Development of Simulation Model in Heterogeneous Network Environment: Comparing the Accuracy of Simulation Model for Data Transfers Measurement over Wide Area Network (WAN)

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Abstract

We present a novel approach for the measurement of one-way delays and throughput between network nodes in heterogeneous environment over Wide Area Network (WAN). This research investigates performance evaluation of remote data transfers on heterogeneous services and technologies environment. We propose an enhanced equation to evaluate the performance of network traffic management via Little Law and Queuing theory to improve the evaluation algorithm. To get accuracy results on the performance of simulation model, we measure (verify and validate) data from lab experiment. We use network management tool to capture those data and Ping Plotter application (network analyzer) to generate traffic. As a result, this simulation model can provide a good approximation of the real traffic (one-way delays and throughput) observed in the real network environment (Wide Area Network, WAN). Through laboratory and field experiments, it shows that the model via simulation is capable of approximating the performance of remote data transfers over heterogeneous services and techniques within a minimum error range.

1.0 Introduction

Considerable research has been conducted to model and quantify the performance of heterogeneous services and technologies (e.g [25], [26], [27]). Accurate measurements and analyses of network characteristics (remote data transfers) are essential for robust network performance and management. Queuing theory [3] has been used as an effective tool to model performance in several technical and social contexts. Evaluating the performance of a computer networking usually involves constructing an appropriate model to predict the heterogeneous environment behaviour via simulation model. The heterogeneous environment model is then analyzed and simulated using mathematical techniques. For example, several flow-level network traffic models have been proposed to describe/stimulate [21], [23], [24]. These models have been used to study fairness, response times, queue lengths and loss probabilities under different assumptions and using a variety of mathematical techniques. Queuing theory has been widely used to model and analyze the network performance of complex systems involving services, communication systems, computer networks and vehicular traffic. In contrast to other works in the literature (e.g., [7], [8], [9], [31]), we developed simulation model to measure the performance of heterogeneous environment. Our model can be used to generate representative packet traffic (one-way delays and throughput) in a live network environment or in a simulated environment.

The significant of this study was to develop a simulation model to measure the performance of one-way delays and throughput in heterogeneous network environment using Queuing theory. This model could assist network administrators to design and manage heterogeneous network systems. This simulation model can be used in various services and technologies to measure heterogeneous environment. Therefore, this simulation model is designed to: i) predict the performance of various services (e.g. video, audio, voice and message) in order to aid technology assessment and capacity planning; ii) predict the expected behavior of new services and designs through qualitative or quantitative estimates of network performance; iii) assist network administrator to prepare, propose, plan and design network topology more effective and systematic; and iv) conduct 'What-If' analysis for evaluating heterogeneous network environment performance. Moreover, in the future, the integration of data and communication services, almost every 'Internet Ready' device will be a communicable device [11]. With the availability of this infrastructure, users are now demanding and expecting more services [19], [20]. Convergence is pushing towards an environment that requires new investment in infrastructure and able to support the delivery of rich services (various services), applications and content [17], [21], [5]. Network deployment is growing increasing complex as the industry lashes together a mix of wired and wireless technologies into large-scale heterogeneous network architecture and as user applications and traffic continue to evolve [2]. The successful evolution of the Internet is tightly coupled to the ability to design simple and accurate models [6]. Many factors may contribute to the congestion of network interface, such as a heavy load in the network that usually generates higher traffic. Once the number of requests exceeds the maximum capability of network, many clients will not able to receive responses from the network [1]. Thus, this research is critical to be conducted in order to predict and measure of remote data transfers in heterogeneous environment.

2.0 Problem Statements

In the 21 century, a network infrastructure is based on multi-service implementation over convergence of network medium such as ISP, PSTN and GSM [12], [15]. Availability of various services has produced multi-traffic in network infrastructure. Therefore, multi-traffic in the network infrastructure has become more complex to observe and analyze [13], [16], [17]. Today, retrieving and sending information can be done using a variety of technologies such as PC, PDA, fix and mobile phones via the wireless, high speed network, ISDN and ADSL lines that are more prone to heterogeneous environment, but unfortunately the optimal capability of technologies are not fully realized. The main factors of network congestion are related to network design and bandwidth capacity [18]. Nevertheless, few studies have been conducted to evaluate the application of computer network technologies and services over heterogeneous environment especially in Higher Education Institutes. Algorithms for actively measuring network physical and available bandwidths have been researched for many years. Many tools have been developed, and only a few tools have successfully achieved a close estimation of network bandwidths [27]. According to Huseyin Simitci [30], distances of network connection is dramatically changes the performance characteristics of storage networks. He shows how analytical queuing network models can be developed to model the performance characteristics of bulk data transfers over long distances [30]. Therefore, retrieving and sending information over heterogeneous environment using convergence of technologies in Higher Educational Institutes should be analyzed and evaluated via simulation model. We have setup a pilot test-bed (real network environment) to analyze and measure of network traffic utilization at University of Kuala Lumpur in Malaysia. This study posits several research questions: i) what is the performance level of the remote data transfers; and ii) Is the simulation model for evaluating and measuring the heterogeneous environment performance effective?

3.0 Methodologies

Whatever modeling paradigm or solution techniques in heterogeneous environment model development are being used, the performance measures extracted from a simulation model must be a good representation of the real network environment. Inevitably, some assumptions must be made about the real network in order to construct the heterogeneous environment model. Figure 3.1 shows the overall framework of the simulation model. There are four performance techniques to validate the simulation model: i) graphical representation; ii) tracing; iii) parameter variability; and iv) predictive validation. In addition, there are two techniques to judging how good a model is with respect to the real network: i) it must ascertain whether the simulation model implements the assumptions correctly (model verification); and ii) assumptions which have been made are reasonable with respect to the real network (model validation). Comparison with a real network is the most reliable and preferred method to validate a simulation model (refer to Figure 3.2).

