Performance Evaluation of Voice over WiFi (VoWiFi) Using IP Multimedia Subsystem (IMS)

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Abstract **- Poor coverage is a leading cause of to use VoWiFi calling to enhance coverage . With Wi-Fi Calling, Mobile network operators has a significant reduction in churn. So that we are keen to invest greatly in VoWiFi. VoWiFi means that we use radio waves in wireless networks to exchange voice instead of using wired networks, it Enables VoLTE subscribers to access EPC network using WiFi register with IMS network so that they can use IMS services such as voice call, SMS and other supplementary services and Subscribers can use WiFi to access EPC network when LTE is unavailable.**

Keywords - Performance Evaluation, VoWiFi, Voice over WiFi, IMS, IP Multimedia Subsystem

I. INTRODUCTION

VoWiFi means that radio waves is used in wireless networks to exchange voice instead wired network. It enables VoLTE subscribers to access EPC network using WiFi register with IMS network. So that, they can use IMS services as voice calls, SMS, and other supplementary services and Subscribers can use WiFi to access EPC network when LTE is unavailable.

VoWiFi is needed for Coverage Enhancement, If there is an area which has poor coverage but WiFi is available, Competence Enhance, Operators are willing to provide new services, Customer Retention, Operators provide free or unlimited services to attract more user, Saving Roaming Cost , Operators has WiFi roaming agreement in a suitable market, Less cost for operators, No need to build BTSs, In VoWiFi the caller and callee do not need to have the same application to talk to each other in contrast to OTT, The callee does not need to have internet connection to accept the call, and VoWiFi is seamless, handover is very simple and smooth VoWiFi has only three available choices, Untrusted access network and Trusted access network, IMS direct access, VoWiFi subscribers access a WiFi network, use the ePDG to attach to an EPC network, and then register with an IMS network, ePDG and AAA server is the new network elements for VoWiFi solution, all traffic is secured by AAA server and IP sec protocol, it depends mainly on VoLTE solution.

In this paper, measurements about some parameters to see the impact of these parameters on WiFi performance as voice codecs, WiFi technology, the impact of the user's speed in the coverage area and the relation between distance with data rate and loss of data.

II. METHODOLOGY

A. Voice over WiFi Access Network

The 3GPP standard has two types of access; trusted and untrusted non-3GPP access. Non-3GPP access includes access from for instance Wi-Fi.

The untrusted model was first introduced in the Wi-Fi specification in 3GPP. At that time Wi-Fi was unsecured by default. Untrusted access means how much the operator knows about this access point, such as public hotspots, subscribers' home Wi-Fi. It also includes Wi-Fi access that does not have authentication or authorization from the operator.

The untrusted model requires no changes to the Wi-Fi Radio Access Network but it is required IPSec in the device. The device is connected directly to the Evolved Packet Data Gateway in the LTE core network through a tunnel which is secured by IPSec then it is connected to packet gateway and then get out for any outer network as showed in figure 1.

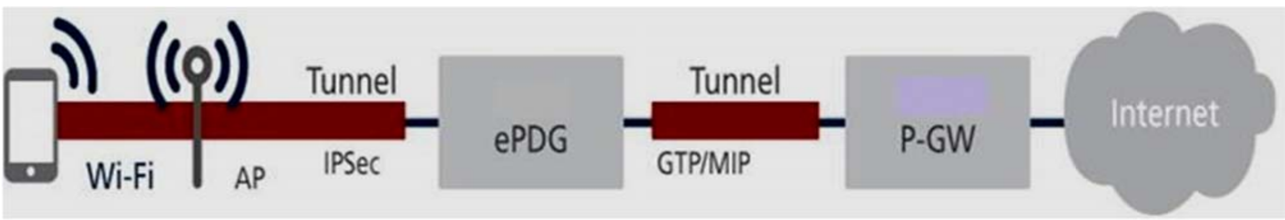

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Figure 1. Untrusted WiFi access

Untrusted Network Components can be divided to the most important following components:

IPSEC: Internet Protocol Security (IPsec) provides for various security services on the IP layer, in IPv4 as well as IPv6, thus offering protection for protocols in upper layers.

ePDG (Evolved Packet Data Gateway): The main function of the ePDG is to secure the data transmission with a UE connected to the EPC (Evolved Packet Core (EPC).

AAA server: The 3GPP AAA Server's authentication function is to identify the user, authorization function is to determine if the user has the right to access this services or not.

PCRF (policy charging control function): it is responsible for all charging issues for all subscribers.

HSS: main data storage for all subscriber and service-related data. _'It's Analogy in GSM (HLR)'.

