Comparative Analysis with Effect of Wavelength on Different Parameters in WDM Passive Optical Networks

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***Abstract*—Data volumes in Internet have experienced an extraordinary growth over the last few years. While provider backbones have been upgraded accordingly in terms of bandwidth to please these demands, access networks remained extensively ignored and are at risk of becoming bottlenecks soon. In this paper, Effect of wavelength assignment on Passive optical networks has been proposed. In WDM networks, each edge node (EN) has its own light sources, and optical channels, called lightpaths, are established by using optical carriers generated from laser diodes (LDs) at the source. However, such networks will suffer from the need for complicated wavelength management. In WDM networks, optical splitting is widely used to achieve multicasting. It removes complications of optical-electronic optical conversions. Effect of wavelength assignment on various parameters is numerically calculated.The important parameters like delay, BER and blocking probability is also analysed. All this work is simulated on MATLAB tool.**

***Keywords*- Passive Optical Networks, WDM-PON, Wavelength Assignment, Parameters.**

I. INTRODUCTION

Optical network are high-capacity telecommunication network based on optical technologies and components that provide routing, grooming and renovation at wavelength level as well as wavelength-based services. It uses Optical Fibers for data transmission. The advantages of Optical networks can be used for long distances, easy to connect and has long-term financial profits, lasts for a long time and has a high bandwidth. Optical networks are based on the emergence of optical layer in transport networks deliver higher capacity and reduced costs for new applications such as net, video and multimedia communication and advanced digital facilities. [1].

In optical network customers are demanding more services and options and are carrying more and different types of data traffic. Optical networks provide the required bandwidth and flexibility to enable end-to-end wavelength services and meet all the high-capacity and varied needs. Optical fiber offers much higher bandwidth than conventional copper cables. A single fiber has a possible bandwidth on the order of 50THz. Meanwhile, it has low cost, extremely low bit error rate (typically 10^{-12}, compared to 10^{-6} in copper cables), low signal attenuation and low signal alteration. In addition, optical fibers are safer from tapping, since light does not radiate from the fiber and it is nearly impossible to tap into it secretly without being detected. As a result, it is favoured medium for data transmission with bit rate more than a few tens of megabits per second over any distance more than one kilo-meter. It is also the preferred means of realizing short distance (a few meters to hundreds of meters), high-speed (gigabits per second & above) interconnection inside large systems. In past few decades, optical fibers have been widely deployed in all kinds of communication systems. [4].

Optical fiber has been used in two generations of optical network. In first generation, it was essentially used for transmission and simply to provide capacity, since it provides lower bit error rates and higher capacities than copper cables. All switching and other intelligent network functions were handled by electronics. Thus, the bandwidth was limited by the electronics at the fiber endpoints. Presently, transmission rates are restricted to 10 Gb/s (OC-192) in commercially available systems. Examples of first generation optical networks are SONET and SDH networks.[3]

Currently, the optical network technology holds the key to the next-generation networks. Wavelength-division-multiplexing (WDM) networks have emerged as a promising candidate for next-generation networks providing large available bandwidth. A WDM network contains WDM switches connected by fiber optical links. In each link, many wavelengths are available. In a dense wavelength-division-multiplexing (DWDM) network, a link can have hundreds of wavelengths. This number can go much higher in the near future. Transmissions in different wavelengths on the same link do not interfere with each other. Each wavelength can carry a huge amount of traffic. 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

ISSN: 2278 – 909X

wavelength should not be reprocessed anymore in order to eliminate communication fault. i.e, allowable number of carrier regenerations per wavelength should not be exceeded [7].

The paper is planned as follows. In section II, we deliberate related literature review with the proposed scheme. In Section III, It describes passive versus active optical networks. In Section IV, it describes system architecture and analyse the different parameters in impairing the upstream signal. Section V contains main results, graphical analysis. Finally, conclusion is given in Section VI.

II. RELATED WORK

In literature, several proposed Rayleigh noise drop in wavelength-division-multiplexed passive optical network. Then they suggest a novel scheme to effectively suppress carrier backscattering problem in carrier-distributed WDM-PONs. By simply replacing upstream modulation arrangement of conventional on-off keying with differential phase-shift keying (DPSK), the system tolerance to carrier RB is substantially improved by 20 dB, as carrier backscattering can be considerably rejected by notch filter-like destructive port of delay-interferometer at optical line terminal, which is used suddenly 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 decrease backscattering light, the standard Delay interferometer used in future arrangement is also more favourable than non-standard filters [6].

