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Predictive Modeling of Data Delay in a Corporate Network Based on Input Characteristics by Applying Simulation Model

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Abstract- Achieving excellent network quality of service (QoS) is the fundamental aim of any internet service provider (ISP), in view of this, a model of a corporate network has been developed, simulated and implemented using optimized network engineering tool (OPNET) technology in the simulation area of 10,000m^2 office topology, to monitor the effect of data delay in a network based on the input characteristics; 50, 100, 150 and 200 host users to predict the network performance. The result shows that the network with the less number of host users has the better network performance, which implies that; the more the number of the host users the higher the data delay. The data delay predicted in the network with 50, 100, 150 and 200 host users are 0.004801/s, 0.006826/s, 0.006969/s and 0.019697/s respectively. The modeling result predicts that the input characteristics have an influence over network performance as well as capacity utilization.

Keywords - Corporate network, local area network, delay, model, traffic monitoring and host users.

I. Introduction

Telecommunication industries in early age used separate technologies to meet their different communication means, for example, traditional telephone system, AM radio, or TV technology and so on but today, the recent growth in telecommunication Industries all these separate means of communications are achieved through single technology. Up to date, more demand of telecommunications service is at the top gear, due to these high demands imposed on the telecommunication service, traffic structure is becoming more and more complex day by day and the network performance is degrading [1][3][4][6]. Therefore, there is a need to constantly monitor the network performance to gain accurate of bill network activities and to predict how the status of the future network will be. Traffic or network monitoring is a very difficult task because the causes of the poor network performance are numerous which

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could come from device malfunctioning, threat's attack, geographic situation and many others, it must not necessarily come from input characteristics along although in this work, our interest is raised because of the increasing volume of traffic more especially with the
introduction of multimedia traffic on the internet network, this prompted us to study the effect of input characteristics on a network performance while ignoring other sources of the cause of poor network performance.

To undertake the design of a workable and scalable corporate network; high quality of service, one must have to take into account; the nature of input characteristics in relation to bandwidth, network equipment’s and others, because when investigating various properties or characteristics of information transfer across the corporate network; brings about issue of developing model of input characteristics that is near the actual characteristics of the data stream.

Many research works had considered that the sources of the cause of poor performance could be attributed to network failure due to equipment’s, threats attack and some outdoor activities. In [2], the study conducted was based on loss and delay measurement; data collected from internet service providers (IPS) in US. The study arrived at the conclusion that some paths experience severe impairments due to network protocol failure, reconfiguration and router operation may be responsible for network delay instead of normal congestion and quality of service. In [5], research was conducted to study network efficiency in terms of measuring network congestion; the result of the work revealed that most congestion problems were experienced due to the network component, which include structural failure, links, nodes, other, such as a natural disaster, and attack from terrorist. In [7][8], says that quality of service depends on the healthy condition of your network; that is a network that is free from service theft, spamming, phishing attacks, viruses and malware. In [9], research was conducted on network security threats; the result of the work revealed that an intruder could consume significant part of the bandwidth that could consequently deny distributed service.

In this work, we propose to develop a corporate network using OPNET simulator to monitor data delay, which is known as one of the major conditions of degrading network performance with different input characteristics say 50, 100, 150 and 200 host users. Next we wish to develop autoregressive (AR) models which can model stationary stochastic data and predict the average data delay in each local area network (LAN). This is hardly mentioned in the literature for this purpose. Curve fitting is used to predict the average data delay to help us show how much is the impact of input characteristics on network performance in terms of data delay in the simulated network.

II. Implementation of the Simulation Model

A simulation area of 10,000m^2 office topology network is first created using a startup wizard. The required numbers of the nodes are dragged into the empty space base on the suitable number of nodes needed for the implementation of the proposed model as shown in Figure 1, then each of the nodes field is set to carry out their functions. These include application configuration, profile configuration, server, switch, person computer in LAN. The Table 1 below gives the model and the simulation matrices parameters.

