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Comparison of UDP$_{UP}$T for Single and Multiple Users Models in IEEE802.11b/g WLANs

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Research Article

Abstract

Wireless Local Area Networks (WLAN) and the Internet are executed through the transport layer of the Open Systems Interconnect (OSI) model, which consists of two major protocols: The User Datagram Protocol (UDP) and the Transmission Control Protocol (TCP). In terms of the initial connection, TCP has a reliable data connection, while UDP has an unreliable data connection. This paper focuses on UDP and the determination of the predictability of the upstream link with regard to throughput under some scenarios. The description of User Datagram Protocol upstream throughput (UDPupT) variation of throughput with signal to noise ratio (SNR) of an IEEE 802.11 network was developed, compared, and analysed in two scenarios: one with a single user on the network performing selected categories of traffic scenarios constituting upload operations, and the second with multiple sets of users carrying out the same categories of activities on upload operations. The experimental data obtained under these conditions was used to develop a model. The models developed were analysed and compared. The results showed that the variation of throughput with respect to SNR did not have a definable model definition due to UDP being erratic in nature. The model comparison showed that the single-user scenario showed better throughput performance with an overall average difference of 14.81 Mbps compared to the multiple-user scenario. This gives a standard deviation of 3.2167 and 1.184, respectively. However, the result shows that throughput decreases as the number of users increases on the channel.

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Keywords
IEEE802.11b/g; Upstream, WLAN, User Datagram Protocol; Throughput, Signal to Noise Ratio

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1. Introduction

Literature throughput analysis of IEEE 802.11 media access control (MAC) protocols is prevalent, probably because it is the most popular wireless local area network (WLAN) standard (Ayidu and Iruansi, 2021). Its commercial success grows per year as more versions become increasingly available, e.g., 802.11e and 802.11n, with increasing throughputs (Bruno et al., 2008). With the proliferation of high-bandwidth applications such as virtual reality and high-resolution video streaming, it seems that this analysis needs to be done. The prediction of throughput seems important because it is a determinant of the quality of real-time video and audio streaming services in low-latency network protocols (Agatha, 2009). The physical layer of the IEEE 802.11 standard used in WLAN systems specifies several communication data rates that vary depending on the connection quality. This variation is usually measured by examining the signal-to-noise ratio (SNR). SNR is an important metric to consider when changing the data link rate (DLR) of a WLAN (Metreaud, 2006). The amount of data bits transferred from a data source or group of data sources to a destination or group of destinations in a particular time is called a throughput. You can measure the throughput by the number of packets per second, the number of bits per second, or the number of bytes per second. You can also define the throughput in real time as the data delivery rate over a period of time. Throughput is a better measure of network performance compared to bandwidth because it is the actual speed of the network. Network monitoring depends heavily on its value. This can be measured using several network monitoring and analysis tools (Akintola et al., 2006). Live measurements and analyses are not always possible, so you may need to be able to predict your network throughput at any time, unless other conditions are specified. Predicting transmission throughput over a network with a limited set of information available to network engineers can be a serious challenge. This is most apparent when the transport medium is User Datagram Protocol (UDP). This is because few or no models provide UDP throughput predictions, especially using probabilistic models. This is especially true for what is considered a downlink throughput or downlink. It's called throughput. 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, and they are presented below:

Ikponmwosa et al, (2014) developed models to predict transmission control protocol (TCP) upstream throughput based on computed SNR from client to server based on IEEE802.11b WLAN in different environments for both single and multiple user scenarios. In this study, the dependence of TCP upstream throughput ($TCP_{up}T$) changes as the SNR value changes from the high signal (strong signal), through low signal (grey signal) to a very low signal (weak signal), in a regressive manner

Bruno et al. (2008) studied the interaction between the collision avoidance mechanism of the 802.11MAC protocol and the dynamics of the upper layer transport protocol. This was done using analytical, simulation, and experimental methods, and the Markov chain model was developed for 802.11 Wireless Local Area Networks (WLAN) for finite-lifetime transmission control protocol (TCP) connections. The distribution of the number of active stations has been calculated. Users compete for Datagram Protocol (UDP) flow. Their study was able to show that the total TCP throughput is independent of the number of open TCP connections and that the UDP flow throughput is superior to the same number of aggregate TCP flows.

Akintola et al. (2006) introduced the power of connectionless data transmission over IP-based wired and wireless networks. This was done using Network Simulator 2 and MATLAB 6.1. The results obtained show that the most effective throughputs of the two networks peak at different times. Wireless networks are unreliable due to the sharp drop after reaching their maximum. The results obtained also show high throughput based on UDP, with no flow control and no retransmission of lost packets. In this work, they did not look at the observed SNRs to estimate the throughput.

Li et al. (2011) developed a mathematical framework and techniques to support heterogeneous network situations in elastic (TCP-based) and inelastic (UDP based) scenarios, as well as optimal network algorithms to account for the multilevel interactions between flows. Largely, their approach was successful.

