



NETWORK TRAFFIC ANALYSIS USING QUEUING MODEL AND REGRESSION TECHNIQUE

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ABSTRACT

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The flow of network traffic on business and academic networks has been on the increase. This necessitates the issue of proper management of traffic network flow in order to ensure optimum performance. Network analysis looks at certain performance measures with a view to gaining insight into the pattern of flow in the network. This research employs a queuing model and regression technique to analyse the performance of the Federal University of Technology, Akure (FUTA) network. Traffic data flows were captured over a period of four weeks using Wireshark capturing tool at different strategic locations in the campus. The arrival rate and service rate were used to obtain the intensity of traffic at these locations. Analysis of the data assisted in determining the variability in the traffic flow. The major contribution of this research is that it developed an empirical model that identified variables that significantly determines network traffic. The model could assist network administrators to monitor, plan and improve on the quality of service.

Contribution/Originality: This paper's primary contribution is that it employed multiple regression to identify the factors that determine network traffic. The model could be used to plan the usage and monitoring of computer networks

1. INTRODUCTION

Computer networks which are the interconnection of a mix of hardware and software are common features in today's globalised world. It has become a major vehicle for communication and movement of data from one source to another. The volume and type of data being moved from one end to another across the network are on the increase. The data being moved across a network constitutes the network traffic. Computer networks are designed to handle a certain amount of traffic in order to ensure an acceptable level of network performance. Network performance deteriorates if the offered traffic exceeds the network capacity [1].

Network traffic analysis involves capturing the flow of data through the network, inspecting it closely to determine the volume, rate and pattern. The analysis enables one to identify performance problems, locate security breaches, analyse application behaviour, capacity planning, investigate the usage of network resources and monitor the quality of service [2]. Network capturing involves monitoring a computer network in order to detect slow or failing components and to notify the network administrator in case of an outage, and to gather statistic for proper administration [3]. Network traffic flow analysis could also be achieved by the application of queuing theory through the study of waiting for lines which are created when the demand exceeds the installed capacity [4].

Queuing theory is a branch of operations research. It uses mathematics formulae and concepts to analyse waiting for lines and obtains the intensity of traffic. Several queuing models have been developed such as a single server, single queue (M/M/1), One server, finite queue (M/M/1/c), multi-server, infinite queue (M/M/c) and so on. The procedures employed include obtaining an average length of items on the queue and waiting time of items in the system. These are used to determine the performance of the network.

2. REVIEW OF RELATED WORKS

Several types of research have been carried out in the area of network traffic analysis with different evaluation techniques proposed in the literature. The performance evaluation and modeling of Internet network traffic in an academic institution using Federal University Technology, Akure (FUTA), Nigeria as a case study has been carried out [5]. The research was motivated by the need to monitor and evaluate network traffic which is a major weakness in internet network system. It evaluates the overall performance of FUTA's internet network based on performance parameters such as the number of users connected, protocols used, byte used, uptime and downtime, and dropped packet. Netflow was used to capture traffic in order to obtain these parameters. Questionnaires were also administered to students at different areas to determine the rate of network availability but only measurement evaluation was carried out.

Analysis and performance evaluation of FUTA network was presented in Dahunsi and Nweithie [6]. The research focuses on the quality of service provided to its users. Data were collected by administering a questionnaire to determine the availability, accessibility and connectivity rate at various areas under the coverage of the network. A four-point likert scale: Strongly agree, Agree, Disagree and Strongly Disagree was used to elicit a response from student. Data was further analyzed using Statistical Package for Social Sciences (SPSS). The limitation of the research is that information provided during data collection could be based on subjective reasoning of individual which will affect the result.

A Service Model Estimation for Technical Efficiency of Internet Service Providers in Western Nigeria was proposed in Alese, et al. [7]. The research was motivated by the increasing demand for service, and the emergence and possibility of new broadband service. The methodology involved the use of questionnaire for data collection, and the collected data were analyzed using descriptive statistics such as mean, standard error, standard deviation, log likelihood, minimum and maximum values. The modeling and estimation of the stochastic Internet service provider function are done using the Statistical Package for Social Scientists (SPSS). The result of the research work shows that network characteristics such as transmission medium and transmission bandwidth have a significant effect on the technical efficiency of a service provider in Western Nigeria.

