Modeling And Comparison Of Tcp Throughput For Wired And Wireless Communication System In Ipv4 Network.

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Abstract

Communication is the transfer of information from one point to another via a channel which could either be wired or wireless. Wired and Wireless networks are standardized by IEEE 802.3 and IEEE 802.11 respectively and vastly installed in local area networks (LANs) due to low cost and reliability. A good network must provide predictable, reliable and guarantee quality of services. This paper investigated the performance of IEEE 802.11g WLAN and IEEE 802.3 Ethernet networks, with emphasis on TCP throughput and Delay in the IPV4 transmission protocol based on bit rate transmitted. The investigation was conducted on two platforms in delta state university e-library wired and wireless network infrastructure. Measurements were taken and data were logged in accordingly. From the results analysis, empirical models were statistically formulated for the TCP throughput for both networks. From the results obtained, the TCP throughput in the IPV4 transmission protocol showed reasonable dependence on bit in both wired and wireless networks. While for the TCP delay model, the throughput is relatively dependent on delay. The formulated models for both networks were assessed using RMSE for statistical adherence. The TCP throughput model showed RMSE value of 0.74 less than the TCP throughput of wireless RMSE value of 1.07, which is an indication of better performance. TCP delay in wireless and wired models were equally compared, the wireless showed RMSE value of $2.33*10^{-4}$ higher than that of the TCP delay wired of RMSE value of $1.53*10^{4}$, which is an indication of poor performance, under the environment being considered.

Keywords: IEEE 802.11, IEEE 802.3, RMSE, throughput, modeling

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1.0 Introduction and Background Study

Communication is the transfer of information from one point to another via a medium, either wired or wireless. Wired and Wireless networks are standardized by IEEE 802.3 and IEEE 802.11 respectively and vastly installed in local area networks (LANS), due to low cost and reliability. A good network must provide predictable, reliable and guaranteed good quality of service. The IEEE 802.3 standard uses carrier sense medium access with collision detection (CSMA/CD) to control access of the shared transmission medium. End hosts monitors the carrier sense signal in the medium and deters-transmission of data frame until the medium is idle and then start data frame transmissions [1-3]. The wireless LAN is based on the IEEE 802.11 standard using carrier sense multiple access with collision avoidance (CSMA/CD) MAC protocol as access method [4].

Transmission control protocol (TCP) used by wired and wireless local area networks make up about 78% of all internet traffics. A reliable and well design LAN is normally evaluated by performance characteristics like, throughput, latency, response time, arrival rate, loss and routing. ln wired and wireless LAN implementations must provide minimum throughput to provide adequate coverage. Predicting the performance of TCP throughput of both wired and wireless LANs is important for thorough understanding of their performance. [5-6]. In [7], the authors developed models to predict TCP and UDP throughputs in wireless

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network and [8] developed a model to predict TCP throughput, all based on the SNR observed in wireless network. [9], evaluated the effect of various security mechanisms on network throughput by varying the factors such as traffic type, packet size and transmits power of access point. Their results showed that the user datagram protocol (UDP) utilizes more bandwidth and the throughput is not all that affected by other factors. In ([10], the authors evaluated and compared the performance of TCP and UDP over wired –cum- wireless LAN. Their comparison was based on throughput and good put and their results showed that the TCP protocol has better performance than the UDP protocol.

