Chapter ONE

Introduction

1.1 Preface

In communication and networking the information that sent from transmitters to receivers represents the network traffic, this traffic generally generated by the application layer by either an application or a protocol in shape of packets, each protocol or application has a certain packet parameters that used by the network processing unit to differentiate between different types of traffic or classify applications by their traffic types for scheduling or priority proposes [1].

When an application is running in a network it starts a session using a dedicated protocol, then when the protocol is initiated between the two communicating nodes, the session will be started and the application start packet production or generating, the packets contains data and commands that requested by users in both sides. This operation is done quickly and internally by encapsulating the application data and control commands in a packet and add some details like source and destination addresses, compression and encryption information's if used by the application [2].

In network design and modeling several components and assumptions that needs to be considered, first the physical layer components which represents the communicating nodes and the medium nodes between them, then the link layer components that meant by the technology used to connect the network nodes with each other, and finally the application layer components which represented by the traffic model used to evaluate the network performance. The traffic model is the

network flow illustration that configured between two or more network nodes to evaluate the connectivity between these nodes and explore different characteristics between these nodes.

1.2 Problem Statement

Any networking system design depends on planning and preparations stages, modeling and simulation introduces a full preparation progress that needed to draw the network architecture that should met the requirements of the users, User's requirements are just summarized in higher throughput and minimum processing time in heavy traffic, the processing time generally is consumed by the queuing system, both throughput and queuing delay depends on inter-arrival time parameter.

1.3 Proposed Solution

In order to improve throughput of a network different configuration parameters can be tuned, but here we will introduce a comparative study between two inter-arrival time distributions to investigate which one will outperform the other one, the distribution process function are the exponential and Poisson inter-arrival time distribution, practically the exponential also known as the regular inter-arrival time distribution has the advantage over the Poisson distribution, this what will be proved in this Thesis.

1.4 Aims and Objective

The main aims of this Thesis "Throughput Enhancement of Local Area Network Queuing Model in Heavy Traffic" are:

- Construct a heavy traffic wired Local Area Network LAN scenario with customized traffic flow.
- Generate two traffic models with Poisson and Exponential packet inter-arrival time in different scenarios.
- Evaluate the performance of the two inter-arrival time distributions and compare them with each other. to determine different network modeling characteristics using OPNET modeler software

1.5 Methodology

In this Thesis, a study of networking and communication essentials is performed in theoretical and practical manners. Considering Ethernet LAN networks as a leading network technology in use, and by using one of the familiar networks simulators which is the OPNET modeler that allows to animate and simulate the network nodes and their operational behavior with their standard characteristics and parameters as it can be also configured with different adjustable attributes to meet the study requirements and experiments before real live deployment.

By creating different scenarios of the same network model with different simulation parameter performances can be compared to evaluate the best configuration can be used. The network model is modeled by a number of workstations that connected to a server through an Ethernet switch, and then these workstations will generate different types of traffics which differ in the packet inter-arrival time; first using Poisson distribution inter-arrival time, and then using an exponential distribution.

1.6 Thesis Outline

Chapter two will discuss the literature review of theoretical topics involved in this Thesis which are the Ethernet LAN. Chapter three expresses the network and the mathematical description of traffic model characteristics considered and network model scenarios. Chapter four figures and discusses the results collected for the performance metrics evaluation. And finally chapter five summarizes the observed results as in conclusion and recommendations.

Chapter TWO

Background Literature Review

2.1 Introduction

This chapter introduces a review study for topics involved in this Thesis while studying its various characteristics, starting from the network technology used which is the Ethernet technology and its networking topologies, because it's one of the famous and familiar wired networks and it's also widely used and deployed in many networking applications. Then a mathematical description of traffic models and queuing theory considered will be expressed and discussed. And finally the simulation and modeling features used and the performance metrics of the comparison study [3].

2.2 Background

Traffic model describes the flow of packets between network communicating nodes in details, this details includes the queuing system or scheduling, the inter-arrival time, the service time, packet size or length, and packet segmentation size if considered [3].

Queuing system is the packet processing scheduler that determines the way of how the packets are hold and waits for processing or service, queuing system can include packet buffer size, maximum queuing delay, or packet priority. Inter-arrival time determines the duration between packets arrives, this time attribute is a major parameter in traffic model and it can be represented by many distribution functions. Service time is the time taken to process packet by direct it to its route destination or executes some command or function it includes. Finally the packet

parameter like packet size and segmentation size which Determines the size of segments that need to be created before sending packets out, If no Segmentation used, then each generated packet is immediately sent to the lower layer whose size is determined based on the value of the Packet Size attribute [4].

2.3 Ethernet LANs

The most widely used local-area network (LAN) access method - defined by the Institute of Electrical and Electronics Engineers (IEEE) - is the 802.3standard Ethernet has become so popular, that most Apple computers and many PCs are fabricated directly with 10/100 Ethernet ports for home use. These ports enable you not only to create a small home network, but also to connect to the Internet via a Digital Subscriber Line (DSL) or cable modem, which requires an Ethernet connection. A 10/100 port was created for a network interface, which supports both 10BASE-T at 10 megabits per second (Mbps) and 100BASE-T at 100 Mbps [5].

Ethernet is a shared-media LAN, which means that all stations on the segment use a part of the total bandwidth. Depending on the type of Ethernet implemented, this total bandwidth is a 10 Mbps (Ethernet), 100 Mbps (Fast Ethernet), or 1000 Mbps (Gigabit Ethernet). In a shared Ethernet environment all hosts are connected to the same bus and compete with each other for the bandwidth. In such an environment packets meant for one machine are received by all the other machines. Thus, any machine in such an environment placed in promiscuous mode will be able to capture packets meant for other machines and can therefore listen to all the traffic on the network using the carrier sense multiple access with collision detect (CSMA/CD) mechanism like in Point-to-Multipoint communication [5].

A switched Ethernet environment - in which the hosts are connected to a switch instead of a hub - is called a Switched Ethernet. The switch maintains a table keeping track of each computer's MAC address and delivers packets destined for a particular machine by sending it to the port on which that machine is connected [6].

The switch is an intelligent device that sends packets to the destined computer only and does not broadcast to all the machines on the network. It means each sender and receiver pair has the full bandwidth available for use e.g. Point-to-Point case. Ethernet LANs use Media Access Control (MAC) address to determine how traffic is transferred between network segments. Ethernet hubs, defined by Open System Interconnection (OSI) model physical layer (Layer 1) repeat only the physical signal; the hub does not look at a source or destination address. Ethernet bridges and switches use the source and destination MAC address, defined by the OSI data link layer (Layer 2) to build an interface table and to determine which segment should receive the frame. Routers use the network address, found at the OSI network layer (Layer 3) to build a routing table [6].

2.3.1 Media Access Control (MAC) Addressing

MAC Address is a unique serial number assigned and burned into each network adapter that differentiates network cards, just as your house number is unique on your street and identifies your home among others. To be a part of any network, you must have an address so that you will be able to be reached. Two types of addresses are found in a network: the logical (OSI model Layer 3, network) and the physical (OSI model Layer 2, data link). For this part of the thesis the physical address (also known as the Media Access Control [MAC] address) is relevant [7].

