EFFECTIVE CONGESTION CONTROL IN OPTICAL SWITCHING NETWORKS

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***Abstract*—**Optical Packet Switching determine a route in the network connecting the source and destination by providing a common free wavelength on the fiber links in the determined route hence known as lightpath. To overcome the limitations of above services, Optical Burst Switching Networks were developed. In Optical Burst Switching instead of packets, bursts are used. Burst is the combination of packets. The header (control packet) is transmitted at low speed on a dedicated control channel. This control packet is processed electronically at each node and activated the switch fabric to connect the associated burst to the appropriate output port. On the channel when burst is transmitted in large amount, then problem of congestion occurs. Due to which performance parameters in OBS network degrades. Performance parameters include traffic intensity, throughput, link utilization, blocking probability and congestion. In the paper we have discussed various performance parameters of OBS network. Also we have developed model for control of congestion. The previous algorithms are analyzed and discussed. The proposed model is based on Erlang's Loss Model which depend on traffic intensity, number of servers and blocking probability. In the proposed model, the new relation is being developed to optimize the congestion in OBS network. We have simulated the proposed model using MATLAB software. The proposed model shows the relation between number of server and blocking probability; as with the increase in number of servers, the blocking probability decreases. Also the relations between congestion and blocking probability have been developed. The results depict that with increase in congestion, the blocking probability increases. The relation between congestion and blocking probability was developed the results of which show that with increase in value of congestion, the blocking probability increases and vice-versa.

Keywords*—component; formatting; style; styling; insert (key words)*

I. INTRODUCTION

The word 'Communication' is not new to us. In earlier centuries, the people use various other modes of communication like fire signals, call for help, announcements etc. to transmit signal from one place to another. But these systems were not pursued actively. To make it faster and more efficient, courier method was adopted. It was discussed by Alan B. Markowitz, James H. Pugsley in 1971. In 1834, telegraph system was wired over the roofs of Gottingen by Gauss and Weber. Then F.B. Morse developed code telegraphy in 1837. In 1849, the first slow telegraph printer link was setup. In 1874 to enable six signals from telegraph machines a ''Multiplexers" was invented by Ban Dot to transmit signal together. In 1876 Bell invented a telephone system. In 1897 Marconi patented a wireless telephone system. In 1938 AT & T laboratories in US introduced crossbar-switching system in the field. Till 1965, computer controlled switching was used transistors and printed circuit technology. Then in late 1960's LASERS (Light Amplification of Stimulated Emission and Radiation) were invented and series of technology development around 1970's were invented which were related to optical fibers.

Telecommunications is always a fascinating, fast paced industry that affects every aspect of our lives including simple voice telephone calls, access to the Internet, high speed data communications, satellite communications, surfing the World Wide Web, fax transmissions, video conferencing and cable TV. The basic elements of Telecommunication systems are: a transmitter that takes information and converts it to a signal. A transmission medium, also called the "physical channel" carries the signal. A receiver takes the signal from the channel and converts it back into usable information. Telecommunication systems are of two types; Simplex and Duplex Systems.

Communication systems have signals either analog or digital signals. Analog signals vary continuously with the information while digital signal is encoded into discrete values. This leads to development of analog communication systems and digital communication system. Earlier analog communication systems were used but now we switch over to digital communication systems because it covers large distance; noise effect is less and provides more services. With advantages it also have disadvantage like bit rate is high and needs synchronization in case of synchronous modulation. Modulation and coding used in digital communication depends on characteristics of channel. There are two channel characteristics; bandwidth and power whether the channel is linear or non- linear.

II. OPTICAL NETWORKS

Optical network is used to convey signals over distances by employing any sort of optical technology. Earlier as well as today, there are sets of optical fibers interconnecting electronic switches known as first-generation (1G) optical networks. In second-generation (2G) optical networks, some routing and switching is performed in the optical domain, without signal conversion to the electrical form.

With the great success of optics in communications networks experts call it “all-optical networks”. This leads to distinction of electrical signals. With high bandwidth optical fibers transmission speeds exceeding Tb/s in a single-wavelength multiplexed optical fiber has to be achieved. Currently, single wavelength can accommodate signals with bit rate of 40 Gb/s. Optical fibers are also characterized by a very low transmission loss per unit length. Andrzej Jajszczyk, 2005.

The electrical signal does not offer high bandwidth as optics, but it facilitates transmission of signals of higher granularity which means that we can accommodate lots of signals of different bit rates instead of a limited number of high bandwidth optical “pipes”. These low rate electrical signals can be easily multiplexed and then transmitted together through a high rate optical channel.

With the success of optical networking technology the reality of the coexistence of optics and electronics is generated. The coexistence can be distinguished by three functional planes:

A. SONET

The Synchronous Digital Hierarchy (SDH) or Synchronous Optical Network (SONET) was widely used, well-understood, mature, and standardized technology. These were initially designed for optimizing the transport of 64 kb/s-based TDM services and were building with bit rates reaching 40 Gb/s. these were developed to replace T1 and E1 technologies to provide high speed (1.544 Mbps and 2.048 Mbps, respectively) digital carrier system for voice traffic. To serve data traffic several enhancements had been proposed which include the Virtual Concatenation (VC) technique, the Link Capacity Adjustment Scheme (LCAS), and the Generic Framing Procedure (GFP).

VC provides effective use of SDH/SONET capacity by allowing a flexible concatenation of several SDH/SONET payloads. LCAS protocol allows a dynamic alteration of bandwidth of SDH/SONET/OTN transport pipes. This automatically decreases the capacity if VC experiences the failure while LCAS increase the capacity when the network recovers.

B. WDM Networks

Earlier optical networks were based on SDH/ SONET technology extensively used by ring-based architectures for increasing IP traffic. The nodes of networks employ Optical Cross-Connects and Optical Add/Drop Multiplexers. OXC select the desired wavelength channels to be added and dropped on the fly.

Optical Cross Connects (OXC)- In mesh network topology nodes are interconnected by fibers to form an arbitrary graph, an additional fiber interconnection device is needed to route the signals from an input port to the desired output port. Various categories of OXCs include electronic, optical, and wavelength selective devices.

Optical add-drop multiplexer (OADM)-It is used multiplexing and routing different channels of light into or out of a single mode fiber. "Add" refers to the capability of device to add one or more new wavelength channels to an existing multi-wavelength WDM signal and "drop" here refer to the capability of the device to drop (remove) one or more channels, passing those signals to another network path.

WDM are static devices and require manual reconfiguration. These were reserved for an optical switch capable of terminating multiple WDM fibers and dynamically reconfigurable on at least a millisecond timescale with remote software control. In WDM networks each fiber carries a multiple number of wavelength channels. Currently, WDM systems support 160 wavelength channels, each carrying a 10 Gb/s stream with transmission speeds per wavelength as high as 40 Gb/s as given in Andrzej Jajszczyk, 2005. This is because of developments in fiber Bragg gratings and development of Erbium Doped Fiber Amplifier (EDFA) technology. Main problems associated with WDM networks were routing and wavelength assignment. Flexible utilization of resources (wavelengths) was allowed at optical cross connects, but it currently requires using opto-electronic converters. It is designed to use high data rate capability of fiber optic cable. The data rate of metallic cable is less than optical fiber. Different signals of different frequencies were combined. The difference is that the frequencies are very high. WDM technology is very complex. One application of WDM is the SONET network in which multiple optical fiber lines are multiplexed and demultiplexed.