Bikash et al. (2011) performed an experimental analysis of UDP performance on mobile ad hoc networks using various routing protocols and variable payloads. Here, four network scenarios with different node movement speeds of 4, 8, 16, and 32 nodes are presented with destination sequence distance vector (DSDV), dynamic source routing protocol (DSR), and ad hoc on-demand distance vector routing (ad hoc on-demand distance vector routing). We investigated three routing schemes (AODV). The throughput and end-to-end packet delay measured using simulation experiments over UDP connections were used as the performance matrix. The results show that due to the limited routing traffic, performance does not converge in 4-node and 8-node DSR and AODV network scenarios. As the number of nodes increases, more routing traffic is generated, and even with high mobility, DSR and AODV are significantly improved with almost 100% throughput in a 16-node and 32-node network, respectively. Because Ad- hoc networks are formed without centralised control, security must be handled in a distributed fashion. Moreover, routing protocols are 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 compared to AODV and DSR. The conclusion was that the DSR protocol allows more packets to be successfully delivered to the destination, and when UDP is considered a transport layer protocol, DSR is best suited for MANET.

2. Materials and Methods

This study investigated the UDP performance of the transport layer of the TCP/IP protocol in a WLAN environment. The performance evaluation was based on the measurement of the data upstream throughput of the user datagram protocol within the transport layer of the network.

The study was carried out on the main campus of the University of Benin. The location lies within the coordinates 6.3350^0N and 5.6037^0E According to Ayidu and Elaigwu (2023), the experiment was carried out in an open-space environment that can fairly represent an actual networking environment for WLAN users and clients. In this study, we used both hardware and software tools to perform fieldwork for data acquisition. The software tools used are Tamosoft Throughput Test and inSSIDer version 2.1 for both server and client ends. Using real-time measurements, according to Ayidu and Akhiideno (2023), The received signal strength level (RSSL) at the client terminal was measured. The throughput is measured in Mbps, and the RSSL is measured in dBm. The experiment was done using an access point (AP) mounted on a pole.

The client comprised a single user on a laptop for the first scenario, while the second scenario involved multiple users with their various laptops, all carrying out a range of activities listed under the following Quality of Service (QoS) categories: best effort, Background, Excellent effort, Audio video, voice, and Control. The specifications of the Access Points (AP) used in the research are shown in Table 1.

Table 1: Access Point Specifications

Hardware Specifications	
Data Speed (MHz)	100
Band (GHz)	2.4
Output Power (V dc)	12
IP Address Range	192.168.1.xx
Cabling	Category 5e Unshielded Twisted Pair (UTP)

3.0 RESULTS

The data collected for the open space environment were analysed, and the results are presented in three separate tables for each sample point (1, 2, and 3). The tables provide the average UDPupT (UDP upstream throughput) data for different QoS traffic types for both single user and multiple user scenarios shown in Tables 2 and 3, respectively. Also, the tables include the standard deviation for all instantaneous UDPupT values.

Table 2: Average of UDPupT data (Single User)

Average of UDPupT at sample point 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 UDPupT Ave.(Mbps)		17.0979	17.4061	17.2520	1.7701
Total sample sizes	108				

Average of UDPPupT at sample point 2

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

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				

Table 3: Average of UDPupT data (Multiple Users)

Average of UDPPupT at sample point 1

QoS Traffic Type	sample size F and B	Ave. UDPupT F (Mbps)	Ave. UDPupT B (Mbps)	UDPupT per QoS Ave. traffic (Mbps)	STD for all Inst. UDPupT (Mbps)
Best effort	18	9.5659	8.8948	9.3240	0.8201
Background	18	9.8448	9.1830	9.5139	0.1039
Excellent effort	18	9.8767	9.3256	9.6011	0.7188
Audio video	18	9.4100	9.0411	10.2141	0.1879
Voice	18	9.3270	9.4115	9.3693	0.4480
Control	18	9.7078	9.3344	9.6350	0.4587
Total UDPupT Ave. (Mbps)		9.6220	9.1984	9.6095	0.4562
Total sample sizes	108				

Average of UDPPupT at sample point 2

QoS Traffic Type	sample size F and B	Ave. UDPupT F (Mbps)	Ave. UDPupT B (Mbps)	UDPupT per QoS Ave. traffic (Mbps)	STD for all Inst. UDPupT (Mbps)
Best effort	18	8.9052	9.1007	9.0030	2.1753
Background	18	8.9407	7.9200	8.4304	1.6688
Excellent effort	18	7.7269	8.6059	8.0773	2.0471
Audio video	18	8.1681	8.5022	8.8793	1.8813
Voice	18	8.1974	8.9978	8.5976	2.2327
Control	18	8.5267	9.2056	8.6554	2.0256
Total UDPupT Ave. (Mbps)		8.4108	8.7220	8.6071	2.0051
Total sample sizes	108				

