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Probability Model for User Datagram Protocol (UDP) Upstream Throughput for Single User in Real Time and Non-Real Time Scenarios in IEEE802.11b/g WLAN

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Abstract

Use of Wireless Local Area Networks (WLAN) for all brand of activities have spiraled in recent times as internet activities have shot up and data requirements have gone through the roof. In addition, the implementation of the user datagram protocol (UDP) in WLAN's has also seen an increase. UDP has a number of advantages over the Transmission Control Protocol (TCP) as it has faster response times due to its lack of non-inherent error correcting capabilities which creates the problem of instability. A number of researches though few, have tried to tackle this trend but with little results. This paper attempt to develop a probability model that would enable the prediction of UDP Throughput in a WLAN environment. Experimental data was obtained for different kinds of traffic scenarios real time and non-real time (RT and NRT) for a single user on the network. The work focuses on Signal to Noise Ratio (SNR), which was varied while measuring the throughput and then obtained a model for the upstream throughput (UDP uploading). Also, a probability model was developed using the cumulative distribution function (CDF) based off on different predefined throughput thresh holds. Using the empirical data obtained, a CDF model of UDP upstream throughput was developed and it showed that despite the erratic characteristic behavior of UDP, a normal cumulative distribution function (CDF) can be obtained and its throughput can be predicted at different intervals of poor, good and outstanding signal classifications of SNR.

1. Introduction

There is an abundance of literature on the throughput analysis of IEEE 802.11 media access control (MAC) protocols, this is probably because it is the most popular wireless local area network (WLAN) standard [1]. Its commercial success grows per year as more versions become increasingly available e.g., 802.11e and 802.11n with increasing throughputs [2]. Driving this would seem to be necessary because of the prevalence of high bandwidth applications such as virtual reality and high-resolution video streaming. The prediction of throughput would seem to be important as it is a determinant of the quality of real time video and audio streaming services on low–latency network protocols [3]. The amount of data bits conveyed from a data source or group of data sources to a destination or group of destinations within a stated time is called the throughput [4]. Throughput can be measured in packet per second, bit per second or bytes per second. Throughput can also be defined in real time as the rate of data delivery over a specific period of time [5]. Throughput is when compared to bandwidth a better measure of network performance because it is the actual speed of a network. Network monitoring relies heavily on its value. It can be measured with the aid of several Network monitoring analysis tools [6]. In some cases, it becomes necessary to be able to predict the throughput of a network at any given time provided there are some other conditions stated as live measurements and analysis are not always possible. Predicting a transmission throughput through a network using a limited set of information available to network Engineer can present a serious challenge. This is most prominent when the medium of transport is the User Datagram Protocol (UDP) as there are few to none models offering a throughput prediction for UDP especially using a probabilistic model, this is especially for what is referred to as upstream throughput or rather uplink throughput. To accurately predict the throughput at specified throughput ranges for uplink transmission of data becomes a challenge. This paper seeks to address this offering a probability model as an alternative method to predict a specific throughput value for pre specified classes of Signal to Noise Ratio (SNR) for UDP for an upstream data scenario.

This is applied to real time and non-real time scenarios, where real time scenarios refer to live data services such as voice and video streaming and non-real time refers to activities such as file transfers and so on.

