Practical Design of Upper-Delay Bounded Switched Local Area Network

*M. O. EYINAGHO***
Electrical and Information Engineering Department, Covenant University, Ota, Nigeria
eyimon@yahoo.com

ABSTRACT

When designing switched Local Area Networks (switched LANs), the network cabling plan must be properly studied; because, this plan, which depends on the interconnections of the switches of which the network is composed, if not properly prepared, can generate bottlenecks, and hence, slow down the network traffic once implemented. It has been generally acknowledged also that, most running switched LANs were not designed in the real sense of the word, but were only installed (network cabling and nodes' placements were just carried out) based on the locations of users' hosts; this of course, frequently leads to expensive networks that fail to satisfy end users in terms of speed in uploading and downloading of information. In addition, certain real-time applications demands that designers' must know the time needed to transfer data from one node of a network to another; which, imply that, there must be deterministic guarantees on network delays. We have reported in previous papers as cited in a subsequent section algorithms and methodologies for designing and installing fast response switched LANs that meets specified end-to-end delays. This paper reports the practical application of these algorithms and methodologies in the design of Covenant University, Nigeria, College of Science and Technology (CST) building switched LAN. The design study found that the switches' placements in this LAN (in the context of Intranet) were not properly done, because, the network end-to-end delays ranges from 42 ms to 168 ms, the network average end-to-end delay is 107 ms, 7 ms above the 100 ms recommended for this type of network. This was worsened by the fact that many of the end-to-end delays ranges from 126 ms to 168 ms, very much above the recommended, therefore, users will not have pleasurable experiences whenever they are logged on to the network.

Keywords: Switched Local Area Networks, Average Maximum End-To-End Delay

---

IJCIR Reference Format:

Eyinagho, M.O. Practical Design of Upper-Delay Bounded Switched Local Area Network. International Journal of Computing and ICT Research, Vol. 7 Issue 2, pp 54-66. http://www.ijcir.org/volume7-issue 2/article 5.pdf

---

** Author's Address: Eyinagho, M.O - Electrical and Information Engineering Department, Covenant University, Ota, Nigeria
eyimon@yahoo.com

International Journal of Computing and ICT Research, ISSN 1818-1139 (Print), ISSN 1996-1065 (Online), Vol. 7, Issue 2, pp. 54-66, December 2013.

1.0 INTRODUCTION

It has variously been argued, (for example, in (Georges, Divoux, and Rondeau, 2005), (Martin, Minet and Laurent, 2005), (Eyinagho, 2012)) that the switched local area networks' (switched LANs') design problem is that of specifying all the switches in the network, so that, either the average of the maximum end-to-end delays of packets for the whole network is upper bounded, or, the maximum of maximum (max. of max.) end-to-end delays of packets is upper bounded; and these should be bounded above, by the maximum of the delay constraints that we desire to be imposed on the network. For example, if the maximum of the end-to-end delay constraints of the applications to be deployed on the network is 3 seconds, while the max of max end-to-end delays of the network is 2 seconds, it implies that the network under all operating conditions, will, be able to transmit packets from an origin host to a destination host within the time constraint imposed by the applications. This is the only way to ensure a high quality best-effort network. A best-effort network does not support quality of service (QoS); an alternative to complex QoS control mechanisms is to provide high quality communication over a best-effort network, by over-provisioning the capacity, so that, it is sufficient for the expected peak traffic load (Koubaa, Jarraya and Song, 2009). Tananbeum (2006, p.398), expressed this idea in this way: one of the techniques for achieving QoS is over-provisioning; this technique seeks to provide so much router (switch) capacity, buffer space, and, the packets just fly through easily, and that, as time goes on and designers have a better idea of how much is enough, this technique may even become practical (Tananbeum, 2006, p.398).

However, in (Eyinagho, 2012), we reported the development of a methodology for enumerating all the end-to-end delays of any switched LAN; in (Eyinagho 2013), we explained the development of an algorithm for designing upper-delay bounded switched LANs, and in (Eyinagho and Falaki, 2012), the development of a maximum delay model of a packet switch was reported. These works, in the main, are part of our efforts at, developing a generalized, practical, methodology for, designing and installing best efforts networks. In this paper, we illustrate a practical application of the methodology, algorithm, and model which were reported in these previous papers.