In [11] the authors evaluated and compared the performance of IEEE 802.11n and IEEE 802.11g in terms of coverage and throughput. Their results showed that IEEE 802.11n has better performance than the IEEE802.11g. In [12], the authors evaluated the performance of wired and wireless communication networks with focused on throughput and delay in TCP, IPV4 and IPV6 networks generally. Their results showed that the IPV6 network has higher throughput. In ([13], the authors investigated the performance of the IEEE 802.3 based on packet size to analyze the network performance. They used simulation for their work. Their results showed that for packet size larger than the maximum transmission unit of the network, throughput increased and that implied better QOS for packet transmitted within the network. In [14, 15], the authors investigated voice over internet protocol (VoIP) traffic that went through heterogeneous networks, the quality of service (QoS) suffers degradations. The magnitude of such degradations were investigated in terms of these performance metrics such as, throughput, jitter and crosstalk. They used OPNET simulator and their results showed that throughput of the WiFi-WiMAX network is lower than that of WiFi alone Most researches were based on general measurements of TCP and UDP throughput and delay in both networks but, TCP throughput models for IEEE 802.11g WLAN and IEEE 802.3 Ethernet LAN based on the Bit Rate are rarely implemented or not available in IPV4 operating networks and this is the focus of this paper. The investigation was conducted in two environment in delta state university e-library wired and wireless network infrastructure. The measurements were taken and multiple linear regression method was used to develop empirical models for the measured throughputs in both platforms. The models performance were compared using root mean square error method (RMSE).

3. Materials and Methods:

The measurement method used in [12] was employed in this research. The Delta State University e-library wired and wireless networks infrastructure were used to carry out the measurements. The measurements were carried out with (10) computers on both wired and wireless networks. The wired network consists of ten (10) computers, one server and a switch. The workstations computers are 'window 10 Pro'. The server is 'window 10 Pro computer' with, the following specifications, processor lntel® Pentium ® CPU 2.66GHZ, installed memory (RAM): 2.00GB and 32-bit operating system. The switch is CISCO SF-100-24, 24-port 10/100 switch. The (LAN) local area network is linked with UTP CAT 6E LAN cable (untwisted pair category). The systems were configured with static configurations. While the wireless network is made up of ten (10) computers, one router and a server. The workstations computers and the server are of the same make with the same specifications like those of the wired network. The router is TP-link with specification IEEE 802.11g, IEEE802.3/3U with frequency of 2.4GHz-2.4835GHZ. One measurements software (wireshark) and three analysis software (Matlab, MS Excel and SPSS) were used to conduct the measurements and analyzed the data.

3.1 Data Computation.

The software gave the TCP throughput statistics captured directly, the delay statistics is the only parameter that is computed from the captured data from the ten test of both wired and wireless networks using equations 3.2 and the average data values are presented in section 4. Note in the computations maximum of 30 captured data serially from the transmission protocols IPV4 were used irrespective of the volume. If the captured data are less than thirty (30) serially such, numbers were used for the computations.

Throughput (T) is computed as: [16]

$$T = \frac{Total\ number\ of\ bytes\ transmitted\ x\ 8}{Total\ duration\ (time)} = \frac{\Delta B}{\Delta t_s} \quad (3.1)$$

T, is throughput

ΔB, is total bytes transmitted

Δt_s, is Total duration (time)

$$Delay\ (D) = \frac{Throughput}{Total\ duration\ time\ (\Delta t_s)} = \frac{T}{\Delta t_s} \quad (3.2)$$

D, is Delay
T, throughput
Δt_s, is total duration time

$$Bit = Total\ number\ of\ bytes\ transmitted\ \times 8 \quad (3.3)$$

3.2 SAMPLE CAPTURED DATA FOR WIRED NETWORK

Table 3.1: Test One of Wired Network TCP Throughput and Delay for IPV4 Captured Traffic Statistics

