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Performance Evaluation Voice over WLAN Capacity in Three Standards IEEE 802.11

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Abstract

In the modern landscape of telecommunication, wireless mobile connectivity and migrating voice telephone services to IP technology are two of the most prominent developments that are transforming the landscape. These two concepts can be utilized together using networks which carry voice services over wireless LAN (VoWLAN). However, due to the unique characteristics of each, certain issues inevitably arise and must be handled to allow for successful deployment. In this paper Dijlia university campus is simulated using OPNET 14.5 modeller carry out extensive simulation scenarios to examine the VoIP capacity in a single cell WLAN in regards to three IEEE 802.11 WLAN standards which are (a, b, and g) as well as applying different packet sizes, data rates and codec types in VoWLAN scenarios. Depending on this evaluation, selection IEEE 802.11g and decrease in the number of users consider the best choice for transmission voices over WLAN in college.

Keywords: Wireless, VoIP, IEEE 802.11, Data rate, Codec types.

الخلاصة: في المشهد الحديث للاتصالات، يعد الاتصال اللاسلكي المحمول وتحول خدمات الهاتف الصوتي إلى تكنولوجيا IP يعدان من أبرز التطورات التي تغير المشهد. يمكن استخدام هذين المفهومين معًا باستخدام الشبكات التي تحمل الخدمات الصوتية عبر شبكة LAN اللاسلكية (VoWLAN). ومع ذلك، نظرًا للخصائص الفريدة لكل منها، تنشأ حتمًا بعض المشكلات ويجب معالجتها للسماح بالارسال الناجح. في هذا البحث، تمت تصميم الحرم الجامعي لكلية دجلة الاهلية باستخدام OPNET 14.5 Modeller لتنفيذ سيناريوهات محاكاة واسعة النطاق لفحص سعة VoIP في شبكة WLAN أحادية الخلية فيما يتعلق بثلاثة معايير IEEE 802.11 WLAN وهي (a و b و g) بالإضافة إلى تطبيق أحجام حزم مختلفة، معدلات البيانات وأنواع الترميز في سيناريوهات VoWLAN . واعتمادًا على هذا التقييم، يعتبر اختيار IEEE 802.11g وانخفاض عدد المستخدمين هو الخيار الأفضل لنقل الأصوات عبر شبكة WLAN في الكلية .

1. INTRODUCTION

Since the early 1970s, the concept of Voice over Internet Protocol (VoIP) was widely discussed, and the idea and technology were developed over time. However, this concept failed to find widespread acceptance and usage by either side of users and telecommunication providers. This is largely due to the lack of infrastructure that can support Internet Protocol (IP). At the time, circuit-switched calling was a far more dependable alternative, amplified by the fact that early VoIP calls had rather poor quality. The rapid growth of internet technology by the 1990s, as well as the World Wide Web, coupled with significant investments in the infrastructures of IP networks by businesses and other stakeholders all led to VoIP becoming a valid replacement for earlier technologies and a viable option for sending voice data over public switched telephone networks (PSTN) [1]. Over time, VoIP quickly rose to become the most desired type of service for wired and infrastructure-based wireless networks of any size [2]. In Wireless Local Area Networks (WLANs) computers are connected through a wireless connection to central devices such as a Wireless router. To prioritize simple and best-effort communication, the IEEE 802.11 WLAN standard was developed by the Institute of Electrical and Electronics Engineers (IEEE). The standard was first released in 1997 but has since gone through various iterations all keeping the same main goals [3].

VoIP over WLAN (VoWLAN) refers to the use of wireless LANS to provide IP voice services, generally 802.11-based (commonly known as voice over WIFI). A VoWLAN system's process is to translate a Private Branch Exchange (PBX) telephone call to IP packets, and then send these packets over an 802.11 WLAN [4]. VoWLAN has been gaining traction as a type of infrastructure that can provide wireless voice services at a low cost. However, the implementation of VoWLAN introduces several challenges due to the nature of wireless networks and contention-based protocols [5].

In the modern wireless communication landscape, Voice over WLAN has grown to become an integral part of business necessities. Allowing users to remain connected greatly improves a company or business in terms of communication and collaboration, at the same time this allows them to maintain a high level of quality whilst the user makes use of the WLAN [6]. In a global market that has been significantly changed post the COVID-19 pandemic, VoWLAN market growth was projected at approximately $35.2 Billion Dollars figure for the year 2022. Furthermore, it is predicted to grow to $89.2 Billion Dollars by 2030, growing at a compound annual growth rate of 12.3% over the of 2022 to 2030 covered by the analysis. Figure 1 shows the trend of independent VoWLAN likely going up in upcoming years [7].

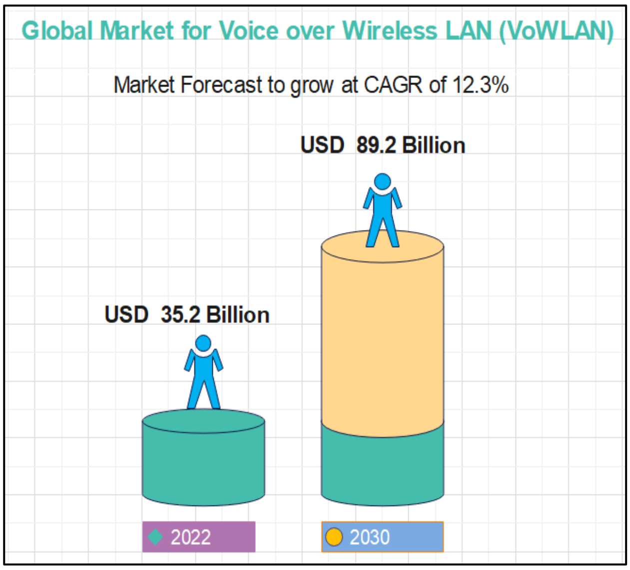

Fig.1. Market Forecasts for VoWLAN.

