LTE Approach for Real Time Applications in Telemedicine Using FMC

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ABSTRACT

Telemedicine is the use of telecommunication and information technologies in order to provide clinical health care at a distance. Mobile telemedicine is used in the cases of emergency needs to communicate with an expert doctor present at a distant location. Real time applications are essential for today's telemedicine scenarios. In emergency situations in an ambulance, the inmates can receive reliable, reduced time delay, increased Quality of Service (QoS) information in order to sustain the life of the patient until the ambulance reaches the hospital. The evolution of Fixed Mobile Convergence (FMC) has lead to provide seamless services using a combination of fixed broadband and local access wireless technologies to the users at surprisingly reduced rates. This paper focuses on a mobile telemedicine system based on FMC by the integration of Long Term Evolution (LTE) and Wireless Local Area Network (WLAN) under perfect mobile conditions. The mobile telemedicine system along with real time channel conditions and background traffic has been simulated in QualNet Developer Network Simulator and the results regarding the throughput, average delay and jitter have been calculated and compared.

Keywords: Fixed Mobile Convergence, Long Term Evolution, Wireless Local Area Network, jitter, average delay.

1. Introduction

Telemedicine is defined as the delivery and sharing of medical information of patient over a distance using telecommunication means. Telemedicine is rapidly growing application of clinical medicine that enables the transfer of medical information through an interactive audio-visual media for the purpose of consulting and for remote examinational procedures. Although there were distant precursors to telemedicine, it is essentially a product of 20th century telecommunication and information technologies [1]. These technologies permit communications between patient and medical staff with both convenience and fidelity, as well as the transmission of medical, imaging and health informatics data from one site to another. Early forms of telemedicine achieved with telephone and radio have been supplemented with video telephony, advanced diagnostic methods supported by distributed client/server applications, and additionally with telemedical devices to support in-home care [2].

Existing telemedicine systems which use fiber optic broadband systems lack mobility to the patient or the user and satellite communication based systems exhibit large latency [3]. One major constraint for telemedicine systems is the latency when a real time video or real time audio is transmitted, which needs to be maintained well below the threshold levels to provide satisfactory communication link between the patient and the doctor. The wireless communication system can solve the mobility issues of the telemedicine system while bandwidth offered by wireless systems is restricted and also has drawbacks like packet loss, high latency, and jitter [4]. The problem with the High Speed Packet Access (HSDPA) that has been proposed in [5] is that the data rates that have been provided by the system is not sufficient for huge real time high definition video which arises due to the transmission of wounds and surgical procedures to doctors from a high velocity ambulance. In order to overcome these drawbacks and to cater today's needs, the telemedicine with the capability of Fixed Mobile Convergence (FMC) has been introduced [6]. The implementation of FMC in the HSDPA would not provide a great leap in the system parameters hence the convergence has been proposed for the upcoming fourth generation telecommunication system of Long Term Evolution (LTE).

In this paper, a mobile telemedicine system based on FMC has been proposed by the integration of LTE and Wireless Local Area Network (WLAN) under perfect mobile conditions. The scenario of a moving ambulance with Rayleigh physical channel conditions communicating with a doctor available on the IP network is considered to improve the Quality of Service (QoS) parameters such as throughput, average delay and jitter. The rest of the paper is organized as follows. In Section 2 FMC and FMC architecture is explained. Section 3 explains about LTE. In section 4 the need of integration of LTE and WLAN is explained. Various scenarios for telemedicine system is explained in section 5.Section 6 describe the results and comparison of different scenario. The paper is concluded in section 7.