2.0 DESIGNED SWITCHED LOCAL AREA NETWORK

Shown in Fig.1 is, Covenant University Nigeria, CST building LAN. It has eight switches and one router. One of the switches (CISCO 3550) is serving as a backbone switch to six other CISCO 2950 switches. A seventh CISCO 2950 switch connects the CISCO 2600 router and the CISCO 3550 switch. DVB is a Digital Video Broadcasting device for receiving digital video signals. The router (CISCO 2600) connects to the VSAT terminal through a Radyme Comstream modem. Six of the CISCO 2950 switches are used to network the users' hosts that are located in CST building. Fig. 2 shows the LAN redrawn, with the attached hosts excluded from the drawing; the router, being a switching device, in the context of a switched LAN, is taken as one of the switches. Fig. 2 is redrawn with the VSAT terminal, DVB receiver and the modem excluded as shown in Fig. 3. The router is S_1 in this figure, since it attaches to the VSAT through the modem. It should be noted here that, the reason why the users' hosts are not included in Figs. 2 and 3 is that, we have previously shown in (Eyinagho, Falaki, and Atayero, 2012 pp. 103-134) that the number of end-to-end delays of a switched LAN depends only on the switches of which the LAN is composed and their interconnections, and not on the hosts that are attached to the LAN.

