Performance Modeling of Ahmadu Bello University Data Network using a Storage Area Network (SAN) Design Concept

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ABSTRACT
In Ahmadu Bello University, students' portal are not stored in the University data Centre but is hosted by the company hosting the University, in this research, a core/edge SAN was modeled into the current data network, thus allowing the students' portal to be hosted directly on a dedicated secondary network in the University. This work was limited to just the storage of students' portal, but gives us a good initial understanding of the viability of this approach. The main components of the network were modeled modularly as Arena Submodels. It involves building a model of a switch and explicitly including this in a discrete event simulation of a SAN in evaluating how the SAN design will perform in its stochastic environment. For every host-device pair in the core/edge SAN two links was utilized for redundancy. The Performance of the proposed core-edge SAN Design model was tested under two component failure scenarios, the failure of an edge link and a core switch. Effective measurement of storage system activity, such as throughput $(T_s)$was checked. The results from the simulation shows that the actual mean through-times for the ABU_I.C.T network was$4.26\ x\ 10^{-06}$seconds, and $1.04\ x\ 10^{-06}$ seconds for the proposed SAN design (a 75.9% reduction on a 95% confidence since p-value was 0.01) and with $\rho = 0.5$ (at max. power) the there was a 33.99%reduction. The mean through time for the failure of an edge link (scenario 1) in the SAN design was $6.21\ x\ 10^{-06}$(72.3% reduction). The mean through time for the failure of core switch (scenario 2) in the SAN design was $7.805\ x\ 10^{-6}$ (a 65.3% reduction) showing that the SAN design is of a higher performance measure.

General Terms
Storage Area Networks Implementation, Enterprise Storage Design concept, core/edge SAN Design model, SAN Fabric.

Keywords
Storage Area Network, SAN Design Model, Network, Storage.

1. INTRODUCTION
It is now standard practice in large organizations to centralize data storage (pool of disk storage), this simplifies the system administration tasks by treating all the organizations storage as a single resource which be implication makes disk maintenance and backups easier to schedule and control [1]. If managed carefully, this results in lower congestion on the Local Area Network (LAN) and improves data security. Data flow between the storage devices and the client servers (hosts) travels exclusively across a dedicated SAN [2]. Students' portal are not stored in the University (ABU) but is being hosted by the company hosting the University due to infrastructure and expertise (man-power). Clearly, the Data Centre should come up with ways of storing its own data within the University and these calls for the University to establish a storage system using a good topology which is easily scalable. One of the most beneficial methods for storage system is a SAN rather than a NAS or Direct Attached Storage (DAS) [3]. A tool would therefore be needed for evaluating how the SANs constructed from a discrete event simulation will perform in their stochastic environments. This would entail developing a Core-Edge SAN design formulation and using it to plan for the implementation of SAN within the University. It is common to refer to switches as either *core* switches or *edge* switches depending on where they are located in the SAN. If the switch forms, or is part of the SAN backbone, then it is the core switch. If it is mainly used to connect to hosts or storage then it is called an edge switch [4]. A discrete event simulation for (Ethernet technology) SAN would be developed to evaluate the performance of the Core-Edge design proposed in the ICT Data Centre of Ahmadu Bello University, Zaria.

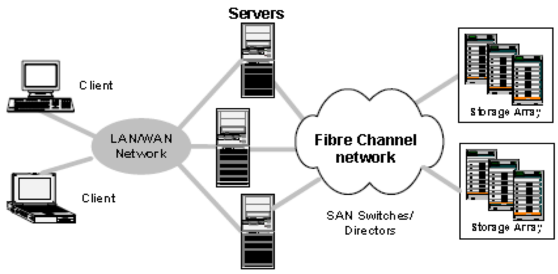

Figure 1: Fibre Channel SAN

SAN operates behind the servers to provide a common link between servers and storage, allowing administrators to independently scale the storage or server processing power as requirements demand and providing an ever-growing number of users access to accurate, reliable information without delay [1]. Figure 1 shows an example of a SAN.

