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A THESIS
on
**ROLE OF WIRELESS TECHNOLOGY IN MOBILE
AUGMENTED REALITY SYSTEM (MARS)**

Submitted to



**SAURASHTRA UNIVERSITY
RAJKOT (GUJARAT)**

For the award of the degree of
**DOCTOR OF PHILOSOPHY IN COMPUTER ENGINEERING
(FACULTY OF ENGINEERING & TECHNOLOGY)**

Under the Guidance of
DR. KETAN KOTecha

Submitted By:
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SEPTEMBER 2010

CERTIFICATE BY THE RESEARCH FELLOW

I declare that the thesis entitled “**ROLE OF WIRELESS TECHNOLOGY IN MOBILE AUGMENTED REALITY SYSTEM (MARS)**” is the result of a study originally carried out by me independently, under the guidance and supervision of Dr. Ketan Kotecha, Director, Institute of Technology, Nirma University, Ahmedabad (Gujarat). This work has not been submitted earlier, in full or in part, for any diploma, degree, or distinction to Saurashtra University, Rajkot or any other university by me.

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I hereby certify that the work which is being presented in the thesis entitled **“ROLE OF WIRELESS TECHNOLOGY IN MOBILE AUGMENTED REALITY SYSTEEMS (MARS)”** by **“KALPESH .H VANDRA”** in partial fulfillment of requirements for the award of degree of *DOCTOR OF PHILOSOPHY in Computer Engineering (Faculty of Engineering & Technology)*. At Saurashtra University, Rajkot. All the analysis, hypothesis, inferences and interpretation of data and strategy are of my own and original work. The application has been developed to a domain and derived optimized performance for different wireless technologies for MARS (Live Streaming through Mobile) Application, which is my own and original work. Moreover, I declare that the work done in the thesis, either the by Saurashtra University or by any other University has not been conferred for any degree, diploma or distinction by me before.

(Kalpesh H. Vandra)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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Chapter 1: Introduction

1.1 Preamble

The main motivation source for me is to choose the research topic on wireless communication technology and it is the day to day increasing demand of the wireless communication media and wireless broadband access. In current era, we need that all the communication device should be wirelessly because of the fast life of human beings. They need portable and mobile wireless medias and service for communication with the help of which wireless communication and wireless broadband access can be possible anywhere and anytime with low cost and high speed. Thus, the field of wireless communication systems and networks has experienced explosive growth and wireless communications has become an important part of everyday life of human being.

The main aim of this research work is to be carried out in two phase . In phase one to specify basic and overall requirements and characteristics of present and expected future of wireless communication technologies. GSM(Global System for Mobile Communication) , GPRS (General Packet Radio Service), UMTS (Universal Mobile Telephone System) ,WLAN (Wireless Local Area Network), Wi-Fi(Wireless Fidelity),Wi-max (Worldwide Interoperability for Microwave Access) and WiBro (Wireless Broadband), study and implementation of the characteristics and utilization possibilities of present wireless communication technologies and how it differs performance wise. Performance parameters are to be compared with one another and compared it with actual and expected simulation results to obtain optimized performance for Mobile Augmented Reality System (MARS) applications. Simulation results are mainly carried out using QualNet5.0. Comparison of various wireless communication technologies, analysis and simulation are based on all possible the aspects like Data rate support, Frequency, & BW ,Modulation Multiple Access ,Mobility & Portability, Coverage, Speed, Bit Error rate Path loss Model, Channel condition (e.g. LOS Line Of Site , NLOS Non Line Of Site),Quality of service, Cost, Architecture ,

Specifications ,IEEE (Institute of Electrical & Electronics Engineers)standards,
Advantages and Disadvantages

In second phase work has been done on development and implementation of MARS application, Augmented Reality System is the system that presents the augmented scenes in mobile environment. With the recent advancement in high-speed computing and Multimedia applications numbers of application areas for MARS (Mobile Augmented Reality Systems) have been identified. The biggest challenge to the augmented reality is to increase the mobility and processing speed together .In this research I have emphasized on the role of wireless technologies for the MARS Real time applications. To facilitate the researchers in this area i have proposed layered architecture for MARS which will enable to concentrate on mobility, processing and data tracking issues independently. Finally I have outlined the comparative result analysis of wireless technologies (GSM/GPRS, UMTS, Wi-Fi, WiMAX and WiBro) on QualNet 5.0 simulator for optimized performance for MARS applications and Implementation of mobile augmentation reality system applications.

1.2 Problem Statement

Wireless technologies play a prominent role in today's global internet infrastructure for different applications. Here, we have very good scope and opportunity to find out the Role of wireless technologies for mobile augmented reality applications

- 1) Global System for Mobile Communication (GSM). It is a circuit switched system and can provide data rates only up to 9.6kbps. This severely limits the services and applications it can support.
- 2) General Packet Radio Service (GPRS), packet based extension to GSM. The packet switched radio transmission enables efficient multiplexing of radio resources and lower data rates (up to 170 kbps) can be achieved and less users can get GPRS service at time
- 3) GSM/GPRS data rate and It is limitation for Mobile Augmentation Reality applications

4) In practical implementations of UMTS, some users may be unable to access the highest data rates at all times. For example, the physical constraints of radio propagation and the economics of operating a network will mean that the system services might only support lower data rates in remote or heavily congested areas. Therefore, in order to ensure that the subscriber is always able to use their terminal, services will be adaptive to different data rate availability and other Quality of Service parameters.

5) Key issue in Wi-Fi are coverage, data rate, number of users and security. Wi-Fi networking standard including 802.11a/g requires ad hoc mode of communication which supports 11Mbps bandwidth with less coverage area

Wi-Fi 802.11b devices when configured to infrastructure mode can transfer data up to 54 Mbps with very good coverage, whereas using ad hoc mode only 11 mbps can be achieved. Ad hoc mode is considered slower in comparison to infrastructure for this reason.

6) WiMAX is designed for service in the 2- to 6-GHz microwave range, where licensed or unlicensed spectrum is available. The outer limit of its capability is a 75-Mbit/s data rate at a range to 30 miles. But it seems doubtful that anyone will use it in that form. Instead, WiMAX will be deployed by building a network of base stations with coverage radii in the 2- to 6-mile range. Entire speed will be divided up among many users, with most getting a solid data rate in the 1-to 3-Mbit/s range. Businesses can pay for more speed as needed.