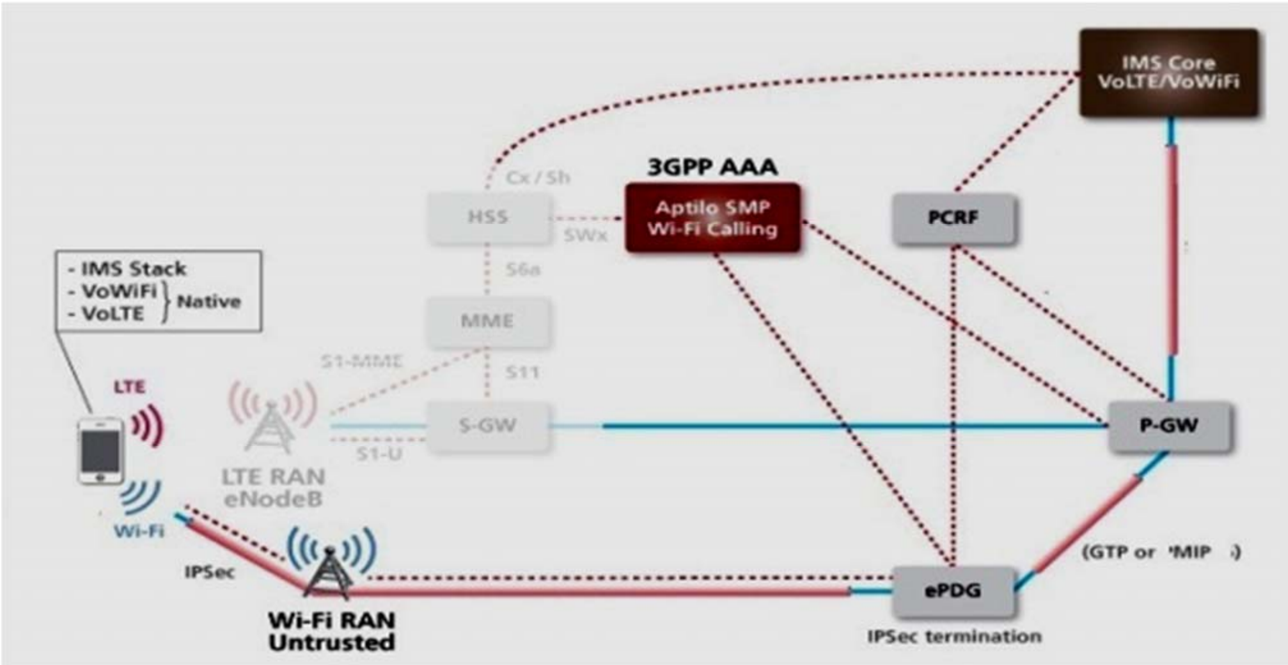

Figure 2. Untrusted WiFi network component

B. IMS Architecture

CSCF: is responsible for signal control of IMS User Equipment (UE) with IMS enhanced services across various network accesses and domains.

P-CSCF: is responsible for Compressing and Decompressing SIP Messages on Gm interface, Establishing IPSec Security Association (SA) within the UE, Identifying emergency calls if found, and Provide Information for Billing and Policy Control.

I-CSCF: is to select S CSCF which will handle incoming call.

HSS: is the main data base in IMS, similar analogy to HLR in GSM.

BGCF: choose where the involving into the circuit switching domain takes place.

MGCF: provide IMS connections with PSTN domain by controlling MGW..

MRFP: under control of MRFC, it's responsible for mixing, sourcing, processing media streams.

