SIMULATION OF NETWORK TRAFFIC BASED ON QUEUING THEORY USING OPNET

Thesis submitted in partial fulfillment of the requirements for the award of degree of

Master of Engineering
In
Computer Science & Engineering

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Certificate

I hereby certify that the work which is being presented in the thesis entitled, **"Simulation of Network Traffic based on Queuing Theory Using OPnet"**, in partial fulfillment of the requirements for the award of degree of Master of Engineering in Computer Science and Engineering submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of Dr. V.P Singh and refers other researcher's works which are duly listed in the reference section.

The matter presented in this thesis has not been submitted for the award of any other degree of this or any other university.

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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(Nitesh Kumar Singh)

Abstract

The simulation approach is the most cost effective and highly useful because it provides a virtual environment for network simulation of desirable features such as modeling a network based on specific criteria and analyzing its performance under different scenarios with no cost. Most networks are built to accommodate the needs of a single organization or group. So in current era, analysis of network simulation is very costly with real equipments, so by using some simulation tools which helps to simulate the data on mathematical view and generate the accurate results. To understand the total data transfer time from user to server and back in the network with network congestion. In this problem the queuing theory application in time especially M/M/1 method is used to define the network congestion and buffer time to provide the output of the query. Network simulation helps to examine problems with much less work and of much larger scope than are possible with experiments on real hardware. An invaluable tool in this case is the free OPNET network simulator that offers the tools for modeling, design, simulation, data mining and analysis. OPNET can simulate a wide variety of different networks which are linked to each other.

Data message flows, packet losses, control/routing message flows, link failures, bit errors, etc. can be calculated. This is the most cost effective solution for to demonstrate the behaviors of different networks and protocols. In this thesis, the simulation of network traffic based on queuing theory has been proposed. Which will helps to reduce the network congestion in the network traffic.

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Chapter 1 Introduction

As the technology is improving now days, demands of end users and their applications also increasing. A wide variety of new applications are being invented daily. These Applications have different demands from the underlying network protocol suite. High Bandwidth internet connectivity has become a basic requirement to the success of almost all of these areas.

Network simulation with queuing theory explains the various related technologies like Simulation of network and OPnet technology, and also the how to use Queuing theory.

1 .1 Background

Why we do simulation? This type of problem is answered by this figure1.1 *i.e.* expensive, big, Complex and distributed.

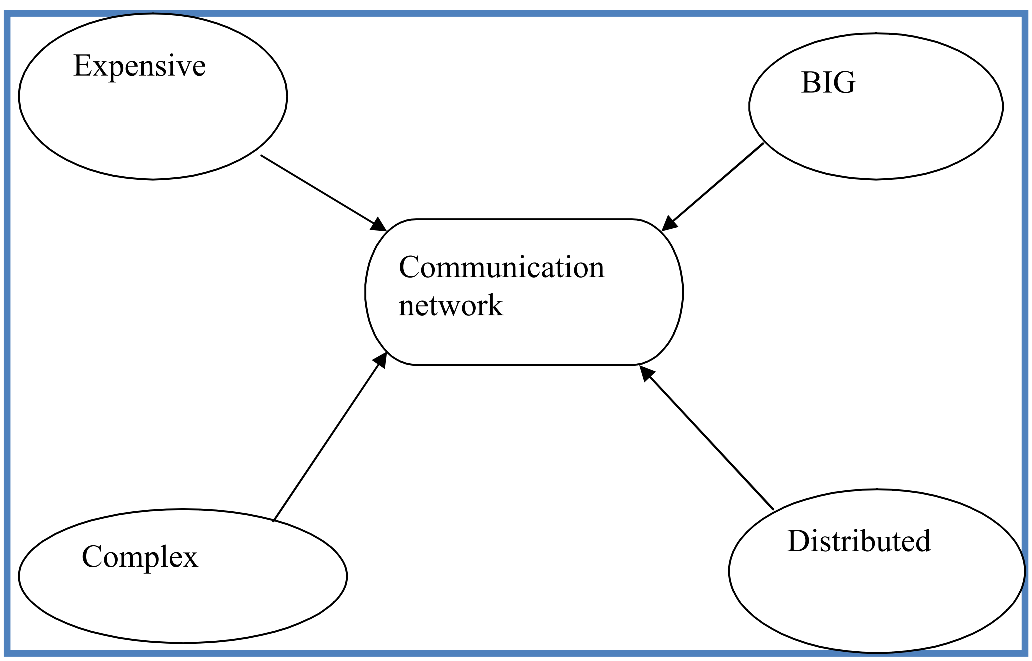


Figure 1.1 Communication network

Simulation software provides a virtual environment for modeling, analyzing, and predicting the performance of IT infrastructures, including applications, servers, and networking technologies.[4]

The application areas include:

1. Network planning (both LAN and/or WAN) and analysis of performance and problems prior to actual implementation.
2. Wireless and Satellite communication schemes and protocols.
3. Microwave and Fiber-optic based Network Management.
4. Protocol Development and management.
5. Routing algorithm evaluation for routers, switches, and other connecting devices.

Some special features that make it such a comprehensive tool are as follows:

1. Hierarchical network models (The model can be nested within layers).
2. Object oriented modeling (Model can be reference and used as logical Extension of Object concepts.)
3. Multiple scenarios can be simulated concurrently and compared.
4. The traffic patterns can be imported into the modeling software
5. Ability to analyze using built-in graphing tools.

Network simulators can be divided into several types (by protocol, technology or processing method), but the most general categorization is their method of simulation. There are two typical methods of simulation: discrete event or analytical simulation. The former methods produce predictions in the network at a low level (packet-by-packet), which makes them accurate but slow to generate results. The latter method, use mathematical models to produce their results at a much faster speed, but may sacrifice accuracy. The usual approach is to combine both methodologies with the aim to provide a reasonable performance in terms of speed but maintaining accuracy in the critical areas. The two simulators used in these experiments are hybrid (star topology + bus topology) simulators. [1]

1.2 Network Queuing

Network queuing is a very important application of queuing theory. The term 'network of queues' describes a situation where the input from one queue is the output from one or more others. This is true in many situations from telecommunication network.

1.3 Computer Networks

The central server network environment is simple example of network queuing CPU (Central Processing Unit), storage units it can access and input devices to access it. The task CPU performed in queued on different criteria. Also, the storage units could have their own individual queues. Queues tend to be ordered in a number of ways. They can also be executed either on a one by one serial basis or bit by bit by time sharing. It is not always necessary to treat customers in a queue equally. A priority queuing system may often be used to give some jobs preferential treatment.

1.3.1Time Sharing

Time sharing is when the CPU is dedicated for one task for a fixed period of time after which it is switched to another task. The task can then be recycled *i.e.* put back in the queue so that the remainder of it is executed at another time. This can be repeated until the task is complete.

1.3.2 Orders for job queues

A job queue can be executed one by one or alternatively via time sharing but either way when the jobs are in the queue, the order in which they are executed is crucial.

1.3.3 First in First out (FIFO)

A first in first out queue is the same basis we would (hopefully) use in real life for a cinema queue or a phone box in that the tasks are executed in the order that they arrived.

1.3.4 Last in First out (LIFO)

A last in first out queue is precisely the opposite as a new job is started as soon as it is queued. This may not be as foolish as it sounds as if the job is done on a time sharing basis it may be sensible to start it as soon as possible then switch back to other jobs for a while. This method may imply the need for preemption *i.e.* the ability to stop a job half way through to start another one. On the other hand the job could be finished before the new one is started or perhaps the queue does not need the feature of being able to add a job half way through.

1.3.5 Smallest job first (SJF)

A smallest job first queue orders the jobs in terms of the smallest one first which means you get as many jobs complete as quickly as possible even though in total the time taken is the same.

1.3.6 Priority Queues

An example of a priority queue is a PC. There is a queue of events received from each input device (i.e. mouse, keyboard etc). Imagine a system with two queues, one for the mouse and one for the keyboard which lead into a master queue of input events. Mouse movement may be given priority over mouse button presses. Any event from the mouse may be given priority in the master queue over any event in the keyboard queue.

1.3.7 Emption and Pre-Emption

It is important in the system to have a way of dealing with a situation where a customer of priority 1 arrives in a queue headed by a customer of priority 2 (i.e. 1 has higher priority than 2). This situation can be dealt with either in an emptive or pre-emptive fashion. In an emptive system the new entry waits for the other to be completed before beginning. In a pre-emptive system the queue can stop the current entry half way through its execution to start the new one.

1.4 Optimum network Performance (OPnet):

A simulation and analysis software for:

Applications

Protocols

Architecture

Devices

OPNET Modeler is the industry's leading network development software first introduced in 1986 by MIT graduate. OPnet allows you to design and study communication networks, devices, protocols, and applications. Modeler is used by the world's most prestigious technology organizations to accelerate the R&D process. Some of the customers include Pentagon, MIT, UIC, and many more.

The virtual network environment represents a network. It can have a slew of components in every salient category. OPnet defines a topology as a “collection of links, nodes and its Configuration”. By “**nodes**” OPnet means to include networking hardware of all kinds (routers, workstations, switches, hubs etc). By “**links**” the underlying connectivity technology (Ethernet, ATM, etc) and relevant characteristics (latency, bandwidth) are meant. In “**configuration**” things like routing protocols, addressing, are included.[5]

1.5 Simulation process in OPnet:

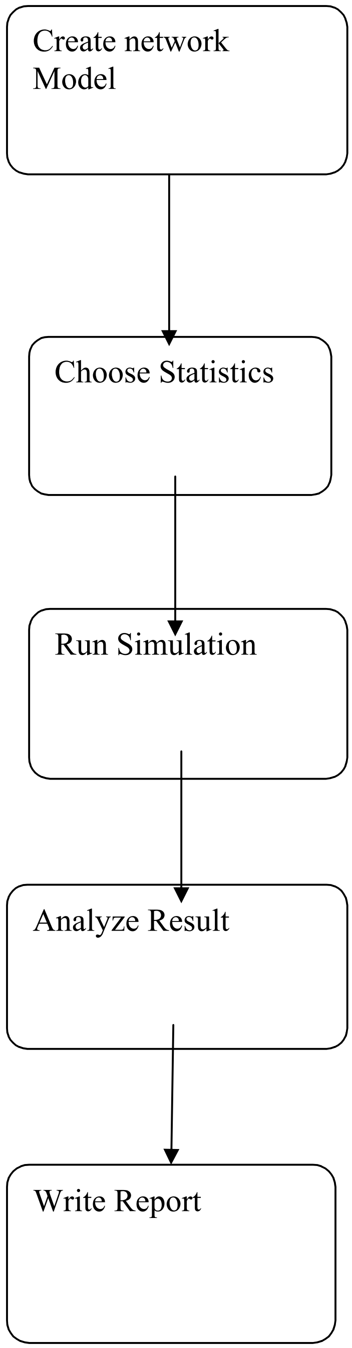


Figure 1.2 DFD of Simulation of Network

1.6 Network Modeling Using OPNET:

OPNET is among the leading discrete event network simulators used both by the commercial and research purpose. It provides a comprehensive framework for modeling wired as well as wireless network scenarios.

Simulation models are organized in a hierarchy consisting of three main levels:

1. The simulation network
2. Node models
3. Process models.

The top level refers to the simulation scenario or simulation network. It defines the network layout, the nodes and the configuration of attributes of the nodes. The node models are at the second level in the hierarchy and consist of an organized set of modules describing the various functions of the node. The modules in the nodes are implemented using process models, the lowest level in the hierarchy. Process models consist of finite state machines, definitions of model functions, and a process interface that defines the parameters for interfacing with other process models and configuring attributes. The hierarchal structure of the models, coupled with support for C language programming, allows for easy development of communication or networking models. [6]

OPNET Modeler uses an object-oriented approach for the development of models and simulation scenarios. The models can be identified as a CLASS, which can be reused any number of times in the simulation by creating its different event, just like the creation of objects in any object-oriented programming language. Besides allowing the creation of multiple instances, OPNET allows the user to extend the functionality of the basic models already available as part of the model library. [7] Thus, by defining the value of the attributes of the basic model the user can develop customized models as particular standards or vendor specifications.