C. Selecting Optical Transport Network (OTN)

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It was originated from digital wrapper of an optical channel technology. Digital wrapper was described in the ITU-T G.709 Recommendation by Andrzej Jajszczyk, 2005 which is a method for encapsulating an existing frame of data, regardless of the native protocol, to create an Optical Data Unit (ODU) similar to that used in SDH/SONET. It allows multiple existing frames of data to be wrapped together into a single entity that can be more efficiently managed through a lesser amount of overhead. It includes a Reed-Solomon Forward Error Correction (FEC) mechanism that improves error performance on noisy links. Digital wrappers have been defined for 2.5-, 10-, and 40-Gbps systems. OTN defines an overhead in the optical layer used to monitor the bit error ratio as well as to implement an efficient coding for improving the observed signal quality. A distinguishing feature was that it provides client independence. Difference between OTN and SDH was that the former operates at the Tb/s or Gb/s level without getting involved in Mb/s transmissions as in the case of SDH/SONET.

OTN offers the following advantages relative to SONET/SDH:

- Stronger Forward Error Correction

- More Levels of Tandem Connection Monitoring (TCM)
- Transparent Transport of Client Signals
- Switching Scalability OTN has the following disadvantages:
- Requires new hardware and management system

D. Optical Circuit Switching (OCS)

A Circuit-Switched Communication system involves three phases:

- Circuit establishment (setting up dedicated links between the source and destination);
- Data transfer (transmitting the data between the source and destination); and
- Circuits disconnect (removing the dedicated links).

In Circuit Switching, before the beginning of data transmission, connection path is established. Therefore throughout the network channel, capacity was reserved between the source and destination and each node must have available internal switching capacity to handle the requested connection. Clearly, the switching nodes must have the intelligence to make proper allocations and to establish a route through the network.

Depending on the transmission technology and the physical transmission media, a switching node was based on electrical (analog or digital) or optical technology. A switching node provides the following basic functionalities:

1. Signaling
2. Switching
3. Control
4. Interfacing

Dr. Farid Farahmand and Dr. Qiong Zhang in 2007, showed that to check the activity of incoming lines and to forward status is the basic function of the signaling element in a switching node. Under control element signaling was used to place control signals on outgoing lines. The switching function was provided by a switching matrix where it was array of selectable cross-points used to complete connections between input lines and output lines. To connect different devices, such as analog, digital TDM lines, optical fibers, etc. to the switch matrix the hardware required was provided by network interface. Wavelength Routing was defined as the use of wavelengths to route data and network which employs this technique was known as a wavelength-routed network.

E. Prepare Optical Packet Switching (OPS)

Optical Packet Network consists of Optical Packet Switches interconnected with fibers running WDM. The operation was performed by determining a route in the network connecting the source and destination by providing a common free wavelength on the fiber links in the route hence known as light path. The entire bandwidth on the light path was allocated to the connection during its holding time.

- A Generic OPS node structure consists of three sub blocks:
- An input interface consists of a synchronizer which aligns incoming packets in real time against a clock.
- A switching core routes the packets to their proper outputs and executes contention resolution.
- An output interface inserts a new header and may have to regenerate the data

One optical packet was comprised in equal time slots. The payload bears data from 622 Mb/s to 10 Gb/s. The header field was 14 bytes: 8 for routing information; 3 for identification of payload type; flow control information, packet numbering for sequence integrity preservation, and header error checking.

III. OPTICAL BURST SWITCHING (OBS)

In the Burst Switching, header was transmitted by source followed by a packet burst. The header (control packet) was transmitted at low speed on a dedicated control channel. This control packet was processed electronically at each node and activated the switch fabric to connect the associated burst to the appropriate output port. The transmission of data bursts and its header are shown as under given by C. Qiao et.al. in 2004:

The main motive was to aggregate incoming packets from the access network into defined size bursts. The most important issue was to perform optimal scheduling schemes like Tell-And-Wait (TAW) and Tell-And- Go (TAG).

In TAW, it provides report about resource reservation until burst waits for control packet and then after confirmation of available resources it was send. In TAG, reservation was made during transmission and burst was sent after control packet. Another scheduling scheme was Just Enough Time (JET) model and Just in Time (JIT).

The deployment of such technology needs to address several critical issues affecting network performances like Contention resolution, QoS support, burst assembly, traffic admission control, performances monitoring, signaling and network resources dimensioning constitute the most critical issues in the development of OBS services.

Contention resolution: Contention occurs when multiple data bursts are switched on the same wavelength are destined to go out through the same output port at the same time. In traditional packet switches, contention was handled by electronic RAM and now Fiber Delay Lines (FDL) was used because of limited size.

QoS support: The emergence of multimedia applications with diverse QoS demands, such as voice-over-IP, video-on-demand, and video conferencing urges the next generation networks to provide QoS guarantees. Efficient admission control and resource provisioning mechanisms were required to provide an absolute QoS over an OBS network.

Burst assembly: Burst assembly is defined as procedure of aggregating and assembling input packets from sources into bursts at the ingress edge nodes of an OBS network. The trigger condition permits the control of the burst arrival into the network. The most frequent burst assembly techniques are timer-based and threshold-based. In timer-based approaches, a burst was created when a timer expired and was generated at periodic time intervals. In threshold-based approaches, a burst was created when the burst length exceeds the fixed threshold and was generated at non-periodic time intervals.

Burst admission control: It aimed at deciding whether to accept or reject a new data burst based on parameters like the burst length, the QoS constraints, and the network resources availability. The development of burst admission control in OBS network may improve the provision of QoS as well as the network resources efficiency. This improved the reliability of network operator towards its customers and provides the effectiveness of network deployment.

Signaling: Signaling was the most important issues and critical. The transmission of a pure payload data burst through an optical burst switched network required the strict respect of control information established during signaling step such as burst arrival time, burst length, burst priority, etc. Different signaling schemes were proposed like TAW and JET.

Resource Dimensioning and Optimization: It specified how to determine the optimal network configuration to support a given input traffic with specified QoS constraints. New optimization problems arise in connection for two main reasons. First, the cost of the optical networking equipment is not still. Second, the development of the optical technology results to control new functional constraints that must be taken into account during network design and dimensioning. The use of WC, burst segmentation, QoS management, and transmission capacity optimization were addressed little.

Performances monitoring: Optical Performance Monitoring issue was used and consists of how to detect and respond to network behaviors or events. These were broken down into three layers. The first layer was transport or WDM layer monitoring, which considered transport and channel management at the physical layer. It considered real time measurements of signal presence, optical signal noise ratio, and power level. The second layer was signal quality layer monitoring. It locked onto a single wavelength and performed signal quality measurements. The third layer was protocol performance monitoring that involved monitoring the performance of deployed network and traffic engineering protocols. It includes network resources utilization supervision, congestion control, and QoS monitoring.

IV. CONGESTION

When the link or node carry large amount of data with which quality of service of the system decreases or deteriorates is called congestion. It occurs when a link or node is carrying large amount of data, so that its quality of service deteriorates. Main effects include queueing delay, packet loss or the blocking of new connections.

Queuing Delay is the time job waits in a queue until it can be executed. When packets arrive at a router, they are processed and transmitted. A router can only process one packet at a time. If packets arrive faster the router puts those into the queue until it transmit it. The maximum queuing delay is proportional to buffer size. The longer the line of packets waiting to be transmitted, the longer the average waiting time is; and when the buffer fills the router must drop packets.

Packet loss occurred when one or more packets of data travelling across a computer network fail to reach their destination. Packet loss can be caused by a number of factors including signal degradation over the network medium due to multi-path fading, packet drop because of channel congestion, corrupted packets rejected in-transit, faulty networking hardware, faulty network drivers or normal routing routines. The lost or dropped packets can result in highly noticeable performance issues or jitter with streaming technologies, voice over IP, online gaming and video conferencing, and will affect all other network applications to a degree.