1.1. Related Work

In the Transport protocol, researchers have looked into different challenges bearing some relation to the set-out area. [2] investigated the interplay between the collision avoidance mechanisms of the 802.11 MAC protocol and the dynamics of upper layer transport protocols. Using analytical, simulative, and experimental methods this was done and Markov chain models were developed to calculate the distribution of the number of active stations in an 802.11 wireless local area network (WLAN) when long-stayed transmission control protocol (TCP) connections compete with finite-load user datagram protocol (UDP) flows. Their work was able to show that total TCP throughput is independent of the number of open TCP connections and that UDP flows have a better throughput than the same number of aggregated TCP flows. [3] analyzed diverse approaches in separating the elastic and inelastic traffic. They found that by using an appropriate queue management approach that separates traffic could be a solution to the problem of coexistence of different types of traffic sent in a shared link. An approach was introduced to separate the traffic which is the first-in-first-out (FIFO) scheduling to ensure that inelastic traffic would not suppress elastic flow by taking over queue space.[7] performed experimental analysis of UDP performance in mobile Ad Hoc networks with different routing protocol and variable payloads. Investigated here were 4 network scenarios of 4, 8, 16 and 32 nodes of various node mobility speeds with three routing schemes viz: Destination Sequence Distance Vector (DSDV), Dynamic Source Routing Protocol (DSR) and Ad hoc On-demand Distance Vector Routing (AODV). Throughput and end to end packet delay were used as performance matrices this was measured over the UDP connection with the aid of simulation experiments. Results show that network scenarios of 4 and 8 nodes DSR and AODV fail to converge in performance due to limited routing traffic. As the number of nodes increases, more routing traffic generates thus DSR and AODV greatly improve with almost 100% throughput in the network of 16 and 32 nodes even mobility is high. Because Ad hoc networks are formed without centralized control, security must be handled in a distributed fashion. Moreover, routing protocols in prime targets for impersonation attacks. Next, we plan to consider the security features of routing protocols for ad hoc networks.

In the four network scenarios of 4,8,16 and 32, simulation results show UDP throughput to be higher compared to two other protocols DSR and AODV. DSDV shows the lowest end to end packet delay for UDP transmission than AODV and DSR. The conclusion was that using DSR protocol more packets could be delivered successfully to their destination and that DSR is best suited for MANET when considering UDP as the transport layer protocol.

2. Methodology

The study was carried out for a few months within the University of Benin main campus, Benin City Nigeria. Its location is given as coordinates 6.3350^0N and 5.6037^0E. To represent a network of a typical WLAN environment consisting of users, three (3) environments within the main campus were considered: open space, hallway, and administrative office building. These environments were labeled for the purpose of this work as environment 1, 2, and 3 respectively.
Upstream assessment of UDP behavior which was monitored in this work using real-time measurements. Received signal strength level (RSSL) at the client terminal was taken into consideration as a parameter to measure. The throughput is measured in Mbps while the RSSL is measured in dBm. In this study, both hardware and software tools were used to achieve the field work involving data collection. The software tools used were *Tamosoft Throughput Test* and *inSSIDer* version 2.1. The experiment was done using an Access Point (AP) mounted on a pole as shown in Figure 1.

Figure 1: Open space (Environment 1)

The client in this particular case consisted of a single user on a laptop carrying out a range of activities listed under the following Quality of Service (QoS) categories:

Table 1 QoS traffic Types

S/N	Traffic Types
1	Best effort
2	Background
3	Excellent effort
4	Audio video
5	Voice
6	Control

2.1. Specifications of Hardware used in the research:

The AP has max data speed listed at 100MHz, operating in the 2.4GHz band. Supported are IEEE 802.11b and g standard. The AP is powered from a 12Vdc output of a power adapter, and connected with a Power over Ethernet (PoE) cable terminated at an RJ45 connector. The AP is configured with a private IP address in the 192.168.1.xx range. Cabling used is unshielded twisted pair Category 5e. Laptops representing servers and clients were also connected to the network.

2.2. Data Presentation

As an example, the results of the experiment for Environment 1 are presented in Table 2.