In Hong, et al. [8] a web-based internet/intranet network traffic monitoring and analysis system was presented, the need for more tools to monitor individual network segment on the network motivated the researcher of this work. The objective of the research work was to design a system that will monitor, analyze and view the result of such analysis from any site, the method used was WebTrafimon which consist of two parts namely; probe and viewer. The work was implemented on portable web-based network and the user could view the network analysis. The limitation of the work is that it could not monitor and analyze traffic in a switch network and requires very large data in Gigabit.

A non-intrusive network traffic monitoring and analysis has been proposed [9]. The research was motivated by the increasing use of the World Wide Web which led to an increase in network traffics and complete reliance on the internet by many institutions and establishments for their jobs. The research aimed at monitoring internet traffic on the basis of host, protocol and time of the day so that University Internet traffics pattern could be determined. The outcome of the research made it possible for the University to monitor live network traffic without adversely impacting the performance and also identify and monitor traffic patterns on basis of host, protocols and time of the day. Result as implemented on Obafemi Awolowo University (OAU) network shows statistical

information about packets and bytes transferred on an hourly, daily and monthly basis. The limitation of the research is that it only monitored four out of over 20 servers in the university.

An overview of different analytic queuing models for traffic on road networks was presented in [Van Woensel and Vandaele \[10\]](#). Congestion, which is a function of the number of vehicles on the road, shows the need for a traffic model needed for analysis. The queuing model was used to adequately model uninterrupted traffic flows. The limitation of this research is that the physical characteristics of the road network cannot be mapped onto the parameters of the queuing model.

Minimization of traffic congestion has been achieved using queuing theory [\[11\]](#). The motivation of this research work was the need to reduce traffic congestion of vehicles on the road because congestion on roads is on the increase. M/M/1 queuing system was used for the analysis, in which traffic police is the service facility, the limitation is that analysis was basically done on road traffic and not on the computer network. Other research on the application of queuing theory in monitoring and estimating the volume of traffic on road networks could be found in [Palash and Saha \[12\]](#); [Kembe, et al. \[13\]](#); [Dike, et al. \[14\]](#); [Mala and Varma \[15\]](#) and [Lartey \[16\]](#).

A study carried out by [Mohammed, et al. \[17\]](#) at Ahmadu Bello University, Nigeria opined that packet sniffers should be installed and configured as a monitoring server on a network to ensure detailed analysis in order to identify productive and unproductive applications. Unproductive network-based applications responsible for consuming valuable bandwidth of the university was identified thereby enhancing the utility of productive applications on the university network. Network congestion estimation using packet time series analysis was presented in [Lu, et al. \[18\]](#). The objective was to estimate network congestion state without congesting or saturating the network and also evaluate the performance of packet time series analysis by comparing it with the typical congestion tool. Packet time series analysis (PTSA) was used as a framework based on queuing theory and inter-arrival time to estimate network congestion-related parameters without saturating the network. Packet time series analysis (PTSA) was proved to be efficient for network congestion estimation based on the simulative and experimental results. However, this analysis is not sensitive to the distribution of background flow.

Network monitoring and analysis by packet sniffing method were presented in [Jadav \[19\]](#). The work describes the process of Network Interface Card (NIC) that captures all traffic that is flowing inside or outside the network. The method was used to monitor the network in order to detect anomalies with a view to designing tools that resolves them so that it would not consume many memories before they are detected. Time series analysis and artificial neural network (ANN) has been employed to develop a model for predicting packet loss rate [\[20\]](#). The ANN was trained using Particle Swarm Optimisation (PSO) algorithm. The model was found to improve the quality of real-time multimedia traffic through accurate prediction of packet loss rate thereby reducing network congestion. The work of [Shoab and Das \[21\]](#) also used ANN to develop a model for time series analysis of FIFA World Cup data. Correlation and Means Square Error of the results showed improved prediction accuracy. [Song and Gan \[22\]](#) employed Ant Colony Algorithm to forecast network traffic as a means of preventing network congestion and paralysis. The method achieved a higher prediction accuracy.

