Prediction and Filtering of Delay Error on a Corporate Network by using Simulation Model

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ABSTRACT
In this work, a model of a corporate network has been developed, simulated and implemented using optimized network engineering tool (OPNET) technology, in a simulation environment of 100m x 100m office network topology. Delay signal was monitored, neural network (NN) was used to predict the error in the delay signal, one-dimensional (1D) multilevel wavelet de-noising technique to filter the error, autocorrelation function (ACF) and fast Fourier transform (FFT) energy spectrum to validate the result of the filtering after the stages of the decomposition and the reconstruction of the delay signal. The result of the filtering revealed that the error in the data delay is de-noised successfully, since the coefficient of the ACF grows above zero and energy rate in the FFT- spectrum increased.

Keywords
Delay, decomposition, compressing, reconstruction, Wavelet, ACF and FFT spectrum

1. INTRODUCTION
Currently, the demand for internet service is growing exponentially more especially with the introduction of multimedia services such as video and audio streaming in addition, to the traditional WWW browsing, e-mail and others [10]. Due to these massive activities imposed on the internet network the data traffic is becoming more complex day by day. Hence, the internet network experience congestion as well as delay phenomenon. When viewing the causes of the network delay on a large scale many factors could be taken into consideration; like low bandwidth, application of many hosts in a broadcast domain, multicasting and inefficient protocols. Network delay, degrades overall network performance, since it is associated with amplified errors, retransmission of data, overflow probability and probably may involve data drop [5]. Delay problem is very difficult to predict because one may not know the exact input characteristics of the network at a particular period. Therefore, in trying to address delay problems on the internet network and to develop the algorithm for the fast flow of data traffic across an IP network, question of constructing a model with input characteristics may arise.

1.1 Related Work
Many research works in this field have justified that recent IP network traffic suffer congestion or delay problems. In [9] a study on internet delay was carried in order to analyze delay and causes of delay across internet; the study shows that internet network exhibits delay cause due to inefficient design of a webpage. In [6] UDP echo method was used to investigate network problems as a faulty network interface card; the study revealed that packet were lost randomly. In [2] the study conducted was based on loss and delay measurement in data collected from internet service providers (IPS) in US; the study arrived to a 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 [7] 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. All the related work mentioned above were concerned about the identifying delay on the network but did not provide solution on how to address the delay problem on the network. While in this work, delay on the network is identified and addressed. In [3], [16], [17], [18], these authors used the wavelet technique as a de-noising tool, but in all their works the speed and accuracy of the wavelet technique is not ascertained. However, in this work, the speed and accuracy of the wavelet technique is ascertained using fast Fourier transform (FFT) and autocorrelation function (ACF).

1.2 Basic Concepts
OPNET is a high class networking tool that is capable of providing performance analysis in most communication networks such as a global system for mobile communication (GSM), computer networking and application, both wired and wireless networks [20]. OPNET has the tendency of analyzing routing protocols. Simulation with OPNET tool provides near practical results. We choose to develop our network with this tool because of its accuracy and applicability in this field.

NN is an intelligent system capable of machine learning and pattern recognition. In various fields, NN has proved to be useful in solving complex problems that some common programmable tools cannot address [19]. Our interest is raised about the use of the NN tool because of its diversity in handling problems and precision of the NN output.

Wavelet simply means wave with short duration with an average value zero. The wavelet tool can analyze smallest part of the signal that older tools like Fourier transform could not be able to analyzed [18]. Wavelet is used to de-noise unwanted signal out of the wanted signal that can be used for different purposes. There are different types of mother wavelet. These include db, coif, .haar, bio, sym and many others. Before choosing any mother wavelet for de-noising, two or three things have to be given consideration that is; there must be correlation between the mother wave and the congested waves, inspecting wave structure is also important and based on total energy interval where wave spikes occurs. Wavelet has demonstrated a couple of significance in filtering processes is the reason for its consideration in this work.