7) WiBro (Wireless Broadband) is a wireless broadband Internet technology being developed by the Korean telecoms industry. It adapts TDD for duplexing, OFDMA for multiple access and 8.75MHz as a channel bandwidth. WiBro was devised to overcome the speed limitation of mobile phone (for example CDMA 1x) and to add mobility to broadband Internet (for example ADSL or Wireless LAN)

- 8) In today's world there are many MARS applications are available which have high cost ,require many other device , don't provide practical mobility and easy to use

1.3 Objectives of Proposed work

The main aim of this research work summarized as follow:

- Specify basic and overall requirements and characteristics of present and expected future wireless communication technologies (GSM/GPRS, UMTS, WLAN, Wi-Fi, WiMAX and WiBro).
- Study and implementation of the characteristics and utilization possibilities of present wireless communication technologies and how it differs performance wise.
- Performance parameters are to be compared with one another and also it with actual and expected simulation results to obtained optimized performance for MARS applications. Simulation results are mainly carried out using QualNet5 Comparison of various wireless communication technologies analysis and simulation are based on few or all the aspects mentioned below
- Data rate support, Frequency & BW, Modulation, Multiple Access, Mobility & Portability, Coverage, Speed, Bit Error rate, Path loss Model, Channel condition (e.g. LOS, NLOS), Quality of service, Cost, Architecture Specifications, IEEE standards, Advantages, Drawbacks, Application and Future expansion Implementation of MARS Applications Algorithm through which user can send data (video, audio and image) and same data received by multi mobile or computer users, on mobile platform. Comparative analysis of various implementations are done.
- Development and Implementations of MARS application through which user can send data (video, audio and image) and same data received by multi mobile or computer which is used by any common users on available wireless technology.
- Testing of MARS application on different mobile handsets.

Chapter 2: Overview of Various Wireless Communication Technologies

2.1 GSM Technology

2.1.1 Introduction to GSM

During early 1980s, analog cellular telephone systems were experiencing rapid growth in Europe, particularly in Scandinavia and the United Kingdom, and also in France and Germany. Each country developed its own system, which was incompatible with everyone else's in equipment and operation. This was an undesirable situation, because not only were the mobile equipment limited to operation within national boundaries, which in a unified Europe were increasingly unimportant, but there was also a very limited market for each type of equipment, so scale of economy and the subsequent savings could not be realized.

The Europeans realized this early on, and in 1982 the Conference of European Posts and Telegraphs (CEPT) formed a study group called the Global System for Mobile Communication (GSM) to study and to develop a pan-European public land mobile system. [1] The proposed system had to meet certain criteria:

- Good subjective speech quality
- Low terminal and service cost
- Support for international roaming
- Ability to support handheld terminals
- Support for range of new services and facilities
- Spectral efficiency
- ISDN compatibility

In 1989, GSM responsibility was transferred to the European Telecommunication Standards Institute (ETSI), and phase I of the GSM specifications were published in 1990. Commercial service was started in mid-1991, and by 1993 there were 36 GSM networks in 22 countries. Although standardized in Europe, GSM was not only a European standard. Over 200

Chapter-3: Overview of Mobile Augmented Reality System and applications

3.1 Augmented Reality (AR):

Mobile augmented reality [50],[51] is a relatively new and intriguing concept. The ability of augmented reality [52] to present information superimposed on our view on the world opens up many interesting opportunities for graphical interaction with our direct environment. Combining this with mobility further increases the potential usage of this technology for direct daily use. However, the technical problems with mobile augmented reality are just as great.

The computer systems that combine the real and the virtual in order to assist users in interacting with their physical environments are called Augmented Reality systems. Augmented Reality and mobile computing are often mentioned together, as many mobile computing platforms rely on some kind of head-up or head-mounted display to provide continuous access to information, often coupled with hands-free operation. The ultimate goal is to make the mobile computer a part of the user's normal daily life. Augmented Reality as a user interface for mobile computing is particularly powerful when the computer has access to information on location and situation, so it can provide contextual information

3.1.1 Definition

There are two commonly accepted definitions of Augmented Reality today. One was given by Ronald Azuma in 1997. [53] Augmented Reality

- combines real and virtual
- is interactive in real time
- is registered in 3D

Additionally Paul Milgram and Fumio Kishino defined Milgram's Reality-Virtuality Continuum in 1994. [54] They describe a continuum that spans from the real environment to a pure virtual environment. In between there are

Augmented Reality (closer to the real environment) and Augmented Virtuality (is closer to the virtual environment).



Figure 3.1: Simplified representation of a "virtuality continuum".

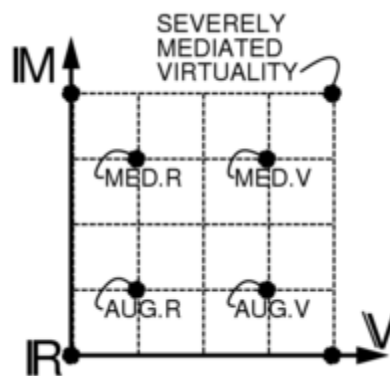


Figure 3.2 Milligram's Continuum

Mediated Reality continuum showing four points: Augmented Reality, Augmented Virtuality, Mediated Reality, and Mediated Virtuality on the Virtuality and Mediality axes. This continuum has been extended into a two-dimensional plane of "Virtuality" and "Mediality". Taxonomy of Reality, Virtuality, Mediality. The origin R denotes unmodified reality. A continuum across the Virtuality axis V includes reality augmented with graphics (Augmented Reality), as well as graphics augmented by reality (Augmented Virtuality). However, the taxonomy also includes modification of reality or virtuality or any combination of these. The modification is denoted by moving up the mediality axis. Further up this axis, for example, we can find mediated reality, mediated virtuality, or any combination of these. Further up and to the right we have virtual worlds that are responsive to a severely modified version of reality. (at right) Mediated reality generalizes the concepts of mixed reality, etc.. It includes the virtuality reality continuum (mixing) but also, in addition to

additive effects, also includes multiplicative effects (modulation) of (sometimes deliberately) diminished reality. Moreover, it considers, more generally, that reality may be modified in various ways. The mediated reality framework describes devices that deliberately modify reality, as well as devices that accidentally modify it. More recently, the term augmented reality has been blurred a bit due to the increased interest of the general public in AR.