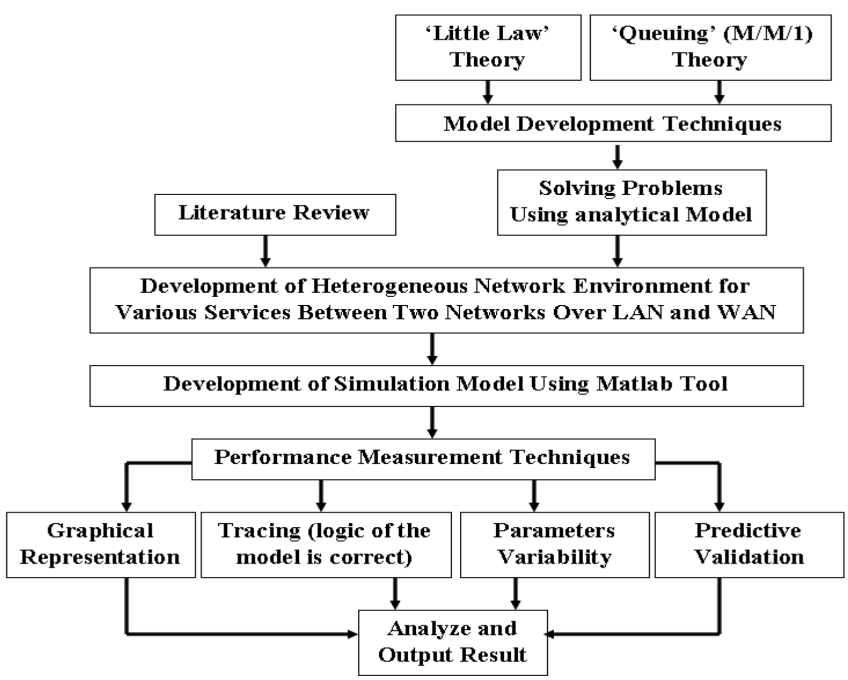

Figure 3.1: Simulation Model Development Methodology

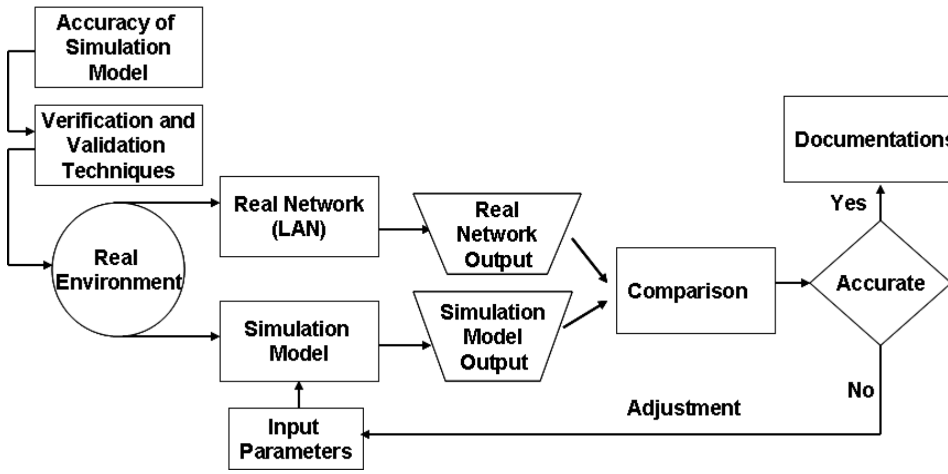

Figure 3.2: Simulation Model Verification and Validation Methodology

4.0 Propose Simulation Model Development for Remote Data Transfer

Many different types of modeling and simulation applications are used in various disciplines such as acquisition, analysis, education, entertainment, research and training [14]. In the Figure 4.1, theoretical model is based on a random distribution of service duration. “Request” defines the way clients use the computer network to request services, while, “Response” represents the way clients receive services from the server. Simulation model is divided as follows: i) to study physical of real heterogeneous network environment; ii) transform physical of real heterogeneous network environment into logical model; and iii) develop and implement the heterogeneous simulation model.

4.1 Physical Model of Real Heterogeneous Network Environment

Before we start to develop simulation model of heterogeneous network environment, we need to define the situation of heterogeneous environment in real world. Figure 4.1 shows the network heterogeneous environment in real world. Then we need to transform from heterogeneous environment in real world into logical model. The logical model is the phase where mathematical techniques are used to stimulate heterogeneous environment.