2. Fixed Mobile Convergence

FMC is the trend towards seamless connectivity between fixed and wireless telecommunications networks. The term also describes any physical network that allows cellular telephone sets to function smoothly with the fixed network infrastructure. The ultimate goal of FMC is to optimize transmission of all data, voice and video communications to and among end users, no matter what their locations or devices. In the near future, FMC means that a single device can connect through and be switched between fixed and mobile networks [6, 7]. FMC is sometimes seen as a way to reverse the trend towards Fixed-Mobile Substitution (FMS), the increasing tendency for consumers and businesses to substitute cellular telephones for hard-wired or cordless landline sets. Consumers prefer mobile phones for several reasons. The most often mentioned factors are convenience and portability. With mobile service, it is not necessary for the user to locate and remain bound to a hard-wired phone set or stay within the limited range of a cordless base unit. Most mobile service providers offer packages in which there is no extra charge for roaming or long-distance calling. Another factor in the acceleration of FMS is the fact that as mobile telephone repeaters have proliferated, the per-minute cost of the services has been declining while coverage has been improving. FMS at the consumer and enterprise level translates to the industry as a whole, offering a major opportunity to mobile companies and threatening the continued existence of traditional telecommunications companies. A number of companies are offering or developing devices that can connect to both traditional and wireless telecom networks as a means of slowing the overall trend to FMS.

The FMC is an evolution from both the technological and marketing points of view. From the technological point of view, convergence can generally be achieved at one of three levels: the terminal level, the intelligent network level, or the switch level. However, incumbent operators and new entrants find that they cannot easily integrate all the current switches. The only level where significant progress has been achieved is the intelligent network level. Solutions based on the intelligent network exactly fit the market demands for flexible, innovative services and fast introduction to the market. Therefore, adoption of an intelligent network solution by mobile operators and implementation of wireless access solutions (with limited mobility) by fixed network operators are the current key drivers toward FMC. Support of both fixed and mobile services on intelligent network architecture brings a number of benefits to operators and customers, helping them to become or remain competitive. Consumers using Global System for Mobile (GSM) and WCDMA phones will now be able to use their mobile phones at home, with the price advantages offered by fixed-line and internet phones. Intelligent network solution includes home base station that is, in itself, the world's smallest mobile base station. The home base station is compatible with GSM and WCDMA phones and also includes Wi-Fi and ADSL.

This solution enables the operator to offer a "home-area" tariff to all the people living in a household. Home base station is connected, plug-and-play, to any existing IP backhaul network (e.g. ADSL), and the user's mobile phone will switch to the indoor home base station automatically as they walk through the door. The Fixed Mobile Convergence can be defined as Fixed and Mobile Convergence (FMC) is concerned with the provision of network and service capabilities, which are independent of the access technique [6]. This does not necessarily imply the physical convergence of networks. It is concerned with the development of converged network capabilities and supporting standards[6].This set of standards may be used to offer a set of consistent services via fixed or mobile access to fixed or mobile, public or private networks. An important feature of FMC is to allow users to access a consistent set of services from any fixed or mobile terminal, via any compatible access point. An important extension of this principle is related to roaming: users should be able to roam between different networks and be able to use the same consistent set of services through those visited networks as they have available in the home network. This feature is referred to as the Virtual Home Environment (VHE).

2.1 FMC Architecture

With the convergence between the mobile and fixed line networks, telecommunications operators can provide services to users irrespective of their location, access technology, and terminal. These trends are stimulating operators and vendors to provide the same services over both fixed and mobile networks, developing a converged intelligent network. Figure1 clearly depicts FMC architecture where the convergence between the Fixed networks like the xDSL, WiMAX, WLAN etc and the mobile networks like the 2G/3G/HSPA/LTE [8]. The integration has been done over an IP network and the signaling has been carried over by a Session Initiation Protocol (SIP).

Fixed-mobile converged intelligent network can provide seamless location, roaming and hand-off of voice calls between indoor network and outdoor network using one mobile phone with a single number. Applicable to data and video services as well, this capability will enable providers to deliver multimedia services to a range of different devices and maintain service continuity and QoS across a range of access networks for users at work, at home, or on the road. The intelligent network can dynamically deliver these services over the most efficient and highest quality network without subscribers having to take action or even acknowledge that any change took place. This results in greater subscriber satisfaction and enhanced customer loyalty.

