

**Performance Modelling of UUM Local Area Network  
(wired)**

**TAIWO, Ayankunle Adegbite**

**University of Utara Malaysia**

**2009**

**Performance Modelling of UUM Local Area Network  
(wired)**

**A thesis submitted to college Arts & Sciences  
in partial fulfillment of the requirement for the degree  
Master of Science (Information Technology)  
University of Utara Malaysia**

**By**

**TAIWO, Ayankunle Adegbite**

**© TAIWO, Ayankunle Adegbite, May 2009. All rights reserved**

## **PERMISSION TO USE**

In presenting this thesis in partial fulfilment of the requirements for a Master of Science in IT degree from University Utara Malaysia, I agree that the University Library may make it freely available for inspection. I further agree that permission for copying of this thesis in any manner, in whole or in part, for scholarly purpose may be granted by my supervisor or, in their absence by the Academic Dean College of Arts and Sciences. It is understood that any copying or publication or use of this thesis or parts thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to University Utara Malaysia for any scholarly use which may be made of any material from my thesis.

Requests for permission to copy or to make other use of materials in this thesis, in whole or in part, should be addressed to

**Dean (Academic) College of Art and Sciences  
University Utara Malaysia  
06010 UUM Sintok  
Kedah Darul Aman.**

## **ABSTRACT**

Slow network connection in accessing resources is a common complaint on a computer network that has switches as dominant network equipment, when certain nodes are heavily loaded with clients more than their capacity. In this study a simulation model was developed and validated for the University of Utara Malaysia wired Local Area Network. The effect of network parameters such as the processing time and the packet arrival rate on the performance metrics such as throughput, end to end delay and utilization of the servers and switches on the network was investigated. The analysis of the results from the simulations carried out can assist the management of computer centre that manages the network in identifying the bottleneck node on the network and for future network capacity building.

## **ACKNOWLEDGEMENTS**

I would like to express my sincere appreciation to the Almighty God, the giver of life, wisdom, knowledge and understanding. Without His grace and mercy this work would not have come to fruition.

My profound gratitude goes to my supervisor Prof. Dr. Ku Ruhana Ku-Mahamud for her constructive advice, scientific proven prowess, motherly encouragement and motivation during the course of this study. My second supervisor, Mr Mohd Samsu Sajat for his advice on networking. Also Mr. Amran bin Ahmad, who taught me Omnet++. Mr Amran and Mr Adli for their assistance on data collection at the computer centre. I am indeed very grateful.

This acknowledgement will not be complete without my mum, for her love and prayers, my brother, Tayo Taiwo and my sister, Rounke Kehinde for their financial support. Gbemisola, your love and prayer is appreciated. My late father, the training you gave with love has always kept me going. I would like to conclude by appreciating all academic scholars that taught me while at UUM, other UUM staff, friends and students that made my studies easier. A big thank you to you all.