S/N	Type of Traffic	Packets	Bytes (MB)	Duration (MS)	Throughput (Mbps)	Delay (MS)	Bit (MB)
1	Video and Document Files	30	3515	3137.1349	8.96	0.003	28120
2		31	3607	3364.8601	8.58	0.003	28856
3		31	3607	3132.6795	9.21	0.003	28856
4		31	3607	3162.1875	9.13	0.003	28856
5		32	3699	3295.7716	8.98	0.003	29592
6		32	3699	3390.8598	8.73	0.003	29592
7		33	3942	3521.4475	8.96	0.003	31536
8		36	4770	3369.1408	11.33	0.003	38160
9		48	24732	2688.293	73.6	0.027	197856
10		48	24732	2688.3	73.6	0.027	197856
11		48	24732	2688.2896	73.6	0.027	197856
12		48	24732	2688.338	73.6	0.027	197856
13		48	24732	2688.287	73.6	0.027	197856
14		48	24732	2688.2629	73.6	0.027	197856
15		52	26797	2691.1441	79.66	0.030	214376
16		60	4124	3174.0755	10.39	0.003	32992
17		70	4880	3398.2775	11.49	0.003	39040
18		72	5026	3553.9452	11.31	0.003	40208
19		102	7216	3486.3229	16.56	0.005	57728
20		104	7362	3579.2109	16.46	0.005	58896
21		114	8092	3505.1437	18.47	0.005	64736
22		118	8384	3536.1532	18.97	0.005	67072
TOTAL		1236	250719	69428.13	698.79	0.246	2005752
AVG		**56.18**	**11396.32**	**3155.82**	**31.76**	**0.011**	**91170.55**

To understand the captured and computed data of table 3.1, few sample computations of the performance metrics being evaluated are shown below.

Throughput (T)

$$\frac{\Delta B}{\Delta t_s} = \frac{28120}{3137.1349} = 8.96\text{Mbps}$$

Delay (D)

$$\frac{T}{\Delta t_s} = \frac{8.96}{3137.1349} = 0.003ms$$

3.3 Developed Models Performance Comparison using Root Mean Square Error (RMSE) Method

The performance of the developed models for both wired and wireless network were compared using the root mean square error (RMSE) method. It is a good measured of how accurately the model predicts the response and is the variance of the residuals that are used to determine the performance of the different models for both positive and negative deviation.

When using the RMSE, the higher negative derivatives are converted to positive values first. That is done by squaring them before adding it to the square of the positive derivatives to get the total deviation from the mean that is squared to get the RMSE. The RMSE indicates the absolute fit of the model to the data collected (that is how closed the observed data points are to the models predicted values. The lower the value of the RMSE indicates better performance of the model.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(\bar{y}_1 - y_1)^2}{n}}$$

y_1 is the observed value for the ì observation
$\hat{y}_1$ is the predicted value.
They can be positive or negative as the predicted value under or overestimates the actual values.
Squaring the residuals, averaging the squares and taking the square root gives the RMSE

4.0: Results and Discussions

Table 4. 1: Measured Variables Average Values For Throughput and Delay Model Development in Wired Network.

Test	Duration (MS)	Throughput (Mbps)	Delay (ms)	Bit (M)
1	3155.82	31.76	0.011	91170.55
2	3200.39	23.23	0.008	68863.27
3	3170.13	26.06	0.009	76270.18182
4	3156.79	23.59	0.008	67982.26
5	3187.57	22.13	0.008	64168.80
6	3163.60	22.18	0.008	64088.80
7	3218.06	21.32	0.007	62066.29
8	3136.34	22.29	0.008	64509.33
9	2750.74	23.04	0.009	62716.80
10	3121.65	25.94	0.009	74712.76

Table 4.2: Measured Variables Average Values for Throughput and Delay Models Development in Wireless Network:

Test	Duration (MS)	Throughput (Mbps)	Delay (ms)	Bit(M)
1	3191.29	30.60	0.010	95538.15
2	3248.45	26.86	0.009	84888.84
3	3288.73	15.68	0.005	51849.60
4	3333.82	23.39	0.007	76202.29
5	3325.00	15.89	0.005	52588.24
6	3321.24	13.27	0.004	44070.48
7	3317.20	22.37	0.007	68435.79
8	3426.52	14.55	0.004	49962.67
9	3290.58	26.95	0.009	82437.57
10	3337.09	19.98	0.006	66684.57

Given in table 4.1 and 4.2 above are the average values for Throughput, Durations, delay and Bits measured and computed for the ten test samples data in both networks. The above statistics were used to develop the empirical models, duration and bit are the independent variables.