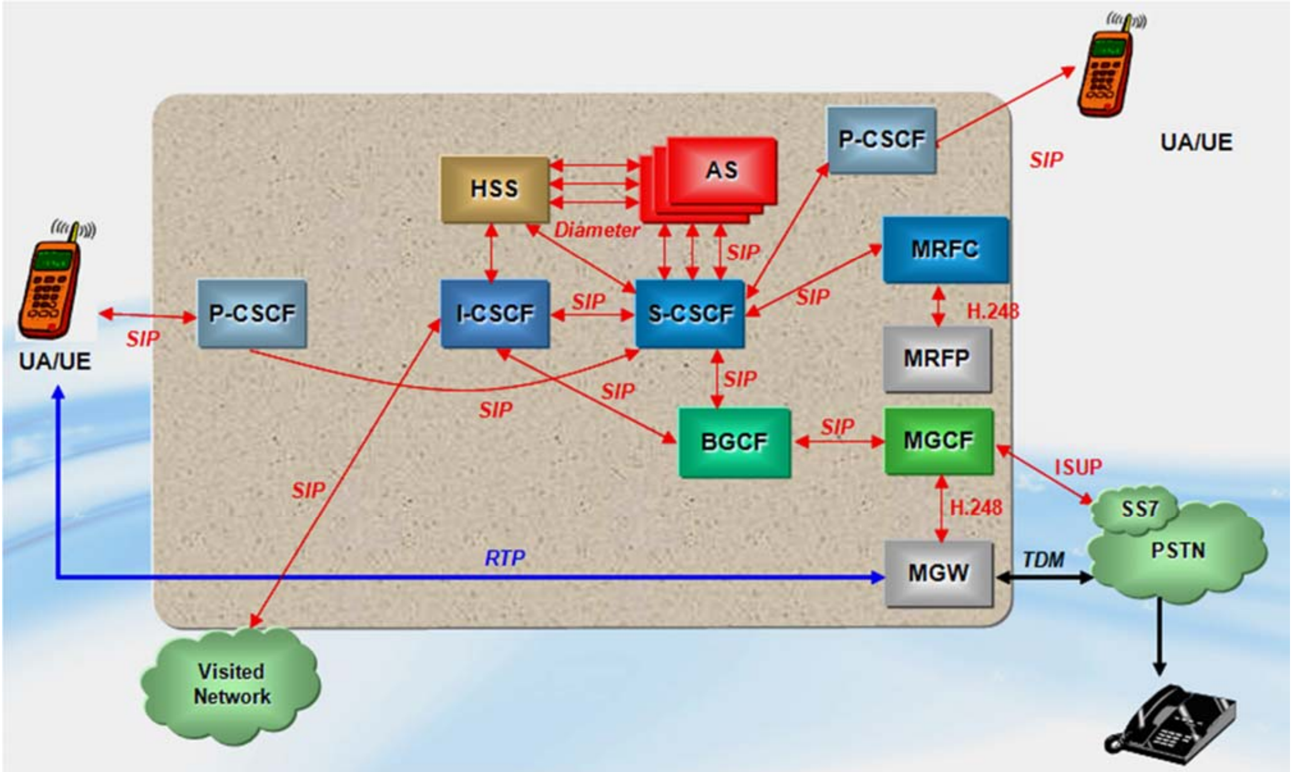

Figure 3. IMS Architecture

C. VoWiFi Technology Releases

The 802.11 WiFi technologies consist of a series of half-duplex over-the air modulation techniques with the same basic protocol.

The 802.11b technology was the first widely spread and widely used, followed by 802.11a, 802.11g, to compare the performance of these technologies we have to know their backgrounds.

1. IEEE 802.11b: Operates at 2.4 GHZ band, its data rate reaches up to 11 Mbps and it uses the same media access method which is defined in IEEE802.11. It has a determinate number of access points. It Uses direct-sequence spread-spectrum technology. It interferes with other devices which operate in the 2.4 GHz band. Devices that are operating at 2.4 GHz range includes, Bluetooth devices, baby monitors.

2. IEEE 802.11a: The protocol used by 802.11a standard is the same used by the original standard. It operates at 5 GHz band, its data rate reaches up to 54 Mbps data rate, as It runs in the 5 GHz range, so less interference with other devices. but, high frequency leads to a disadvantage: the range of higher effect in 802.11a is less than that of 802.11b/g. The more it operates in high frequency band the more it has a higher wavelength so, it can be absorbed easily by walls and solid objects in comparison with 802.11b,g.

3. IEEE 802.11g: Use the 2.4 GHz band, its data rate reaches up to 54 Mbps data rate because of using OFDM media access technique, The technology used by IEEE 802.11g is frequency division multiplexing. It has a shorter wavelength than 802.11b. IEEE 802.11g is more flexible as multiple channels can be combined for faster throughput. Sometimes devices affected by interfering with other devices that they are operating at 2.4 GHz band.

TABLE 1. IEEE 802.11 STANDARDS

Standard	Frequency band	Band width	modulat ion	Max. data rate
802.11b	2.4 GHz	20 MHz	DSSS	11 Mb/s
802.11a	5 GHz	20 MHz	OFDM	54 Mb/s
802.11g	2.4 GHz	20 MHz	OFDM	54 Mb/s

D. VoWiFi Codecs

The codec is the conversion of analog signals to digital form for transmitting data and from digital to analog form.

DOI 10.5013/IJSSST.a.24.02.05

ISSN: 1473-804x online, 1473-8031 print

This term is used for coder –decoder. There are many codecs used for audio. The most common codecs which are used for VoIP applications are G.711, G.723, and G.729.

1. G.711: G.711 is a logarithmic representation of (PCM) pulse-code modulation with 8 bits per sample, it is sampled at a rate of 8000 samples/second so, we get 64 kbps channel. Using G.711 audio codec for VoIP as it's the best voice quality.

2. G.723.1: G.723.1 compresses voice in 30 ms frames. An algorithmic produces 7.5 ms duration which means that total elay is 37.5 ms. It's also called Dual rate speech coder for communications transmitting at 5.3 and 6.3 Kbit/s.

3. G.729: G.729 is an ITU standard which gives a good quality speech at a data rate of 8Kbps; it is a costly codec regarding of processing time, so some VoIP phones have just one G.729 call at a time not more. This codec gives a good quality but at the price of its complexity. However, this can cause calls to fail.

E. Effect of User Distance on The Data Rate

The coverage is the area at which the access point signal can reach with reasonable power and can be described as the probability that a user will connect without facing any problems with reliable connection to any AP within the WLAN, The farther a wireless device is from its Access Point, the more shadowing, reflection ,refraction and diffraction will be faced by the signal so, less power it will have , On average, the data rate will fall off in direct relation with the distance from the access point.

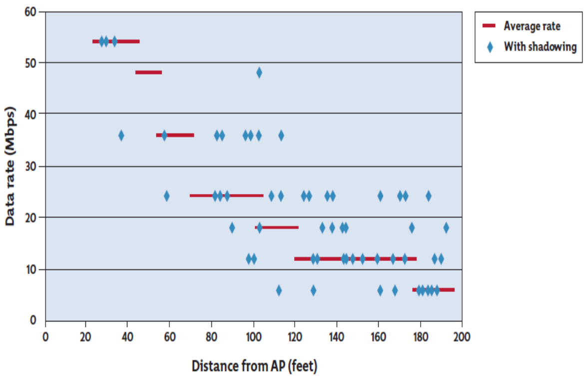

Figure 4. Data rate versus Distance from AP

The red data points in Figure 4 show a plot of the average data rate users might experience as a function of their distance to the AP. In our real life connection there are obstacles, so the data rates will not uniform or not will be as expected in ideal cases according to the number and types of solid things between the device unit and the APs at each specific location. These obstacles cause signal absorption resulting in what is called "shadowing."