Table 2: UDP upstream Throughput for a single user client in Environment 1

Average of UDPupT at sample point 1 in Environment 1					
QoS Traffic Type	sample size F and B	Ave. UDPupT F (Mbps)	Ave. UDPupT B (Mbps)	UDPupT Ave. (Mbps)	STD for all Inst. UDPupT (Mbps)
Best effort	18	17.3688	18.2533	17.8111	1.3634
Background	18	16.5388	17.7500	17.1444	1.4489
Excellent effort	18	17.4822	17.2022	17.3422	3.6465
Audio video	18	17.0033	16.8333	16.9183	1.4716
Voice	18	17.4822	17.2355	17.3588	1.0597
Control	18	16.7122	17.1622	16.9372	1.6305
Total UDPupTAve.(Mbps)		17.0979	17.4061	17.2520	1.7701
Total sample sizes	108				
Average of UDPPupT at sample point 2 in Environment 1.					
QoS Traffic Type	sample size F and B	Ave. UDPupT F (Mbps)	Ave. UDPupT B (Mbps)	UDPupT Ave. per QoS traffic (Mbps)	STD for all Inst. UDPupT (Mbps)
Best effort	18	25.2955	26.5433	25.9194	2.3515
Background	18	25.7955	26.1311	25.9633	2.4481
Excellent effort	18	2600000	24.9894	10.5309	1.4082
Audio video	18	24.4300	24.7355	24.5827	4.0819
Voice	18	24.4211	23.3377	23.8794	3.5182
Control	18	24.5244	25.7777	25.1511	3.0375
Total UDPupT Ave. (Mbps)		25.0777	25.2525	22.6711	2.8075
Total sample sizes	108				
Average of UDPPupT at sample point 3 in Environment 1.					
QoS Traffic Type	sample size F and B	Ave. UDPupT F (Mbps)	Ave. UDPupT B (Mbps)	UDPupT Ave. per QoS traffic (Mbps)	STD for all Inst. UDPupT (Mbps)
Best effort	18	22.0566	22.6944	22.3755	6.0617
Background	18	20.4741	24.5566	22.5158	5.3328
Excellent effort	18	15.9702	8.4161	7.5808	0.8371
Audio video	18	22.5555	23.0044	22.7800	2.7204
Voice	18	2468.20	24.6777	1246.4400	2996.1765
Control	18	21.1688	23.2700	22.2194	3.3364
Total UDPupT Ave. (Mbps)		428.4041	21.1032	223.9852	502.4108
Total sample sizes	108				

2.3. Probability prediction

The cumulative distribution function (CDF) probability prediction provides an additional way to predict a particular throughput value and not a range of values, so we can define the probability of obtaining specific throughputs for predefined SNR scenarios. SNR values can be summarily described as either very high or low. Realistically, network engineers are more interested in the probability that throughput falls above or below a certain value rather than that the throughput is a specific value. This is because values of throughput are continuous random variables.

Different signal ranges are defined, classified according to SNR ranges. Data collected was used to predict the probability of obtaining UDP upstream Throughput (UDPupT) on the network for different signal ranges. Normal distribution was applied to obtain a general function for predicting the cumulative distribution function (CDF) for throughputs. The mathematical model shown in Equation (1) defines the Normal/Gaussian distribution.

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\frac{(x-\mu)^2}{\sigma^2}} (-\infty<x<+\infty) \quad (1)$$

where σ is the standard deviation of the population, μ = population mean, x = variable (UDPupT) been measured. F(x) =probability distribution function of obtaining x Mbps. Network engineers require an estimation of a range of x Mbps values obtainable. This leads to the evaluation of the cumulative distribution function (CDF) in terms of standard units where the throughput is never negative but always at the range from zero to infinity ($0 \le x \le \infty$). In order to achieve this, Equation (1) is thus transformed to a standard normal form shown in Equation (2).

$$f(Z) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\frac{(Z)^2}{\sigma^2}} (-\infty<x<+\infty) \quad (2)$$

The normally distributed random variable is standardized for researchers to determine with ease the probability associated with a range of values of that variable by using a standardized distribution table. The standardized value of the normally distributed random variable is called Z score and is calculated using the formula shown in Equation (3).

This section describes the probability of obtaining the variables for different ranges in the single user scenario where from the statistical parameters, the mean and standard deviation are inserted into the CDF for a combined environment consisting of UDPupT.