The regression analysis results for the various throughput and delay predicting models developed for both wired and wireless networks are presented as follows:

Table 4.3: TCP throughput Model Regression Statistics for wired

Regression Statistics	
R. Square	0.97367
F. Value	296
Significance F Value	1.33E-07
Intercept	0.455
Bit	0.0003
Standard Error	0.52

Model Equation

$$\hat{Y} = 0.0003 * x + 0.4546 \quad \text{.......................} \quad 4.1$$

Throughput = 0.0003(slope)* x (bit) + 0.4546 (intercept)

4.1: Predicting TCP Throughput Model for Wired

From the regression statistics of table 4.3 above, the throughput predicting model is presented in equation (4.1). Y, is the throughput, 0.0003 is the slope, (x) is the bit and 0.4545 is the intercept. The model has R Square value of 0.973673458. The high value of R^2 indicates a high correlation between the computed Throughput and the predicted Throughput data, which also shows the validity and reliability of the developed model. The model also has F value of 295.8758, 1.33E-07 significance F value.

Table 4.4: Residual Output for TCP Throughput Model (wired)

RESIDUAL OUTPUT			PROBABILITY OUTPUT	
Observation	*Predicted Throughput (Mbps)*	*Residuals*	*Percentile*	*Throughput (Mbps)*
1	21.57210085	-0.253053233	5	21.31905
2	22.28746306	-0.158963061	15	22.1285
3	22.26024376	-0.077743756	25	22.1825
4	22.40332657	-0.11570752	35	22.28762
5	21.79343268	1.242567317	45	23.036
6	23.8847166	-0.652443871	55	23.23227
7	23.58495997	0.00199655	65	23.58696
8	25.87495444	0.065045558	75	25.94
9	26.40485303	-0.340307574	85	26.06455
10	31.47457223	0.288609589	95	31.76318

The predicted throughputs and their residual values are given in table 4.4. The observation column is the ten test of data being analyzed. The residual value added to the predicted Throughput value gives the computed throughput values of table 4.1.Take observation(1) in table 4.4 for an example, predicted throughput, (21.57210085 + (-0.253053233) = 21.31905Mbps also equal to the probability output of table 4.4. And this indicates the validity and reliability of the developed predicting model.

Table 4.5: Summary Output for TCP Wireless Throughput Model.

Regression Statistics	
R. Square	0.9909
F. Value	877
Significance F Value	1.83E-09
Intercept	-2.2716
Bit	0.0003
Standard Error	0.61

Model Equation

$$\hat{Y} = 0.0003 * x - 2.2716 \qquad 4.2$$

Throughput = 0.0003(slope)* x(bit)- 2.2716(intercept)

4.2. TCP Throughput Model for (Wireless)

From the regression statistics of table 4.5, the throughput predicting model is presented in equation (4.2). Y, is the throughput, 0.0003, is the slope, x is the bit and (-2.2716) is the intercept. The model has R Square value of 0.990959931, the high value of R^2 indicates a high correlation between the computed throughput and the predicted throughput data, which also shows the validity and reliability of the developed model. The model also has F value of 876.949.

Table 4.6: Residual Output for IPV4 Wireless TCP throughput Model.

RESIDUAL OUTPUT			PROBABILITY OUTPUT	
Observation	*Predicted Throughput (Mbps)*	*Residuals*	*Percentile*	*Throughput (Mbps)*
1	12.94476648	0.320948	5	13.26571
2	14.97918694	-0.42752	15	14.55167
3	15.63069605	0.048304	25	15.679
4	15.88572765	0.005449	35	15.89118
5	20.75282669	-0.77426	45	19.97857
6	21.35747683	1.014628	55	22.37211
7	24.03904643	-0.64857	65	23.39048
8	27.03828892	-0.17513	75	26.86316
9	26.19192663	0.753291	85	26.94522
10	30.7152199	-0.11714	95	30.59808

The predicted Throughput and their residual values are given in table 4.6 above. The observation column is the ten test of data samples being analyzed. The Residual value added to the predicted Throughput value gives, the computed throughput values of table 4.2. And this indicates the validity and reliability of the developed throughput prediction model.

