Performance Analysis of IIUM Wireless Campus Network

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Abstract. International Islamic University Malaysia (IIUM) is one of the leading universities in the world in terms of quality of education that has been achieved due to providing numerous facilities including wireless services to every enrolled student. The quality of this wireless service is controlled and monitored by Information Technology Division (ITD), an ISO standardized organization under the university. This paper aims to investigate the constraints of wireless campus network of IIUM. It evaluates the performance of the IIUM wireless campus network in terms of delay, throughput and jitter. QualNet 5.2 simulator tool has employed to measure these performances of IIUM wireless campus network. The observation from the simulation result could be one of the influencing factors in improving wireless services for ITD and further improvement.

1. Introduction
The Internet is one of the most powerful, cost effective and easy resources in the educational institutions especially at tertiary level for state-of-the-art research activities. Good connectivity with the Internet is not luxury to a university, in fact is a basic necessity of today’s modern education. Today’s Internet is the combinations of multiple set of technologies like WiFi, WiMAX, GSM. The next generation wireless technology systems are being devised with the vision of heterogeneity where a mobile user will be connected with multiple wireless networks like GPRS/UMTS, IEEE 802.11x, WiMAX and satellite etc. [1]. The Internet Provides vast amount of information to the users to enhance research activities by the students and lecturers. Therefore, a university needs to be connected with high speed connections to provide satisfactory services to its users. However, educational institutions face budgetary constraints and limited resource that makes a complicated decision to allot bandwidth in proper way to the campus users. The demand for bandwidth is increasing every year due to rising number of new student’s enrolment with multiple devices like, laptops, smart phones, etc. Hence, it is important to allocate bandwidth in proper way among campus users.
It has been observed that available bandwidth of a university is generally not enough to meet rising demand to support optimal usage. Management of the bandwidth is a generic term that describes different techniques, technologies, tools and policies employed by an organization to provide optimum usage of its resources [2]. It is noted that bandwidth management procedures can be classified into three broad categorized including techniques and technologies, organizational management policies and monitoring. Some commonly used techniques are [3]:

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IEEE 802.11g has been deployed in IIUM to provide wireless services. The Information Technology Department (ITD) of IIUM has set some rules and regulations for its users that reduces burden on the overall network and improves the quality of wireless facilities. For example, ITD has set restriction on social sites (facebook, twitter, youtube) during office time (8am to 6pm) so that essential activities can be performed smoothly. It also limits the download capacity for an individual user and given an equal priority to all users. The ITD is trying to increase the quality of wireless services by taking many managerial polices. The analysis of technical aspects also needs to be considered. Therefore, this paper aims to investigate the performance of IIUM wireless campus network in terms of throughput, delay and jitter.

The rest of the paper organized as follows. Section II addresses the issues of WiFi in details. The background of IIUM wireless campus network has mentioned in section III. Simulation scenario has drawn and highlighted in section IV. Performance analysis is discussed in section V. Finally, section VI concludes this paper.

2. Wireless Network (WiFi)

Wireless Fidelity (WiFi) is a popular technology that has been used for data transmission from last decade for small coverage area. Data transmission can be performed either connected with an Access Point (AP) at broadband speed or in ad hoc mode. In 1997, Institute of Electrical and Electronic Engineer (IEEE) drafted 802.11 standard for Wireless Local Area Network (WLAN) that is known as IEEE 802.11. This protocol was capable to transmit only 2 Mbps which is too slow for many applications and therefore, it was not manufactured at that time. Later on some versions have been released namely IEEE 802.11a and IEEE802.11b that work independently. In 1999, some network hardware companies have manufactured IEEE 802.11a that operating at 5 GHz with transmission speed of 54Mbps. However, it was not well accepted due to its heavy power consumption and high cost.

![Figure 1: Channel distribution of WiFi](image)

Subsequently, in the same year IEEE 802.11b standard was also released operating at 2.4 GHz with transmission speed 11Mbps that has been accepted widely. It is also known that both 11a and 11b are
the extension of original IEEE 802.11 and IEEE 802.11b released before IEEE 802.11a in same year and gained popularity. IEEE 802.11a is mostly used in business networks and IEEE 802.11b is suits with home networks but they are incompatible with each other.

