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Gain Based Quality Computation in WDM Routing

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ABSTRACT: Typically, optical fibre cables are used in WDM networks to send signals that take the form of light pulses between the transmitter and receiver. These systems have the capacity to broadcast many signals at once. However, we are aware that light signal quality suffers as it traverses a substantial portion of the fibre. To restore the original light signal after it has travelled a given distance, it is necessary to increase the light signals simultaneously. The light signals are amplified in the situation using optical amplifiers. There are several different kinds of optical amplifiers. EDFA and Raman amplifier, respectively.

This thesis uses opti system software to analyse a WDM network while taking EDF amplification into consideration. Consequently, optical amplifiers are used to lessen attenuation losses following a long distance transmission. In this analysis, the gain and noise figure of the EDFA with various pumping approaches are evaluated. Following that, the Raman amplifier has been highlighted, and the gain has been calculated using one mathematical model. Following that, one WDM network with ten nodes coupled to one another bidirectionally through a Raman amplifier is considered. Gain has been determined for each route using that mathematical model. Possible pathways are observed for a particular source and destination; gain is computed for each path; and the one with the highest gain is chosen as the optimal path for that source-destination combination. The likelihood of call losses for a collection of identical parallel resources is known as blocking probability. Here, blocking probability of each node is computed and examined to see how it changes when gain margin, number of routes, and wavelength all change for a particular wavelength number and a certain load.

I. INTRODUCTION

WDM optical systems are revolutionising information transmission due to their high limit, quick and improved data transfer capacity, and low loss. So, there is a lot of research being done in this area. The fundamental component of an optical system, optical amplifiers improve the signal by compensating for losses in the fibre as well as other factors. Due to its great pick up and low pump power, EDFA optical amplifiers are the most often used amplifiers. So it is necessary to think about EDFA behaviour in a WDM system. Therefore, EDFA gain and noise figure at various pumping wavelengths are explored in this project.

Because of the nonlinearities in the fiber's composition and the lengths to which signals travel inside the fibre, fibres also suffer from the negative effects of scattering. Therefore, this scattering needs to be reduced by several times. One method to counteract the dispersion caused by single mode fibres is to introduce DCF fibres. Different information rates and settings have been used to analyse the DCF in order to characterise the optimum outcomes.

Prachi Shukla and Kanwar Preet Kaur's Performance Analysis of EDFA for Different Pumping Configurations at High Data Rate establishes several pumping techniques and analyses gain and noise figure in relation to fibre length.

The mathematical model of amplified stimulated Raman scattering and fibre Raman amplifier released in 2011 by Hani j. Kbashi, Mohammed A. Hameed, and Amer A. Ramadan illustrates how the gain of a Raman amplifier changes with fibre length.

Fiber Types and Raman Gain Coefficient Measurements and Calculations Ira Jacobs, Roger H. Stolen, and Inuk Kang Ahmad Safaai-Jazi, Chair, explaining how pumping power and frequency affect the Raman gain coefficient in Blacksburg, Virginia on December 9, 2002.

Measuring the quality of a service By Santos Kumar Das and Professor S. K. Patra of the National Institute of Technology in Rourkela, proposing techniques of route length calculation for an optical virtual private network over WDM/DWDM Network

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II. LITERATURE REVIEW

Measuring the quality of a service By Santos Kumar Das and Professor S. K. Patra of the National Institute of Technology in Rourkela, proposing techniques of route length calculation for an optical virtual private network over WDM/DWDM Network

For more information on how blocking probability changes based on gain margin and wavelength count, see Estimating the blocking probability in wavelength-routed optical, published by Luiz H. Bonani and Iguatemi E. Fonseca on July 4, 2013.
to investigate and examine the gain and noise figure of an EDFA at different pumping methods utilising varied pumping wavelengths and power levels. Co-pumping, counter-pumping, and bidirectional pumping are some of the different pumping systems.
to evaluate the Raman amplifier's features, determine the gain using a mathematical model, and track the gain with respect to the length of the fibr

III. OPTICAL FIBRE COMMUNICATION SYSTEM

Figure 2.1 [6] depicts the transmitter, receiver, and transmission line as the three main parts of the system.

optical fibre communication systems include the transmitter, receiver, and transmission line as seen in the image to the right.[fig 2.1].