Applying the RMSE Model of Equation 3.2 for the RMSE Computations for Wired and Wireless Networks

Wired network

TCP throughput model
Predicted throughput residuals for wired in table 4.7

-0.253053233, – 0.158963061, – 0.077743756, – 0.11570752, 1.242567317, -0.652443871, 0.00199655, 0.06504558, -0.340307574, 0.288609589

$$RMSE = \sqrt{\frac{\sum(0.0640 + 0.0253 + 0.0006 + 0.1157 + 1.2426 + 0.4257 + 0.0019 + 0.0650 + 0.1158 + 0.2886)^2}{10}}$$

$$= \sqrt{\frac{\sum(2.3452)^2}{10}}$$

$$= \sqrt{\frac{5.49996304}{10}}$$

$$= \sqrt{0.549996304} \quad = 0.7433249868 \quad \approx 0.74$$

TCP delay model
Predicted delay residuals for wired in table 4.8

$$-5.741x10^{-5} - 3.74x10^{-5} - 1.428x10^{-5} - 3.668x10^{-5} - 0.00045194 - 0.000204 - 5.479x10^{-7} - 6.858x10^{-6} - 0.0001256 - 3.0751x10^{-5}$$

$$= \sqrt{\frac{\sum\left(3.2959081x10^{-9} + 1.39876x10^{-9} + 2.039184x10^{-10} + 1.3454224x10^{-9} + 0.00045194 + 4.1616x10^{-8} + 3.0019441x10^{-13} + 1.577536x10^{-8} + 3.0751x10^{-5}\right)^2}{10}}$$

$$= \sqrt{\frac{\sum(4.827544788 \times 10^{-4})^2}{10}}$$

$$= \sqrt{2.33054886 \times 10^{-8}} \quad = 1.526603704 \times 10^{-4}$$

$$= 1.53 \times 10^{-4}$$

Wireless network
TCP Throughput Model Table 4.9

Predicted throughput residuals of table 4.2.2.

0.320948, –0.42752, 0.048304, 0.005449, -0.77426, 1.014628, -0.64857, -0.17513, 0.753291, -0.11714

$$RMSE = \sqrt{\frac{\sum(0.320948 + 0.182773 + 0.048304 + 0.005449 + 0.599479 + 1.014628 + 0.420643 + 0.030671 + 0.753291 + 0.013722)^2}{10}}$$

$$= \sqrt{\frac{\sum(3.389908)^2}{10}}$$

$$= \sqrt{1.149147625} \quad = \quad 1.071983034 \approx 1.07$$

Predicted delay residuals for wireless in table 4.10

0.000104, -9.7x10⁻⁵, 1.43x10⁻⁵, 2.61x10⁻⁸, -0.00024, -0.00022, 0.000357, -6.5x10⁻⁵, 0.000261, -0.00012

$$= \sqrt{\frac{\sum\left(0.000104 + 9.409x10^{-9} + 1.43x10^{-5} + 2.61x10^{-8} + 5.76x10^{-8} + 4.84x10^{-8} + 0.000357 + 4.225x10^{-9} + 0.000261 + 1.44x10^{-8}\right)^2}{10}}$$

$$= \sqrt{\frac{\sum(7.36460134 \times 10^{-4})^2}{10}}$$

$$= \sqrt{5.42373529 \times 10^{-8}} \quad = \quad 2.328891429 \times 10^{-4} \quad \approx \quad 2.33 \times 10^{-4}$$

In table 4.7 to 4.10, is the computed RMSE for TCP throughput and delay models for both wired and wireless networks.