2. BACKGROUND

Ahmadu Bello University Data Centre is not an exception to this. The Management Information System (MIS) of the University currently has 29,871 undergraduate student and 7,569 postgraduate student data stored in the usable disk space in the Storage Device (SD) of its hosts. The usable disk space will reduce exponentially yearly as more students are being admitted. Averagely 7,109 undergraduate students and 4,198 postgraduate students are being admitted every year within the University. And a total of 18,835 graduate students currently have their profile saved in the server. SAN allows multiple servers to access the same data so that duplication of information can be reduced, and permits data backup to take place directly over storage channels, eliminating the bottleneck of the relatively slow LAN. By shifting data transactions and I/O away from application servers, application server performance is improved [5]. Another added benefit of SAN architecture is the increase in LAN bandwidth resulting from backup operations being moved to

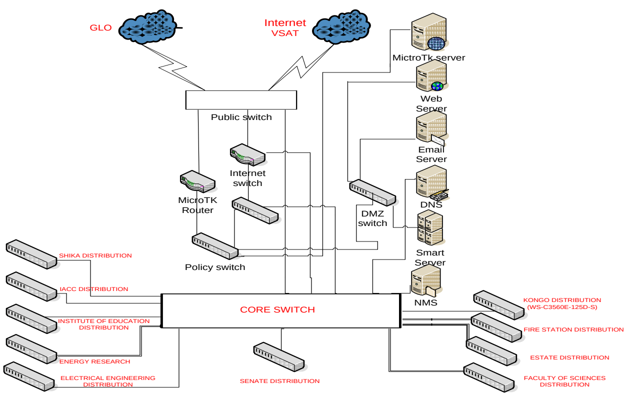

Figure 2: Schematic diagram of ABU – Core to Distribution Physical Connectivity

SAN sub-networks. Performing backup on the SAN frees up servers from performing backup tasks and makes them available for other applications and tasks thereby disk utilization is being increased, storage maintenance costs reduced, improved protection of critical data, and CPU loads reduced [6]. Figure 2 shows the current ABU data network.

3. PROBLEM STATEMENT

This work presents the development of a SAN, modeled into the current University network and thus, evaluating how the design constructed from a discrete event simulation will perform in its stochastic environment. The performance evaluation of the SAN model is to be done, and also to evaluate the performance under various component-failure scenarios. The viability of the software to be used as an evaluation tool for Storage Area Network designs would also be considered as a secondary aim of the analysis.

4. CORE/EDGE SAN METHODOLOGY

1. The Discrete Event Simulation for the Proposed Core edge SAN Design was built using Arena® simulation package. The main components of the network was modeled modularly as Arena submodels.
2. Arena entities was used tomodel the traffic across the network as packets (rather than streams of bits, or completemessages). Discussion of the implementation of the SAN design on the University Data Network.
3. The performance of the simulation model of the SAN design was evaluated. The calibration and validation process the SAN design was also discussed.
4. Evaluation of the Performance of the Proposed core-edge SAN Designunder Component Failure was done. Thefollowing two scenarios were tested:
   a. Scenario 1: The failure of an edge link (i.e between a device and an edge switch).
   b. Scenario 2: The failure of a core switch.

4.1 The proposed Network Server Layout

The University, ABU is connected to the Internet via the STM-1 (Synchronous Transport Module layer 1) from GLO (Globalcom). Mail and Web Server are on the reduced 2Mbps Internet link via Intelsat by Vsat**.** Figure 3 is the proposed Core/Edge sever layout.

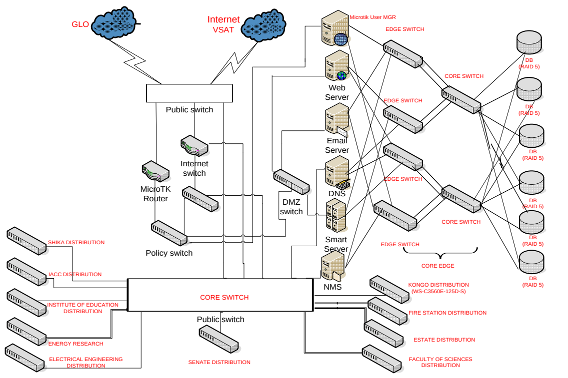

Figure 3:The proposed Core-edge SAN fabric design

4.2 The Core/Edge SAN Fabric Design

ARENA uses event driven method to develop the simulation model. Storages and networks in ARENA are virtualized to upper level in the virtual device concept. The servers are classified as those which send broadcasts across SAN while the databases as those which do not send broadcasts across SAN [7].Storage capabilities and processing speeds, areexcluded

