Data Rates Performance Analysis of Point to Multi-Point Wireless Link in University of Ilorin Campus

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Abstract - ***The wireless link form basis for the success of the technology and knowledge transfer platform, it is an essential service being utilized by the researchers, teachers and students in higher education system especially within the universities and colleges. It is therefore important for service provider to have an improved quality of service offer to the users of point to multi-point wireless network. The inconsistent poor performance of the link of point to multi-point wireless networks result from packet loss, high latency, interference and obstructions. The point to multi-point connections could be achieved with the aid of Ubiquiti Rocket M5 Titanium wireless device located at the Network Operation Centre (NOC) linking to the selected five access points of the University of Ilorin. Multi Router Traffic Grapher (MRTG) and Paessler Router Traffic Grapher (PRTG) throughput monitoring software served as an interface to record transmitted data rates, received data rates, signal strength, noise, latency and overall throughput of the inbound and outbound traffics. This paper provides the impact of impairments on the network performance of wireless link to various locations of access points. It provides the overview of Wireless Local Area Network (WLAN) technology. It also describes the Quality of Service (QoS) in relation to the network performance. The analyses are performed to compute the regression coefficients, predicted standard error to show the variation of the packet losses with respect to these access points.***

Key Words: *MRTG, PRTG, Latency, and Linear Regression*

1. NTRODUCTION

The wireless link form basis for the success of the technology and knowledge transfer platform, it is an essential service being utilized by the researchers, teachers and students in higher education system especially within the universities and colleges. The institutions take advantage of educational data transfer over a large networks range for the purpose of computational research work. Based on the relative small distances involved in wireless networks within building or from site to site on a campus, it is often a common factor in reception problem. The impairments could result in the received signal which will cause the multipath fading, shadowing of the receiver from the transmitter by obstructions and interference from other radio sources [1]. According to [2], open spaces without obstructions, radio waves naturally fade in direct proportion to the square of the distance from the transmitter. The wavelength and frequency (the overall pattern of the wave) remain the same; however, the wave's overall energy and therefore amplitude decreases. It is generally observed that bulk data transfer has been plagued by poor performance for various circumstances. These include improper configuration of the sending and receiving hosts and packet loss caused by the high latency, external wireless environmental factors such as interference and malfunction of hardware components [15].

Many research have been conducted on throughput analysis of point to point and point to multi-point wireless link [3-8]. However, fewer were carried out using an integrated MRTG and PRTG tools to monitor the performance of the point to multi-point networks. Paessler Router Traffic Grapher (PRTG) is an advance tool compared with the Multi Router Traffic Grapher (MRTG). Though the MRTG is a free software use for monitoring and measuring traffic, it is not easy to install on window based operating system and the configuration file can be complex. While the PRTG can be used for packet sniffer based traffic monitoring, NetFlow based traffic monitoring, latency monitoring and easy to install on window based operating system.

The research will presents the data rates performance analysis of point to multi-point wireless in University of Ilorin campus network for the purpose of proffering solution to the challenges of wireless network.

1.1 WIRELESS DISTRIBUTION SYSTEM

A Wireless Distribution System (WDS) is a system that enables the wireless interconnection of access points (APs) in an IEEE 802.11 network [21 - 24]. It allows a wireless network to be expanded using multiple access points (APs) without the need for a wired backbone to link them, as is traditionally required. The notable advantage of WDS over other solutions is that it preserves the MAC (Media Access Control) addresses of client packets across links between access points (APs) [22]. An access point (AP) can be either a main, relay or remote base station. A main base station is typically connected to the wired Ethernet. A relay base station relays data between remote base stations, wireless clients or other relay stations to either a main or another relay base station. A remote base station accepts connections from wireless clients and passes them on to relay or main stations. Connections between "clients" are made using MAC (Media Access Control) addresses [22].

1.2 WIRELESS LAN TECHNOLOGY

A wireless local area network (WLAN) is a flexible data communications system implemented as an extension to, or as an alternative for a wired LAN [15].Using radio frequency (RF) technology, wireless LANs transmit and receive data over the air, minimizing the need for wired connections. Thus, wireless LANs combine data connectivity with user mobility. The diagram in Fig.1 illustrates wireless local area network. There are three major types of wireless local area network (LAN) technology namely: Narrowband, Spread Spectrum, infrared technologies. The spread spectrum technology is the most common type used today in wireless LAN [6, 15].