3.2 A R Technology

Hardware

The main hardware components for augmented reality are: display, tracking, input devices, and computer. Combination of powerful CPU, camera, accelerometers, GPS and solid state compass are often present in modern Smartphone's, which make them prospective platforms for augmented reality.

Display

There are three major display techniques for Augmented Reality:

Head Mounted Displays

Handheld Displays

Spatial Displays

Head Mounted Displays

A Head Mounted Display (HMD) places images of both the physical world and registered virtual graphical objects over the user's view of the world. The HMD's are either optical see-through or video see-through in nature. An optical see-through display employs half-silver mirror technology to allow views of physical world to pass through the lens and graphical overlay information to be reflected into the user's eyes. The HMD must be tracked with a six degree of freedom sensor. This tracking allows for the computing system to register the virtual information to the physical world. The main advantage of HMD AR is the immersive experience for the user. The graphical information is slaved to the view of the user. The most common

products employed are as follows: Micro Vision Nomad, Sony Glasstron, and I/O Displays.

Handheld Displays

Handheld Augment Reality employs a small computing device with a display that fits in a user's hand. All handheld AR solutions to date have employed video see-through techniques to overlay the graphical information to the physical world. Initially handheld AR employed sensors such as digital compasses and GPS units for its six degree of freedom tracking sensors. This moved onto the use of fiducial marker systems such as the AR Tool Kit for tracking. Today vision systems such as SLAM or PTAM are being employed for tracking. Handheld display AR promises to be the first commercial success for AR technologies. The two main advantages of handheld AR is the portable nature of handheld devices and ubiquitous nature of camera phones.

Spatial Displays

Instead of the user wearing or carrying the display such as with head mounted displays or handheld devices; Spatial Augmented Reality (SAR) makes use of digital projectors to display graphical information onto physical objects. The key difference in SAR is that the display is separated from the users of the system. Because the displays are not associated with each user, SAR scales naturally up to groups of users, thus allowing for collocated collaboration between users. SAR has several advantages over traditional head mounted displays and handheld devices. The user is not required to carry equipment or wear the display over their eyes. This makes spatial AR a good candidate for collaborative work, as the users can see each other's faces. A system can be used by multiple people at the same time without each having to wear a head mounted display. Spatial AR does not suffer from the limited display resolution of current head mounted displays and portable devices. A projector based display system can simply incorporate more projectors to expand the display area. Where portable devices have a small window into the world for drawing, a SAR system can display on any number of surfaces of an indoor setting at once. The tangible nature of SAR makes this an ideal technology to support design, as SAR supports both a graphical visualization and passive haptic

sensation for the end users. People are able to touch physical objects, and it is this process that provides the passive haptic sensation. [2] [8] [9] [10]

Tracking

Modern mobile augmented reality systems use one or more of the following tracking technologies: digital cameras and/or other optical sensors, accelerometers, GPS, gyroscopes, solid state compasses, RFID, wireless sensors. Each of these technologies have different levels of accuracy and precision. Most important is the tracking of the pose and position of the user's head for the augmentation of the user's view. The user's hand(s) can tracked or a handheld input device could be tracked to provide a 6DOF interaction technique. Stationary systems can employ 6DOF track systems such as Polhemus, ViCON, A.R.T, or Ascension.

Input devices

This is a current open research question. Some systems, such as the Tinmith system, employ pinch glove techniques. Another common technique is a wand with a button on it. In case of smart phone, phone itself could be used as 3D pointing device, with 3D position of the phone restored from the camera images.

Computer

Camera based systems require powerful CPU and considerable amount of RAM for processing camera images. Wearable computing systems employ a laptop in a backpack configuration. For stationary systems a traditional workstation with a powerful graphics card. Sound processing hardware could be included in augmented reality systems.

Software

For consistent merging real-world images from camera and virtual 3D images, virtual images should be attached to real-world locations in visually realistic way. That means a real world coordinate system, independent from the camera, should be restored from camera images. That process is called Image registration and is part of Azuma's definition of Augmented Reality.

Augmented reality image registration uses different methods of computer vision, mostly related to video tracking. Many computer vision methods of augmented reality are inherited from similar visual odometry methods.

3.3 Applications of AR [55]

Advertising: Marketers started to use AR to promote products via interactive AR applications.

Entertainment and education: AR can be used in the fields of entertainment and education to create virtual objects in museums and exhibitions, theme park attractions (such as Cadbury World)

Military and emergency services: AR can be applied to military and emergency services as wearable systems to provide information such as instructions, maps, enemy locations, and fire cells.

Navigation devices: AR can augment the effectiveness of navigation devices for a variety of applications.

Industrial Applications: AR can be used to compare the data of digital mock-ups with physical mock-ups for efficiently finding discrepancies between the two sources. It can further be employed to safeguard digital data in combination with existing real prototypes, and thus save or minimize the building of real prototypes and improve the quality of the final product.

Architecture: AR can be employed to simulate planned construction projects.

Sightseeing: Models may be created to include labels or text related to the objects/places visited. With AR, users can rebuild ruins, buildings, or even landscapes as they previously existed.

Support with complex tasks: Complex tasks such as assembly, maintenance, and surgery can be simplified by inserting additional information into the field of view.

Prospecting: In the fields of hydrology, ecology, and geology, AR can be used to display an interactive analysis of terrain characteristics. Users could use, and collaboratively modify and analyze, interactive three-dimensional maps.

Art: AR can be incorporated into artistic applications that allow artists to create art in real time over reality such as painting, drawing, modeling, etc.

Collaboration: AR can help facilitate collaboration among distributed team members via conferences with real and virtual participants. The Hand of God is a good example of a collaboration system.

Music: Pop group Duran Duran included interactive AR projections into their stage show during their 2000 *Pop Trash* concert tour.