In the next chapter we explain how we create a network environment in simulation technique and which factors are affected in simulation method

Chapter 2 Literature Survey

This Chapter presents a comprehensive literature survey on different perspectives of Network Simulation and Queuing theory. The detailed information about various functions affecting the Congestion rate in network simulation model is also elaborated.

2.1 Network Simulation Environment:

In communication and computer network research, **network simulation** is a technique where a program models the behavior of a network either by calculating the interaction between the different network entities (hosts/routers, data links, packets, etc) using mathematical formulas, or actually capturing and playing back observations from a production network. The behavior of the network and the various applications and services it supports in simulation problem, various attributes of the environment can also be modified in a controlled manner to assess how the network would behave under different conditions. When a simulation program is used in conjunction with live applications and services in order to observe end-to-end performance. [8]

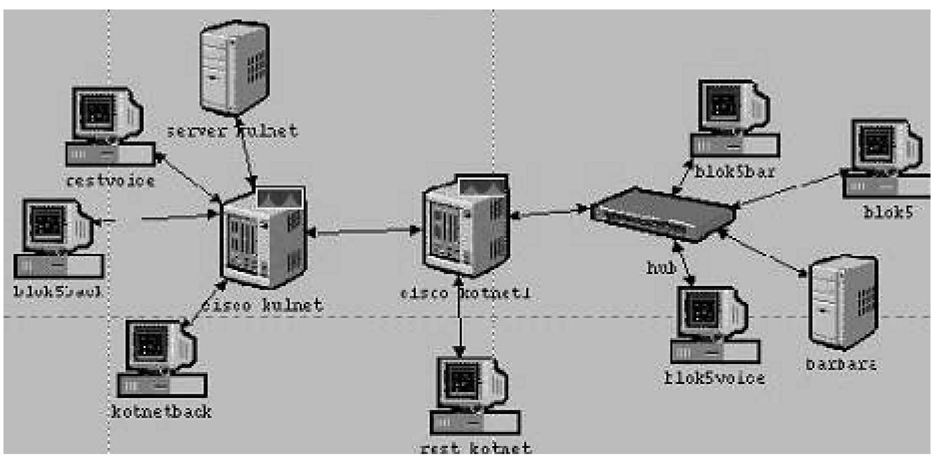


Figure 2.1 Network Topology

The following are software tools which are used for network simulation:

1. N/S-2 or N/S-3
2. OPNET
3. GloMoSim
4. NetSim

Most of the commercial simulators are GUI based, while some network simulators require input scripts or commands (network parameters). The network parameters describe the state of the network (node placement, existing links) and the events (data transmissions, link failures, etc). An important output of simulations is the trace files. Trace files can document every event that occurred in the simulation and are used for analysis. Certain simulators have added functionality of capturing this type of data directly from a functioning production environment, at various times of the day, week, or month, in order to reflect average, worst-case, and best-case conditions. Network simulators can also provide other tools to facilitate visual analysis of trends and potential trouble spots.[9]

Simulation of networks can be a difficult task. For example, if congestion is high, then estimation of the average occupancy is challenging because of high variance. To estimate the likelihood of a buffer overflow in a network, the time required for an accurate answer can be extremely large.

2.2 Simulation with OPNET

OPNET (Optimized Network Engineering Tool) provides a comprehensive development environment for the specification, simulation and performance analysis of communication networks.

OPNET provides four tools called editors to develop a representation of a system being modeled. These editors, the Network, Node, Process and Parameter Editors, are organized in a hierarchical fashion, which supports the concept of model level reuse. Models developed at one layer can be used by another model at a higher layer.

2.3 Simulation configuration:

In **OPnet** common setting Tab of Simulation we performed with the following features:

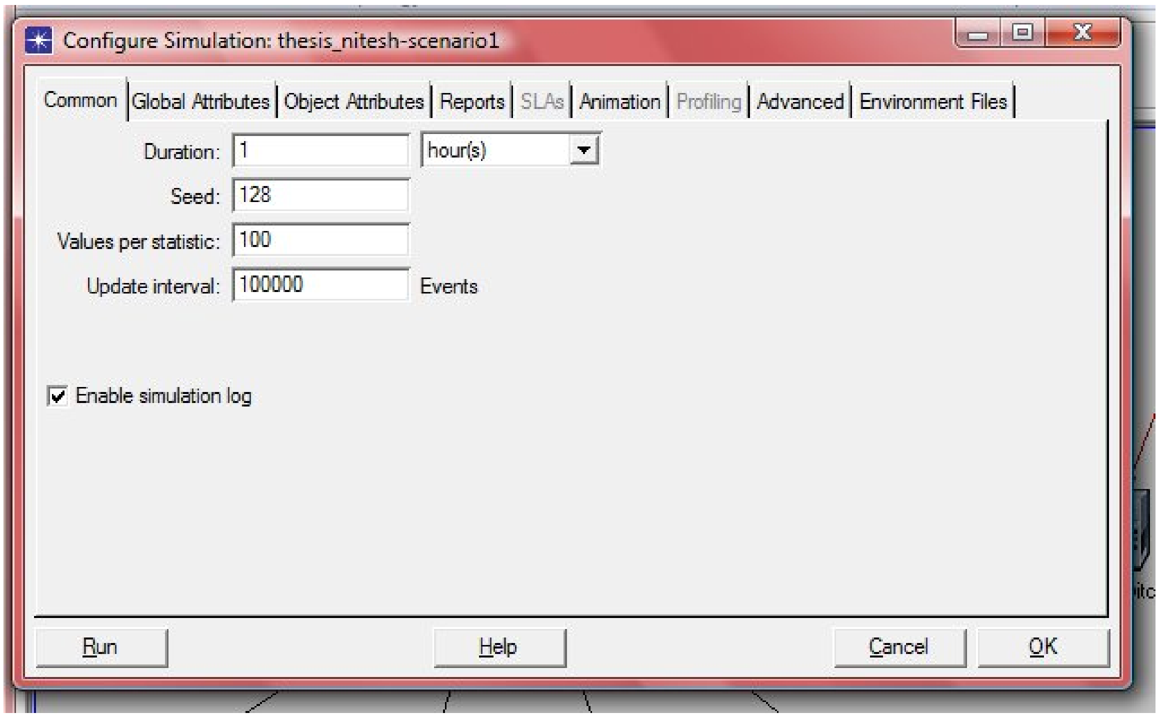


Figure 2.2 Common Attributes Data Filling in thesis_nitesh-scenario1

- **Duration** - Shows the duration of the simulation in units specified by the pull down menu next to the text entry field.[10]
- **Seed** - Random number generation seed.
- **Values per statistic** field -- Set the number of values collected for each statistic
- **Update interval** – Select the interval in simulation events between simulation performance updates sent back to the GUI
- **Simulation set name** - Name of the simulation configuration. Only applicable for advanced simulation configurations with multiple simulation configurations per scenario. This control will not appear when the dialog box is invoked from the Project editor.

- **Enable simulation log** -- Simulation will produce a log that can be examined using the "Results->Open Simulation Log" menu command
- **Generate web report for simulation results** check box -- Simulations results are included in a report viewed from a web browser.
- **Use optimized simulation kernel** check box -- Initial state is based on the kernel type preferences. When checked, the simulation will execute with the optimized version of the kernel which executes much faster than the development version, but at the expense of reduced error reporting information. Changing the state of this checkbox will modify the 'kernel type' preference setting. [11]

In Global attributes tab we performed with the following features:

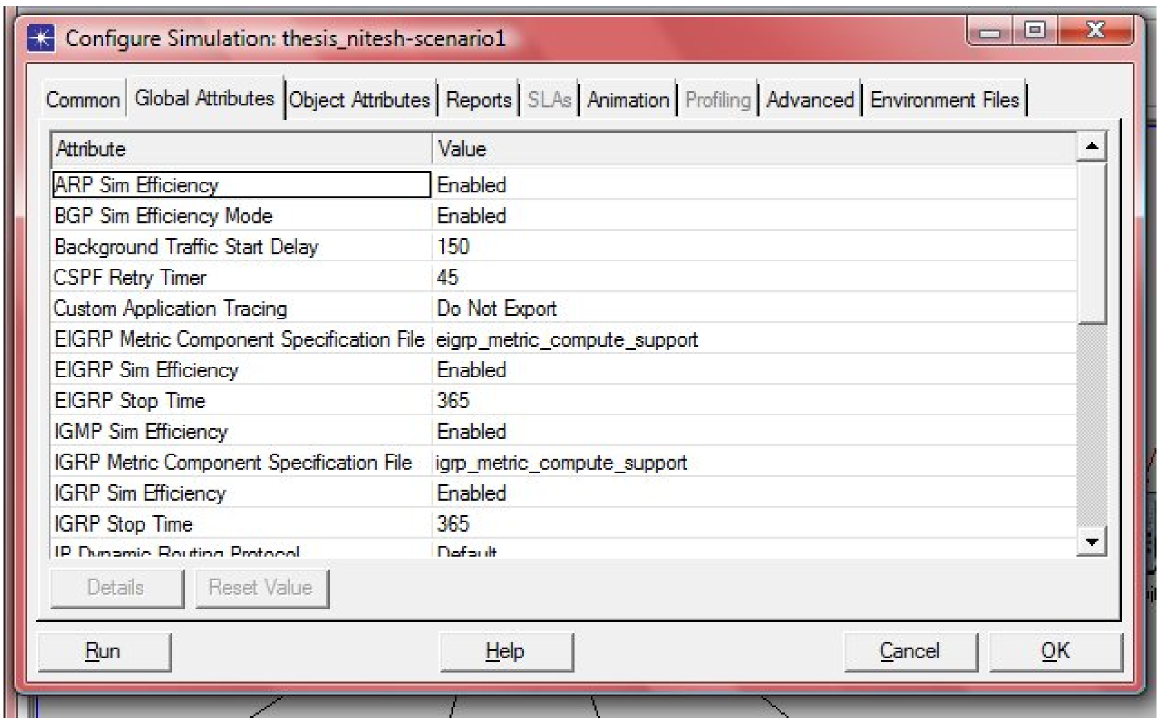


Figure 2.3 Global Attributes Data checking in thesis_nitesh-scenario1

- **Attributes table** allows to change value for all Simulation Attributes declared by all models involved in the simulated scenario
- **Details** button -- brings up a dialog with information describing the attribute selected in the global attributes table

- **Reset Value** button -- resets to default value of the attribute selected in the global attributes table

Animation tab perform the following Task:

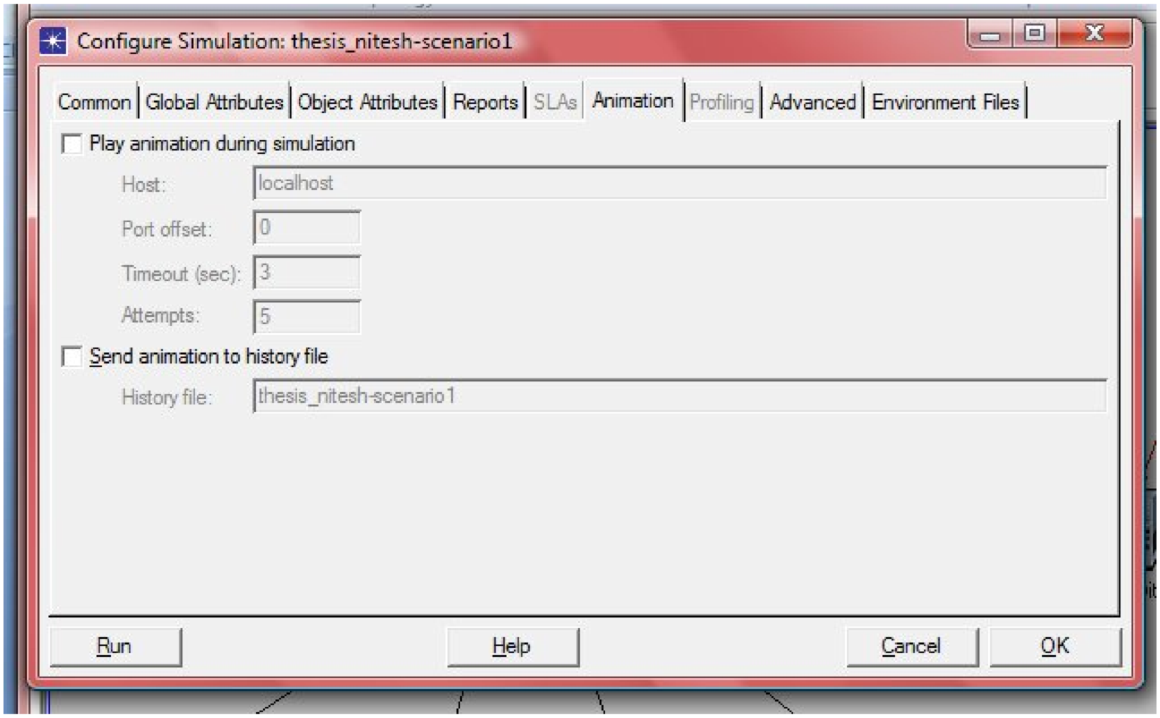


Figure 2.4 Animation Attributes Data Setting in thesis_nitesh-scenario1

Create options for collection of animation generated by simulation

- **Play animation during simulation** -- when selected, simulation will attempt to connect the Animation Viewer (op_vuanim) process running on the specified host to perform the live simulation animation. Please note that simulator will not launch the animation viewer, it is expected to be already running on the host.[12]
- **Send animation to history file** -- when selected, animation generated by the simulation will be collected to the named file. That file can later be played in the op_vuanim program.

Advanced Tab performs the following task:

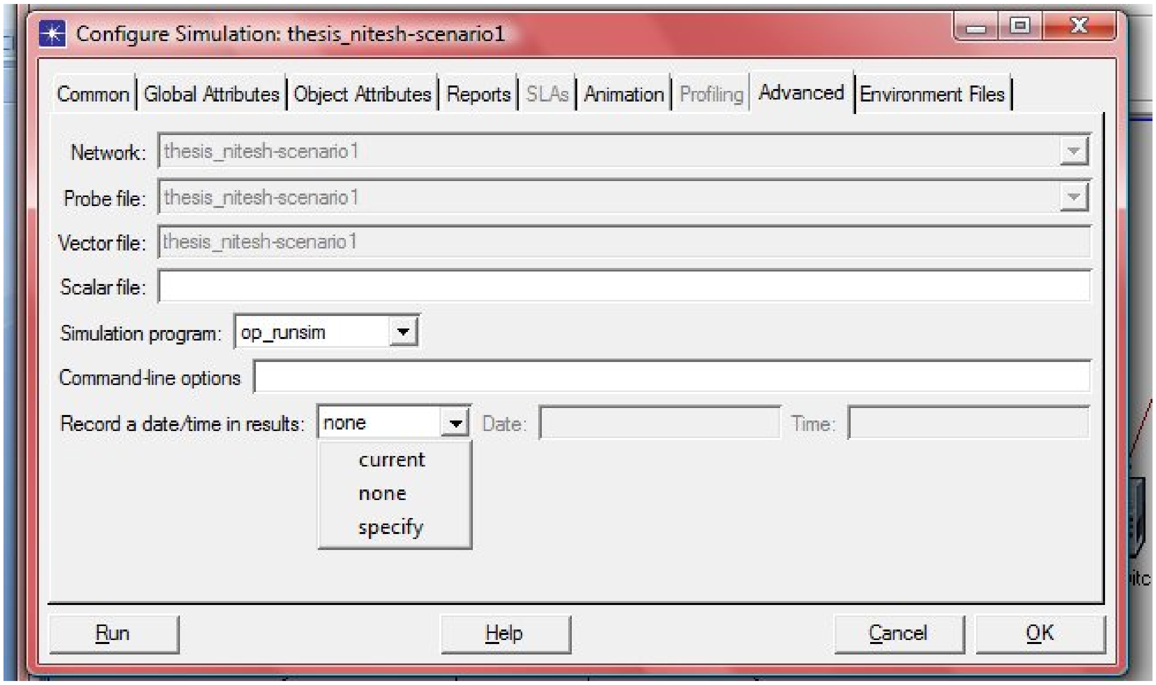


Figure 2.5 Advanced Attributes Data Filling in thesis_nitesh-scenario1

- **Network:** pull down menu -- specify the network model to be simulated. This option is only enabled in the "Advanced Simulation Configuration" editor.
- **Probe file**: pull down menu -- specify the probe model that defines the set of statistics to be collected by the simulation. This option is only enabled in the "Advanced Simulation Configuration" editor.
- **Vector file** – Select name of the output vector model file that will hold all statistic values collected during simulation
- **Scalar file** -- Select name of the output scalars model file that will hold collected scalar values.
- **Simulation program** pull down menu -- Choose the program executable to be used as a simulator. Normally this is set to "op_runsim" but may select the "statically linked" simulation executables if created any.
- **Command-line options** -- Specify arbitrary command-line options to the simulation program, as would be done when invoking it from a UNIX or a windows console. These

arguments will appear after the ones automatically generated by the dialog box settings and will take precedence over the latter.[13]

- **Record a date / time in results**: Specify the real world data and time for the simulation time 0. This time will be kept in simulation results and later may be displayed in graphs with simulation results.

2.4 Elements of OPnet

In OPnet Simulation the following Elements are used to construct a Network environment:

2.4.1 Ethernet Server

General Node Functions:

The ethernet_server model represents a server node with server applications running over TCP/IP and UDP/IP. This node supports one underlying Ethernet connection at 10 Mbps, 100 Mbps, or 1 Gbps. The operational speed is determined by the connected link's data rate.

The Ethernet MAC in this node can be made to operate either in full-duplex or half-duplex mode. Note that when connected to a Hub, it should always be set to "Half Duplex". A fixed amount of time is required to route each packet, as determined by the "IP Forwarding Rate" attribute of the node. Packets are routed on a FCFS basis and may encounter queuing at the lower protocol layers, depending on the transmission rates of the corresponding output interface.[14]

Protocols:

RIP, UDP, IP, TCP, Ethernet, Fast Ethernet, Gigabit Ethernet, OSPF

Interconnections: 1 Ethernet connection at 10 Mbps, 100 Mbps, or 1000 Mbps

Attributes:

Supported Services: This attribute allows for the specification for various services supported on the node.

Server Address: This attribute allows for the specification of the address of the node.

2.4.2. Ppp_wkstn

General Node Functions:

The ppp_wkstn node model represents a workstation with client-server applications running over TCP/IP and UDP/IP. The workstation supports one underlying SLIP connection at a selectable data rate.

This workstation requires a fixed amount of time to route each packet, as determined by the "IP Forwarding Rate" attribute of the node. Packets are routed on a first-come-first-serve basis and may encounter queuing at the ports, depending on the transmission rates of the output interface.

Protocols: RIP, UDP, IP, TCP, OSPF

Interconnections: One SLIP connection at a selectable data rate.

Attributes:

Client Custom Application, Client Database Application, Client Email,

Client Ftp, Client Remote Login, Client X Windows, Client Video Conferencing,

Client Start Time: These attributes allow for the specification of application traffic generation in the node.

Transport Address: This attribute allows for the specification of the address of the node.

"IP Forwarding Rate": specifies the rate (in packets/second) at which the node can perform a routing decision for an arriving packet and transfer it to the appropriate output interface.

"IP Gateway Function": specifies whether the local IP node is acting as a gateway. Workstations should not act as gateways, as they only have one network interface.

"RIP Process Mode": specifies whether the RIP process is silent or active. Silent RIP processes do not send any routing updates but simply receive updates. All RIP processes in a workstation should be silent RIP processes.[15]

"TCP Connection Information": specifies whether diagnostic information about TCP connections from this node will be displayed at the end of the simulation.

"TCP Maximum Segment Size": determines the size of segments sent by TCP. This value should be set to largest segment size that the underlying network can carry unfragmented.

"TCP Receive Buffer Capacity": specifies the size of the buffer used to hold received data before it is forwarded to the application.

2.4.3. 100BaseT_LAN

General Node Functions:

Use 100BaseT_LAN object to represent a Fast Ethernet LAN in a switched topology. The object contains any number of clients as well as one server. Client traffic can be directed to the internal server as well as external servers.

Supported applications include: FTP, Email, Database, Custom, Rlogin, Video, X windows, HTTP etc. These applications run over TCP or UDP. For each application, specify traffic for group of clients, allowing quickly characterize the entire LAN. Attributes:

Switching Speed: (default = 500,000pkts/sec)

Number of Workstations: (default = 10)

LAN Server Name: (default = Auto Assigned)

2.4.4. Local switch

This device can be created using the device creator utility and contains the following technologies:

Technology Port Count

Ethernet, Ether Channel, FDDI and Token Ring all are maximum 16 used in local switch to construct in a network.[16]

2.4.5. 100BaseT

General Description:

The 100BaseT duplex link represents an Ethernet connection operating at 100 Mbps. It can connect any combination of the following nodes (except Hub-to-Hub, which cannot be connected):

1) Station
2) Hub
3) Bridge
4) Switch
5) LAN nodes

Packet Formats: Ethernet

Data Rate: 100 Mbps

Model Attributes:

"Propagation Speed": specifies the propagation speed (in meters/sec) for the medium. If the "delay" attribute of the link is set to "Distance Based", this speed is used to calculate the propagation delay based on the distance between two nodes.

Restrictions:

This link cannot be used to connect two Ethernet hubs.

2.4.6 IP32_Cloud:

This IP cloud supports up to 32 serial line interfaces and we can select the data rate at which the IP packets will be transmitted. This cloud will require equal amount of time to route each data packet. The delay can be changed by editing the packet latency attribute. The packet discard ratio can be changed that will change these attributes during the various scenarios.

General Node Functions:

The ip32_cloud node model represents an IP cloud supporting up to 32 serial line interfaces at a selectable data rate through which IP traffic can be modeled.

IP packets arriving on any cloud interface are routed to the appropriate output interface based on their destination IP address. The Routing Information Protocol (RIP) or the Open Shortest Path First (OSPF) protocol may be used to automatically and dynamically create the cloud's routing tables and select routes in an adaptive manner.

In the cloud requires a fixed amount of time to route each packet, as determined by the "Packet Latency" attribute of the node. Packets are routed on a first-come-first-serve basis and may encounter queuing depending on the transmission rates of the corresponding output interfaces.

Protocols:

RIP, UDP, IP, OSPF, BGP, IGRP, TCP

Interconnections:

32 Serial Line IP connections at a selectable data rate

Attributes:

"Packet Latency": specifies the delay (in second) after which the incoming IP datagram get transferred through the cloud.

"Packet Discard Ratio": Determines the number of packets to be dropped out of the total packets transferred.

2.4.7 IP Traffic Flow:

Represents the IP layer traffic flow between the specified "source" and "destination". The following attributes can be configured for this flow:

1. Traffic Intensity: Use the "Traffic (bits/sec)" and "Traffic (packets/sec)" to configure the actual flow -- note that both these profiles are based on time-series.
2. Traffic Characteristics: Use IP TOS and DSCP to configure quality of service parameterization, distributions (e.g., normal, exponential) to model packet size and inter arrival variability.

General Description: Connects two nodes running IP.

Packet Formats: ip3_dgram

2.5 Action between Client and server:

Client send requests to a Servers trough the Switches.

