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IMPROVING TRAFFIC MANAGEMENT IN A DATA SWITCHED NETWORK USING AN ADAPTIVE DISCRETE TIME MARKOV MODULATED POISSON PROCESS

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ABSTRACT

In the ever-evolving landscape of modern telecommunications, the increased demands on data networks driven by the proliferation of connected devices and the escalating requirements of bandwidth-intensive applications, the need for advanced traffic management strategies has become increasingly pronounced, thus presenting the aim of this paperto improving traffic management in a data switched network using an adaptive discrete-time Markov modulated Poisson process. The characterization of the data switched network and development ofa Poisson process algorithm was done for data throughput improvement. MATLAB Simulation was carried out to determine how to improve traffic Management by achieving effective capacity and effective bandwidth for QoS requirements. The result from the characterization of the data network showed that bandwidth usage was above 20Mbps most times and traffic congestion set in always.Results showed that the Poisson Process algorithm developed follows a Gaussian normal distribution pattern as flow throughput declines when traffic exceeds network capacity. The result also showed that traffic capacity is a function of transmission rate and that the higher the transmission rate, more the bandwidth is required. This work was able to achieve a 16.4% improvement in traffic management by implementing a hybrid of Poisson and Markov processes for effective capacity management in fixed-rate wireless transmission networks.

Keywords: QoS,Poisson model,Markov process,GPS,Capacity,

1. INTRODUCTION

The development of viable communication networks and network applicationsis becomingvery difficult in current-day’s communication industries (Ejimofor, et al, 2022). Having a thorough comprehension of the features of the traffic is the way towards solving this inherent problem (Ifeagwu, et al, 2017). The efficiency of a computer network must be accurately predicted. Both voice and data networks are built with a wide range of factors in mind.Regardless of the available bandwidth or occurrence of problems,good network performance management involves managing how networks function to optimize capacity,decrease latency,and deliver high-quality signal to users (George, et al,2019).To ensure that computer networks transport traffic at the speed,capacity, and reliability expected by the programs using the network or called for by a given scenario,network administrators conduct duties such as measuring,modeling,planning,and optimizing the network in question.Quality of service (QoS) in the networking world signifies the control processes that are capable of ensuring a certain performance level for data flows in response to requests

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from an application or user via the intranet (Ifeagwu and Enebe, 2017). In Iffat(2020), the link layer's model that can provide QoS in a time-varying wireless channel is effective capacity. Effective capacity is the highest constant arriving rate that a time-varying service process can handle while still meeting QOS requirements (Alor, et al, 2022). Therefore, modeling of traffic becomes a crucial and necessary step in the analysis of the traffic to provide information like the average load, the bandwidth requirements for different applications, and numerous other details. Traffic models enable network designers to make assumptions about the networks being designed based onexperience and also enable prediction of performance for future requirements.

This paper focused on improving traffic management in a data switched network using an adaptive discrete-time Markov-modulated Poisson process. To achieve the aim, the characterization of the data switched network and development of a Poisson process algorithm was done for data throughput improvement. The Poisson distribution is the predominant model used for analyzing traffic in networks (Heikalabael,et al,2022).

2. POISSON PROCESS ALGORITHM

For the modeling of the algorithm, let's consider the number of packets arriving in a gateway with a specific rate $\lambda_1$during a time interval (t_0, t) given by y_1. Then,y_1 has a Poisson distribution with mass function given by (Rappaport, 2003)

$$g_1(y_1) = \frac{e^{-\lambda_1}\lambda_1^{y1}}{y_1!}, y_1 = 0, 1, ... \quad (1)$$

Poisson distribution considers the number of packets that reach their destination to constitute the amount of throughput of the specific network within the given time interval.