This work, propose to develop a corporate network using OPNET technology with complex input say 200 host users, to monitor the traffic with the interest of studying delay on the network. Also, propose to use NN [15] to predict error on the network, 1D wavelet de-noising technique will be apply to filter the error present in the signal. In addition, validate the filtering technique using ACF and FFT energy spectrum. Even though, there are many methods in which error from delay can be reduced among all are segmenting the network using some equipment like switch, bridge and routers, using high bandwidth, suitable protocols [14]. Wavelet de-noising technique is chosen because it seems to be one of the best and promising methods in de-noising errors that are associated with delay on the entire network. To ascertained that, the de-noising technique is effective. Emphasis will be stressed on the properties of the ACF in terms of a strong relationship with delay; one obvious observation with ACF is that as the presence of delay on the network increases its coefficient decay to near zero [11], which means the signal monitored has no correlation with the error on the network and in the FFT energy spectrum; the energy in the spectrum or the traffic volume transmission reduces to a considerable extent as the error increases on the network.

2. IMPLEMENTATION OF SIMULATION MODEL

A simulation area of 100m x 100m office topology network is first created using a startup wizard. The topology is then created. The required number of the nodes is dragged into the empty space based on the number of nodes needed for a particular section, and then each of the node field is set to carry out their functions. These include application configuration, profile configuration, server, switch, personal computer and LANs. The Table 1 below gives the model and the simulation metric parameters.

Table I. Simulation Metric Parameters

Nodes	Simulation Metrics
Simulation size	100m x 100m
Traffic monitored	HTTP, FTP, Telnet, Email, Database
Simulation time	30 minutes
Application config. Setting	Default
2 LANs	50 and 100 host users
Information department	14 host users
Technical department	6 host users
Administrative department	30 host users
Total host users	200 host users

2.1 Collection of Statistics

Large amount of data traffic from different sources is introduced into the model. The goal is to monitor delay with the huge data traffic. In optimized network engineering tools there are two major statistics available, these are; global statistics and node statistics. Global statistics tell us about the statistics of the entire network while node statistics tell us about the statistics of an individual node. Appropriate statistics are then imposed on the scenario model, simulation is run, and results are taken, the Ethernet data delay monitored is then presented in Figure 2, below as a signal.

3. MATHEMATICAL APPROACH

This section describes the mathematical approach of all the tools used in this work such as neural network error prediction, one-dimensional wavelet filtering technique the ACF and the FFT energy spectrum.

3.1 Neural Network Error Prediction

Let's donate $x(t) = x_1, x_2, \ldots\ldots, x_n$ is the delay data measured in $t \in (1,2,\ldots\ldots N)$. Assuming that Fig. 1 presents how a neural network operates. In the hidden layers there are 10 neurons, 2 delays and the soft threshold were used for the prediction to be effective; this is because soft threshold is quite differentiable and realizable. Soft threshold is often realizable by using tanh so that, hard threshold can be replicated.

$$\tanh\theta = \frac{e^{s} - e^{-s}}{e^{s} + e^{-s}} \qquad (1)$$

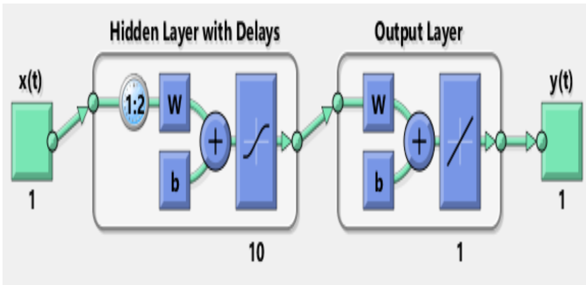

Fig 1: Neural architecture

By initializing the weight, the following parameters and arrays can be defined as W_{ij}. Let X_i be the input signal, S_j be the signal after passing through the nonlinear elements θ (neurons). The weight of the signal becomes $W_{ij=}X_i+S_j$, λ_i be the input layer and λ_0 be the output layer. Therefore, the weight of the signal may be initialized as

$$W_{ij} \quad \begin{Bmatrix} 1 \le \lambda \le \lambda_0 & \\ 0 \le i \le d^{(\lambda-1)}, & (\lambda-1) \\ 1 \le j \le d^{(\lambda)} & \end{Bmatrix}$$