The expansion and widespread deployment of VoWLAN has proven to be an exceptionally challenging task for many network experts and engineers. The most critical parts of a VoWLAN system are considered to be Voice codec and IEEE 802.11. Due to this, accurate analytical models capable of capturing the characteristics of network traffic are a vital part of maximizing the efficiency of data transfer in future network design. This paper order as follows; introduce and background about the development of VoIP and VoWLAN first given in section 1. Then we will discuss in section 3 the features of IEEE 802.11 WLAN architecture. In order to understand some inhibitors and challenges in transfer voice over WLAN will be discussed in section 4. System model design and simulation results are described and analysed in section 5. Finally, section 6, has concluded the whole work.

2. LITERATURE REVIEW

Several studies have investigated the voice services over WLAN performance and the utilization of different service classes coupled with different network types. Researchers in [4], discussed the general issues arising from the use of voice over WLAN, the research compared the functionality and features of 802.11 phones available in the market. From testing VoWLAN new challenges were introduced such as greater latency when tests in which both nodes are wireless and observed that there was a slight disruption in the sound when a handoff occurred for the node connected to the wireless network during a call. Researchers when comparing the insecure and secure calls noticed that the sound quality was the same as in both cases. Nattavut Smavatkul et al [8] on the other hand, examined the general transmission of voice as well as isochronous traffic over an 802.11a WLAN, then compared the practical and simulation-based methods of capacity estimation as well as studying the impact of traffic in the network on voice capacity. A metrics-based analogue voice signal measurement was presented by Robert Blatnik et al [10] alongside performance testing for Voice over WLAN 802.11a enabled equipment in academia, reasonably controlled RF environment, automating of testing scenarios and improved synchronization of captured voice samples with several thousand statistically analysed measurement, with experimental VQ test-beds results assured adequate qualification. Sangho Shin et al, [11] also utilized a wireless IEEE 802.11b testbed to compute the VoIP traffic capacity and contrast it with the capacity theoretically obtained via simulation. Capacity estimates for both the experimental and simulated network were 15 calls for 64 kb/s CBR VoIP traffic and 38 calls for VBR VoIP traffic with a packetization interval of 20ms and an activity ratio of 0.39 respectively. A quality of service management architecture that is session-based was proposed by Badis Tebbani et al [12] to accommodate for the low capacity of VoIP calls in an IEEE 802.11 wireless local area network as well as resolve the issues that occur when new calls are added to a network that has reached its capacity. Several researchers have studied the throughput and traffic generation parameters of an 802.11 wireless local area network [13] [14]. On the other hand, a performance model was proposed by Nidhi Hegde et al [15] for voice over WLAN with distributed control. By using classical decoupling arguments, the model allows for an analytical approach to evaluating the capacity of the network based on tuning the protocol parameters. Ali M. Alsahlany [16], analysed the performance VoIP based integrated wireless LAN/WAN and evaluated it based on different voice encoding schemes. The codes, G.711, G.729A, and G.723.1 were used for the comparison since they are the most suitable for improving QoS for VoIP. The results of the evaluation suggested that G.729A produces the best results for VoIP. In research by Shreekant Gurrapu et al [17], the performance of various VoIP codes was compared and studied in non-mobility scenarios by adjusting some parameters and plotting the throughput, End-to-end Delay, MOS, Packet delivery Ratio, and Jitter graphs using Network Simulator version. Ziyad Khalaf Farej et al. [18], evaluated the Quality of Service (QoS) application and its effect on the performance of random topology WLAN using IEEE 802.11n, according to the results, a maximum improvement of 86.4%, was shown for throughput, as well as 33.9% for delay, 52.2% for data drop and 68.9% for retransmission attempts.

3. IEEE 802.11 WLAN ARCHITECTURE

In the field of network architecture, two categories have been defined for 802.11 WLAN standards: Infrastructure and Ad hoc networks. The infrastructure networks aim to provide a communication medium between devices known as the Basic Service Set (BSS), which are wireless clients, wired network resources, and an access point connecting them. Via a distribution system, multiple BSSs can be connected to a backbone, wired or wireless, to support an Extended Service Set (ESS). In comparison, the Ad hoc or point-to-point network achieves reciprocal communication between wireless clients and is typically a spontaneous creation that does not allow access to wired networks. This configuration, shown in Figure 2, is referred to as an Independent Basic Service Set (IBSS) [19] [20]. IEEE employed various standards for the development of the 802.11 family which are (a, b, and g). IEEE 802.11a operates in the 5-GHz band i.e., at frequencies between 5,150 and 5,825 MHz, and at a speed of up to 54 Mbps. Although it is notably fast, its transmission range is limited to about 60% that of IEEE 802.11b by the higher frequencies it utilizes. IEEE 802.11g operates in the 2.4-GHz band, similar to IEEE 802.11b and at 802.11a speeds. [21] A full breakdown of the three standards is shown in Table 1.

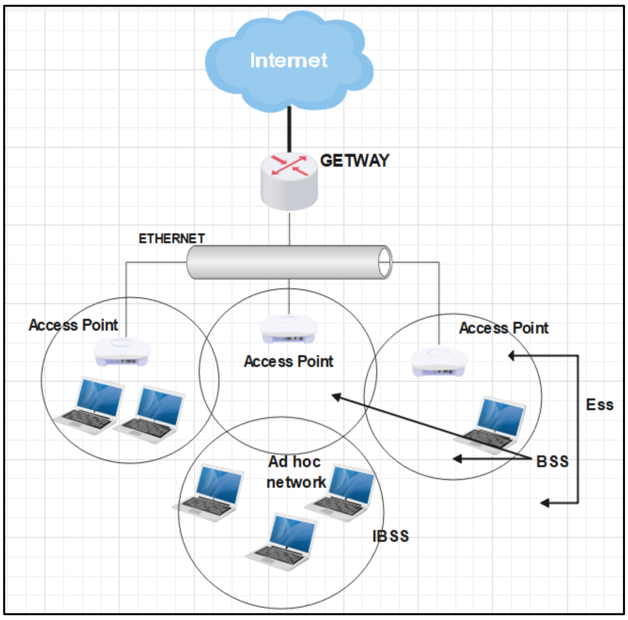

Fig. 2. IEEE 802.11 network architecture.