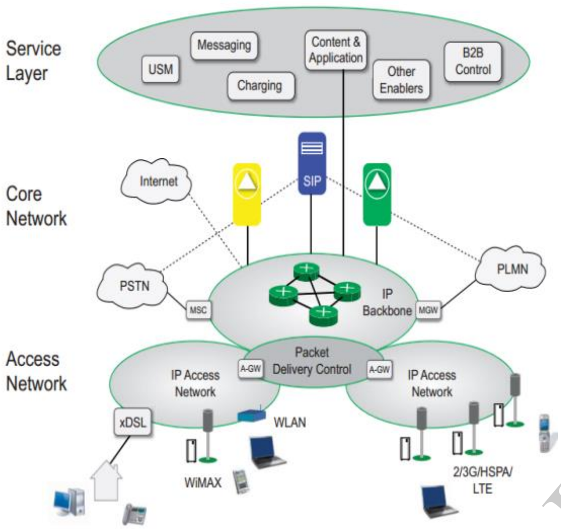

Figure 1. Fixed Mobile Convergence Architecture

3. Long Term Evolution

LTE is developed by Third Generation Partnership Project (3GPP) for providing true 4G broadband mobile access [9]. The architectural evolution of 3GPP LTE [8, 9] based on the functionality, the architecture is split into two parts: a radio access network called E-UTRAN (Evolved Universal Terrestrial Radio Access Network) and a core network called EPC (Evolved packet Core) (Figure 2). The E-UTRAN supports all radio related services such as scheduling, radio-resource handling, retransmission protocols, coding and various multi-antenna schemes. It contains network elements called evolved NodeBs (eNBs), which provide E-UTRAN user plane and control plane termination towards the UE. EPC supports robust IP-based services with seamless mobility and advanced QoS mechanism. LTE air-interface supports both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) modes of operation. In TDD mode, several uplink/downlink allocations are allowed. The downlink of a LTE air-interface uses Orthogonal Frequency Division Multiple Access (OFDMA) and uplink uses Single Carrier Frequency Division Multiple Access (SCFDMA). Unlike HSPA, LTE's E-UTRA is an entirely new air interface system, unrelated to and incompatible with W-CDMA. It provides higher data rates, lower latency and is optimized for packet data. EUTRAN consists only of enodeBs on the network side [10]. The enodeB performs tasks similar to those performed by the nodeBs and RNC (radio network controller) together in UTRAN. The aim of this simplification is to reduce the latency of all radio interface operations. eNodeBs are connected to each other via the X2 interface, and they connect to the packet switched (PS) core network via the S1 interface. Table 1 gives the specifications of LTE. For enhancing air-interface capacity Link adaptation, Hybrid Automatic Repeat reQuest (HARQ) and various multiple antenna techniques are used [11].

