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

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Abstract: This study presents a novel approach for the measurement of one-way delays and throughput between network nodes in heterogeneous environment over Wide Area Network (WAN). This study investigates performance evaluation of remote data transfers on heterogeneous services and technologies environment. This study proposes 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, it measures (verify and validate) data from real experiment. This project uses 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 (WAN).

Key words: Simulation, queuing theory, heterogeneous services, delay, WAN

INTRODUCTION

Considerable research has been conducted to model and quantify the performance of heterogeneous services and technologies (e.g (Kawasaki *et al*., 2006; Tsalgatidou *et al*., 2006; Liu *et al*., 2006). Accurate measurements and analyses of network characteristics (remote data transfers) are essential for robust network performance and management. Evaluating the performance of a computer networking usually involves constructing an appropriate model to predict the heterogeneous environment behaviour via simulation model. For example, several flow-level network traffic models have been proposed to describe/stimulate (Fred *et al*., 2001; Cong and Wolfinger, 2006). 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 (Puigjaner, 2003) in contrast to other studies in the literature (Barakat *et al*., 2002; Bu and Towsley, 2001; Kherani and Kumar, 2000). This simulation 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. The beneficial and contribution of this model could assist network administrators to design and manage heterogeneous network systems. Therefore, this simulation model is designed to: i) predict the performance of various services 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 (Zhao *et al*., 2005). With the availability of this infrastructure, users are now demanding and expecting more services (Barakat *et al*., 2003; Bu and Towsley, 2001). 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 (Podhradsky, 2004; Nogueira, 2006). 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 (Heidemann *et al*., 2001). The successful evolution of the Internet is tightly coupled to the ability to design simple and accurate models (Barakat *et al*.,

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2002). Many factors may contribute to the congestion of network interface, such as a heavy load in the network that usually generates higher traffic (Chang and Hon, 2002). Thus, this research is critical to be conducted in order to predict and measure of remote data transfers in heterogeneous environment.

RELATED WORKS

In the 21 century, a network infrastructure is based on multi-service implementation over convergence of network medium such as ISP, PSTN and GSM (Lee *et al*., 2003; Li and Sun, 2004). Therefore, multi-traffic in the network infrastructure has become more complex to observe and analyze (Lee *et al*., 2003; Thai *et al*., 2003). 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. The main factors of network congestion are related to network design and bandwidth capacity (Curtis and McGregor, 2001).

Many tools have been developed and only a few tools have successfully achieved a close estimation of network bandwidths (Liu *et al*., 2006). According to Simitci (2004), 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 (Simitci, 2004). This study has setup a 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?

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 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) model verification and ii) model validation. Comparison with a real network is the most reliable and preferred method to validate a simulation model (Fig. 2).