Table 1. The standards used by IEEE for the advancement of the 802.11 family [10].

IEEE 802.11 Standard	Frequency Band (GHz)	OTA estimates (Mbps)	MAC SAP estimate (Mbps)
a	5	54	25
b	2.4	11	5
g	2.4	54	25

4. VOWLAN CHALLENGES

VoIP is expected to become a necessity for multi-hop wireless networks of future cities. However, the deployment of VoIP service in wireless networks that cover large areas and consist of several hops comes with several challenges. With VoIP calls occurring in a network consisting of multiple hops, interference can cause packet loss and increased delay, which would greatly affect the VIP calls' quality from beginning to end. Increased amounts of traffic will increase the amount of medium conflict, which in turn leads to significantly higher packet loss compared to there being only a single hop in the network [22].

In order to achieve high-quality conversational voice transmission, the desired end-to-end one-way delay is lower than 150 milliseconds. Otherwise, the delay becomes noticeable to the average user. Several factors can contribute to the one-way delay in VoIP connections. As such, a WLAN setup is only allowed to utilize a small portion of the 150-millisecond allocated for delay. In a representative Enterprise network, the delay in communications between a wireless phone and an access point should not exceed 50 ms, the phone on the other hand must be able to roam in under 50 ms from one access point to the other [23]. Due to several limitations, it is difficult to achieve widespread implementation of VoWLAN in the enterprise. A traditional WLAN infrastructure approach will produce a few inhibitors [24]:

- Extreme latency.
- Sensitivity to jitters.
- Limited coverage.
- Deployment of insecure services.
- Transmission degradation and missing packets.
- Lower call capacity.
- Voice and data convergence quality of service.
- Power consumption considerations.

5. VOWLAN SIMULATED SCENARIOS

In this research, the OPNET simulator was utilized for network modelling. OPNET which is developed by OPNET Technologies is a certified communication system simulator [15]. In this paper, the maximum VoIP capacity in a single-cell WLAN is evaluated for different standards, specifically a, b, and g. The goal is to examine the effect of changing packet payload size (in terms of the number of frames) as well as the effect of changing the data rate for each standard under acceptable QoS constraints in VoIP systems utilizing the G.711 voice codec.

5.1 Simulation Parameter

The VoIP application and profile parameters have the same value in the same subnet in wireless LAN network attributes are shown in Table 2 and Table 3.

Table 2. Application Definition Window.

Parameter	**Value**
Silence length (sec)	Default
Talk spurt length (sec)	Default
Symbolic Destination Name	Voice Destination
Encoder Scheme	G.711
Voice Frames per Packet	1
Type of Service	Best Effort
Signaling	SIP

Table 3. Profile Definition Window.

Parameter	Value
Profile Name	Profile
Start time Offset (sec)	Constant (0.0)
Duration (sec)	Exponential (120)
Number of repetitions	Unlimited
Repetition pattern	Serial
Duration (sec)	End of Simulation
Repeatability	Once at the start time

The wireless network will be connected to the Internet, which will be represented by (the IP32 cloud from the Internet toolbox in the object palette) through a point-to-point link. Furthermore, an SIP (Session Initiation Protocol) Server used to manage VoIP sessions will be connected to an IP cloud through a (PPP) link. The configuration of this server and each mobile node that used the SIP protocol service is shown in Figure 3.

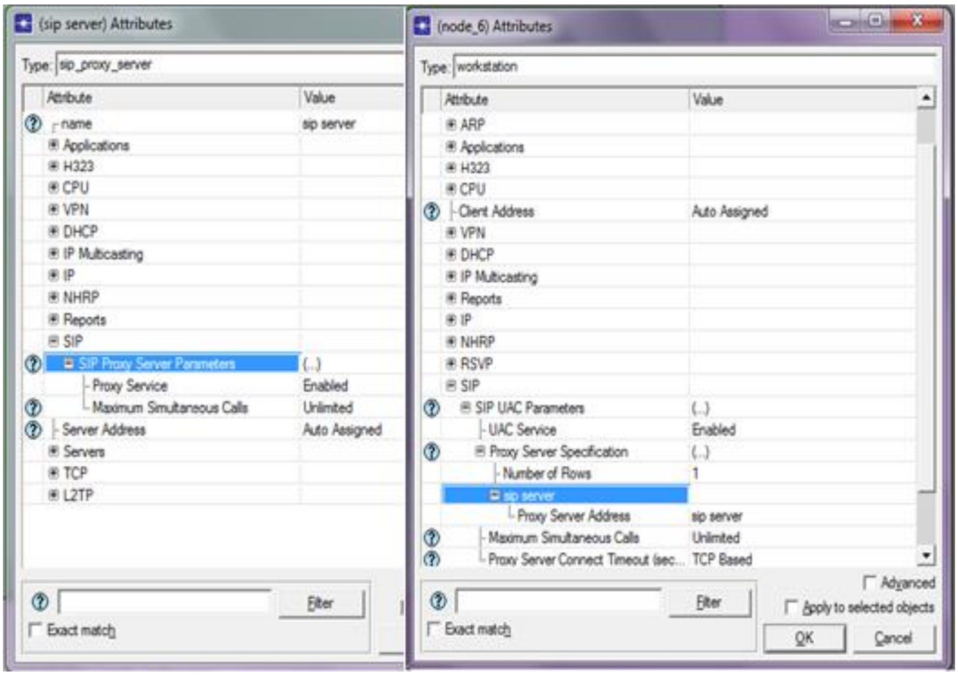

Fig. 3. SIP configuration

5.2 Simulated Projects

VoIP stations are configured to converse in pairs. In essence, this means each station is talking with exactly one other station permanently. The caller (red) station is assigned by a VoIP profile station which is assigned by a VoIP service as shown in Figure 4. The simulated projects are:

***1. Simulation VoIP in Wireless Campus Network with Increased Number of Users*:**

This simulation provides a high-level overview of a generalized network topology. In this setting, a campus network is configured to represent a simplistic proposed model for Dijlah University in the Al-Sydea campus in Baghdad-Iraq. The simulated network is built to connect one main building with the aim of achieving cost-effective data and voice communication. The network is comprised of 10 subnets for each department in the college (Computer sciences, Building and construction engineering, Business administration, Computer techniques, Law, Finance and Banking, Optics techniques, medical, analysis, and media). Each subnet contains one WLAN cell of IEEE 802.11g standard. These subnets are connected to a main switch using a 1000 base duplex link of 1Gbps Ethernet connection, then to a firewall device using 10Gbps Ethernet connections, and lastly to the IP cloud through a router as shown in Figure 5. There is also an SIP server used to manage VoIP sessions. These sessions are created as peer-to-peer calls between two nodes in different subnets. The networks are tested for two cases: First, when 6 mobile nodes (minimum number of customers in each room department in college) are connected at each cell, and second, when the number of nodes is increased to 12 (maximum number of customers in each room in each department in college). This is done on the G.711 codec for one-voice frames per packet and assumes there is another application in the network.

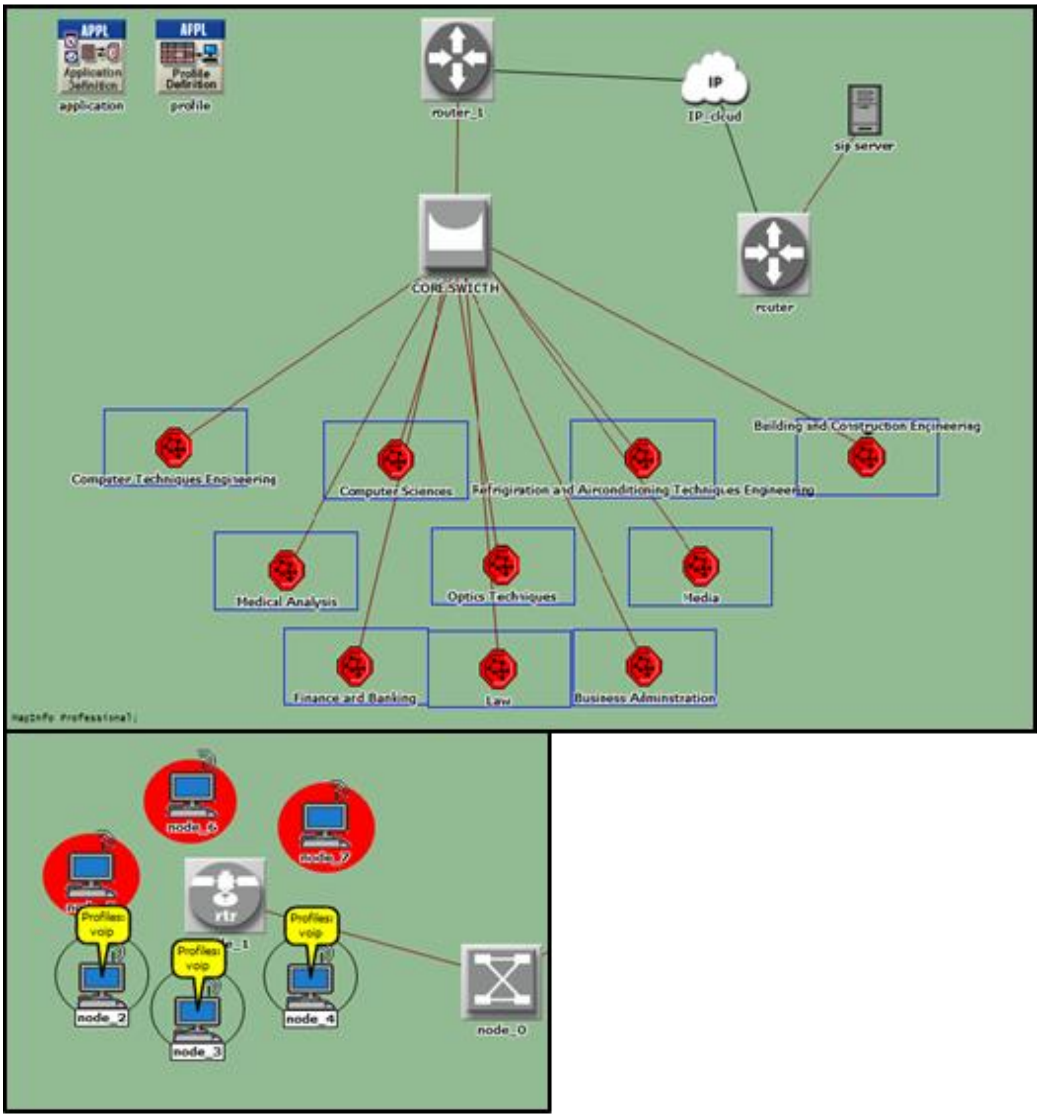

Fig. 4. Dijlah campus network for 10 department (proposed design).

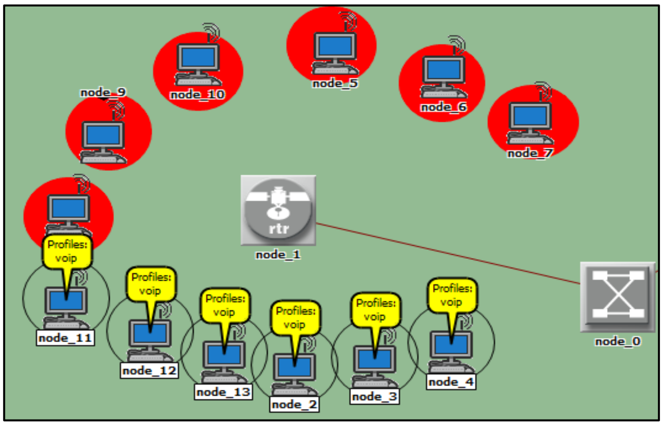

Fig. 5. Dijlah campus network with an increase in the number of users.