Most wireless LAN systems use spread spectrum technology, which is a wideband radio frequency technique, developed by the military for use in reliable secure mission critical communications systems. Spread-spectrum is designed to trade off bandwidth efficiency for reliability, integrity and security [9]. In other words, more bandwidth is consumed than in the case of narrowband transmission, but the tradeoff produces a signal that is, in effect, louder and thus easier to detect, provided that the receiver knows the parameters of the spread spectrum signal being broadcast. If a receiver is not tuned to the right frequency, a spread spectrum signal looks like background noise. There are two types of spread spectrum radio: frequency hopping and direct sequence [6, 15].

Frequency - Hopping Spread Spectrum (FHSS) uses a narrowband carrier that changes frequency in a pattern known to both transmitter and receiver. Properly synchronized, the net effect is to maintain a single logical channel. To an unintended receiver, FHSS appears to be short-duration impulse noise [15]. Direct - Sequence Spread Spectrum (DSSS) generates a redundant bit pattern for each bit to be transmitted. This bit pattern is called a chip (or chipping code). The longer the chip, the greater the probability that the original data can be recovered (and, of course, the more bandwidth required). Even if one or more bits in the chip are damaged during transmission, statistical techniques embedded in the radio can recover the original data without the need for retransmission [15].

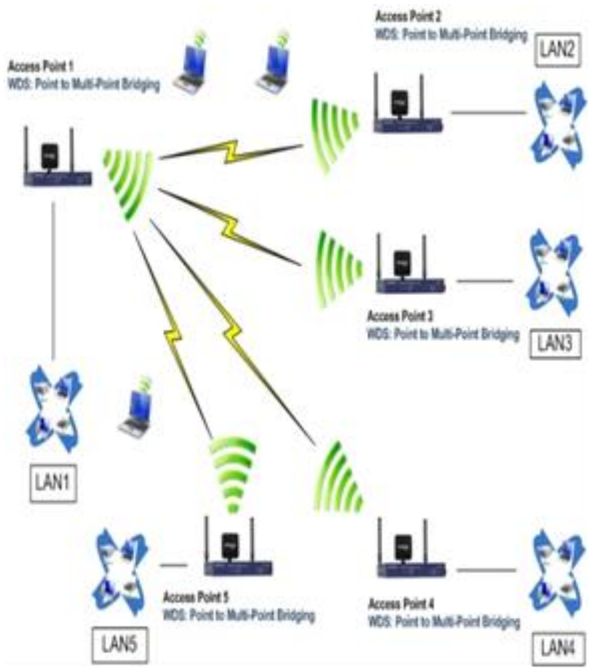

Figure 1: Wireless LAN access points [17]

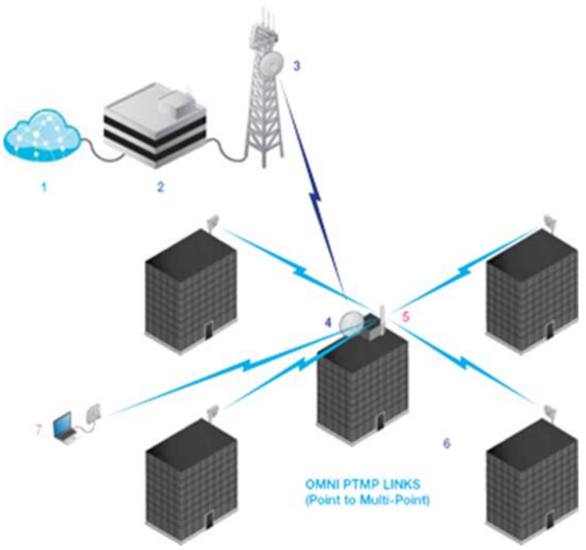

Figure 2: Network operating center with five access points [18].

Point to Multi – Point link is having several nodes connected to a central point of access whereby yielding

point to multi – point application [19]. The wireless local area network of access points and network operating center linking to the Mini campus, Jalala quarters, Senate building, Faculty of education building and Faculty of engineering building are shown in Figure 1 and Figure 2 respectively.
The specifications of the Rocket M5 Titanium Radio are given as follows:
Operating Frequency of 5170 - 5825 MHz
Range Performance 50+ km (Outdoor - Antenna Dependent).
Output Power 27 dBm.