The performance of modern large scale network is affected by many factors which may lead to chaotic changes thus making network traffic unpredictable. Network prediction model proposed in [Xiang, et al. \[23\]](#) was able to monitor the trends of network traffic thereby reducing network congestion and paralysis. Non-linear prediction algorithms have been used in monitoring and predicting network traffic [\[24\]](#). The method showed greater efficiency in prediction, parameter optimization and reduction in prediction error. The present work employs the use of a queuing model and regression technique to monitor and analyse network traffic in a tertiary educational institution.

3. DESCRIPTION OF FUTA NETWORK

The Federal University of Technology, Akure (FUTA) is an academic and research environment with a campus area network that has a single server system with many nodes attached, users of the network are Staff and students of the University. The University comprises of two axes which is Obanla and Obaekere. The university's network is a Local Area Network (LAN) managed by the Computer Resource Center (CRC) located at Obanla and uses CISCO networking equipment. The network comprise different segments which are connected via cables and Wireless LAN. It employs Star topology and its Host Internet Service Provider (ISP) are MTN and Main One. CRC uses 2 Gigabyte Downlink and 1Gigabyte Uplink from Main One, while 1Gigabyte Downlink and 500Mb Uplink is supplied by MTN. This gives a total of 3Gigabyte Downlink and 1.5Gig Uplink as at the time of taking the measurement. If ISP fails, then the other comes up. The two could also combine together to boost signal strength. The masts located at Obanla serves both axes. The mast is a ground-based structure that supports antennas at a height where they can send and receive radio waves and signals. The internet service is received via radio signals at CRC and distributed to other buildings on campus via radio link which is the wireless outdoor radio. When signals are sent, the outdoor radio of the building receives it and pulls them down to access point. Access point (transceiver) enables the transmitting and receiving of signal and are then sent to the switch. Packets sent from a source then form queues at these intermediate node.

4. PARAMETERS FOR QUEUING MODEL ANALYSIS

The parameters that were used for queuing model analysis include the arrival rate and service rate of TCP and UDP protocol-based packets.

- a. Arrival Rate is the rate at which packets arrive at an intermediate node from a source and these packets arrives at time intervals. For the purpose of this research, the arrival rate of packets captured was set to packets per second. For instance, there can be up to 600 packets arriving at the intermediate node per second due to high signal strength. However, loss or low signal strength can disrupt data capturing as it causes delay and un-orderly arrival of packets that is, when the number of packets that arrives within one second is displayed, the next arrivals might be after 10 seconds, then 15 seconds and keep increasing. Thereafter, the Mean Arrival Rate (MAR) of packets for each day was computed as shown in Equation 1.

$$MAR = \frac{\text{total number of packet captured per day}}{\text{total time of packets arrival in seconds}} \quad (1)$$

- b. Service Rate is obtained after the service time is determined. It is the time it takes for a packet to be processed by its intermediate node before transmission to its destination. The service time for each conversation is determined by Equation 2.

$$\text{service time} = \frac{\text{packet size (bits)}}{\text{bit rate (bit/sec)}} \quad (2)$$

where bit rate is the number of bits that is transmitted in bits per second for each conversation, and packet size represents the bytes of the packet. The bit rate and packet size (bytes) was obtained in the 'conversation window' of Wireshark. After the service time for each is obtained, the Mean Service Rate (*MSR*) per day is computed using Equation 3.

$$MSR = \frac{\text{total service time for each conversation per day}}{\text{total number of conversations per day}} \quad (3)$$

In queuing theory, when service rate is less than the arrival rate ($\mu < \lambda$), traffic intensity is high, thereby, resulting in an unstable system. A traffic intensity greater than one Erlang means that the rate of packet arrival exceeds service rate. Therefore, for a stable system, traffic intensity is lesser than one Erlang (i.e. $\mu > \lambda$). With high traffic, performance is reduced and could result in high latency and packet loss. Comparison of the mean arrival rate and mean service rate, that is, traffic intensity (T) at each strategic location based on weekly capture was done mathematically to determine the week with the highest and lowest traffic.