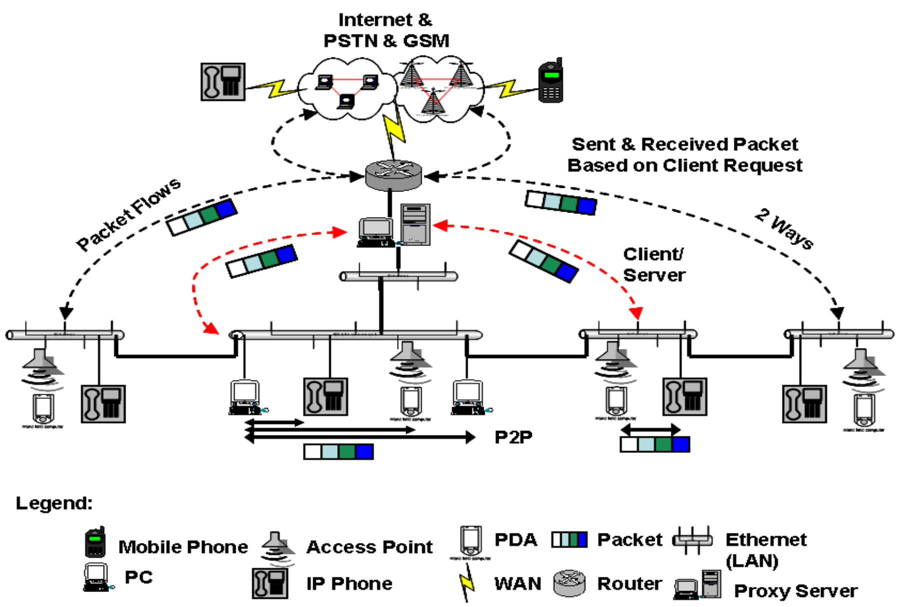

Figure 4.1: Real Heterogeneous Network Environment at Main and Branch Campus

4.2 Logical Model of Heterogeneous Network Environment

Figure 4.2 depicts the open queuing network based on M/M/1 will use to develop logical model of heterogeneous network environment for remote data transfers. Queuing theories are powerful enough to include many different combinations [1]. Parameters like bandwidth capacity, size of packet services and distances between two networks are used to 'characterize' the application traffic. The logical model is the important area need to define which mathematical techniques should be used in development of heterogeneous environment.

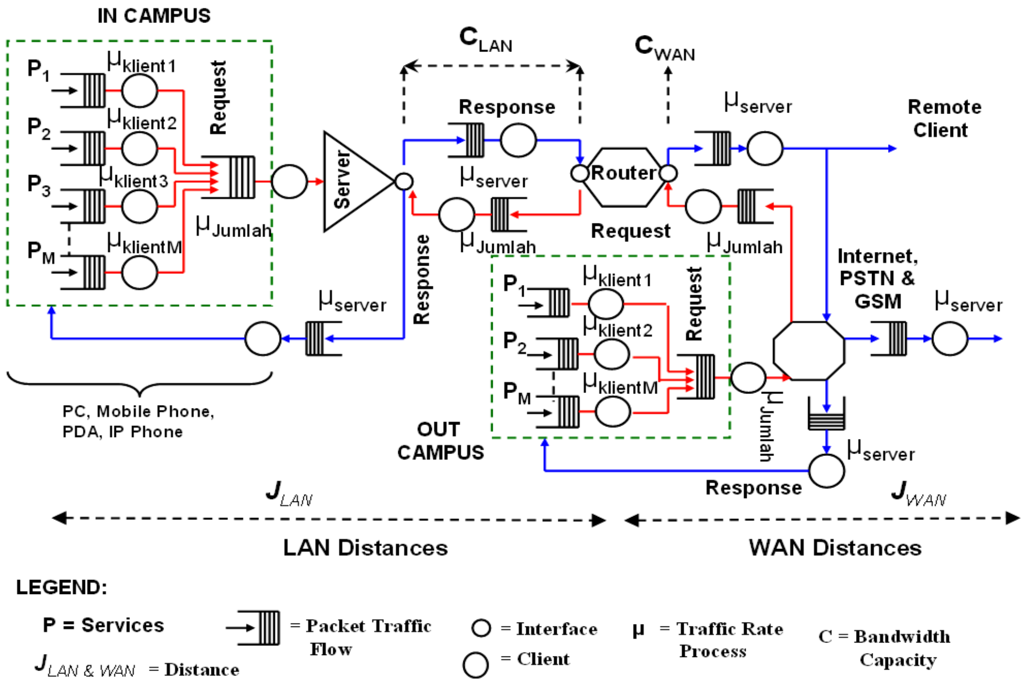

Figure 4.2: Logical model of Heterogeneous Network Environment at Main and Branch Campus

4.3 Development of Heterogeneous Network Environment Model

This section describes a simple analytical queuing and little law theories that capture the performance characteristics of remote data transfer operations. A link refers to a single connection between routers and hosts. The link bandwidth is the rate at which bits can be inserted into the medium. The faster bandwidth the more bits can be placed on the medium in a given time frame [22]. At this stage, we assume the data are transported between the two network sites (source and destination) as previously shown in Figures 4.1. Table 4.1 shows the parameters that have been used in the model development. In open queuing network, the throughput of the heterogeneous network environment is determined by the input rate in the system. Table 4.2 summarizes all the input and output parameters used in the model.

Table 4.1: Notations for Model Development

Model Parameters	Meaning
L	*Size of packet services*
R	*Bandwidth capacity*
v	*Speed of Light $2x10^8$*
n	*Total of node connected between two networks*
d	*Distances between two networks*
C_{LAN} dan C_{WAN}	*Bandwidth of LAN and WAN interface ports*
P (P1,P2,P3,...Pm)	*Various services*
P1	*Client uses single service*
J_{LAN} dan J_{WAN}	*LAN and WAN distances*
μ_{Jumlah}	*Total size of packet services request by clients (traffic)*
$\mu_{klientl}$	*Size of packet service request by client (traffic)*
Trafik_P1	*Total size of packet services used by clients (traffic)*
Trafik_Heter	*Total size of various packet services in heterogeneous network environment used by clients (traffic)*

Table 4.2: Input and Output Metrics for Model Development

Input Parameters	Output Parameters
Type of Services	Throughput traffic in bit per second (bps)
Size of packet services in bit per second (bps)	Total time taken (delay) in second (sec) due to transmission and propagation delay
Size of bandwidth in bit per second (bps)	
Total of nodes	
Distances in kilometres (KM)	

The original theory [28] is defined as a throughput (variable name is 'Throughput') in equation 1. While [29], equation 2 is defined as a delay, time taken for packet transmission depends on size of packets and hop (variable name is 'Time'). Equation 1 and 2 are derived based on logical model that has been designed to meet requirements for heterogeneous network environment. Logical model is derived and formulated in a single service (homogeneous concept) as in equations 3, 4 and 5. Then, the logical model is derived to the heterogeneous network environment in equations 6 and 7.