Taiwo, Ayankunle Adegbite  
May 19, 2009

# TABLE OF CONTENT

<i>PERMISSION TO USE</i> .....	<i>I</i>
<i>ABSTRACT</i> .....	<i>II</i>
<i>ACKNOWLEDGEMENT</i> .....	<i>III</i>
<i>TABLE OF CONTENT</i> .....	<i>IV</i>
<i>LIST OF TABLES</i> .....	<i>VI</i>
<i>LIST OF FIGURES</i> .....	<i>VII</i>
<i>LIST OF ABBREVIATIONS FOR THE DISTRIBUTION SWITCHES</i> .....	<i>VII</i>
<b>CHAPTER ONE</b> .....	<b>1</b>
<i>INTRODUCTION</i> .....	<i>1</i>
<i>1.1 PROBLEM STATEMENT</i> .....	<i>2</i>
<i>1.2 OBJECTIVE</i> .....	<i>3</i>
<i>1.3 SCOPE OF STUDY</i> .....	<i>3</i>
<i>1.4 SIMULATION METHODOLOGY</i> .....	<i>3</i>
<i>1.5 SIGNIFICANCE OF STUDY</i> .....	<i>6</i>
<i>1.6 ORGANIZATION OF THE REPORT</i> .....	<i>6</i>
<b>CHAPTER TWO</b> .....	<b>8</b>
<i>LITERATURE REVIEW</i> .....	<i>8</i>
<i>2.1 INTRODUCTION</i> .....	<i>8</i>
<i>2.2 MODELLING TECHNIQUES OF COMPUTER NETWORK</i> .....	<i>8</i>
<i>2.2.1 ANALYTICAL MODELING</i> .....	<i>8</i>
<i>2.2.2 SIMULATION MODELLING</i> .....	<i>11</i>
<i>2.2.3 OPERATIONAL MODELING</i> .....	<i>13</i>
<i>2.3 LAN PERFORMANCE MODELING</i> .....	<i>16</i>
<i>2.4 SIMULATION TOOLS</i> .....	<i>19</i>
<i>2.5 SUMMARY</i> .....	<i>20</i>
<b>CHAPTER THREE</b> .....	<b>21</b>
<i>OMNET++, THE DISCRETE EVENT SIMULATION SYSTEM AND UUM LAN</i> .....	<i>21</i>
<i>3.1 INTRODUCTION</i> .....	<i>21</i>
<i>3.2 MODELLING IN OMNET++</i> .....	<i>21</i>
<i>3.2.1 OMNET MODULES CONNECTION</i> .....	<i>23</i>
<i>3.2.2 OMNET++ MODEL COMPONENTS</i> .....	<i>24</i>
<i>3.3 UUM LOCAL AREA NETWORK</i> .....	<i>24</i>
<i>3.3.1 THE LAN STRUCTURE</i> .....	<i>25</i>
<i>3.3.1.1 CORE SWITCHES</i> .....	<i>26</i>
<i>3.3.1.2 THE DISTRIBUTION SWITCHES</i> .....	<i>26</i>

3.3.1.3	EDGE SWITCHES.....	27
3.3.1.4	USERS NODE.....	27
3.3.1.5	CABLES.....	28
3.3.1.6	ROUTER.....	29
3.3.1.7	FIREWALL.....	29
3.3.1.8	SERVERS AT THE DATA CENTRE .....	29
3.3.2	OPERATION AND CONNECTIONS ON THE NETWORK.....	29
3.4	SUMMARY.....	30
<b>CHAPTER FOUR.....</b>		<b>31</b>
	MODEL DEVELOPMENT AND VALIDATION.....	31
4.1	INTRODUCTION.....	31
4.2	THE SIMULATION MODEL.....	31
4.3	MODEL VALIDATION.....	36
4.4	SUMMARY.....	37
<b>CHAPTER FIVE.....</b>		<b>38</b>
	SIMULATION RESULTS.....	38
5.1	INTRODUCTION.....	38
5.2	EXPERIMENTAL DESIGN.....	38
5.3	VARIATION IN THE PROCESS TIME.....	39
5.3.1	EFFECT ON THROUGHPUT.....	40
5.3.2	EFFECT ON THE END TO END DELAY.....	42
5.4	VARIATIONS IN PROCESS TIME USING HALF OF THE NUMBER OF USER NODE.....	43
5.4.1	EFFECT ON THE INTERNET AND SERVERS AT THE DATA CENTRE THROUGHPUT.....	44
5.4.2	EFFECT ON DISTRIBUTION SWITCHES THROUGHPUT.....	45
5.4.3	EFFECT ON THE END TO END DELAY.....	47
5.5	VARIATION IN PROCESSING TIME USING MAX USER NODES.....	48
5.5.1	EFFECT ON INTERNET AND THE SERVERS AT THE DATA CENTRE.....	48
5.5.2	EFFECT ON THE DISTRIBUTION SWITCHES.....	49
5.5.3	EFFECT ON END TO END DELAY.....	51
5.6	VARIATION IN THE ARRIVAL RATE USING HALF USER NODE.....	52
5.6.1	EFFECT ON THE INTERNET AND DATA CENTRE SERVERS.....	53
5.6.2	EFFECT OF ARRIVAL RATE ON THE DISTRIBUTION SWITCHES USING HALF NUMBER OF USER NODES.....	54
5.6.3	EFFECT ON THE END TO END DELAY.....	56
5.7	VARIATION IN THE ARRIVAL RATE USING MAXIMUM USER NODE ON THE NETWORK.....	57
5.7.1	EFFECT OF ARRIVAL RATE ON THE INTERNET AND SERVERS AT THE DATA CENTRE.....	57
5.7.2	EFFECT ON THE ARRIVAL RATE ON THE SWITCHES.....	59
5.7.3	EFFECT ON END TO END DELAY.....	61
5.8	UTILIZATION OF THE SWITCHES .....	62