TABLE I SIMULATION MATRICES PARAMETERS

Nodes	Simulation Matrices
Simulation size	10,000m2
Traffic monitored	HTTP, FTP, Email, Database
Simulation time	1800s
App. config. setting	Default
Profile configuration	Support app. Config.
Link	10BaseT
Server	Support the service
LAN Scenario 1	50 host users
LAN Scenario 2	100 host users
LAN Scenario 3	150 host users
LAN Scenario 4	200 host users

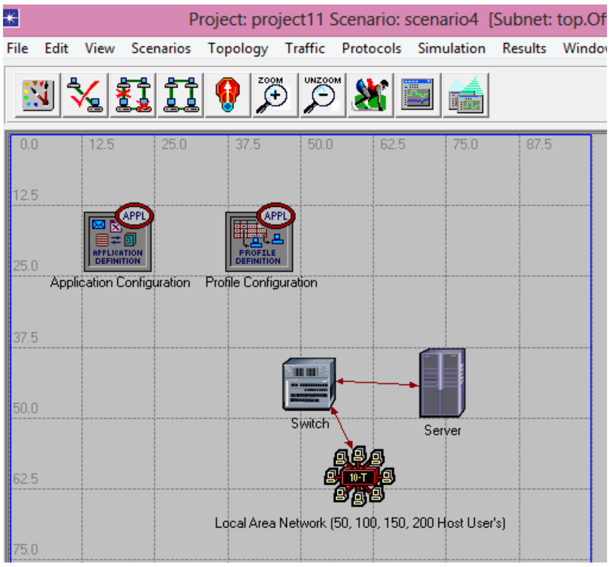


Figure 1. Developed simulated model of the corporate network

A. *Traffic Monitoring and Collection of Statistics*

Data traffic such as high web browsing (HTTP), high file transfer protocol (FTP), high database and high email from different sources say 50, 100, 150, 200 host users were introduced into the model and monitored. The goal is to test the network performance in terms of input characteristics. In OPNET, there are two major statistics available, these are; global statistics and nodes statistics. Global statistics tells us about the statistics of the entire network while node statistics tells us about the statistics of an individual node, in this work we monitored only delay traffic in the global statistics to test which input has less data delay with better network performance. Simulation is run and results are taken, the monitored delay data traffic is presented in Figure 2 below as signals.

B. *Choice of Model*

Based on the traffic monitored and captured; we considered the properties of the data delay captured in terms of stationary and non-stationary process to enable us choose the appropriate model. We identified that the traffic captured (data delay) is stochastic stationary based on the following observations; autocorrelation decay quickly at 2 lag, the correlogram has spikes at very small lag, the mean and variance show no systematic change. These features allowed us to picked autoregressive (AR) model high-order polynomials type.

C. *Model*

Usually, when choosing a model it is expected that the model should be able to predict near real values of the data observed. Our prediction starts with polynomials first order, and continues up to polynomials seventh order. The reason is to arrive at the best model that can predict the average data delay in all the different input characteristics, naturally, as prediction order increases the accuracy of the model also increases but, taking into account its limit. We realized that at the seventh order simple curve fitting follows almost the same pattern with the observed. Let's consider the length of data delay observed as

$$x = x_1 + x_2 + \dots\dots + x_n \qquad (1)$$

Then the generalized AR model may be given as in (2)

$$A_t = \beta_1 x_{t-1} + \dots + \beta_a x_{t-p} + r_t \qquad (2)$$

Where A_t is the data delay in respect to time, a is the process or lag and r is a random element (error). The model given in (3) is derived from (2), that is the seventh order polynomial; we considered (4) as a test model while (5) as a normalized model.

$$A_i = \beta_1 x^7 + \beta_2 x^6 + \beta_3 x^5 + \beta_4 x^4 + \beta_5 x^3 + \beta_6 x^2 + \beta_7 x + \beta_8 \qquad (3)$$

Where A is the data delay, i is the number of host users in each LAN, β_1 to β_7 are the coefficient of x and x=1800 which is the time of the simulation and β_8 random element; the coefficients of x were obtained to enable us predicts the average data delayed in each LAN as shown in (4) below.