Some authors propose 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 optical transmitter for optical network unit is composed of an electro-absorption modulated laser, a photo sensitive coupler and amplifier. Through cross-gain modulation in amplifier, the upstream data from pump light are imposed onto a continuous-wave probe light provided from central office. An optical delay interferometer at CO tailors the chirp of upstream signal to increase bandwidth of the system and dispersion tolerance. The proposed optical transmitter is based on fast gain recovery of amplifier governed by carrier-carrier scattering and carrier-phonon relations [6]. End-to-end real-time optical orthogonal frequency-division multiple-access passive optical networks (PONs) with adaptive dynamic bandwidth allocation (DBA) and colourless optical network units (ONUs) are experimentally established, for first time. Next generation Passive Optical Network (PON) technology has been developing to consolidate metro and access networks in order to offer improved capacity, high split ratio and compact deployment cost per subscriber. However, transmission of signals to long distances up to100km leads to increased propagation delay whereas high split ratio may lead to long cycle times resulting in large queue occupancies and long packet delays.

This paper investigates problem of dynamic wavelength allocation and fairness control in WDM optical networks. A network topology, with a two-hop path network, is considered 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 take full advantage of 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 inferior channel utilization when individual sessions do not need entire channel bandwidth[5].

III. PASSIVE VERSUS ACTIVE OPTICAL NETWORKS

In active networks management and collecting traffic statics from remote locations is possible. Based on these statistics the network can be reconfigured from remote locations. For passive configurations active monitoring is only possible at the SNI and UNI. The path between SNI and UNI acts like a black box. Any modification, like rerouting, in the network should be done on side. Besides this problem, there are more differences between Passive and Active networks, they are summarized now [8].

(i) Dynamic links and management

In active optical networks the switching and routing hardware can create isolated optical paths from source to destination. These are called “Point-to-Point” (P2P) connections. Network operators can configure the manageable, or active, hard- ware to create a network with the required functionality. In case of a passive configuration as described [9] and [15] the splitters have a static configuration. As a result only at the termination points management is possible.

(ii) Topology

Active networks can be configured as P2P or “Point-to-Multipoint” (P2MP) net- works at the physical level. The networks defined only are configured as a P2MP at the physical level. However with the use of software a P2P topology can be emulated in a passive configuration. A P2P network is most secure since each link is a physical link between two nodes. In passive and active P2MP configurations all information is broadcasted in the Down stream direction to all users which can be a security problem.

(iii) Physical reach

The physical reach between head end and user is for active networks many times more than passive networks. This is due the fact the active components can act as an optical amplifier or repeater. In a passive network all power at the head end has to be enough to serve at least 64 users as defined. Another aspect which limits the maximum distance to 20 km is the ranging procedure.

(iv)Upgrading a network

When networks or sub-networks are upgraded, an active network can partially shut down depending on its configuration. For passive networks the whole network should be down to modify it [9].

(v) Bandwidth Usage

The usage of bandwidth in an active network differs from the use in passive networks. In active networks there are separate transmitters and receivers connected by a physical link; therefore they can have their own wavelength and capacity. Passive networks use a shared fiber between provider and splitter which has to serve multiple users per

ISSN: 2278 – 909X

wavelength. These are some examples to deal with when designing and working with PONs. To control the development of PONs some standards have been published. Each standard describes several solutions and regulations which can help to design a network. Some of these standards are still in development and are not finalized this.