3.4 Augmented Reality and Ubiquitous Computing

By definition, the goal of augmented reality is to make computational devices ubiquitous in the everyday world. Although oft described as making these devices "invisible," most efforts have focused on replication and dissemination. The vision is something like "Computing devices will be everywhere. They will be smaller so that we can carry them around with us and they will be able to communicate back and forth with each other." [56] The end result is that although computational devices are more likely to be seen as ubiquitous, they are far from invisible. Our world is now cluttered with various computational things that vie for our attention. Augmented reality and ubiquitous computing is an inevitably evolving topic in computing. Many devices, which are already equipped with computers, can be found in our homes or offices.

Nevertheless people still use their washing machines and telephones not considering them as a computer. Additionally, growing communication possibilities and the advent of small computers like Personal-Digital-Assistance (PDA) let Mark Weiser's vision come true [57]. In the ubiquitous computing research we consider technology and applications, using PDAs, other mobile devices and extended "dump" machines (like TV) to set up prototypes for the demonstration of ubiquitous computing scenarios.

A common focus shared by researchers in mobile, ubiquitous and wearable computing is the attempt to break away from the traditional desktop computing paradigm. Computational services need to become as mobile as their users. Whether that service mobility is achieved by equipping the user with computational power or by instrumenting the environment, all services

need to be extended to take advantage of the constantly changing context in which they are accessed.

Attaining the goals of augmented reality and ubiquitous computing will require a highly sophisticated infrastructure. In the ideal system, a real-time tracking mechanism will derive the locations and operational status of many system components and will use that context to deliver messages more intelligently. Users will be able to choose from among a variety of devices to gain mobile, high-bandwidth access to data and computational resources anywhere on the network. These devices will be intuitive, attractive and responsive. They will automatically adapt their behavior to suit the current user and context.

The wireless communication revolution is bringing fundamental changes to telecommunication and computing. Wide-area cellular systems and wireless LANs promise to make integrated networks a reality and provide fully distributed and ubiquitous mobile computing and communications, thus bringing an end to the tyranny of geography. Furthermore, services for the mobile user are maturing and are poised to change the nature and scope of communication

Recent advances in wireless networks and computer down-sizing technologies have led to the development of the concept of mobile computing. In the near future, millions of mobile users will be equipped with small, powerful and battery-operated palmtops. Through the wireless networks, this portable equipment will become an integrated part of existing distributed computing environments, and mobile users can access to data stored at information servers located at the static portion of the network even while they are on the move. In our increasingly mobile world, the ability to access information on demand at any location can satisfy people's information needs as well as conferring on them a competitive advantage. As such, the potential market for mobile computing applications is estimated to be billions of dollars annually. For example, passengers will access airline schedules, investors will access stock activities, travelers will access weather or traffic conditions.

For wireless computing to be widely accepted, there are two obstacles to be cleared. First, for palmtops that operate on AA batteries, power conservation is a key issue. For an 'average user', the power source is expected to last 2 to 3 hours before replacing or recharging becomes necessary. What makes it worse is the predictions by battery experts of the modest improvement in battery capacity of only 20%-30% over the next 5-10 years. Second, the bandwidth of the wireless channel is also very limited. The bandwidth of a wireless channel can vary from 1.2 Kbps for slow paging channels, through 19.2 Kbps (e.g. Cellular Digital Packet Data) to about 2Mbps for the wireless LAN. Therefore, mobile computers would frequently be disconnected from the network or be kept in a weak connection status to conserve energy, and transmission be kept at a minimum to avoid channel contention. These two issues pose a great challenge to researchers in the community.

3.4.1 Handheld Devices

Handheld devices like PDAs are a key technology and build the base for many mobile computing and ubiquitous computing projects [58][59].

3.4.2 Location

Knowledge about the location of a person or device is useful for many applications in ubiquitous computing. An examples is the routing of phone calls; to provide this service a user has to be located all around a building or area (absolute location). But even relative location, where only devices and persons in the direct proximity are detected (e.g. in a room), could be useful. One example is the ad-hoc meeting, supported by PDAs, where social communication is supported by PDAs. The research in this area focuses on how to get this location information and how to present this information in the background computer system.

3.4.3 Context of use

There is more to context than location - For example, context is also the social situation the user actually was in. In this research area it is worthwhile to find out what sensor information could be useful to detect situations and how applications could profit from this information.

3.4.4 Information Access

The relation between direct and indirect information access is one of the most exciting areas of research in ubiquitous computing. Ubiquitous computing environments give a lot of possibilities to retrieve, to input and to output information, so combining only these possibilities leads to a lot of new challenges for new applications. Different information access scenarios are built to find out how information access works in ubiquitous computing scenarios.

3.4.5 Privacy

When building global communication and network infrastructures and "computerizing" the user as described in ubiquitous computing the question of privacy arises. Technologies like active badges or even GSM mobile phones enable computer systems to track any person using such technologies. These issue of privacy and security as well as individualism is underestimated by current ubiquitous computing proposals and collides with the real world. As a solution we suggest a concept that integrates a personal device (PD) into ubiquitous computing to overcome these problems.

3.4.6 Encryption

New network technologies like infrared or wireless radio communication need encryption technology to ensure security to its users. But available bandwidth of these networks is small and therefore a precious resource. The ongoing research tries to find solutions, based on available and well introduced technologies.

3.5 Mobile Use Contexts are the Challenge

"The coherence of situated action is tied in essential ways not to individual predispositions or conventional rules but to local interactions contingent on the actor's particular circumstances." Suchman

The characteristic feature of interaction with context-aware computers is that it typically takes place while being away from the desktop. Some researchers call the paradigm "technology beyond the desktop" (Bellotti & Bly, 1996). The

hypothesis advocated here is that the core of the problem of context-aware HCI has been that use contexts of the desktop based computing are radically different from the use context of context-aware computers. The concepts and theories we talk about HCI [60] have been conceptually inadequate; in other words, weak from the point of view of explanatory power. Mobile contexts differ from desktop-contexts: internal factors such as tasks, needs, and goals are different, as are external factors such as social resources and present objects and events. Indeed, when data from our mobility data (Paper II, Kankainen & Oulasvirta, 2002; Oulasvirta, 2004) were classified, shopping, evaluating people, selecting routes, ad hoc meetings, SMS messaging, relaxing, waiting, surprising and delighting others, rendezvousing, being late, safety, acquiring information, collecting memories, and gags were among the most frequent, in contrast to “desktop contexts”. Moreover, mobile contexts encompass larger geographical area for movement, involve many unidentifiable users and devices, loosely defined leisure oriented tasks, dynamic environment and objects, more interruptions and disrupting stimuli etc. Therefore, new conceptual approaches are needed for describing, explaining, and predicting human behavior in mobile contexts.