(William Stallings, [28]):

$$Throughput = \frac{L}{\frac{d}{v} + \frac{L}{R}} \quad \text{------------- (1)}$$

(Darren L. Spohn, [29]):

$$Time = \frac{L}{R}(n+1) \quad \text{------------- (2)}$$

Where L, d, v and R > 0

Equation 1 and Equation 2 are derived

$$\text{Laluan\_Trafik\_Hop} = \frac{L}{\frac{d}{v} + \frac{L}{R}(n+1)} \quad \text{---------} \ (3)$$

Client uses single service for remote data transfer from LAN to WAN interface ports

$$\text{Trafik\_P1} = \left[\frac{P1}{(\frac{J_{LAN}}{v}) + (\frac{P1}{C_{LAN}}(n+1))}\right] + \left[\frac{P1}{(\frac{J_{WAN}}{v}) + (\frac{P1}{C_{WAN}}(n+1))}\right] \quad \text{-------} \ (4)$$

$$\text{Trafik\_P1} = \left[\frac{\mu_{klient\,1}}{(\frac{J_{LAN}}{v}) + (\frac{\mu_{klient\,1}}{C_{LAN}}(n+1))}\right] + \left[\frac{\mu_{klient\,1}}{(\frac{J_{WAN}}{v}) + (\frac{\mu_{klient\,1}}{C_{WAN}}(n+1))}\right] \quad \text{-------} \ (5)$$

Client uses various services for remote data transfer from LAN to WAN interface ports Heterogeneous Environment

$$\text{Trafik\_Heter} = \left[\frac{P1+P2+P3+..+Pm}{(\frac{J_{LAN}}{v}) + (\frac{P1+P2+P3+..+Pm}{C_{LAN}}(n+1))}\right] + \left[\frac{P1+P2+P3+..+Pm}{(\frac{J_{WAN}}{v}) + (\frac{P1+P2+P3+..+Pm}{C_{WAN}}(n+1))}\right] \quad \text{---} \ (6)$$

Where $P1+P_2+P_3+\ldots+Pm = U_{klient1}+U_{klient2}+U_{klient3}+\ldots+U_{klientm} = \mu_{jumlah}$

$$\text{Trafik\_Heter} = \left[\frac{\mu_{Jumlah}}{(\frac{J_{LAN}}{v}) + (\frac{\mu_{Jumlah}}{C_{LAN}}(n+1))}\right] + \left[\frac{\mu_{Jumlah}}{(\frac{J_{WAN}}{v}) + (\frac{\mu_{Jumlah}}{C_{WAN}}(n+1))}\right] \quad \text{----} \ (7)$$

Figure 4.3 shows how the model has been formulated from real network environment to simulation model. The main valuable aspects of the simulation study is to explain and understand real world phenomena that are costly to perform in the laboratory or difficult to collect in field experiments. A successful simulation model that is able to provide a sufficiently credible solution that can be used for prediction. Since it is not feasible to construct a simulation model that represents all the details and behaviors of the real network, some assumptions must be made about the real network to construct a simulation model. Therefore, a simulation model is an abstract representation of real network environment.

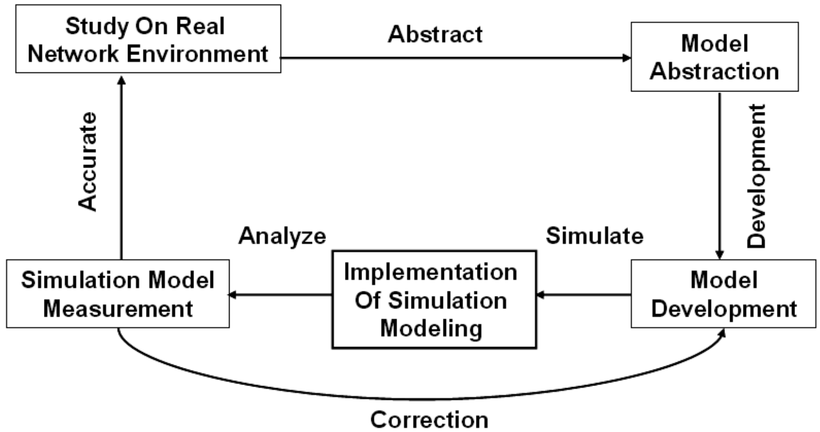

Figure 4.3: Model and Simulation Development Phases

5.0 Verification and Validation of Simulation Model with Wide Area Network (Real Network) Experimental

In this section, we verify the little law and queuing theories for heterogeneous simulation model environment between two networks through experiments. Lab experiment is based on ideal network in which there is no packet losses, no jitter in delays and network bandwidth is sufficient for all requirements. While, real experiment is based on real network and need to consider as follows: i) network bandwidth is limited and is not enough for all application and users at the same time; ii) delay due to the network overloads; and iii) packet losses.

5.1 Real Network (WAN) Setup

We used a network management application to capture traffic between two networks link in real network environment. Figure 5.1 shows the experimental setup of real network used in our tests. The real network used switch with Gigabit Ethernet interface, Router interface and Ping Plotter application can be configured to insert size of packet services to generate traffic into the network interface (see Figure 5.2). By using varying number of clients and size of packet services, we are able to simulate network for remote data transfers. Ping Plotter application is based on round trip time (RTT) measurement.