1.3 TRAFFIC ROUTING IN WIRELESS NETWORK

The volume of traffic capacity required in a wireless network is highly dependent upon the type of traffic carried. It is the type of traffic carried by a network that determines routing services, protocols and data handling techniques which must be employed [4].Two general routing services are provided by network: these are connection – oriented services and connectionless services. In connection – oriented routing, the communications path between the message source and destination is fixed for the entire duration of the message. Connectionless routing does not establish a firm connection for the traffic, and instead relies on packet – based transmission [4].
Circuit-switching was the first switching technique used in communication networks due to its ability to carry analogue signals [20]. According to [4], the system decides on which route to follow, based on a resource-optimizing algorithm, and transmission goes according to the path. While packet switching, all the data coming out of a machine is broken up into chunks, each chunk has the address of where it came from and where it is going [4]. This enables chunks of data from many different sources to co-mingle on the same lines, and be sorted and directed along different routes by special machines along the way. Also in [20], packet switching is the basis for the Internet Protocol (IP). The information flows are broken into variable-size packets (or fixed-size cells as in the case of Asynchronous Transfer Mode (ATM). It involves the transmission of data in packets of fixed length across a shared network. Each packet is individually addressed, in order that the packet switches can route each packet over the most appropriate and available circuit.

1.4 PACKET LOSS CHARACTERISTIC

The sources of packet loss can be categorize into two broad categories: (a) channel losses induced by the long distance wireless channel; (b) protocol-induced losses due to the 802.11 MAC protocol [9]. Our study is based on a point to multi-point wireless network consisting of five access points with the distance varying from 0.1 – 16.9 km. Channel loss characterizations are external Wi-Fi interference, non-Wi-Fi interference and multipath interference. Among these, it will show that the external Wi-Fi (wireless fidelity) interference is the most significant source of packet losses in the point to multi-point wireless of the studied environments. The effects of multipath and non-Wi-Fi interference are not significant [10]. This is because the lower delay spreads in wireless link significantly reduce interference due to multipath. The two factors contributing to lower delay spreads in wireless networks are the long distance between the two end hosts and the line-of-sight deployment of the nodes [2]. In the case of protocol-induced losses, the stock 802.11 MAC protocol is not all that suitable for wireless links due to the breakdown of CSMA (carrier sense multiple access) over long distances and propagation delays. Further explanation was given in [11] of how radio channel suffers from multipath effect which may leads to delay of same signal. The received delayed symbol from far distance propagation may overlap with each other whereby resulting in intersymbol interference (ISI).

1.5 PACKET LOSS CHARACTERISTIC

Quality of Service (QoS) is closely related to network performance, but QoS metrics are oriented towards a user's end-to-end experience [12]. Network performance is measured mainly from the network provider's viewpoint. Network performance metrics are defined to provide a meaningful portrait of network behavior to the network provider or network manager. In contrast, QoS is the end-to-end network performance seen from the viewpoint of a user's particular connection. QoS parameters are defined to quantify the performance needed and experienced by a user's application [12]. The QoS solution is being given supported end to end in the converging of the Internet connection and Telecommunications yielding to IP (Internet Protocol) packet transfer in the Next Generation Network [13]. It is further explained in [16] as the prioritization technique used by the network devices in the IP header of packets.

2. DATA ACQUISTION AND ANALYSIS

The method used in this research work involved the study of University of Ilorin point to multi - point wireless link and the location of some of the access points around the campus. Twenty samples of Data were acquired using Multi-Router Traffic Grapher (MRTG) software package. The analysis for the set of data recorded from various locations of the access points was performed. The parameters for the collection of data include number of packets, transmitted data rates, received data rates, signal strength, noise, and latency. Table 1 gives the distances of the access points from the network operation center. Table 2 shows the computation of the predicted standard error (packet loss) for the five location of point to multi-point wireless link and series of graphs will serve as references for the conclusion.

Table -1: Name of Access Point and its Location

S/N	Access point Location	Distance from NOC
1	Mini campus college of medicine	16.9 Km
2	Jalala Staff's Quarters	4.6Km
3	Senate Building	0.9Km
4	Faculty of Engineering	0.1Km
5	Faculty of Education	0.08Km

This implies that $Y = a_0 + a_1X$ which is called Regression Equation of Y on X.

$$a_0 = \frac{\sum Y \sum X^2 - \sum X \sum XY}{n\sum X^2 - \left(\sum X\right)^2} \quad (1)$$

$$a_1 = \frac{n\sum XY - \left(\sum X\right)\left(\sum Y\right)}{n\sum X^2 - \left(\sum X\right)^2} \quad (2)$$

$$PSE = \sigma\sqrt{1 - r^2} \quad (3)$$

where:

X represents the Transmitted data rate
Y represents the Received data rate.
PSE represent predicted standard error.
r represents product standard error,
σ represents standard deviation.

