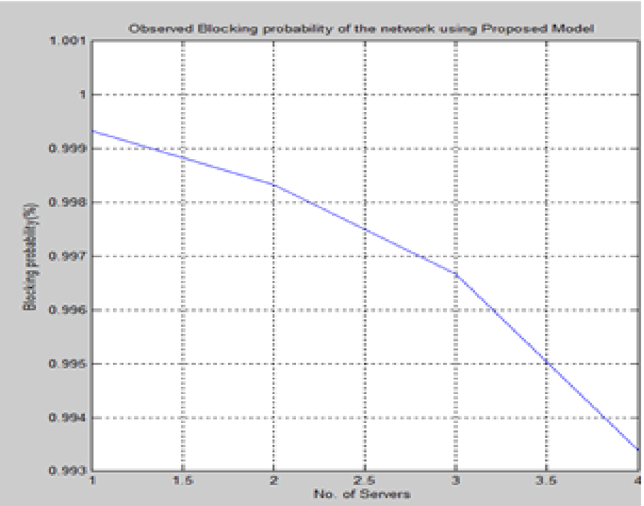

Fig 5: Blocking Probability for No. of Servers

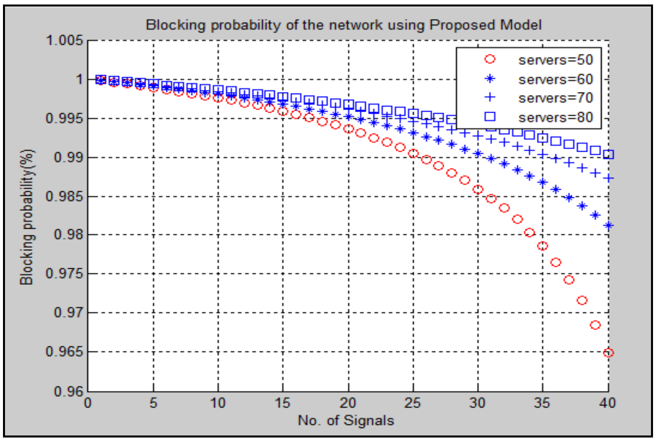

Fig 6: Blocking Probability vs Servers

Here, figure 5 & 6 provides a relation between blocking chance with no. of servers. As no. of servers rise, blocking probability started decreases and vice versa. Blocking Probability characterizes in terms of percentage (%). It is represented in terms of Erlangs. Erlang-B, also known as Erlang loss formula, is a formula for blocking probability that describes the probability of call losses for a group of identical parallel resources [16].

F. Load Vs. Wavelength Relation

Assume N is total no. of nodes, λ is the wavelength of signal and L is the length of route, then Load is given by (14):

$$Load = \frac{N \times \lambda}{L} \qquad (14)$$

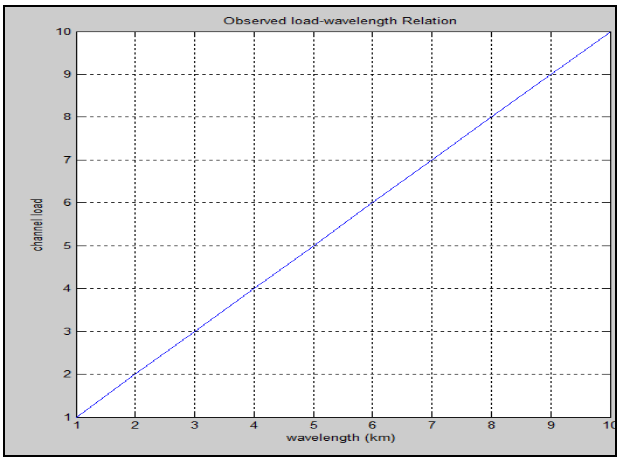

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Fig 7: Channel Load for different wavelengths

In Fig. 7, we present the traffic load varying the different number of wavelengths of fiber for each link. The approach is used for time-slot assignment. In the graph, channel load varies directly with wavelength. As we increase wavelength, load increases and vice-versa. In this, N is no. of nodes which is fixed value which we want to use and it also depends upon length of route which it gets over a network [15].