With increase in network load there is decrease of useful work done which is known as congestive collapse. Congestive collapse was caused by spurious retransmissions, undelivered packets, fragments, control traffic and stale or unwanted packets. Hence, to avoid congestive collapse, congestion control concerns controlling traffic entry into a telecommunications network and various congestion control algorithms were defined. These are classified as under:

- By the type and amount of feedback received from the network: loss; delay; single-bit or multi-bit explicit signals
- By incremental deploy ability on the current Internet: Only sender needs modification; sender and receiver need modification; only router needs modification; sender, receiver and routers need modification.
- By the aspect of performance it aims to improve: high bandwidth-delay product networks; lossy links; fairness; advantage to short flows; variable-rate links
- By the fairness criterion it uses: max-min, proportional, "minimum potential delay"

To prevent network congestion and collapse two major components are required:

1. A mechanism in routers to reorder or drop packets under overload,

2. End-to-end flow control mechanisms designed into the end points which respond to congestion and behave appropriately.

Traffic congestion increases when its use increases means when demand increases and it is characterized by slower speeds, longer trip times and increased vehicular queueing. As demand approaches the capacity of a road, it leads to congestion. The demand is directly proportional to traffic intensity. The Traffic Intensity (T) is defined as the product of the calling rate (λ) and the average holding time (h) as $T = \lambda/h$, hence demand $D = cT = c\lambda/h$.

V. Congestion

When the transmission of burst is more than reception, then congestion occurs. It means, the burst is transmitted at regular interval and due to less delay between the bursts a queue is formed at the reception which causes congestion. In OBS network to minimize the congestion various algorithms were developed. Some of the congestion control algorithms were:

For a generic network a simulation based burst level congestion controller was introduced in 2001 by Gang Wu et.al. this regulated the traffic to achieve high network efficiency. When the structure of service rate model was exploited then network performance was improved. In this approach, congestion control architecture was developed which contained a state observer, a traffic simulator and a rate calculator.

Modified TCP decoupling approach was proposed in 2003 by S.T. Wang as congestion control mechanism to congestion-control the offered traffic and regulates the timing of sending bursts. In this approach a management TCP connection was set up which was used for the purpose of congestion control. The bandwidth of channel was set up to 10 Mbps and queue length to 0. Also self clocking property was used to reduce the risk of burst collision to guide the sending times of bursts which resulted in reduced packet drop rate.

To avoid congestion two routing techniques were developed in 2003 by Guru P. V. Thodime. First, Congestion based dynamic route selection technique using fixed alternate SP routes. In this path was selected based on congestion information. The congestion was shown if load was exceeded the threshold value. Then path was selected where bust was transmitted. Secondly, least congested dynamic route calculation technique with different weight function. In this weight function was set equal to congestion metric results in least congested path. This resulted in low packet loss probability when burst was sending on least congested route. After simulation, the proposed congestion based approach performed better than network without any alternate routing scheme. As compared to network without any contention avoidance, both techniques reduce packet loss probability.

In 2005, ICCM was proposed by Sungchang Kim et.al. as schemes like FDL, WC and DR were unable to prevent congestion. This mechanism combined congestion avoidance with recovery mechanism. To prevent congestion the amount of burst flow entered into the network was restricted. Also the overloaded traffic was dropped to support fairness, so a flow policing scheme was proposed. Here in this scheme, two different fairness properties were defined: rate fairness; according to offered rate bandwidth of each flow was allocated fairly and distance fairness; with respect to hop count of each burst the data burst was treated fairly as flows with large hops got low throughput. In rate decision mechanism, the rate at which each flow was allowed to enter the network was regulated. Main goal was to converge on set of per flow transmission rates that prevents congestion due to overloads.

In 2006, M. Klinkowski studied two adaptive routing strategies, the MP and the BP in addition to SP algorithm. In case of SP, a route of the shortest distance was assigned between source and destination nodes for each burst. If number of path exists then first was selected. So that if contention occur burst was lost. In case of MP, between each pair of source and destination nodes there were number of pre-established paths. For each burst, routing decision was made by this algorithm. If the burst was not transmitted on first route then higher or equal length burst was selected. Also the routing algorithm could reroute the path when congestion occurs. In case of BP, the burst was transmitted through other node by by-pass the congested node. Hence isolated routing does not cope with the congestion in OBS network.

True congestion estimation model in which router's behavior was considered uses a rip-up and reroute method when face congested tracks. Using congestion prediction method the congestion was predicted more accurately. But routing blockage effects the congestion prediction. Then an efficient congestion reduction technique was proposed in 2006 by Mehdi Saeedi which was based on contour plotting. By local modifications the congestion was tried to reduce in the congested regions and this could be done by: congested region detection, region expansion and local congestion reduction. Then in 2007 author modified the model by introducing congestion related metrics which estimated congestion more accurately by 21%. In congestion region detection and congestion reduction, new methods were proposed in which congestion reduction decreased the peak congestion metric by about 25% and increased the total wire-length less than 0.22% on average and reduced congestion by 10% than other method.

Then in 2007, A. Abid proposed FCRB of the SRS as a congestion control mechanism for OBS Networks. To increase the throughput and to overcome the limitation of burst segmentation SRS scheme was proposed. This scheme used FCRB as the segments length indicator rather than flags. Network capacity was used by edge nodes while reacted to the congestion by using an explicit congestion avoidance technique. Here the bits of FCRB were used to indicate the amount of data transmitted and received. This approach worked in one of two directions either Forward or Backward.

To handle bursts as short as 100 ms with switching within 10 ms in networks less than 200 km long a congestion-controlled OBS Network was designed. Two-way signaling was used to guarantee the connections, requiring a RTT for each of established and released optical burst path in which an optical burst was transferred without dropping. A Congestion Control scheme was designed to reduce call blocking probability which required 3 approaches:

1) Solve the wavelength assignment problem

2) Setting detours

3) Scheduling in the time domain.

At various traffic loads the call blocking probability was measured. When traffic load was 0.1, congestion probability was 6%. 77% of congested optical bursts were detoured and transmitted by the alternative route, when congestion control with detour was applied. When traffic load was 0.4, congestion probability was 18%. 45% of the congested optical bursts were detoured which indicated that congestion was successfully controlled with detour in the OBS Network.

A. Proposed Model

Various algorithms were used to control or avoid congestion. But they control congestion upto some extent. In this thesis, we propose congestion control algorithm using Erlang's B formula. In earlier algorithms, Erlang formula was used as the relation between blocking probability and traffic intensity which was given as:

B=(A^n/n!)/(∑_(i=0)^n▒A^i/i!) (i)

Where, n = Number of channels

B= Blocking Probability

A= Traffic Intensity

To control congestion, we modified the Erlang's Loss Formula. We develop the relation between Congestion, C_gand blocking probability, B. From the papers, it came into light that demand is directly proportional to congestion. As demand of the signal increases congestion increases and vice-versa. Also, demand, Dis directly proportional to traffic intensity, A.

Dα A ….……….. (ii)

D=cA …..………. (iii)

Where, c is constant.

The Traffic Intensity is given as:

A=λh=λW=λ/μ ……..…… (iv)

Where, h or W= Call holding time

λ = Call arrival rate

μ = Average number of requests processed per time

Hence,

D=cλh=cλW=c λ/μ …….…….. (v)

Congestion is directly proportional to traffic intensity.

So,

D=cλh=cλW=c λ/μ=C_g ………….. (vi)

Now, the modified model of Erlang Loss Model are:

B=(C_g/C_1)^n/(∑_(i=0)^n▒(C_g/C_1)^i) …….. (vii)

Where, B = Blocking Probability

C_g= Congestion

C_1= Constant value

n = Number of channels

For congestion control, the function of modified Erlang's Model is developed in MATLAB Software. Now a program is written to calculate blocking probability in terms of congestion. First the relation between number of servers (n) and blocking probability (B) will be calculated. Secondly the relation between traffic intensity (ρ) and blocking probability (B) will be calculated. Then, the relation between congestion 〖(C〗 g) and blocking probability will be generated.