Table -2: Linear Regression Analysis of the Data Recorded from the Access Points at Operating Frequencies

Access point (AP)	**Regression (a_1)**	**Intercept (a_0)**	**Product moment correlation (r)**	**Predicted standard error PSE**
Mini Campus(1)	0.903007	-6.0364	0.934109	10.53664
Jalala Quarters(2)	0.666635	-1.312	0.962868	6.447254
Senate Building(3)	1.100727	-17.2891	0.960969	6.17919
Engineering Building(4)	0.873379	-6.9000	0.936567	2.717458
Education Building(5)	0.858371	-4.7467	0.993749	2.086313

3. RESULTS AND DISCUSSION

The transmitted (Tx) data rate is the predictor while the received (Rx) data rate is the dependent variable. The impact of external Wi-Fi interference on wireless link can leads to high latency which further result in data packet loss. Packet loss due to external Wi-Fi interference is far more significant in point to multi-point wireless deployments than local mesh networks. From the analysis conducted, the values of the predicted standard error (PSE) or packet loss and intercept (a_0) for each access point are presented in Table 2. In Figure 3 we have the graph showing the intercepts of the regression lines with the variation in the slope. The results of the non - linear relationships are shown in Figure 4 - Figure 8. This is to see the degree of relationship between the transmitted and received data rates of the radio at different location of the access points from the network operation center (NOC). This is followed by the graphs of latency with respect to the five access points as shown in Figure 9 – Figure 13 namely: Mini Campus (AP1), Jalala Staff's Quarters (AP2), Senate building (AP3), Faculty of Engineering building (AP4) and Faculty of Education building (AP5).

The overall network traffic monitoring of the University of Ilorin is shown in Figure 14 at an interval of time to depict the network performance metric for the quality of service (QoS) as well as indicating bandwidth utilization at the peak hours of the day. The higher the latency of the packets received, the poorer the quality of service and vice versa.

Going by the environment investigated with respect to packet loss the Mini campus has high level of packet loss of 10.54 due to the external Wi-Fi interference, long distance of transmission and delay of the wireless link. Other access points are Jalala Staff's quarters, Senate building, Engineering building and Education building with 6.44, 6.18, 2.72, and 2.09 respectively.

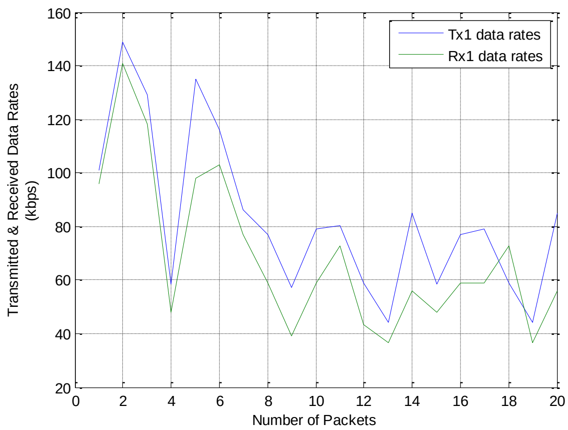

Figure 4: Transmitted and Received data rates for radio at Mini Campus.

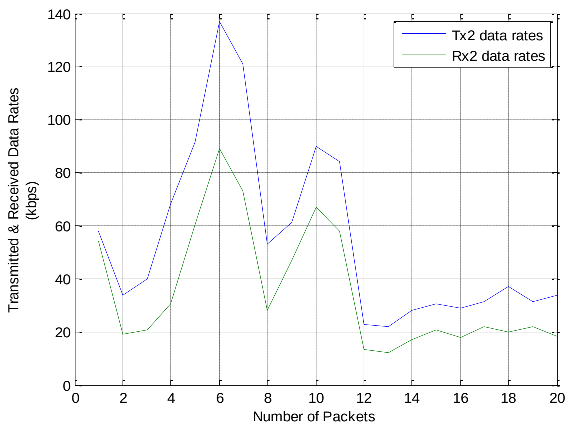

Figure 5: Transmitted and Received data rates for radio at Junior Staff's Quarters.