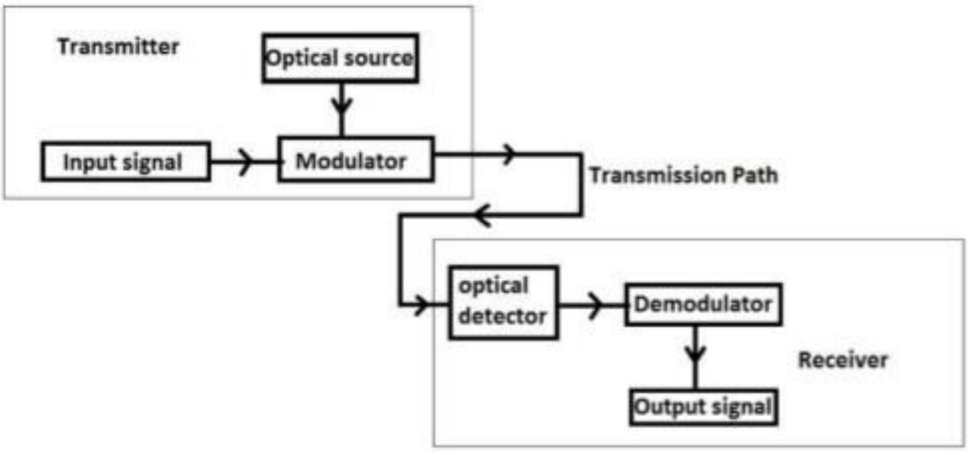

Fig 2.1 Optical fibre communication system

An input signal is produced at the transmitter side by a data source. The use of a single laser source as

a source of light with the ability to produce optical signals at certain wavelengths. An optical fibre is a thin, flexible filament formed of silica glass that converts electrical signals into optical signals. Along the length of the fibre, the optical signal is sent before being transformed back to an electrical signal at the receiving end.

The modulator receives both the optical signal and the data source, creating a modulated signal that an optical fibre generates as it travels via the transmission line. The optical signal is subsequently detected at the receiver side using an optical detector. The digital signal is then routed via the demodulator to produce the required output.

3.1 Optical Amplifiers

A signal may experience a number of flaws in an optical fibre, including attenuation-related losses in the fibre, splice losses, and tap losses in the fibre. These losses at the receiver end make signal detection challenging. Therefore, if transmission is being done over a long distance (over 100 km), it is crucial to make up for fibre loss.

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The process of converting optical signals to electrical signals, amplifying them, and then converting them back to optical signals in early technology was time-consuming and costly. Signal amplification became significantly simpler once optical amplifiers were introduced since there was no longer a need to convert the signal to an electrical signal. The optical amplifiers revolutionised the world of optical fibre communication.
Fiber amplifiers and semi conductor opamplifiers are the two main categories of optical amplifiers.
Thus, Fabry-Perot semiconductor optical amplifiers, Fabry-Perot SOAs, and travelling wave SOAs were added to the classification of optical amplifier. Fibre
EDFA, Raman, and Brillouin amplifiers are all types of amplifiers. Three kinds of fibre amplifiers exist: Erbium-doped fibre amplifiers, Raman amplifiers, and Brillouin amplifiers are a few examples.

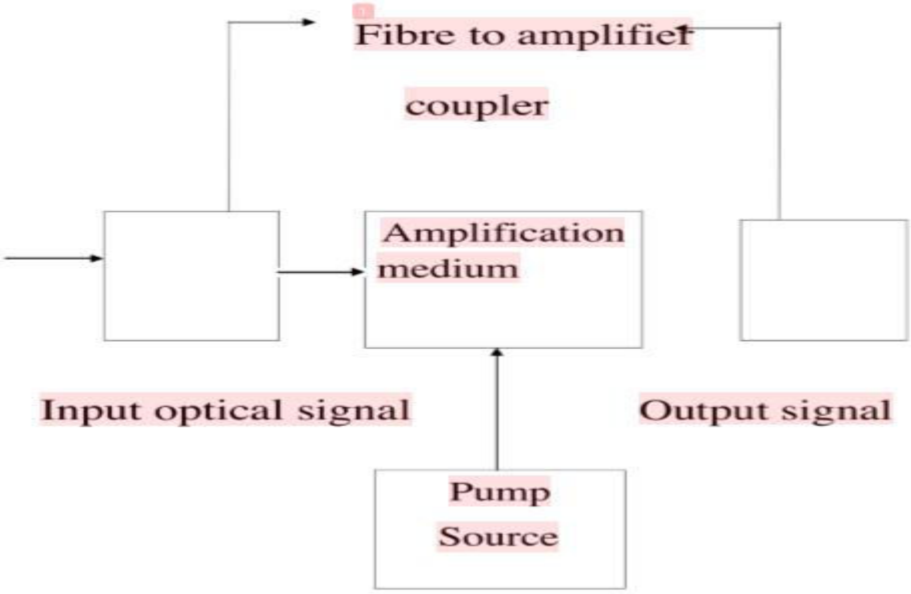

Fig 2.2 Block Diagram of basic optical amplifier

3.2 Basic EDFA Design

An Erbium Doped Fibre Amplifier (EDFA) is the acronym for this device. The signal and pump wavelengths are multiplexed or combined in a coupler to allow them to both propagate. The pump is a wavelength-selective laser diode and an Erbium doped fibre length.
merged inside the fibre. This signal and the pump may both move in the same direction or concurrently move in the opposite direction inside an EDFA. This article provides a succinct overview of the many pumping kinds. The length of an erbium-doped fibre cable is really determined by the input signal strength, pumping power, ion density, and wavelength of both the pump and the signal.