What, then, are the characteristic features of “the mobile context”, becomes the overarching question for researchers. Three closely related questions emerge from the interests of the three main stakeholders in this research enterprise:

- *Social science*: What are the relevant (for the user) contextual factors and resources in mobile use situations and user activities?
- *Psychology*: How can the context be used to support the user, without distracting the original on-going tasks and activities?
- *Computer science*: What are the context sensors that can recognize these meaningful contexts and, moreover, help discriminating among them?

To date, hardly anyone seems to have paid attention to the two first vital questions, although millions of euros have been spent every year for the

technology side of the enterprise (Thackara, 2001). A recent meta-review of empirical work in mobile HCI echoes this claim (Kjeldskov & Graham, 2003)

3.6 Mobile Augmented Reality System

The Mobile AR System can be defined as; “A mobile AR system is one in which augmentation of the data occurs through available knowledge of where the user is (the user's location and therefore the surrounding environment)”.

A prominent example that served cause us to study the role of wireless technology issues in MARS is Columbia's "Touring Machine", which is used as a mobile multimedia information system and journalistic tool [61].

3.6.1 Features of MARS: A mobile AR system combines the following features:

- Application and data sharing between a mobile and a stationary user or two mobile users
- 3D stereographic display of computer generated images. This enhances the sensation of seeing virtual objects.
- Direct manipulation and interaction with the virtual objects.
- Instant collaboration with another user wearing another mobile kit.

3.6.2 Applications of MARS: There are numerous applications of MARS, few important application areas out of them are listed bellow.

- Disaster management
- Virtual classroom
- Computer Assisted Surgery
- Situated documentary
- Battlefield
- Entertainment

3.6.3 Architecture of MARS - The Layered Approach [62] : The architecture of MARS can be depicted in many ways .There can be no restriction on which of the basic unit lies at which end. But broadly based on the functional requirement the we propose following MARS can have following layer model modules..

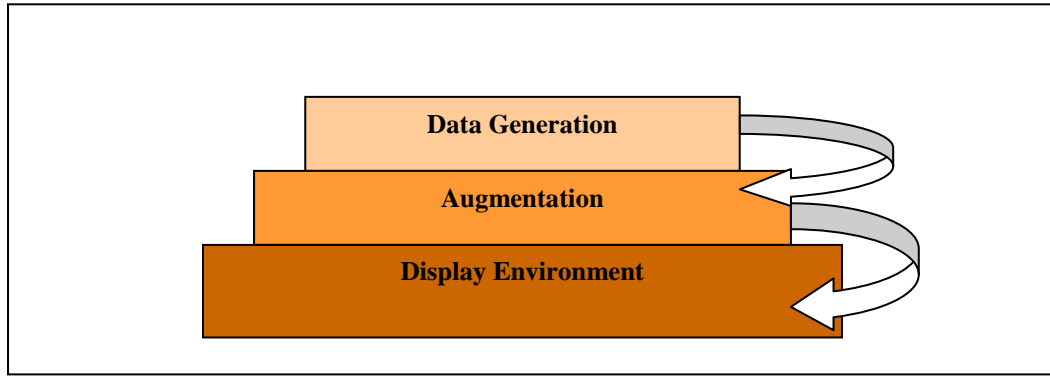


Figure 3.3 Layered Architecture of MARS

Although it is not mandatory that each MARS should have strict distinction among this layers we propose this approach since distinct layers can be studied and explores independently to enhance the capabilities of the MARS

3.6.4 Operation of MARS: In the architecture that we have proposed the data generation module tracks the position of the scene/object using various tracking devices, it also involves human operator to enter the data using sophisticated devices such as touch pad, graphic tablet gloves and sensor. Then the recorded data is temporarily stored in the buffer and forwarded to augmentation Unit. In case of the mixed Reality Systems This unit may be responsible to mix the virtual and augmented environment. The mobile computing device within the Data generation Unit then Sends the data to the augmentation unit (In case if the Augmentation Unit is not within the data generation unit itself) which after augmentation Send the data to the display unit (again if it is different from other two units). Each layer communicates with the layer down using wired Connection Or Wireless connection

Wired Connection: Generally when the two layers do not have strict distinction at that time such connections can be used. For example in case of the situated documentaries as shown in Figure 3.3 the augmentation unit may be within the Data generation unit.

Wireless Connection: But wired connection is not wise approach in the sensitive application like ones in the battlefield where the data generation unit(The soldier carrying Data Tracking Mobile devices)should be loaded with

minimum weight and even the units can be hidden easily. So in such applications there is a strict distinction in all the layers described above. So each layer communicates with each other via GPRS ,UMTS, WLAN ,Wi-Fi , Wimax and WiBro wireless technology

3.7 Wireless technology in MARS

Generally in the MARS system of today uses both above said approach but the ultimate goal of the MARS system are

- 1) Maximum Mobility
- 2) Optimum Augmentation
- 3) Better Display
- 4) Real time environment

Unfortunately some of these goals are contradictory. For example we are having now computers that can process in GHZ but there are not so mobile .We are having mobile and wireless devices that can operated from all most any place in the world but their computing power is limited. More over the requirement to use bulky tracking device such as 3D camera, Gloves, graphic tablet etc also imposes restriction on the mobility.

In addition to that in case of the MARS which has cleared distinction in layers we need to send the augmented data to the display system the can immerse the user in real like environment. Again such a systems are available up to somewhat extent (Walk through Displays).But their size again becomes the limiting factor in mobility A solution to that may be devices like HMD .But we need to have the devices that enable us to communicate data in two ways that means the a single unit should play a role of DATA generation and display ensuring the mobility as well This gives rise to following model.

Answer to all this questions may be the mobiles of next generation that have such capabilities. Now let's see whether the mobile generations are capable of fulfilling our requirements or not.

We are now living in the 2.5 generation of the Mobile and using GPRS,GSM Technology .The UTMS 3G mobiles will change the scenario. The following

graph [63] shows how the rapid change in the wireless transmission technology are going to take place.