5.9 SUMMARY.....	63
<b>CHAPTER SIX.....</b>	<b>65</b>
CONCLUSION.....	65
6.1 RESEARCH CONTRIBUTION.....	65
6.2 PROBLEMS AND LIMITATION.....	65
6.3 RECOMMENDATION AND FUTURE WORKS.....	66
<b>REFERENCES.....</b>	<b>68</b>
APPENDIX A: RESEARCH SCHEDULE (GANTT CHART).....	73
APPENDIX B: UUM LOCAL AREA NETWORK (WIRED) DIAGRAM.....	74
APPENDIX C: TOTAL NUMBER OF USER NODES ON THE NETWORK.....	75
APPENDIX D: ROUND TRIP TIME ON THE NETWORK.....	78
APPENDIX E: THE SWITCH PORT USAGE ON THE NETWORK.....	79
APPENDIX F: THE DISTRIBUTION SWITCH UTILIZATION(HALF USER NODES).....	80
APPENDIX G: THE DISTRIBUTION SWITCH UTILIZATION(MAX USER NODES).....	81
APPENDIX H: THE INTERNET AND SERVER AT THE DATA CENTRE UTILIZATION(MAX USER NODES).....	82



## LIST OF TABLES

Table 1: A comparison of Actual RTT and model Acknowledgement.....	37
Table 2: The initial parameters and symbols.....	39
Table 3: The process time against the internet, and server2 and server3 throughput .....	39
Table 4: The min end to end delay and process time on the Internet and the servers at the Data Centre.....	42
Table 5: The process time and the throughput on the internet and the servers.....	44
Table 6: The process time and the corresponding throughput on the switches.....	45
Table 7: The processing time and the minimum end to end delay on the network....	47
Table 8: The results of processing time on the internet and the Servers at the data centre. ....	48
Table 9: The processing time and throughput on the core switch and distribution switches. ....	49
Table 10: The processing time and end to end delay on the internet and the servers at the data centre. ....	51
Table 11: The arrival rate and the corresponding throughput on the Internet and Servers at the data centre.....	53
Table 12: The arrival rate and the corresponding end to end delay on the switches...54	
Table 13: The classification of low, medium and high throughput on the distribution switch .....	55
Table 14: The arrival rate and the corresponding end to end delay on the Internet and Servers at the data centre.....	56
Table 15: The results of arrival rate variation the internet and servers at the data centre.....	57
Table 16: The results of arrival rate variation on the distribution switches.....	59
Table 17: The classification of low, medium and high throughput on the distribution switch .....	61
Table 18: The results of arrival rate on min end to end delay.....	61
Table 19: The utilization of the Internet when using max user nodes.....	62
Table 20: The utilization of the distribution switches when using max user nodes....	63