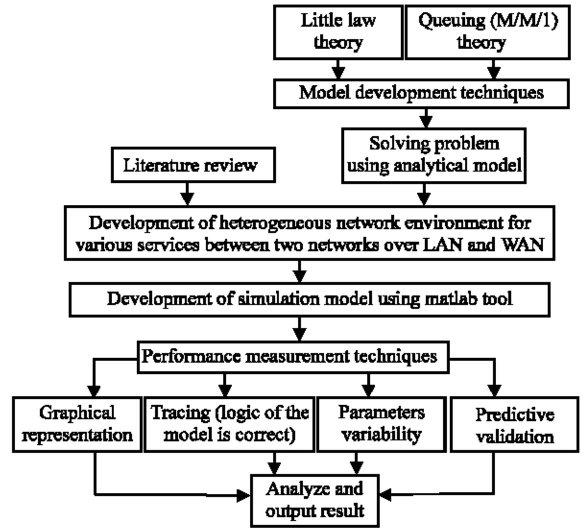


Fig. 1: Simulation model development methodology

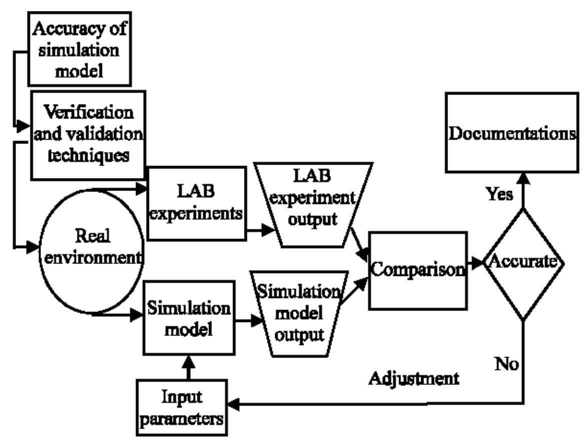


Fig. 2: Simulation model verification and validation methodology

PROPOSED 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 (Gerhan and Mutula, 2005). In the Fig. 4, theoretical model is based on a random distribution of

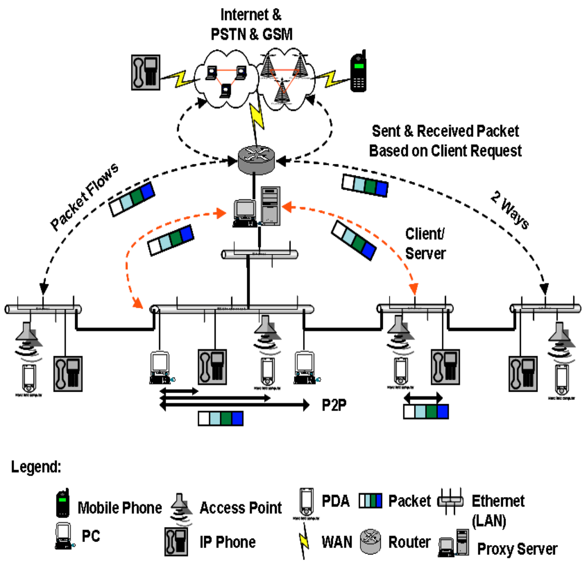


Fig. 3: Real heterogeneous network environment at main and branch campus

service duration. 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.

Physical model of real heterogeneous network environment: Before conduct and start to develop simulation model of heterogeneous network environment, it needs to define the situation of heterogeneous environment in real world. Figure 3 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.

Logical model of heterogeneous network environment: Figure 4 shows 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. The logical model is the important area need to define which mathematical techniques should be used in development of heterogeneous environment.

Development of heterogeneous network environment model: This study describes a simple analytical queuing and little law theories that capture the performance

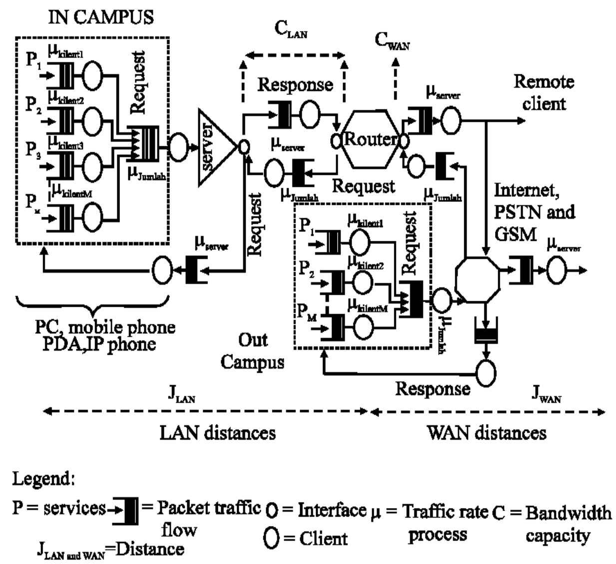


Fig. 4: Logical model of heterogeneous network environment at main and branch campus

Table 1: Notations for model development

Model parameters	Meaning
L	Size of packet services
R	Bandwidth capacity
v	Speed of Light is 3×108
n	Total of nodes connected between two networks
d	Distances between two networks
C_{LAN} dan C_{WAN}	Bandwidth of LAN and WAN interface ports
P (P_1,P_2,P_3,...P_m)	Various services
P_1	Client uses single service
J_{LAN} dan J_{WAN}	LAN and WAN distances
μ_{Total}	Total size of packet services request by clients (traffic) Size of packet service request by client (traffic)
Trafik_P_1	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)

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 (Sommers and Barford, 2004). At this stage, it assumes the data are transported between the two network sites (source and destination) as previously shown in Fig. 3. Table 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.