The coverage of an AP can also be viewed in two dimensions as seen in Figure 2. The left side of Figure 5 shows the average coverage of an 802.11g AP where the physical rates have been color-coded. It is worth noting that the maximum rate of 54 Mbps is only achieved within the center ring representing only four percent of the total AP coverage area.

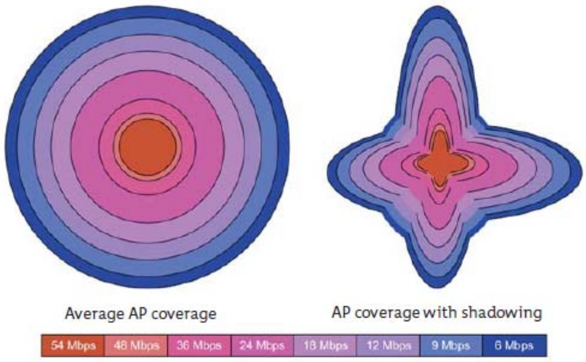

Figure 5. Distance vs. data rate

III. QOS AND QOS PARAMETERS

A. QOS

QOS can be defined as the ability of the network to support good accommodations to be accepted by customers. The QoS is measured by performance metrics such as end-to-end delay, Mean Opinion Score (MOS), and jitter, and the difference between traffic sent and traffic received.

B. QOS Parameters:

1. Jitter: Jitter Is known as a difference of the delay in the received packets' from sent packet. At the sending side, packets are being sent in a continuous stream with the packets spaced apart. Due to queuing, network congestion, or buffering delay, this steady stream becomes messy in its order, or the delay between each packet changes, so, it loses its consistency.

2. Delay: Delay refers to the consuming in time by just one bit can be transmitted from transmitter to receiver. Delays are caused by errors, retransmission attempts, congestion, propagation delay, processing delay, queuing delay and buffering delay.

3. Throughput: How much information is to be transmitted from transmitter to receiver in a certain amount of time. The more bandwidth the channel has the more throughput increases.

4. Mean Opinion Score: MOS stands for "Mean Opinion Score." MOS measures the observed quality of audio after it has been compressing, transmitted, and decompressed.

TABLE II. MOS

5	Excellent
4	Good
3	Fair
2	Poor
1	Bad

IV. VOWIFI NETWORK DESIGN AND CONFIGURATION

Figure 3 shows our Network Model; we have one access point and five clients with IP cloud and HTTP server.

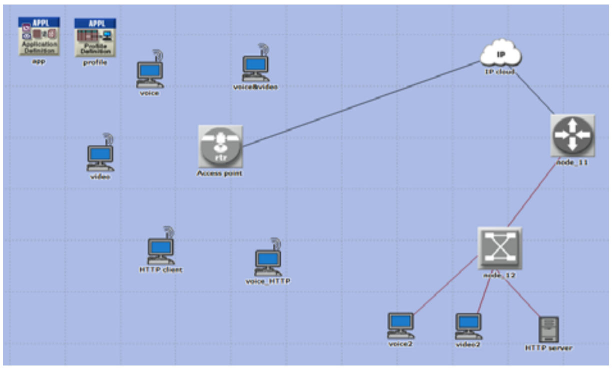

Figure 6. OPNET structure network

The following configurations are applied to OPNET Modeler and simulated them. Two fixed PC_WKSTN and one HTTP server are connected to an IP cloud by PPP_DS3 link, WKSTN and servers are connected with routers by100Base_T links. The video resolution “Low resolution” has been selected in the partition of video application and, EIGRP was selected as a routing protocol, When comparing voice codecs, 802.11g, was selected as a WiFi technology, When comparing WiFi technology, G.711 was used as a voice codec When comparing cell sizes, we have seven users three users are voice and four users video.

V. NETWORK SIMULATION RESULTS

A. VoWiFi technologies simulation and results

In this part of simulation the comparison is between VoWiFi technologies 802.11(a,g,b).