WiFi has 11 channels with 3 non-overlapping that uses direct-sequence spread-spectrum depicted in figure 1 [7]. Channel 1, 6 and 11 are typically used for large coverage of area. However, this protocol is criticized for lacking of security. IEEE 802.11g is the extension of IEEE 802.11b that released in 2003 and operates at 2.4 GHz with transmission speed at 54Mbps. This standard is backward compatible with IEEE 802.11b. Frequency Division Multiplexing (FDM) technology is used for this protocol. Finally, the newest IEEE 802.11n has been released in 2009 for high data transmission. MIMO technology has utilized to maximize transmission speed that is up to 600 Mbps using 2.4 GHz. A comparison of different versions’ of WiFi is listed in table 1. The performance of WLAN, particularly delay and jitter has been addressed and showed an improvement for interactive multimedia transmission [8,9].

### Table 1. Comparison of wireless technologies

| Technology   | Data Rate | Tx-Range | Frequency Band | Coding Technique |
|--------------|-----------|----------|----------------|------------------|
| IEEE 802.11a | 54Mbps    | 35/120m  | 5.5 GHz        | OFDM             |
| IEEE 802.11b | 11 Mbps   | 38/140m  | 2.4 GHz        | FDM              |
| IEEE 802.11g | 54Mbps    | 38/140m  | 2.4 GHz        | OFDM             |
| IEEE 802.11n | 100Mbps   | 70/250m  | 2.4 GHz        | MIMO             |

2.1 Radio Channel

Wi-Fi protocol uses spread spectrum techniques in the 2.4 GHz band that is unlicensed in most countries and known as the Industrial, Scientific, and Medical (ISM) band. Wi-Fi utilizes Direct Sequence Spread Spectrum DSSS (802.11), Complementary Code Keying (CCK, 802.11b), or OFDM modulation (802.11a/g/n) with 14 Radio Frequency (RF) channels (11 available in US, 13 in Europe, and just 1 in Japan) and 22 MHz bandwidth [10].

2.2 Network Size

The basic cell of IEEE 802.11 is known as Basic Service Set (BSS) that is a set of mobile or fixed stations. If a Mobile Device (MD) moves from the BSS coverage area, it can not communicate with other BSS directly. The coverage area of a BSS is typically 38 meter and 140 meter for indoor and outdoor respectively for IEEE 802.11b/g and the range is listed in table 1.

2.3 Security

IEEE 802.11 uses the RC4 stream cipher for encryption and the CRC-32 checksum for integrity. WiFi Protected Access (WPA) and WAP2 encryption mechanisms are employed to WiFi technology for further enhancement that includes IEEE 802.11i standard which are AES block cipher and CCM.

2.4 Mobility

Mobility is one of the most important issues that has been supported by WiFi. WiFi provides high speed data transmission with low mobility as its coverage area is very limited. To support seamless mobility for the MD, the coverage area must be extended to the certain level.

3. IIUM Wireless Network

International Islamic University Malaysia (IIUM) is one of the unique universities in the world in terms of internationalization, Islamization and comprehensive excellence of teaching and learning. It has four campuses including Gombak - the main campus, Kuantan campus, Petaling Jaya campus and Kuala Lumpur campus. The wireless network of IIUM has been maintained and monitored by ITD in
all these campuses. The wireless network has been covered in academic and residential areas where there are approximately thirty thousand users are being benefited from wireless facilities. The IIUM wireless network has implemented in three phases in 2003, 2009 and 2013. In first phase, it covers the entire academic area at Gombak Campus, Kuantan campus and Kuala Lumpur campus which includes; administrative office areas, class rooms, meeting rooms, conference rooms, cafeteria etc.[11]. In second and third phases, the wireless coverage has been increased to the full campus including academic and residential areas. For example, the main campus Gombak has more than 700 acres and most of the places have covered by the wireless network.

This research only discusses on the performance of wireless network of Gombak campus particularly for a small coverage area. There are two wireless controller are connected with the Internet and these two controllers connect all the APs with wire. IEEE 802.11g technology has deployed to provide IIUM wireless services. One AP can support concurrently maximum 50 nodes either static or mobile. Considering the population density of a specific location, numbers of APs have been deployed in those areas. In this research, some nodes are considered static and some are considered mobile.