5. MULTIPLE REGRESSION MODEL

Multiple regression model was used to determine the relationship between the total bytes used, the total number of users connected to the Internet, and the total number of users connected to the network. The equation for multiple regression model is specified in Equation 4.

$$Y = a + b_1X_1 + b_2X_2 + e \quad (4)$$

where Y is average bytes used, X_1 is total time spent on the network, X_2 is total number of users connected to the network, a is constant term while b_1 and b_2 are parameters to be determined and e is residual error. Analysis was done based on data collected from captured traffic.

6. DATA CAPTURING ON THE NETWORK

Packets flowing across the network are routed from source to destination and are either governed by a 'stateful' or 'stateless' protocol (TCP/IP protocol suite). When a request is sent over the network, data packets are routed from source to destination via network devices such as routers and switches. If over a period of time, a number of packets queue up and wait, then it results in traffic [20]. This research monitors the flow of packets across FUTA network. Wireshark, which is an open source real-time capturing tool with cross-platform capability and graphical user interface was used. Packets were captured three times daily namely morning, afternoon and night for a period of one month.

6.1. Preprocessing Captured Data

The captured traffics usually contains both bad and good packets hence, it is necessary to perform preprocessing in order to filter the good packets from the bad packets. Wireshark has two filtering methods namely

- a. Filtering while capturing, that is, instructing wireshark to only record those packets that meet specified criteria while capturing; and
- b. Display filter

The display filter is used for the purpose of this research in order to view all captured traffic, thereafter, packet of interest were filtered. It involved selecting from the packets that have been captured based on the color coding. By default, green indicates TCP traffics, light blue is identified as UDP traffic, blue color is for DNS traffics, and black color indicates bad packets or packets with checksum error. Bad packets are packets that were either dropped because the connection is not established, packets with checksum errors or packets that are delivered out of order. Packets with checksum errors are packet with the incomplete parity bit.

7. DATA ANALYSIS AND DISCUSSION

7.1. Data Analysis

M/M/1 queuing model which is a single server queuing system with infinite capacity was used for the performance measure. The standard equations adopted from the work presented in [Asrodia and Sharma \[3\]](#) was used for the analysis. Traffic intensity (T) which is a measure of the strength of traffic in the buffer memory of an intermediate node is given in [Equation 5](#).

$$T = \frac{\lambda}{\mu} \quad (5)$$

where λ represents the arrival rate and μ denotes the service rate. $T < 1$ denotes a steady state, but unstable if $T > 1$, this factor measures the efficiency of the system.

Average number of packet in the system (L_s) which is the number of packet in queue plus the number being served is given as depicted in [Equation 6](#).

$$(L_s) = \frac{T}{1-T} \quad (6)$$

Average number of packet in the queue (L_q) that is, the average number of packets waiting in the queue before it is served is described in [Equation 7](#).

$$(L_q) = \frac{T^2}{1-T} \quad (7)$$

Waiting time of packets in the system (W_s) is the average time a packet spends in queue plus the average time required for service is depicted in [Equation 8](#).

$$(W_s) = \frac{L_s}{\lambda} \quad (8)$$

Waiting time of packets in the queue (W_q): the time a packet spends on the queue is described in [Equation 9](#).

$$(W_q) = \frac{L_q}{\lambda} \quad (9)$$

It can also be expressed as shown in [Equation 10](#).

$$(W_q) = \frac{T}{\mu - \lambda} \quad (10)$$

7.2. Summary of Packets Arrival Rate and Service Rate per Week

[Table 1](#) shows the summary of arrival and service rate for each week, the service rate of packet for week 2 and week 4 is high, which is the reason for less traffic intensity during these periods.

Table-1. Arrival rate and Service rate of Packets for each week.