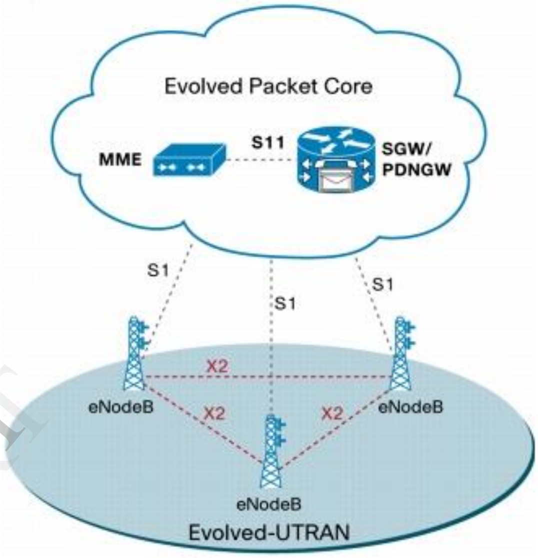

Figure 2. Simplified LTE architecture

4. Need for Integration of LTE and WLAN

The IEEE 802.11 standard provides less cost and wireless LAN service effectively. The deployment of high speed network (11Mbps in 802.11b and 54Mbps in 802.11a/g) can be established by unlicensed spectrum (2.4GHz in 802.11b/g and 5GHz in 802.11a) [12].The IEEE 802.11b standard for the WLAN can offer coverage of 100m. Access Point is an entity which function similar to base station is used in an Infrastructure type WLAN network. The LTE standard was developed by 3GPP with data rate of 150 Mbps [9].LTE can support inter system handover between LTE and 3G latency systems such as UMTS, GSM, etc. The following needs have been the driving force in order to choose the LTE and WLAN networks to be integrated to realize the FMC. In a separate network, the each mobile terminal is served by the base stations with the strongest signal strength, while the unwanted signals received from other base stations are usually treated as interference. Such principles can lead to significantly suboptimal performance.

In such systems, smarter resource coordination among base stations, better server selection strategies and more advanced techniques for efficient interference management can provide substantial gains in throughput and user experience as compared to a conventional approach of deploying cellular network infrastructure. There is a possibility of range expansion and reduction in interference level. Apart from these the FMC have its own advantages of utilizing the capable technologies of providing access to both residential and business users and users that are moving. Since the FMC uses a fixed network in it the security is more.

WLAN access method provides a low-cost high-bandwidth method for data and in the future other multimedia applications. The long-awaited roaming with 3G networks makes WLAN a key access technology for FMC. A user with WLAN access either at home, or at an enterprise location or in another public location could be connected through appropriate multi-access (WLAN and cellular) terminals to the Internet, to the PSTN or to the mobile network(s).

5. Simulation scenario and parameters

A mobile telemedicine system is the system in which the patient is mobile and is connected to the expert doctor at the other and all types of data needs to be transferred to the expert doctor to know condition of the patient. The scenario has been constructed in Qualnet 6.1by considering that a patient is moving in an ambulance and the doctor is at a remote place. A fully fledged LTE scenario and the equivalent WLAN network have also been constructed and both of them have been integrated to meet the FMC standards.

The general parameters have been summarized here. In the LTE scenario the mobile stations are configured to be User Equipments (UEs) its physical layer to carry the LTE PHY model and its MAC layer to constitute the LTE MAC model. The base stations which serve the UEs are configured to be eNodeBs. The physical and MAC layer of the enodeB constitute the same LTE PHY and LTE MAC models available in the Qualnet simulator software. The system parameters are tabulated in table 1.

Table .1 System parameters

Parameter	Metric
Terrain	1500 x 1500 (adjustable)
Radio type	LTE PHY
Mac protocol	LTE MAC
eNB Transmission power	46 dbm
eNB Antenna height	36 m

5.1 Mobile LTE Scenario in Qualnet

The LTE scenario with the required criteria has been constructed on the GUI (Graphic User Interface) of the Qualnet software. In this scenario the UEs are attached to their corresponding eNodeBs. The terrain that has been considered in this scenario is 1500 x 1500 m. The scenario has been shown in figure 3