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VI. Results and Discussion

Relation between Number of Servers (n) and Blocking Probability (B)

Using MATLAB, the results have been developed by using the proposed model and the value of blocking probability is calculated terms of number of servers. These results are shown in figure (5.1)-figure (5.16):

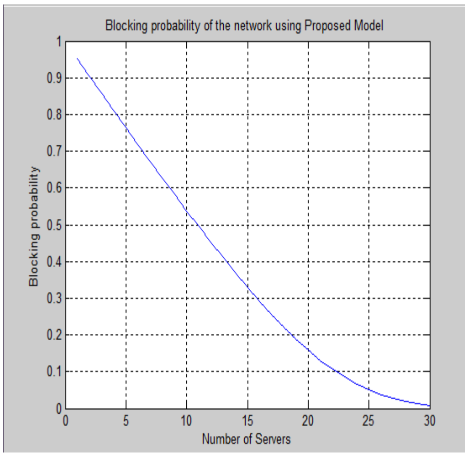

Figure 5.1 Blocking probability vs. Number of servers for n= 30 and ρ= 20

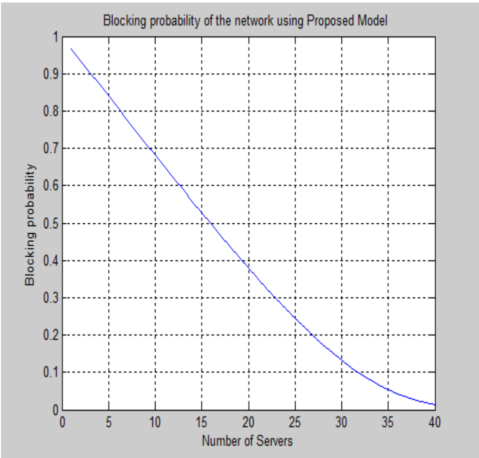

Figure 5.2 Blocking probability vs. Number of servers for n= 40 and ρ= 30

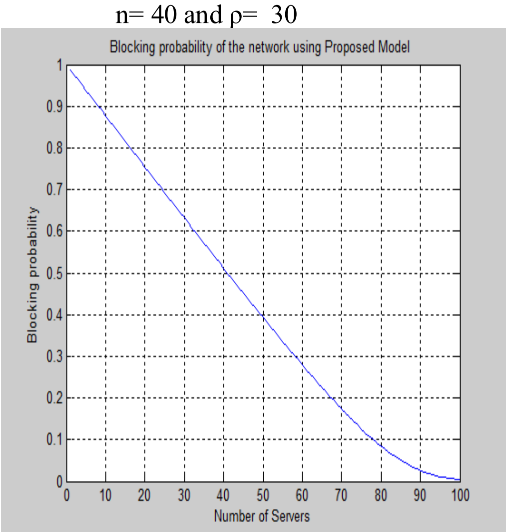

Figure 5.3 Blocking probability vs. Number of servers for n=100 and ρ= 80

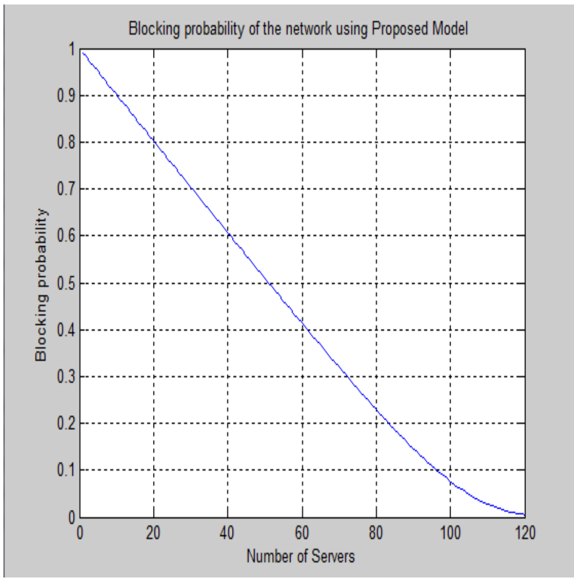

Figure 5.4 Blocking probability vs. Number of servers for n=120 and ρ= 100

The result shows that when the number of servers increases then blocking probability decreases and reaches nearly zero. Figure 5.1 show that when the number of servers is 30 and traffic intensity is 20 then with increase in number of servers, the blocking probability decreases and when the number of servers reached 30, then the value of blocking probability becomes approximately zero. Figure 5.2 depicts that when the number of servers is 40 and traffic intensity is 30 then with increase in number of servers, the blocking probability decreases and reaches approximately to zero. In figure 5.3 when the number of servers increases from 40 to 100 and traffic intensity from 30 to 80 respectively, then there is decrease in blocking probability. Results in figure 5.4 show that when the number of servers is 120 and traffic intensity is 100, the blocking probability minimizes to zero.