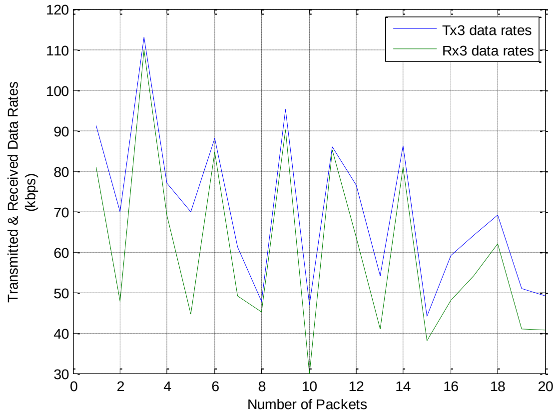

Figure 6: Transmitted and Received data rates for radio at Senate building.

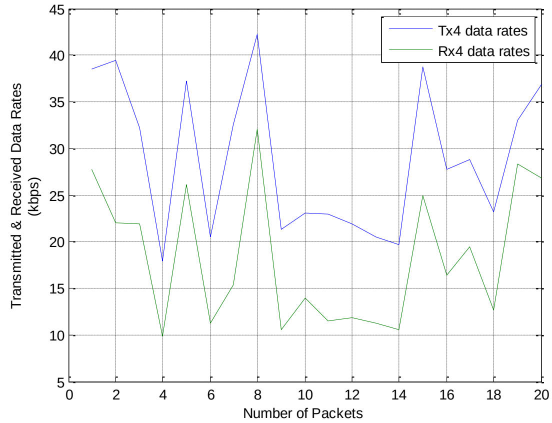

Figure 7: Transmitted and Received data rates for radio at Faculty of Engineering.

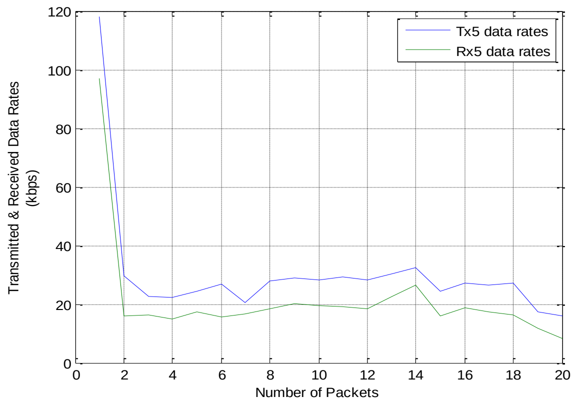

Figure 8: Transmitted and Received data rates for radio at Faculty of Education.

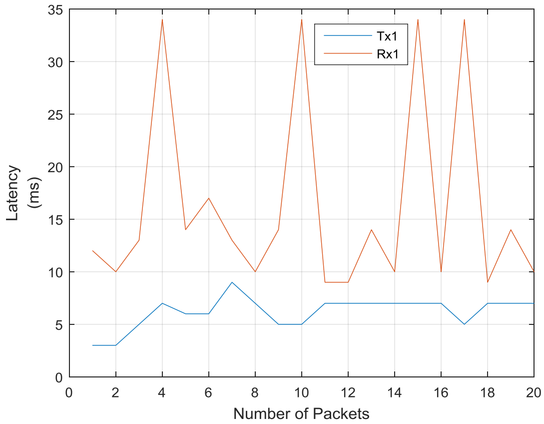

Figure 9: Latency of Tx1 and Rx1 for radio at Mini Campus.

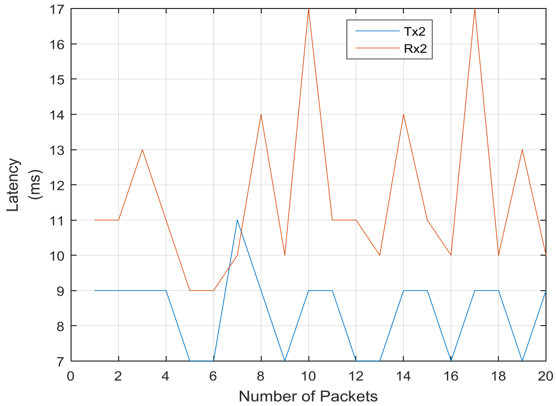

Figure 10: Latency of Tx2 and Rx2 for radio at Junior Staff's Quarter.