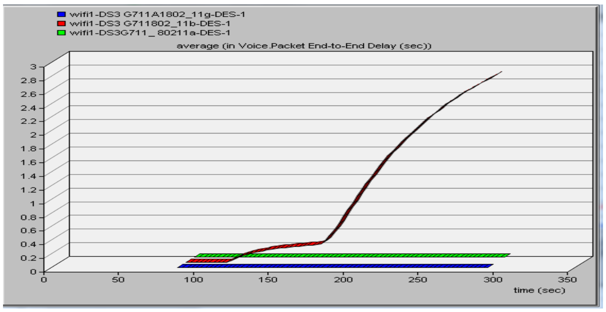

Figure 7. Voice packet end to end delays

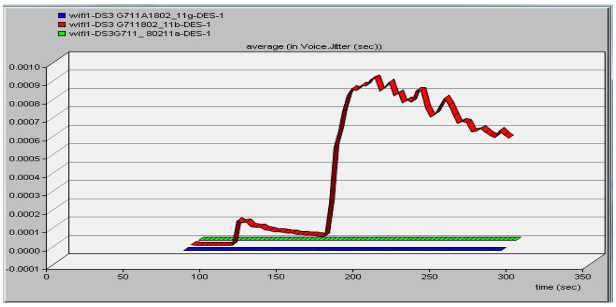

Figure 8. Voice Jitter

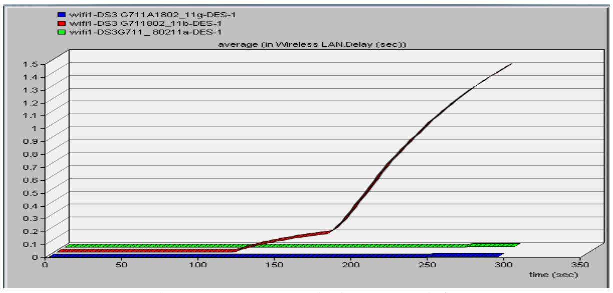

Figure 9. Average wireless LAN delay

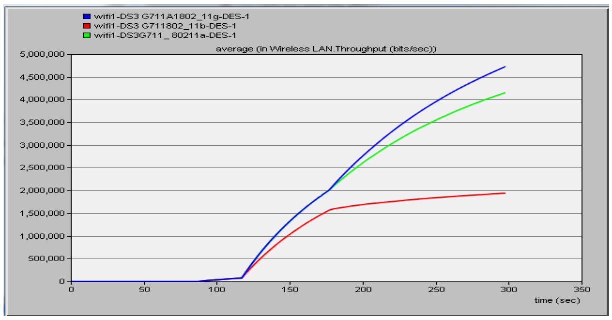

Figure 10. Average wireless LAN throughputs

TABLE III. COMPARISON BETWEEN VOWIFI TECHNOLOGIES

Point Of Comparison	802.11a	802.11b	802.11g
Voice Packet End To End Delay	The best	Bad	The best
WLAN Delay	The best	Bad	The best
WLAN Throughput	Good	Bad	The best
Jitter	The best	Bad	The best

DOI 10.5013/IJSSST.a.24.02.05 ISSN: 1473-804x online, 1473-8031 print

B. VoWiFi Codecs Simulation and Results

In this part the comparison is between VoWiFi codecs (G.711,G729,G723).

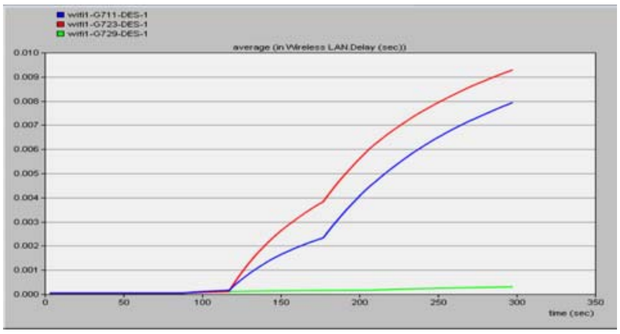

Figure 11. Average wireless LAN delay

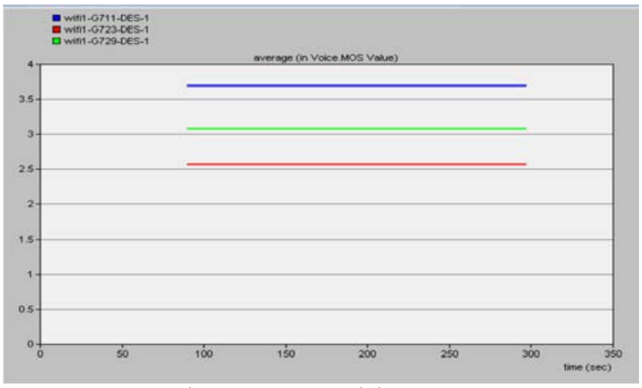

Figure 12. Mean opinion score

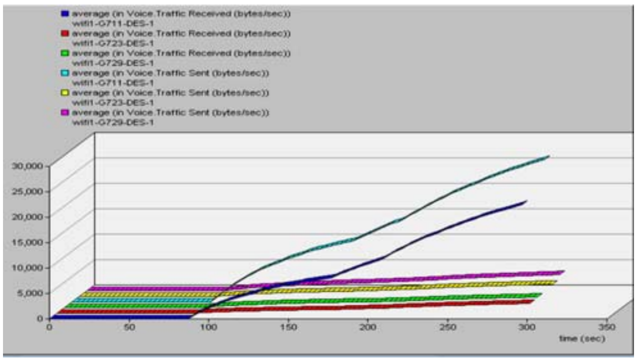

Figure 13. Voice traffic received

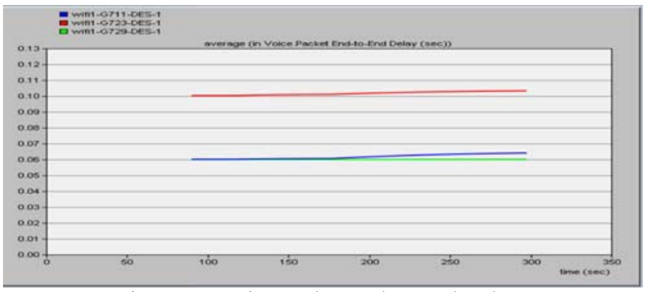

Figure 14. Voice Packet End-to-End Delay

TABLE IV. COMPARISON BETWEEN CODECS

Point Of Comparison	G.711	G.729	G.723
WLAN Delay	Good	The best	Bad
Traffic(sent &received)	The best	Good	Bad
Voice Packet End to end delay	Good	The best	Bad
MOS	3.7	3.1	2.6

C. Comparing Motion in Different Cell Sizes Results

This part the comparison is between different cell sizes to test the effect of coverage (8x13,15x14, 30x20)m^2.