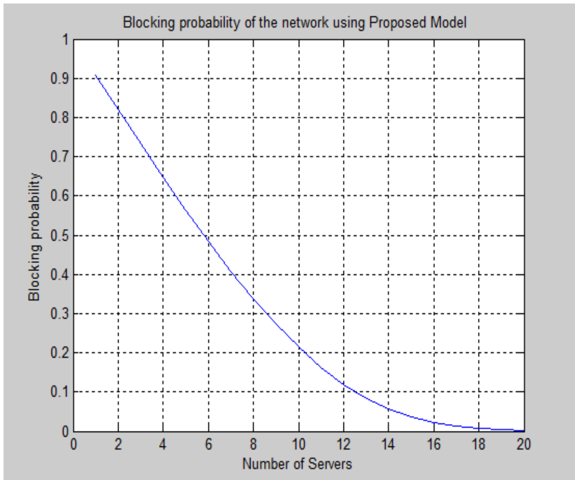

Figure 5.5 Blocking probability vs. Number of servers for n=20 and ρ= 10

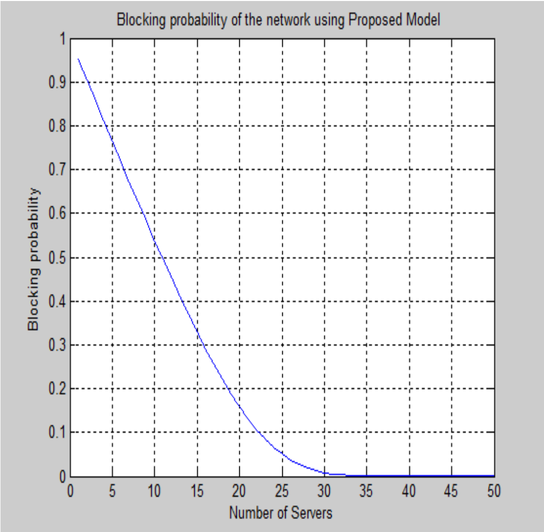

Figure 5.6 Blocking probability vs. Number of servers for n=50 and ρ= 20

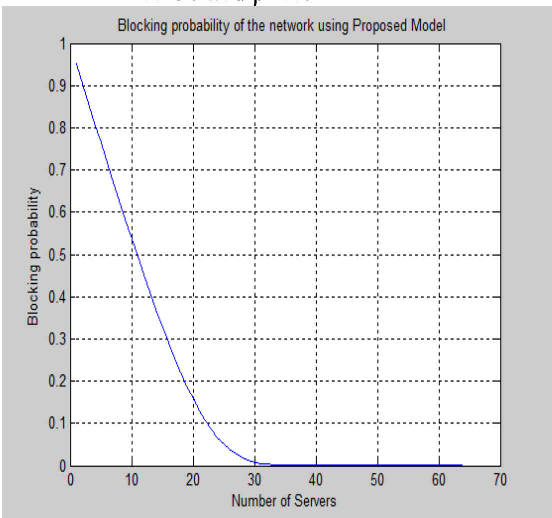

Figure 5.7 Blocking probability vs. Number of servers for n= 64 and ρ= 20

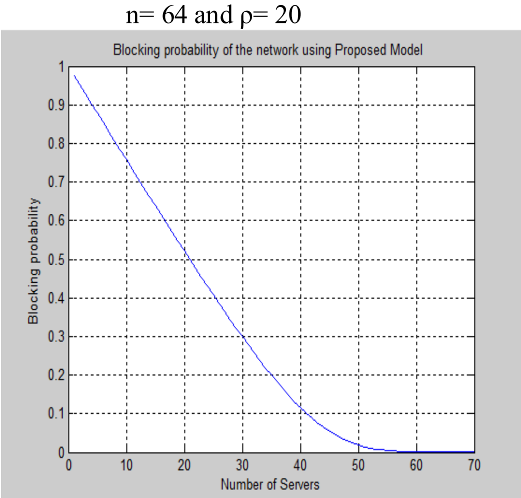

Figure 5.8 Blocking probability vs. Number of servers for n= 70 and ρ= 40

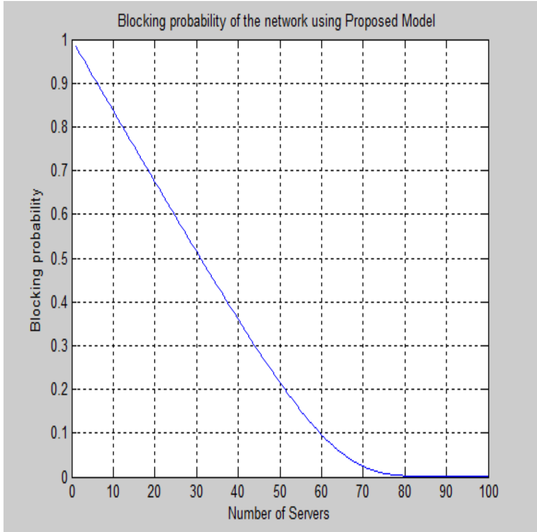

Figure 5.9 Blocking probability vs. Number of servers for n= 100 and ρ= 60

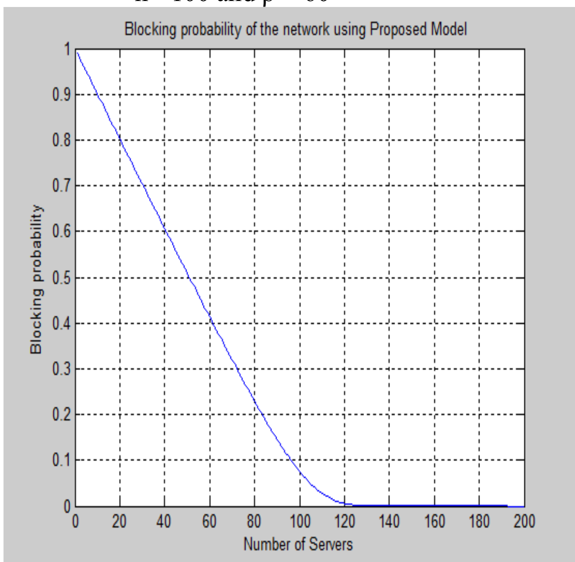

Figure 5.10 Blocking probability vs. Number of servers for n= 200 and ρ= 100

From figure 5.1 to 5.4 results show that with increase in number of servers the blocking probability decreases. Also in figures 5.5 to 5.9 it shows the same results but with a distinction. In figure 5.5 when the number of servers increases from 18 to 20 then blocking probability decreases and are approximately zero. Figure 5.6 show that from 30 to 50 when the number of servers increases, the blocking probability reduces to zero. Figure 5.7 depicts that when the number of servers increases from 30 to 64 then value of blocking probability minimize to zero. Result of figure 5.8 show that when the number of servers increases from 55 to 70 then the blocking probability minimizes to zero. Figure 5.9 and 5.10 shows that when number of server increases from 75 to 100 and from 120 to 200 then blocking probability reaches to zero.

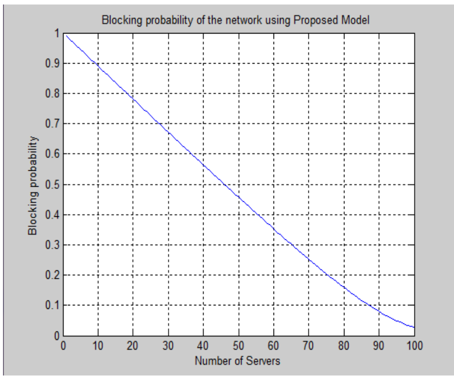

Figure 5.11 Blocking probability vs. Number of servers for n= 100 and ρ= 90

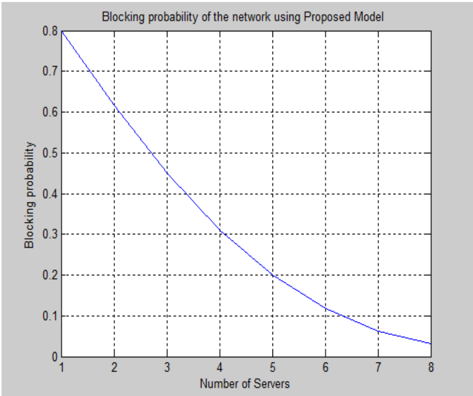

Figure 5.12 Blocking probability vs. Number of servers for n= 8 and ρ= 4

In figure 5.11 and figure 5.12, results show that the blocking probability decreases with increase in number of servers. In figure 5.11, show that when the number of servers is 100 and 8 and traffic intensity is 90 and 4, respectively then the blocking probability decreases and approximately reaches to zero.