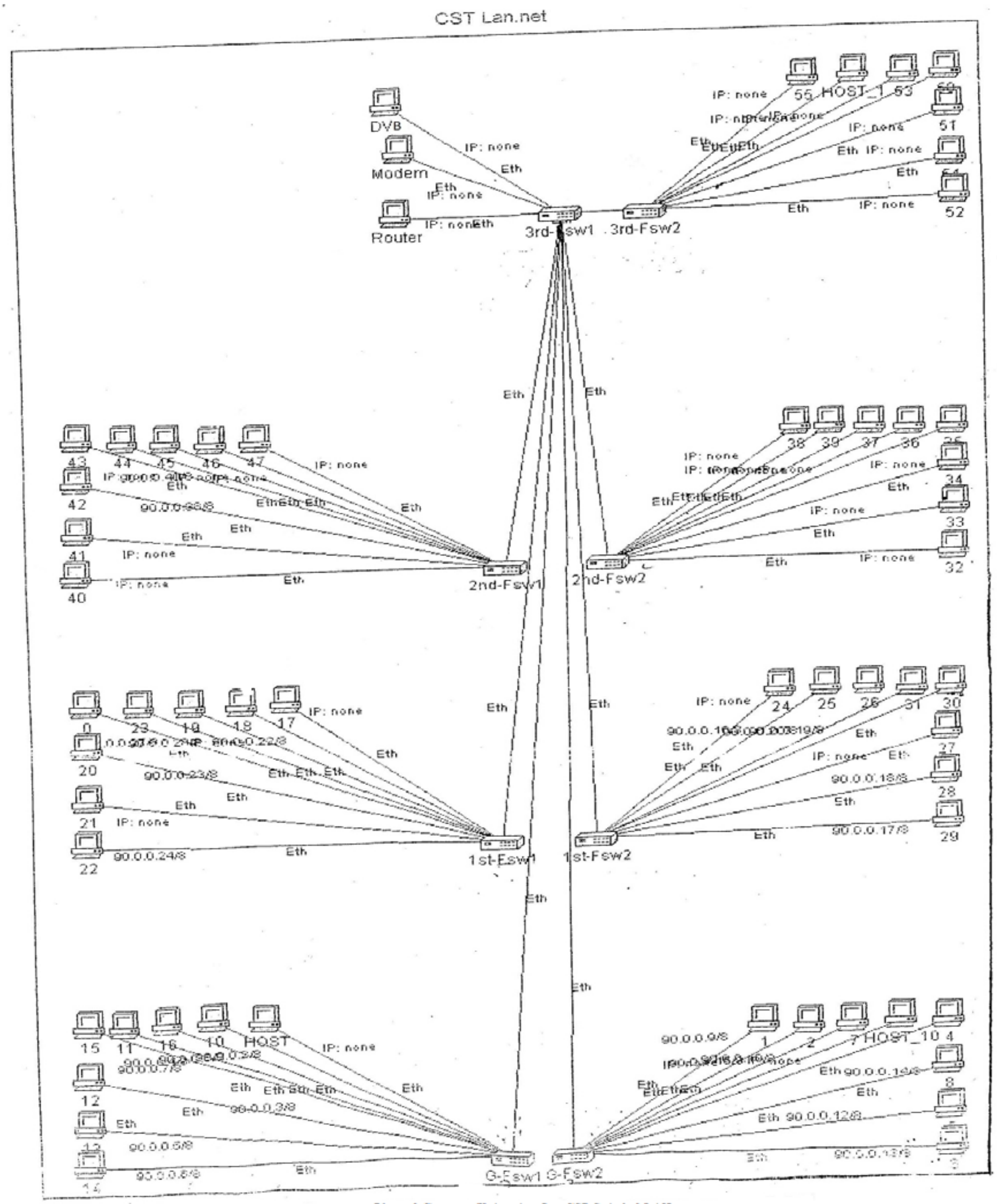

Figure 1 Covenant University, Ota, CST Switched LAN

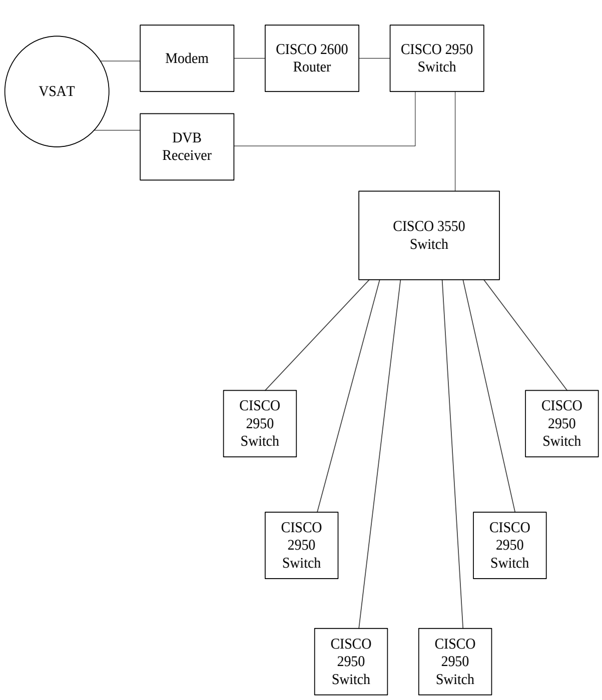

Figure 2 Covenant University CST Building LAN (excluding users' hosts that are attached to the LAN)

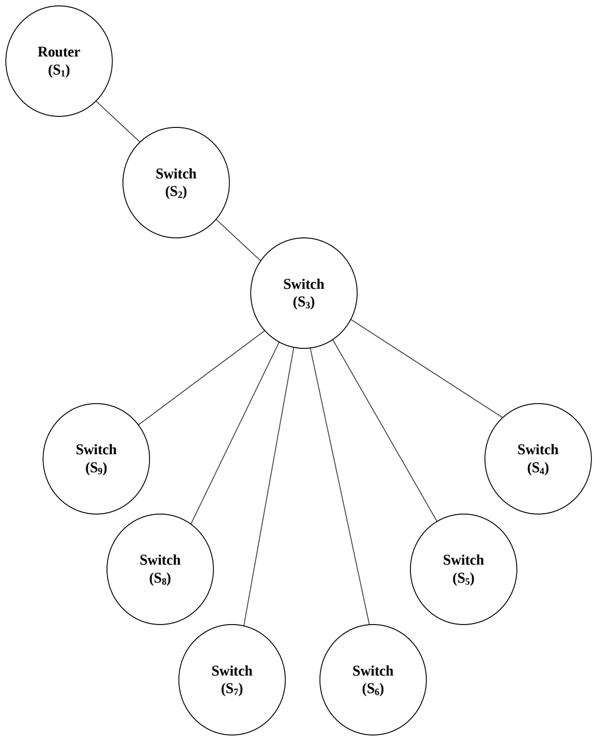

Figure 3 Covenant University CST Building LAN (with only switching devices – router and switches)

2.1 Covenant University's CST Switched LAN End-To-End Delays Enumeration

We now describe the enumeration of the end-to-end delays of Covenant University switched LAN - a necessary procedure in the design of any switched LAN using our methodology. It entails the following steps.