The original theory (Stallings, 2000) is defined as a throughput (variable name is Throughput) in Eq. 1. While (Spohn, 1997), Eq. 2 is defined as a delay, time taken for packet transmission depends on size of packets and hop (variable name is Time). Equations 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 Eq. 3-5. Then, the logical model is derived to the heterogeneous network environment in Eq. 6 and 7.

(Stallings, 2000):

$$\text{Throughput} = \frac{L}{\frac{d}{v} + \frac{L}{R}} \tag{1}$$

(Spohn, 1997):

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

where, L, d, v and R>0

Equation 1 and 2 are derived:

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

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

$$\text{Trafik\_P1} = \left[\frac{P_1}{(\frac{J_{LAN}}{v}) + (\frac{P_1}{C_{LAN}}(n+1))}\right] + \left[\frac{P_1}{(\frac{J_{WAN}}{v}) + (\frac{P_1}{C_{WAN}}(n+1))}\right] \tag{4}$$

$$\text{Trafik\_P1} = \left[\frac{\mu_{klient1}}{(\frac{J_{LAN}}{v}) + (\frac{\mu_{klient1}}{C_{LAN}}(n+1))}\right] + \left[\frac{\mu_{klient1}}{(\frac{J_{WAN}}{v}) + (\frac{\mu_{klient1}}{C_{WAN}}(n+1))}\right] \tag{5}$$

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

$$\text{Trafik\_Hetere} = \left[\frac{P_1 + P_2 + P_3 ... + P_m}{(\frac{J_{LAN}}{v}) + (\frac{P_1 + P_2 + P_3 ... + P_m}{C_{LAN}}(n+1))}\right] + \left[\frac{P_1 + P_2 + P_3 ... + P_m}{(\frac{J_{WAN}}{v}) + (\frac{P_1 + P_2 + P_3 ... + P_m}{C_{WAN}}(n+1))}\right] \tag{6}$$

Where $P_1+P_2+P_3+\ldots+P_m = U_{klient1}+U_{klient2}+U_{klient3}+\ldots+U_{klientm} = \mu_{jumlah}$

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

VERIFICATION AND VALIDATION OF SIMULATION MODEL WITH WIDE AREA NETWORK (REAL NETWORK) EXPERIMENTAL

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.