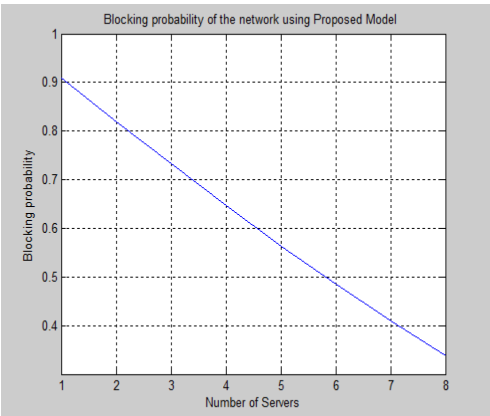

Figure 5.13 Blocking probability vs. Number of servers for n= 8 and ρ= 10

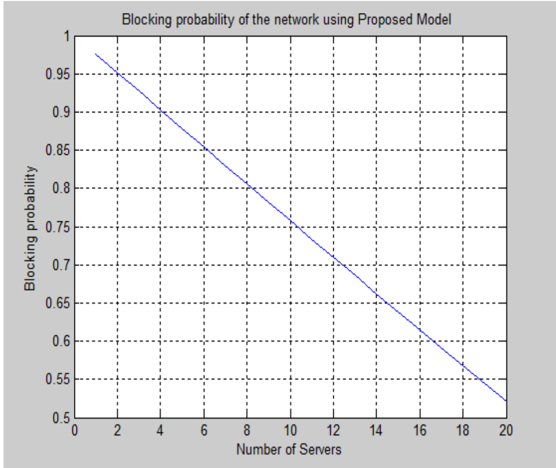

Figure 5.14 Blocking probability vs. Number of servers for n= 20 and ρ= 40

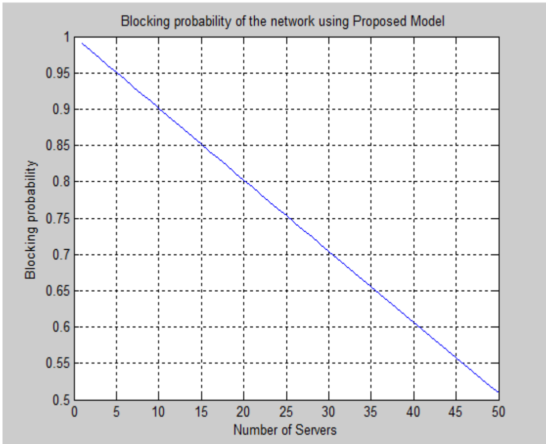

Figure 5.15 Blocking probability vs. Number of servers for n= 50 and ρ= 100

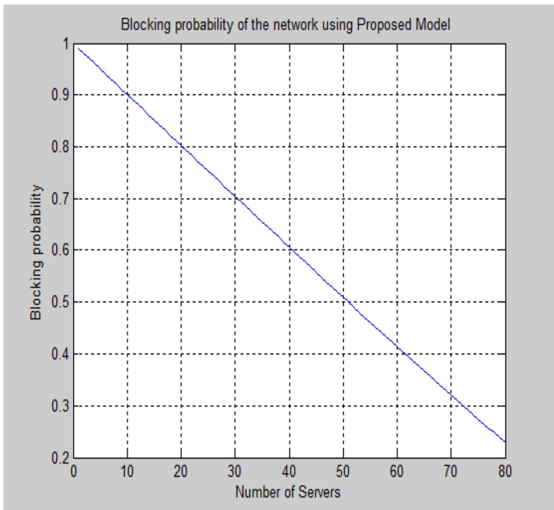

Figure 5.16 Blocking probability vs. Number of servers for n= 80 and ρ= 100

But when the number of servers is less than the traffic intensity, it results in linear reduction in blocking probability with increase in number of servers. From figure 7.13 to 7.16 results show that with increase in number of servers the blocking probability decreases. When the number of servers is 8, 20 50 and 80 then the blocking probability decreases linearly.

1. **Relation between Traffic Intensity and Blocking Probability**

Using MATLAB, the values of blocking probability is calculated in terms of the traffic intensity and is shown by the results shown in figure (5.17) - figure (5.32) as:

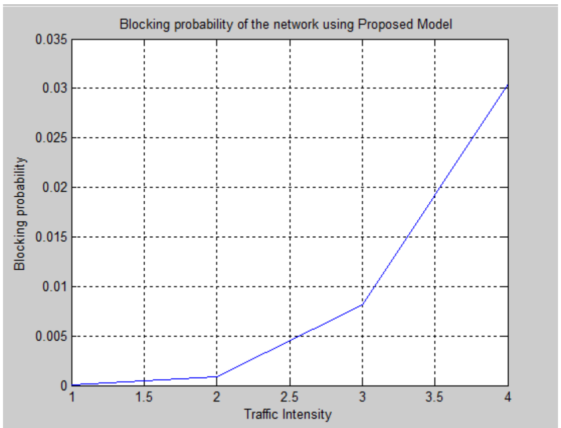

Figure 5.17 Blocking probability vs. traffic intensity for n= 8 and ρ= 4

In figure 5.17, with increase in traffic intensity, the blocking probability increases. Here we have taken the case when number of servers is more than traffic intensity. It shows a drastic change when traffic intensity increases from 3 to 4.

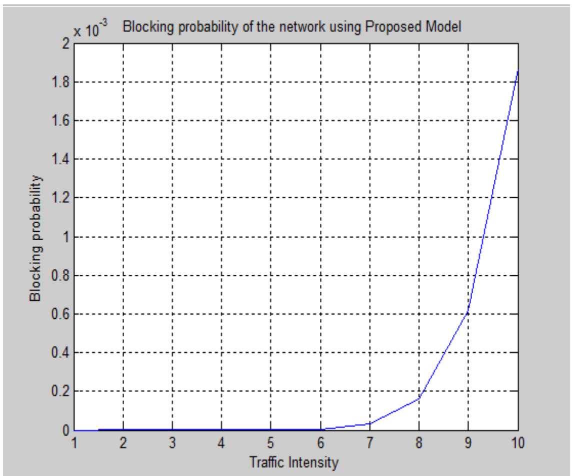

Figure 5.18 Blocking probability vs. traffic intensity for n= 20 and ρ= 10

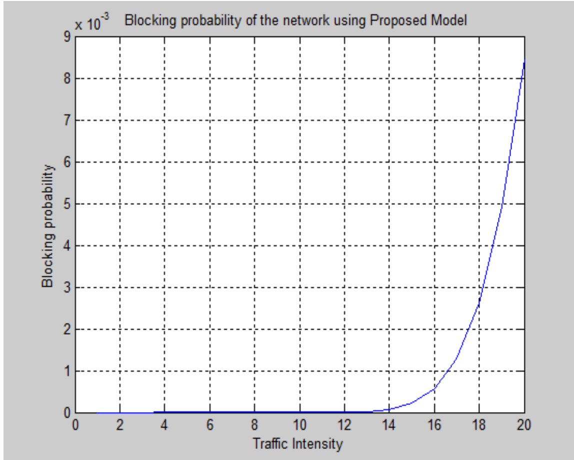

Figure 5.19 Blocking probability vs. traffic intensity for n= 30 and ρ= 20

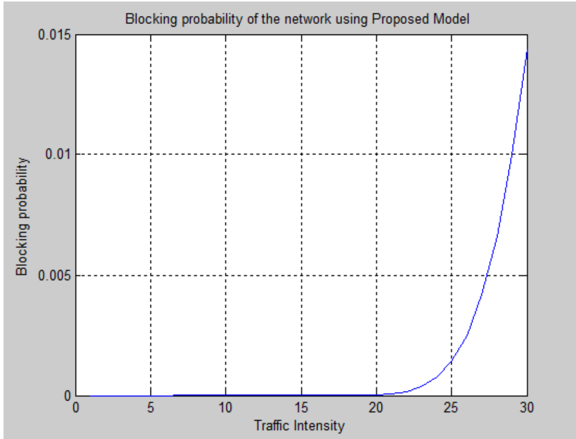

Figure 5.20 Blocking probability vs. traffic intensity for n= 40 and ρ= 30

The results show that when the traffic intensity increases then the blocking probability increases. Figure 5.18 – figure 5.20 shows that when the traffic intensity is 10, 20 and 30 respectively, then the blocking probability increases. In figure 5.18 when the value traffic intensity is 6 the value of blocking probability is zero. But with increase in traffic intensity from 6 to 10, the blocking probability increases. Figure 5.19 depicts that when the traffic intensity increases from 14 to 20 the blocking probability increases. In figure 5.20 the traffic intensity increases from 20 to 30 it causes increase in blocking probability.