Average of UDPPupT at sample point 3

QoS Traffic Type	sample size F and B	Ave. UDPupT F (Mbps)	Ave. UDPupT B (Mbps)	UDPupT per QoS Ave. traffic (Mbps)	STD for all Inst. UDPupT (Mbps)
Best effort	18	6.7522	7.6330	7.1620	1.3602
Background	18	6.7441	6.7789	6.4839	0.2950
Excellent effort	18	7.7474	6.9889	7.3681	1.4016
Audio video	18	5.4681	5.1565	4.9889	0.9582
Voice	18	6.5656	6.6704	6.6180	2.2542
Control	18	7.4533	7.4389	7.3970	1.5836
Total UDPupT Ave. (Mbps)		6.7884	6.7777	6.6696	1.3088
Total sample sizes	108				

NOTE: F and B represent Front and Back

The above tables provide valuable insights into the performance of the different QoS traffic types in single and multiple user scenarios, as well as their average UDP upstream throughput values at different sample points. The result also shows the standard deviation values, which offer information about the variability of instantaneous UDPupT measurements, which is important for assessing the stability and consistency of the results. Also, analysis and interpretation of the data can be done based on these results.

3.1 Comparison of Single and Multiple Users Environments

Figure 1. shows the comparison between the single user scenario (data 1) and the multiple user scenario (data 2) after analysis with MATLAB 2017.

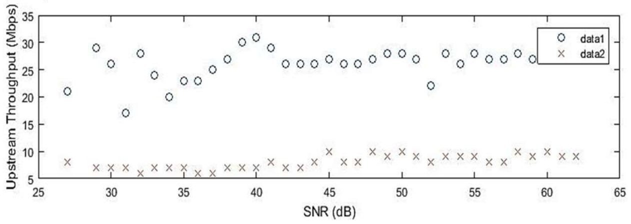

Figure 1: Comparison of UDPupT QoS traffic for Single and Multiple User

Figure 1 compares the UDPupT for the single user model (data 1) and the multiple user model (data 2) in IEEE 802.11b/g WLANs. The graph visually represents the performance of UDP upstream throughput plotted against the signal-to-Noise Ratio (SNR) as an additional factor influencing the performance of the UDPupT. The relationship between UDPupT for single and multiple users and SNR shows a trend between the two variables. It was observed that the single-user scenario (data 1) shows higher SNR values, giving rise to higher UDPupT. This is due to the fact that a higher SNR is associated with better signal quality, which can lead to improved data transmission rates and higher throughput. The multiple user scenario (data 2) shows lower SNR values due to decreased UDP upstream throughput, as multiple users might lead to increased interference and reduced signal quality. Comparing to Ikponmwosa et al, (2014) who predicted transmission control protocol upstream throughput ($TCP_{up}T$) based on computed SNR. The throughput ($TCP_{up}T$) changes as the SNR value changes from the high signal (strong signal), through low signal (grey signal) to a very low signal (weak signal).

The graph, however, shows an average throughput difference of 14.81 Mbps between the two scenarios (UDPupT single user and UDPupT multiple users). This provides valuable insights into the relationship between UDP upstream throughput, SNR, and the impact of single and multiple user scenarios in IEEE 802.11b/g WLANs. The results can aid in understanding how network performance is affected by the number of users and the signal quality, allowing for better network management and optimisation to ensure reliable and efficient data transmission in WLAN environments.

It is, however, recommended that there be an optimal number of multiple users in order not to degrade the network throughput below a set accepted value.

The standard deviations of the two scenarios are as follows:

Single user: 3.21676151

Multiple users: 1.184358694

There is, however, more variation in the average throughput in a single user transaction compared with its alternate scenario.

4. 0 Conclusion

The study aimed to investigate and compare the upstream throughput of User Datagram Protocol (UDP) in IEEE 802.11b/g WLANs for both single-user and multiple-user scenarios. Through extensive experimentation and analysis, several key findings were obtained for both scenarios. The single-user scenario, shows higher SNR values, giving rise to higher UDPupT. In contrast, the UDPupT multiple-users shows lower SNR values as the number of simultaneous users increased, the throughput experienced degradation due to increased contention for the shared wireless medium. The presence of collisions and packet retransmissions contributed to a reduction in overall throughput. Considering the optimal number of multiple users in order not to degrade the network throughput, would yield a better network management and optimisation to ensure reliable and efficient data transmission in WLAN environments. These would potentially improve the overall throughput of both single and multiple-user scenarios and help to optimize network configurations to improve user experience.

In conclusion, this research provides valuable insights into the performance of UDPupT in IEEE 802.11b/g WLANs under different user scenarios. By monitory throughput, network engineers can make informed decisions to enhance the efficiency and reliability of WLAN deployments for various usage scenarios. However, further research may be needed to explore other factors and technologies that can further optimize the performance of UDP in WLANs.

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