A MAC address is the physical address of the device. It is 48 bits (6 bytes) long and is made up by two parts: the organizational unique identifier (OUI) and the vendor-assigned address, as illustrated in Figure (2-1).

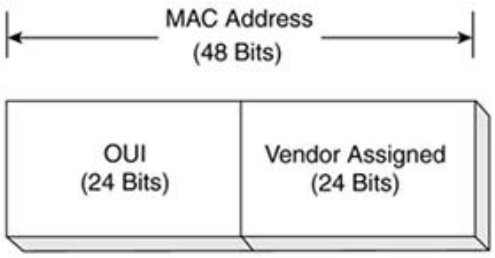

Figure (2-1) : Stucture of the MAC Address

The MAC address on a computer might look like this: 00-08-a1-08-c8-13. This MAC address is used for the Fast Ethernet adapter on a given computer. The OUI is 00-08-a1, and the vendor-assigned number is 08-c8-13 [7].

The OUI is administered by the IEEE and identifies the vendor of the network adapter. The vendor-assigned part of the MAC address is assigned by the vendor. The combination of the OUI and the vendor-assigned number ensures that none of the network adapters could have the same MAC address [7].

2.3.2 Carrier Sense Multiple Access with Collision Detect (CSMA/CD)

CSMA/CD **Error! Reference source not found.** is a set of rules determining how network devices respond when two devices attempt to use a data channel simultaneously (called a collision). Standard Ethernet networks use CSMA/CD to physically monitor the traffic on the line at participating stations. If no transmission is taking place at the time, the particular station can transmit. If two stations attempt to transmit simultaneously, this causes a collision, which is

detected by all participating stations. The stations that collided attempt to transmit again after a random time interval. If another collision occurs, the time intervals from which the random waiting time is selected are increased step by step. This is known as exponential back off [8].

CSMA/CD is a type of contention protocol. Networks using the CSMA/CD procedure are simple to implement, but do not have deterministic transmission characteristics. The CSMA/CD method is internationally standardized in IEEE 802.3 and ISO 8802.3 [8].

2.3.3 Full-Duplex Ethernet

Full-duplex is an optional mode of operation allowing simultaneous communication between a pair of stations. The link between the stations must use a point-to-point media segment, such as twisted-pair or fiber optic media, to provide independent transmit and receive data paths. With full-duplex mode enabled, both stations can simultaneously transmit and receive, which doubles the aggregate capacity of the link. For example, a half-duplex Fast Ethernet twisted-pair segment provides a maximum of 100 Mbps of bandwidth. When operated in full-duplex, the same 100BASE-TX twisted-pair segment can provide a total bandwidth of 200 Mbps [9].

Another major advantage of full-duplex operation is that the maximum segment length is no longer limited by the timing requirements of shared channel half-duplex Ethernet. In full-duplex mode, the only limits are those set by the signal carrying capabilities of the media segment. This is especially useful for fiber optic segments [9].

2.4 Ethernet LAN Equipment

This subchapter addresses the suitability for different environments of various types of hardware, hubs, bridges, and switches and how each piece of hardware functions specifically in an Ethernet environment [9] [10].

2.4.1 Hubs

Hub is a multiport repeater and is used to create collision domains, in which all devices on the network can see each other. If the distance between devices increases, the signal quality begins to deteriorate as segments exceed their maximum length, often a couple hundred feet. Hubs provide the signal amplification required to allow a segment to be extended a greater distance. A hub takes an incoming signal from anyone of the ports and repeats on each of its out ports to enable users to share the Ethernet network resources [10].

Ethernet hubs create star topologies in 10-Mbps or 100-Mbps half-duplex Ethernet LANs. It is the hub that enables several point-to-point segments to be joined together into one single network, and this network of hubs sets up a shared Ethernet, just as several point-to-point roads join together a single large network of roads you use to get around in a town [10].

Figure (2-2): Hub

2.4.2 Bridges

Bridges add a level of intelligence to the network by using the MAC address to build a table of hosts, mapping these hosts to a network segment and containing traffic within these network segments [10].

Ethernet bridges map the MAC addresses of the network devices, or nodes, residing on each network segment. Bridges allow only necessary traffic to pass through the bridge, such as traffic is destined for a segment other than the source. When a frame is received by the bridge, the bridge looks at the frame header and reads the source and destination MAC addresses, determining the frame sender and destination. If the frame's source and destination segments are the same, the frame is dropped, or filtered by the bridge; if the segments differ, the bridge forwards the frame to the correct segment [10].

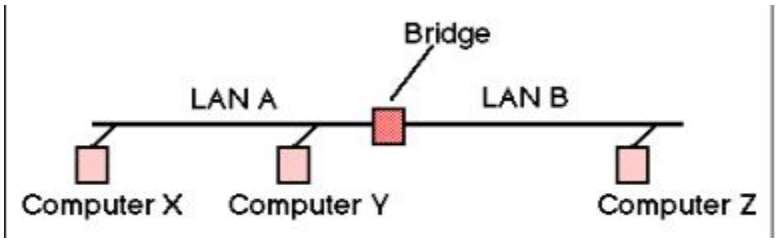

Figure (2-3): A bridge connecting two LAN segments (A and B)

2.4.3 Switches

A switch performs the same functions as a bridge; so when the switch receives a frame, it examines the destination and source MAC addresses and compares them to a table of network segments and addresses. If the segments are the same, the frame is dropped, or filtered; if the segments differ, the frame is forwarded to the proper segment. The frames filtering and regeneration of forwarded frames enables switches to split a network into separate collision

domains. Frame regeneration enables greater distances and more network devices, or nodes, to be used in the total network design, and lowers the overall collision rates [11].

Ethernet switches are an expansion of Ethernet bridging in that switches can link several LANs together. In linking several LANs together, switches forward frames between these LAN segments using one of two basic methods: cut through and store and forward [11].

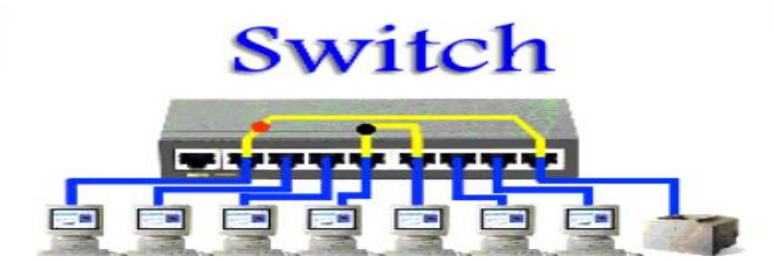

Figure (2-4): Switch

2.5 Network Traffic Modeling

Traffic theory is the application of mathematics to the measurement, modeling, and control of traffic in telecommunications networks (Willinger and Paxson, 1998). The aim of traffic modeling is to find stochastic processes to represent the behavior of traffic. Working at the Copenhagen Telephone Company in the 1910s, A. K. Erlang famously characterized telephone traffic at the call level by certain probability distributions for arrivals of new calls and their holding times. Erlang applied the traffic models to estimate the telephone switch capacity needed to achieve a given call blocking probability. The Erlang blocking formulas had tremendous practical interest for public carriers because telephone facilities (switching and transmission) involved considerable investments. Over several

decades, Erlang's work stimulated the use of queuing theory, and applied probability in general, to engineer the public switched telephone network [12].