2. Simulation VoIP in Wireless Campus Network Compare between WLAN Standards (a, b, g)

This simulation uses different standards in WLAN cells and provides a comparison among them. The first is a WLAN (IEEE 802.11a) standard that is capable of supporting data rates up to 54Mbps. All mobile nodes in this cell have their physical characteristics assigned as OFDM (802.11a) as shown in Table 4.

Table. 4. WLAN parameters using 802.11a standard.

Parameter	Value
BSS Identifier	1
Physical characteristic	OFDM (802.11a)
Data Rate	54 Mbps
Access Point Functionality	Enable
Roaming Capability	Disable
Transmit Power	0.005 W
Power Threshold	-95 db
Short Retry Limit	7
Long Retry Limit	4

The second scenario is using WLAN IEEE 802.11b which can support data rate up to 11Mbps, a scenario is conducted to evaluate the effect of call capacity for this data rate. All mobile nodes in this cell have the physical characteristics assigned as a direct sequence according to 802.11b physical layer characteristics as shown in Table 5.

Table 5. WLAN parameters using 802.11b standard.

Parameter	Value
BSS Identifier	1
Physical characteristic	Direct Sequence
Data Rate	11 Mbps
Access Point Functionality	Enable
Roaming Capability	Disable
Transmit Power	0.005 W
Power Threshold	-95 db
Short Retry Limit	7
Long Retry Limit	4

The third scenario uses the IEEE 802.11g standard which extends the 802.11b standard data rate up to 54Mbps. In this scenario, the project is implemented with the same settings as the WLAN project. All mobile nodes in this cell have the physical characteristics assigned as extended rate PHY (802.11g) as shown in Table 6.

Table 6. WLAN parameters using 802.11g standard.

Parameter	Value
BSS Identifier	1
Physical characteristic	Extended Rate PHY (802.11g)
Data Rate	54 Mbps
Access Point Functionality	Enable
Roaming Capability	Disable
Transmit Power	0.005 W
Power Threshold	-95 db
Short Retry Limit	7
Long Retry Limit	4

5.3 Simulation Results

The results of the simulated projects were plotted using OPNET. OPNET can demonstrate two types of statistics as results: Global and Object Statistics. Global statistics represent results collectively gathered from all nodes in a network; meanwhile, object statistics are collected from the discrete nodes in the network.

1. Simulation VoIP in Wireless Campus Network with Increased Number of User Results:

The first global statistics performance metric used to quantify voice services over WLAN is the delay variation (Jitter). This is done on a different number of WIFI SS nodes as shown in Figure 6. In this scenario, the same distances for all WIFI SS nodes are kept 50 meters away from the AP. Within the same office, the number of WIFI users is increased from 6 to 12 users. The packets arrive at a different time, resulting in a notable voice jitter, which makes it difficult to understand. Increasing the number of users accessing the same AP, increases the end-to-end delay and the packet delay variation for voice service.

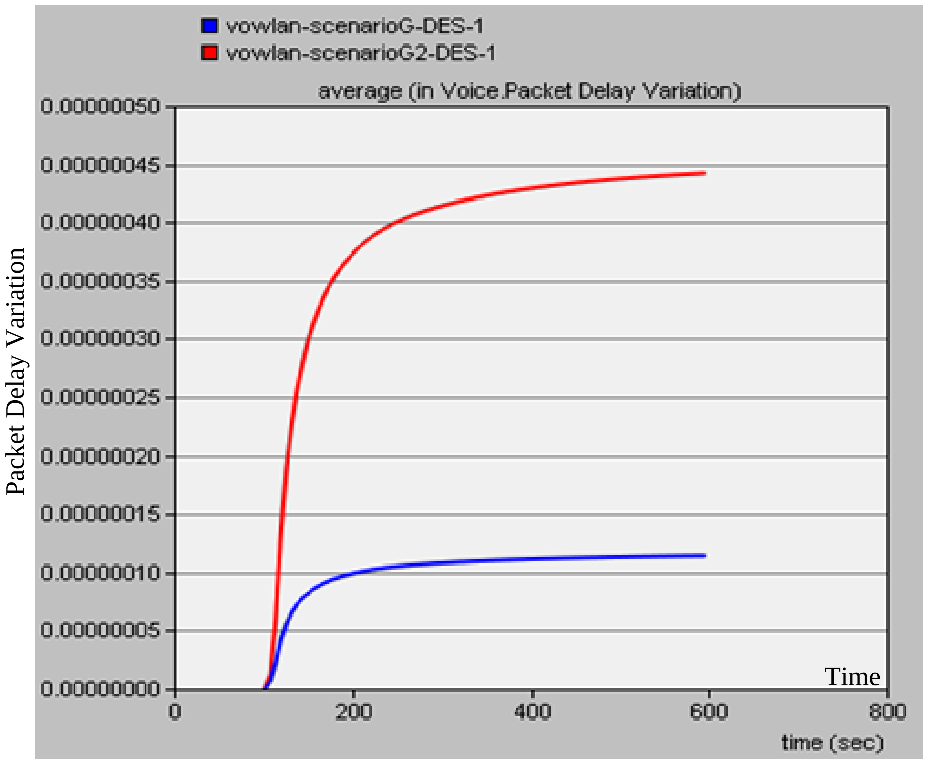

Fig. 6. The delay-variation (Jitter).

As well as the rate of traffic received (packet/sec) in both global and object statistics are shown in figures 7 and 8 represent the average number of packets per second forwarded to all voice application nodes in the same department by the transport layer in the network. When increased number of users time of the packet arrived increased.