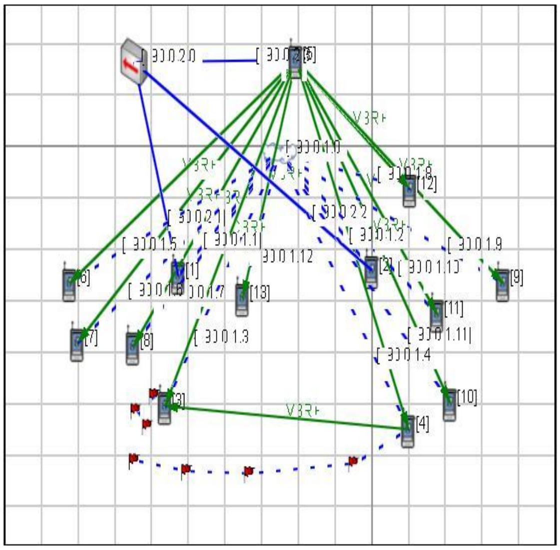

Figure 3. Mobile LTE scenario for the proposed system

In the figure3 the node 4 is the ambulance (vehicular user) moving at an average speed of 80 kmph. The node 3 is the doctor at the remote place who is a pedestrian user within the hospital campus moving at a speed of 10 kmph. The nodes 1 and 2 are the enodeBs covering the node 4 and 3 respectively. Some other nodes are also considered in order to create sufficient traffic and interference. The users are kept apart so that it s not possible for one enodeB to serve it, hence there is a process of handover taking place. All the users and the enodeBs are connected to a common subnet. There is also a common gateway for both the networks which is the node 5. The ambulance which is the node 4 is allowed to move along the waypoints mentioned in the terrain. The waypoints are mentioned using red flags on the terrain. The node 3 is considered to be the doctor at a remote distance. The wireless channel is configured to be Rayleigh's fading channel. The Hub in the network provides the wired interconnection between the nodes.

5.2 WLAN Scenario

The same scenario explained in the LTE scenario has been designed using the 802.11b protocol. The scenario is shown in figure 4

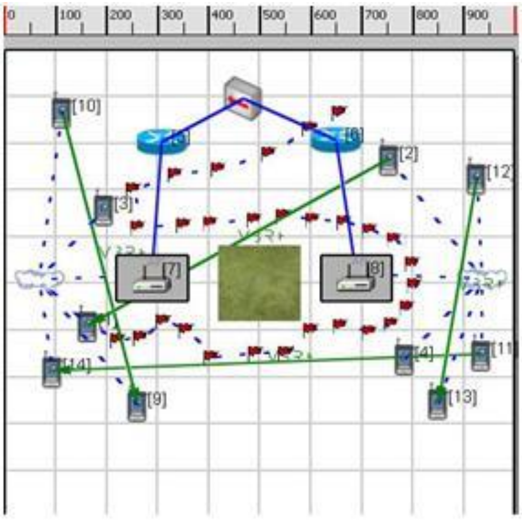

Figure 4. WLAN scenario for the proposed system

In this scenario the nodes 7 and 8 are the Access Points (AP) and the nodes 1 and 2 are the ambulance and doctor respectively. The modes 5 and 6 are the routers which routes the packets between them. Here the users are separated with sufficient distance that they need the routers to contact each other. The node 1 moves in such a way that it needs to handover between the two access points twice before it reaches the destination. Other users are included in order to create sufficient traffic. In the scenario shown in the figure 4 the users are attached to their corresponding Access points (APs). The terrain that has been considered in this scenario is 1500 x 1500 m. The ambulance which is the node 1 is allowed to move along the waypoints mentioned in the terrain. The nodes 7 and 8 are the Access points for the users on the left and the right sides. The average velocity of the ambulance is considered to be 80 kmph. The node 2 is considered to be the doctor at a remote distance. The wireless channel is configured to be Rayleigh's fading channel. The Hub in the network provides the wired interconnection between the routers corresponding to the two access points.

5.3 LTE – WLAN Integrated Scenario

The above system has been remodeled in order to simulate the Fixed Mobile Convergence. The corresponding scenario in Qualnet has been shown in figure 5. Here the nodes 1 and 3 denote the enodeBs and the nodes 2 and 4 denote the access points. Thus the ambulance toggles between LTE and WLAN networks. There is a vertical handover taking place between the two networks. The ambulance tries to send and receive data to and from the doctor. The scenario requires a gateway which is the node 8 in order to aid the handover process.