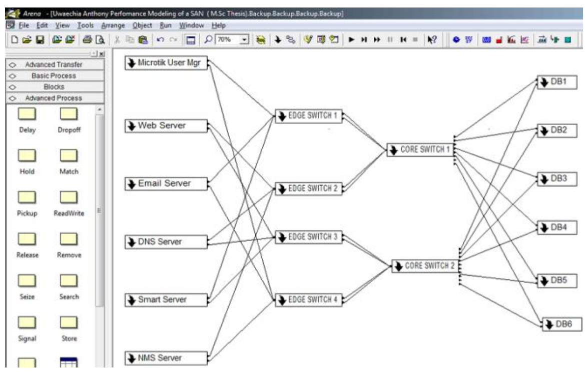

Figure 4:The SAN design Model

from our simulation model. The only pertinent features to the network are the rates at which each end-device supplies and demands for data. Therefore the end-devices are all modeled as simply creating and receiving traffic in the form of packets.

The traffic creation rate at each device is calculated using the live data drawn from the Ahmadu Bello University dude server network outflow data. Database DB1, is read-only. DB2 which is the master database is responsible for carryingout updates. Database DB3 is the backup database for DB2. Updates are sent periodically from DB2 to both DB3 and DB1, keeping them up-to-date with changes that have been made by students and staff. DB4, DB5 and DB6 are all added capacity. All links in this system are duplex gigabit links (i.e. transmission speed of 1 Gbps) in both directions (upload and download). If a component (that is, a switch or a link) fails the network is not expected to fail, as every flow using that component has a second available path that does not use it.The core of this design will consists of two Cisco Catalyst switches (Ethernet switches that use the store and forward method for arriving packets) and can handle both gigabit and non-gigabit Ethernet links, with three Cisco switches used in the edge. Each link in the network should be a 1 Gbps link. These catalyst switches were chosen because of the fact that they can handle both gigabit and non-gigabit links making use of the ongoingFibre link network currently being implemented in Ahmadu Bello University, Zaria. Figure 4 shows the model in Arena simulation as Submodels.

4.2.1 Modeling the Server and Databases

Storage capabilities and processing speeds of a Server and Database are considered independent of the network layout and so would be excluded from the simulation model. But, the rate at which the end-devices supplies and demands for data are the only feature that is pertinent to the network and so will be considered in the design. Therefore, the end devices (Servers and Databases) will be modeled as simply creating and receiving traffic in the form of packets. The flowchart in Figure 5 is the creating packet device module while Figure 6 is the receiving packet device module.

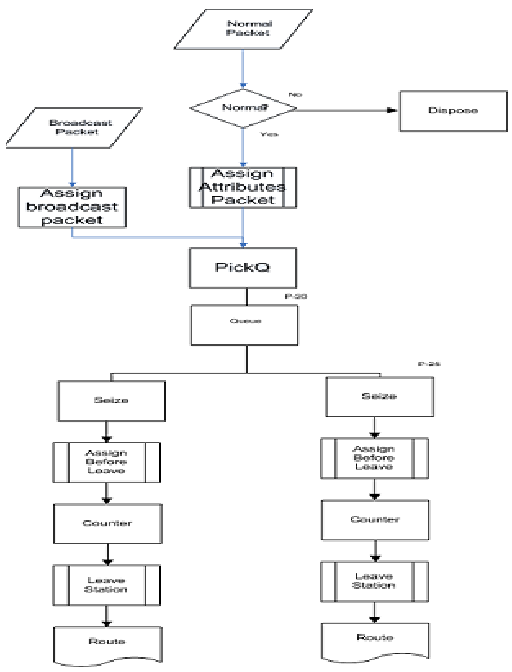

Figure 5.Creating packet device module

From Figure 5, the task is to map our process of a server and how the model of a server was built. The logic steps that would be used in building the Server includes:

Create arrivals

- Create arriving broadcast packet
- Create arriving normal packet
- Decide if "normal" then assign attributes like time of creation, packet size, source and destination else (packet not required) dispose
- Send "normal" traffic to databases as well as broadcast traffic to server within their category.
- Place packet and broadcast on a FIFO link (pickQ)
- If a trunk link is available – seize queue and wait for link resources seize the available link resource.
- Record module counts if packet leaves just once since broadcast packets violates

- Source and destination address are to be added to the packet
- Release the available link resource.