# LIST OF FIGURES

Title	Pages
Figure 1: The Flow Diagram of the simulation methodology.....	4
Figure 2: Hierarchy of Modules in OMNeT++ .....	22
Figure 3: A snapshot the computer centre, Faculty of Economics, and the data centre on the Simulation Model.....	33
Figure 4: A snapshot of the data centre, gateway to the internet and FTM on the Simulation Model.....	34
Figure 5: A snapshot of convention centre, Kolej Eon, Palapes, PKP on the Simulation Model.....	34
Figure 6: A snapshot of Buka Kachi, FSK, FWB and FPK on the Simulation Model.....	35
Figure 7: A snapshot of 12 pc on a switch in the Simulation Model.....	35
Figure 8: A snapshot of 23 pc on a switch in the Simulation Model.....	36
Figure 9: The graph of the process time on against the internet, server2&3 throughputs.....	40
Figure 10. The graph of the process time on against the throughputs on the distribution switches.....	41
Figure 11: The graph of the process time on against the end to end delay on the network.....	43
Figure 12: The graph of the process time on against throughput on the internet and data centre servers.....	44
Figure 13: The graph of the process time on against the switches throughput on the network. ....	46
Figure 14: The graph of the processing time and end to end delay.....	47
Figure 15: The graph of the process time on against the throughput on the Internet, and the Servers at the data centre.....	49

Figure 16: The graph of the process time on against the throughput of the distribution switches.....	50
Figure 17: The process time and the end to end delay on internet and the servers at the data centre.....	52
Figure 18: The graph of the arrival rate and the throughput on the internet and the servers at the data centre.....	53
Figure19: The graph of arrival rate and throughput on the switches.....	55
Figure 20: The graph of arrival rate and the end to end delay.....	56
Figure 21: The graph of arrival rate on internet and the servers at the data centre..	58
Figure 22: The graph of arrival rate on the distribution switch.....	60
Figure 23: The graph of arrival rate on the end to end delay on the network.....	61

## LIST OF ABBREVIATIONS FOR THE DISTRIBUTION SWITCHES

Switch B1	COMPUTER CENTRE
Switch B2	FSKP/FKBM
Switch B3	FPP/FSK
Switch B4	RACK A PERPUSTAKAN
Switch B5	BENDAHARI
Switch B6	CONVENTION CENTRE
Switch B7	KOLEJ EON
Switch B8	PALAPES
Switch B9	BKP
Switch B10	FWB/FPAU
Switch B11	BUKIT KACHI
Switch B12	KOLEJ B.MUAMALAT
Switch B13	FTM
Switch B14	FACULTY OF ECONOMICS
Switch B15	PPK
Switch S	CORE SWITCH
Switch X	DATACENTER SWITCH 1
Switch Y	DATACENTRE SWITCH 2
Switch Z	SWITCH AT THE DMZ

# **CHAPTER ONE**

## **INTRODUCTION**

Computer networking enables people or devices to communicate with one another. The telephones are networked in the GSM and public telephone systems. Data networks connect several computers, making it possible for them to connect and exchange data. A data network can simply be created by connecting two computers together with a cable.

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. Local Area Network makes it possible for multiple users in a small geographic area to access shared resources, exchange files and messages on a data network. WANs interconnect the LAN to make it possible for geographically dispersed users to share information. It is slower in comparison to a LAN, and usually requires a connection request in order to send data. This is made possible by service providers with a monthly tariff paid (Teare, 2008).

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, so as to ensure that packet flows receive a specific share of the link's bandwidth and that the packets are not delayed in the switch for more than a certain length of time. When a network allows such packets flow to request the above treatment, it is said to

