Locating Bottleneck Nodes on a Large Wired Local Area Network

Ayankunle Adegbite Taiwo
Computer and Information Science dept.
University of Technology Petronas, Malaysia
kunletaiwong@gmail.com

Ku Ruhana Ku-Mahamud, Mohd Samsu bin Sajat
Computer and Information Science dept.
Universiti Utara Malaysia
{ruhana,mohdsamsu}@uum.edu.my

Abstract— **When certain nodes are heavily loaded with clients more than their capacity, slow connection in accessing network resources is a common complaint on such a computer network with switches as dominant network equipment. In this study, performance simulation model was developed and validated for a federal university in Malaysia. The effect of network parameters such as the processing time on throughput and utilization of the servers and switches on the network was investigated through simulations. In conclusion, results from the simulation model suggest some bottleneck nodes on the network.**

Keywords: LAN, modeling, simulation, UUM, bottleneck

I. INTRODUCTION

Data networks connect several computers, making it possible for them to connect and exchange data. A voice and data network Local Area Network (LAN) is a collection of individual networks connected by network equipments to function as a single large network known as internetworking [1]. In a computer network that has switches as dominant network equipment, data packets are sent on a shared link via the switches. The switch will have to make a decision on which packet goes first. In a packet switched network a switch could be designed to service packets on a FIFO basis to foster good Quality of Service (QoS). But when packets are dropped before it is been processed by the switch nodes, then the network is said to be congested [2].

A model gives an organized procedure for the analysis of a problem [3]. The formal models of performance necessary for the efficient, reliable design and optimization are stochastic (queuing-based model) and simulation. The University Utara Malaysia (UUM) computer network has been undergoing expansions with additional network nodes with increasing number of users, and there are some complaints from the users on the network connection [4]. When traffic bottleneck nodes exist on the network, congestion is imminent in some sections. The objective of this paper is to identify the bottleneck nodes on the network by modeling the performance of the network. In the remaining section of the paper, previous studies relating to our study were briefly discussed, followed by the methodology we adopted for the study, simulation result and the utilization of the servers at the data center.

II. LITERATURE REVIEW

Simulation models are widely used because it can handle the complexities of large networks. The ease of use, intuitive understanding and no theoretical limitation also makes it a widely selected choice [5]. Simulation modeling can be easily used to locate bottlenecks and evaluate alternatives in system. Kiran et al. [6] developed a flexible simulation model to analyze a new airport. The model was flexible enough to allow modification of different parameters in the system.

Fitzgerald & Harper [7] proposed a simulation model for Air Force Enterprise IT transformation initiatives. A Service Delivery Point (SDP) is a combination of routers, switches, and firewalls which connect the base Local Area Network (LAN) to the Air Force’s Wide Area Network (WAN). Information Packets move from a location X to Y. The objective of the model was to examine the current and future ERP end user response time. The study successfully measured the performance of the ERP on the Network and to determine the utilization of the system. Simulation models have gained recognition because of the need to evaluate the performance of large networks.

A local area network (LAN) model with regards to problems of digital device technical diagnosis was proposed by [8]. The problems are fault simulation, test generation and default search. Existing methods and algorithms of digital devices were used. The authors represented the computer network for the users as a computer with virtual representation on the screen of information. The network was represented with a two dimensional model of a personal computer (PC) as hardware while the software is represented as the third dimension. The model creation is brought to execution by representing the LAN as a graph and testability analysis of the network using Boolean equation. The model efficiency of the LAN model was tested on about two hundred (200) workstation. Modifications were made on the methods and algorithms of digital devices and the problems were tested for minimization of timing expenditure at diagnosing procedure executions.

Zaitsev [9] modelled a sample Local Area Network with coloured Petri net. The model consists of places, drawn with different shapes as circles (ellipses), transitions, bars, and arcs.

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The dynamic elements of the model were represented by tokens, and a detailed representation of the real network was derived. The response time of the servers to the clients were measured. Most of the above author carried out their investigation and studies in organizations and research institutes. The domain of our study is a University community.

III. METHODOLOGY

For this study, we adopted the simulation modeling methodology similar to [10]. We identified the problem as slow connection to network recourses and made a clear goal for the study. Data was collected by interviewing network engineers at the University Network operating Centre (NOC). Furthermore, documented physical and operational data was also collected for the link speed, packet size, throughput etc. A definition of the topology of the domain area UUM LAN was made and transferred to a computer network simulation model using Omnet++ [11]. The simulation model was validated, ran, analysed and documented. Since, the movement of data packets is such that it path is to and fro from the pc user nodes through the edge switches to the distribution switches and passing through the core switches to the data centre and internet. Proper planning and design of the model was made to avoid misleading results. Table 1 below shows the initial parameter set on the model.