Servers reply by sending the data streams to the Clients through the Switches.

2.6 Action performs by network:

Delay between request and response.

Ratio between Servers / Switches / Clients which still allows proper functionality of the application.

2.7 How the server and client works:

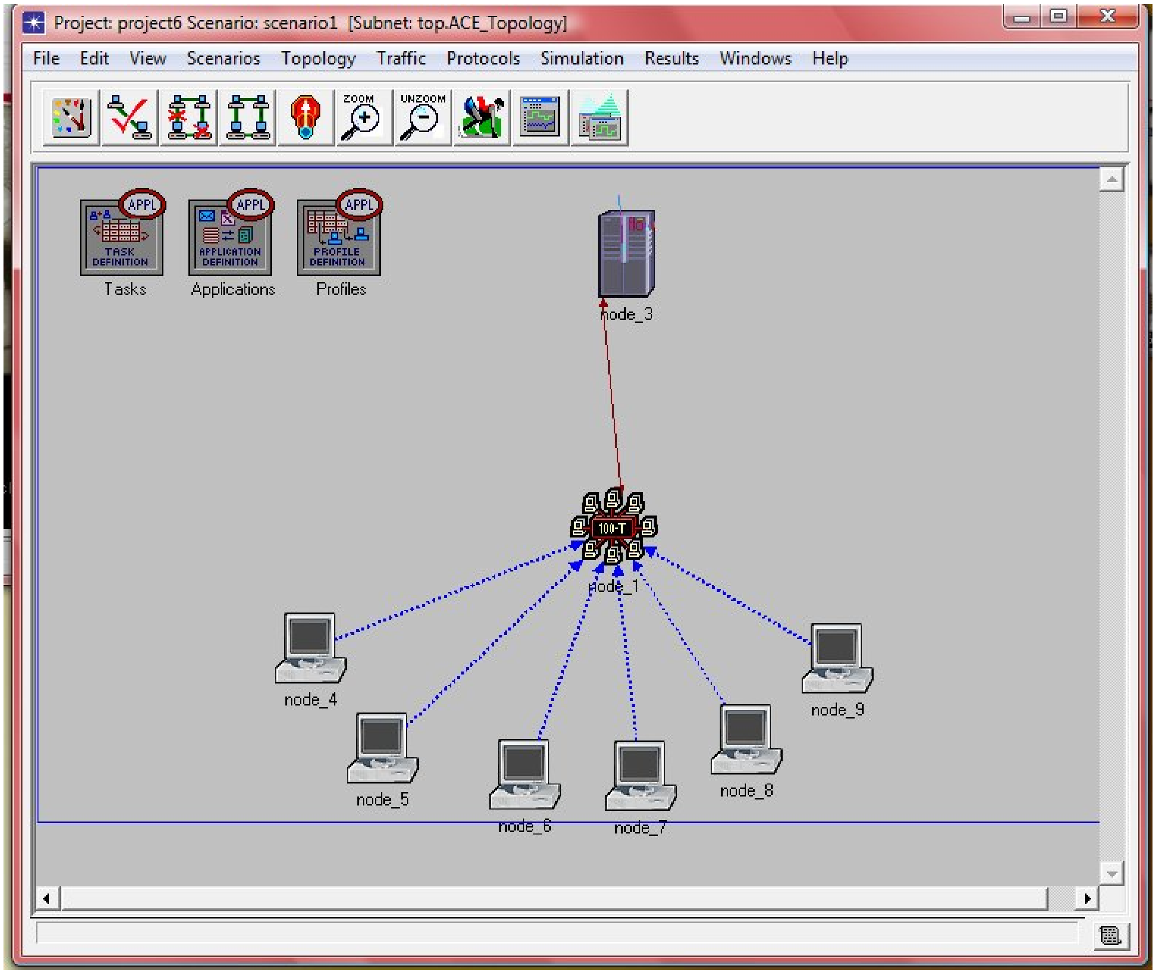


Figure 2.6 Clients-server interactions in one environment

- Clients send “Short” requests to Control Servers.(node4,5,6,7,8,9)
- Control Servers compose and send “Long Request” to Data Servers.(node 1)
- Data Servers reply by sending the “Large Files”.(node 3)
- Control Servers broadcast the “Large Files” to all clients.(node 1)

2.8 Queuing Theory

A Queueing model is an abstract description of such a system. Typically, a Queueing model represents (1) the system's physical configuration, by specifying the number and arrangement of the servers, which provide service to the customers, and (2) the stochastic (that is, probabilistic or statistical) nature of the demands, by specifying the variability in the arrival process and in the service process.[17]

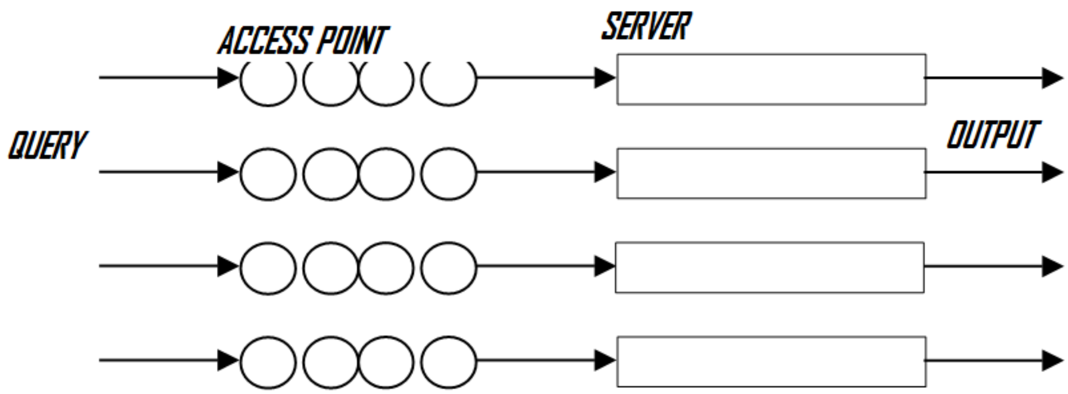


Figure 2.7 Queuing theory applications on server

Queue = waiting line

A queue is a waiting line. The elements of a queue are

1. Arrivals that need service of some kind,
2. Service facilities that take care of the arrivals,
3. Where the arrivals wait until they can be serviced.

Here are some examples of queues:

Table 2.1 Example of Queuing theory in Daily life

Arrivals	**Servers or "Channels"**	**The queue**
Shoppers	Clerks	Checkout line
Patients	Doctor	In waiting room
Patients	Operating teams	Waiting list
Customers	Stock	Back orders
Machine breakdowns	Repair persons	Broken machines
Finished goods	Dealer	Inventory
Pharmaceuticals	Pharmacy in hospital	Inventory
Airplanes	Runways	Stack in air
Telephone calls	Circuits	Uncompleted calls
Fires	Fire fighters	Burning buildings
Automobiles	Intersection	Traffic jam
Streams, rain	Water users	Reservoir

Some flow charts of queues:

Single-Server Single-Stage Queue

Arrivals → Queue → Service → Done

Several Single Server Single Stage Queues in Parallel

Arrivals → Queue → Service → Done

Arrivals → Queue → Service → Done

Arrivals → Queue → Service → Done

Multiple Server Single Stage Queue (M/M/1)

┌→ Service → Done

Arrivals → Queue ─┼→ Service → Done

└→ Service → Done

Single Server Multiple Stage Queue

Arrivals → Queue → Service → Service → Service ... → Done

The Multiple Stage model is like a cafeteria, in which customers waiting to get their main dishes may prevent customers behind them from getting their salads.

Single Server Queues in Series

Arrivals → Queue → Service → Queue → Service ... → Done

The Queues-in-Series model has queues between the stages of service, which the Multiple Stage model does not. This might be appropriate for a doctor's office. Patient waits in the waiting room until seen by a nurse. Then they wait again in examining rooms until the doctor arrives.

How queues behave depends on:[18]

Arrival factors:

1. **Arrival distribution** -- When do new job arrive? At random/ in groups or singly?
2. Size of population from which jobs are drawn -- Is the population effectively infinite or Small enough that each arrival means one less new job in the future?

Service factors:

1. Service time distribution -- how long it takes to serve an arrival
2. Number of parallel channels or servers, such as how many checkout counters at the grocery store
3. How many stages of service there are?

Queue factors:

1. How many queues -- one or more than one?
2. Service priority among customers. Possibilities include First come first served.

2.9 Problems in a queuing system

Experience with the telephone systems tells us that the size of the buffer that accommodates our call while waiting to get a free line is important as well.

Queue discipline.

All other factors regarding the rules of conduct of the queue can be pooled under this heading. One of these is the rule followed by the server in accepting customers for service. In this context, the rules such as “first-come, first-served” (FCFS), “last-come, first-served” (LCFS), and “random selection for service” (RS) are self-explanatory. Others such as “round robin” and “shortest processing time” may need some elaboration, which is provided in later chapters. In many situations customers in some classes get priority in service over others. There are many other queue disciplines which have been introduced for the efficient operation of computers and communication systems. Also, there are other factors of customer behavior such as balking, reneging, and jockeying that require consideration as well.

2.10 Markov model: M/M/1

1. Average number of nodes in system for M/M/1 in steady-state condition

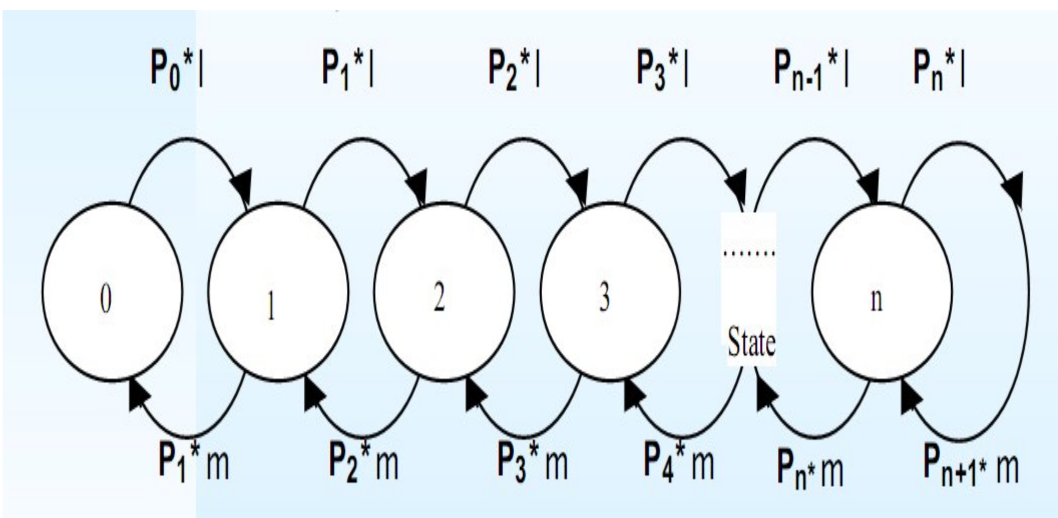


Figure 2.8 Morkov process on n numbers of server

2. Steady state, so P0 * l = P1 * m
3. But also: P0 * l + P2 * m = P1 * (l + m)
4. P n = l (n/m) n*P0.

This type of model consists of several servers where each of the servers has a different queue. Different cash counters in an electricity office where the customers can make payment in respect of their electricity bills provide an example of this type of model.

2.11 Congestion rate

Analyze the model with exponential inter arrival times with mean1/λ, exponential service times with mean 1/μ and a single server. Customers are served in order of arrival. We require that [3]

$$\rho = \frac{\lambda}{\mu} < 1 \quad \text{.... (1)}$$

The M/M/1 model is characterized by the following assumptions:

• Jobs arrive according to a Poisson process with parameter t λ, or equivalently,

The time between arrivals, t, has an exponential distribution with parameter λ,

i.e., for $t \leq 0$, the probability density function is

$$f(t) = \lambda e^{-\lambda t} \quad \text{.... (2)}$$

• The service time, s, has an exponential distribution with parameter μ, *i.e.,* for

$S \leq 0$, the probability density function is

$$g(s) = \mu e^{-\mu t} \quad \text{.... (3)}$$

• There is a single server;

• The buffer size is infinite.