Week	Average Arrival Rate (sec)	Average Service Rate (sec)
Week 1	1328.0	1400.0
Week2	483.0	2166.0
Week 3	1280.0	1460.0
Week 4	638.0	3167.0

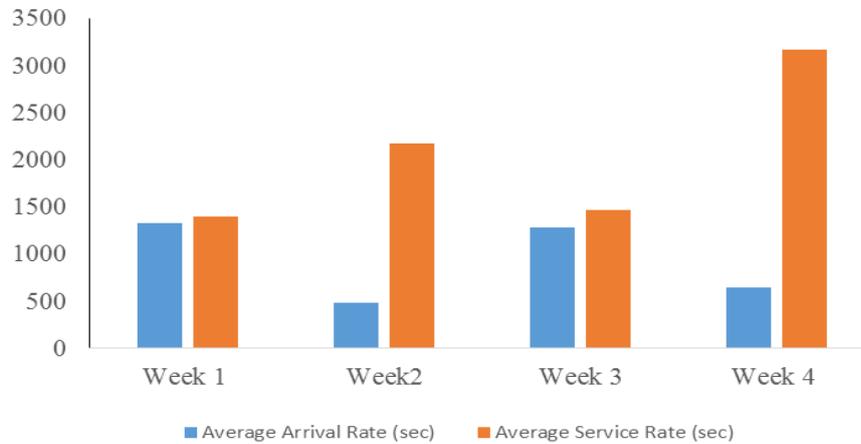


Figure-1. Arrival rate and service rate of Packets for each week.

Figure 1 gives a clear view of packets arrival rate and service rate per week at various locations per week. At Obaekere, packet arrival rate and service rate are relatively close compared to week 4 with a low rate of arrival and high service rate.

7.3. Empirical Analysis using Queuing Model

7.3.1. Traffic intensity

Traffic intensity is referred to as the measure of the strength of traffic. Table 2 depicts the tabular representation of the results of traffic intensity obtained from the analysis, based on the capturing locations. The result of other queuing parameters estimated is also presented in Table 3.

Table-2. Traffic intensity per week based on capturing location.

Week	Traffic Intensity
Week 1(Obaekere)	0.95
Week 2(Undergraduate Hostel)	0.23
Week 3 (Obanla)	0.87
Week 4(Postgraduate Hostel)	0.20

Table-3. Empirical Result of the Analysis done using Queuing Model.

Weeks	Arrival Rate (Sec)	Service Rate (Sec)	Traffic intensity (Erlang)	Average number of packet in the system (L_s)	Average number of packet in the queue (L_q)	Average waiting time in the system (W_s) in seconds	Average waiting time in the queue (W_q) in seconds
Week1	1329	1400	0.95	18	19	0.141	0.134
Week 2	487	2166	0.225	0	0	0.0006	0.000014
Week3	1280	1460	0.87	7	6	0.005	0.006
Week 4	638	3176	0.20	0	0	0.007	0.00039

7.3.2. Analysis Based on Protocols Used

Details of the number of protocols used were also analysed and the result is presented in Table 4.

Table-4. Analysis based on protocols used.

Weeks	% of TCP users	% of UDP users
Week 1	57.10	60.00
Week 2	16.00	2.80
Week 3	14.90	32.45
Week 4	12.10	4.72
Total	100.01	100.07
Average		

7.3.3. Analysis Based on Bytes Used

Table 5 shows the average of byte used per week.

Table-5. Summary of bytes used per week.

Week	Average byte used
Week 1	14406
Week 2	15036
Week 3	18398
Week4	20585
Total	68425

7.3.4. Analysis Based on the Number of TCP and UDP Packets

The number of TCP and UDP packets on the network is shown in Table 6.

Table-6. Summary of TCP and UDP packets.

Week	TCP packet	UDP packet	Total packet (TCP+UDP)
Week 1	428829	1964185	2393014
Week 2	97648	261142	358790
Week 3	360133	245902	606035
Week4	52194	220360	272554
Total	938804	2691589	3630393

7.3.5. Analysis Based on Weekly User's Connection

Table 7 depicts the average number of users connected per week. The number of users connected was obtained from the number of unique IP addresses from endpoints in the statistics menu of Wireshark. The number of Unique IP address corresponds to the number of users connected.