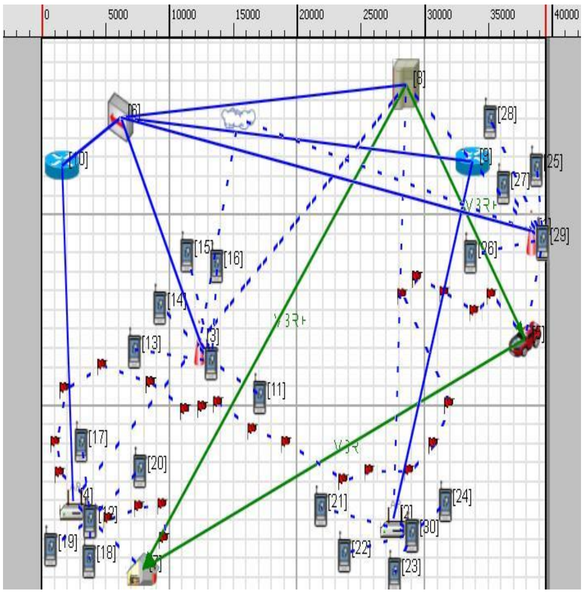

Figure 5.LTE –WLAN integration to realize FMC

The LTE enodeBs are connected to a common subnet whereas the APs are all connected to their routers through which they are connected to the core network through a Hub. There are several other LTE users and WLAN users connected to the enodeBs and APs respectively in order to create sufficient traffic and enable the measurement of the system parameters at a robust scenario. The ambulance which is the node 5 is allowed to move along the waypoints mentioned in the terrain. The average velocity of the ambulance is considered to be 80 kmph. The node 7 is considered to be the doctor at a remote distance. The wireless channel is configured to be Rayleigh's fading channel. The Hub in the network provides the wired interconnection between the routers corresponding to the two access points.

5.4 Priority Assignment

The telemedicine system proposed can handle all the types of data that are needed in a telemedicine system i.e., real time audio, video, heavy data and background data. The problem that is encountered while handling all such data is the queue management at the network layer of the network. An improperly managed queue leads to extremely large latency and low throughput which will make the system not suitable for operation. The system simulated consisted of 4 types of Constant bit rate (CBR) flows in the telemedicine system corresponding to the real time audio, video, heavy data and background data. The IP headers of the data packets of the different types of flows are assigned priority as shown in the following Table 2.

Table 2 Priority Assignment to data

S.No	TYPE OF FLOW	PRIORITY
1.	Conversational audio	6-7
2.	Streaming video	4-5
3.	Heavy data	1-3
4.	Background data	0

6. Simulation results of the mobile telemedicine system

6.1 LTE scenario results

The simulation results that have been considered include the throughput, average delay and the jitter that has incurred during the transmission process. The following figures 6, 7, 8 and 9 shows the data bytes sent, data bytes received, average delay and jitter.