Packet-switched networks started to be deployed on a large scale in the 1970s. Like circuit-switched networks, packet networks are designed to handle a certain traffic capacity. Greater network capacity leads to better network performance and user satisfaction, but requires more investment by service providers. The network capacity is typically chosen to provide a target level of quality of service (QoS). QoS is the network performance seen by a packet flow, measured mainly in terms of end-to-end packet loss probability, maximum packet delay, and delay jitter or variation (Firoiu, et al., 2002). The target QoS is derived from the requirements of applications. For example, a real-time application can tolerate end-to-end packet delays up to a maximum bound [13].

2.5.1 Poisson Distribution Model

The Poisson arrival process has been a favorite traffic model for data and voice. The traditional assumption of Poisson arrivals has been often justified by arguing that the aggregation of many independent and identically distributed renewal processes tends to a Poisson process when the number increases (Sriram and Whitt, 1986) [13].

The Poisson equation:

$$P(X = x \mid \lambda) = \frac{e^{-\lambda}\lambda^{x}}{x!} \qquad X = 1,2,\ldots\ldots\ldots,\infty \quad (2.1)$$

Where λ can represent the average number of events, e is the Euler's mathematical constant = 2.7183, and λ is the mean or expected value of the variables, and $x!$ is the factorial of x [13].

2.5.2 Markova Chin Model

The simple on/off model is motivated by sources that alternate between active and idle periods. An obvious example is speech where a person is either talking or listening. The time in the active state is exponentially distributed with mean $1/\alpha$ and the time in the idle state is exponentially distributed with mean $1/\beta$. The state of the source can be represented by the two state continuous-time Markov chain shown in Figure (2-5) [13].

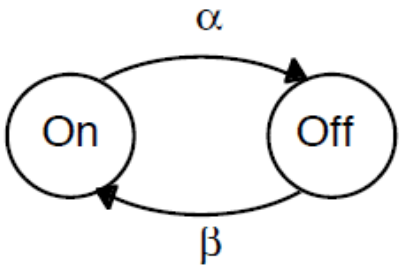

Figure (2-5): Two-state Markov chain

2.5.3 Self-Similar Traffic Models

One of the earliest objections to self-similar traffic models was the difficulty in mathematical analysis. Existing self-similar models could not be used in conventional queuing models. This limitation was rapidly overturned and workable models were constructed. Once basic self-similar models became feasible, the traffic modeling community settled into the “detail” concerns. TCP’s congestion control algorithm complicated the matter of modeling traffic, so solutions needed to be created. Parameter estimation of self-similar models was always difficult, and recent research addresses ways to model network traffic without full understanding it [14].

2.5.4 Exponential Distribution Models

Exponential distribution models are statistical models in which the probability distribution is of a special form This class of models represents a generalization of the exponential family of models which themselves play an important role in statistical theory because they have a special structure which enables deductions to be made about appropriate statistical inference [15].

$$f(x) = \begin{cases} \lambda e^{-\lambda x} & (x \geq 0) \\ 0 & (x < 0) \end{cases} \quad (2.2)$$

Where λ can represent the average number of events, e is the Euler's mathematical constant = 2.7183, and λ is the mean or expected value of the variables, and x is a random variable [17].

2.6 Related Study

Performance evaluation of queuing can contribute other research studies in varieties of areas. For instance, one of the important issues in wireless Networks is power limitation [18] Focused on the behavior of the buffered packets in the queue to propose a power management scheme in the IEEE 802.11 for Wireless Local Area Network. They also modeled their scheme as an M/G/1 queue with bulk service and gained the results for the performance metrics. Based on the analytical model and simulation results, they provided some suggestion to satisfy performance metrics.

Moreover [19] investigated finite multi server queuing system with queue dependent heterogeneous servers. Average number of customers obtained in the

system used to establish a cost function. They tried to gain maximum profit by determining the threshold values of queue length at servers. They examined the effect of number of servers and input rate on average queue lengths by looking at a numerical illustration.

In addition, [20] evaluated a queuing system consisting of two parallel queues and two servers. Their model had a threshold based control policy. Two thresholds called control level are set up in one of the two queues. According to the control level and the number of customers in the second queue reaches, the server decides which queue is to be served next at each time. In their scenario, both queues have the Poisson arrival processes, and the exponentially distributed service times.

The M/GI/1/s queue with a limit buffer of size s was considered in [21]. They assumed λ to be the Poisson arrival rate and the packet sizes with a generic packet length.

In addition, according to [22], all classes arrive based on independent Poisson distribution and have a general service times. They presented database systems without queuing in their studies. They demonstrated the insensitive property of the system, and derived analytical expressions for performance measurements such as blocking probabilities, throughput, etc.

Moreover, [22] modeled the communication system consists of S stations (queues) and a single server which visits the stations in cyclic order. Frames arrive at queue j according to a Poisson process with rate λ j, j= l,…,S. Poisson process is used as the superposition of the arrival processes in all queues. In this Thesis two different scenarios (Poisson distribution and exponential distribution) are

compared in a queuing model, and then their performances are evaluated in terms of queuing delay, throughput and utilization.

2.7 performance metrics

In this section we will discuss the performance metrics used to evaluate the network performance in the simulation, these performance metrics are available in OPNET modeler and will be chosen in the project simulation scenarios to be collected as resulted statistics which also are compared as can be seen later in next chapters.

2.7.1 Queuing Delay

One of the most important factors to design and evaluate the performance of a computer network is queuing delay. It determines how long it takes for a bit of data to travel across the network from one node or endpoint to another. The end-to-end delay implies the average time taken between a packet initially sent by the source, and the time for successfully receiving the message at the destination. Measuring this delay takes into account the queuing and the propagation delay of the packets [23].

2.7.2 Utilization

Utilization is the percentage of total bandwidth that is used at a particular point of time. In this study, server utilization is used as a comparison metric. The server utilization is the percentage of time during which the server is busy in processing jobs during a simulation [23].

2.7.3 Throughput

Throughput is the ratio of the data packets delivered to the destinations until the last packet received by the receiver to duration time [1]. The throughput can be altered based on various changes in topology, limited bandwidth, limited power, and unreliable communication. In communication networks, such as Ethernet, the definition of throughput is the average rate of successful message delivery over a communication channel [23].

Chapter THREE

METHODOLOGY

3.1 Introduction

Our method used in this Thesis explained briefly in this chapter. It covers the evaluation and analyzing two different scenarios Poisson and exponential inter-arrive time distribution are defined to use mathematical analysis.