• The number of potential jobs is infinite.

Since, otherwise, the queue length will explode. The quantity ρ is the fraction of time the server is working.

In the next chapter we create a network environment in simulation technique and which factors are affected in simulation method.

Chapter- 3 Problem Statement

In current era, analysis of network Simulation is very costly with real equipments, so we are using some simulation tools which help to simulate the data on mathematical view and generate the accurate results. The OPnet tool mostly shows the accurate result on network topology data, which is available with its tool kit.

Objectives:

- To study the existing OPnet tools and its application on network Simulation.
- To configure the network environment with Nodes, switch and Server.
- Implementation of a simulation environment for a defined protocol, using as many of the simulator's features as possible, according to the modeling paradigm.
- Implementation of Queuing theory technique in network simulation in OPnet tool.
- Calculate the Network Congestion Rate by Result of network simulation Data.

Chapter-4

Design and Implementation

Network of simulation environment has been created with FTP Server, local switch, Control Terminal, access point and end users.

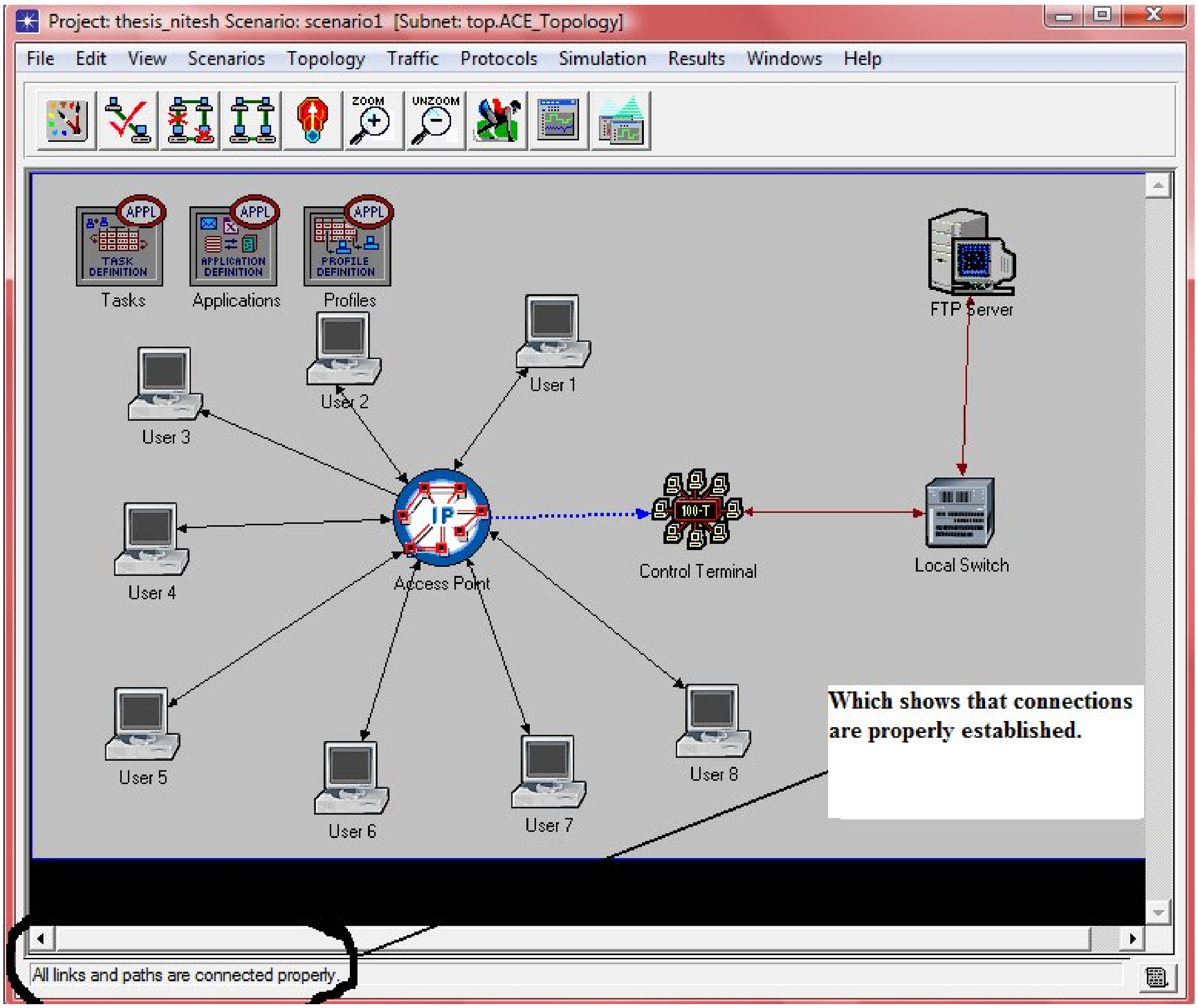


Figure 4.1 Creation of network and verify link

The verification of the link between different devices has been checked for proper data connectivity

Simulation of network contained with the given Attributes

Duration: 2 hours (~=8000 sec)

Seed value: 128 (Random number generation seed).

Value per static: 100(collected for each).

Update Interval: 100,000(In simulation events between simulation performance updates sent back to the GUI).

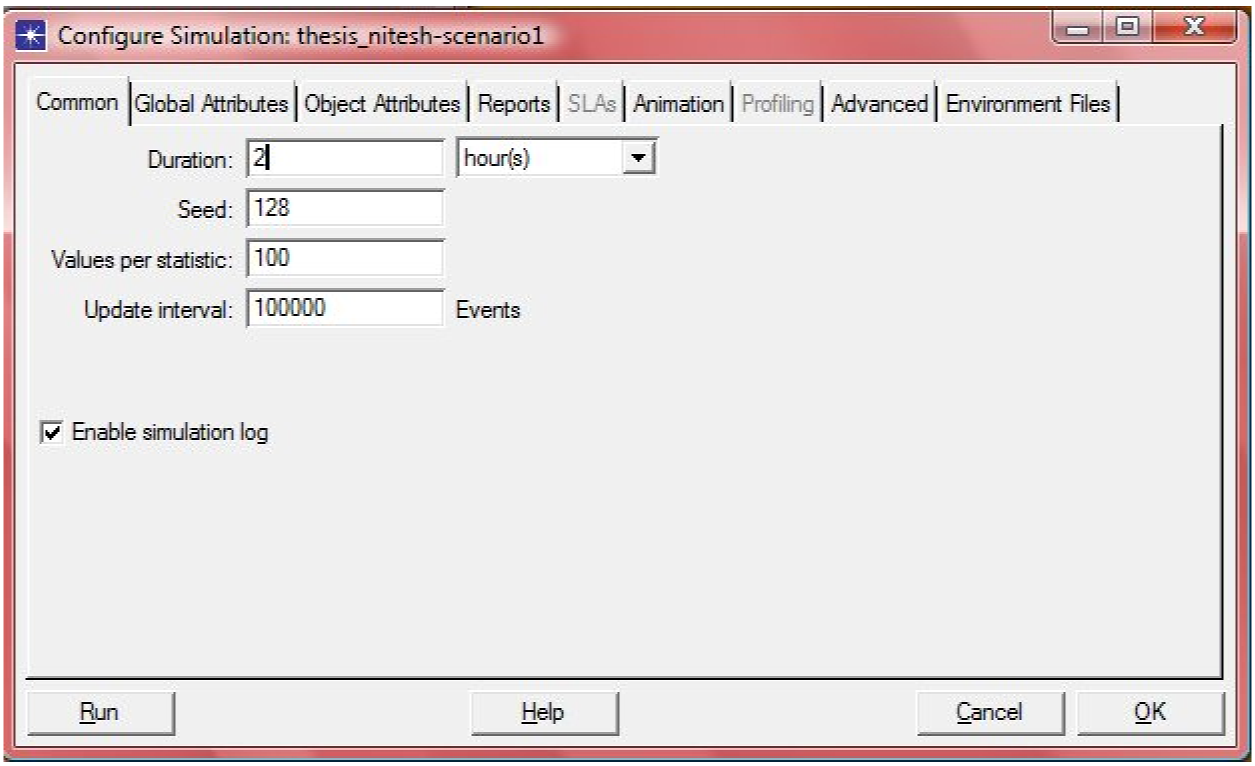


Figure 4.2 Input the duration and seed value in Simulation

Duration = 2 hrs =7200 sec

Seed value =128

Value per Statics = 100

Update interval = 100.000 events

And set the options: Enable Simulation log

The global attributes such as ARP Sim efficiency, background traffic start delay are added in the simulation process with the objective attributes:

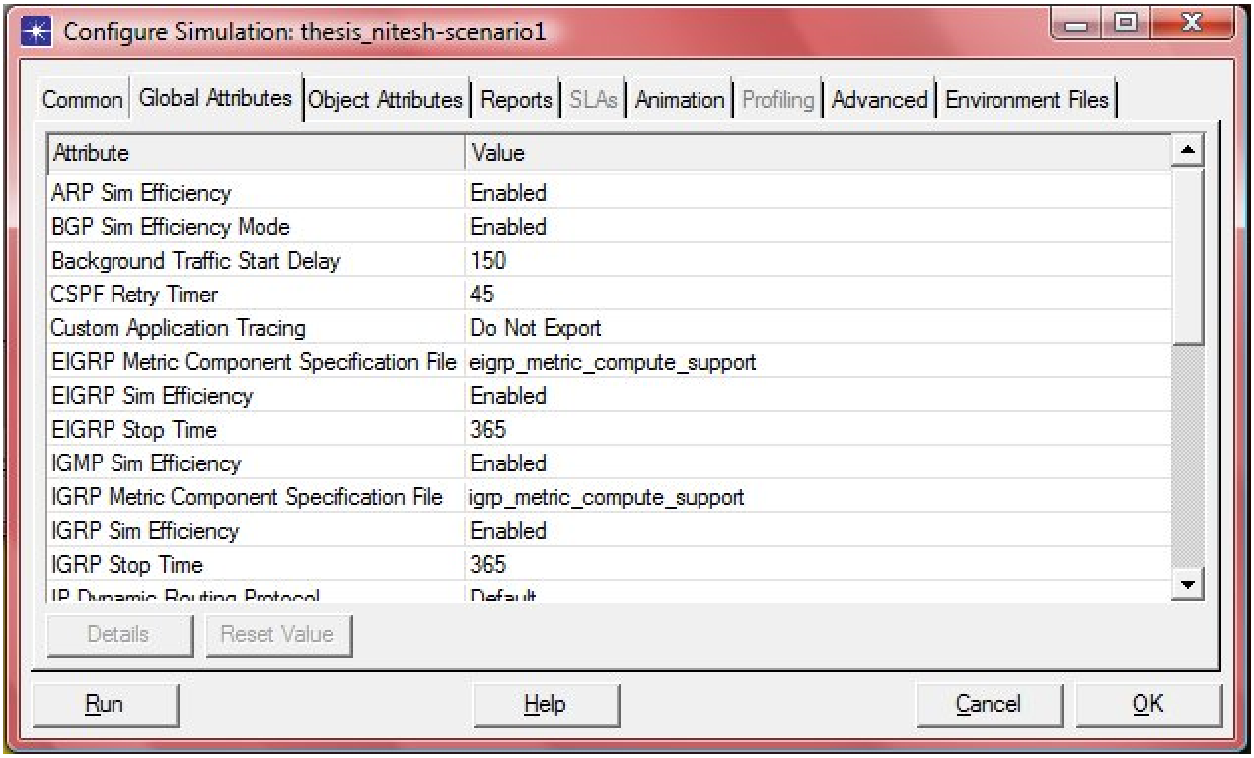


Figure 4.3 To enable the global attributes

To generate the results Simulation executed:

Figure 4.4 shows the new results in simulation

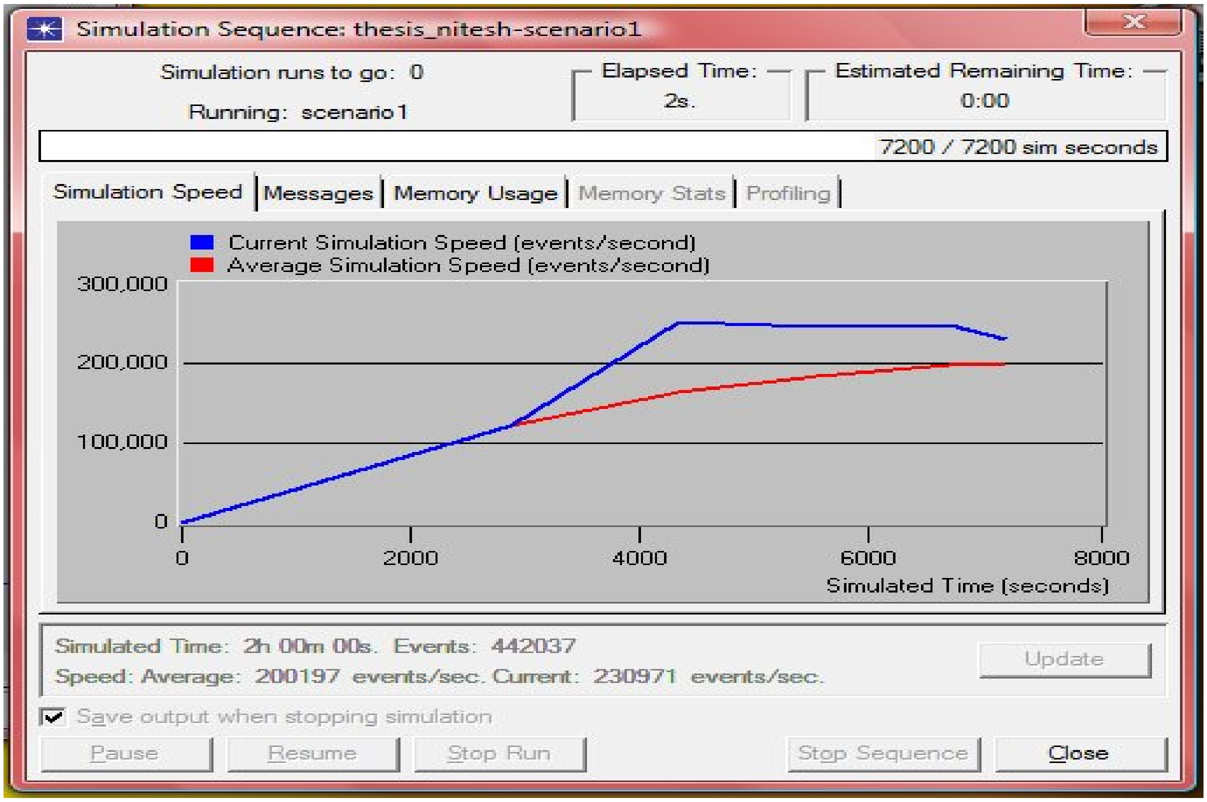


Figure 4.4 Graph of Simulation

The output of the simulation shows us following results:

Simulated Time: 2 hrs

Total elapsed time for simulation: 2sec

Event Happens: 442037 in 2 hrs

Speed average: 200197 events /sec

Speed current: 230971 events /sec

The graph shows that at 2200 seconds 120,000 events are occurring at the same speed .but after this lot of events happening and average speed is very less than current speed.

With this result we are calculating the network congestion rate, and queuing delay in packet transfer and other features.

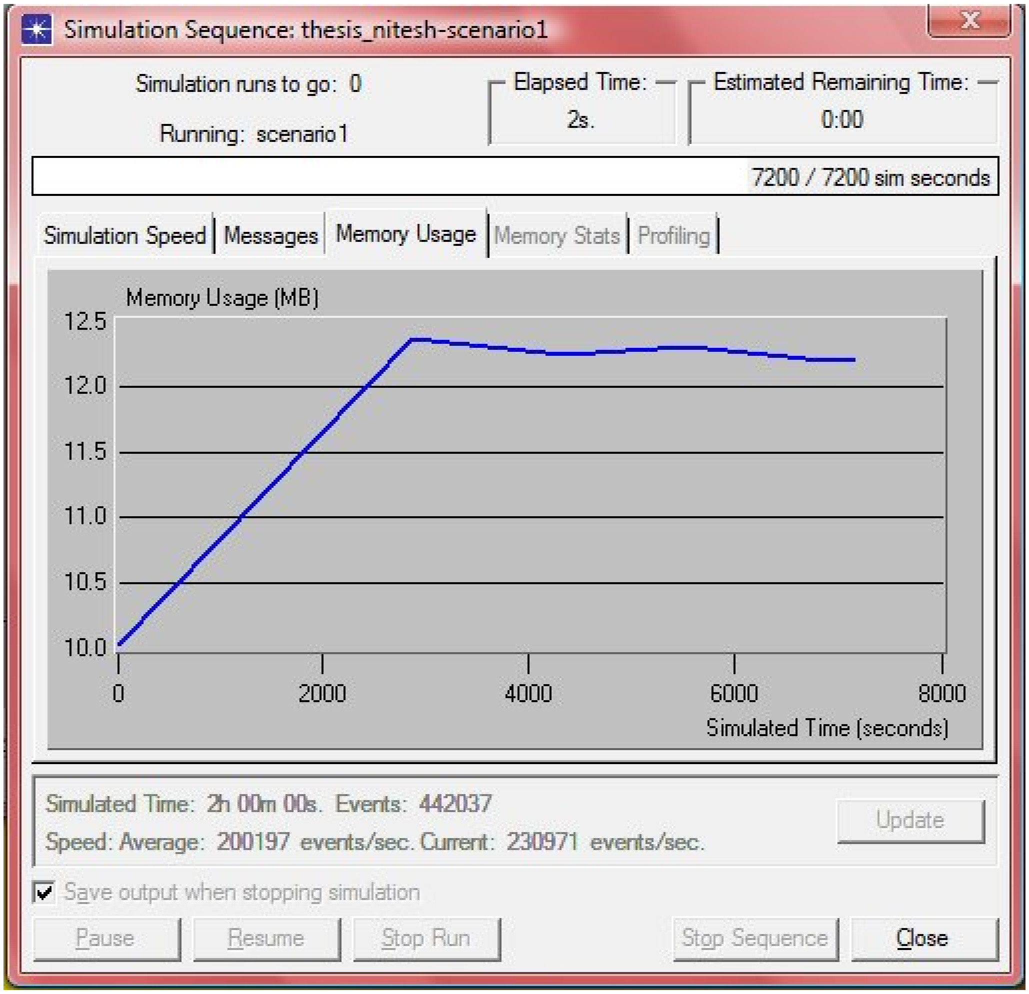


Figure 4.5 Graph of memory Used in simulation

In this graph we got that memory uses at 2200 sec is proportional ratio, but after this it's come on saturation point and runs parallels to 12.25 to 12.00 at last.

The massage comes after simulation is:

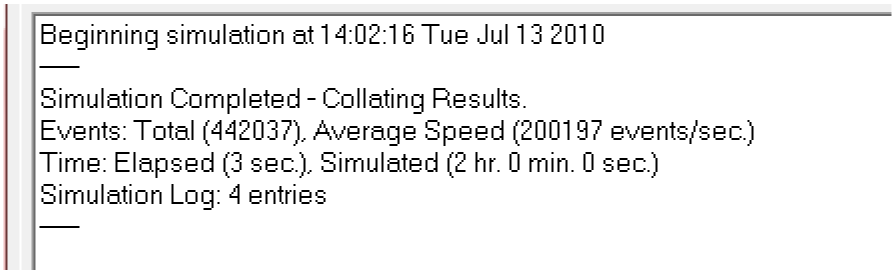


Figure 4.6 Massage of simulation results and Completion

This shows that Simulation Completed.

Chapter-5

Testing & Results

5.1 Congestion Rate

Network congestion rate is changing all the time [2], the instantaneous congestion rate is used to analysis the network traffic in network monitor. The instantaneous rate $A_c\,(t)$ is the congestion rate at the moment of t, the $A_c\,(t)$ can be obtained by solving the system length of the queue's probability distributing, which is called $P_{n-1}(t)$. According to some properties of Markov Process, we know that $P_i(t)$ (i =0, . . . , C+1) satisfies the following equation and By solving this equation, we get the network congestion rate $A_0\,(t)$ [3]

$$A_0\,(t) = P_1(t) = \frac{\lambda}{\mu+\lambda}(1 - e^{-(\mu+\lambda)t}) \qquad .... (4)$$

The results observed during the simulation are:
Simulated Time: 2 hrs

Total elapsed time for simulation: 3 sec

Event Happens: 442037 in 2 hrs

Speed average: 200197 events /sec

Speed current: 230971 events /sec

In the given results,

Event Happens: 442037 in 2 hrs = 2 sec

Therefore in 1 sec = 442037/2 = 221019 is arrival time in 1 second.

Average speed for 1 second is = 200197 is service time in 1 second.

Exponential inter arrival times with mean1/λ = 221019 .... (5)

Exponential service times with mean 1/μ = 200197 .... (6)

Then we calculate,

$$\rho = \frac{\lambda}{\mu} < 1$$

$$\rho = \frac{1/\mu}{1/\lambda} = 200192/221019$$

$$\rho = \frac{\lambda}{\mu} < 1$$

The Value of λ, μ are calculated from equation (5) and (6) as
λ= 1/221019,   μ = 1/200197.

For t ≤ 0, the probability density function is

$$f(t) = \lambda e^{-\lambda t}$$

Then the probability density function of arrivals time with mean 1/ λ is

$$f(t) = 1/221019 e^{-1/221019t} \qquad \text{... (7)}$$

Similarly
For 0 ≥ t, the probability density function is

$$g(s) = \mu e^{-\mu t}$$

Then the service time t is $g(s) = 1/200197 e^{-1/200197t}$ .... (8)
To getting μ and λ we calculating the value of

$$A_0(t) = P_1(t) = \frac{\lambda}{\mu + \lambda}(1 - e^{-(\mu+\lambda)t})$$

$$A_0(t) = P_1(t) = 0.5263(1 - e^{-(1/221019 + 1/200197)t})$$

$$A_0(t) = P_1(t) = 0.5263(1 - e^{-0.000095t})$$

For t = 1, for first congestion in 1 sec *i.e.* 1 hours

$$A_0(1) = 0.5263(1 - e^{-0.000095})$$

From table the value of e^ (-0.000095) = 0.999905005

$$A_0(1) = 0.5263$$

It is observed from the above calculation that the congestion rate increased by 0.5263 percent in 1 hour is predicted in network. If the more number of switches are added in a network then it reduces the network congestion and increase the performance of network.

5.2 Queuing delay in the network:

The following graphs demonstrate the queuing delay in the network during the simulation the network traffic. Figure 5.1 to 5.2 depicted the traffic from the FTP server to end user node with data i.e. Traffic sent (packet/sec) FTP_with_loss.