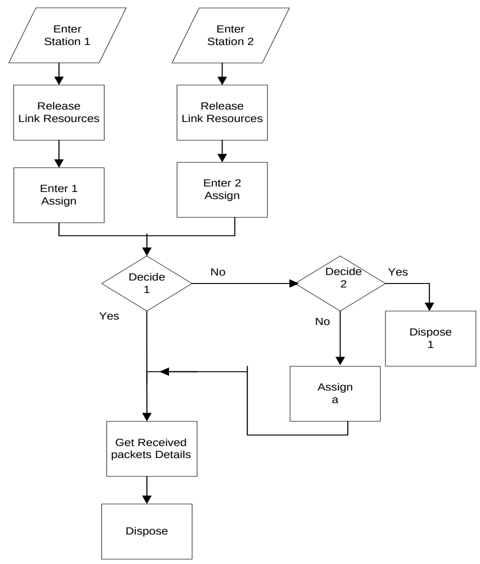

Figure 6: Receiving packet device module

4.2.2 Modeling the Links

An entity being transferred across a link will first seize the appropriate link resource and then undergo a delay to represent the transfer time across the link, and finally releases the link. In the model, the links is made to transfer one packet at a time (in each direction). Each link in the system is modeled as two resources (one operational in each direction).

4.2.3 Modeling the Switch

LAN switches vary in physical design. Currently, there are three popular configurations in use [8]:

- Shared−memory
- Matrix
- Bus−architecture

In the model, the Shared-Memory configuration was used. In this configuration, the switch stores all incoming packets in a common memory buffer that all the switch ports (input/output connections) share. Then, the switch sends the packets out the correct port for the destination node. In modeling the switch the design was narrowed down to the following:

- The Input ports where the packets arriveand the switching decisions are made
- The output port where the packets are switched out of the switch.

This is because, for a real physical switch, for each real physical port, the physical port's input actions are distinct from its output actions. In this model, the VBA (Visual

Basic® for Application) of the Arena Software will carry out this task. The VBA in this case will send the packet to the first available link available to route to.

If a device in the simulation model is connected directly to an edge switch then the port used as the output for that destination in the switch is the output port to which the device is connected since it was not envisaged that the level of congestion would stop the use of a direct link. In the case of a device not connected directly to the switch, then the switch will have to send the packets for that destination to a core switch.

The model's input port and output port combination is equivalent to the real situation of having one port which carries out two distinct, disjoint actions. Thus splitting a physical port into an "output" port and an "input" port in the model, and having a separate radial channel between each of them and the memory is equivalent to the real situation.

4.2.3.1 The Switch Inport

The packets arrive the input port and the switching decisions are made here. Building a model of the switch input port includes the following logic steps:

i. packets arrive at the input port of the switch
ii. packet should releases the link resource used.
iii. input port should be modeled to deal with only one packet at a time so if another arrives while one isbeing processed it must be dropped therefore a queuing system should be incorporated
iv. If the port is free then the packet should seize the inputport resource
v. forwarding transfershould be made by locating the packet's "DestinationID" attribute in the switch lookup table VBA.
vi. Once outputs have been identified, the packet can be transferred to memory, the input must check and decide if there is sufficient memory space available to store the packet if no disposed but yes it should be sent to the switching port.
vii. The input port will create a notification signal to be sent to the affected output port(s)that the port(s) have a packet to transfer out through a separate module entity whose job is to copy the incoming entity and duplicate. Figure 7 shows the switch inport.

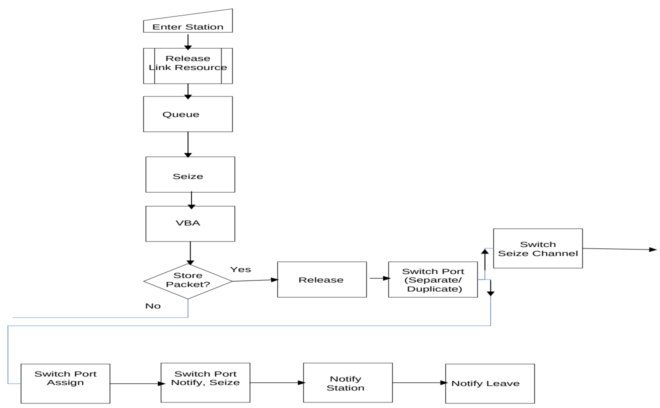

Figure 7: Switch Inport

4.2.3.2 The Switch Outport

i. The outport station waits to receive packets from the Station_1 leave.
ii. It makes a copy and releases the original
iii. It then checks to see if the output port is busy and then places the notification in a queue.
iv. Once the packet is found in memory, it's been sent to the outport radial channel to be switched to the output port. Figure 8 shows the switch outport structure.