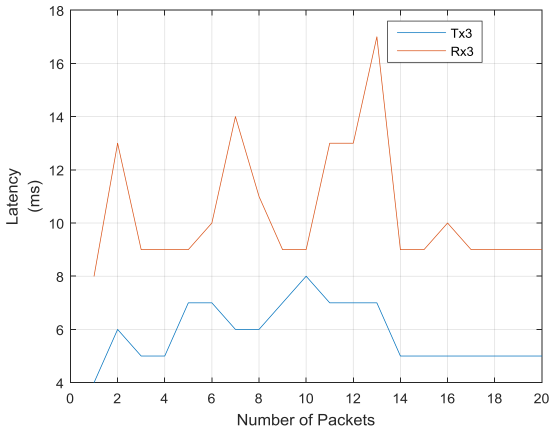

Figure 11: Latency of Tx3 and Rx3 for radio at Senate Building.

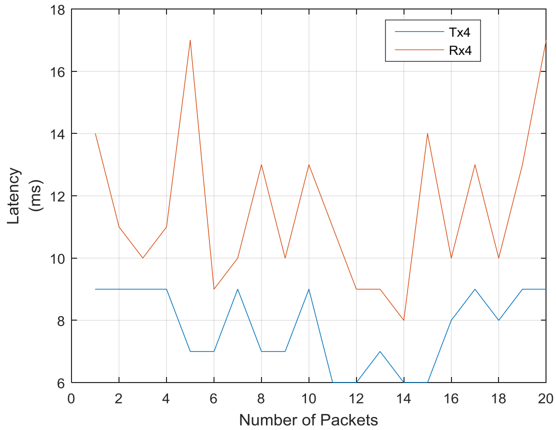

Figure 12: Latency of Tx4 and Rx4 for radio at Faculty of Engineering.

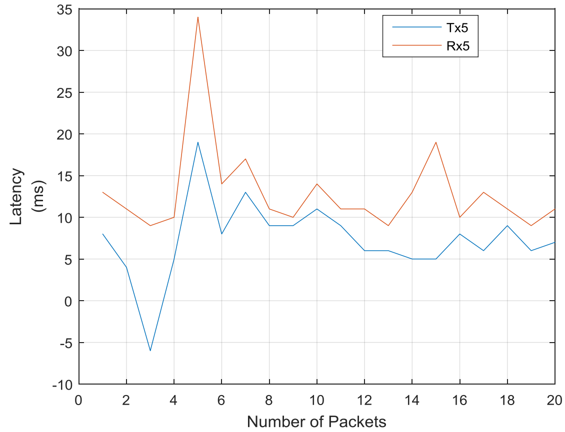

Figure 13: Latency of Tx5 and Rx5 for radio at Faculty of Education

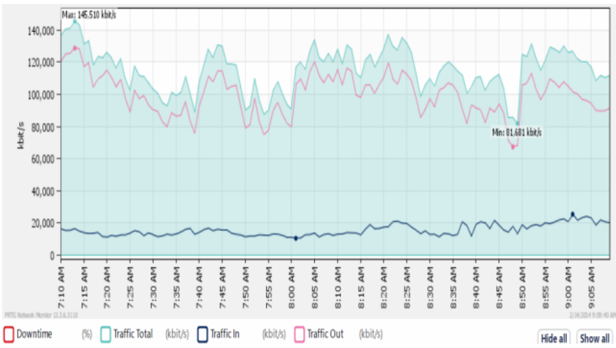

Figure 14: PRTG Network Monitor (GLO1 TITAN) |Sensor Details '(10101) University of Ilorin.

3. CONCLUSIONS

The analysis have been computed as stated above using linear regression equation to predict the standard error. This corresponds to data packet loss along the channel of communication as a result of the interference from multipath and high latency at the receiving end. It shows that latency is very important in the determination of the quality of service of point to multi – point wireless link. The results depict the random variation of data rates and latency fluctuation which was due to the impairments on the network. The overall performance of the throughput illustrates the maximum bandwidth and minimum bandwidth consumption in the network. High burst speed bandwidth need to be dedicated for improve performance in order to reduce the rate of data packet loss.

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