Step 1: Calculate the number of end-to-end delays of the switched LAN

Being able to carry out the enumeration is contingent on knowing the number of end-to-end delays of the switched LAN. In (8, p.124], we derived a formula for calculating this number, and is given by Eq. (1),

$$p = \sum_{x=0}^{m-1}(m-x) \qquad (1)$$

where, m = the number of switches in the LAN, p = the number of maximum end-to-end delays required for the design of an upper delay bounded switched LAN. For the LAN shown in Fig. 3, m = 9, therefore,

$$p = \sum_{x=0}^{9-1}(9-x) = (9\text{-}0)+(9\text{-}1)+(9\text{-}2)+(9\text{-}3)+(9\text{-}4)+(9\text{-}5)+(9\text{-}6)+(9\text{-}7)+(9\text{-}8)$$

$$= 9+8+7+6+5+4+3+2+1 = 45 \text{ maximum end-to-end delays}$$

Step 2: Label the switches and routers in the switched LAN, using, the right-most, pre-order transversal approach proposed in Eyinagho (2012).

This is reflected in Fig. 3 for this particular switched LAN.

Step 3: Place the switches and routers in the switched LAN, using, the right-most, pre-order transversal approach described in Eyinagho (2012).

This step is necessary in order to obtain all the switched LAN's maximum end-to-end delays. For this particular switched LAN, assume that the maximum time for any data packet to cross $S_i = x_i$ seconds, for i = 1, 2,…,9, then, associated with each of the switches S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8, and S_9, is a maximum end-to-end delay of $x_1(t_1)$, $x_2(t_2)$, $x_3(t_3)$, $x_4(t_4)$, $x_5(t_5)$, $x_6(t_6)$, $x_7(t_7)$, $x_8(t_8)$, and $x_9(t_9)$ respectively. All the other maximum end-to-end delays as each of the switches is being placed are now listed.

When S_2 is placed, the maximum end-to-end delay is: $x_2 + x_1 = t_{10}$
When S_3 is placed, the maximum end-to-end delays are: $x_3 + x_2 = t_{11}$; $x_3 + x_2 + x_1 = t_{12}$
When S_4 is placed, the maximum end-to-end delays are: $x_4 + x_3 = t_{13}$; $x_4 + x_3 + x_2 = t_{14}$; $x_4 + x_3 + x_2 + x_1 = t_{15}$
When S_5 is placed, the maximum end-to-end delays are: $x_5 + x_3 = t_{16}$; $x_5 + x_3 + x_2 = t_{17}$; $x_5 + x_3 + x_4 = t_{18;}$ $x_5 + x_3 + x_2 + x_1 = t_{19}$
When S_6 is placed, the maximum end-to-end delays are: $x_6 + x_3 = t_{20;}$ $x_6 + x_3 + x_2 = t_{21}$; $x_6 + x_3 + x_4 = t_{22}$; $x_6 + x_3 + x_5 = t_{23}$; $x_6 + x_3 + x_2 + x_1 = t_{24}$
When S_7 is placed, the maximum end-to-end delays are: $x_7 + x_3 = t_{25;}$ $x_7 + x_3 + x_2 = t_{26;}$ $x_7 + x_3 + x_4 = t_{27;}$ $x_7 + x_3 + x_5 = t_{28;}$ $x_7 + x_3 + x_6 = t_{29;}$ $x_7 + x_3 + x_2 + x_1 = t_{30}$
When S_8 is placed, the maximum end-to-end delays are: $x_8 + x_3 = t_{31;}$ $x_8 + x_3 + x_2 = t_{32;}$ $x_8 + x_3 + x_4 = t_{33;}$ $x_8 + x_3 + x_5 = t_{34;}$ $x_8 + x_3 + x_6 = t_{35;}$ $x_8 + x_3 + x_7 = t_{36;}$ $x_8 + x_3 + x_2 + x_1 = t_{37}$
When S_9 is placed, the maximum end-to-end delays are: $x_9 + x_3 = t_{38;}$ $x_9 + x_3 + x_2 = t_{39;}$ $x_9 + x_3 + x_4 = t_{40;}$ $x_9 + x_3 + x_5 = t_{41;}$ $x_9 + x_3 + x_6 = t_{42;}$ $x_9 + x_3 + x_7 = t_{43;}$ $x_9 + x_3 + x_8 = t_{44;}$ $x_9 + x_3 + x_2 + x_1 = t_{45}$; where t_1, t_2, t_3,…,t_{44}, t_{45} are the maximum end-to-end delays of this switched LAN.