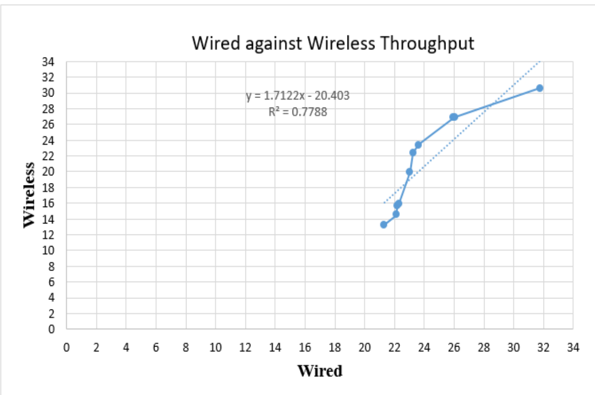

Figure 4.1 Graph of Wired and Wireless Computed Throughput

Figure 4.1 is a plot of computed throughput of both wired and wireless network. The low value in the computed wireless throughput was due to signal fluctuation, intermittent connectivity, packet loss and interference in the network.

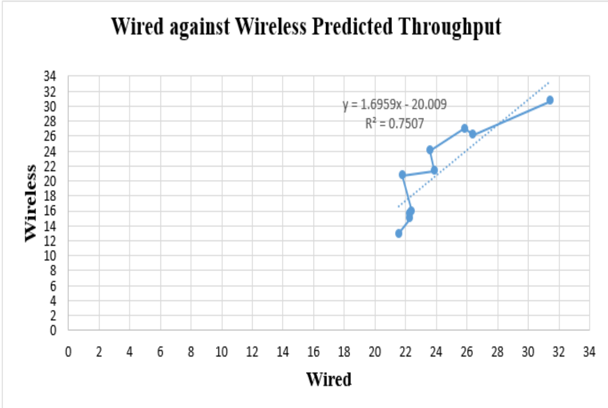

Figure 4.2 Graph of Wired and Wireless Predicted Throughput

Figure 4.2 is a plot of predicted throughput of wired and wireless network. The low value in the wireless predicted throughput were due to signal fluctuation, intermittent connectivity, packet loss and interference in the network.

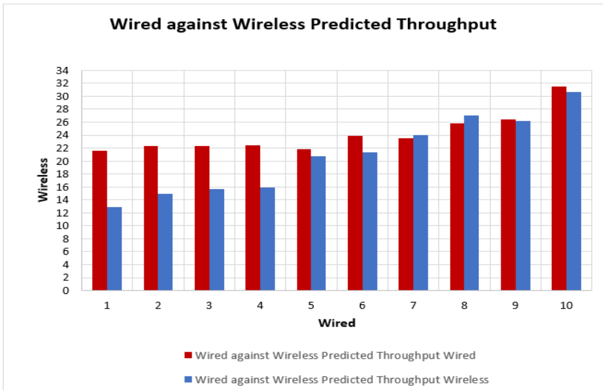

Figure 4.3 Bar Chart of Wired and Wireless Predicted Throughput

Figure 4.3 above is the bar chart comparing the wired against the wireless predicted throughputs. The low values in the wireless predicted throughput were due to signal fluctuation and load variability in the network.

4.3: Discussion

The developed empirical models for both wired and wireless networks performance assessment were compared using the RMSE method. The TCP throughput empirical model for the wired network has RMSE value of 0.74 which is less than the TCP throughput empirical model for wireless with RMSE of 1.07 which is an indication of better performance of the wired developed model. The poor performance or low value of the RMSE of the wireless network is due to signal fluctuation, intermittent connectivity and packet loss due to channel interference in the network and that is shown in figure 4.1, 4.2 and 4.3. The wired developed model is preferable under the area being considered. The practical application of this wired model is that it can be deployed to predict throughput in any of the infrastructures.

4.4: Conclusion

The performance assessment of the developed empirical models for both wired and wireless were compared using the RMSE method and the wired showed lower RMSE than the wireless which is an indication of better performance under the area being investigated.

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