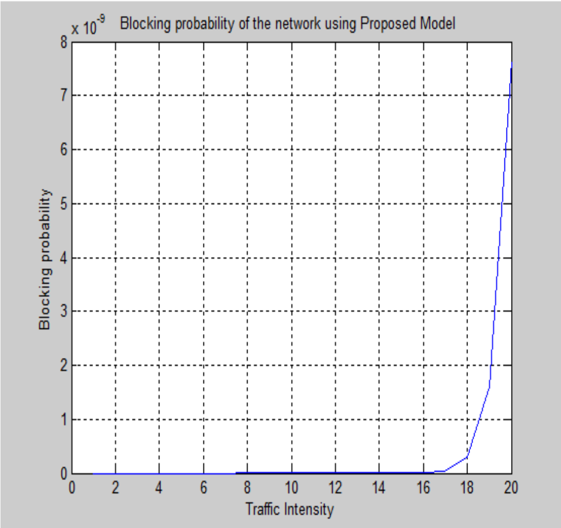

Figure 5.21 Blocking probability vs. traffic intensity for n= 50 and ρ= 20

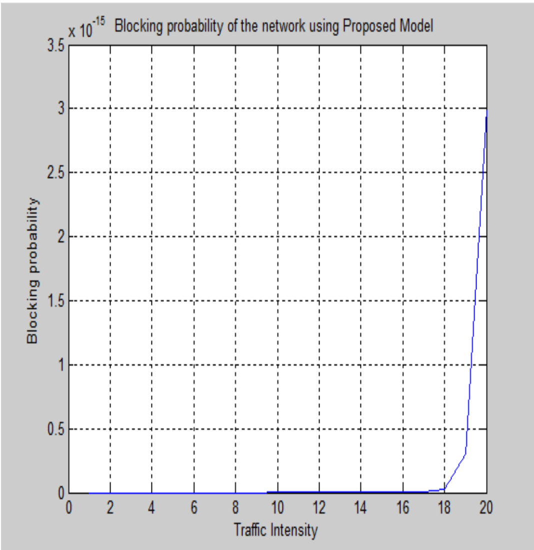

Figure 5.22 Blocking probability vs. traffic intensity for n= 64 and ρ= 20

When the traffic intensity increases then the blocking probability increases this is shown in results. Figure 5.21 and figure 5.22 shows that when the traffic intensity is 20 but the number of servers is changed, then the blocking probability increases accordingly. In figure 5.21 when the value traffic intensity is less with the value of number of servers is 50 then the blocking probability is approximately zero but with increase in traffic intensity from 17 to 20, the blocking probability increases drastically. Figure 5.22 depicts that with increase in traffic intensity from 18 to 20 and having number of servers 64 then the blocking probability increases.

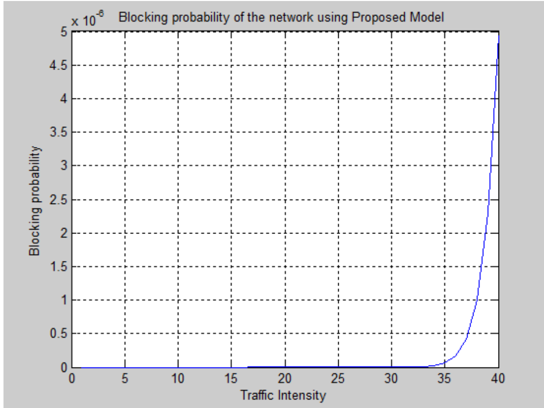

Figure 5.23 Blocking probability vs. traffic intensity for n= 70 and ρ= 40

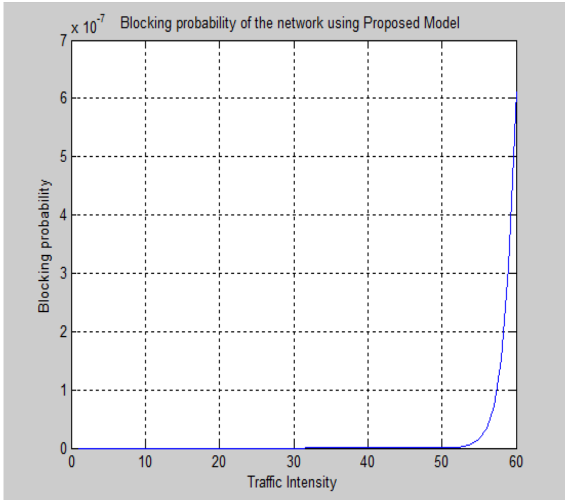

Figure 5.24 Blocking probability vs. traffic intensity for n= 100 and ρ= 60

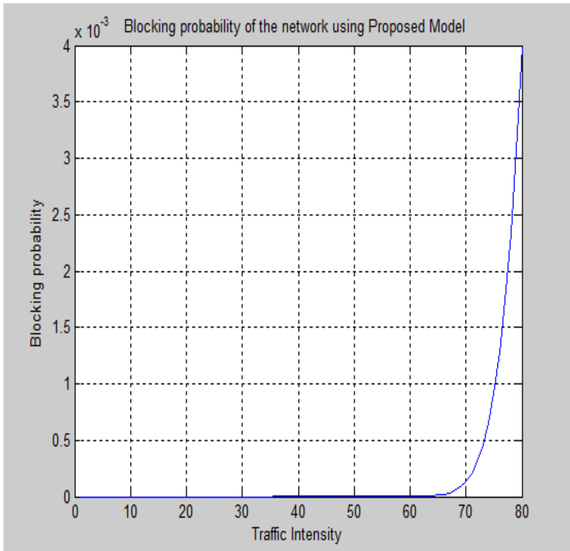

Figure 5.25 Blocking probability vs. traffic intensity for n= 100 and ρ= 80

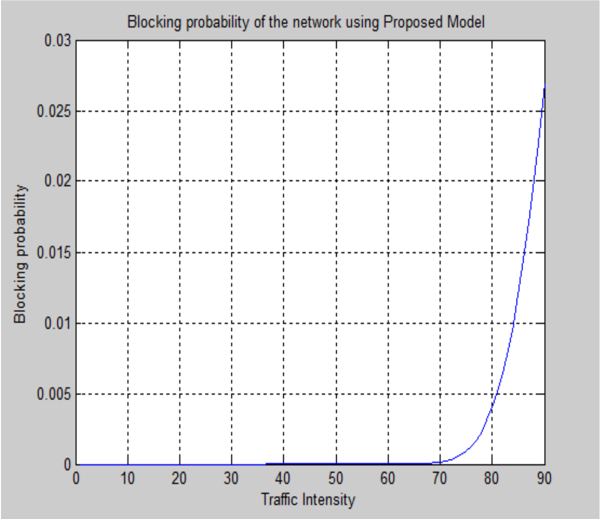

Figure 5.26 Blocking probability vs. traffic intensity for n= 100 and ρ= 90

The blocking probability increases when the traffic intensity increases are shown in Figure 5.23; figure 5.24 – figure 5.26. This increase also depends on number of servers. In figure 5.23 the blocking probability shows a drastic change when the traffic intensity increases from 34 to 40 when the number of servers is 70. Figure 5.24 shows the same when the value traffic intensity increases from 54 to 60. Figure 5.25 depicts that when the traffic intensity increases from 65 to 80 the blocking probability increases. Result of figure 5.26 shows that the traffic intensity increases from 70 to 90 which lead to increase in blocking probability. The number of servers in figure 5.24 to figure 5.26 is 100.

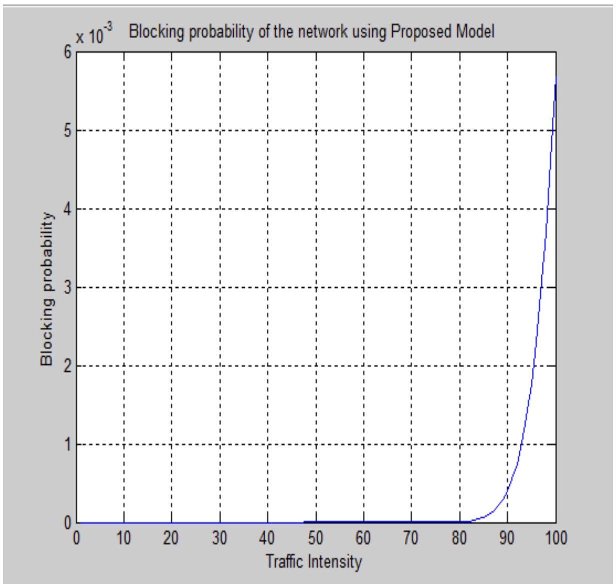

Figure 5.27 Blocking probability vs. traffic intensity for n= 120 and ρ= 100

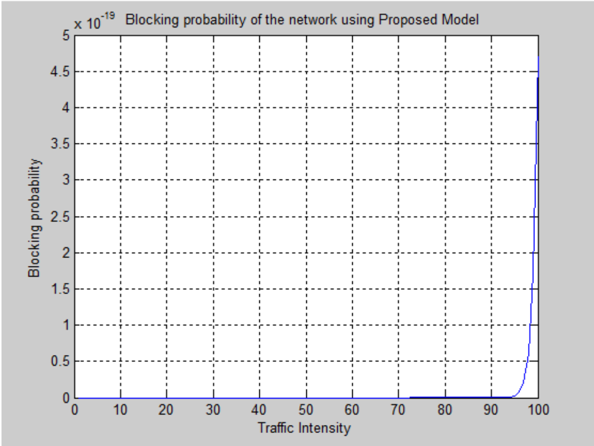

Figure 5.28 Blocking probability vs. traffic intensity for n= 200 and ρ= 100

In figure 5.27 and figure 5.28, the numbers of server are different with the value of 120 and 200 respectively. But the traffic intensity will be taken same as 100. The results of both depict that with increase in traffic intensity, the blocking probability increases.