2.2 Computing the Switched LANs Maximum End-To-End Delays

For the switched LAN shown in Fig.3, S_2, S_4, S_5, S_6, S_7, S_8, and S_9 are CISCO 2950 switches, S_3 is a CISCO 3550 switch while S_1 is a CISCO 2600 router. The 2950 is a 24-port switch, the 3550 is a 48-port switch, while the router has 2 onboard LAN ports. We now proceed to calculate the maximum delay of an Ethernet (since it is a switched Ethernet LAN) packet through each of these devices. In Eyinagho and Falaki (2012), the maximum delay of a packet through a packet switch was given as Eq. (2).

$$D_{max}\text{ (seconds)} = \frac{L}{C_{N-1}} + (N-1) \times \left(\frac{L}{2 \times \sum_{i=1}^{N} C_i} \right) + \frac{\sigma}{C_{out}} + \frac{L}{C_{out}} \qquad (2)$$

where,

D_{max} = maximum delay in seconds for a packet to cross any N-port packet switch,
N = No of input/output ports,
C_i, i = 1, 2, 3,…,N = bit rates of ports 1, 2, 3,…,N in bps,
= channel (for example, Ethernet) rates of input ports in bps,
C_{out} = bit rate of the N^{th} output link in bps,
= output port (line) rate of the N^{th} port (the destination of the other N-1 input traffics)
C_{N-1} = bit rate of the $(N-1)^{th}$ input port in bps,
L = maximum length in bits of a data (for example, Ethernet) packet,
σ = maximum amount of traffic in bits that can arrive in a burst.

This equation is composed of four components, which are, $\frac{L}{C_{N-1}}$ = Maximum Packet Forwarding Delay, (N-1) $\times\left(\frac{L}{2\times\sum_{i=1}^{N}C_i}\right)$ = Maximum Packet Routing or Switching delay (RSD) + Simultaneous arrivals of packets delay (SAD), $\frac{\sigma}{C_{out}}$ = Maximum Packet Queuing Delay, $\frac{L}{C_{out}}$ = Maximum Packet Transmission Delay.

The first two delays – packet forwarding delay and packet routing and switching delay constitute what is generally called processing delay; which is the time required for nodal equipment to perform the necessary processing and switching (Comer, 2004, p.244) of data at a node (Bertsekas and Gallager, 1992, Gerd, 1989, p.110). Included here are error detection and address recognition, and transfer of packet to the output queue (Gerd, 1989, p.110). Queuing delay is the time between when the packet is assigned to a queue for transmission and when it starts being transmitted; during this time, the packet waits while other packets in the transmission queue are transmitted (Bertsekas and Gallager, 1992 p.150). Transmission delay is the time required to transmit a packet (Gerd, 1989, p.110), it is the time between when the first bit and the last bit are transmitted (Bertsekas and Gallager, 1992, p.150). In addition to these commonly known delays/latencies, there is a delay associated with the concurrent arrivals of packets/frames to a switch. This delay has been mentioned by some researchers in the literature, but we have not seen any work where an attempt was made to include it in a delay model of a packet switch. According to Christensen et al (1995), if two stations try to transmit to the same station at exactly the same time, then one of the stations will get through, while the other will be temporarily buffered in the switch. There will be periods of times when several stations will try to transmit to the same station, thus, resulting in multiple frames being buffered.