Table-7. Average number of users connected.

Week	Average number of users connected
Week 1	837
Week 2	635
Week 3	465
Week 4	240

7.3.6. Results of Multiple-Regression Analysis

The empirical results of the multiple regression model are presented in Tables 8 and Table 9. X_1 is the total time spent on the internet and X_2 is the total number of users connected.

Table-8. Coefficients Table

Model	Regression Coefficients		t	Sig.
	B	Std.Error		
Constant	22819.973	3816.733	5.979	0.106
X_1	9.651	18.892	0.511	0.699
X_2	-12.364	3.765	-0.3284	0.188

From Table 8, the estimated Y (number of bytes used) can be estimated using the model derived as depicted in Equation 11 as follows:

$$Y = 22819.973 + 9.651X_1 - 12.364X_2 \quad (11)$$

The value of Y could be obtained by substituting for the value of X_1 and X_2 in equation 11. The t -values and significant values test whether X_1 and X_2 are statistical determinants of Y . The result showed that at critical value 0.05, both X_1 and X_2 are statistical determinants of Y . Table 9 shows the model summary.

Table-9. Model summary of Regression Analysis.

Model Summary				
Model	R	R square	Adjusted R Square	Std. Error of the Estimate
1	0.963	0.927	0.781	1361.044

Table 9 gives the Pearson(R), R^2 , adjusted R^2 and the standard error of the estimate. These values are used to determine how the estimated regression model fits the data. R is a measure of the correlation between the actual value and the estimated value of the dependent variable. It indicates the direction of relationship which could be either direct or inverse and it ranges between 1 and -1. The value of R obtained is 0.963, which indicates a good level of correlation. R^2 is the coefficient of determination which is the measure of goodness of fit of the estimated model. It is the proportion of variance in the dependent variable (Y) that are jointly explained by the independent variables (X_1 and X_2). The result shows that the independent variables explain 92.7% of the variability in the number of bytes used.

8. CONCLUSION

The upsurge in the use of computer networks for various forms of the transaction has led to an increasing volume of traffic on the network. Computer networks are usually designed to handle a certain amount of traffic. Lower quality of service often results whenever the installed capacity is exceeded. There is therefore the need to monitor the flow of data across the network in order to ensure a high quality of service. This research work carried out an analysis of network traffic using the queuing model and regression technique. The queuing model was used to analyse the performance of the network. Also, a multiple regression model was developed to determine the significant determinants of the number of bytes used at any point in time. The empirical result revealed that total time spent on the network and the total number of users connected are the significant determinants of network traffic. The model could be used for monitoring and predictive purposes. The result of this research will assist network administrators to plan the usage and monitor computer networks thereby ensuring good quality of service.

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REFERENCES

- [1] K. Chen, *Performance evaluation by simulation and analysis with applications to computer networks*: John Wiley & Sons, 2015.