For each value of input in the array we will have different values of W_{ij}. However,

$$X_j^{(\lambda)} = \theta\left(S_j^{\lambda}\right) = \sum_{j=1}^{d(\lambda-1)} W_{ij}^{(l)} X_i^{(\lambda-1)} \qquad (2)$$

In order to determine the error in the signal, by definition the error weight may be given as

$$e(w) = e(H(x_n),\ y(n)) \qquad (3)$$

To implement the SGD, we need the gradient of (3)

$$\nabla e(w) = \frac{\partial e(w)}{\partial W_{ij}^{(\lambda)}} \quad \text{for all i, j, } \lambda. \qquad (4)$$

For efficient computation, chain rule will be applied to the (4)

$$\nabla e(w) = \frac{\partial e(W)}{\partial W_{ij}^{(\lambda)}} = \frac{\partial e(W)}{\partial S_j^{\lambda}} * \frac{\partial S_j^{\lambda}}{\partial W_{ij}} \qquad (5)$$

Therefore, $\frac{\partial S_j^{\lambda}}{\partial W_{ij}^{(\lambda)}} = X_i^{(\lambda-1)}$ (6)

Also, $\frac{\partial e(W)}{\partial S_j^{\lambda}} = \delta_j^{\lambda}$ Recall that, $e(w) = e(H(x_n),\ y(n))$. Then, we propagate forward until we have δ_j and δ for the final layer following the conditions that $\lambda=\lambda_0$ and j=1that is a scalar function. The error may be estimated as

$$e(W) = e\left(X_j^{\lambda_0} - y(n)\right) \qquad (7)$$

We know that $X_j^{\lambda_0} = \theta\left(S_j^{\lambda_0}\right)$

3.2 One-dimensional Filtering Technique

The delay signal is decomposed using 1D multilevel wavelet. The decomposed signal gives information about the signal as given in (8)

$$y = a_x(J,k)\,\psi_0(J,k) + \sum_{k=1}^{j} d_x(j,k)\,\psi_0(j,k) \qquad (8)$$

The coefficients are situated on the upper and lower scale on the octave range [17][23] from 1 ≤ J ≤ Jn , and 1 ≤ j ≤ Jn for the approximated and the detail signal, where J_n is the maximum scale. Usually, the wavelet coefficients $a_x(J,k)$, $d_x(j,k)$ are derived from the relationship below after full decomposition.

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right) \qquad (9)$$

Where a is the positive number which defines the signal scale that is neither by stretching or compressing the length of the signal and b is the real number that defines the signal shift that is neither by delaying or hastening the signal. While, (9) is sometimes called child wavelets derived from the mother wavelet.

3.3 Autocorrelation Function

The general form of evaluating ACF coefficient of the data observed may be evaluated by the expression (10).

$$r(q) = \frac{1}{N}\sum \frac{\left(x_1 - \overline{X}\right)\left(x_{\tau+q} - \overline{X}\right)}{\sigma(x)} \qquad (10)$$

Where $\overline{X}$, the mean of the observed data, σ is the standard deviation of x, $q \in (0,1,2.........n)$ and $-1 \le r(q) \le 1$. When r (q) is negative the signal and error are negatively correlated, r (q) is zero the signal and the error have no correlation and r(q) is positive the signal and the error are positively correlated. As the r(q) gets closer to 1, the correlation between the signal and error increases and vice versa.

3.4 First Fourier Transforms

The most common method to know the amount of the error in the signal is by applying the FFT spectrum analysis. In this work, the FFT energy spectrum of the filtered signal will be examined with respect to the growth of the signal spectrum as the filtering process continues. Our expectation is that, as the filtering level increases the signal spectrum will also increase, the evidence may be confirmed in the later part of this work. The use of the FFT technique tells us about the size of the spectrum and speed in the FFT energy spectrum. Discrete Fourier transform (DFT) may be computed using the expression (11),

$$X_k = \sum_{n=0}^{N=1} x_n e^{-i2\pi k\frac{n}{N}} \qquad (11)$$

$k \in 0. . . N-1$. In DFT, the evaluation of X_k may require N^2 operation to determine the signal spectrum size and the speed; this may be slow and difficult to investigate, while FFT requires mathematical operation $N\log_2 N$ to improve the spectrum size and the speed of the signal spectrum in the DTF spectrum. This means that as the filtering process increases the FFT speed increases by the ratio of $N^2/N\log_2 N$ which may also be written as $N/\log_2 N$, this is approximately 10 times the speed of the signal in DFT spectrum. See [21][22][24] for further details. Where $e^{-\frac{2\pi i}{N}}$ denotes N^{th} primitive root of unity and N represents the vector sum of the sampled sets.