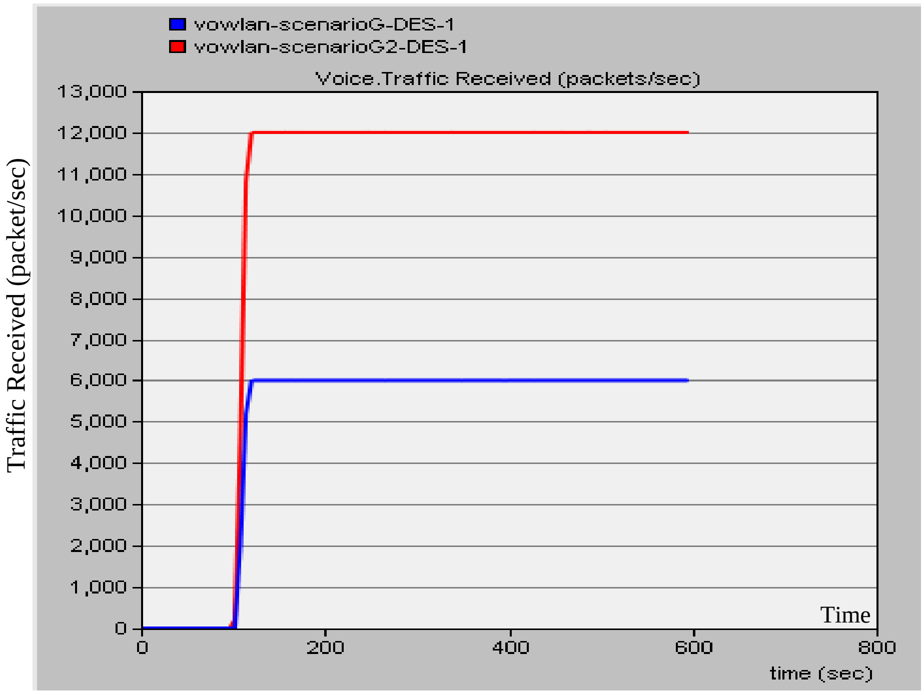

Fig.7. traffic received P/S.

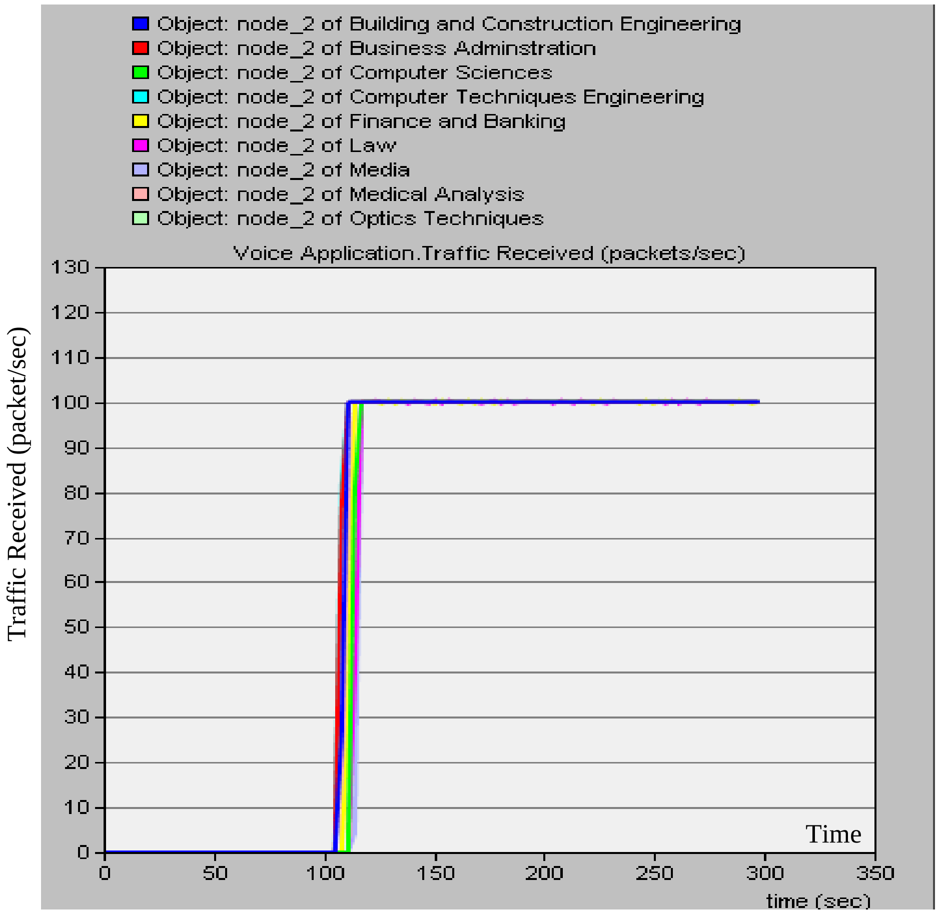

Fig.8. Traffic Received P/S in Each Subnet.

The WLAN throughput, measured by bit/sec represents the total number of bits forwarded from WLAN layers to the higher layer per second in all the network's WLAN nodes. The WLAN router (AP) buffer size is 1024000 bits. As the number of users increases, the number of bits received at the WLAN router increases, and the buffer quickly overflows which leads to an increase in data dropped. In addition, the average IP traffic drop and throughput increase approximately in the same order as the number of users increases. Figure 9 and 10 shows the WLAN throughput results for both global and object statistics in each department in the college with the increased number of the user.

