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Managing and Improving Upon Bandwidth Challenges in Computer Network

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Abstract

Managing the bandwidth of a computer network is always faced with great challenges. This research was necessitated by the urgent need to manage the University network currently experiencing congestion in both the local LAN and on the internet backhaul with a view to improving network performance and reduce the huge recurrent on the WAN link. However, there exists various ways that have been deployed towards solving these problems. In this paper we examined existing bandwidth management, effect of limited bandwidth on the network performance and profound solutions of techniques that enhanced or improved the bandwidth efficiency. Also, included in this research work are the studies of the effect of limited bandwidth on work load, type of protocol used and the effect of network congestion on the quality of service of a Wide Area Network (WAN). By comparison, from the modeling of the effect of work load and limited bandwidth on the throughput of a wide area network based on experimental simulation and real time simulation scenarios, some observations were made and recommendation of solutions were given from the analyzed results.

Keywords: computer network management, bandwidth challenges, wide area network, computer network performance

INTRODUCTION

If the bandwidth of a Local Area Network (LAN) is in abundant (Gigabit/sec), with minimal latency (less than 1ms) and also, if the packets drop rate was minimized, then the throughput will be relatively high. In this case the applications are fast with the performance regarded as good (Ian, 2009). It was important to identify whether utilization factors, collision rate or bandwidth congestion are responsible for most computer network problems (Addison, 2006). We considered the case of limited bandwidth of a remote computer network service, where majority of the employees needed to access the head office server through different medium characterized with slow links, high latency, high packet drop rate, and used of chatty protocols. Knowing these problems, we decided to study the effect of limited bandwidth on the performance of the network (Kimberly et. al, 2001).

Our objective was to determine ways to achieve maximum throughput while delivering services to remote end-users at the same level of efficiency similar to those that exists within a typical LAN (Tony et. al, 2002). The major cause of network degradation was when the workload equates to or became greater than the channel capacity, leading to congestion across the WAN, which resulted to bottleneck (Mohd et. al., 2009). The overall effect was packet contention and high latency causing some packet to be loss or dropped for retransmission. All these accumulated to network degradation and poor performance in the quality of service delivered across the WAN. The other driving factor for this research was the huge cost saving that corporate body would benefit through bandwidth management and optimization. In 2009 alone, Nigerian banks achieved up to 30 percent cost savings, Manufacturing Companies 25 percent and Schools about 20 percent cost saving on WAN recurrent costs through bandwidth optimization and management (John et. al., 2010). This paper looked at the factors that affected network performance within the WAN segment. We examined what caused network congestion and also the role of TCP, UDP traffic and CSMA/CD in a bottleneck network (Hu et. al, 2005). We equally established the optimum load for a given WAN link carrying voice, video and data traffic (Miroslaw et. al., 2006). We also, looked at Little's law and Queuing Theory and used them to explain the principles of mean waiting time in the queue, mean system response time, mean utilization of service facility, and distribution of traffic in the system. We simulated a WAN network under different load conditions and extracted network performance statistic from real time network statistic for further analysis to show the effect of latency, jitter, packet drop, number of clients and limited bandwidth on the quality of service of applications running across the WAN (Giovonni, 2005). Included in this work was the presentation of the management of bandwidth challenges in computer network in order to improve network performance and quality of service (QoS) delivery.

METHODOLOGY

It was imperative to provide a platform for the technical assessment of the cause-effect or otherwise of the latency and throughput of a network. Thus, the system performance of a corporate network was assessed to verify such factors as connection rate, transaction rate, maximum users, mode of data exchange, bandwidth efficiency and its long term stability and robustness. In carrying out this research work, three approaches were considered in the method of research to determine the bandwidth challenges in computer network.

(a) In our first method of approach we used NetCracker Professional Software® to simulate a WAN scenario in which files of various sizes were copied across the WAN links from a server to a remote desktop. The latency for the different file sizes was noted. In a similar manner, different numbers of PC's were used to copy same size of files simultaneously across the WAN links to stimulate different bandwidths and the associated throughputs were recorded.

(b) In our second approach we use IBM Trivoli, whats-up-gold and PRTG® software to obtain readings of bandwidth, latency, throughput, and CPU utilization as well as user voice and video experience on a life, corporate network running on fiber links. These tests were conducted in six different cities on the network. During this period of varying traffic pattern, 5.00am to 7pm, local time, several observations were made and data collated for a consecutive period of five working days.