4. RESULT AND DISCUSSION

Fig 2, depicted below is the Ethernet delay signal monitored after the simulation. This delay signal is collected from OPNET simulator, as it can be seen the delay signal varies with time, the inconsistency or the variation may be attributed to the input characteristics of the data traffic at the time of the day that shows stationary behavior with time. This is one of the major characteristics of suspecting congested or delay in the network.

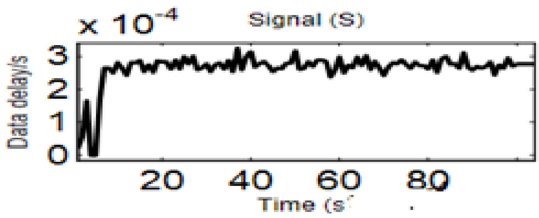

Fig 2: Data delay (original signal)

While Fig 3, presents the histogram of the data traffic showing the suspected delay part in the network; the greatest delay concentration is towards the later part of the signal which means at that point the signal have high frequency which could be undesirable for the network.

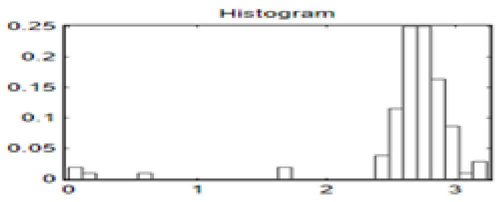

Fig 3: Histogram of the data delay

To further validate the presence of the congestion or delay on the network, the NN technology is applied to predict the error in the delay signal. We then introduced the data from the simulated network into the NN tool in order to obtain a weight that could give us desired output. In the process, the network trained several times, as the training continues; it is noticed that the successive training pairs negate the change in each stage of training to a reasonable point that is up to the stage, that the error goes below the threshold. This now confirms the degree of error on the network; at that point NN tends to recognize the input as the error reduces. Fig 4, shows the amount of the error predicted after the training, while Fig 5, and shows NN output with better data traffic even when the de-noising is not performed since at each stage of training the error reduces.

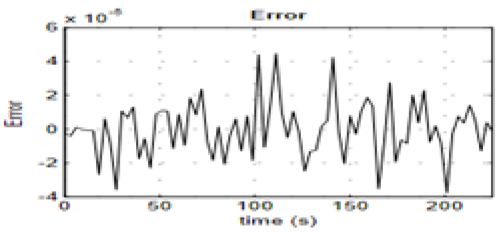

Fig 4: Error signal predicted after NN training

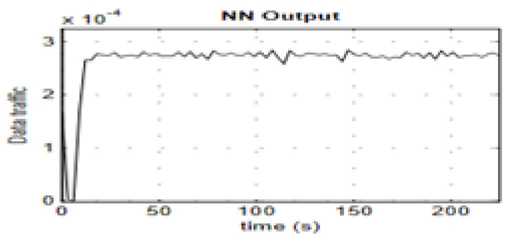

Fig 5: NN output after training

As mentioned in the previous part of this text congestion or delay is undesirable for any network user. However, it becomes necessary to monitor our network in order to provide a reasonable quality of service (QoS) to the end user, this is one of the factors that prompt us to use the wavelet technique as one of the promising methods suitable for decongesting delay in the network. The wavelet technique utilizes decomposition, compressing and reconstruction process before the signal is de-noised [8][12][13]. After the error prediction, the signal is then decomposed and analyzed with wavelet db10 type at level 3, which is a3 on J and d1, d2 and d3 on j scale respectively. The process of decomposition consist of down sampling and filtering while the reconstruction process involved up sampling and filtering, during the process of the filtering in any of the stages attention must be given to the choice of the appropriate filter because if care is not taken some vital part of the information may be lost since at that time the signal is compressed and is difficult to know the exact information about the signal which may consists of high and low frequencies. Usually, the approximated signal is situated on J octave on high scale has low frequencies and the detail signals on j has low scale and contains high frequencies.