3.2 Mathematical Analysis

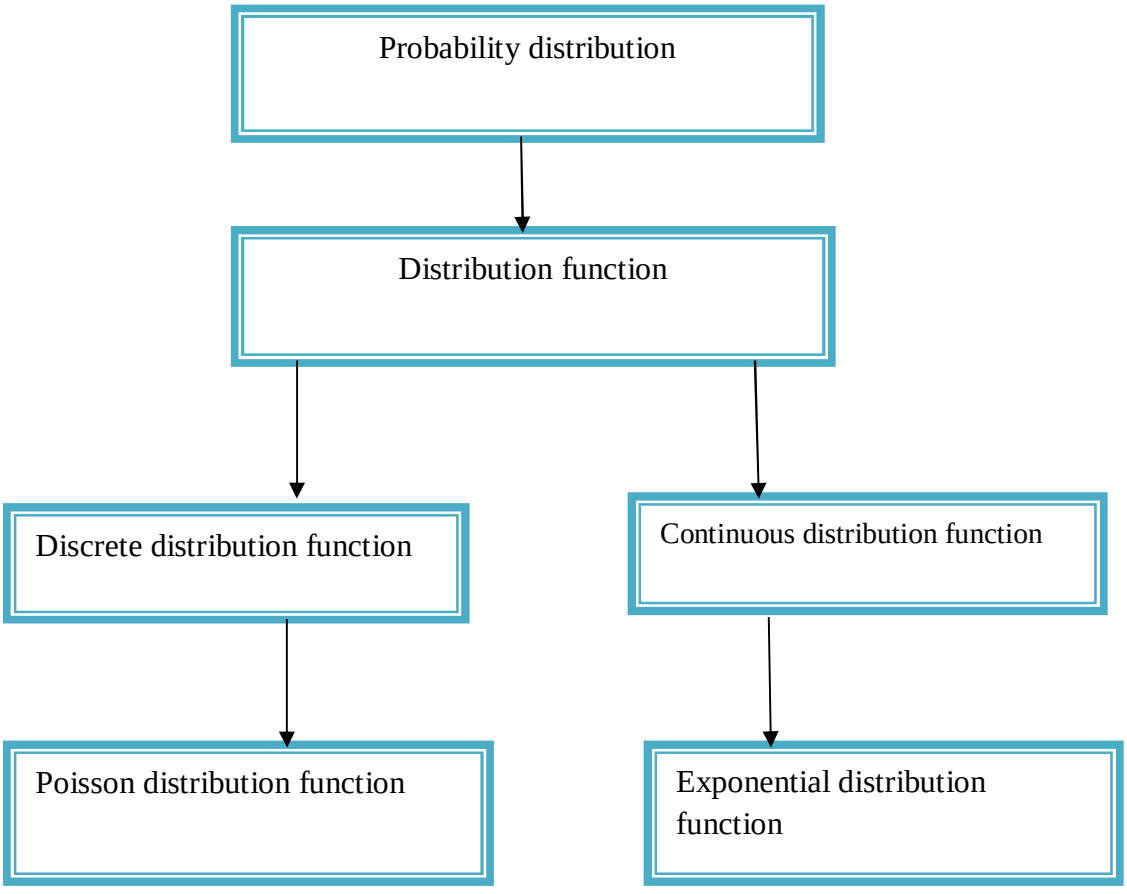

Figure (3-1): Mathematical Analysis

3.2.1 Probability Distributions

Certain random variables occur very often in probability theory due to many natural and physical processes. Their distributions therefore have gained special importance in probability theory. Some fundamental discrete distributions are the discrete uniform, Bernoulli, binomial, negative binomial, Poisson and geometric distributions. Important continuous distributions include the continuous uniform, normal, exponential, gamma and beta distributions [24].

3.2.1.1 Distribution Functions

If a random variable defined on the probability space (Ω, A, P) is given, we can ask questions like "How likely is it that the value of X is bigger than 2? .This is the same as the probability of the event which is often written as P(X > 2) for short. By recording all these probabilities of output ranges of a real-valued random variable X yields the probability distribution of X. The probability distribution forgets about the particular probability space used to define X and only records the probabilities of various values of X. Such a probability distribution can always be captured by its cumulative distribution function and sometimes also using a probability density function [24].

$$F_X(x) = P(X \leq x) \quad (4.1)$$

While F is the probability density function, X a random variable and P is the probability of various values of X.

3.2.1.1.1 Discrete Distribution

If X is a variable that can assume a discrete set of values X1, X2, X3,……., Xk with respect to probabilities p1, p2, p3,……., pk, where p1+ p2 + p3,……., + pk = 1, we say that a discrete probability distribution for X has been defined. The

function p(X), which has the respective values p1, p2, p3,...,pk for X= X1, X2, X3,…….., Xk is called the probability function, or frequency function of X. Because X can assume certain values with given probabilities, it is often called a discrete random variable. A random variable is also known as a chance variable or stochastic variable [24].

If a discrete event experiment is performed a large number of times (M), one would expect x1 to appear p1×M times, x2 to appear p2×M times, etc., so the total is x1× (p1×M) + x2× (p2×M) + … + xk× (pk×M), which can be divided by M to get the average/ mean/ expected value:

$$E(X) = \mu x = \sum_{i=1}^{k} (x_i p_i) \quad (4.2)$$

Besides the mean, the next important quantity of a random variable is its variability, i.e. how widely its possible values are spread around the mean. This can be measured by the variance of a random variable:

$$Var(X) = \sum_{i=1}^{k} (x_i - \mu_x)^2 pi \quad (4.3)$$

3.2.1.1.1.1 Poisson distribution

In probability theory and statistics, the Poisson distribution is a discrete probability distribution that expresses the probability of a number of events occurring in a fixed period of time if these events occur with a known average rate, and are independent of the time since the last event. The distribution was discovered by Siméon-Denis Poisson (1781–1840). The Poisson distribution is sometimes called a Poissonian, analagous to the term Gaussian for a Gauss or normal distribution [25].

The Poisson distribution is used when the variable occurs over a period of time, volume, area etc…it can be used for the arrival of airplanes at airports, the number of phone calls per hour for a station, the number of white blood cells on a certain area, and as the number of packets to be served. The probability of x successes is:

$$P(X = x \mid \lambda) = \frac{e^{-\lambda}\lambda^{x}}{x!} \quad X = 0,1,2,\ldots, \quad (4.4)$$

Where λ can represent the average number of events, e is the Euler's mathematical constant = 2.7183, small λ is the mean or expected value of the variables, and x! Is the factorial of x [25].

3.2.1.1.2 Continuous Distribution

Suppose X is a continuous random variable. A continuous random variable X is specified by its probability density function which is written f(x) where f(x) ≥ 0 throughout the range of values for which x is valid. This probability density function can be represented by a curve, and the probabilities are given by the area under the curve, the total area under the curve is equal to 1. The area under the curve between the lines(x=a) and (x=b) gives the probability the X lies between (a) and (b), which can be denoted by P(a<X<b). p(X) is called a probability density function and the variable X is often called a continuous random variable. Since the total area under the curve is equal to 1, it follows that the probability between a range spaces between (a) and (b) is given by [25]:

$$P(a \leq X \leq b) = \int_{a}^{b} f(x)dx \quad (4.5)$$

3.2.1.1.2.1 Exponential Distribution

The exponential distribution is a continuous probability distribution, and it's often arises in the consideration of lifetimes or waiting times and is a close relative of the discrete Poisson probability distribution. The probability density function is [25].

$$f(x) = \begin{cases} \lambda\, e^{-\lambda x} & (x \geq 0) \\ 0 & (x < 0) \end{cases} \quad (4.6)$$

Where X is the random variable, λ can represent the average number of events and e is the Euler's mathematical constant = 2.7183 [25].