G. System Margin Vs. Gain

The required gain *Gonu* can be given by (15):

$$Gonu = \frac{M \times Pr \times (\alpha 1 \times \alpha A \times \alpha 2)^2 \alpha cir}{Pc} \qquad (15)$$

with *M*, *Pr* and *αcir* being the system margin, minimum received upstream power and the insertion loss from port 2 to 3 of the circulator respectively [17].

At the upstream receiver in OLT, the signal-RB beating noise and signal-amplified spontaneous emission (ASE) beating noise are dominant. Thus, an attractive feature of the proposed scheme is that all ONU's with similar length ratios can be set to a fixed gain even for a large change in system reach, avoiding the incurred operation complexity of setting different gains for ONUs with different reaches. The first graph shows the actual relation while second graph shows the observed relation between them. This shows the exponentially increasing curve having increase in gain with change in system margin. Thus, we can calculate the maximum system margin and the required optimal ONU gain for different system reaches. Thus, an attractive feature of proposed scheme is that all ONU's with similar length ratios can be set to a fixed gain even for a large change in system reach. Note that for the scheme employing conventional OOK in upstream, the variation of optimal ONU gain is 8 dB for a 20-km change in system reach [18].

According to the experimental results in Figure 8 & 9, the minimum received upstream power needed to achieve BER is -26.7dBm when L1=50 km, L2=10 km, and Gonu=11dB. The measured average received power by upstream receiver module is -18.7 dBm, implying 8 dB system margins. Then based on (15) we can calculate the maximum system margin and the required optimal ONU gain for different system reaches [19]. The theoretical model predicts well the system performance and thus can be used as a guideline in system design [20].

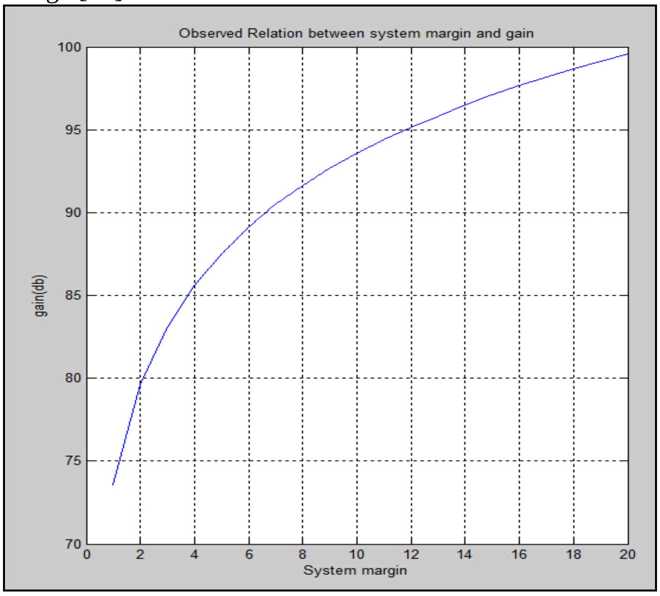

Fig 8: The maximum system margin and the required optimal ONU gain for different system reaches.

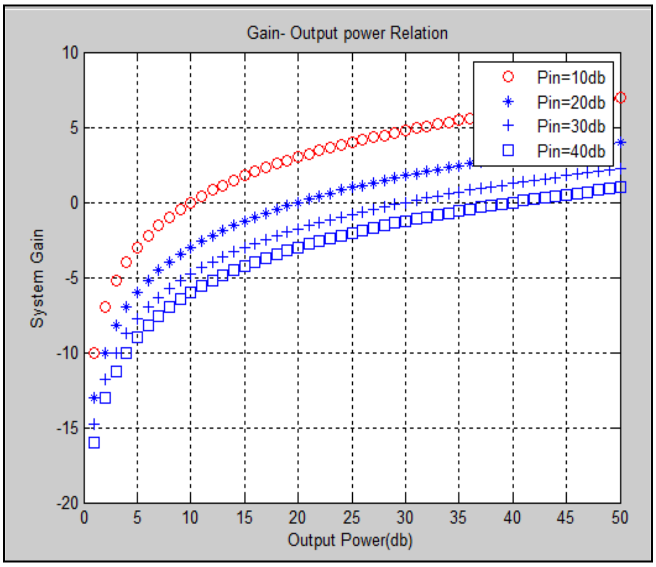

Fig 9: Gain vs System Power

H.Bit Error Rate Vs. Noise Relation

The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unitless performance measure, frequently expressed as a percentage. It is often the case when measuring low bit error rates (BERs) or measuring low data rates that direct measurement of BER on a communication link consumes considerable time. With slower data rates or improved BERs, the amount of time to directly measure BER is impractical. As an alternative approach to directly measuring the BER, it is common to extrapolate the BER from a few data points that require less time to measure. It is important to note that due to the random nature of the noise, the noise levels of the baseline link and the noise generator are not simply added together when determining the overall link noise level. The graph shows the relation between BER with noise power. As power increases, BER decreases and vice-versa as shown in fig 10 [21].