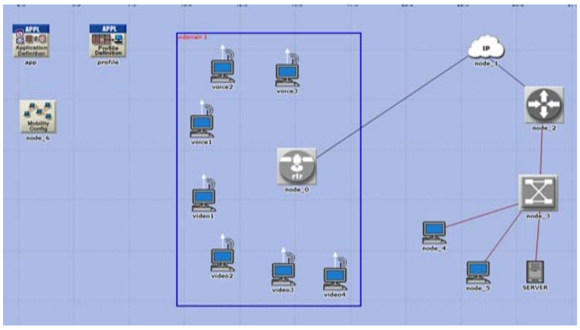

Figure 15. model size (8x13)m^2

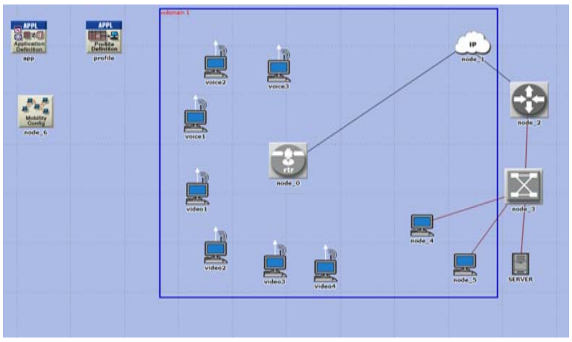

Figure 16. Model size (15x14)m^2

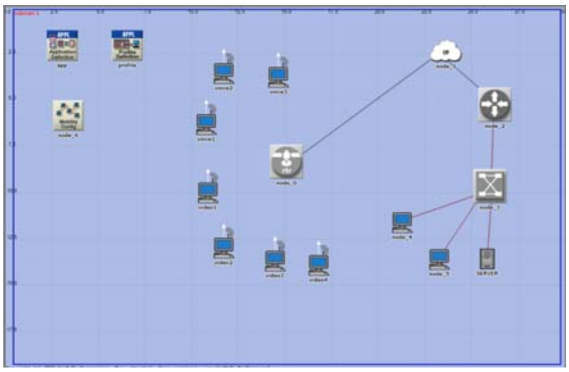

Figure 17. Model size (30x20)m^2

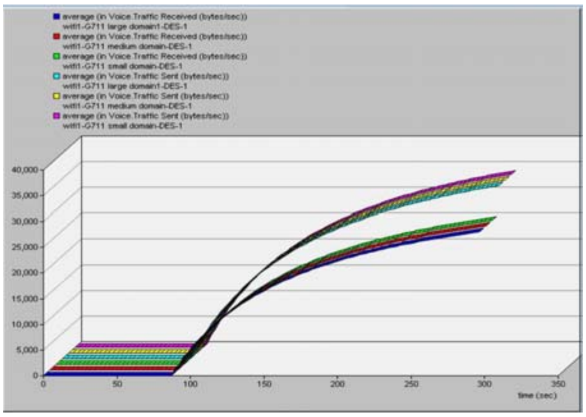

Figure 18. Voice Traffic Sent and Received

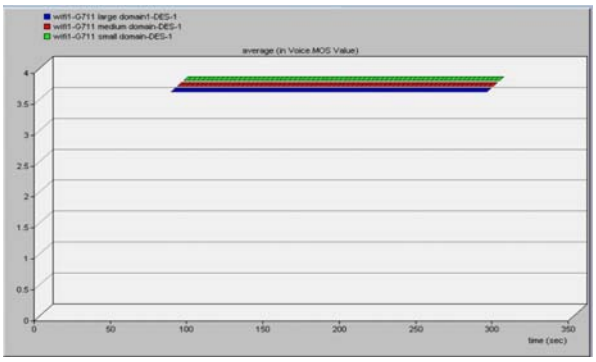

Figure 19. MOS

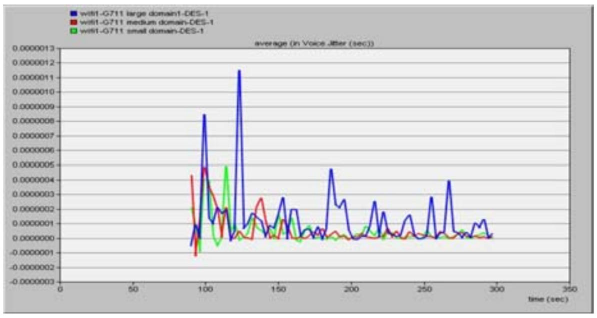

Figure 20. Jitter

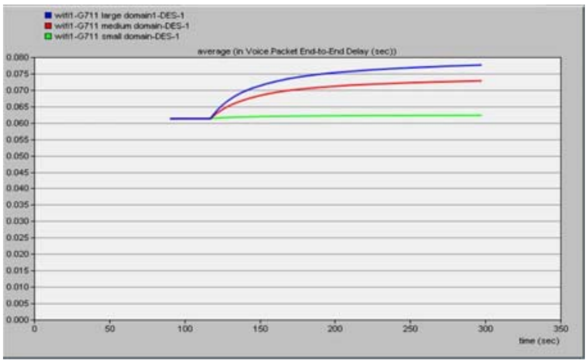

Figure 21. Voice Packet End-to-End Delay

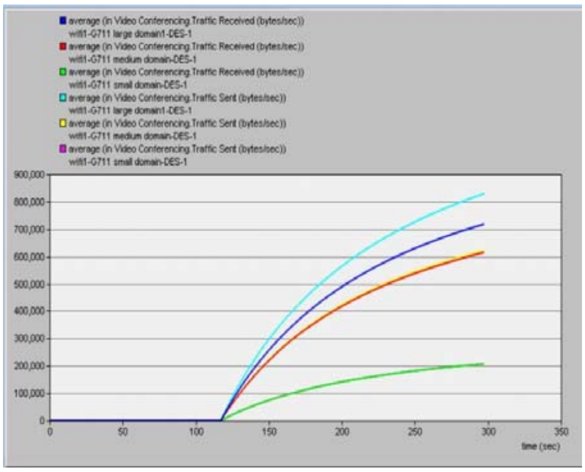

Figure 22. Video Traffic Sent and Received

TABLE V. COMPARISON BETWEEN DIFFERENT CELL SIZES

Point Of Comparison	Large Domain	Medium Domain	Small Domain
Voice Traffic (Sent & Received)	Good	Good	Good
Video Traffic (Sent & Received)	Bad	Good	The best
Voice Packet End to End Delay	Bad	Good	The best