3.3 Model Description

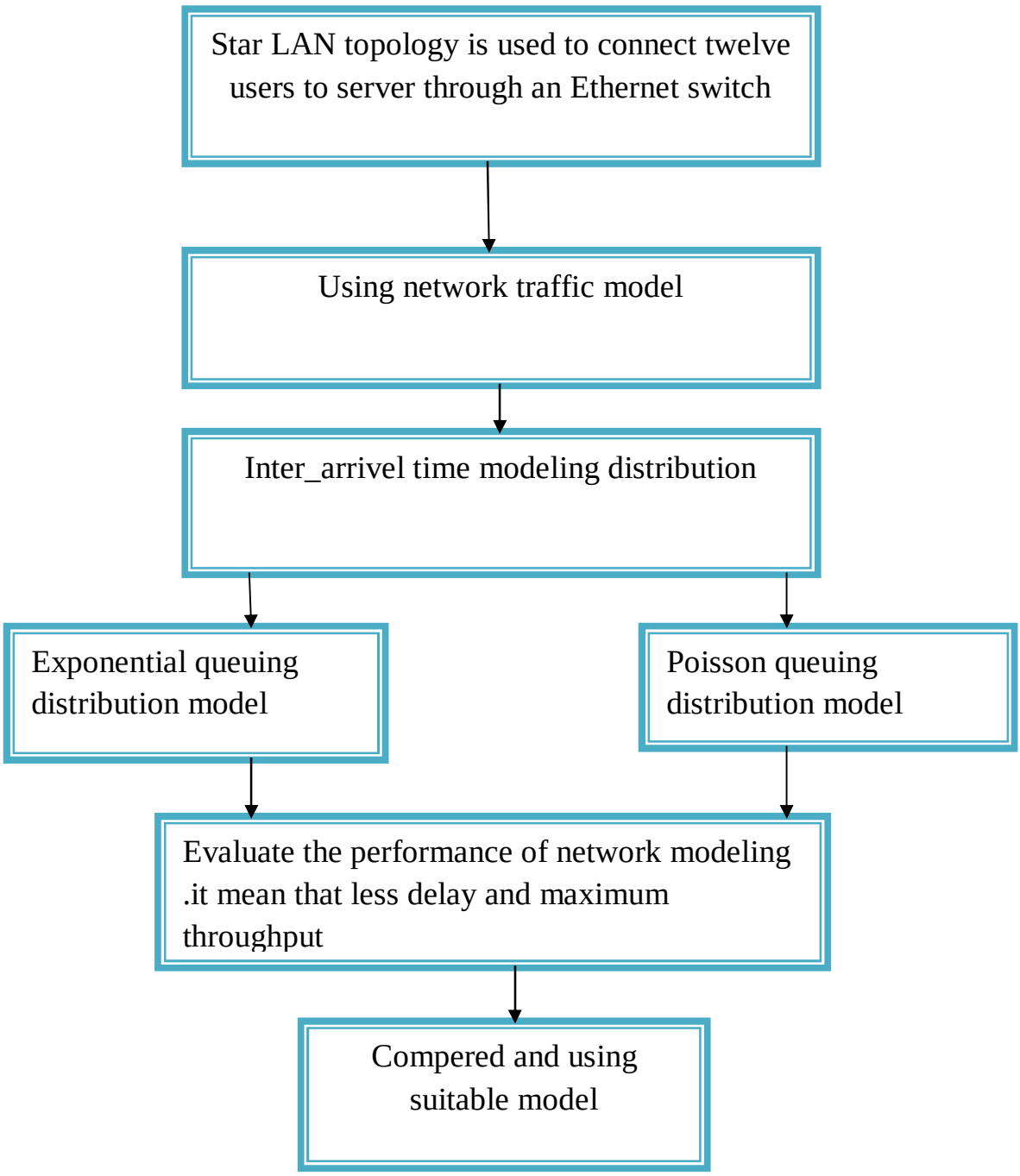

Figure (3-2): Model Description

Model description show the connect between twelve users and server through central switch in Local Area Network, traffic model describes the flow of packets between network communicating nodes in details, this details include the inter –arrival time and queuing system, inter –arrive time determine the duration between packets arrive, this time attribute is a major parameter in traffic model and it can be represented by many distribution functions.

Distribution of the inter-arrival time can be obtained by many probability distribution functions; this probability distribution function can be either discrete or continuous probability distribution function, we had evaluated both continuous and discrete, using Poisson distribution as discrete probability distribution, and the exponential distribution for continuous probability distributions , by comparing the two traffic model it can be conclusion a better performance where the higher throughput and less delay.

Chapter Four

Results and Discussion

4.1 Simulation Analysis

The use of OPNET modeler software make easy of this Thesis to be accomplished, OPNET modeler provide a comprehensive platform for networking and communication planning, design, and testing levels. We used it to evaluate the performance of the network under the two different scenarios Poisson and exponential inter-arrive time distribution and we choose the proper statistics to be collected for results and discussion.

Generally there are three types of statistics can be chosen to be collected from a simulation execution; global, node, and link statistics. We had chosen the point to point from link statistics and Ethernet from node and global statistics, then these chosen statistics will be collected in two results; global and object results. In global results we get the delay in Ethernet, which represent the delay happens in the physical layer. From the object result we get the queuing delay, throughput, and utilization results from point to point statistics for the link between the central switch and the server

The Poisson and exponential inter-arrive time distribution are evaluated and analyzed by simulation environment through the analyzing metrics. OPNET simulator is used to simulate in this research. It is quite expensive for commercial usage, but there are also free licenses for educational purposes. Finally, the results of this section are compared by results of mathematical analysis to prove the idea and improve the validity.

4.2 Simulation Description

In the simulation Thesis model we create two different scenarios Poisson and exponential inter-arrive time distribution with the same network topology; star LAN network topology is used with twelve users or clients for traffic production connected with the destination server through a central switch. Figure (4-1) below shows the system model of the network simulation used for the three traffic models evaluation and comparison.