4. Simulation Setup
QualNetT is one of the network simulators that can predict and act like real network and the performance of a specific network can be measured through simulation or emulation. Wired, wireless and combined network platforms can be developed using this simulator. QualNet is developed by Scalable Network Technologies; Inc. [12]. QualNet comes with different libraries such as Wi-Fi, WiMAX, CDMA, GSM etc. This experiment uses WiFi libraries. It is a quite simple and easy to design as it is Graphical User Interface (GUI) based simulator. In this experiment, a small wireless network of IIUM has been designed for the analysis. Three parameters, namely; throughput, delay and jitter have been considered for the analysis.

| Parameters          | Values                                      |
|---------------------|---------------------------------------------|
| Physical layer technology | IEEE 802.11                                |
| Data rates bits/sec  | 54 Mbps                                     |
| Area in meters       | 100m X 100m                                 |
| Nodes                | 4 APs, 16 static nodes and 20 mobile nodes  |
| Simulation time      | 1000 seconds                                |
| Traffic type         | CBR                                         |
| Packet size          | 512 Bytes                                   |
| Mobility model       | Random waypoint                             |
| Mobility speed       | Minimum 5m/s and maximum 30m/s              |

There are 4 nodes are considered as APs those are directly connected with the wireless controller. 16 nodes are static and 20 nodes are mobile moves at the speed from 5m/s to 30 m/s based on random way point model. The Constant Bit Rate (CBR) traffic is employed to with packet size 512 bytes in a 100m X 100m area with 54MBps data rate. The simulation scenario has shown in figure 2.
5. Performance Analysis

5.1. Average delay
A packet experienced of end-to-end delay due to queuing and different routing paths travelling that takes time to reach to the desired destination. The end-to-end delay occurred by the packets for each flow the individual packet delay are summed and the average is computed [13]. The delay is usually measured in seconds and delay calculation is given in equation 1 and 2.

$$\text{Average end-to-end delay} = \frac{\text{Total of Transmission Delays of All Received Packets}}{\text{Number of Packets Received}}$$  \hspace{1cm} (1)

Where,

Transmission Delay of a Packet = (Time Packet Received at Server – Time Packet Transmitted at Client) \hspace{1cm} (2)

here ‘time’ is in seconds.
According to the simulation result that has been depicted in figure 3, it can be said that the maximum end to-end delay occurred 0.76 seconds for 7\textsuperscript{th} node and minimum is 0 for some nodes. The average delay is 0.22 seconds. This delay seems too high for many data transmission particularly for real time data transmission.

5.2. Throughput
Throughput is the average rate of successful message delivery over a communication channel. Data may be delivered over a physical or logical link, measured in bits per second. The system throughput or average throughput is the sum of the data rates that are delivered to all the terminals in a network [14]. Throughput is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second or data packets per time slot and the calculation is written in equation 3.

\[
\text{Throughput} = \frac{\text{(Total Bytes Sent \times 8)}}{\text{(Time Last Packet Sent - Time First Packet Sent)}} \quad (3)
\]

where “time” is in seconds.

![Throughput](image)

The simulation result shows in figure 4 that the average throughput is achieved around 4000 bps when CBR traffic is transmitted in the designed network.

5.3. Average Jitter
Jitter is a variation in packet transit delay caused by queuing, contention and serialization effects on the path through the network. In general, higher levels of jitter are more likely to occur on either slow or heavily congested links. The usual causes include connection timeouts, connection time lags, data traffic congestion, and interference. Simply put, this jitter is an undesirable output of system flaws and interruptions. Thus when jitters occur, computer monitors and computer processors may malfunction, files may get lost, downloaded audio files may acquire noise, Internet phone calls may get interrupted, suffer time lags or get disconnected. The jitter calculation is provided in equation 4 and 5.

\[
\text{Average Jitter} = \frac{\text{(Total Packet Jitter for all Received Packets)}}{\text{(Number of Packets Received - 1)}} \quad (4)
\]

Where,

\[
\text{Packet Jitter} = \text{(Transmission Delay of Current Packet - Transmission Delay of Previous Packet)} \quad (5)
\]

Jitter can be calculated only if at least two packets have been received.
According to the simulation result, the maximum jitter shows 0.21 seconds and minimum is 0 for some nodes. The average jitter is approximately 0.08 seconds.

6. Conclusion
This paper discusses the basics of WiFi and its applications. The performance of IIUM campus network has been analysed in terms of throughput, delay and jitter. The average throughput is 4000 bps, average delay is 0.22 seconds and jitter is 0.08 seconds. It can be said from above simulation results that the delay and jitter is quite high for data transmission. This research only considers a small coverage area of IIUM while the large coverage will be analysed in future work. The real time applications are not considered for this research that will be considered in further research.

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