Fig 6 shows the reconstructed signal after all stages of decomposition and filtering. Comparing Fig 2 and 6 it can be seen that some parts of the signal in Fig 2 have been smoothed meaning that the signal is de-noised which evident that Fig 2 contained a reasonable amount of noise though both the signal follows the same trend.

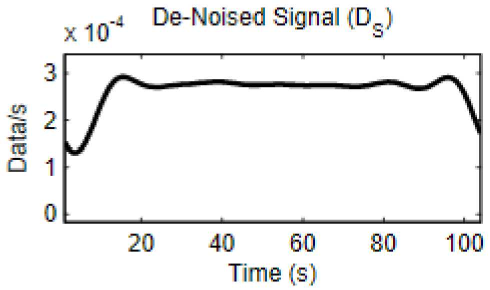

Fig 6: Reconstructed signal.

Fig 7 shows the residual signal; this is an undesirable or the signal content filtered from Fig 2, it consumes almost all the content of the signal in Fig 2. This is evidence that error occupied the larger portion of the original signal and it may be attributed to the cause of the delay in the Ethernet network.

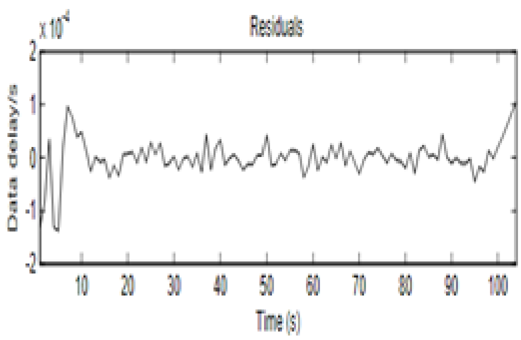

Fig 7: Residual signal after de-noising technique.

Fig 8 and 9, show the fast Fourier transform spectrum and autocorrelation function respectively. When comparing the ACF and original delay signal after decomposition and the reconstruction show poor correlation which means the network is de-noised to a reasonable extent since ACF characteristics does not comply in terms of delay while looking at the FFT spectrum in Fig 8, indicates that data traffic flow rate is tremendous due to the de-noised process compared to the traffic flow rate in Fig 2.

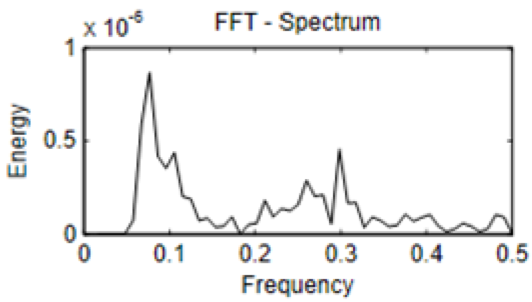

Fig 8: Fast Fourier transform spectrum

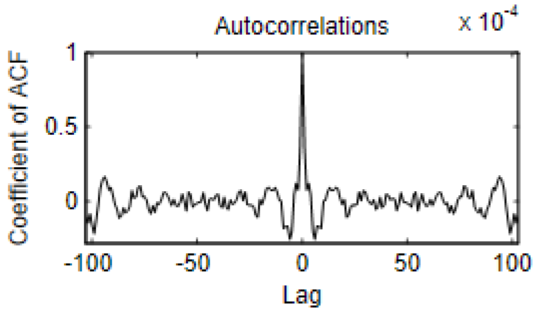

Fig 9: Autocorrelation function

5. CONCLUSION

An Ethernet corporate network had been developed, simulated and implemented with several data traffic loads. Data traffic is monitored; error is predicted in the network using NNPC. The NNPC result shows that the corporate network experience high delay due to the high input characteristics of the network. 1D de-noising is applied to de-noised error while ACF and FFT confirmed that the error content of the network has been successfully de-noised. This work is focused on the error prediction and de-noising process in the corporate network. It does not take in consideration the other causes of the network error apart from the input characteristics. It is believed that, this work has provided some vital information on how to predict and de-noise signal from congested network. We recommend that such work should use ACF and FFT to relate the affinity between delay and longtime dependence or self-similarity.