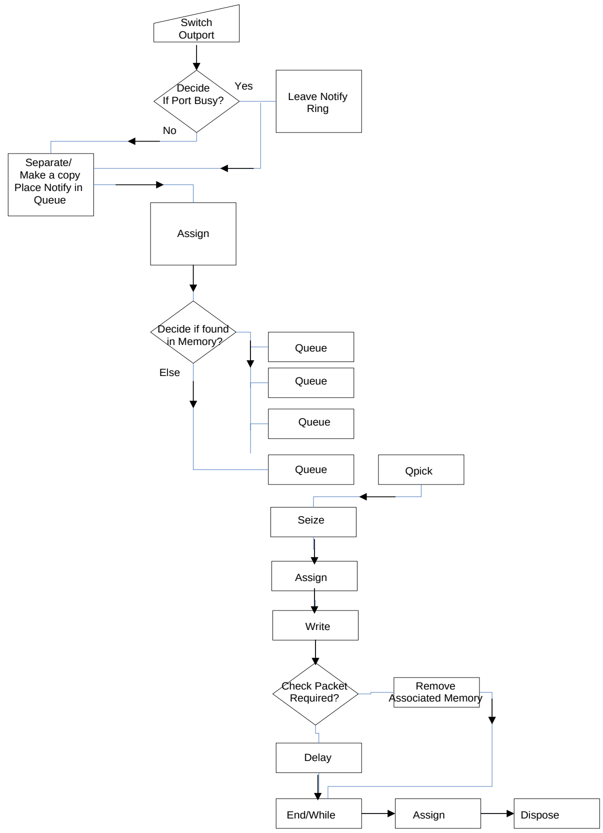

Figure 8: the outport structure of a switch.

A discrete event simulation for the SAN design was built. Server, databases, switch and links were modeled, calibrated and validated using Arena V7.01 simulation package. The structure of the full Arena model for the SAN design is shown in Figure 4.6. Each node represents an Arena submodel.It is well understood from queuing theory that bursty traffic produces higher queuing delays, more packet losses, and lower throughput. The performance of this SAN model would be checked in this vain analyzing the Traffic-Through-Time of the proposed model.

4.3 Input Distribution via the Input Analyzer

Input analyzer is a standard tool that accompanies Arena and is designed specifically to fit distribution to observed data [9]. It provides the best estimates on the data and presents a readymadeexpression on how the distribution fits out data [10].
Two months of live data was taken from ABU dude server captured 10am daily. The distributions were created from the live data using the input analyzer function of the ARENA simulation tool.

A text file containing the data values in an ordinary ASCII text file format using a word processor editor was created and saved with a “text only” format.

To Fit the best distribution to the data, load the data in the input Analyzer, and then attaching the data file through File>Data file> Use Existing menu option. The Input Analyzer displays a histogram of the data in the top part of the window and a summary of the data characteristics in the bottom part as shown in Figure 9.

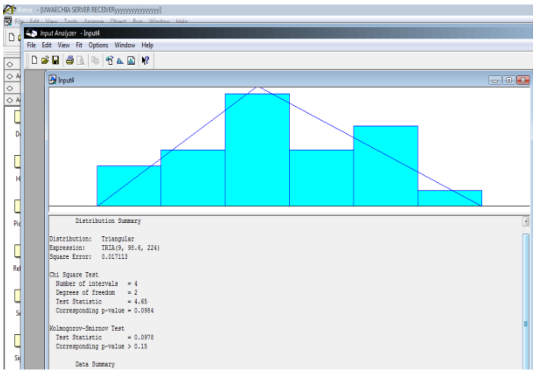

Figure 9: Histogram and Summary of transmit.dst

Clicking the Fit All Summary item causes a dialog box to appear, showing the results of the best fit calculations. All of the applicable distribution functions are listed, along with their corresponding square errors, ranked from best to worst. This listing permits one function to be compared with another for the current data file. The Triangular Fit was selected from the Input Analyzer Fit All Summary. Figure 4.8 shows the Fit All Summary dialog box. And since the corresponding P-Value (the probability of getting a data set that is more inconsistent with the fitted distribution than the data set derived) of the distribution is above 0.05 indicates that the distribution is of a very good fit [9].