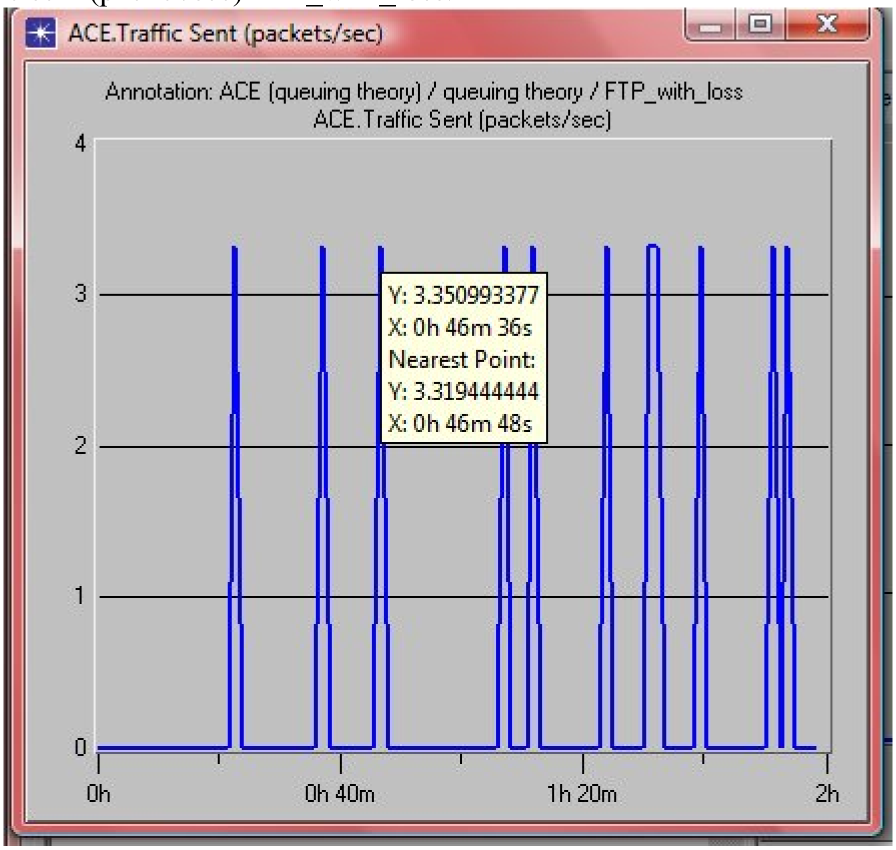


Figure 5.1 Graph of Traffic sent (packet/sec) in Queuing theory

It is observed from the above graph that for the time during the traffic sent in packets, the network congestion initially low as compared to the traffic sent for longer period i.e as per the queuing theory and reduced the network congestion. But due to using of this process model network performance is increased.

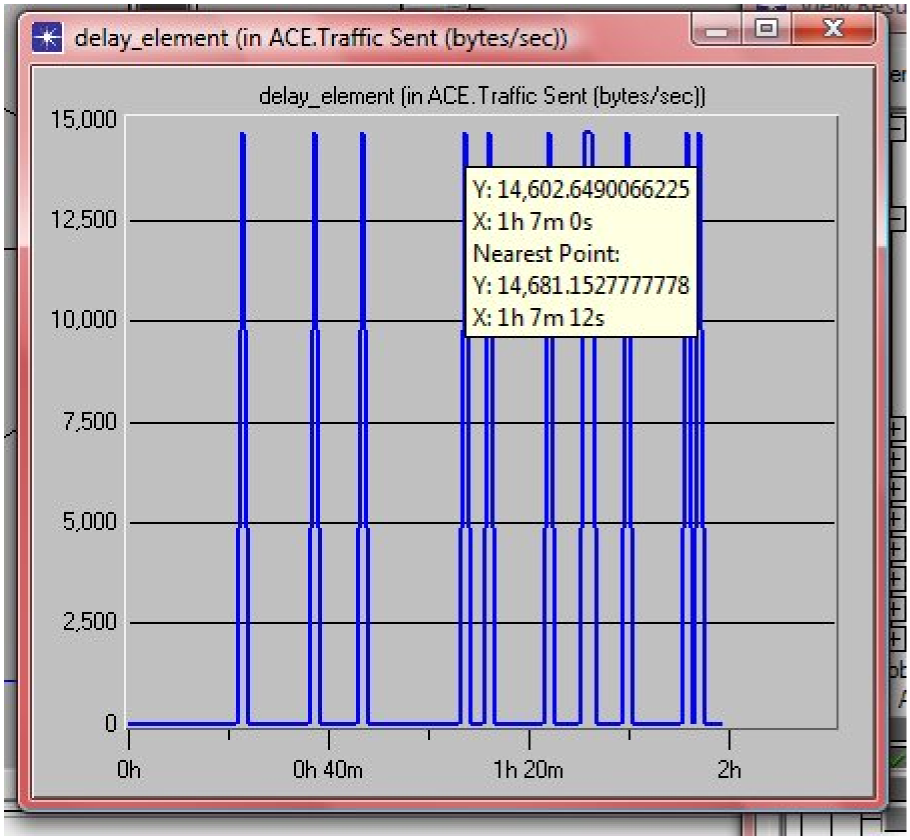


Figure 5.2 Graph of Traffic sent (bytes/sec) in Queuing theory

It is observed from the above graph that for the time during the traffic sent in bytes, the network congestion initially low as compared to the traffic sent for longer period i.e as per the queuing theory and reduced the network congestion.

Figure 5.3 to 5.4 depicted the traffic from the FTP server to end user node with data i.e. Traffic received (packet/sec) FTP_with_loss.

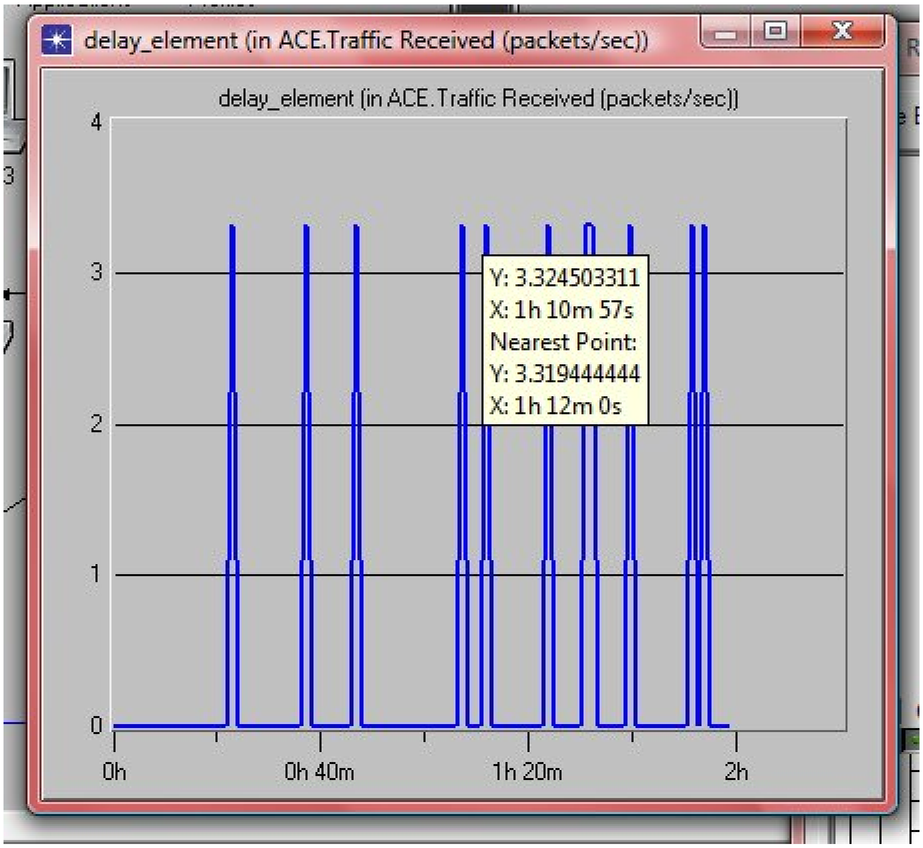


Figure 5.3 Graph of Traffic Received (packets/sec) in Queuing theory

It is observed from the above graph that for the time during the traffic received in packets, the network congestion initially low as compared to the traffic sent for longer period *i.e.* as per the queuing theory and reduced the network congestion. But due to using of this process model network performance is increased.

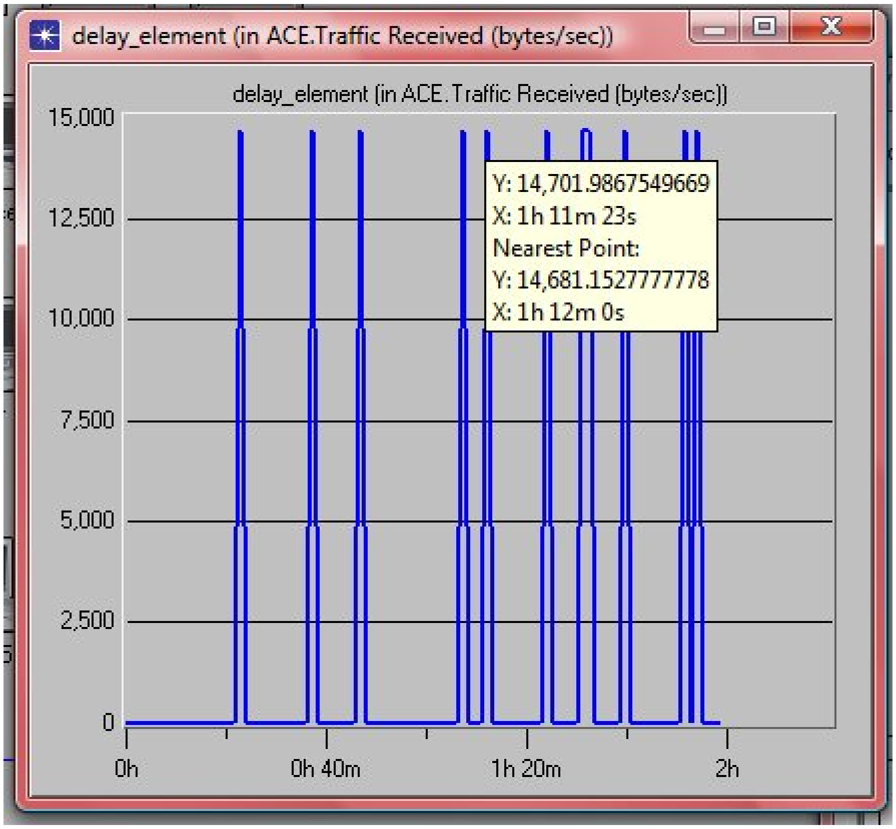
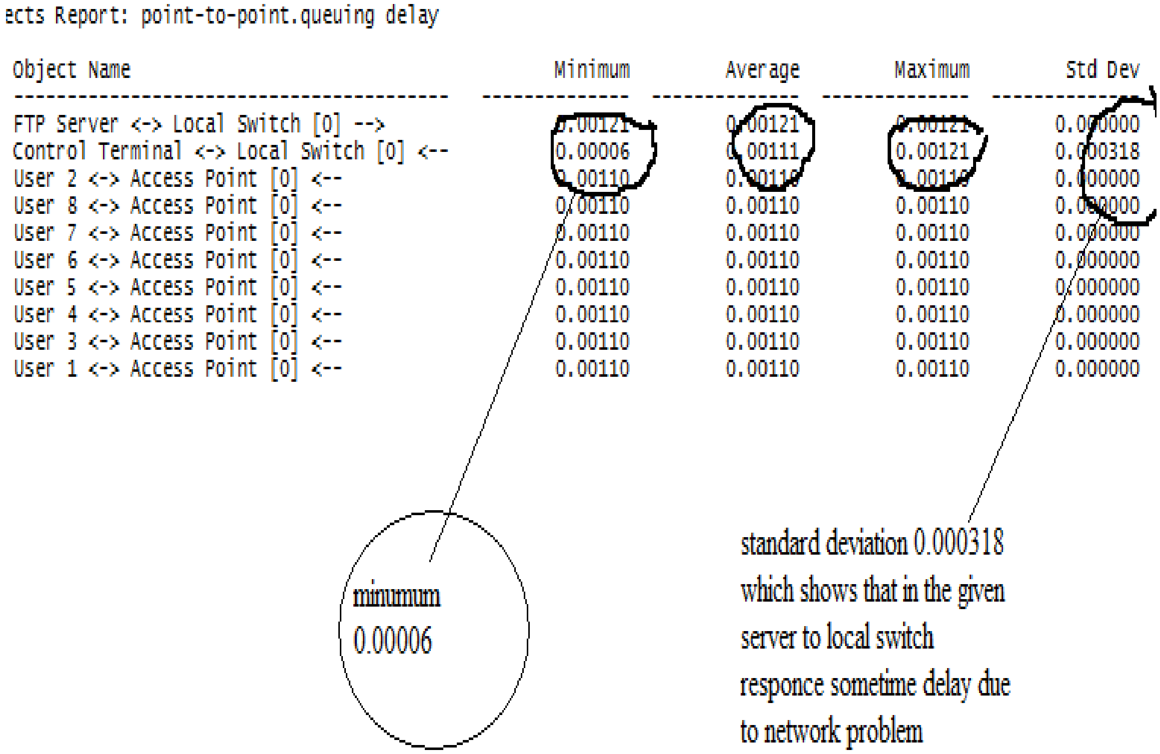


Figure 5.4 Graph of Traffic received (bytes/sec) in Queuing theory

It is also observed that the loss of network simulation data *i.e.* the difference between received and sent data are14701-14602 = 99bytes at 1 hours duration of given data.