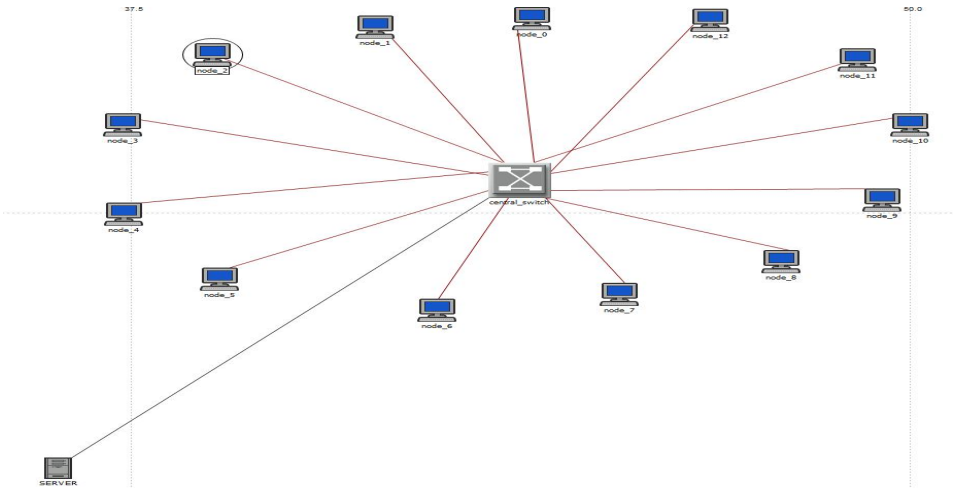

Figure (4-1): Network simulation model

As mentioned before the network simulation model shows the twelve user nodes connected with the server through the central switch, all client nodes are traffic generation sources, they generated packets with different inter-arrival time distribution and send it to the server just one way communication.

4.3 Simulation parameters

Simulation parameters shown in table (4-1) are the attributes that configured in the network nodes, these parameters are general and set in all scenarios accept the inter-arrival time attribute which is different for each scenario.

Table (4-1): Simulation parameters

Parameter	**Value**
Network technology	Ethernet
Link	10 base-T
No. of users	13
Link operational mode	Full duplex
Simulation time	30 minutes, 1 hour
Packet size	1024 bytes
Mean outcome	0.05 sec

4.4 Execution results

OPNET modeler uses Discrete Event Simulation DES method to simulate the network behavior according to the attributes configurations, so in order to evaluate the performance of any network model first we look at the simulation execution result performance as memory usage, number of events, elapsed time is the time consumed by the OPNET modeler to simulate the network, and the simulation speed. Table (4-2) below shows the simulation execution statistics for two experiments with different execution time durations; first running the simulation to simulate the network behavior for 30 minutes, and then four one hour, and as expected the time elapsed by the simulator is doubled as the number of events, while the memory usage remain constant in both experiments.

Table (4- 2): Discrete event simulation statistics

	Poisson		Exponential	
Running duration/sec	1800	3600	1800	3600
Elapsed time/sec	8	17	170	307
Number of events/sec	3,621,794	7,247,468	69,493,014	139,195,516
Memory usage/ MB	19	19	19	19

The results next are figured from the 1800 second execution time, because performance metrics are not affected by the simulation time and still approximately the same but with longer period.

The following results show the simulation speed by number of events per second and the effect of the inter-arrival time distribution. Figure (4-2) shows Poisson distribution scenario simulation speed captured with the average simulation speed, it’s obvious that there is no crowding or few events are occurs.

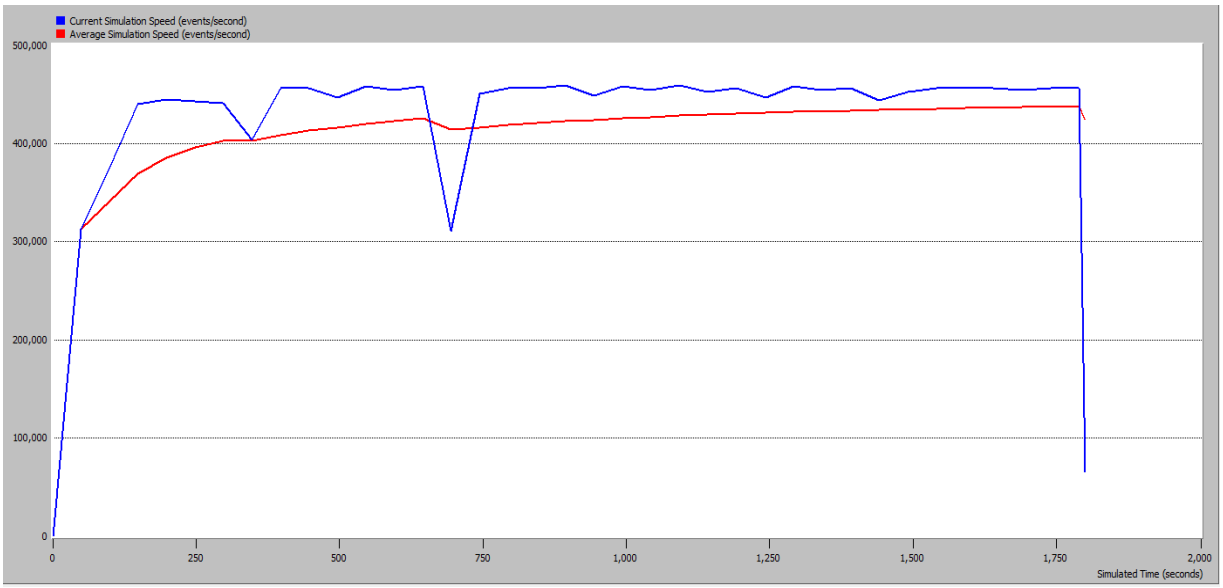

Figure (4-2): Poisson distribution scenario simulation speed

Figure (4-3) shows Exponential distribution scenario simulation speed captured with the average simulation speed, here more events happen and can be obviously seen in figure.

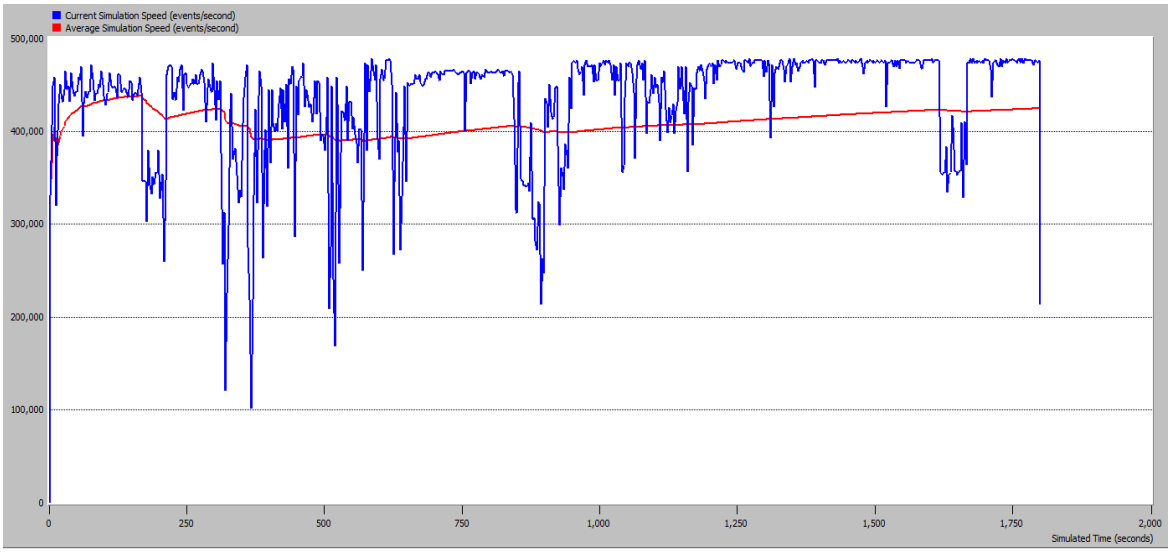

Figure (4-3)**:** Exponential distribution scenario simulation speed

4.5 Network performance results

In this section we will figure out the results exported from OPNET and visualized by using MS Excel software. These results are also related to the first experiment of 30 minutes execution time as the time scale axis shows 1800 seconds.