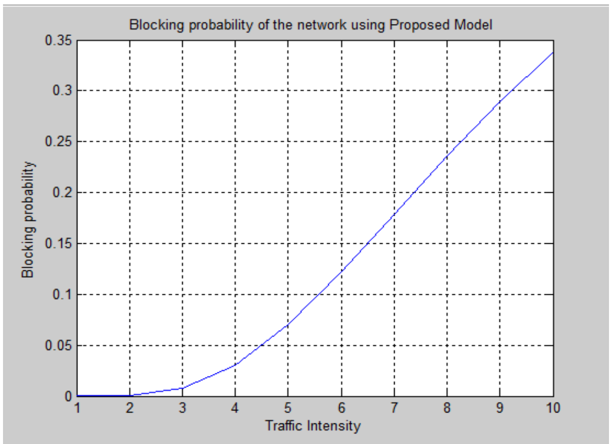

Figure 5.29 Blocking probability vs. traffic intensity for n= 8 and ρ= 10

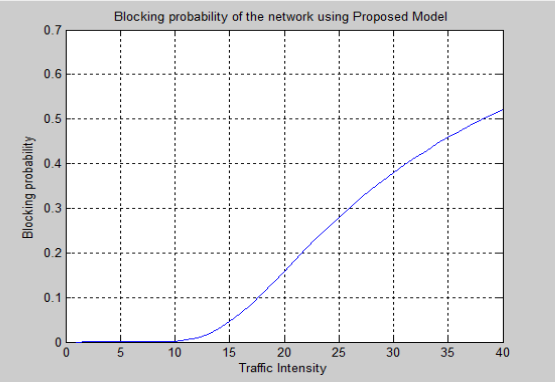

Figure 5.30 Blocking probability vs. traffic intensity for n= 20 and ρ= 40

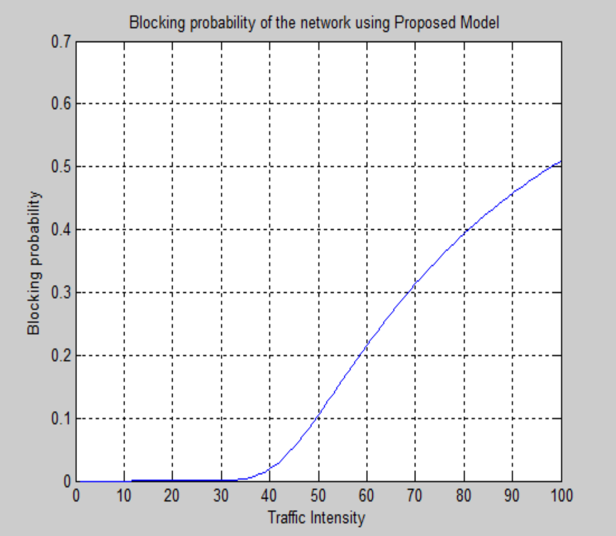

Figure 5.31 Blocking probability vs. traffic intensity for n= 50 and ρ= 100

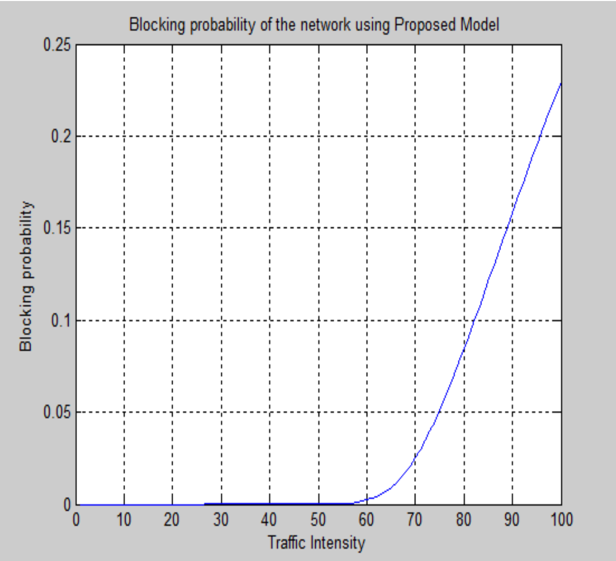

Figure 5.32 Blocking probability vs. traffic intensity for n= 80 and ρ= 100

The blocking probability also increases with the increase in traffic intensity as shown in Figure 5.29 to figure 5.32. From the above results it is different because number of servers is less than traffic intensity.

VII. Conclusion

Due to development in communication services, the network structure also changes. Earlier WDM network was used which transmit the signal in form of wavelength. It worked on routing the wavelength to its destination. Due to which only limited amount of wavelength were transmitted. To overcome this limitation, Optical Circuit Switching was introduced. In OCS before the beginning of data transmission, connection path was established. Hence, capacity was reserved between the source and destination throughout the network channel and each node must have available internal switching capacity to handle the requested connection. In the system capacity was limited so limited amount of data was transmitted. For the elimination of this Optical Packet Switching was introduced which determine a route in the network connecting the source and destination by providing a common free wavelength on the fiber links in the route hence known as *light path*. The entire bandwidth on the light path was allocated to the connection during its holding time. In OPS data was transmitted in form of packets. Packet is the combination of bytes. If the numbers of bytes are more than the capacity of the channel the congestion occurs. To reduce the congestion Optical Burst Switching was introduced. In OBS instead of packets, bursts were used. Burst was the combination of packets. Here header was transmitted by source followed by a packet burst. The header (control packet) was transmitted at low speed on a dedicated control channel. This control packet was processed electronically at each node and activated the switch fabric to connect the associated burst to the appropriate output port. On the channel when burst was transmitted in large amount, then problem of congestion occurs. Due to which performance parameters in OBS network degrades. Performance parameters include traffic intensity, throughput, link utilization, blocking probability and congestion. To control congestion various congestion control algorithms were developed which were discussed in literature review.

In this thesis, in effect to dissatisfaction by the algorithms for congestion control, a new method is developed to control congestion in OBS network. In this Erlang's Loss Model is modified, developing the relation between blocking probability and congestion. In basic Erlang's Loss Model, there is the relation between blocking probability, traffic intensity and number of servers. The results depict that with increase in number of servers, blocking probability decreases and with increases in value of traffic intensity, the value of blocking probability increases. With MATLAB software, the results are obtained by using Modified Erlang's Loss Model. The results show that with increase in number of servers, the blocking probability decreases. In relation to this, with increase in value of congestion, the blocking probability increases. The results of both, earlier algorithms and our proposed algorithms are compared which shows the improved performance of proposed algorithm.

For further investigation of this work it is considered under future work area. The value of congestion and number of server are increased further to investigate the performance of the system using the proposed algorithm.

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