- [2] B. Tomasx, "Classification and analysis of computer Network traffic\", PhD Thesis, Department of Electronic Systems, Aalborg University, Denmark, 2014.
- [3] P. Asrodia and V. Sharma, "Network monitoring and analysis by packet sniffing method," *International Journal of Engineering Trends and Technology*, vol. 4, pp. 2133–2135, 2013.
- [4] S. Sani and O. Daman, "Trends in the mathematics of queuing systems, department of mathematics, Botswana-gaborone," *International Journal of Engineering Research and Management*, vol. 2, pp. 34 – 40, 2015.
- [5] O. J. Mebawondu, "Performance evaluation and modeling of internet traffic in an Academic Institution (FUTA)," M.Tech Thesis Federal University of Technology Akure, Ondo-state, Nigeria, 2014.
- [6] F. Dahunsi and S. Nweithie, "Analysis and performance of FUTA network," *Journal of Sustainable Technology*, vol. 6, pp. 1 – 9, 2015.
- [7] B. K. Alese, S. A. Ogunbanjo, S. O. Falaki, and O. S. Adewale, "Service model estimation for technical efficiency for technical efficiency of internet service providers in Western Nigeria," *Journal of Information Technology Impact*, vol. 6, pp. 135 – 152, 2006.
- [8] J.-K. Hong, S.-S. Kwon, and J.-Y. Kim, "WebTrafMon: Web-based Internet/Intranet network traffic monitoring and analysis system," *Computer Communications*, vol. 22, pp. 1333-1342, 1999. Available at: [https://doi.org/10.1016/s0140-3664\(99\)00130-9](https://doi.org/10.1016/s0140-3664(99)00130-9).
- [9] O. Abiona, C. Onime, A. Oluwaranti, E. Adagunodo, L. Kehinde, and S. Radicella, "Development of a non intrusive network traffic monitoring and analysis system," *African Journal of Science and Technology (AJST) Science and Engineering Series*, vol. 7, pp. 54-69, 2006.
- [10] T. Van Woensel and N. Vandaele, "Modeling traffic flows with queueing models: A review," *Asia-Pacific Journal of Operational Research*, vol. 24, pp. 435-461, 2007. Available at: <https://doi.org/10.1142/s0217595907001383>.
- [11] S. V. Mala and P. Varma, "Minimization of traffic congestion by using queueing theory," *IOSR Journal of Mathematics (IOSR-JM)*, vol. 12, pp. 116-122, 2016.
- [12] S. Palash and S. Saha, "Monitoring of networks traffic based on queueing theory, national institute of technology, department of mathematics, Rouleka, India," *Journal of Science and Technology*, vol. 1, pp. 1-2, 2011.
- [13] M. Kembe, E. Onah, and S. Iorkegh, "A study of waiting and service costs of a multi-server queueing model in a specialist hospital," *International Journal of Scientific & Technology Research*, vol. 1, pp. 19-23, 2012.
- [14] D. Dike, V. Obiora, and C. Eze, "Improving congestion control in data communication network using queueing theory model," *IOSR Journal of Electrical and Electronics Engineering*, vol. 11, pp. 49-53, 2016.
- [15] Mala and S. P. Varma, "Minimization of traffic congestion by Using queueing theory," *IOSR Journal of Mathematics (IOSR-JM)*, vol. 12, pp. 116-122, 2016.
- [16] J. D. Lartey, "Predicting, traffic congestion: A queueing perspective," *Open Journal of Modelling and Simulation*, vol. 2, pp. 57-66, 2014.
- [17] S. B. Mohammed, S. M. Sani, and D. D. Dajab, "Network traffic analysis : A case study of ABU network," *International Institute for Science, Technology and Education, Zaria*, vol. 4, pp. 33–40, 2013.
- [18] G. Lu, L. Cong, Y. Chen, B. Deng, and X. Li, "Network congestion estimation using packet time series analysis," *IET Communications*, vol. 4, pp. 980-989, 2010. Available at: <https://doi.org/10.1049/iet-com.2009.0506>.
- [19] V. Jadav, "Traffic management," *International Journal for Research in Applied Science & Engineering Technology*, vol. 5, pp. 1976-1980, 2017.
- [20] P. Manish, Ganvir, and S. S. Salankar, "Tme series forecasting of packet loss rate using artificial neural network based on particle swarm optimization," *International Journal of Engineering Research and General Science*, vol. 3, pp. 466-472, 2015.
- [21] Y. Shoaib and O. Das, "Modelling website workload using neural networks," pp. 1-25. Available: <https://arxiv.org/abs/1507.07204>. [Accessed July, 2017], 2015.

- [22] H. Song and L. Gan, "The research on the prediction of the network traffic based on the improved IAC-Gray method," *Chemical Engineering Transactions*, vol. 46, pp. 127-132, 2015.
- [23] C. Xiang, P. Qu, and X. Qu, "Network traffic prediction based on MK-SVR," *Journal of Information and Computational Science*, vol. 12, pp. 3185 – 3197, 2015.
- [24] T. Peng and Z. Tang, "A small scale forecasting algorithm for network traffic based on relevant local least squares support vector machine regression model," *Journal of Applied Mathematics*, vol. 9, pp. 653-659, 2015.

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