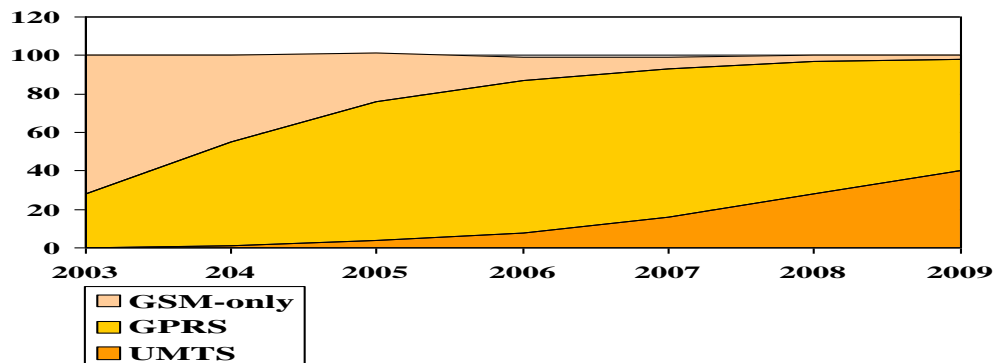


Figure3.4 : Rapid change in wireless communication

The UMTS Third Generation Cellular Networks will cover following objectives.

- The ability to speak to another user, face-to-face, by videophone
- Impressive high data rates for data transmission
- Simultaneous communication by voice and packet transmission
- The capacity to download and e-mail multimedia content
- Videoconferencing for up to eight participants
- Secure purchasing thanks to high levels of confidentiality and authentication
- I-mode mobile internet service
- Following graphs shows the How the data rates are likely to change with the upcoming generations.

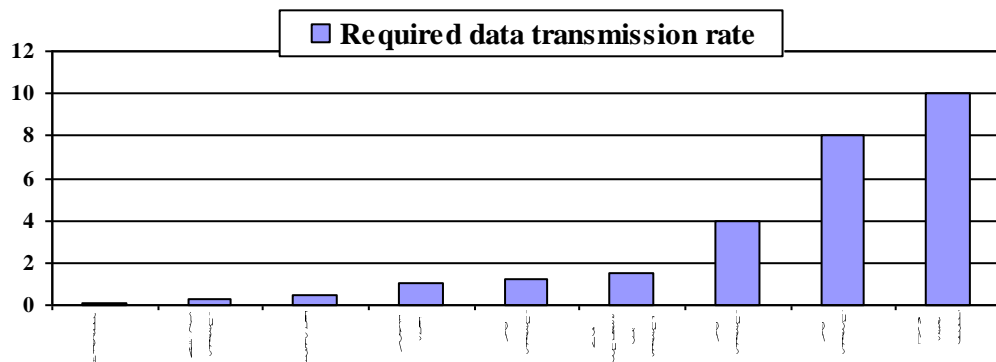


Figure 3.5 Various Data Rates for Different Applications

GSM networks (including DCS1800 and PCS1900) are operational in 110 countries around the world. In the beginning of 1994, there were 1.3 million subscribers worldwide, which had grown to more than 55 million by October 1997. With North America making a delayed entry into the GSM field with a derivative of GSM called PCS1900, GSM systems exist on every continent, and the acronym GSM now aptly stands for Global System for Mobile communications.

The developers of GSM choose an unproven (at the time) digital system, as opposed to the then-standard analog cellular systems like AMPS in the United States and TACS in the United Kingdom. They had faith that advancements in compression algorithms and digital signal processors would allow the fulfillment of the original criteria and the continual improvement of the system in terms of quality and cost. Over 8000 pages of GSM recommendations tried to allow flexibility and competitive innovation among suppliers, but provide enough standardization that guarantee proper interworking between the components of the system. This was done by providing functional and interface descriptions for each of the functional entities defined in the system.

2.1.2 GSM Specifications [2] [3]

Specification Summary for GSM Cellular System

Multiple access technology	FDMA / TDMA
Duplex technique	FDD
Uplink frequency band	933 -960 MHz (basic 900 MHz band only)
Downlink frequency band	890 - 915 MHz (basic 900 MHz band only)
Channel spacing	200 kHz
Modulation	GMSK
Speech coding	Various - original was RPE-LTP/13
Speech channels per RF channel	8
Channel data rate	270.833 kbps
Frame duration	4.615 ms

2.1.3 GSM Subscriber Services [4]

There are two basic types of services offered through GSM: telephony (also referred to as teleservices) and data (also referred to as bearer services). Telephony services are mainly voice services that provide subscribers with the complete capability (including necessary terminal equipment) to communicate with other subscribers. Data services provide the capacity necessary to transmit appropriate data signals between two access points creating an interface to the network. In addition to normal telephony and emergency calling, the following subscriber services are supported by GSM:

Dual-tone Multi-Frequency	Cell broadcast
Facsimile group III	Voice mail
Short message services	Fax mail

Supplementary Services

GSM supports a comprehensive set of supplementary services that can complement and support both telephony and data services. Supplementary services are defined by GSM and are characterized as revenue-generating features. A partial listing of supplementary services are as follows.

- Call forwarding
- Barring of outgoing calls
- Barring of incoming calls
- Advice of charge (AoC)
- Call hold
- Call waiting
- Multiparty service
- Calling line identification presentation/restriction
- Closed user groups (CUGs)

2.1.4 GSM Network Architecture [5]

The GSM technical specifications define the different elements within the GSM network architecture. It defines the different elements and the ways in which they interact to enable the overall network operation to be maintained. The GSM network architecture is now well established and with the other later cellular systems now established and other new ones being deployed, the basic GSM network architecture has been updated to interface to the network elements required by these systems. Despite the developments of the newer systems, the basic GSM network architecture has been maintained, and the elements described below perform the same functions as they did when the original GSM system was launched in the early 1990s.