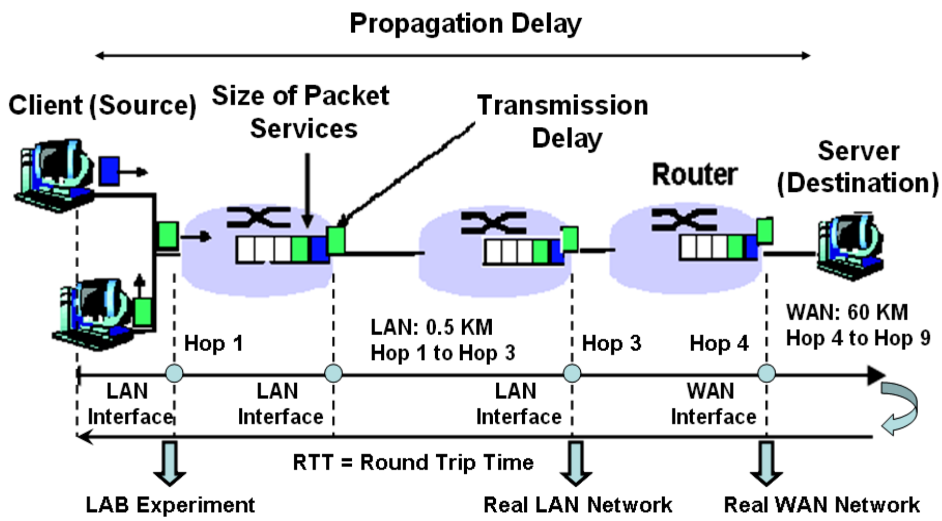

Figure 5.1: Real Network Environment (WAN) Setup

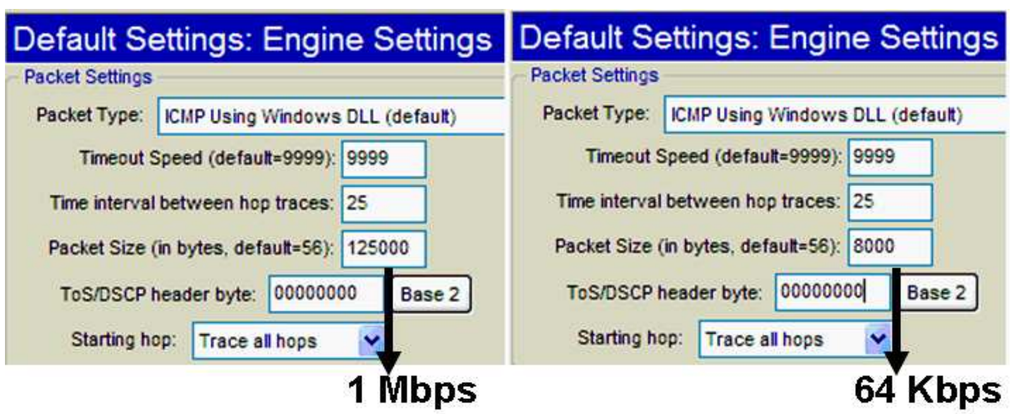

Figure 5.2: Ping Plotter Engine Setting for Size of Packet Services

5.2 Wide Area Network (Real Network) Experiment

We have setup a Wide Area Network, WAN (real network) environment of data transfer flow measurement that generates measurement data to analyze network performance at the main campus. Low bandwidth link affects the size of packet services and number of clients access to the network server. The data transfers from source (client: 10.5.1.252) to destination (router interface: 56.26.25.1) is based on Wide Area Network (WAN) with traffic congestion from operational network (see Figure 5.3). Number of hops occurs between source and destination in real network is four hops (see Figure 5.1). Therefore, we run network management application to measure delay (propagation and transmission time) performance (see Figure 5.3).

Target Name: N/A
IP: 219.94.43.77
10 Samples Timed: 9/11/2007 9:50:07 AM - 9/11/2007 9:50:24 AM

125000 Bytes

Hop	Err	PL%	IP	DNSName	Avg	Min	Max
1			10.6.3.252	--------------	2	2	3
2			10.51.1.254	--------------	8	7	11
3	2	50	58.26.25.1	--------------	726	109	1344
4			219.94.15.185	--------------	544	544	544
5	1	25	210.187.133.1	--------------	883	288	1799
6			210.187.135.2	brf-odsy02-srp1-0.tm.net.my	887	265	1988
7	1	25	210.187.143.3	--------------	1310	718	2205
8			210.187.15.254	--------------	1265	459	2453
9			202.188.126.146	--------------	1455	680	2618
10	1	25	219.93.216.10	--------------	1780	879	2850
11				Destination Address Unreachable			

Target Name: N/A
IP: 219.94.43.77
10 Samples Timed: 9/10/2007 9:24:26 AM - 9/10/2007 9:24:49 AM

8000 Bytes

Hop	Err	PL%	IP	DNSName	Avg	Min	Max
1			10.5.1.252	--------------	1	1	2
2	2	29	10.51.1.254	--------------	1	1	1
3	5	83	58.26.25.1	--------------	9	9	9
4	4	67	219.94.15.185	--------------	38	38	38
5	4	67	210.187.133.1	--------------	16	14	18
6	5	83	210.187.135.2	brf-odsy02-srp1-0.tm.net.my	18	18	18
7	4	67	210.187.142.3	--------------	21	20	23
8	5	83	210.187.15.254	--------------	24	24	24
9	4	67	202.188.126.146	--------------	30	19	42
10	5	83	219.93.216.10	--------------	35	35	35
11				Destination Address Unreachable			

Target Name: N/A
IP: 219.94.43.77
5 Samples Timed: 9/10/2007 9:27:43 AM - 9/10/2007 9:27:53 AM