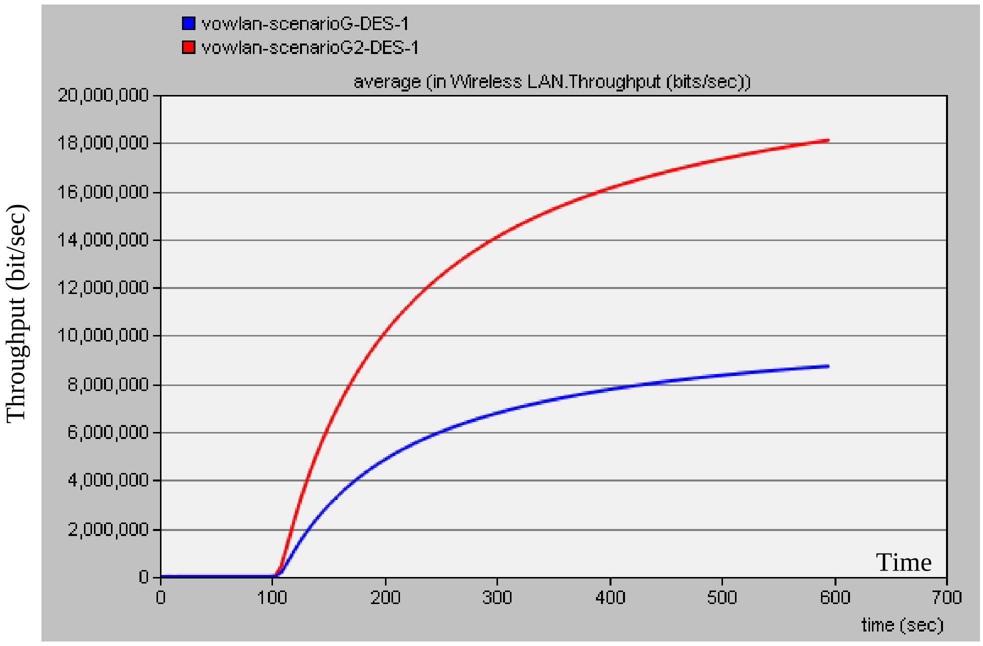

Fig.9. WLAN Throughput (bit/sec).

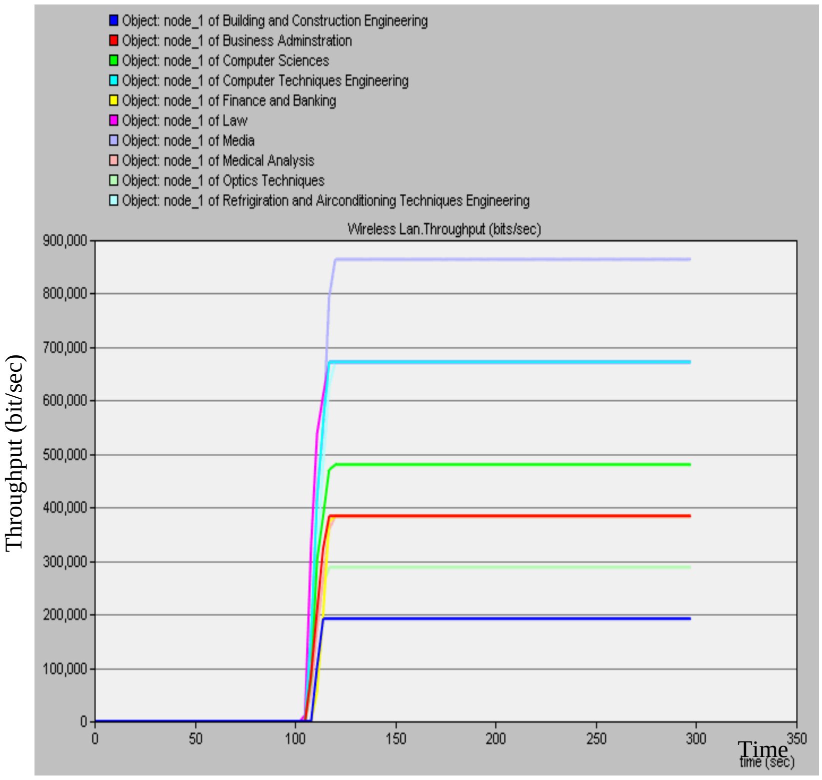

Fig. 10. WLAN Throughput (bit/sec) in each subnet.

The total end-to-end delay of all data packets successfully received by the WLAN MAC and forwarded to the higher layer is represented by Wireless LAN delay as shown in Figure 11 called analogue-to-analogue or mouth-to-ear delay with the increased number of users showing the bad quality of speech.

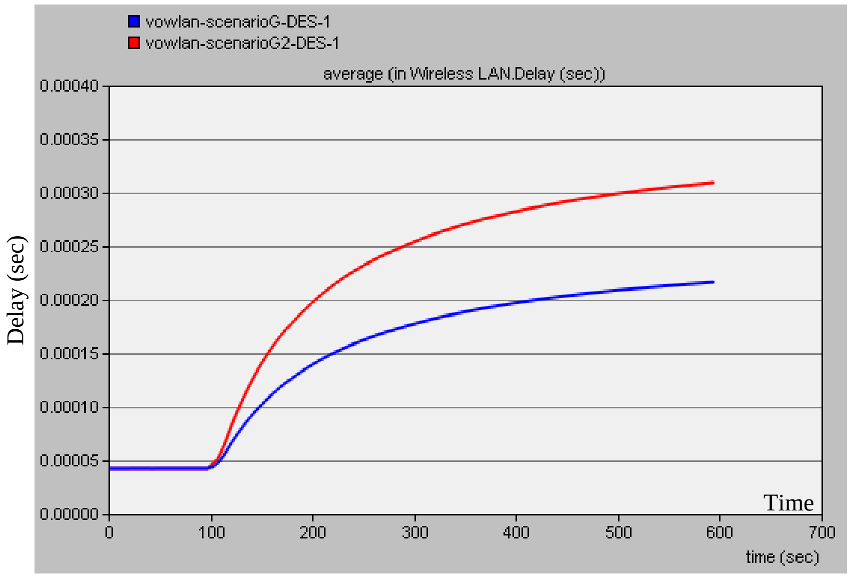

Fig. 11. The wireless LAN delay in (sec).