In Eyinagho, Falaki and Atayero, (2012, pp. 169-171), the maximum delay of an Ethernet packet in the CISCO 2950 switch, the CISCO 3550 switch and the CISCO 2600 router were each calculated using (2) to be 42 ms; therefore, this is the maximum delay for switches $S_2(x_2)$ seconds, $S_4(x_4)$ seconds, $S_5(x_5)$ seconds, $S_6(x_6)$ seconds, $S_7(x_7)$ seconds, $S_8(x_8)$ seconds, $S_9(x_9)$, $S_3(x_3)$ seconds, and the router, $S_1(x_1)$ seconds. The different maximum end-to-end delays in milliseconds for the Covenant University, CST switched LAN are, therefore, t_1= 42, t_2= 42, t_3= 42, t_4= 42, t_5= 42, t_6= 42, t_7= 42, t_8= 42, t_9= 42; $t_{10} = x_2 + x_1$= 42 + 42= 82; $t_{11} = x_3 + x_2$ = 42 + 42= 82; $t_{12} = x_3 + x_2 + x_1$= 42 +42 + 42 = 126; $t_{13} = x_4 + x_3$ = 42 + 42= 82; $t_{14} = x_4 + x_3 + x_2$ = 42 +42 + 42 = 126; $t_{15} = x_4 + x_3 + x_2 + x_1$ = 42 +42 + 42 + 42 = 168; $t_{16} = x_5 + x_3$ = 42 + 42= 82; $t_{17} = x_5 + x_3 + x_2$ = 42 +42 + 42 = 126; $t_{18} = x_5 + x_3 + x_4$ = 42 +42 + 42 = 126; $t_{19} = x_5 + x_3 + x_2 + x_1$ = 42 +42 + 42 + 42 = 168; $t_{20} = x_6 + x_3$ = 42 + 42= 82; $t_{21} = x_6 + x_3 + x_2$ = 42 +42 + 42 = 126; $t_{22} = x_6 + x_3 + x_4$ = 42 +42 + 42 = 126; $t_{23} = x_6 + x_3 + x_5$ = 42 +42 + 42 = 126; $t_{24} = x_6 + x_3 + x_2 + x_1$ = 42 +42 + 42 + 42 = 168; $t_{25} = x_7 + x_3$ = 42 + 42 = 82; $t_{26} = x_7 + x_3 + x_2$ = 42 +42 + 42 = 126; $t_{27} = x_7 + x_3 + x_4$ = 42 +42 + 42 = 126; $t_{28} = x_7 + x_3 + x_5$ = 42 +42 + 42 = 126; $t_{29} = x_7 + x_3 + x_6$ = 42 +42 + 42 = 126; $t_{30} = x_7 + x_3 + x_2 + x_1$ = 42 +42 + 42 + 42 = 168; $t_{31} = x_8 + x_3$ = 42 + 42 = 82; $t_{32} = x_8 + x_3 + x_2$ = 42 +42 + 42 = 126; $t_{33} = x_8 + x_3 + x_4$ = 42 +42 + 42 = 126; $t_{34} = x_8 + x_3 + x_5$ = 42 +42 + 42 = 126; $t_{35} = x_8 + x_3 + x_6$ = 42 +42 + 42 = 126; $t_{36} = x_8 + x_3 + x_7$ = 42 +42 + 42 = 126; $t_{37} = x_8 + x_3 + x_2 + x_1$ = 42 +42 + 42 + 42 = 168; $t_{38} = x_9 + x_3$ = 42 + 42 = 82; $t_{39} = x_9 + x_3 + x_2$ = 42 +42 + 42 = 126; $t_{40} = x_9 + x_3 + x_4$ = 42 +42 + 42 = 126; $t_{41} = x_9 + x_3 + x_5$ = 42 +42 + 42 = 126; $t_{42} = x_9 + x_3 + x_6$ = 42 +42 + 42 = 126; $t_{43} = x_9 + x_3 + x_7$ = 42 +42 + 42 = 126; $t_{44} = x_9 + x_3 + x_8$ = 42 +42 + 42 = 126; $t_{45} = x_9 + x_3 + x_2 + x_1$ = 42 +42 + 42 + 42 = 168

It was shown in Eyinagho (2012) that, if t_1= maximum end-to-end delay 1, t_2= maximum end-to-end delay 2, t_3= maximum end-to-end delay 3,…, t_p= maximum end-to-end delay p, respectively, and Davmax = average of the maximum end-to-end delays of a switched LAN, then

$$\text{Davmax} = \frac{t_1 + t_2 + t_3 + ... + t_p}{p} \text{ seconds} \qquad (3)$$

where p = number of end-to-end delays inherent in the LAN. From Eq. (3), the average maximum end-to-end delay =Davmax = $\frac{t_1 + t_2 + t_3 + ... + t_p}{p}$ seconds = $\frac{4814}{45}$ ms = 107ms

Figs. 4 to 9 are flow-charts for the different aspects of the algorithm, which we developed for the design of upper delay-bounded switched LANs, as applied in the previous sections. An initial version of an application program have been developed using this algorithm, which is, being improved upon in terms of coding, for ultimate use, as an automated switched LAN design package.