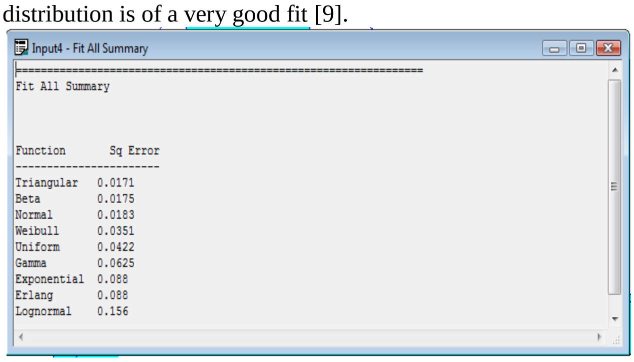

Figure 10: Fit All Summary

The triangular fit was chosen since it has the least square error as compared with the beta, weibull, gamma, exponential, erlang, lognormal etc. figure 10 is the fit all summary.

4.4 Calibrating the Model through the Determination of Traffic Creation Rates

This expression generated from the fit was then copied and pasted (the art of calibration) into the simulation model CREATE module (Server). This would then enable the modeled server to create or transmit packets at that rate [8].
Coping and placing the expression generated by the Input Analyzer which is TRIA (9, 98.6, 224) into the appropriate field of our server model.

4.5 Verification and Validation of the Model

Verification of model construction and validation of the model was done to ensure that the model is a sufficiently accurate representation of the system.

The primary response for the simulation, ARENA output packet half width. The responses obtained showed a range that was wide enough to encompass the variation found in the system, while being sufficiently accurate [8]. The primary metrics used for the validation is the half width confidence interval matching.

5. RESULTS AND ANALYSES

We determine the equality of variance associated with the data collected from the network and the simulated results. Performance evaluation is then carried out using the Welch T-Test and traffic-through time on the switch utilization measurement taken. PAN is then used to analyses the Inter-Switch-Link (ISL) scenarios.

5.1 The Simulation Results

The results from ten repetitions of the simulations were carried out, each for a 10 second period. The Table 1 is the SAN simulation results obtained from the simulation.

Table 1: SAN simulation Result

Compliance -Simulation result (sec)	
1	0.000002217
2	0.00000161
3	0.000000138
4	0.000000123
5	0.000000101
6	0.00000113
7	0.000002523
8	0.000000296
9	0.000001973
10	0.000000241

5.1.1 Switch Utilization of the Proposed Model

Edge Switch_1, Edge Switch_2, Edge Switch_3 and Edge Switch_4 are all the edge switches while Core Switch_1 and Core Switch_2 are the core switches in the design. Figure 6.2 contains the switch notify ring usage of the proposed core/edge SAN design.

Table 2: Switch Notify Ring of the SAN Design

Time (Sec)	Edge Switch _1	Edge Switch _2	Edge Switch _3	Edge Switch _4	Core Switch _1	Core Switch _2
0-0.1	88	67	77	66	88	83
0.1-0.2	55	75	67	64	70	79
0.2-0.3	70	77	66	69	77	67
0.3-0.4	76	66	69	60	74	80
0.4-0.5	77	66	74	65	78	69
0.5-0.6	64	65	77	59	73	68
0.6-0.7	70	76	73	70	80	69
0.7-0.8	70	77	60	61	81	76
0.8-0.9	77	63	69	67	76	79
0.9-1.0	67	69	70	71	78	80

Figure 6.2 contains the switch notify ring usage of the proposed core/edge SAN design.

5.2 Switch Utilization of A.B.U Data Network

The switch utilization measurements and plots of the current (A.B.U_ICT) and the modeled Core/Edge SAN design are thus analyzed. Data for the switch utilization (switch notify ring usage) of the ABU_ ICT design based on the number (packets) through per interval for each 24hrs time measurement on ABU WEST (10.x.x.8) and East were taken (data was taken daily – 10am). Figure 6.1 is the ABU_ICT (West) Switch Notify Ring Usage.