$$\sum \begin{bmatrix} p & x_i & x_i^2 & \dots & x_i^6 \\ x_i & x_i^2 & x_i^3 & \dots & x_i^7 \\ x_i^2 & x_i^3 & x_i^4 & \dots & x_i^8 \\ . & . & . & . & . \\ . & . & . & . & . \\ . & . & . & . & . \\ x_i^6 & x_i^7 & x_i^8 & \dots & x_i^{13} \end{bmatrix} \begin{bmatrix} \beta_8 \\ \beta_7 \\ \beta_6 \\ . \\ . \\ . \\ \beta_1 \end{bmatrix} = \sum \begin{bmatrix} A_i \\ A_i x_i \\ A_i x_i^2 \\ . \\ . \\ . \\ A_i x_i^6 \end{bmatrix} \qquad (4)$$

III. Results and Discussion

A. Modeling Results

The test and the normalized model are given in (5) and (6) below.

$$A_{50} = 1.5e^{-23}x^7 - 1.1e^{-19}x^7 + 3.3e^{-16}x^5 - 5.2e^{-16}x^4 + 4.5e^{-10}x^3 - 2.1e^{-8}x^2 + 4.9e^{-5}x + 0.00002 \quad (5)$$

$$A_{50} = 1.1e^{-4}z^7 + 2e^{-4}z^6 - 4e^{-4}z^5 + 7.9e^{-4}z^4 - 4.8e^{-4}z^3 + 8.1e^{-4}z^2 - 2.6e^{-4}z + 0.004801 \quad (6)$$

The values of A_{100}, A_{150} and A_{200} can be obtained in the same manner for the test and the normalized model.

TABLE II SUMMARY OF THE DATA DELAYED PREDICTED BY TEST AND NORMALIZED MODELS

Input	**Test Model**	**Normalized Model**
50 host users	0.0000268	0.0048012
100 host users	0.0000493	0.0068261
150 host users	0.0000711	0.0069693
200 host users	0.0031421	0.0197677

B. Discussions

Network performance is the measure of overall quality of service (QoS) of a particular network more especially; the performance received by the end users of the network. QoS is an important parameter for transporting data traffic or packets from source to destination without losing any meaningful information. The measure of QoS is usually considered in terms of throughput, bandwidth, and transmission delay and so on. Among all mention above data delay could be responsible for the cause of error rate, low throughput, data drop in a network that is why we choose the data delay parameter to monitor, to test and to develop a model that will model the input characteristics of the simulated network. AR model yields high predictive accurate results; as we can see in this work; sufficient information about the data delay from the simulated network model is adequately predicted. This prediction model is a vital tool in time-series that are stationary stochastic process in nature as shown in Figure 2

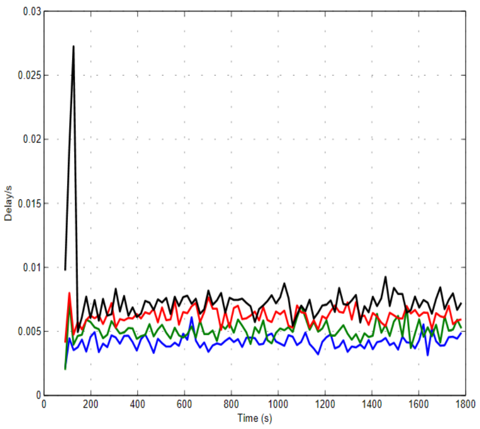
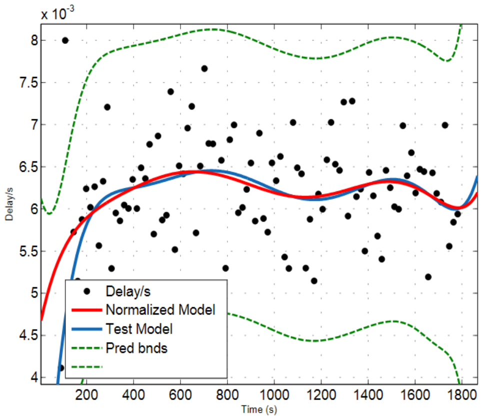


Figure 2. Delay measured in all the scenarios

Figure 2, present the data delay measured in all the scenarios, it exhibits stationary stochastic behavior; blue color



graph represent LAN with 50 host user's, green color graph 100 host user's, red color graph 150 host user's while black color graph 200 host users.