4000 Bytes

Hop	Err	PL%	IP	DNSName	Avg	Min	Max
1			10.5.1.252	--------------	20	1	89
2			10.51.1.254	--------------	1	1	1
3			58.26.25.1	--------------	2	2	3
4	1	25	219.94.15.185	--------------	19	19	19
5			210.187.133.1	--------------	22	13	32
6	2	40	210.187.135.2	brf-odsy02-srp1-0.tm.net.my	29	17	38
7			210.187.142.3	--------------	29	13	57
8	1	20	210.187.15.254	--------------	32	14	58
9			202.188.126.146	--------------	32	15	69
10			219.93.216.10	--------------	42	18	77
11	1	25	219.94.43.77	--------------	190	153	222
				Round Trip:	**190**	**153**	**222**

Target Name: N/A
IP: 219.94.43.77
1 Samples Timed: 9/11/2007 9:41:28 AM

1000 Bytes

Hop	Err	PL%	IP	DNSName	Avg	Min	Max
1			10.6.3.252	--------------	1	1	1
2			10.51.1.254	--------------	1	1	1
3			58.26.25.1	--------------	1	1	1
4			219.94.15.185	--------------	6	6	6
5			210.187.133.1	--------------	10	10	10
6			210.187.135.2	brf-odsy02-srp1-0.tm.net.my	10	10	10
7							
8			210.187.15.254	--------------	26	26	26
9			202.188.126.146	--------------	12	12	12
10			219.93.216.10	--------------	34	34	34
11			219.94.43.77	--------------	59	59	59
				Round Trip:	**59**	**59**	**59**

Figure 5.3: WAN Experiment (Real Network) Using Network Management Application

Four sets of experiments were conducted with different scenarios (see Table 5.1). We used the same input variables that have been used in simulation model (see Figure 5.4, Table 5.1) to estimate our data that must be closely resemble to real network environment (see Table 5.2). We used several variables such as 1 Gbps and 100 Mbps to estimate our data that must be closely resemble to LAN and WAN (real network) environment. We conclude that base on our findings, the simulation model is able to predict and estimate data transfers for LAN and WAN (real network) environment (Table 5.2).

Table 5.1: Type and Size of Services Using in Simulation Model

Data Transfer Flow From Source to Destination Over Network Testbed	
Type of Services	Size of Services
Video	1 Mbps (125000 Bytes)
Audio	64 Kbps (8000 Bytes)
Voice	32 Kbps (4000 Bytes)
Message	8 Kbps (1000 Bytes)

Again, we predict and estimate our data using simulation model to define size of bandwidth and distance between two networks. We used two scenarios to measure and estimate our data as follows: i) data transfer over WAN using LAN bandwidth 100 Mbps; and ii) data transfer over WAN using LAN bandwidth 1 Gbps. Figure 5.4 shows an example of variables have used in simulation model to compare with real network environment. The simulation results must closely accurate with real WAN network interface port. We conclude all our findings in Table 5.2 and it shows all our testing in simulation model compare with real network.

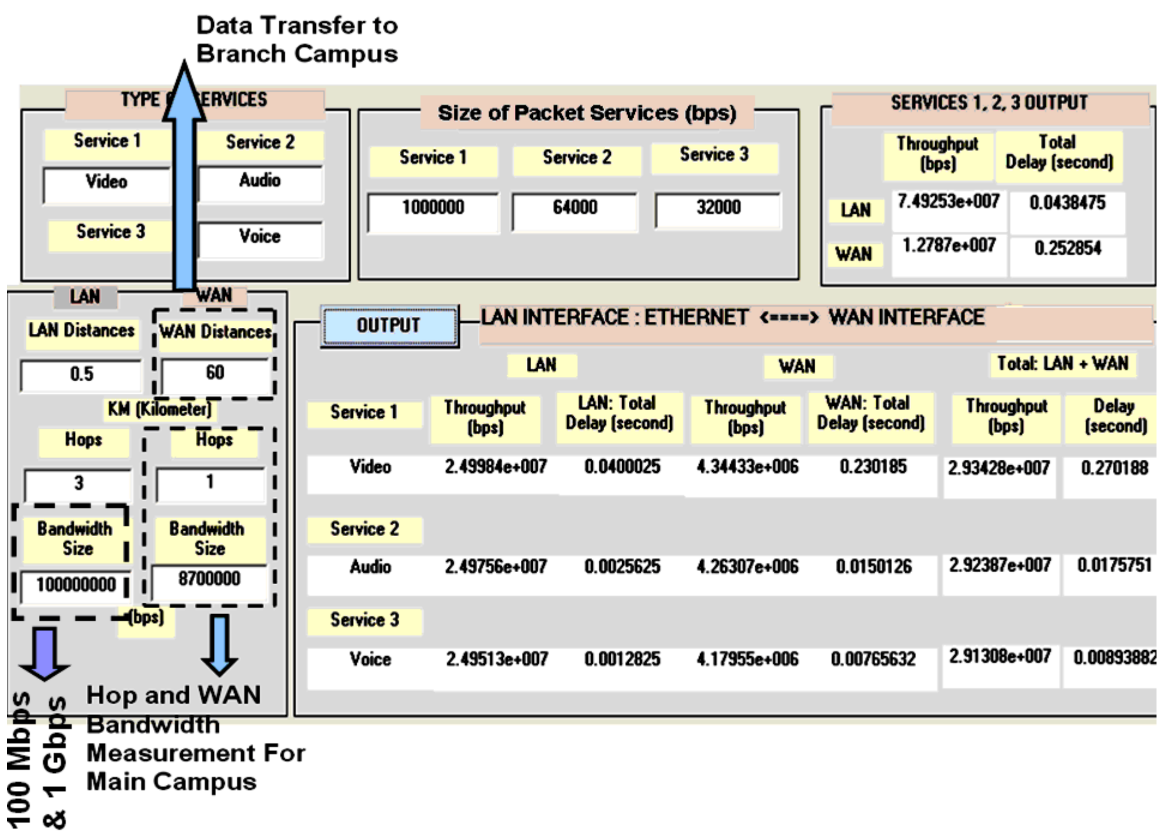

Figure 5.4: Prediction and Estimation of 100 Mbps and 1 Gbps Variables for Remote Data Transfer Using Simulation Model