5.3 calculate the point to point queuing delay in control terminal to local switch:



ects Report: point-to-point.queuing delay

Object Name	Minimum	Average	Maximum	Std Dev
FTP Server <-> Local Switch [0] -->	0.00121	0.00121	0.00121	0.000000
Control Terminal <-> Local Switch [0] <--	0.00006	0.00111	0.00121	0.000318
User 2 <-> Access Point [0] <--	0.00110	0.00110	0.00110	0.000000
User 8 <-> Access Point [0] <--	0.00110	0.00110	0.00110	0.000000
User 7 <-> Access Point [0] <--	0.00110	0.00110	0.00110	0.000000
User 6 <-> Access Point [0] <--	0.00110	0.00110	0.00110	0.000000
User 5 <-> Access Point [0] <--	0.00110	0.00110	0.00110	0.000000
User 4 <-> Access Point [0] <--	0.00110	0.00110	0.00110	0.000000
User 3 <-> Access Point [0] <--	0.00110	0.00110	0.00110	0.000000
User 1 <-> Access Point [0] <--	0.00110	0.00110	0.00110	0.000000

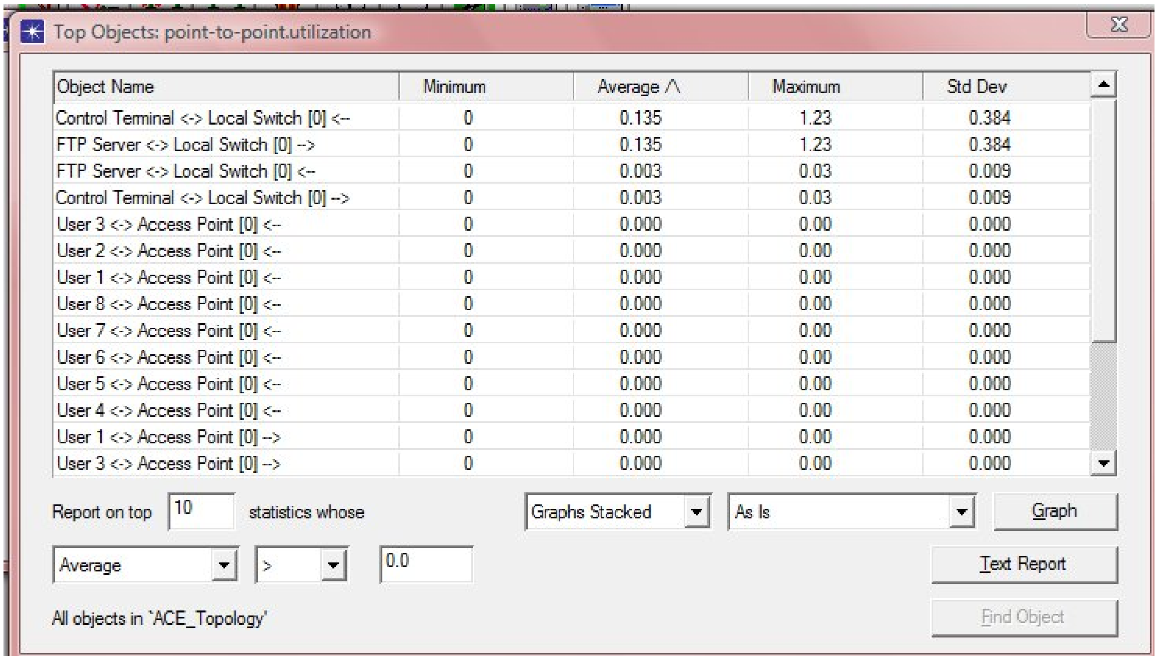
Figure 5.5 Data generated point to point queuing delay in network simulation

It is observed from the above graph that for the,

Here the standard deviation in data transfer,

In case of control terminal to local switch is =0.000318

Its shows that some time Congestion is established and this reduced the data flow between sever to user.



Object Name	Minimum	Average /\	Maximum	Std Dev
Control Terminal <-> Local Switch [0] <--	0	0.135	1.23	0.384
FTP Server <-> Local Switch [0] -->	0	0.135	1.23	0.384
FTP Server <-> Local Switch [0] <--	0	0.003	0.03	0.009
Control Terminal <-> Local Switch [0] -->	0	0.003	0.03	0.009
User 3 <-> Access Point [0] <--	0	0.000	0.00	0.000
User 2 <-> Access Point [0] <--	0	0.000	0.00	0.000
User 1 <-> Access Point [0] <--	0	0.000	0.00	0.000
User 8 <-> Access Point [0] <--	0	0.000	0.00	0.000
User 7 <-> Access Point [0] <--	0	0.000	0.00	0.000
User 6 <-> Access Point [0] <--	0	0.000	0.00	0.000
User 5 <-> Access Point [0] <--	0	0.000	0.00	0.000
User 4 <-> Access Point [0] <--	0	0.000	0.00	0.000
User 1 <-> Access Point [0] -->	0	0.000	0.00	0.000
User 3 <-> Access Point [0] -->	0	0.000	0.00	0.000

Figure 5.6 Data generated point to point queuing utilization in network simulation

It is observed from the above figure 5.6 that control terminal and FTP server are utilized in the point to point data transfer in network simulation.

Control terminal to Local switch standard deviation = FTP server to local switch = 0.384
Local switch to Control terminal standard deviation = Local switch to FTP server =0.009

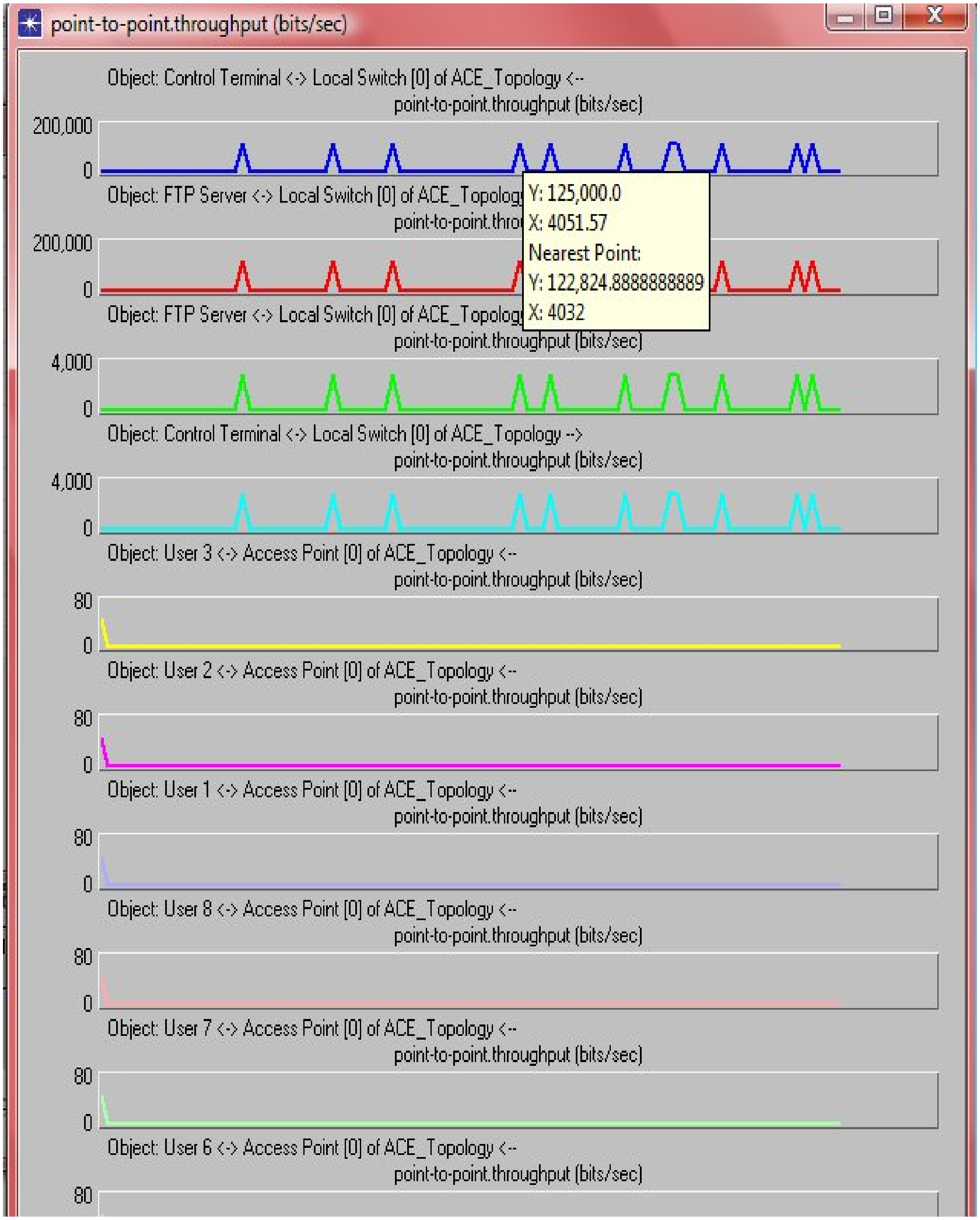


Figure 5.7 Point to point queuing delay in control terminal to local switch and other nodes

This graph shows the congestion in network occur at some time duration especially in case of server to switch and switch to control terminal.

Chapter -6

Conclusion and Future Scope

The aim of this thesis is to simulate of network traffic in order to reduce the network congestion using queuing theory. OPnet simulator environment was used by experimenting with different network traffic data available with this tool kit. The simulation was performed using the M/M/1 model of queue theory. The congestion rate observed during the simulation is 0.5263 percent in 1 hour without increasing a single node in network. If number of switches in a network increased then it only reduces the network congestion and increase the performance of network. But due to using of this process model, network performance is increased and service is available for longer times. In traffic received by switch in sending the data is same, but this type of observation is not measure in long period (In case of packet transfer). It is also observed that the loss of network simulation data i.e. the difference between received and sent data are14701-14602 = 99bytes at 1 hours duration of given data.

This all states shows that in network environment, congestion is always possible but it can be reduced by apply Queuing theory approach in modeling. Otherwise use the extra switches in the network, which will reduce the congestion on particular server and increase the speed of server and overall speed in the network will increase.

At last explain the future scope of thesis work, to develop a freeware tools likes: NetSim, with different parameter. And work with other technology e.g. neural network, which is also used for simulate the network traffic.

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List of Paper Published/Communicated

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