3.0 PRACTICAL IMPLICATIONS OF THE COMPUTED END-TO-END DELAY VALUES

According to Nielson (2009),

- 100 ms is the maximum delay before a user no longer feels that a network is reacting instantaneously,
- 1 second is the maximum delay before a user's flow of thought is interrupted, and
- 10 seconds is the maximum delay before the user loses focus on the current dialog.

This view is in concurrence with IETF RFC 2815: (Integrated Services Mappings on IEEE 802 Networks, 2009). It can be seen from this recommendation that the highest delay bound for IEEE 802 networks (the switched Ethernet LAN is an example of an IEEE 802 network) is 100 ms. In the context of these two views, it is seen that the switches' placements in Covenant University's CST building LAN (in the context of Intranet) have not been properly done. This is because, there are end-to-end delays that are much more than100 ms – many of them range between 126 ms and 168 ms.. Therefore, users at both ends of these origin-destination paths will not have pleasurable experiences when-ever they are logged on to the network and the network is heavily loaded. Even the average maximum end-to-end delay (Davmax) of 107 ms is above the 100 ms maximum that is recommended, therefore, from good engineering point of view, this is a poorly installed LAN. From the above values therefore, Switch S_2 (CISCO 2950) in this LAN is redundant; hence, it is a bottleneck to pleasurable Internet sessions (uploading and downloading of information). Therefore, it should be removed, as it is only increasing end-to-end delays of some paths by 42ms. Also, the CISCO 2600 router should be removed, since the CISCO 3550 switch performs both layers 2 and 3 functions; that is, it performs the layer 3 functions of the CISCO 2600 router.

4.0 CONCLUSION

This paper has demonstrated the practical utility of algorithms, illustrated in flow-chat form, for designing and installing switched LANs that meet applications' specified maximum delay constraints. It was shown in the paper that, the switches' placements in the LAN that was designed using the algorithms (in the context of Intranet) were not properly done; therefore, connected end users will not have pleasurable experiences whenever they are logged on to the network.

5.0 REFERENCES

BERTSEKAS, D. AND GALLAGER, R. (1992), "Data Networks", Prentice-Hall,Englewood Cliffs, USA

CHRISTENSEN, K., HASS, L., NOEL, F. AND STOLE, N. (1995), "Local Area Networks – Evolving from Shared to Switched Access", IBM Systems Journal, pp.347-374

COMER, D. (2004), "Computer Networks and Intranets with Internet Applications", Pearson Prentice Hall, New Jersey, USA

EYINAGHO, M. O. (2012), "Determination of the End-To-End Delays of Switched Local Area Networks" *International Journal of Computer and ICT Research, Vol. 6, Issue 1, pp. 24-30*

EYINAGHO, M. O. (2013), "An Algorithm for Designing Upper-Delay Bounded Switched Local Area Networks", Nigerian Society of Engineers, Technical Transactions, Vol. 47, No. 1, pp. 34-40

EYINAGHO, M. O. AND FALAKI, S. (2012), "A Maximum Delay Model of a Packet Switch" *Journal of Computer Science and Its Applications, Vol. 19, No. 1, pp. 67-73, June, 2012*

EYINAGHO, M. O., FALAKI, S., AND ATAYERO, A. (2012), "Determination of End-To-End Delays of Switched Local Area Networks", LAP LAMBERT Academic Publishing GmbH and Co., Saarbrucken, Germany. ISBN 978-3-8484-4096-2 (205 Pages)

GEORGES, J., DIVOUX, T. AND RONDEAU, E. (2005), "Confronting the Performances of Switched Ethernet Network with Industrial Constraints by using Network Calculus", International Journal of Communications Systems, vol.18, pp. 877-903

GERD, K. (1989), "Local Area Networks", McGraw-Hill Book Co., New-York, USA

"Integrated Services Mappings on IEEE 802 Networks", Available: http://tools.ietf.org/html/rfc2815 (20-08-2009)

KOUBAA, A., JARRAYA, A., AND SONG, Y. (2009), "SBM Protocol for Providing Real- Time QoS in Ethernet LAN" Available: http://www.dei.isep.ipp.pt/akoubaapublications (03-04-2009)