4.5.1 Physical layer delay

Here the general delay of the network in the Ethernet physical layer is shown in figure (4-4), and it show that the Poisson distribution scenario has the maximum delay values above all other scenarios, the average value of Poisson distribution scenario delays is equal to 0.006677.While the exponential distribution scenario has the medium or average values, the average value of Exponential distribution scenario delays is equal to 0.001807 which less than Poisson scenario by approximately 72.9%.

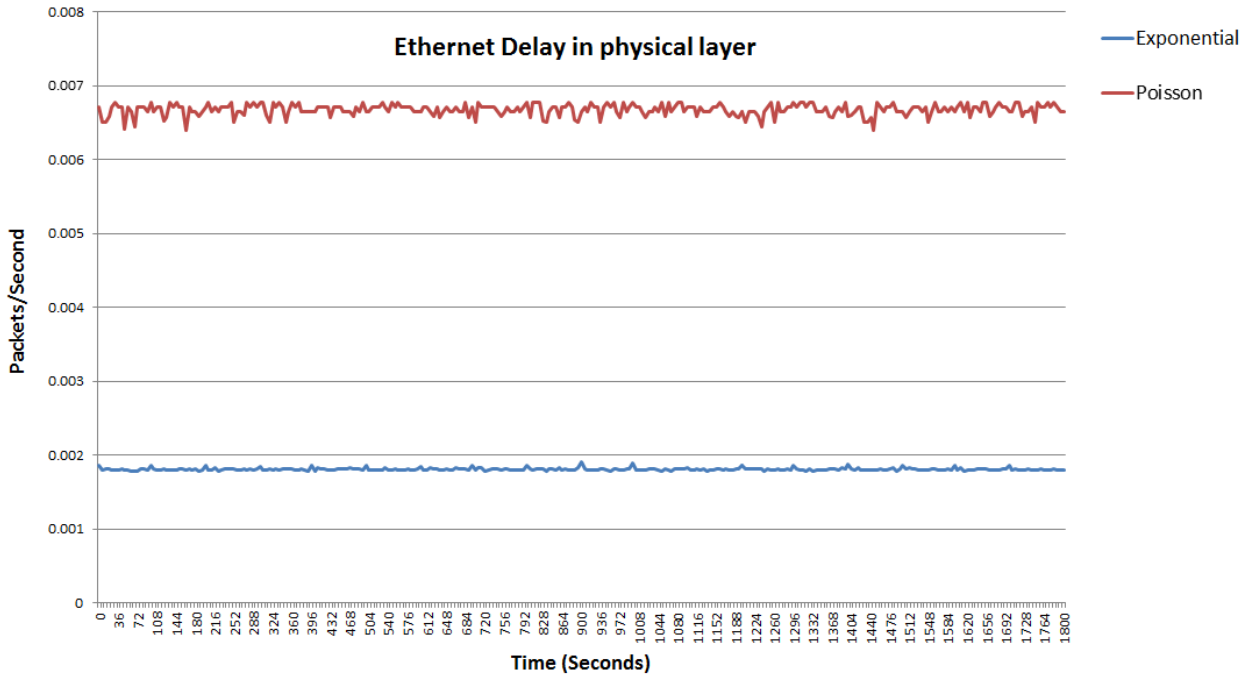

Figure (4-4)**:** Ethernet delay in physical layer

4.5.2 Queuing delay

Queuing delay is defined before in previous chapters, and it's also considered as a type of delays which affect negatively in network performance when increased. Figure (4-5) below shows the queuing delay of different scenarios, both Poisson and an exponential distribution scenario achieves same queuing delay values in average of 0.00084.

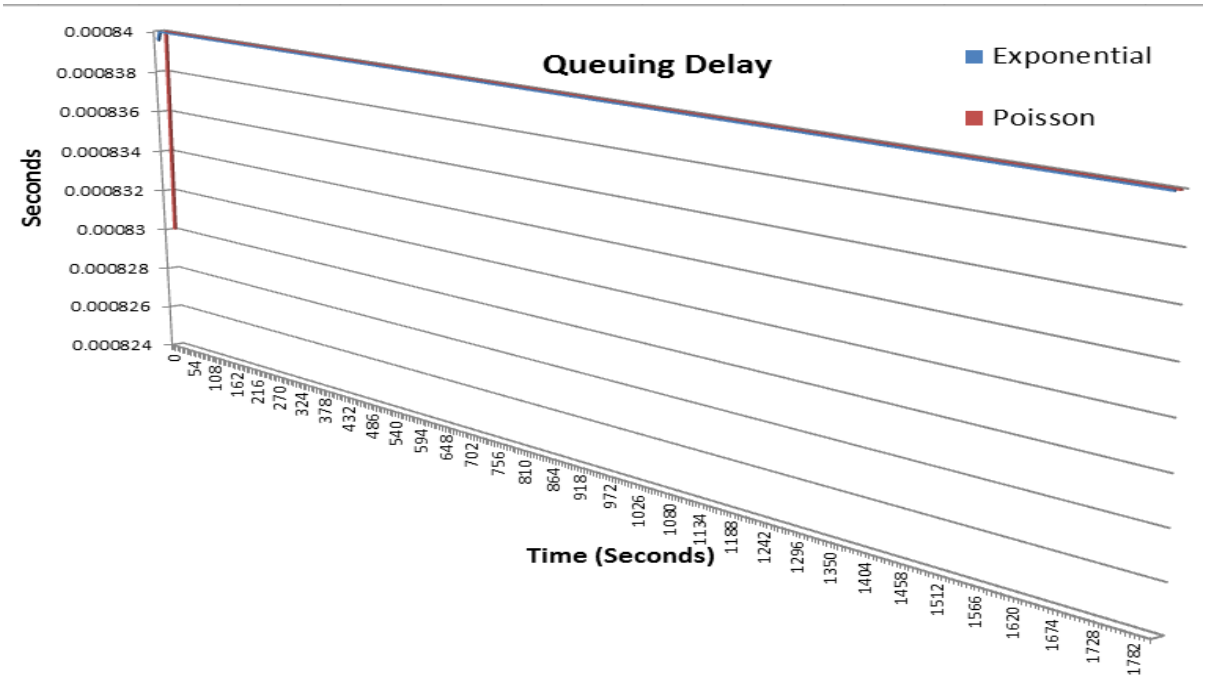

Figure (4-5)**:** Network Queuing Delay

4.5.3 Throughput

Throughput is the biggest concern in networking; here figure (4-6) shows the throughput results, Poisson distribution scenario has the minimum records which equal 12.74086 packets per second average value, while exponential distribution has 259.902 packets per second average throughput.