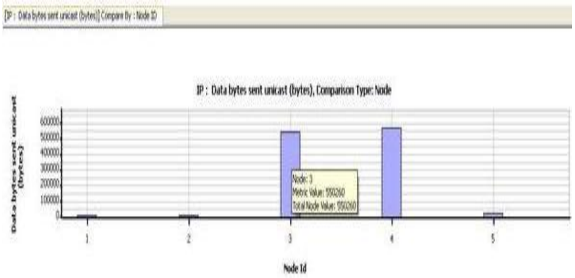

Figure 6. Data bytes sent at the doctor end in LTE

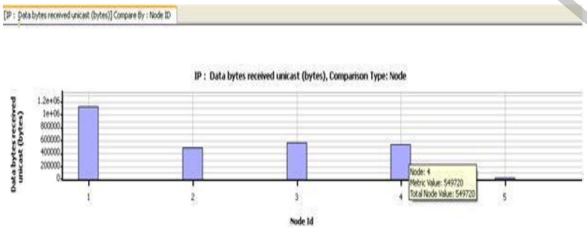

Figure 7. Data bytes received at the ambulance end of LTE

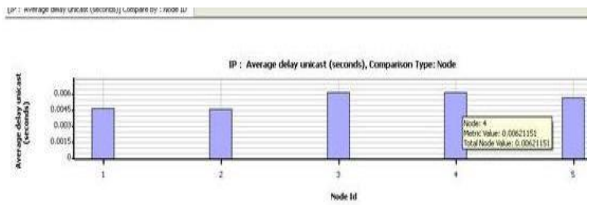

Figure 8. Average delay at the ambulance end of LTE

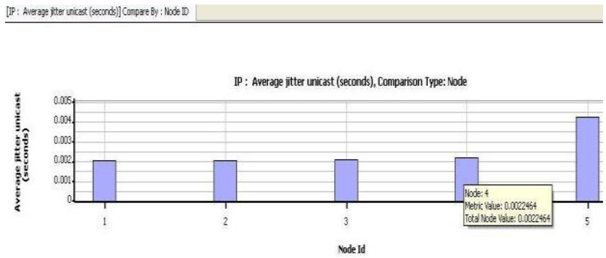

Figure 9. Average jitter at the ambulance end in LTE

The results that have presented above shows the performance of the LTE network of the design. The discussion of these results will be summarized in the section 6.4.

6.2 WLAN scenario results

The simulation results that have been considered include the throughput, average delay and the jitter that has incurred during the WLAN transmission process. The following figures 10, 11, 12 and 13 shows the data bytes sent, data bytes received, average delay and jitter.

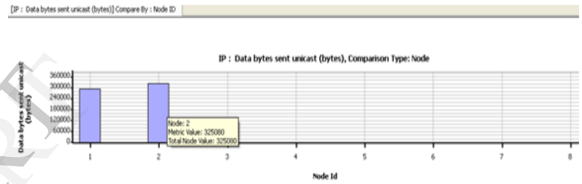

Figure 10. Data bytes sent at the doctor end in WLAN

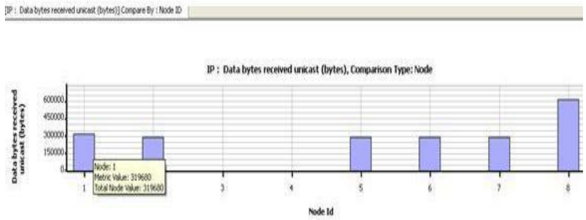

Figure 11. Data bytes received at the ambulance end in WLAN

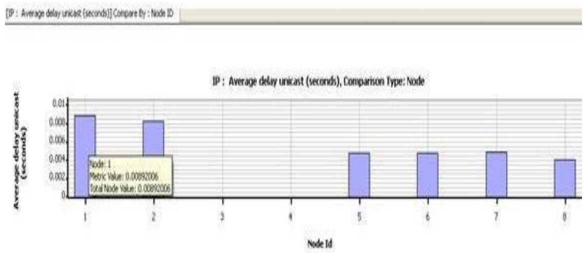

Figure 12. Average end to end delay at the ambulance in WLAN

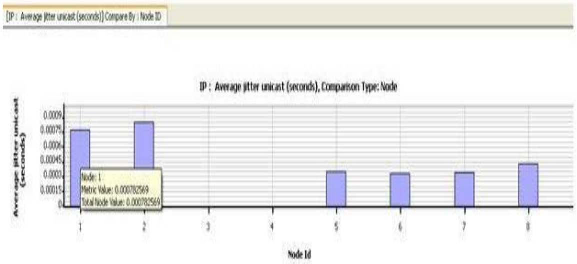

Figure 13. Average jitter at the ambulance end in WLAN

The results that have presented above shows the performance of the WLAN network of the design. The discussion of these results will be summarized in the section 6.4

6.3 FMC Network of LTE and WLAN system results

The simulation results that have been considered include the throughput, average delay and the jitter that has incurred during the WLAN transmission process. The following figures of 14, 15, 16 and 17 shows the data bytes sent, data bytes received, average delay and jitter.