Z score is the standard deviation away from the mean. Hence, for the various values of UDP the following Z values can be obtained for the single user scenario in all environments combined:

Where $Z=\frac{x-\mu}{\sigma}$ (3)

3. Results

Substituting the values of UDPupT for single user scenario from the experiment and by applying normal standard distribution tables gave the plot of the CDF as:

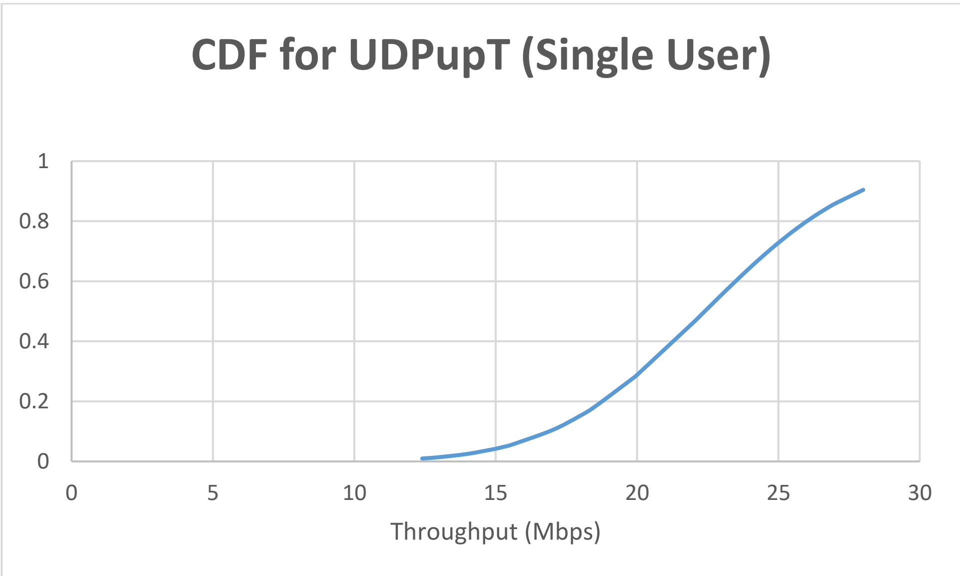

Figure 2: CDF probability plot UDP upstream Throughput (Single User)

Despite the erratic characteristic behavior of UDP, this work was able to shows the CDF plot for throughput prediction for UDP upstream Throughput (UDPupT) as shown in Figure 2. The predicted throughput value falls above or below a certain throughput rather than the probability that is equal to a particular throughput. That is, the probability that a throughput will be less than or equal to a certain range of throughput values.
Table 3 shows the probability look up values for UDPuT. For example, it shows that at any given throughput range over 25Mbps would have a probability greater than 0.7.

Table 3: CDF Probability Look up Table for UDP upstream Throughput

UDPupT (Mbps)	Statistical Parameter	CDF Probability model value
>28	Probability	>0.9042
26-27.99	Probability	0.9042
24-25.99	Probability	0.796
22-23.9	Probability	0.640
20-21.99	Probability	0.468
18-19.99	Probability	0.288
16-17.99	Probability	0.153
14-15.99	Probability	0.100
12 - 13.99	Probability	0.025
10 -11.99	Probability	0

Based on the probability model developed, the SNR used for the experiment for ranges are shown in Table 4 for UDPupT:

Table 4: SNR Ranges Relationship with developed Probability model

<table>
<tr><th>SNR Ranges</th><th>SNR</th><th>Throughput probability</th></tr>
<tr><td rowspan="2">A
Excellent - Outstanding</td><td rowspan="2">31-60</td><td>0.9042</td></tr>
<tr><td>0.796</td></tr>
<tr><td rowspan="5">B
Fair -Good</td><td rowspan="5">20-30</td><td>0.640</td></tr>
<tr><td>0.468</td></tr>
<tr><td>0.288</td></tr>
<tr><td>0.153</td></tr>
<tr><td>0.100</td></tr>
<tr><td>C
Poor</td><td><20</td><td>0.025</td></tr>
</table>

4. Conclusion

This paper presented a proposed User Datagram Protocol (UDP) upstream throughput probability model for a user on a network under different conditions of SNR. This work was able to successfully develop a CDF model, which was used to determine the probability of picking a specific throughput range from a list of ranges. The model was used to classify SNR into three main categories. A-Excellent/outstanding, B-Fair/Good and C- Poor. The work would enable Network Engineers predict Throughput QoS for Single user upload operations on IEEE802.11b/g WLAN networks

Although UDP which does not consider any recovery mechanism for errors, a good throughput can be obtain provided they are in the SNR range, which ranges from 30dB upward.

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