Therefore, the rate of packet departure at any time within the interval λ_2 and has a Poisson distribution. Also, it is evident that the number of packets that departed successfully within the interval (throughput) may be denoted by y_2 depending on the number of packets that arrived in the gateway within each time instance of the given interval (t_0, t). So the joint distribution of the number of packet arrivals and the number of packet departures is shown in equation (2):

$$g(y_1, y_2) = g(y_2|y_1). g(y_1) = \frac{e^{-\lambda_1}\lambda_1^{y1} e^{-\lambda_{2y1}} (\lambda_{2_{y1}})^{y_2}}{(y_1!y_2!)}, y_2 = 0, 1, ..., \quad (2)$$

Where y_2i's are assumed to be mutually independent. The number of packets departed, Y_2, out of Y_1= $y_1$arrivals, in any time interval, is Poisson with parameter $\lambda_2 y_1$. In a time interval, the possible number of packets to be departed, Y_2 can be shown as the sum of departed packets corresponding to each of 1, 2,..,,, y_2 possible arrivals and the variable Y_2 is defined as (Rappaport,2003)

$$y_2 = y_{21} + y_{22} + , , , , y_{2y1} \quad (3)$$

Then, the conditional probability of the total number of packets departed as throughput among the y_1 arrivals occurring in a time interval denoted by $P(Y_2 = y_2 \mid Y_1 = y_1)$) is shown as Poisson with parameter $\lambda_2 y_1$. Then it can be shown that

$$g(y_2|y_1) = \frac{e^{-\lambda_{2y1}} (\lambda_{2_{y1}})^{y_2}}{(y_2!)}, y_2 = 0, 1, ..., \quad (4)$$

Where Y_{2i} is a random variable with the number of packets departed (becoming throughput) resulting from i^{th} arrival, and suppose it has a Poisson distribution with parameter; that is,

$$g_2(y_{2k}) = \frac{e^{-\lambda_2}\lambda_2^{y2k}}{(y_{2k}!)}, y_{2k} = 0, 1, ... \quad (5)$$

For the above Poisson-Poisson model (5), it can be shown that

$$E(Y_1) = \mu_1 = \lambda_1 \text{ and } E(Y_2) = \mu_1 = \lambda_1\lambda_2 \quad (6)$$

Equations (1) to (6), is the Poisson Process Algorithm

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Analysis of the models and their relevance to network traffic management: Equation 2 represents the joint distribution of the number of packet arrivals (y1) and departures (y2) within a given time interval in a data-switched network. It utilizes the Poisson distribution to model the rate of packet departure and conditional probabilities. Equation 3 is defined as the total number of packets departed (throughput) within a time interval, calculated as the sum of individual departures corresponding to each possible arrival. equation 4 represents the conditional probability distribution, indicating the probability of observing a certain number of packet departures given a specific number of arrivals. It follows a Poisson distribution with parameter Equation (5) describes the individual departure probability for a specific arrival. It follows a Poisson distribution with a constant parameter representing the probability of a certain number of packets departing. Equation (6) presents the expected valuesfor the number of packet arrivals and departures, respectively. These expected values are calculated based on Poisson distribution parameters. In summary, these equations collectively form the Poisson Process Algorithm, offering a probabilistic framework for understanding and modeling the dynamics of packet arrivals and departures in a data-switched network. The model is particularly valuable for analyzing traffic management strategies and optimizing network performance.

3. MATERIALS AND METHOD

3.1Materials

The materials used to carry out this research include a drive test van, inverter, HP laptop, Global Positioning System (GPS) andmobile station. During the drive test experimentation, the drive testmonitoring Van was used with a 1.5KVA Inverter (1000VA) connected to the battery of the van which converts direct current to alternating current for steady power supply to the HP laptop. The HP Laptop with TEMS software installed on it was used in the Van to measure, analyze and optimize mobile networks. The GPS (Global Positioning System) was used for navigating along the routes of the drive test areas, usually connected to the laptop along with the mobile station. Mobile Station (MS) i.e. wireless phones e.g. Samsung S5 with TEMS software installed by the manufacturers.Data cables and USB hubs were also used for interconnectivity between the mobile station and the base station.