Table 5.2: Comparison of Remote Data Transfer between Simulation Model and WAN (Real Network)

Number of Hops to Wan Interface = 4; Size of Bandwidth = 100 Mbps and 1 Gbps over LAN; WAN: 8.7 Mbps (Simulation Model)			
Data Transfer Over WAN	Simulation Over LAN 100 Mbps Simulation WAN Interface: 8.7 Mbps (ideal network)	Simulation Over LAN 1 Gbps	Real LAN Bandwidth: 1 Gbps Real WAN Interface: 8 Mbps (must consider network traffic)
Video	540.38 ms	468.376 ms	544 ms
Audio	35.15 ms	30.5422 ms	38 ms
Voice	17.87 ms	15.573 ms	19 ms
Message	4.922 ms	4.347 ms	6 ms

In real situation our server at main campus is connected with 1 Gbps (LAN) and 8 Mbps (WAN) link to Internet. The result from our simulation model using 1 Gbps is lowest than real network compared to 100 Mbps variable (see Figure 5.5). The reason is simulation model will capture data based on ideal network (no traffic congestion); however in real network environment the data may affect output result caused by traffic congestion from operational network. Simulation model with variable 1 Gbps (LAN) and 8.7 Mbps (WAN) have shown the result more closely resemble to WAN (real network) for all services (video, audio, voice and message) during data transfer (Table 5.2 and Figure 5.5). As a result, it confirms that our simulation model using 1 Gbps (LAN) and 8.7 Mbps (WAN) variables are closely resemble with real network environment for video, voice, audio and message (see Figure 5.5). Therefore, we will reject 100 Mbps experiment variable and accept 1 Gbps experiment variable in our simulation model. We can conclude and predict that the average of data transfers from source to destination in real network is using 1 Gbps (LAN) and 8.7 Mbps (WAN) bandwidth link.

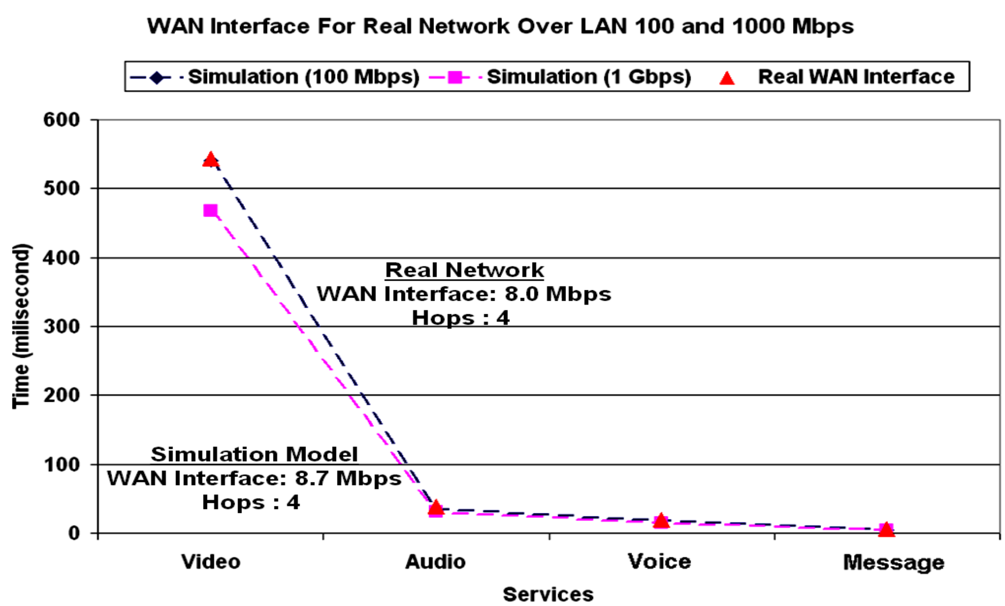

Figure 5.5: Comparison of Simulation Model Using 100 Mbps and 1 Gbps Variables with Real Network Environment

6.0 Conclusion and Future Work

In this article, we have shown how an analytical queuing network model can be used to understand the behaviors of heterogeneous environment over Wide Area Network, WAN (real network). The most apparent aspect is the delay due to the propagation and transmission time. Our simulation model, has demonstrated that it can measure accurately the performance of heterogeneous services and technologies to transfers data between two networks. Through WAN (real network) experiments, the simulation model is verified and validated for providing accurate performance information for various services. We believe the simulation modeling framework described in this study can be used to study other variations, tunings, and similar new ideas for various services and technologies. In network management, by monitoring and analyzing network delay we can monitor the performance of the network, thus to study whether network is normal, optimal or overloaded. Future work is to develop a simulation model to analyze bandwidth capacity requirement for various services and technologies in heterogeneous environment.

References

[1] J.kontio & R.Conradi, "Evaluating the Performance of a Web Site via Queuing Theory" Software Quality - ECSQ 2002: 7th International Conference, Helsinki, Finland, June 9-13, 2002, pp. 63-72. Springer-Verlag Berlin Heideberg.

[2]. John Heidemann, Kevin Mills, Sri Kumar. 2001."Expanding Confidence in Network Simulation", IEEE computer, Vol. 15 (5), p.p 58-63.

[3] Ramon Puigjaner ,"Performance Modelling of Computer Networks", IFIP/ACM Latin America Networking Conference 2003, October 3 - 5, 2003, La Paz, Bolivia. ACM 2003.