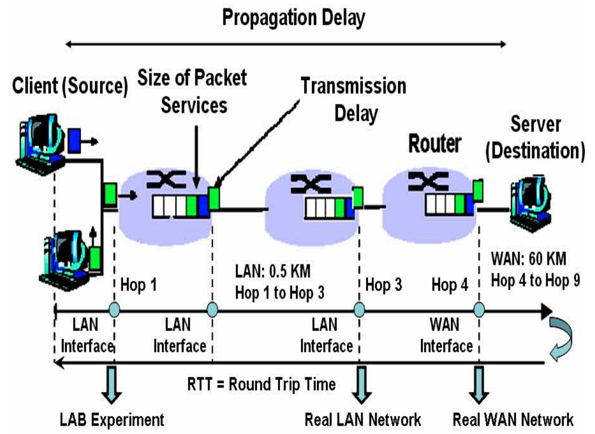


Fig. 5: Experimental laboratory for lab environment setup

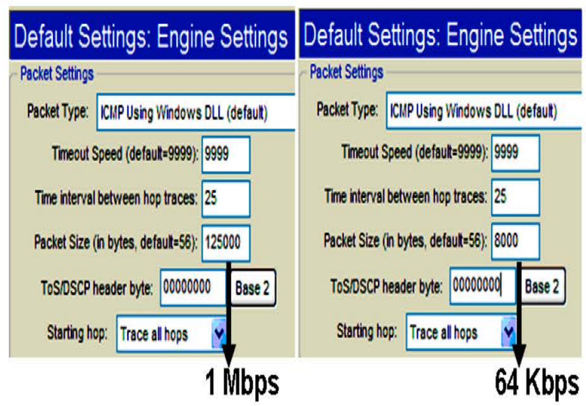
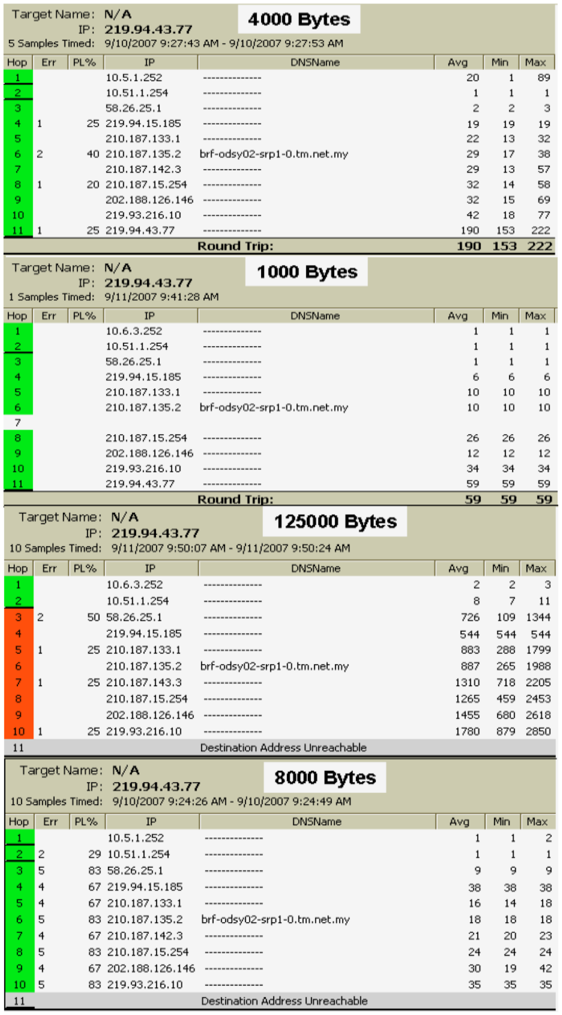


Fig. 6: Ping plotter engine setting for size of packet services

Real network (WAN) setup: This research used a network management application to capture traffic between two networks link in real network environment. Figure 5 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 (Fig. 6). By using varying number of clients and size of packet services, this simulation model is able to simulate network for remote data transfers. Ping Plotter application is based on Round Trip Time (RTT) measurement.

Wide area network (real network) experiment: This experiment has 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. The data transfers from source (client: 10.5.1.252) to destination (router interface:



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

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			

Fig. 7: WAN experiment (real network) using network management application

56.26.25.1) is based on Wide Area Network (WAN) with traffic congestion from operational network (Fig. 7). Number of hops occurs between source and destination in real network is four hops (Fig. 5). Therefore, this experiment has run network management application to measure delay (propagation and transmission time) performance (Fig. 7).

Four sets of experiments were conducted with different scenarios (Table 2). The real environment used the same input variables that have been used in simulation model (Fig. 8, Table 2) to estimate our data that must be closely resemble to real network environment (Table 3). 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.