3.2 Method

In this paper, the drive test method of collecting traffic data was adopted first. The second method adopted was the Poisson and Markov method for the implementation of traffic management. The drive test data obtained was used to test the performance of the network, reliability and latency in the existing 4G network. The characterizationofthe data-switched network was done by measuring the network parameters to know their impact on the network. The network and application performance was measured using key traffic performance indicators such as bandwidth, throughput, end-to-end delay, number of packets sent/received per seconds, and number of bytes sent/Received per second. The MTN testbed used in the implementation has several tools to collect the network and application metrics. The metrics are collected on both hosts and the communication links between two hosts considering parameters such as packet sent, received packet, processing time, disk time, yet sent and received respectively per seconds. The software used is the Matlab and Iperf software programming tools.The bandwidth utilization on the said network was tested using the net-box software. The net-box software (Net-box) is simply software used by MTN Nigeria to monitor customer performance, and data usage on the network. The procedure used to test the bandwidth includes firstly identification of the customer or client with the

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help of information from the server provided by the support staff.Secondly, the client detail in Table 2 on the Net-box software of the Laptop was used to collect the traffic dataas stated in Table 4

Table 2: Client details used for measurement of bandwidth

S/N	Parameter	Values
1	VLAN	1061
2	IP	197.210.185.25
3	Client Bandwidth	20Mbps

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Table 2 shows the client details used for the measurement of bandwidth. It consists of a VLAN of value 1061, an IP address of 197.210.185.23 and a bandwidth of 20Mbps. The simulation carried out inMATLAB Simulink was to determine the effective capacity for data transmission in a data-switched network.The simulation parameters used are as shown in Table 3.

Table 3: Simulation Parameters

Parameter	Value
Simulation time	90s
Rayleigh fading block coefficients	1
Transmission fixed rate r	0 – 10 bps
Channel state	ON/OFF
SNR	10, 100
QoS exponent θ	1 – 10
Traffic Pattern	CBR
channel negotiation (Δ)	1.27 ms
UPD traffic flow	1 Mbps
Packet size	64 Kb

4. RESULTS AND DISCUSSIONS

4.1 Results from Data Switched Network Characterization

The data obtained during the characterization of the data-switched network is shown in Table 4.Thedata in Table 4 was collected from the conventional data network using the client's details in Table 2. The graphical presentation is shown in Figure 1

Table 4: Measurements of bandwidth utilization from conventional data switched network

Measurement Day	Data Rate (Mbps)	Cross Traffic	Contending Traffic
1	11	None	None
2	5.5	None	None

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3	2	None	None
4	11	Yes	None
5	5.5	Yes	None
6	2	Yes	None
7	11	Yes	None
8	5.5	Yes	None
9	2	Yes	None
10	11	Yes	Yes
11	5.5	Yes	Yes

Figure 1: Bandwidth Utilization

Table4shows bandwidth utilization while the graphical presentation is showninFigure 1. In Figure 1 the usage of bandwidth above 20Mbps indicates overutilization and congestion sets in.From the nature of the graph; at some points in the graph below 20Mbps, the graph was smooth and this shows that the Subscribers have not started overstressing the network by exceeding the allocated bandwidth. When the data indicator goes beyond 20Mbps the client has started over-utilizing or exceeded the allocated bandwidth, the graph is no longer smooth, but starts clipping, showing that the network is being over-stressed at this time causing congestion.

4.2 Results from the Effective Network Capacity as a function of SNR with fixedtransmission rate r = 1 bps and QoS exponent θ = 1

The result of effective network capacity as a function of SNR with fixed transmission rate r = 1 bps and QoS exponent θ = 1 is shown in Table 5 using the developed equation (6) and simulation parameters in Table 2.The graphical presentation is shown in Figure 2.Table 5:

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Effective Network Capacity as a function of SNR with fixedtransmission rate r = 1 bps and QoS exponent θ = 1

SNR	**CE QoS exponent θ = 1**
0	0
10	0.3229
20	0.4146
30	0.4691
40	0.5081
50	0.5383
60	0.5631
70	0.5841
80	0.6023
90	0.6184
100	0.6328