Figure 3 to 6, show the test and the normalized model; the test model is shown in blue color graph while normalized model is shown in red color graph both enclosed in a 95% prediction boundaries. In the test prediction, we tested robust LAR and robust Bisquare; but, we adopted robust Bisquare in this work because it gave us better root mean square error (RMSE), higher R-adjusted and R-square values. However, we noticed that the coefficients of the test model in (5) are susceptible to high sensitive random error, in order to avoid or improve the accuracy of the test model we normalized the observed data to the center and zero scale as in (6), so that we can compute the z-scores using (6).

$$z\sigma = x - \mu \qquad (7)$$

Where μ is the mean and σ is the standard deviation. The normalized model with z-scores becomes more robust than the test model while the norms of the residual remain intact. Though, all the prediction models are reasonable. Perhaps, the normalized model gives better and more accurate prediction when comparing the results of the two models. We then used the normalized model to predict the actual average amount of the data delayed in the simulated network. Base on the amount of average data delay predicted, as shown in Table 2, it is clear that; as the input characteristics of the network increases the network experience more delay, hence, reduce the network performance, this also implies that capacity utilization will also be affected.

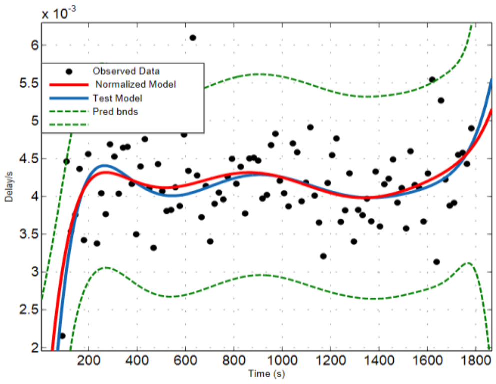


Figure 3. Test and normalized models for 50 host users

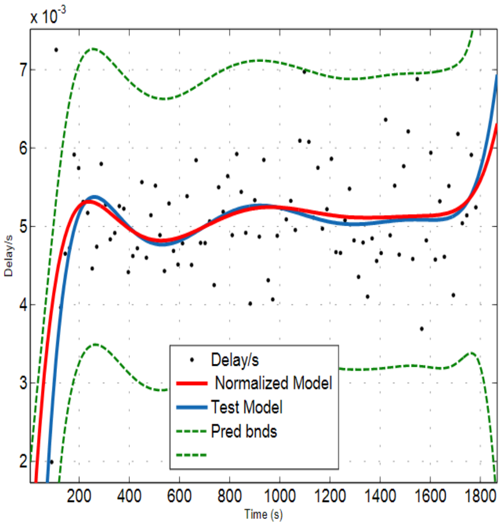


Figure 4. Test and normalized models for 100 host users

Figure 5. Test and normalized models for 150 host users

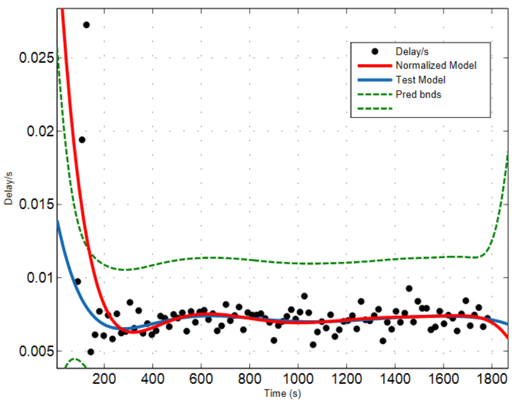


Figure 6. Test and normalized models for 200 host users

iv. Conclusion

A corporate network has been developed, simulated and implemented using OPNET technology; data delay is monitored with varying input characteristics say 50, 100, 150 and 200 host users. AR model is developed to predict the network performance based on data delay. The model predicts that the input characteristics have a significant influence on network performance. Therefore, when designing a network of any type, input characteristics is one of the factors to put into consideration for the network to have good network performance. This work takes into consideration only input characteristics, but, does not consider other sources that could affect network performance. Hope this modeling work has provided some vital information on the effect of input characteristics on network. We recommend that other researches should be carried out to find out the other possible causes of poor network performance.

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