Table 1: The Initial Parameters and Symbols

Parameter/Symbol	**Initial Value**
Internet Process time (S) @ Datacenter	0.2s
Internet Link Speed	155Mbps
Server1 Link Speed	100Mbps
Server2 Link Speed	100Mbps
Internet No of Nodes (N)	1100
Server 2 No of Nodes (N)	700
Simulation Time (T)	1000s
Throughput (χ)	0
Utilization (U)	0

IV. SIMULATION RESULTS AND DISCUSSIONS

The simulation model was validated with data collected from the university's network operation centre (NOC). Table 2 shows the actual RTT on the network and the derived RTT from our simulation model, the low error value indicates that our simulation model is near to real life. The percentage error of the first packet acknowledgment (RTT) is stated below.

$$\text{Percentage Error} = \frac{100(\text{Model RTT} - \text{Network ActualRTT})}{\text{Model RTT}}$$

Table 1: A Comparison of the Actual and Model RTT

System	Processing Time(s)	Model RTT(ms)	Actual RTT(ms)	Error %
Internet	0.2	5.45	5	8.25
Server1	0.2	1.201	1	16.74
Server2	0.2	1.208	1	17.22

The experiment was performed by running simulation using the initial parameters in Table 1. Variations were made by increasing the processing time on the internet, switches and servers on the network from 0.2s to 1.0s in a range of 0.2, while the initial parameters were kept constant. Furthermore, variations were made by increasing the packets arrival rate from 2/s to 10/s in a range of 2, while other initial parameters were still kept constant. Simulation data was collected when the simulation reached steady state/condition (after the transient state). Actual number of (2000) users on the LAN network was first used for the first experiment and then increased to (3000) users. On the internet server and the two servers at the data centre (server1&2), there exist an inverse relationship between the process time and the throughput in both experiments. The lowest throughput was recorded on the internet server for each of the experiment (See Table 3). Figure 1&2 shows the relationship between the proceeding times and throughput for both experiments. Similar relationship exists on the distribution switches (x, y, z, B1-15) on the school network. On the servers the internet server has the lowest throughput while noticed that switch Z has the highest throughput while switch B13 has the lowest throughput during both experiments (See table 4; Figure 3&4). Furthermore, the utilization of the system was further investigated.

a. Utilization of the Internet, Servers and Switches

Utilization (U) = χS is the percentage of time that the switches are busy. Table 5 and 6 shows U, while $0 \leq U \leq 1$, the idle time and the fraction of packets dropped per second when process time is 0.2s for total user nodes. Switches with U=1 has no idle time while processing. Switch Z in has 66% to process and rest for 34% per second. Switches with U=1 are of concern because they do not have a resting time while processing. Furthermore, Table 5 shows that the internet and servers are underutilized, while Table 6 shows there are some switches that are highly utilized while others are less busy. Thus, this implies that the Internet and servers at the data centre can still process higher number of packets as compared to present data packets being processed, while some switches have no idle time.

Table 3: The Process Time and the Throughput on the Internet and the Server 1&2

Process Time	**Internet χ 1**	**Internet χ 2**	**Server1χ1**	**Server1χ2**	**Server2χ1**	**Server2χ2**
0.2	0.862	1.444	1.317	2.912	0.639	2.914
0.4	0.413	0.746	0.646	1.307	0.318	1.307
0.6	0.277	0.526	0.424	0.734	0.220	0.738
0.8	0.221	0.385	0.349	0.490	0.121	0.490
1.0	0.164	0.328	0.282	0.436	0.077	0.436

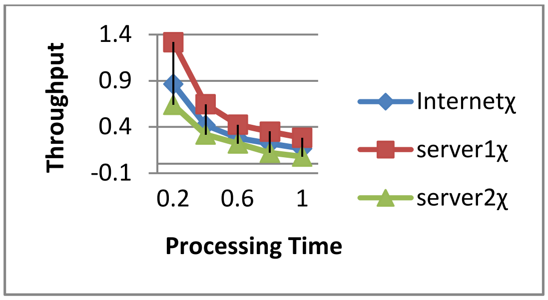

Figure 1: The Graph of the Process Time against Throughput on the Internet server (2000 users)