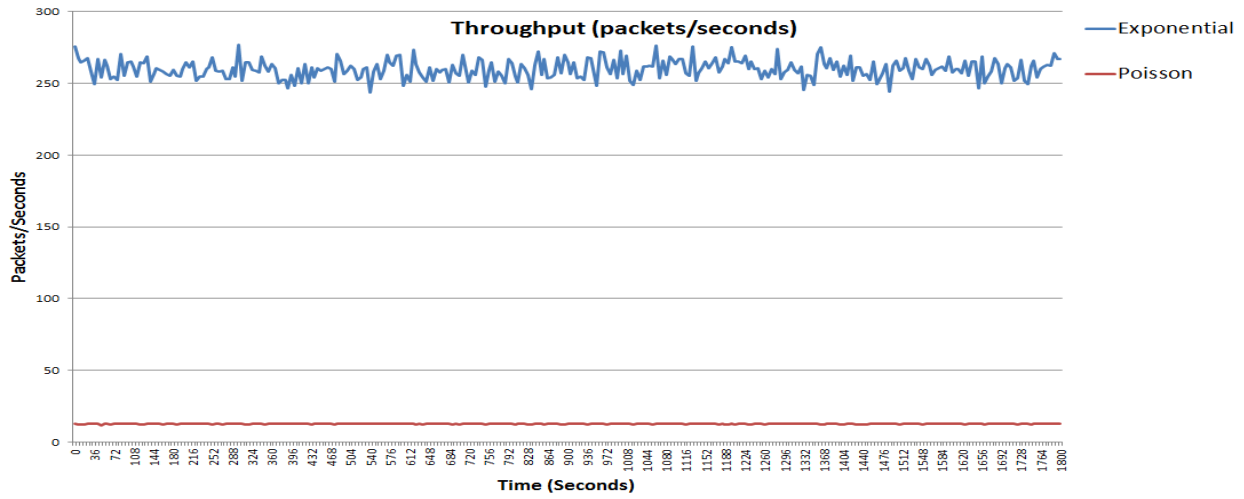

Figure (4-6): Network Throughput

4.5.4 Utilization

Hence that utilization is the percentage of used bandwidth at the particular time, and then less utilization value refers to using fewer network resources or maintaining better system capacity. Here figure (4-7) shows utilization captured from simulation scenarios, the Poisson distribution scenario has the minimum utilization values averaged by 1.070189 percent.

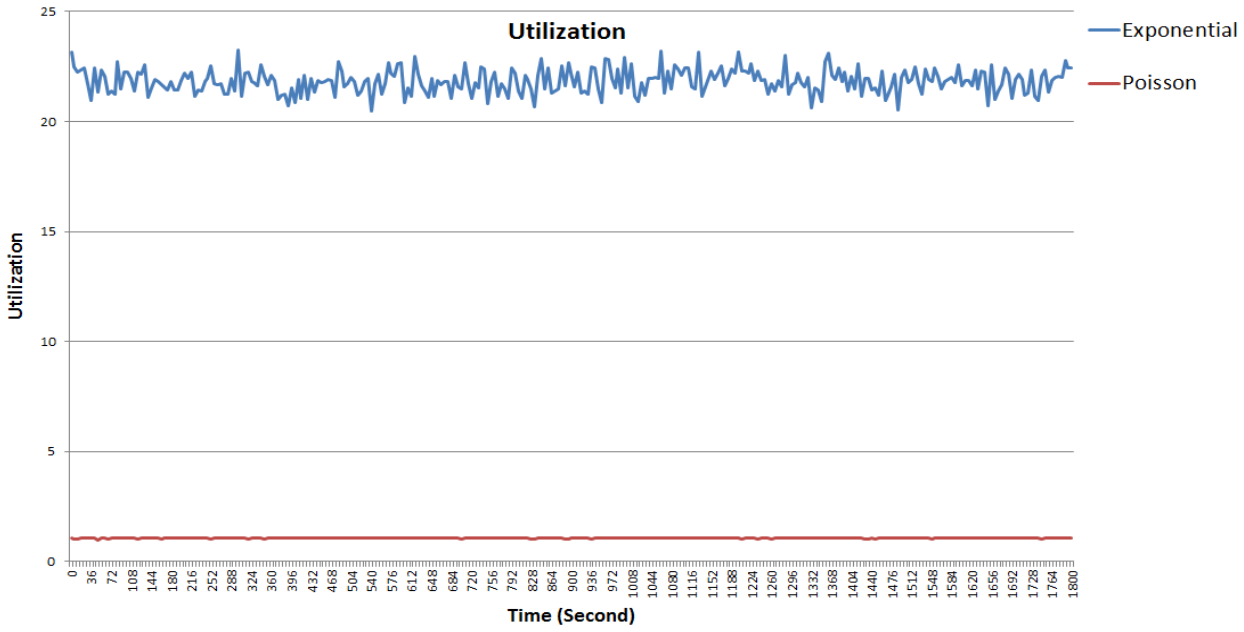

Figure (4-7)**:** Network Utilization

In addition, by comparing the results, it can be concluded that Exponential has a better performance where the higher traffic and bigger load received, but it can still maintain less delay.

Table (4-3): Result Comparison

Scenario	Delay	Throughput	Utilization
Poisson	Higher	Lower	Lower
Exponential	Lower	Higher	Higher

Chapter Five

Conclusion and Recommendations

5.1 Conclusion

As a summary of this Thesis traffic modeling's characteristics have been expressed and carefully understood in addition to the valuable acknowledge we get. One of the important traffic models parameters is the inter-arrival time, which defines the time duration between the arrivals of packets to be served; this parameter can shape the traffic type. Distribution of the inter-arrival time can be obtained by many probability distribution functions; this probability distribution function can be either discrete or continuous probability distribution function. In the Thesis we had evaluated both continuous and discrete, using Poisson distribution as discrete probability distribution, and the exponential distribution for continuous probability distributions.

Traffic model with exponentially distributed packet inter-arrival time has the advantage over traffic model with Poisson distributed packet inter-arrival time in terms of network throughput and Ethernet physical layer delay, but they have the identically the same result in term of queuing delay, in addition to that Poisson distributed packet inter-arrival time traffic model has the advantage in term of utilization and this because it has fewer throughput.

This Thesis can be summarized as comparing two different traditional traffic models; Poisson and Exponentially distributed packet inter-arrival time traffic models.

5.2 Recommendations

Generally this Thesis was intended to only perform a comparison study between Poisson and Exponentially distributed packet inter-arrival time traffic models, but when fetching OPNET traffic generation parameter we find the self-similar traffic model and it seems like a topic related to our research so we took the adventure and examine it. So if we need to make an advanced step from this Thesis the Self-Similar traffic model will be very exciting issue to start from and exercise all its different modes.

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