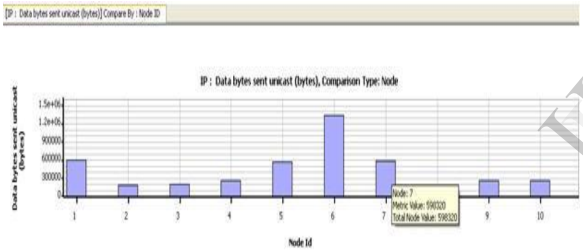

Figure 14. Data bytes sent at the doctor end in FMC network

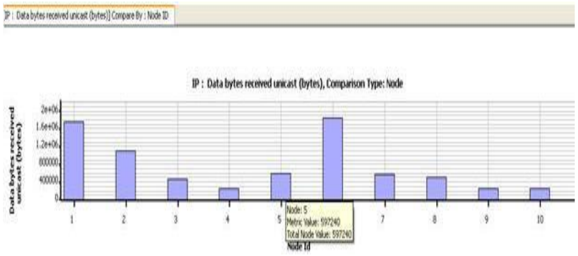

Figure 15. Data bytes received at the ambulance end in FMC network

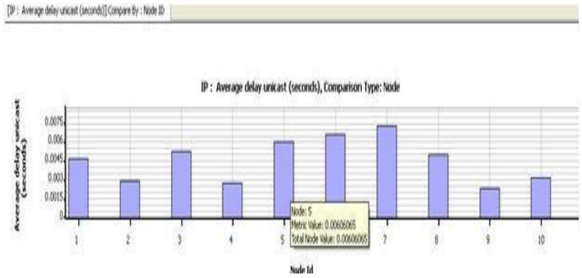

Figure16. Average end to end delay at the ambulance in FMC network

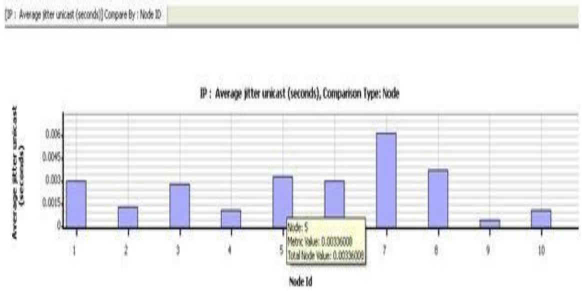

Figure 17. Average jitter at the ambulance end in FMC network

The results that have presented above shows the performance of the LTE-WLAN network of the design. The discussion of these results will be summarized in the section 6.4

6.4 Comparison of Different Scenario

Based on the above results obtained from the various networks of LTE, WLAN and the FMC networks, the following table has been derived in order to find the throughput, average delay and jitter of the various systems and to compare them. The values have been tabulated in the Table 3

Table 3 Comparison of system properties

Parameters	LTE scenario	WLAN scenario	FMC
Data bytes sent	550260	325080	598320
Data bytes received	549720	319680	597240
Delay	6.21 ms	8.9 ms	6.06 ms
Jitter	2.24 ms	0.78 ms	3.3 ms
Throughput	88.52Mbps	35.84Mbps	98.55Mbps

The throughput of the corresponding systems have been calculated based on the number of bytes successfully received and average delay incurred in the corresponding network. By comparing the results of the three networks it is quite clear that LTE has a throughput of 88.52 Mbps whereas the WLAN (802.11b) could support only 35.84 Mbps. The converged version of the two networks could give an enhanced throughput of 98.55 Mbps with acceptable delay and jitter values.

7. Conclusion

In this paper a mobile telemedicine system based on FMC by the integration of LTE and WLAN has been simulated on the Qualnet network simulator. All the types of data that are needed in a telemedicine system – real time audio, video, heavy data i.e., MRI scans, X-ray scans, and background data like email, etc have been considered and background congestion in the network was assumed to make the simulation real time. The proposed FMC generated network is compared with the same scenarios of LTE and WLAN networks separately by altering different components in order to successfully obtain a network with the best system parameters. It can be seen that proposed converged networks provide enhanced throughput with acceptable delay and jitter. This network is considered to be robust based on the traffic that has been created during the process of this simulation. The work done is a novel approach by which the integration of such elements for the generation of the FMC is made feasible.

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