6. REFERENCES

[1] P. Abry and D. Veitch. Wavelet analysis of long range dependence traffic. IEEE Transaction on information theory., 1998.

[2] M. Athiama, T. Fouad, and K. Mansour. Loss and delay measurement of internet backbone. Computer communication special issue on monitoring and measurement , 2005.

[3] P. Hamibindu , Z. Ying, Z. M. Morley and Y. H. Charlie Understanding network delay changes by routing events. Proceeding of ACM SIGMETRICS , 2007.

[4] D. Hayes and G. Armitage. Improving co-existence and loss tolerance for delay-based TCP congestion control. Proceeding of IEEE LCN, 2010, pp. 24-31

[5] R. Jain. A . delay – based approach for congestion avoidance in interconnected heterogeneous computer network. ACMSIGCOMM computer communication review 19-5 ,1989, pp. 56-71

[6] C. B. Jean. End to end packet delay and loss behavior in the internet. SIGCOMM's-Ithaca, N.Y US., 1993.

[7] A. Nagurney, Q. Qiang. A effeciency measure for congested network. Epl Journal, 2007.

[8] J. L. Passmore, B.C. Collings, and J. P. Collings, . Autocorrelation of electrical noise. Journal Physics 63, 1999, pp. 592-596

[9] G. Pradeep. Study on internet delays. Masters Theses department of computing science Umea Sweden, 2005.

[10] A. Qazi, L. L .H Andrew, and T. Znati. Congestion control with multipacket feedback. IEEE/ACN transaction, on networking 20-6, 2010, pp. 1721-1733.

[11] P Quan , Z . Lei , D. Guanzahang, and Z. Hongcai , Two de-noising methods by wavelet transforms. IEEE transaction of signal processing, 47 -12 , 1999, pp. 3406-3409

[12] R. Q. Quian and H. Garcia. Single-trial event-related potential with wavelet de-noising. Clinical Neuro physiology, 2003, pp. 376-390

[13] C Rami. Signal de-noising using wavelets. Project report. Http//tx.technion.ac.cl/rc, 2011.

[14] D. A. Shalangwa. Evaluation of bandwidth performance in a corporate network. Academic Journal of Engineering and Technology Research 6 (1):1-5, 2014.

[15] Matlab neural network toolbox user's guide. www.mathworks. com/contact_TS.html

[16] Z. Xizheng, R. Yuanqing, W. Weixiong, "A new filtering methods in the wavelet domain for bowel sound" , International Journal of advance computer science and applications, vol. 1 no. 5, November, 2010.

[17] A. Aouinet, and C. Adnane, "Electrocadiogram denoised signal by discrete and continuous wavelet transform" signal processing international journal, 8(1):1-9, 2014.

[18] M. Misiti, Y. Misiti, G. Oppenheim and J. Michael Poggi. Wavelet toolbox for use with matlab, user's guide version 1. http://www.matworks.com

[19] A. Khotanzad, H. Elragal and T. L. Lu. Combination of neural-network forcasters for prediction of natural gas consumption. IEEE transactions on neural-network, vol 11 no 2, 2000, pp. 464-473.

[20] Reports of the Network design projects homepage: http://www.esat.kuleuven.ac.be/~h239/reports.htm.

[21] B. Peters. "FFT making technology fly" SIAM News, 26(3) May, 1993. http//www.siam.org/siamnews/mtc/mtc593.htm

[22] R. Peters, "Fourier transform construction by vector graphics", Am Journal of Physics 60, 439-441, 1992.

[23] Danladi Ali, Mukaila A. Application of Wavelet De-noising Technique on a Congested Internet Protocol (IP) Network. International Journal Computer Application 100(5):12-15. August, 2014.

[24] Danladi Ali and Vlada N. Y. Wavelet based path loss modeling for global system for mobile communication in an urban environment International Journal of Science and esearch 3(7): 1929-1932