(c) The third approach was to test user's perception when copying big files, watching videos, playing interactive games and making concurrent calls across WAN links. We compared the observed result in each case.

Queue Length and Waiting Time

The average numbers of customers N, are determined from the following equation: $N = \lambda T$, where, λ - average customer arrival rate and T - average service time for a customer.

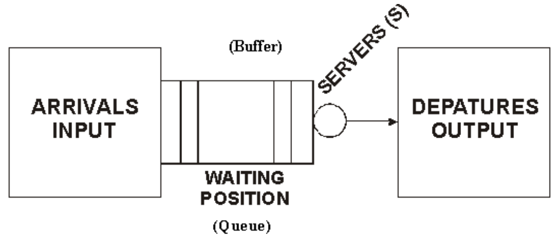

Figure 1. Model of a Simple Queue System

The modeling of a simple queueing system of a transmission link shown in Figure 1 was used to explain queuing theory (Andreas, 1999). When a packet entered an initially empty system, it immediately entered the transmitter and begins transmission. But when the packet arrived at a busy system, it was held temporarily in a buffer waiting for a time when the link was freed or decongested before it was transmitted.

The performance of Queue system was a measure of its utilization factor ρ defined as

$$\rho = \frac{demand \quad for \quad service}{\max imum \quad rate \quad of \quad \sup ply}, \qquad (1)$$

where, ρ = arrival rate * mean service time = $\frac{\lambda}{\mu}$, *service time*=μ and this was referred to as traffic intensity. Service rate was often controlled by the output transmission rate and the packet length. For a single node to avoid congestion we had $\lambda\rho_0 = \mu\rho_1$.

Average delay or waiting time at the node was expressed as:

$$T = \frac{Average \quad Queue \quad Lenght}{Average \quad Arrival \quad Rate} = \frac{N}{\lambda} = \frac{\rho}{\lambda(1-\rho)} \qquad (2)$$

using $\rho = \frac{\lambda}{\mu}$, then

$T = \frac{1}{\mu(1-\rho)} = \frac{1}{\mu - \lambda}$, these gave the average delay at a node.

Therefore, for a packet transmitted over a given bandwidth of capacity R_b bits per seconds, k the packet size, the mean packet delay was:

$$T = 1 \Big/ \frac{R_b}{k} - R_b = \frac{k}{R_b(1-k)}, \qquad (3)$$

where, R_b/k represent packet transmission/service rate in packet/second and λ was the arrival rate.

The effective capacity of a link reduced substantially due to queuing. A link was replaced with two links, one with same link capacity and the other with capacity depending on the queue size. The additional link was described with respect to the packet arrival rate λ, average packet length L and the original link capacity C. Utilization factor $p=1$, was an indication that the node was congested while $p<1$ ensures that there are more capacity at the node.

Analysis Simulation and case Study

Simulation was conducted on both 10Mbps and 100Mbps WAN links respectively, in order to monitor the variation of latency with throughput and variation of bandwidth with throughput.

First, files of various sizes (800Kb, 1600Kb, 2400Kb, 3200Kb, 4000Kb, 4800Kb, 5600Kb, 7200Kb) were sent from a server to a workstations. Measurements were taken for the corresponding delay (in milliseconds). The numbers of concurrent connections (varying from 5 users, 10 users, 15 users, 20 users, 25 users, 30 users, 35 users, 40 users, 45 users, 50 users) were made to the server, with all users downloading files simultaneously from the server. This experiment was repeated on a life network environment with the corresponding values of bandwidth and latency recorded. Then, graphs of the results were plotted and analyzed as follows:

(i) Variation of throughput with changing latency
(ii) Variation of throughput with changing bandwidth
(iii) Determine the optimum throughput consumption of the network
(iv) Determine traffic pattern of the various packet types

Figure 2 showed the effect of file sizes and users on the network performance. The increase in the number of users had a corresponding increase in file sizes that resulted in an increase in the network throughput. This condition was maintained until it reaches the network threshold and the performance starts to degrade as the congestion, packet retransmission, collision etc occurs. The increase was noticed with file size of maximum 0.2Mbyte and drastic drop in throughput of the network caused by the type of QoS available and other factors affecting the network performance.