[4] Performance analysis of distributed information retrieval architectures using an improved network simulation model". Information Processing and Management 43 (2007) 204-224, Science Direct, 2006.

[5] Georges Nogueira. 'Measurement based validation of GPRS/EDGE Analytical Models'

[6] Chadi Barakat, Patrick Thiran, Gianluca Iannaccone, Christophe Diot, Philippe Owezarski "A flow-based model for Internet backbone traffic**".** Proceedings of the 2nd ACM SIGCOMM Workshop on Internet measurment **,** p.p: 35 – 47,2002, Marseille, France.

[7] S. Ben Fredj, T. Bonald, A. Proutiere, G. Regnie and J. Roberts, "Statistical Bandwidth Sharing: A Study of Congestion at Flow Level", *ACM SIGCOMM*, August 2001.

[8] T. Bu and D. Towsley, "Fixed Point Approximation for TCP behavior in an AQM Network", *ACM SIGMETRICS*, Jun. 2001.

[9] A.A. Kherani and A. Kumar, "Performance Analysis of TCP with Nonpersistent Sessions", *Workshop on Modeling of Flow and Congestion Control*, INRIA, Ecole Normale Superieure, Paris, September 4-6, 2000.

[10] Osman Balci. 'Quality Assessment, Verification and Validation of Modeling and Simulation Applications'. Proceeding of the 2004 Winter Simulation Conference. Simulation Conference, 2004. Proceedings of the 2004 Winter Vol. 1, Issue , 5-8 Dec. 2004 Page(s): - 129

[11] Qigang Zhao; Xuming Fang; Qunzhan Li; Zhengyou He. 2005. "WNN-based NGN traffic Prediction". *ISADS 2005. Proceedings Autonomous Decentralized Systems*: 230-234.

[12] Kyung-Hyu .L; Kyu-Ok .L; Kwon-Chul .P; Jong-Ok .L & Yoon-Hak .B.2003. "Architecture to be deployed on strategies of next-generation networks". *Communications ICC '03. The IEEE,Vol. 2*, ms:819 – 822.

[13] Xianxin Jiang; Fangchun Yang; Hua Zou. 2003. "A novel architecture to customer service management for the NGN". *ICCT 2003. International Conference*, 1: 123-126.

[14] David R.Gerhan & Stephen M. Mutula. 2005. "Bandwidth bottlenecks at the University of Botswana", Published by Emerald Group, Vol. 23 (1), p.g 102-117.

[15] Jianqiang Li; Zhaohao Sun. 2004. "Internet/Web technology in higher education in China". Advanced Learning Technologies, 2004. *Proceedings. IEEE International Conference*,:993 – 997.

[16] Binh Thai, Rachel Wan, Aruna Seneviratne, Thierry Rakotoarivelo.2003. "Integrated Personal Mobility Architecture: A Complete Personal Mobility Solution".*Kluwer Academic Publishers*.

[17] Podhradsky, P. 2004." Migration scenarios and convergence processes towards NGN (present state and future trends)". *Electronics in Marine Proceedings Elmar. 46th International Symposium*, :39-46.

[18] J. Curtis and T. McGregor, "*Review of bandwidth estimation techniques*, " in Proc. New Zealand Computer Science Research Students' Conf., vol. 8, New Zealand, Apr. 2001.

[19] C. Barakat, P. Thiran, G. Iannaccone, C. Diot, and P. Owezarski. "Modeling Internet backbone traffic at the flow Level". IEEE Transactions on Signal Processing (Special Issue on Networking), August 2003.

[20] T. Bu and D. Towsley. "Fixed point approximation for TCP behavior in an AQM network". In Proceedings of ACM SIGMETRICS '01, San Diego, CA, June 2001.

[21] S. Fredj, T. Bonald, A. Proutiere, G. Regnie, and J. Roberts. "Statistical bandwidth sharing: A study of congestion at flow level". In Proceedings of ACM SIGCOMM '01, San Diego, CA, August 2001.

[22] Sommers, Joel; Barford, Paul. *Self-Configuring Network Traffic Generation*, In Proceedings of ACM Internet Measurement Conference, October, 2004.

[23] Guojun Jin & Brian L. Tierney. 2003. 'System capability effects on algorithms for network bandwidth measurement'. Proceedings of the 3rd ACM SIGCOMM conference on Internet measurement, p.g 27-38.

[24] Jing Cong & Bernd E. Wolfinger. 2006. "*A unified load generator based on formal load specification and load transformation*", Proceedings of the 1st international conference on Performance evaluation methodolgies and tools, ACM International Conference Proceeding Series, Pisa, Italy,Vol. 180 (53).

[25] Kawasaki, S., Niwa, et. al. 2006. *"A Study on Formulation of the Ubiquitous Cloud Model"*, Mobile Data Management, 2006. MDM 2006. 7th International Conference, pg:148 – 148.

[26] A. Tsalgatidou, G. Athanasopoulos & et. al. 2006. Developing scientific workflows from heterogeneous services, ACM SIGMOD, Vol. 35 (2), pg: 22 - 28

[27] Qingwen Liu, Shengli Zhou, et. al,. 2006. "Cross-layer modeling of adaptive wireless links for QoS support in heterogeneous wired-wireless networks", Wireless Networks, Vol. 12 (4), Kluwer Academic Publishers.

[28] William Stallings. 2000."Data & Computer Communications", 6th Edition, pg 262- 516, Prentice-Hall, New Jersey.

[29] Darren L. Spohn. 1997."Data Network Design", 2 second edition, pg 694, McGraw-Hill, New York.

[30] Huseyin Simitci."An Analytical Throughput Model for Bulk Data Transfers over Wide Area Networks". IEEE International Symposium on Cluster Computing and the Grid, p.p 602-609, 2004.