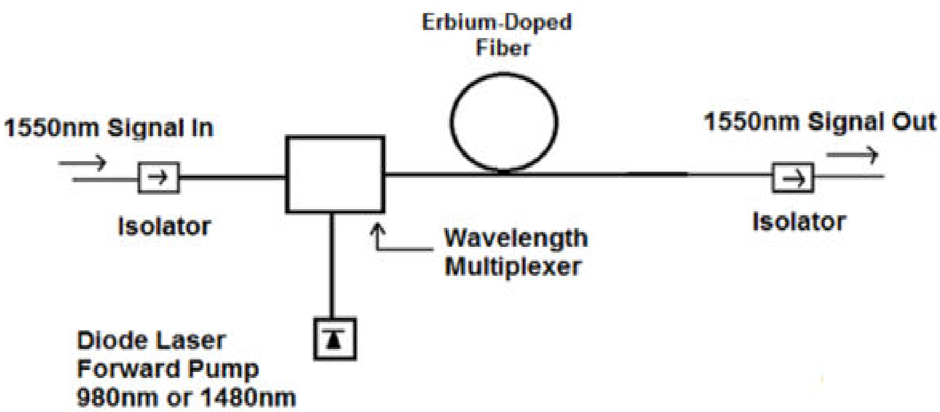

Fig 2.5 Block diagram of an EDFA

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Fig 2.4 is a graph when the laser and EDFA amplifier are co-pumped. The optical signal being delivered has a wavelength of 1550 nm. Then, a laser diode is used to combine this optical signal using a wavelength multiplexer. At that time, a combined signal is delivered via an EDFA, causing both signals to associate with and get excited by Er3+ particles. If we continued this procedure, we would get a stronger signal of the data we had provided at a wavelength of 1550 nm.

IV. SIGNIFICANCE OF CALCULATION AND MEASUREMENT OF FIBRE RAMAN AMPLIFIER

The transmission line is used as the Raman gain medium by the Fibre Raman Amplifier (FRA). It is a new and intriguing discovery that has the potential to completely transform conventional correspondence frameworks, especially in light of Wavelength Division Multiplexing (WDM), which makes use of simultaneous amplification of many channels of light wave signals. It may also be used for repeater-less transmission, which makes use of optical gain to make up for fibre loss. The optical signal in optical fibre is improved via FRA. It is accounting for the norm of transferring force from pump power to input signal. Raman collaboration in the centre of light and lasers is used for this.

the glass's modes of vibration. When silica is mixed, the Raman gain coefficient rises at a Stokes movement of around 13.2 THz and a 3 dB transmission capacity of roughly 6 THz. The following are a few FRA components that are used in transmission frameworks to draw in users

4.1 1Spontaneous Raman Scattering

The fundamental working concept is that when one incident light with frequency 0 is scattered from a substance's molecules, the frequency of the scattered light will nearly exactly match the frequency of the incoming light. This approach also allows for the observation of low intensities of light that are either higher or lower frequency than the incoming light. SRS is the name given to this phenomenon [8]. Landsberg, Mandelstam, and Raman independently and concurrently discovered this in 1928.

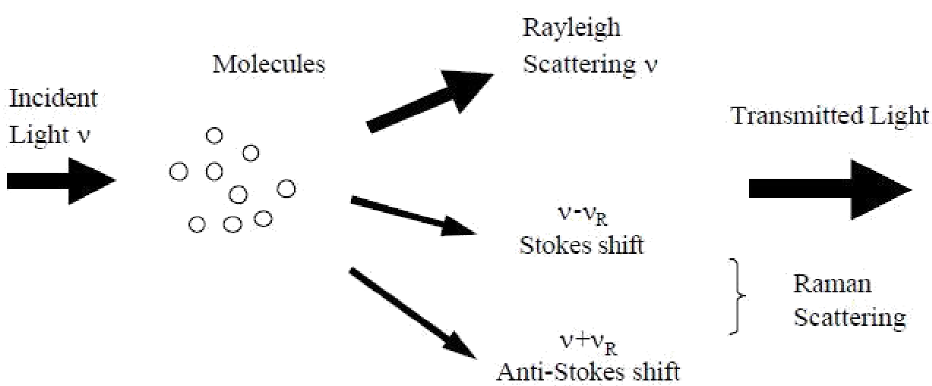

Fig3.1 Spontaneous Raman scattering

4.2 Raman Gain and Raman Gain Coefficient Calculations

It has already been mentioned that SRS would boost an already weak Stokes signal when it is released into the fibre with a stronger pump. Following equations may be used to explain the signal amplification:

$$P_s(L)=P_s(0)\ \exp((g_R(\nu)P_0L_{eff})/KA_{eff}) - \alpha_s L) \quad (8)$$

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$$g_R(\nu)=\sigma_0(\nu) \cdot (\lambda_s^3/c^2h\ n(\nu)^2) \quad (9)$$

Where n (v) is the refractive index, which depends on frequency, K is the polarisation factor, c is the speed of light, h is Planck's constant, S is the Stokes wavelength, and Sl is the Stokes wavelength. The spontaneous zero Kelvin Raman cross section 0vs is defined as the product of the power emitted at Stokes wavelengths and the power generated by the pump at 0K temperature. With the help of the thermal population factor, this is possible.

∟ (v, T) and the Raman cross-section $\sigma_T(v)$ at temperature TK .

V. GAIN BASED ANALYSIS

A single mode fiber's capacity is divided into many channels utilising various wavelengths via WDM. In a WDM network, we must establish up a route between the source node and destination node in response to a request. Routing is the process of creating a route for a certain request. Following route creation, wavelength is allocated to that path using various methods (with or without converters).).

Fig 4.1WDM network structure

No of links	Source node	Destination node	Distance(in km)
1	1	2	70
2	1	4	70
3	1	5	140
4	2	3	70
5	2	4	140
6	2	9	280
7	3	5	140
8	4	7	140
9	5	6	70
10	5	9	210
11	5	10	210
12	6	7	70
13	6	8	70
14	7	10	140
15	8	10	70
16	9	10	70

Fig 4.2 Distance between nodes

VI. SIMULATION RESULTS AND DISCUSSIONS

Here we want to send signal from node2 to node3. For that all the routes possible between 2 and 3 has been calculated using DFS algorithm which is being shown below. After that gain is being calculated for each route and routes are being sorted in decreasing order of gain.

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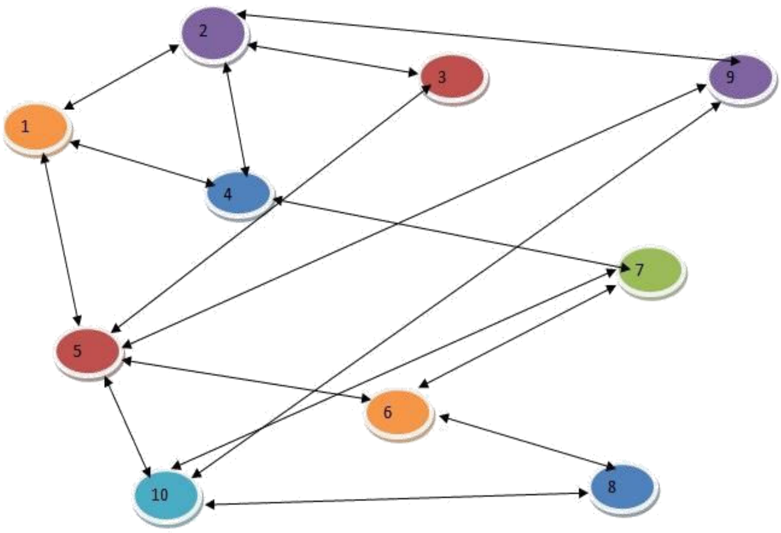
All possible routes for source as 2 and destination as 3



2	3	0	0	0	0	0	0	0	0
2	1	5	3	0	0	0	0	0	0
2	9	5	3	0	0	0	0	0	0
2	4	1	5	3	0	0	0	0	0
2	9	10	5	3	0	0	0	0	0
2	4	7	6	5	3	0	0	0	0
2	4	7	10	5	3	0	0	0	0
2	1	4	7	6	5	3	0	0	0
2	1	4	7	10	5	3	0	0	0
2	4	7	10	9	5	3	0	0	0
2	9	10	7	6	5	3	0	0	0
2	9	10	8	6	5	3	0	0	0
2	1	4	7	10	9	5	3	0	0
2	4	7	6	8	10	5	3	0	0
2	4	7	10	8	6	5	3	0	0
2	9	10	7	4	1	5	3	0	0
2	1	4	7	6	8	10	5	3	0
2	1	4	7	10	8	6	5	3	0
2	4	7	6	8	10	9	5	3	0
2	1	4	7	6	8	10	9	5	3
2	9	10	8	6	7	4	1	5	3