The contents of  
the thesis is for  
internal user  
only

## REFERENCES

- Alberti, A.M., Filho, S.R.A., & Garcia, A. S. (2006). Modelling, Simulation and Performance Evaluation for a CIOQ Switch Architecture. *Proceedings of the 39th Annual Simulation Symposium (ANSS'06)*.
- Avramidis, A. N. & L'Ecuyer, P. (2005). Modelling And Simulation Of Call Centers. *Proceedings Of The 2005 Winter Simulation Conference* .eds. M. E. Kuhl, N. M. Steiger, F. B. Armstrong, and J. A. Joines
- Barton, R.R. (2001). Designing Simulation Experiments. *Proceedings of the 2001 Winter simulation Conference*, editors, Peters, B.A., Smith, J.S., Menderros, D.J., Rhorer, M.W., 47-52. Pennsylvania State University, USA: Department of Industrial and Manufacturing Engineering.
- Batraneanu, S. M., Al-Shabibi, A., Ciobotaru, M. D., Ivanovici M., Leahu L., Martin, B., & Stancu, S. N. (2008). Operational Model of the ATLAS TDAQ Network. *Journal of IEEE Transactions On Nuclear Science*, Vol. 55, No. 2, April 2008 687.
- Burmeister, C., Killat, U., and Bachmann, J. (2006). TCP over Rate-Adaptive WLAN -An Analytical Model and its Simulative Verification. *Proceedings of the 2006 International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM'06)*.
- Chen, C.L. (2002). DiffServ Operational Model. *Proceedings of the 27th Annual IEEE Conference on Local Computer Networks (LCN.02)*
- Cho, Y-G, Chandrasekar, V., & Vivanco, D. A. (2002). Network Model for Clustered Radar Operating Application. *Proceedings of the 27th Annual IEEE Conference on Local Computer Networks (LCN.02)*

- Demiriz, A. (2006). A framework for balanced service and cross-selling by using queuing science. *In Proceedings of 5th International Symposium on Intelligent Manufacturing Systems*, May 29-31, 2006: 933-941. Sakarya University, Department of Industrial Engineering.
- Fitzgerald, L.M., & Harper, T.J. (2008) Application of simulation modelling for air force enterprise it transformation initiatives. *Proceedings of the 2008 Winter Simulation Conference*. eds. S. J. Mason, R. R. Hill, L. Mönch, O. Rose, T. Jefferson, J. W. Fowler
- Fang, Y. (2003). Movement-based location management and tradeoff analysis for wireless mobile networks, *IEEE Trans. Comput., Special Issue on Wireless Internet*, vol. 52, no. 6, pp. 791–803, Jun. 2003.
- Fang, Y. (2002). General modelling and performance analysis for location management in wireless mobile networks,” *IEEE Trans. Comput., Special Issue on Data Management Systems and Mobile Computing*, vol. 51, no. 10, pp. 1169–1181, Oct. 2002.)
- Fang, Y. (2005). A new analytical approach to modelling the performance of wireless mobile networks. *IEEE Trans. Computer, Special Issue on Data Management Systems and Mobile Computing*.
- Hahanov, V.1, Babich,A.V &Halil, Abu Zanuneh I. M. (2001). Designing Of LAN Models for Diagnostis Problem Solving. *Proceedings of the 6th international conference on the experience of designing and application of CAD system in Microelectronics*.
- Ji, J., & Gu, Q. (2006). An operational model of closed-loop logistics based on the end-customer's willingness. *Proceedings of IEEE International Conference on Service Operations and Logistics, and Informatics*, 2006. SOLI '06.



- Kher, V. H. (2000). Examination of workers and dispatching rules for managing vital customer priorities in dual resource constrained jobs shop environment. *Journal of Computer and Operation Research* 27, 525-537
- Kiran, Ali S., Cetinkaya T., Og S. (2000). Simulation modelling and analysis of a new international terminal .*Proceedings of the 2000 Winter Simulation Conference*. J. A. Joines. R. R. Barton, K. Kang, and P. A. Fishwick, eds
- Kogekar, A, & Gokhale, A, (2006). Performance evaluation of the reactor pattern using the OMNeT++ simulator. *Proceedings at ACM SE'06 March 1012, 2006, Melbourne, Florida, USA*
- Kristensen, L. M, Mitchell, B., Zhang, L., & Billington, J. (2002). Modelling and initial analysis of operational process using colored petri nets. *Proceedings at Workshop on Formal Methods Applied to Defence Systems*. Adelaide. June 2002.
- Law & McComas. (2001). How to build valid and credible simulation models. *Proceedings of the 2001 Winter simulation Conference*, editors, peter, B.A., Smith, J.S., Mendeiros, D.J., Rohere, M.W., 22-29
- Lee, B.C., Supinski, B.R., Singh, K., Brooks, D. M., Schulz, M., & McKee, S. A. (2007). Methods of inference and learning for performance modeling of parallel applications. *Proceeding at PPOPP'07 March 14–17, 2007, San Jose, California, USA* .
- Moradi, F., Nordvaller, P., & Ayani, R. (2006). Simulation model composition using BOMs. *Proceedings of the Tenth IEEE International Symposium on Distributed Simulation and Real-Time Applications (DS-RT'06)*