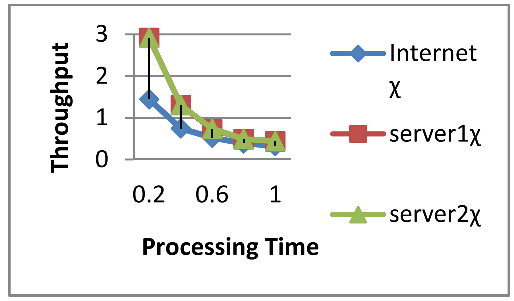

Figure 1: The Graph of the Process Time against Throughput on the Internet server (3000 users)

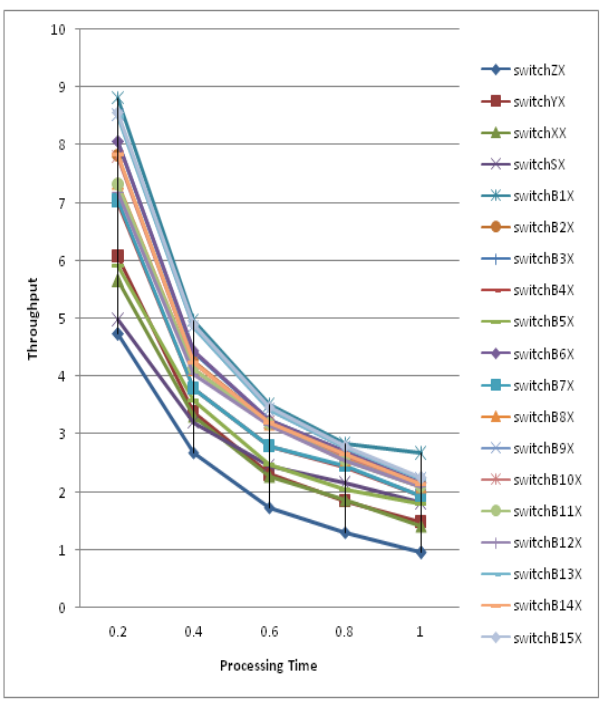

Figure 3: The graph of the Process Time against the Switches Throughput on the Network (2000 users)

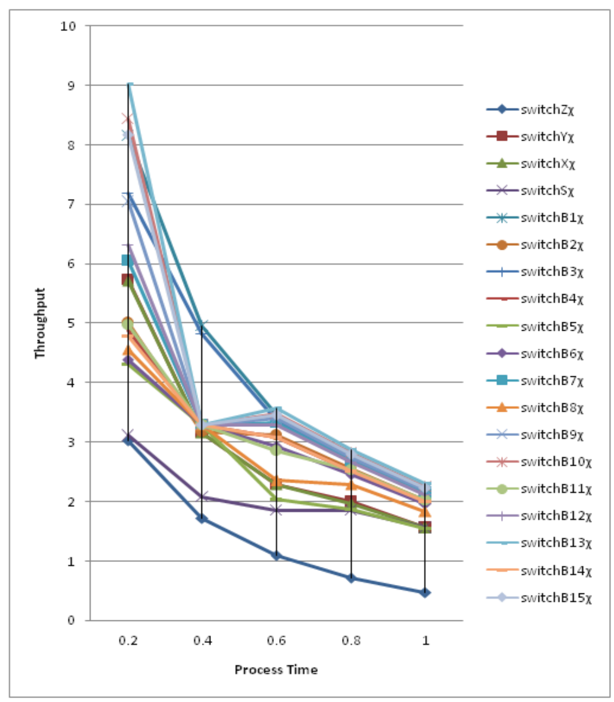

Figure 4: The graph of the Process Time against the Switches Throughput on the Network (3000 users)

Table 4: The Processing Time and Throughput on the Core Switch and Distribution Switches.