IV. SYSTEM ARCHITECTURE AND RAYLEIGH PARAMETERS

A. *System Architecture*

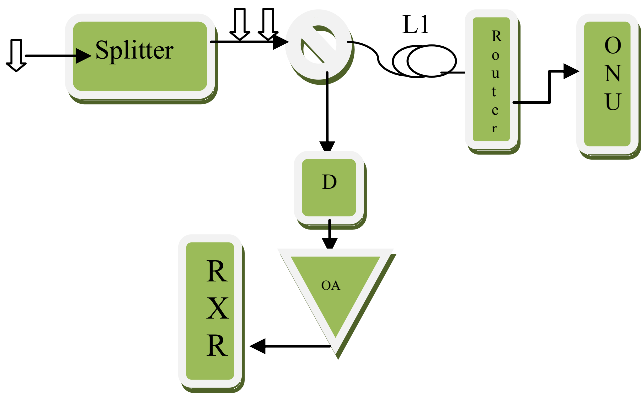

Figure 1: Proposed System Architecture
OA: optical Amplifier, ONU: Optical Network Unit, D:Delay Interferometer, RXR: Receiver

Fig. 1 shows the proposed architecture of a WDM-PON. As downstream plus upstream signals are transmitted over different wavelength bands in carrier-distributed WDM-PON, backscattering from upstream signal will not affect with the downstream signal, and vice versa. 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.

In multi-hop network design, selection of a proper logical topology is followed by the wavelength allocation process. The wavelength allocation process is important because it determines wavelength requirements, and operation of network. The simplest scheme for the wavelength assignment assigns one wavelength channel to each of the logical links. An alternative scheme, which needs a smaller number of wavelengths and transmitters, is assignment of one wavelength channel per end-node. If number of wavelength channels in network is smaller than number of end-nodes, these schemes will flop. In such a case, shared channel methods can be useful in the wavelength assignment process. If the required number of wavelengths exceeds available number of wavelengths, it is possible to employ multiple broadcast stars in the network. In this case, the number of available wavelengths will be scaled up by the number of broadcast stars in the network.

At the CO, the upstream signals are first sent to a DI before being de-multiplexed by an arrayed waveguide grating (AWG). The DI which filters out red-shifted chirp of the converted signal substantially improves the receiver sensitivity and dispersion tolerance. A single DI can be used to equalize multiple WDM channels provided that the free-spectral range (FSR) of DI is equal to a factor of the channel spacing. To avoid using additional optical filters on the link, we can employ non-cyclic AWGs at the remote node and at the CO [6].

B. *Components Used*

1. *Transponders*

Transponder is basic element for transmission and reception of optical signal from channel. A transponder is generally characterized by 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 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 [15].

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 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 [15].

3. *Couplers*

A passive optical network services a passive (not requiring any power) device to split optical signal (power) from one fiber into many fibers and reciprocally, to add optical signals from several fibers into one. This device is an optical coupler. In modest form, an optical coupler consists of two fibers attached 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 [13].

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 same principles as isolators[14].

ISSN: 2278 – 909X

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 [7].

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 [6].

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. Interferometers are useful as both filters and de-multiplexers. 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 [12].

C. Proposed Algorithm

Algorithm:
1. Interface GUI with MATLAB.
2. Enter the input parameters at its desired value.
3. Assign the wavelength on given network.
4. Enter length of fibre and calculate various parameters like attenuation, SNR, effective length of fibre.
5. Also calculate various performance parameters like blocking probability, delay, BER and scattering parameters.
6. Assign different wavelengths and check effect on various parameters.
7. Find the graphical relations between various parameters.

D. Estimation of Blocking Probability

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 eq.(1):

$$B.P = \frac{TNCB}{TNCR} \quad (1)$$

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 the ratio of total number of calls blocked to the total number of calls expressed in percentage. Minimum blocking is always the desired condition for provisioning. A connection requests can be blocked either due to the availability of QoS satisfied path or due to the absence of free light-path.

E. Estimation of Gain

The required gain *Gonu* can be given by equation (2):

$$Gonu = 10log10 \frac{Pout}{Pin} \quad (2)$$

Where Pout is output Power and Pin is the input power. The input power to the feeder fiber is assumed to be *Pin=100 dBm*.

Then by using equation number (2) we can calculate the maximum system margin and the required optimal ONU gain for different system reaches. 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.