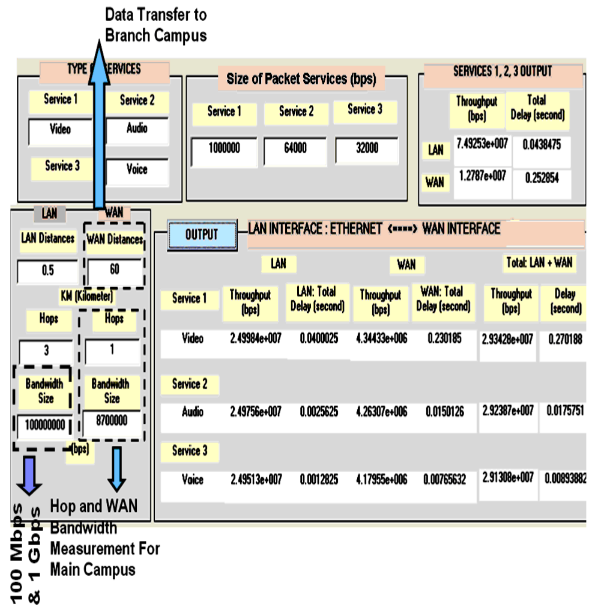


Fig. 8: Prediction and estimation of 100 Mbps and 1 Gbps variables for remote data transfer using simulation model

Table 2: 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)

Table 3: Comparison of remote data transfer between simulation model and WAN (Real Network)

No. of hops to Wan Interface = 4; LAN bandwidth = 100 Mbps and 1 Gbps; WAN: 8.7 Mbps (Simulation Model)

			Real ethernet: 1 Gbps Real WAN interface: 8 Mbps
Data transfer over wan	Simulation over lan 100 Mbps	Simulation over lan 1 Gbps	(consider network traffic)
Simulation WAN interface: 8.7 Mbps (ideal network)			
Video	540.38 ms	468.37 ms	544 ms
Audio	35.15 ms	30.542 ms	38 ms
Voice	17.87 ms	15.573 ms	19 ms
Message	4.922 ms	4.347 ms	6 ms

It is conclude that base on our findings, the simulation model is able to predict and estimate data transfers for WAN (real network) environment (Table 3).

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 100 Mbps and (ii) data transfer

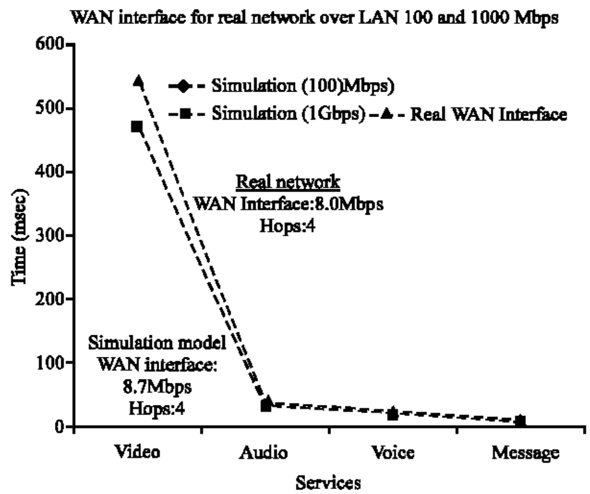


Fig. 9: Comparison of simulation model using 100 Mbps and 1 Gbps variables Over WAN (real network)

over WAN using LAN 1 Gbps. Figure 5 shows an example of variables have used in simulation model to compare with WAN environment. The simulation results must closely accurate with real WAN network interface. It is conclude all our findings in Table 3 and it shows all our testing in simulation model compare with real network.

In real situation the server at main campus is connected with 1 Gbps (LAN) and 8 Mbps (WAN) link to Internet. The result from study simulation model using 1 Gbps is lowest than real network compared to 100 Mbps variable (Fig. 9). 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 3, Fig. 9). As a result, it confirms that our simulation model using 1 Gbps (LAN) and 8.7 Mbps (WAN) variables are closely resemble with WAN environment for video, voice, audio and message (Fig . 9). Therefore, we will reject Ethernet 100 Mbps and WAN 8.7 Mbps experiment variable. We can conclude and predict that the average of data transfers from source to destination in real network is using Ethernet 1 Gbps and 8.7 Mbps (WAN) bandwidth link.

CONCLUSION

In this article, we have shown how an analytical queuing network model can be used to understand the behaviors of heterogeneous environment over 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. 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. Network delay rate will directly affect the network performance. 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. Network delay rate also plays an important role in benchmark setting and network troubleshooting. Future work is to develop a simulation model to analyze bandwidth capacity requirement for various services and technologies in heterogeneous environment.

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