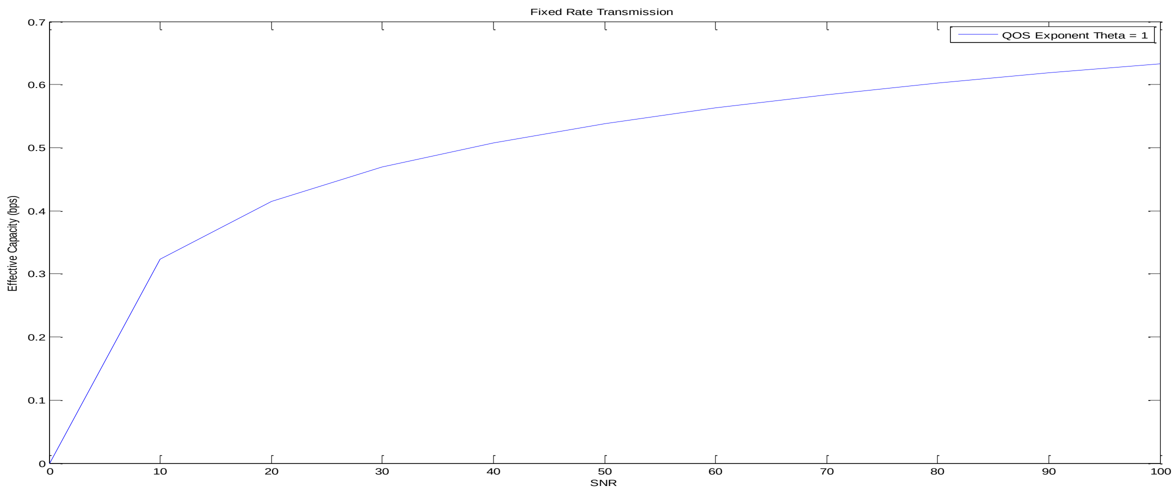

Figure 2: Simulation result of Effective Network Capacity as a function of SNR with fixed transmission rate r = 1 bps and QoS exponent θ = 1.

Figure 2 shows the effective network traffic Capacityobtained from Equation 6 as a function of SNR for the fixed value of transmission rate r. The simulation considers SNR whose values are linear (0 to 100). The QoS exponent (θ) used is 1. The simulation shows that effective network traffic capacity increases more when SNR increases and we have QoS exponent (θ)as. So QoS exponent is a determinant in improving traffic management in data networks. However, effective capacity gradually slows its improvement in larger values of SNR. The increase in SNR produces a drastic boost at a certain point in effective network traffic capacity due to the fixed transmission rate which may lead to a waste of scarce resources.

4.3 Discussions

In Figure 1, the characterization of the conventional data switched network was done. That was to determine the yardstick upon which the threshold of the data network would be measured. The effectiveness of the conventional data network will be ascertained from this characterization before the introduction of the Poison Model. Therefore, the threshold used for the conventional data network in terms of traffic is 20Mbps.Once,20Mbps is exceeded,

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the traffic on the network starts to increase and the continuity in the transmission of the network becomes discontinued. Then, there arises the need for the proposed model using Poisson model. Figure 2 shows the effective network traffic Capacity obtained from Equation 6 as a function of SNR for a fixed value of transmission rate. The simulation considers SNR whose values are linear (0 to 100). The QoS exponent (θ) used 1. The simulation shows that effective network traffic capacity increases more when SNR increases and we have QoS exponent (θ) as 1. So QoS exponent is a determinant in improving traffic management in data networks. However, effective capacity gradually slows its improvement in larger values of SNR. The increase in SNR produces a drastic boost at a certain point in effective network traffic capacity due to the fixed transmission rate which may lead to a waste of scarce resources.

5. CONCLUSION

Employing an adaptive discrete-time Markov modulated Poisson process to efficiently oversee traffic in a data-switched network constitutes a significant advancement in the realm of data communication systems. This innovative approach introduces an adaptive model that dynamically responds to the intricate nature of data traffic patterns. Unlike traditional methods, which struggle to adapt to fluctuating network conditions, this new solution integrates discrete-time Markov-modulation and Poisson processes, offering a sophisticated solution for real-time traffic management.The adaptability of this model is a key departure from conventional static approaches, allowing it to evolve and adjust in response to the dynamic demands of modern data networks. Incorporating the adaptive discrete time Markov modulated Poisson process provides a practical and efficient solution to the complex challenges associated with contemporary data communication systems.

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