V. RESULTS

A. Simulation Environment Tool

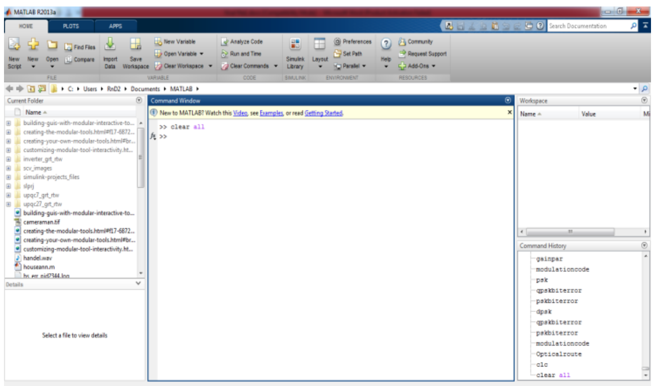

Figure 2: MATLAB Tool

MATLAB is one of a number of commercially available, sophisticated mathematical computation tools, which also include Maple, Mathematical, and Math CAD. Each allows to perform basic mathematical computations. They differ in the way they handle symbolic calculations and more complicated mathematical processes, such as matrix manipulation. For example, MATLAB (short for Matrix Laboratory) excels at computations involving matrices,

ISSN: 2278 – 909X

whereas Maple excels at symbolic calculations. It is shown in fig 2.

B. Graphical User Interface

Figure 3: Graphical User Interface

MATLAB apps are self-reliant MATLAB programs with GUI front ends that systematize a task or calculation. The GUI typically comprises controls such as menus, toolbars, buttons, and sliders.

C. Input Optical Parameters

Table 1 show the various input parameters used by this proposed network.

Table 1: Input Optical Parameters

Input Parameters	Value
Wavelength	1300nm-1550nm
I/P Mean Optical Power	100 db
O/P Mean Optical Power	10 db
Length of Fibre	20 km
Servers	5
No. of wavelengths	4
Blockage	1
Energy	100 db
Bandwidth	100 Mhz
Total links	10
Noise	10 db

D. Output Parameters

The output parameters are important in every network. Because their value decide whether network holds good or not. Attenuation is given by eq. (3) and its calculated result is shown in fig 4.

$$Attenuation * length = 10log10\frac{Pin}{Pout} \qquad (3)$$

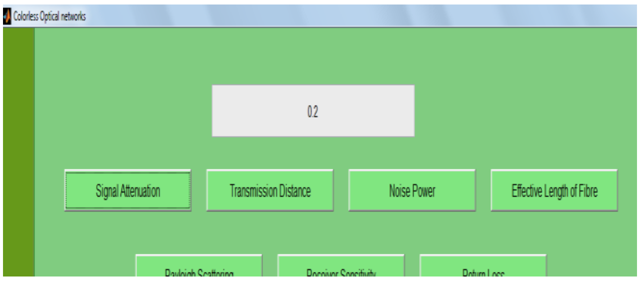

Figure 4: Attenuation Output

The Rayleigh scattering is given by eq (4) and its output is given by fig 5.

$$\gamma = \frac{8\pi^3 \eta^8 p^2 \beta kT}{3\lambda^4} \qquad (4)$$

Where γ is Rayleigh scattering, η is the refractive index of medium is, λ is the wavelength. β is isothermal compressibility.

Figure 5: Rayleigh Scattering

Receiver sensitivity is given by eq (5) and its output is given in fig 6.

$$S = SNR * kTB * NF \qquad (5)$$

Where SNR is signal to noise ratio and NF is noise figure

Figure 6: Receiver Sensitivity

The blocking probability is given by eq (6) and its output is shown in fig 7.

ISSN: 2278 – 909X

$$B.P = \frac{rho*(m-n+1)*energy}{n+(rho*(m-n+1)*energy)} \quad (6)$$

Where rho is expected blockage, m is no. of servers, n is no. of signals respectively.

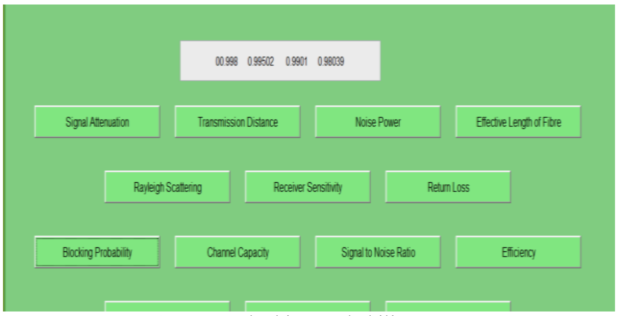

Figure 7: Blocking Probability

E. Graphical Analysis

1. Gain Vs Power

At the upstream receiver in OLT, the signal-RB beating noise and signal-amplified spontaneous emission (ASE) beating noise are dominant. The graph shows the observed relation between parameters. This shows the exponentially increasing curve having increase in gain with change in power. Thus the maximum system margin and the required optimal ONU gain for different system reaches can also be calculated.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. 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. The figure 8 shows the variation of gain with different values of system power. This shows that as value of input power increases, the gain decreases and vice versa.