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Bar graph plot for gain VS routes for (2, 3) pair

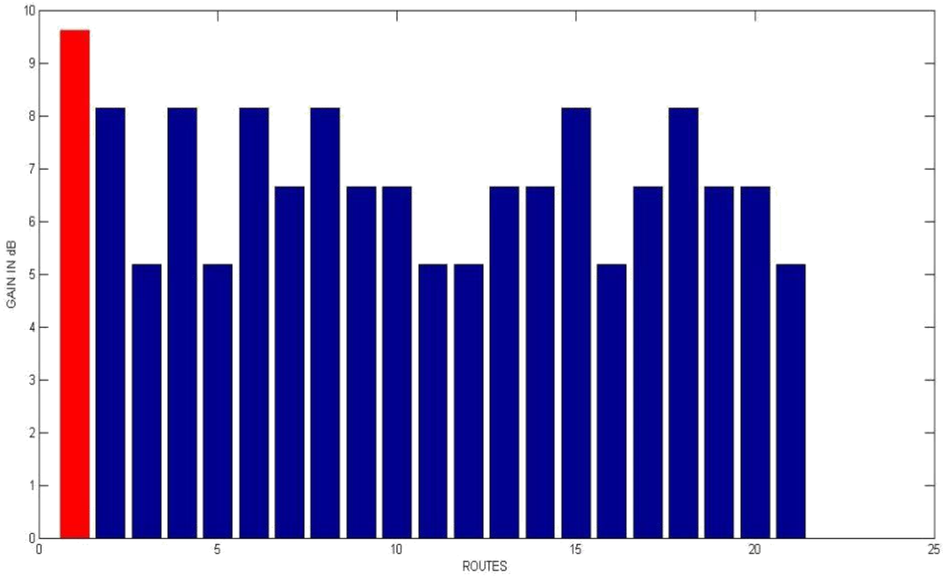

Fig 4.3 unsorted gain for source=2 and destination=3

6. Sorted bar graph for gain VS routes for (2, 3) pair

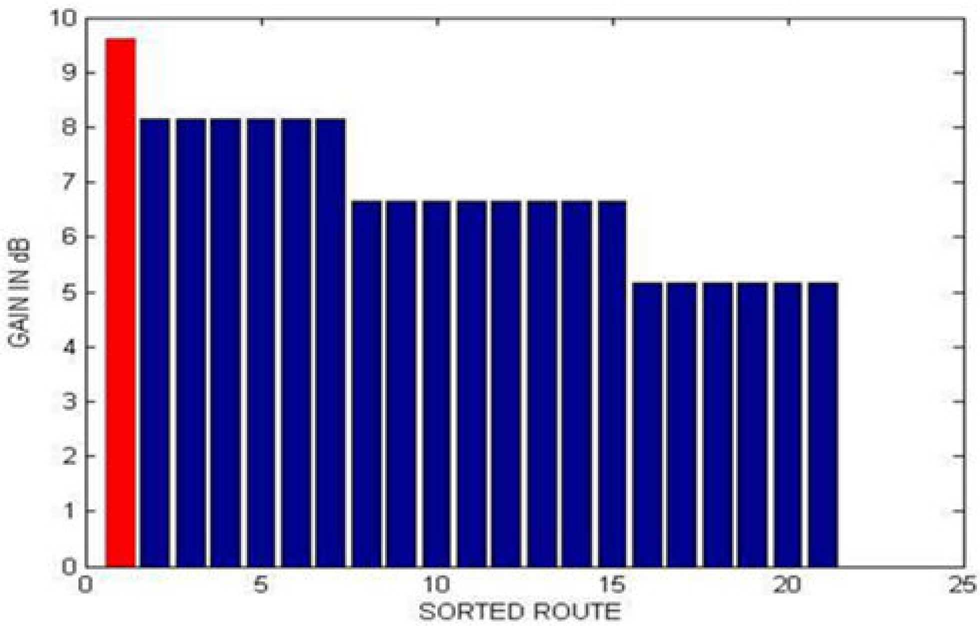

Fig4.4 sorted bar graph for source=2 and destination=3

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Bar graph for gain VS routes for (3, 4) pair