2. Simulation VoIP in Wireless Campus Network Compare between WLAN Standards (a, b, g) Results:

In these scenarios, results are collected in global statistics only for three projects to find the max VoIP capacity in three IEEE 802.11 WLAN standards (b, a, g). According to these campus models. Figure 12 shows the traffic received by the VoIP application for three IEEE 802.11 WLAN standards (b, a, g) and data rate changes in Mbps. The traffic received by the network with IEEE 802.11b (11 Mbps) shows less deviation from the comparative traffic received with IEEE 802.11a (54 Mpbs) and IEEE 802.11g (54 Mpbs). Based on the analysis it can be observed that the noise added in IEEE 802.11g networks is lower compared to the other network setups. As such this standard is considered more efficient.

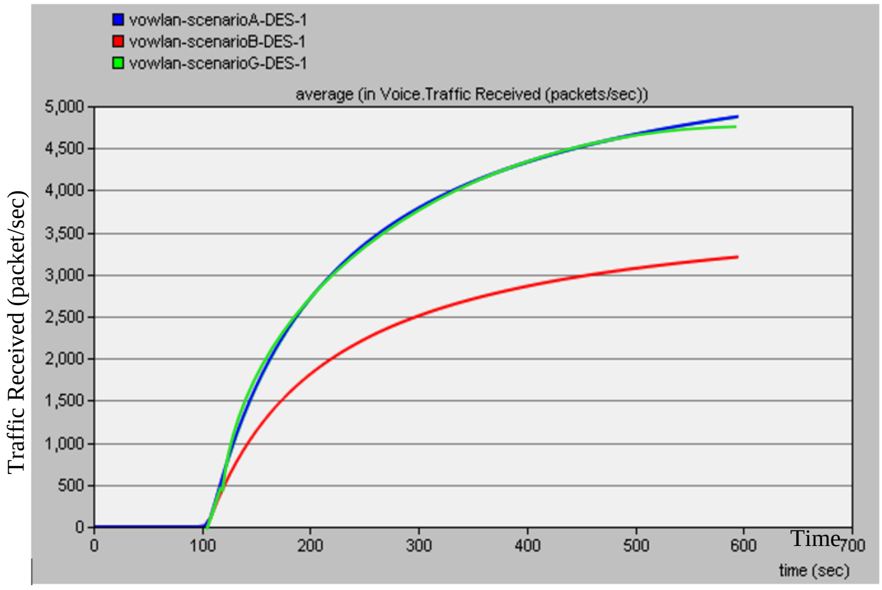

Fig.12. traffic received P/S IEEE802.11 (A, B, and G).

Figure 13 shows that in the category of End-to-End delay, the max value of this parameter when comparing the three IEEE 802.11 WLAN standards (b, a, g) shows that IEEE (802.11 a, g) presents the best performance with respect to other setups. These results are a consequence of a lower transfer rate and packet size in AP. On the other hand, the transfer rate and packet size significantly increased the end-to-end delay.

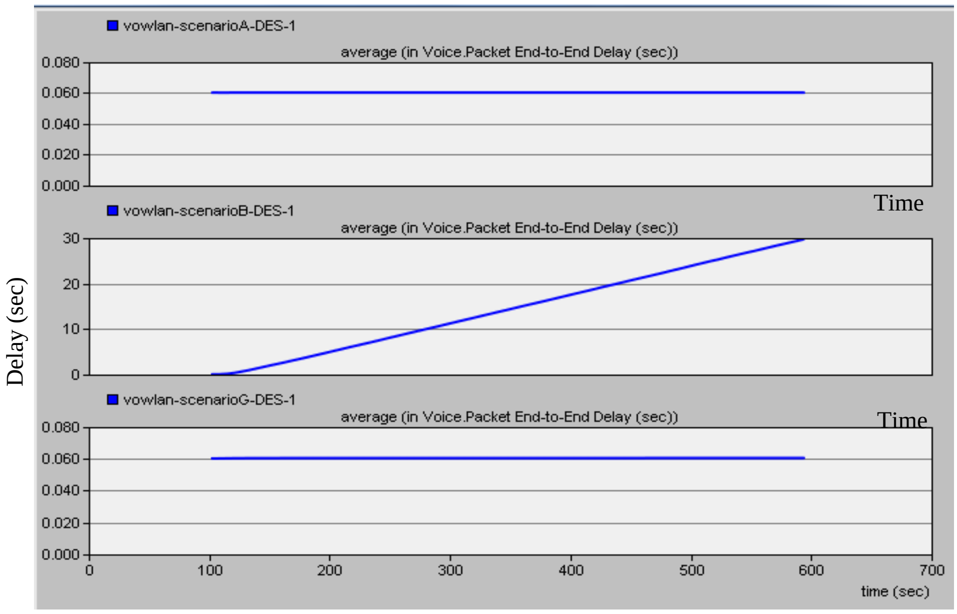

Fig. 13. VoIP End-to-End delays For IEEE 802.11 (A, B and G) Time

6. CONCLUSIONS

In this paper, several findings can be concluded from the system test of the modified scheme applied in a wireless campus network. The simulated results showed that the VoIP service deployed will affect the performance of the application when the number of users increases and the overall WIFI link performance degrades. Furthermore, the WLAN single-cell VoIP capacity has been examined for three WLAN standards (a, b, and g) by means of using different data rates. It was shown for each data rate. Cells of IEEE 802.11a and IEEE 802.11g standards provide the max VoIP capacity compared to IEEE 802.11b standard since it provides up to 54Mbps data rate, while the max data rate for IEEE 802.11b standard is 11Mbps. The IEEE 802.11g standard is considered preferable to the IEEE 802.11a standard since it operates in the 2.4 GHz (ISM band), which is compatible with the b-standard that operates in the same band. As well as being supported by most vendors.

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