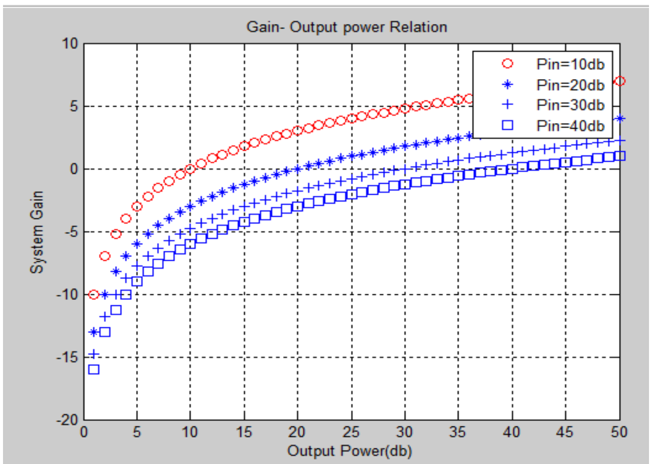

Figure 8: Gain Vs System Power

2. Blocking Probability-Servers Relation

As traffic increases, blocking probability started increases and vice versa. Blocking Probability represents in terms of percentage (%).It is represented in terms of Erlangs. The blocking probability of the centre call is computed to minimize edge effects. 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.

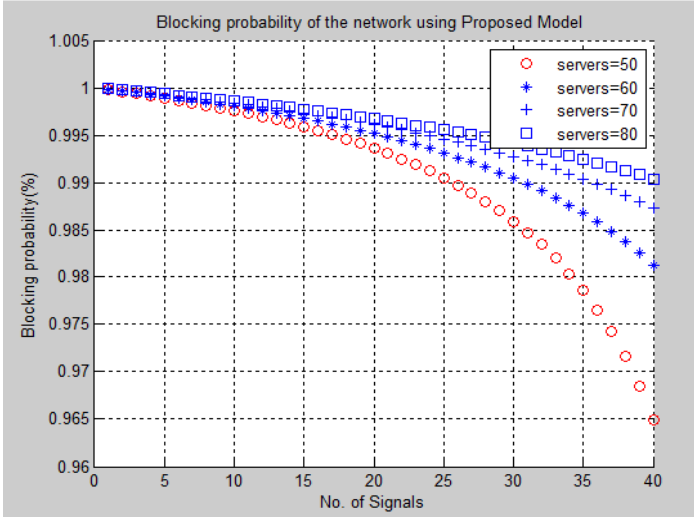

Figure 9: Blocking Probability Vs Servers

F. Output Using Different Length of Fibre

Table 2 shows that effect of wavelength assignment on various parameters.

Enter the wavelength of signal 1500 nm
No. of signals 4

Table 2: 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 signals 4

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

ISSN: 2278 – 909X

VI. CONCLUSION

In this dissertation, it investigated the wavelength assignment problem in WDM network. It also investigates various performance parameters which are important in this system. An optical delay interferometer at the central office tailors the chirp of the converted upstream signal to improve the system bandwidth and the dispersion tolerance. As wavelength of network increases, it affects delay interferometer's performance and hence delay gets increases. Increase in wavelength also affects other parameters like Rayleigh scattering and channel load. Scattering gets reduced while load increases. It also increases the delay in network with increase in wavelength. It is proved that the results for the transmission through the two hop networks are successful with reduced BER. The graph between gain and power is plotted and it shows that as output power increases, gain is also increases exponentially. The bandwidth of the system can be increased by increasing the capacity of the system. The capacity of the system can be increased by increasing the number of users without disturbing the working of another user. The blocking probability increases with increase in no. of servers and decreases with increase in no. of signals. Hence the performance of the optical WDM networks can be improved in terms of blocking.

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ISSN: 2278 – 909X