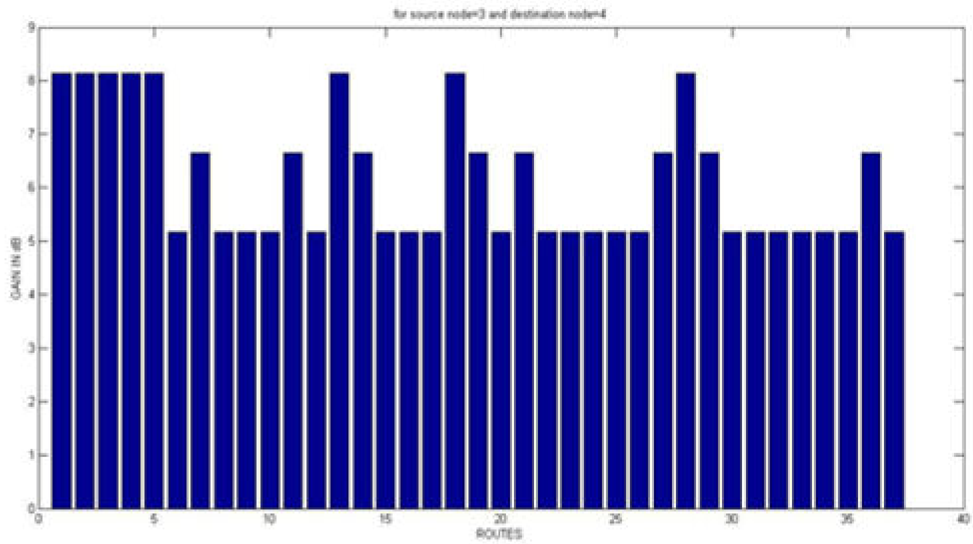

Fig 4.5 bar graph for source=3 and destination=4

Sorted Bar graph for gain VS routes for (3,4) par

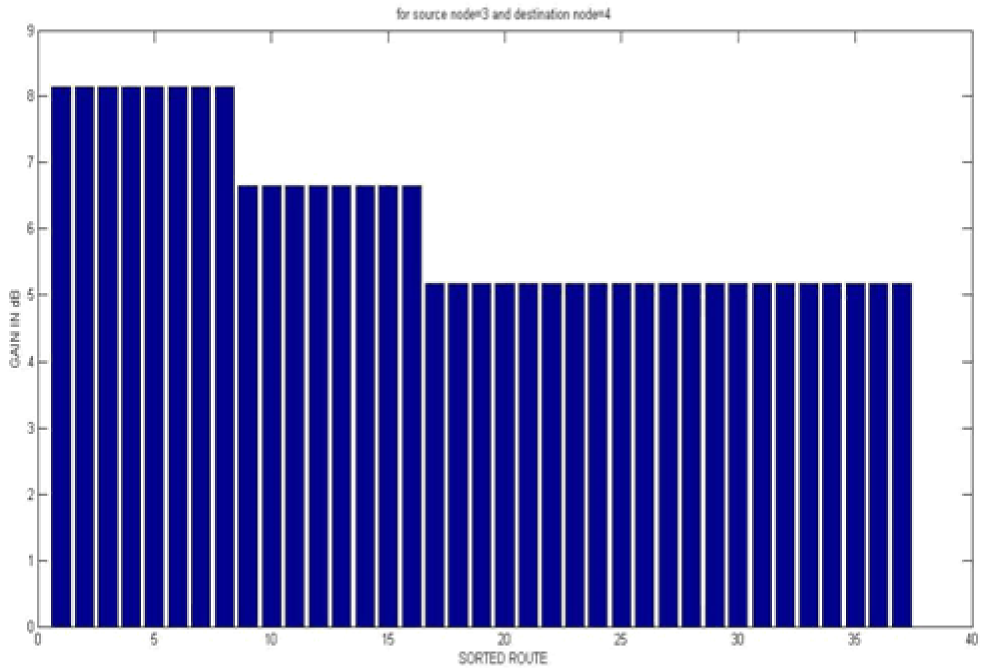

Fig 4.6 sorted bar graph for source=3 and destination=4

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VII. BLOCKING PROBABILITY CALCULATION

In this case, the formula for blocking probability of nodes has been used to compute the blocking probability VS nodes. The following graphs show the effect of varying the number of wavelengths and the gain margin on the blocking probability.