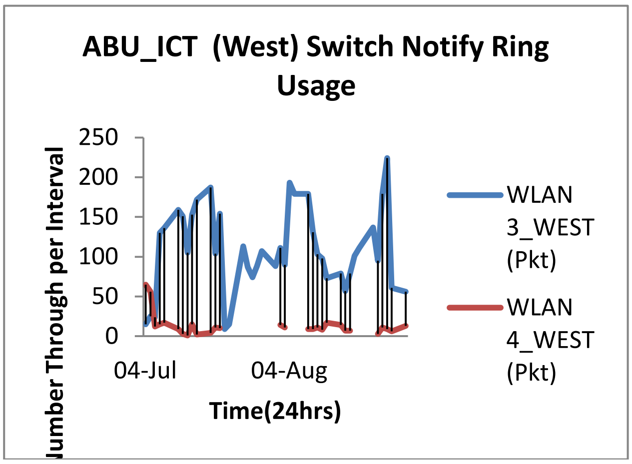

Figure 11: ABU_ICT (West) Switch Notify Ring Usage

Figure 11 shows the notify ring usage, and from the plot it can be seen that the WLAN 3_West switch is highly utilized and being particularly overtaxed (appendix D- live data extracted from Appendix A) while for the WLAN 4_West switch, results shows that it is highly under low utilization and is seen to fail on the 21st of July - the 1st of August 2011, was functional for two days and failed again on the 4th of August till on the 8th of August where it picked and failed on the 18th of August, 2011. The result of this was from the low utilization of the switch which results in failure.Figure 12 shows the ABU_ICT (East) Switch Notify Ring Usage, it can be seen that switch 3 in the aspect of utilization failed on the 7th of July 2011, at this point, switch 4 which has been down became functional and stayed alive as it was been overtaxed. These continued till on the 23rd of August 2011, after switch 3 "came alive" the utilization ring usage of switch 4 decreased as all traffic are been diverted through switch 3, and as the diversion stopped (switch 4 increases), WLAN 3 failed due to its low utilization.

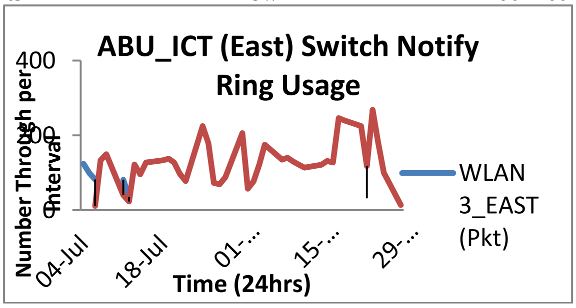

Figure 12: ABU_ICT (East) Switch Notify Ring Usage

5.3 Switch Utilization of the Proposed Model

From simulation results of Table 2, the switch utilization is been plotted as shown in figure 13, is the plot from the Core/Edge SAN simulation results, the five switches are seen to be equally utilized and shows no possible area of congestion in the network as well as indicating where the network is likely to fail. No switch is under extremely low utilization and thus no failure.

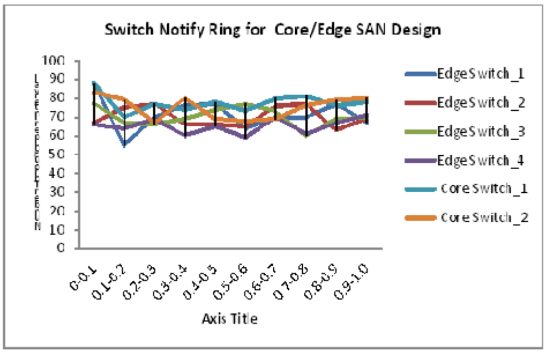

Figure 13: Switch Notify Ring for SAN_Design

Under low utilization of an edge switch (figure 13), the edge switch likely to fail (out of the three edge switches) is Switch 2 (from the plot of figure 13). If failure should arise all flow would be forced to pass through either switch 1 or switch 3. This is the reason why in the SAN design, both switch 1 and switch 3 are both connected directly to DB2 which is the busiest device, this means that the failure of switch 2 will results in an improvement in the average through-times of the network design at the expense of switch utilization of the design (since all flow into it when this happens will no longer pass through the core).

Failure resulting in high utilization of the edge switch would result in congestion of the network [11]. Since it is a SAN design, all flows would have a reasonable distribution of traffic – flow in the network and this effect would be neutralized [12].

The data collected in the ABU_ICT dude server was used for comparison with the SAN simulation results in this study. The use of the actual data provides more realistic results for the simulation output for the developed ARENA model.