GSM network architecture elements

The GSM network architecture as defined in the GSM specifications can be grouped into four main areas:

- Mobile station (MS)
- Base-station subsystem (BSS)
- Network and Switching Subsystem (NSS)
- Operation and Support Subsystem (OSS)

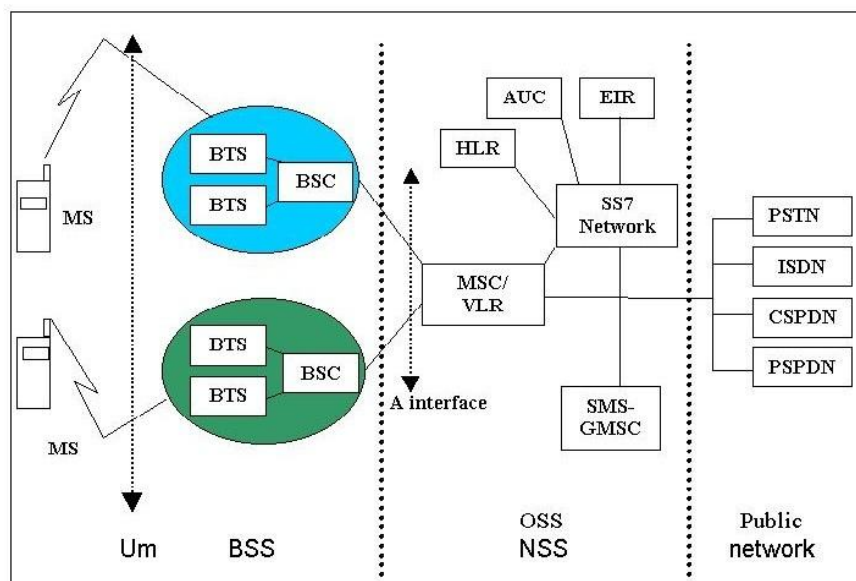


Figure 2.1: GSM network architecture

Mobile station

Mobile stations (MS), mobile equipment (ME) or as they are most widely known, cell or mobile phones are the section of a GSM cellular network that the user sees and operates. In recent years their size has fallen dramatically while the level of functionality has greatly increased. A further advantage is that the charges between the time limits reduced.

Base Station Subsystem (BSS)

The Base Station Subsystem (BSS) section of the GSM network architecture that is fundamentally associated with communicating with the mobiles on the network. It consists of two elements:

- **Base Transceiver Station (BTS):** The BTS used in a GSM network comprises of the radio transmitter receivers, and their associated antennas that transmit and receive to directly communicate with the mobiles.
- **Base Station Controller (BSC):** It controls a group of BTSs, and is often co-located with one of the BTSs in its group. It manages the radio resources and controls items such as handover within the group of BTSs, allocates channels and the like, It communicates with the BTSs over what is termed the Abis interface.

Network Switching Subsystem (NSS)

The GSM network subsystem contains a variety of different elements, and is often termed as the core network. It provides the main control and interfacing for the whole mobile network. The major elements within the core network include:

- **Mobile Switching services Centre (MSC):** The main element within the core network area of the overall GSM network architecture is the Mobile switching Services Centre (MSC). Functions include registration, authentication, call location, inter-MSC handovers and call routing to a mobile subscriber.
- **Home Location Register (HLR):** This database contains all the administrative information about each subscriber along with their last

known location. In this way, the GSM network is able to route calls to the relevant base station for the MS.

- **Visitor Location Register (VLR):** This contains selected information from the HLR that enables the selected services for the individual subscriber to be provided.
- **Equipment Identity Register (EIR):** The EIR is the entity that decides whether given mobile equipment may be allowed onto the network. Dependent upon the information held in the EIR, the mobile may be allocated one of three states - allowed onto the network, barred access, or monitored in case of problems.
- **Authentication Centre (AuC):** The AuC is a protected database that contains the secret key also contained in the user's SIM card. It is used for authentication and for ciphering on the radio channel.
- **Gateway Mobile Switching Centre (GMSC):** The GMSC is the point to which a ME terminating call is initially routed, without any knowledge of the MS's location. The GMSC is thus in charge of obtaining the MSRN (Mobile Station Roaming Number) from the HLR based on the MSISDN (Mobile Station ISDN number, the "directory number" of a MS) and routing the call to the correct visited MSC.
- **SMS Gateway (SMS-G):** The two gateways handle messages directed in different directions. The SMS-GMSC (Short Message Service Gateway Mobile Switching Centre) is for short messages being sent to an ME. The SMS-IW MSC (Short Message Service Inter-Working Mobile Switching Centre) is used for short messages originated with a mobile on that network.

Operation and Support Subsystem (OSS)

It is used to control and monitor the overall GSM network and it is also used to control the traffic load of the BSS.

2.1.5 GSM Network Interfaces [2]

The network structure is defined within the GSM standards. Additionally each interface between the different elements of the GSM network is also defined. It enables to a large degree that network elements from different manufacturers can be used.

1. **Um interface** The "air" or radio interface standard that is used for exchanges between a mobile (ME) and a base station (BTS / BSC). For signaling, a modified version of the ISDN LAPD, known as LAPDm is used.
2. **Abis interface** This is a BSS internal interface linking the BSC and a BTS. The Abis interface allows control of the radio equipment and radio frequency allocation in the BTS.
3. **A interface** The A interface is used to provide communication between the BSS and the MSC. The interface carries information to enable the channels, timeslots and the like to be allocated to the mobile equipments being serviced by the BSSs. The messaging required within the network to enable handover etc to be undertaken is carried over the interface.
4. **B interface** The B interface exists between the MSC and the VLR. It uses a protocol known as the MAP/B protocol. The interface is used whenever the MSC needs access to data regarding a MS located in its area.
5. **C interface** The C interface is located between the HLR and a GMSC or a SMS-G. When a call originates from outside the network it has to pass through the gateway so that routing information required to complete the call may be gained. The protocol used for communication is MAP/C.
6. **D interface** The D interface is situated between the VLR and HLR. It uses the MAP/D protocol to exchange the data related to the location of the ME and for the management of the subscriber.
7. **E interface** The E interface provides communication between two MSCs. The E interface exchanges data related to handover between the anchor and relay MSCs using the MAP/E protocol.
8. **F interface** The F interface is used between an MSC and EIR. It uses the MAP/F protocol. The communications along this interface are used to confirm the status of IMEI of the ME about gaining access to the network.
9. **G interface** The G interface interconnects two VLRs of different MSCs and uses the MAP/G protocol to transfer subscriber information, during e.g. a location update procedure.