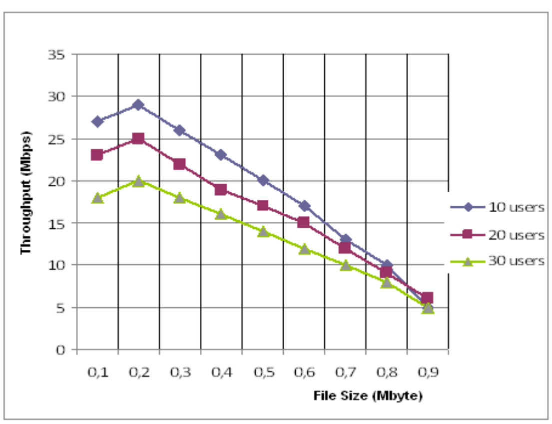

Figure 2. Effect of increase in file sizes and users on the network performance

Another scenario was the impact of latency on the network throughput which can be seen in Figure 3, with the throughput decreasing exponentially as latency increases. At single digit (0-9ms) latency, the network throughput was excellent with near-zero packet queues in the network, however, as volume of traffic increases, the link became congested and network performance drops with very low throughput. Furthermore, as the latency tends towards three digits, throughput of the network tends to zero and the network became
virtually grounded or hanging i.e. degraded as shown in Figure 3.

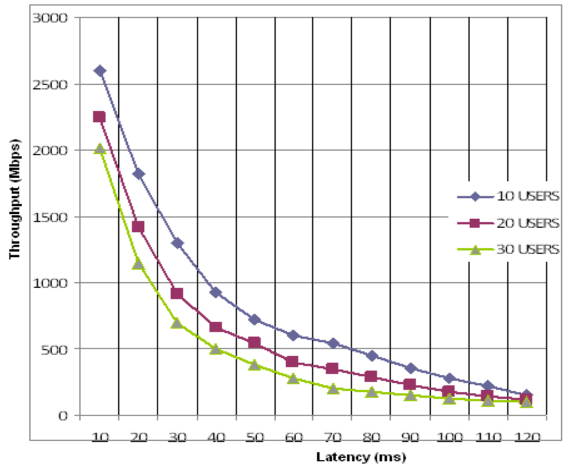

Figure 3. Impact of latency on the throughput of the network performance

From Figure 4 the throughput decreased as packet-drop-rate increased. Fiber links had a better throughput than VPN across the internet, which in turn had better throughput than VSAT link for the same packet-drop-rate.

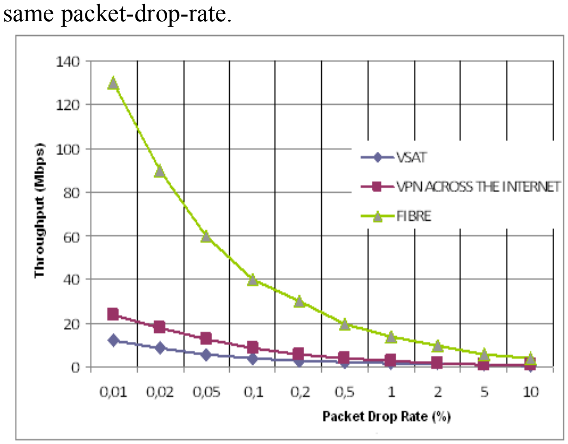

Figure 4. Effect of packet drop on the throughput of a network

From the graphs it was observed that throughput tend to increase linearly with bandwidth, until it reaches peak value below optimum channel capacity and afterward the throughput dropped. It was also observed that the throughput was always less than the link capacity because of protocol encapsulation overheads, media access delay, queuing delay, server latency and many other factors in the network. However, as file sizes were increased, the throughput also increased within the linear section. At threshold value, the optimum bandwidth was in use, packets were forwarded as soon as they arrived at the buffer, creating a zero buffer state. But when the threshold throughput was exceeded, more packets arrived at the buffer than the number that left the buffer, creating congestion and causing packet drop rate to increase.

Consequently, the TCP started to re-send the dropped packets which further aggravate the traffic situation and the throughput began to drop even though the bandwidth was increased. Typical applications that suffer from network delay included online interactive games, voice over IP calls, remote data backup, and remote video services among others. It was observed that the network performance was better in the 100Mbps WANS simulation compared to the 10Mbps simulation, with NetCracker professional Software. Apart from latency and bandwidth, the used protocols affected WAN performance especially when it came to managing retransmission. Some protocols retransmitted the whole congestion window when a single packet was lost. This had a catastrophic effect on the performance of the already congested networks. Another problem observed was that the different types of traffic packets had different latency, bandwidth and protocol requirements and attempts to transmit voice; video and integrated data on a base-band (unclassified) channel will suffer quality deterioration especially during high latency and bandwidth congestion at the peak of the traffic.