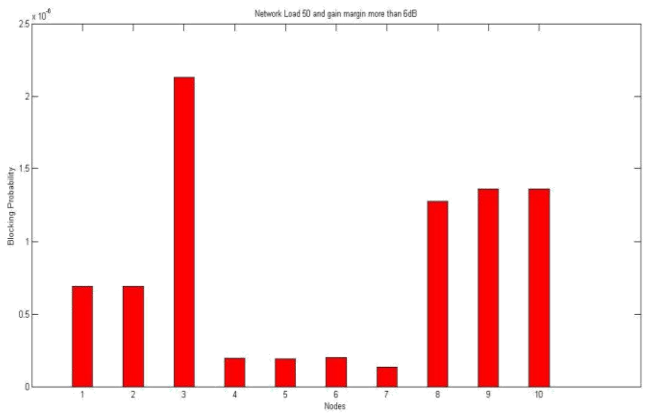

Fig 4.13 Blocking probability VS Nodes for load=50E, gain >6dB
No of wavelength=8

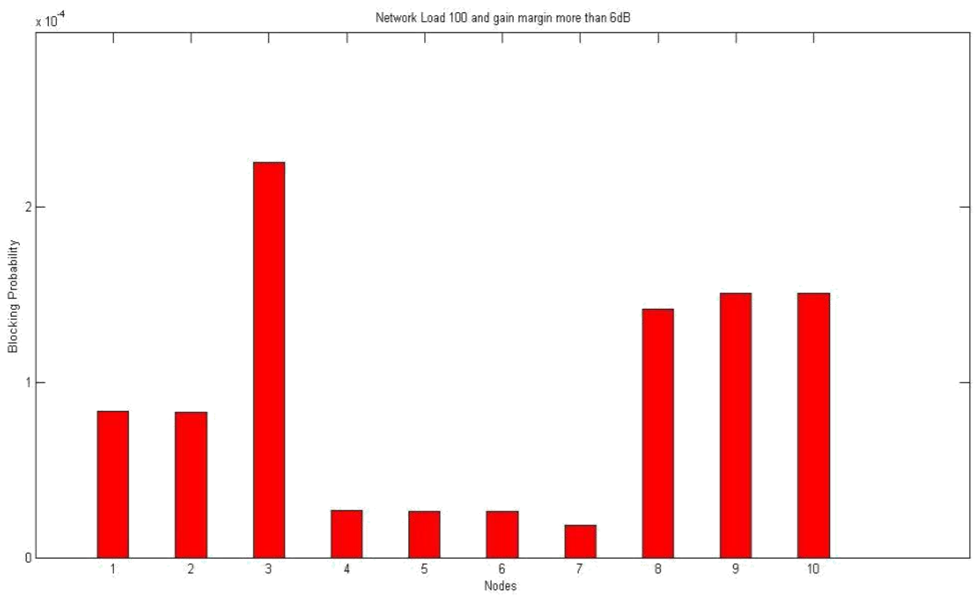

Fig 4.14Blocking probability VS Nodes for load=100E, gain >6dB
No of wavelengt

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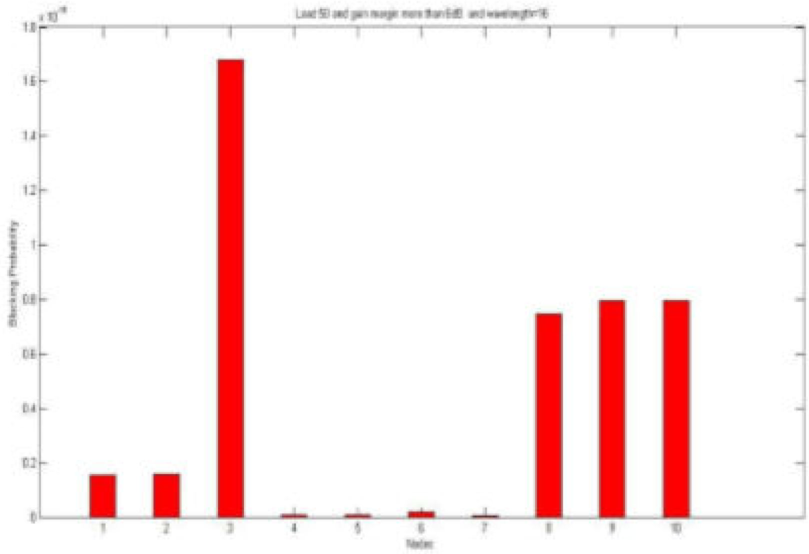

Fig 4.15 Blocking probability VS Nodes for load=50E, gain >6dB
No of wavelength=16