Performing the Welch t-tests on the traffic through-times for all host-device pairs was done, figures 6.5 and 6.6 shows the results. And, from the results, t-statistic – the welch t was seen to be greater than the t – critical value ($t > tcp$) meaning that there is a statistically significant difference between the ABU _ICT (background) and SAN design model (compliance point) population means indicating that the performance measure of the SAN design model is of a higher performance than that of the current model with 95% confidence, since the p-value is less than 0.01.

A1	t-Test: Two-Sample Assuming Unequal Variances

	A	B	C	D	E
1	t-Test: Two-Sample Assuming Unequal Variances				
2					
3		*Variable 1*	*Variable 2*		
4	Mean	4.26047E-06	1.14731E-06		
5	Variance	1.373E-10	1.18377E-12		
6	Observations	93	10		
7	Hypothesized Mean Dif	0			
8	df	101			
9	t Stat	2.465240898			
10	P(T<=t) one-tail	0.007689228			
11	t Critical one-tail	1.660080631			
12	P(T<=t) two-tail	0.015378457			
13	t Critical two-tail	1.98373095			
14					

Figure 14: Welch t-test for a $d_f = 101$

From figure 14, for a $d_f = 101$, the actual mean through-times for the ABU_I.C.T network were $4.26\ x\ 10^{-06}$ seconds, and $1.04\ x\ 10^{-06}$ seconds for the proposed design (a 75.9% reduction on a 95% confidence since p-value = 0.01), indicating the SAN to be of higher performance measure.

$$\left(\frac{4.26\ x\ 10^{-06} - 1.04\ x\ 10^{-06}}{4.26\ x\ 10^{-06}}\right) x\ 100\% = 75.9\%$$

5.4 Results under Component Failure Scenarios

Comparing the performance of the network (mean through time) under each of these scenarios to both the ABU network ($\rho = 1.0$)

5.4.1 SCENARIO 1

The mean through time for the failure of an edge link in the SAN design was $6.21\ x\ 10^{-06}$ as compared to the previous ABU_ICT mean through time which is $4.26\ x\ 10^{-06}$ (a 72.3% reduction).

$$\left(\frac{4.26\ x\ 10^{-06} - 1.18\ x\ 10^{-06}}{4.26\ x\ 10^{-06}}\right) x\ 100\% = 72.3\%$$

Notice that the performance of the network is close to 73% which is almost negligible since there are two links between every host device pair

5.4.2 SCENARIO 2

The mean through time for the failure of core switch in the SAN design was $7.805\ x\ 10^{-6}$ as compared to the previous ABU ICT mean through time which is $2.15\ x\ 10^{-5}$ (a65.3% reduction).

$$\left(\frac{4.26\ x\ 10^{-06} - 1.48\ x\ 10^{-06}}{4.26\ x\ 10^{-06}}\right) x\ 100\% = 65.3\%$$

Notice that the performance of the network is close to 73% which is almost negligible since in the failure of a core switch there are edge switches that resources could be routed through.

6. CONCLUSION

The network based on core/edge topology is symmetrical; every device has an equivalent path to other devices connected in the network. One problem of the Core/Edgetopology is that when one of the Inter-Switch-Link (ISL) fails, the network becomes asymmetrical. Therefore, in this design, there are two paths for each host-device pair to retain its symmetric nature should an ISL fails.

For every host-device pair in the core/edge SAN two links was utilized for redundancy. The Performance of the proposed core-edge SAN Design model was tested under two component failure scenarios, the failure of an edge link and a core switch. Effective measurement of storage system activity, such as throughput(T_s)was checked. The results from the simulation shows that the actual mean through-times for the ABU_I.C.T network was$4.26\ x10^{-06}$seconds, and $1.04\ x\ 10^{-06}$seconds for the proposed SAN design (a 75.9% reduction on a 95% confidence since p-value was 0.01) and with $\rho = 0.5$ (at max. power) the there was a 33.99%reduction. The mean through time for the failure of an edge link (scenario 1) in the SAN design was $6.21\ x\ 10^{-06}$(72.3%reduction). The mean through time for the failure of core switch (scenario 2) in the SAN design was $7.805\ x\ 10^{-6}$(a 65.3% reduction). With the failure of an inter-switch-link (ISL), the network performance remained almost the same since there are two links between every host device pair showing that the proposed SAN is of a high performance measure. This research thesis also shows that if the routing policy of a switch is poorly done and a switch in a network experiences low utilization, it results in switch failure.

7. ACKNOWLEDGMENTS

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