Jitter	Bad	Good	The best
MOS	3.6	3.6	3.6

D. Comparing Voice Codec Performance at Different Speeds

This part is comparison between different users' speed and its effect on WiFi performance, speeds are (10,100,1000)m/s.

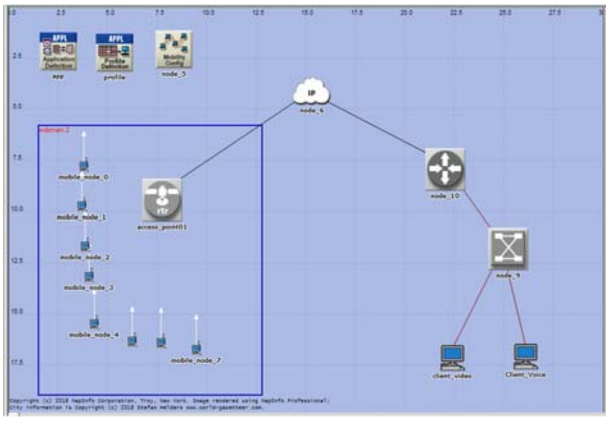
Figure 23. Model structure of speeds

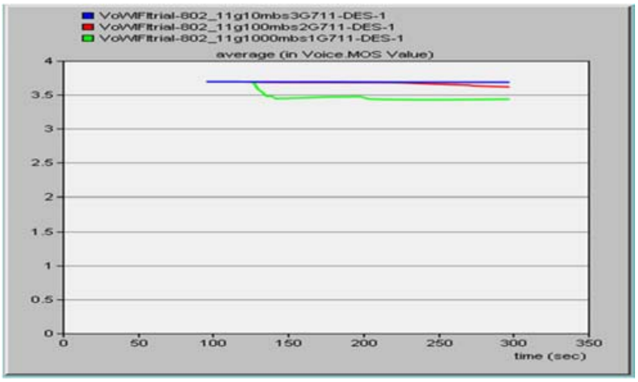

Figure 24. MOS Of G711 in Different Speeds

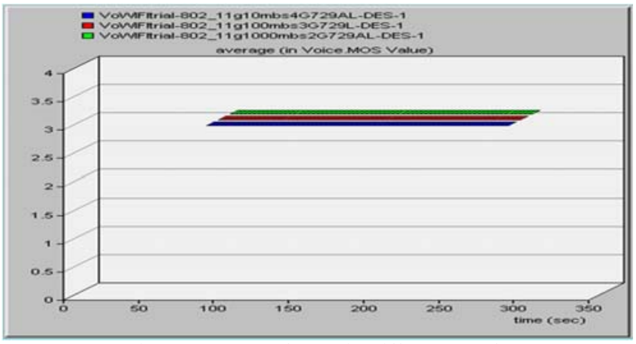

Figure 25. MOS Of G729 in Different Speeds

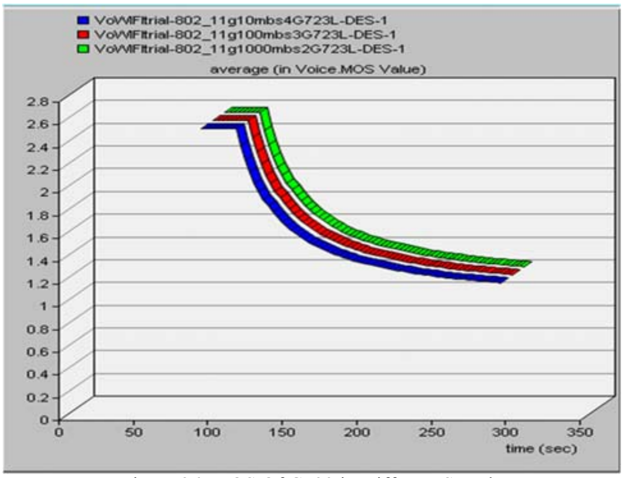

Figure 26. MOS Of G723 in Different Speeds

TABLE VI. COMPARISON BETWEEN VOICE CODECS AT DIFFERENT SPEEDS

	10m/s (max)	100m/s	1000m/s
G.711	3.7	3.7	3.7
G.729	3	3	3
G.723	2.5	2.5	2.5

D. Comparing Video Resolution Effect on Traffic

This part the comparison is between different video resolution the resolutions are (128x120,128x240,352x240)pixel