Process Time	T11 0.2	T1 2	T21 0.4	T22	T31 0.6	T32	T41 0.8	T42	T51 1	T52
switchZ	3.027	3.297	1.72	1.771	1.096	1.155	0.716	0.801	0.472	0.478
switchY	5.728	5.508	3.156	3.039	2.289	2.279	1.996	1.824	1.562	1.457
switchX	5.718	5.566	3.156	3.123	2.285	2.338	1.966	1.857	1.562	1.468
switchS	3.113	2.833	2.083	2.237	1.858	1.806	1.847	1.816	1.559	1.549
switchB1	8.149	8.789	4.953	4.995	3.451	3.471	2.790	2.804	2.230	2.239
switchB2	5.013	5.516	3.183	3.657	3.116	3.159	2.541	2.567	2.028	2.046
switchB3	7.190	8.073	4.820	4.766	3.368	3.390	2.721	2.738	2.174	2.185
switchB4	4.885	5.274	3.295	3.747	3.082	3.100	2.508	2.521	1.996	2.005
switchB5	4.313	4.393	3.295	2.752	2.040	2.124	1.859	1.878	1.554	1.561
switchB6	4.387	4.388	3.295	3.300	2.930	3.003	2.457	2.491	1.960	1.984
switchB7	6.059	7.701	3.295	4.613	3.326	3.346	2.690	2.704	2.148	2.158
switchB8	4.560	4.806	3.295	3.001	2.352	2.508	2.288	2.288	1.834	1.847
switchB9	7.046	8.211	3.295	4.915	3.393	3.416	2.745	2.76	2.194	2.204
switchB10	8.434	8.94	3.295	5.037	3.479	3.99	2.813	2.023	2.250	2.257
switchB11	4.972	5.24	3.295	3.59	2.850	3.054	2.535	2.564	2.023	2.046
switchB12	6.308	7.461	3.295	4.497	3.289	3.11	2.659	2.673	2.123	2.133
switchB13	9.031	9.504	3.295	5.157	3.564	3.581	2.877	2.887	2.303	2.309
switchB14	4.789	5.093	3.295	3.62	3.077	3.094	2.504	2.519	1.995	2.004
switchB15	8.169	8.854	3.295	5.00	3.453	3.730	2.792	2.805	2.233	2.239

Table 5: Utilization of the Internet and Servers at the Data Centre when using the Maximum User Nodes

	S=0.2	**Utilization**	**Dropped packet fraction**	**Idle Time**
Internet	**1.460**	0.292	0	0.708
server 1	**2.897**	0.5794	0	0.4206
server 2	**2.878**	0.5756	0	0.4244

Table 6: Utilization of the Distribution Switches

Switch	**S=0.2**	**Utilization**	**Dropped packet fraction**	**Idle Time**
switchZ	**3.297**	0.6594	0	0.3406
switchY	**5.508**	1	0.1016	0
switchX	**5.566**	1	0.1132	0
switchS	**2.833**	0.5666	0	0.4334
switchB1	**8.789**	1	0.7578	0
switchB2	**5.516**	1	0.1032	0
switchB3	**8.073**	1	0.6146	0
switchB4	**5.274**	1	0.0548	0
switchB5	**4.393**	0.8786	0	0.1214
switchB6	**4.388**	0.8776	0	0.1224
switchB7	**7.701**	1	0.5402	0
switchB8	**4.806**	0.9612	0	0.0388
switchB9	**8.211**	1	0.6422	0
switchB10	**8.94**	1	0.788	0
switchB11	**5.24**	1	0.048	0
switchB12	**7.461**	1	0.4922	0
switchB13	**9.504**	1	0.9008	0
switchB14	**5.093**	1	0.0186	0
switchB15	**8.854**	1	0.7708	0

CONCLUSION

In this study a simulation model was developed and validated for UUM wired Local Area Network. The effect of network parameters such as the processing time on the performance metric such as throughput of the servers and switches on the network was investigated. As expected, process time is inversely related to throughput (see fig. 1-4 and Table 3- 4). This implies that when data packets sent from a user node queue longer at a switch node, the rate at which the switch serve the data packets arriving at its node reduces, hence a bottleneck region is formed. We discovered that the servers are underutilized while some distribution switches are too busy and there are packet drops, thus the complaints of slow connection by the students.

Furthermore, analysis on utilization shows that switches with high percentage of utilization drop some data packets which invariably promote slow connection. Server utilization is low as there are lots of idle time, but there are no idle time on distribution switch X&Y at the datacenter, B1-B4, B7, B9-B15 at other sections of the network, see[11]; these are the bottleneck sections on the network (see table5 &6). It is recommended that load shedding be performed on the aforementioned bottleneck switches. Future works could include investigation of more network performance metrics and investigating different segment of the wired LAN separately. In addition, the small segment of the network could be meticulously analyzed using other network performance metrics that are not used in this study.

ACKNOWLEDGMENT

I would like to appreciate Mr Amran bin Ahmed for tutorial on Omnet++,Amran (computer center)for data collection,'Tayo Taiwo and 'Ronke Kehinde for their assistance while at Universiti Utara Malaysia.

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