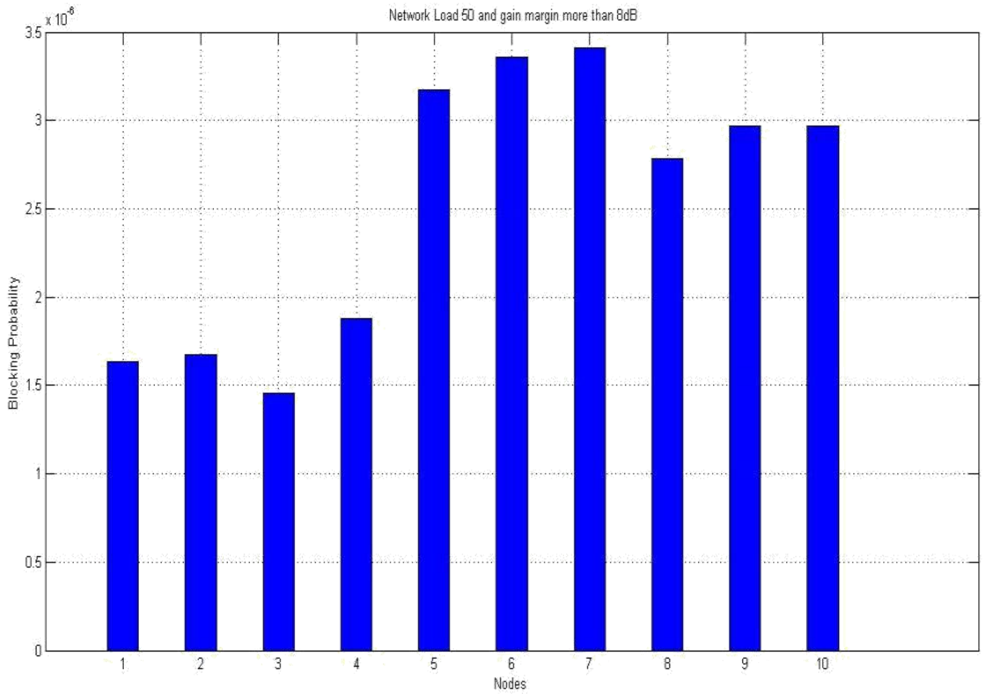

Fig 4.16 Blocking probability VS Nodes for load=50E, gain >8dB
No of wavelength=8

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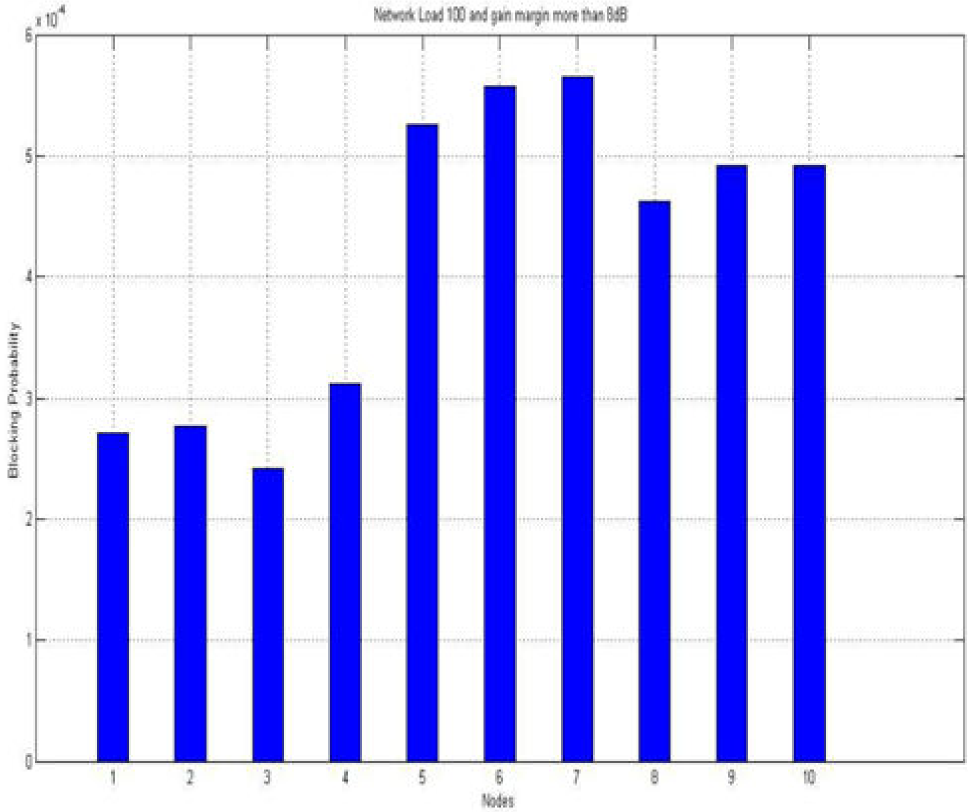

Fig 4.17 Blocking probability VS Nodes for load=100E, gain >8dB
No of wavelength=8

VIII. CONCLUSION

As the load grows from 50E to 100E, blocking chance increases.

- From 8 to 16 wavelengths allocated, the blocking likelihood drops.
- The number of possible paths diminishes as the gain margin rises from 6 dB to 8 dB. As a result, the likelihood of being blocked rises.

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