RECOMMENDATION

WAN acceleration resulted in improved data transfer rate across the WAN. WAN acceleration does address the latency issue by being very selective about the data that were sent over the WAN at both protocol and application layer. Its latest technique was data reduction. It recognizes repetitive information and delivered it locally. This eliminated the transfer of significant portions of data across the WAN, which could have significantly delayed data transfer time (Sanjay, 2002)

Data compression generally enabled devices to transmit or store the same amount of data with fewer bits. The primary objective was to minimize the amount of data to be transmitted or stored. Data compression transforms a string of bytes into a new string containing the same information with a much smaller length. There was a direct correlation between the amount of data transmitted or stored and cost. Compacting of the data both in motion and at rest minimized cost.

The choice of protocol to be used depended on the type of packet to be routed, the number of branches involved, and the expected speed of the application, application tolerance limit for packet loss and packet size. Since error rate increases with packet size, there is an optimum packet size above which protocol efficiency will start to fail. Protocol optimization can be used to improve the efficiency of traffic that uses CIFS, FTP, HTTP, MAPI and TCP protocols. However, protocol efficiency can be improved by means of protocol tuning and protocol pruning. Some of the applications running on todays WAN are bandwidth greedy and latency sensitive for instance, centralized application database requiring backup, video and voice over IP services. To provide remote users with smooth application performance over the WAN, Quality of Service (QoS) should be used to control traffic flow and prioritize application handling to improve overall performance. Non-time-critical events such as video conference and data-backup can be schedule at off-peak periods when it may not impact on other services on the network. It can be automated to proceed over the weekend or at night. This will reduce memory utilization and bandwidth consumption during the peak period of traffic across the network. It will also reduce the completion time for scheduled events such as backup and give better quality of service for video conferencing because all bandwidth and network resources are dedicated to these few services.

CONCLUSION

In general, the effects of congestion on the performance of a network can be seen from the fact that as the offered load increases, the throughput also increases until a point where the queue in the system starts to fill up and the increase in throughput levels up. When the offered load becomes too large and the buffers becomes totally filled up, packets begins to get dropped by the system and throughput of the network starts to decrease in which case, improving the file-size cannot improve the network performance.

REFERENCES

Addison-Wesley (2006), Network latency effects on application performance.

Andreas Willig (1999), A short introduction of Oueuing Theory Technical University Berlin, Telecommunication Network Group, Pp 1 – 11.

Giovonni Giambene, (2005) Queuing theory and Telecommunication networks application Publisher: Springer; 1 edition, May 6.

Hu T. C., Tolendino L.F. (2005), Network Protocol Changes can improve DisCom WAN Performance: Evaluating TCP modifications and SCTP in the ASC Tri-lab Environment.

Ian Molyneaux (2009), The Art of application performance testing Publisher: O Reilly Media Inc.

John S.N, Okonigene R.E, Akinade B.A, Chukwu I.S (2010): Optimized Remote Network Using Specified Factors As Key Performance Indices. Global Journal of Computer Science and Technology Volume 10 Issue 5 Version 1.0:, July 12-15, Pp.14-17.

Kimberly C. Claffy, Constantinos Dovrolis, DOE SCIDAC Proposal (2001): Bandwidth estimation: measurement methodology and applications

Miroslaw Narbutt, Mark Davis (2006), Effect of free bandwidth on VOIP performance in 802.116 WLAN networks., IEE Irish Signal and Systems Conference, Dublin.

Mohd Naziri Ismail and Adullah Mohd Zin, (2009) Traffic Engineering: Simulation model and real network Environment over single and multiple links, European Journal of Scientific Research, January, ISSN 1450-216X Vol.25 No.1, Pp.54-67

Sanjay K. Bose (2002), An Introduction to Queuing Systems, Publisher: Kluwer Academic/Plenum Publishers, New York.

Tony Kenyon, Elaina Kenyon (2002), High performance Data Network Design: Design Techniques and Tools (idc Technology) Publisher: Digital Press.