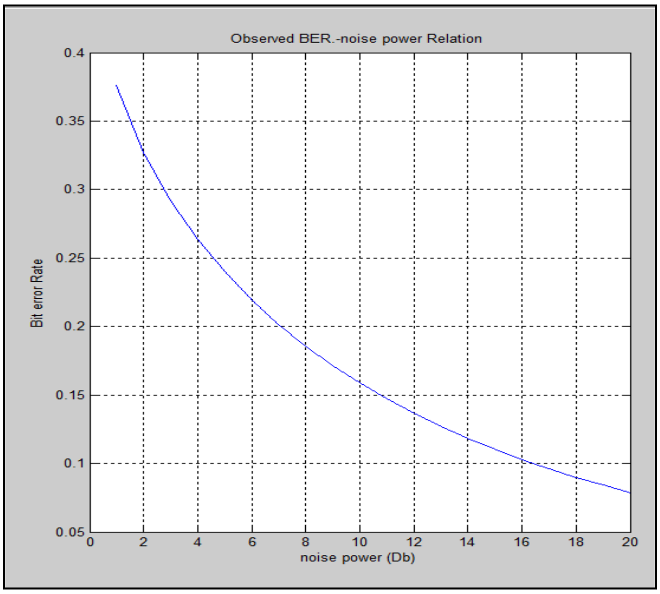

Fig 10: BER-Noise Relation

I. Output Using Different Length of Fibre

Table 1 shows that effect of wavelength assignment on various parameters.

Enter the wavelength of signal 1500 nm
No of signals 4

Table 1: Wavelength Assignment Output

Blocking Probability	0.998	0.995	0.99	0.98
Delay	2994	2985	2970	2941
Rayleigh Scattering	7.96*10^-42			
Channel Load	600			

Enter the wavelength of signal 1520 nm

No of wavelengths 5

Blocking Probability	0.998	0.995	0.99	0.98
Delay	3033	3024	3009	2980
Rayleigh Scattering	7.55*10^-42			
Channel Load	608			

VI. CONCLUSION

This paper investigated the wavelength allocation problem in WDM network with optical carrier regeneration. The wavelength transfer problem was transformed into the vertex colouring problem. An optical delay interferometer at central office tailors the chirp of the converted upstream signal to improve the system bandwidth and the dispersion tolerance. It is proved that results for the transmission through the two hop networks are successful with reduced BER. The bandwidth of system can be increased by increasing the capacity of the system. The capacity of system can be increased by increasing the number of users without disturbing the working of another user. If a=0.44 and b=0.4, then it provides extinction ratio of 17 which is useful for providing carrier suppression. It provides a load of 3 for a wavelength of 10 km. We know that blocking probability decreases with increase in no. of servers. Initially, blocking probability is 0.85, then, it started falling. BER starts increasing with wavelength and also with energy of signal.

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Vikas Chhabra, received his B.Tech degree with Honours in Electronics & Communication Engg from Ambala College of Engg & Applied Research, Ambala, Haryana in 2013. Now, He is pursuing M.Tech in ECE Engg from Galaxy Global College, Ambala. He has worked in Alfa Electronics Ltd. as a R&D Engineer from 2013 to 2014. He is Gate 2014 Qualified. His area of interest is in research work using MATLAB. Mainly fields are optical networking, wireless networks, Simulink Modelling, Image Processing etc.

Monika Dhiman, received her B.Tech Degree in Electronics & Communication Engg from Punjab Engg. College, Lalru in 2011. She received her M.Tech Degree from Ambala College of Engg & applied Research, Ambala in 2013. Now, she is doing a job as Assistant Professor in ACE, Mithapur. Her area of Interest is in Optical Communication and wireless networks. She has published papers in Optical Networks.