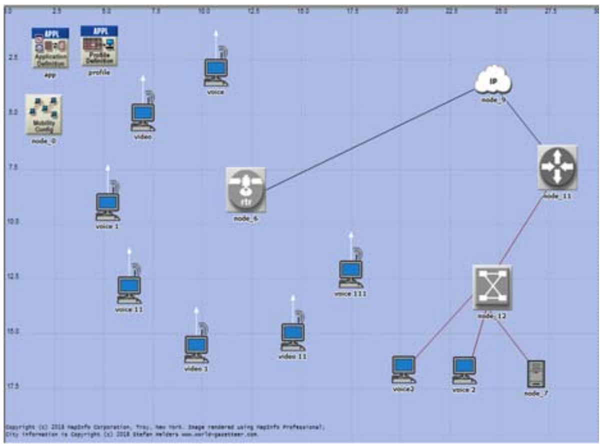

Figure 27. Simulation model

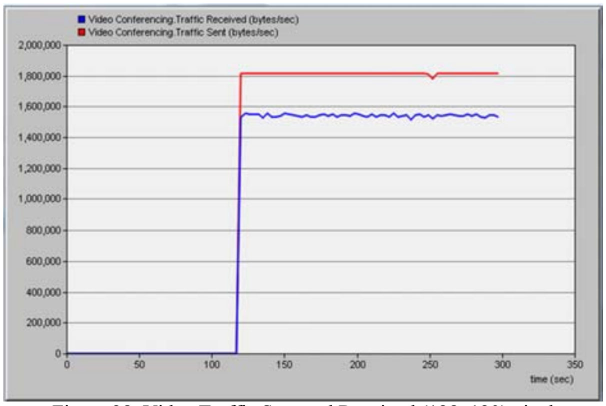

Figure 28. Video Traffic Sent and Received (128x120) pixel

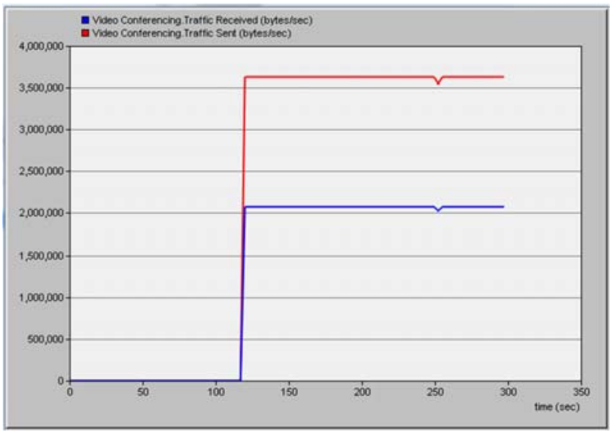

Figure 29. Video Traffic Sent and Received (128x240) pixel

DOI 10.5013/IJSSST.a.24.02.05 ISSN: 1473-804x online, 1473-8031 print

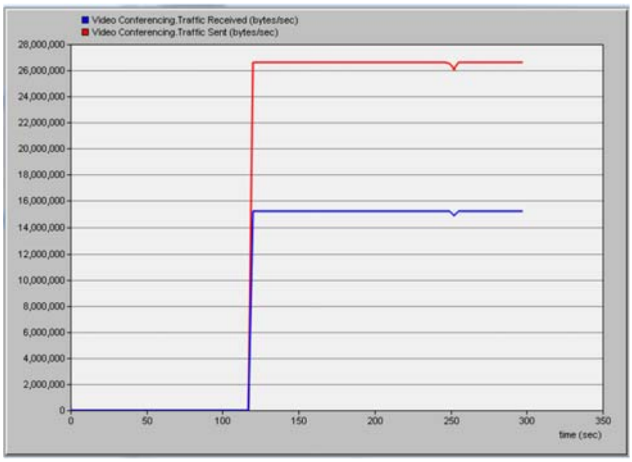

Figure 30. Video Traffic Sent and Received (352x240) pixel

TABLE VII. COMPARISON BETWEEN VIDEO CODECS

Point Of Comparison	128x120 Resolution	128x240 Resolution	352x240 Resolution
Video traffic (sent& received)	Best traffic reliability	Good traffic reliability	Bad traffic reliability

VI. CONCLUSION

In this paper we studied a lot of parameters to find the best performance for VoWiFi and we find that to achieve the best performance with respect to WiFi technology , use 802.11g cause it has best performance least delay least packet loss, to get the best performance with respect to voice codecs , use G.711 cause it has the best traffic sent and received and highest MOS ,also in high speeds G.711has the best performance which is obvious in the highest MOS, the coverage of the AP is 48 m so ,keep near to the AP to get best power and lowest traffic loss and finally to get reasonable packet loss, use moderate video resolution (128x120) or (128x240).

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