- Motoyama S., & Santos C.R. (2004). A QoS Provisioned CIOQ ATM Switch with m Internal Links. *In proceeding at 11th International Conference on Telecommunications – ICT 698 – 703.*
- Odom W., Healy R. and Mehta N. (2008). *CCIE Routing and Switching Exam Certification Guide*, 3rd Ed, Cisco Press. Indianapolis USA .Pg 436-465.
- Orfanus, D., Janacik, P., Lessmann, J., & Lachev, L. (2008). Performance of wireless network simulators. *Proceedings at PM2HW2N08*, October 31, 2008. Vancouver, BC, Canada.
- Park, S., Choi, K., Yoon, K., Bae, D. (2007). Deriving software process simulation model from SPEM-based Software Process Model. *Proceeding 14th Asia-Pacific Software Engineering Conference.*
- Puigjaner, R. (2003, October). Performance modelling of computer networks. *Proceedings at the IFIP/ACM Latin America Networking Conference, La Paz, Bolivia.*
- Rahman, A. Ab., & Ghazali, O. (2008) TCP-Friendliness of modified explicit rate adjustment. *In proceeding at International Conference on network applications, protocols and services (Netapps)* .University of Utara Malaysia.
- Riley, G, F. (2003). The georgia tech network simulator. *Proceedings at the ACM SIGCOMM 2003 Workshops.*
- Sadiki ,T and Paimblanc, P. (2009). Modelling New Indoor Propagation Models for WLAN Based on Empirical Results. *Proceedings of the 11th International Conference on Computer Modelling and Simulation.* uksim, pp.585-588, UKSim 2009
- Teare, D. (2008). *Designing for Cisco Internetwork Solutions (DESGN): Authorized Self-Study Guide.* (2nd ed), Indianapolis, IN: Cisco Press

- Theelen, B. D. (2004). *Performance Modelling For System-Level Design*. PHD Thesis  
.Technische Universiteit Eindhoven Netherlands
- Thakkar, D., Hassan A.E., Hamann, G., & Flora, P. (2008) A framework for measurement based performance modelling. Proceeding at WOSP'08, June 24–26, 2008, Princeton, New Jersey, USA.
- Vargas, A.(1999).Using the OMNeT++ discrete event simulation system in education. *IEEE Transactions on Education*, VOL. 42, NO. 4, NOVEMBER 1999
- Vargas, A. (2005). OMNeT++: *Discrete event simulation system*. Version 3.2 user manual.  
At [www.omnetpp.com](http://www.omnetpp.com)
- Virendra, M., Upadhyaya, S. and Wang X. (2004). GSWLAN: A New Architecture Model for a Generic and Secure Wireless LAN System. *Proceedings of the 2004 IEEE Workshop on Information Assurance United States Military Academy, West Point, NY*.
- Zaitsev, D. A. (2004). An evaluation of network response time using a coloured petri net model of switched LAN. Kurt Jensen (Ed.). *In Proceedings of the Fifth Workshop and Tutorial on Practical Use of Coloured Petri Nets and the CPN Tools*, Aarhus, Denmark, October 8-11, 2004, DAIMI PB - 570, pages 157-166. October 2004.