10.H interface The H interface exists between the MSC and the SMS-G. It transfers short messages and uses the MAP/H protocol.

11.I interface: This interface can be found between the MSC and the ME. Messages exchanged over I interface are relayed transparently through the BSS.

Although the interfaces for the GSM cellular system may not be as rigorously defined as many might like, but they at least provide a large element of the definition required, enabling the functionality of GSM network entities to be defined sufficiently

2.1.6 GSM Radio Air Interface, GSM Slot and Burst

One of the key elements of the development of the GSM was the development of the GSM air interface. There were many requirements that were placed on the system, and many of these had a direct impact on the air interface. Elements including the modulation, GSM slot structure, burst structure and the like were all devised to provide the optimum performance.

GSM signal and GMSK modulation characteristics

The core of any radio based system is the format of the radio signal itself. The carrier is modulated using a form of phase shift keying known as Gaussian Minimum Shift Keying (GMSK). GMSK was used for the GSM system for a variety of reasons:

- It is resistant to noise when compared to many other forms of modulation.
- Radiation outside the accepted bandwidth is lower than other forms of phase shift keying.
- It has a constant power level which allows higher efficiency RF power amplifiers to be used in the handset, thereby reducing current consumption and conserving battery life.

GMSK has advantages in terms of spectral efficiency as well as having almost constant amplitude which allows the use of more efficient transmitter power amplifiers, thereby saving on current consumption. The nominal bandwidth for the GSM signal using GMSK is 200 kHz. The unwanted or spurious emissions

outside the nominal bandwidth are sufficiently low to enable adjacent channels to be used from the same base station.

The basic carrier is able to support the data throughput of approximately 270 kbps, but as some of this supports the management overhead, the data rate allotted to each time slot out of eight is only 24.8 kbps. In addition to this error correction is required to overcome the problems of interference, fading and general data errors that may occur. This means that the available data rate for transporting the digitally encoded speech is 13 kbps for the basic vocoders

GSM slot structure and multiple access scheme

GSM uses a combination of both TDMA and FDMA techniques. The FDMA element involves the division by frequency of the (maximum) 25 MHz bandwidth into 124 carrier frequencies spaced 200 kHz apart as already described.

The carriers are then divided in time, using a TDMA scheme. This enables the different users of the single radio frequency channel to be allocated different times slots. They are then able to use the same RF channel without mutual interference. The slot is then the time that is allocated to the particular user, and the GSM burst is the transmission that is made in this time.

Each GSM slot, and hence each GSM burst lasts for 0.577 mS ($15/26$ mS). Eight of these burst periods are grouped into what is known as a TDMA frame. This lasts for approximately 4.615 ms (i.e. $120/26$ ms) and it forms the basic unit for the definition of logical channels. One physical channel has one burst period allocated in each TDMA frame.

There are different types of frame that are carry different data, and also the frames are organized into what are termed multiframes and superframes to provide overall synchronization.

GSM slot structure

This GSM slot is the smallest individual time period that is available to each mobile. It has a defined format because a variety of different types of data are required to be transmitted.

Although there are shortened transmission bursts, the slot is normally used for transmitting 148 bits of information. This data can be used for carrying voice data, control and synchronization data.

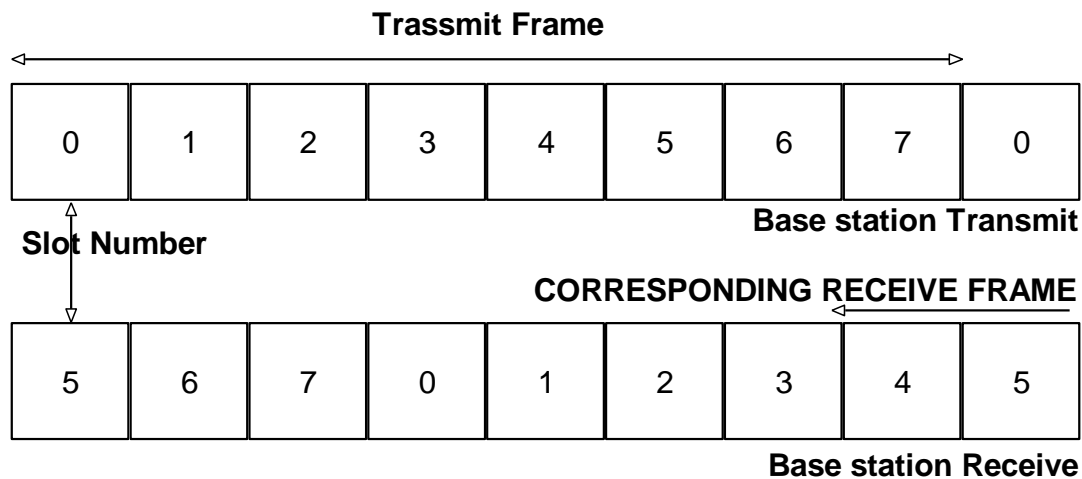


Figure 2.2: GSM Slot offset between transmit and receive frame

It can be seen from the GSM slot structure that the timing of the slots in the uplink and the downlink are not simultaneous, and there is a time offset between transmit and receive. This offset in the GSM slot timing is deliberate and it means that a mobile that which is allocated the same slot in both directions does not transmit and receive at the same time. This considerably reduces the need for expensive filters to isolate the transmitter from the receiver. It also provides a space saving

GSM burst

The GSM burst, or transmission can fulfill a variety of functions. Some GSM bursts are used for carrying data while others are used for control information.

Normal burst *uplink and downlink*

- Synchronization burst *downlink*
- Frequency correction burst *downlink*
- Random Access (Shortened Burst) *uplink*

GSM normal burst

This GSM burst is used for the standard communications between the base station and the mobile, and typically transfers the digitized voice data. The structure of the normal GSM burst is exactly defined and follows a common format. It contains data that provides a number of different functions

T 3	Info 57	F 1	Training 26	F 1	Info 57	T 3	GP 8.25
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Figure 2.3: GSM Normal Burst

GSM synchronization burst

The purpose of this form of GSM burst is to provide synchronization for the mobiles on the network.

T 3	Info 39	Long Training sequence 64	Info 39	T 1	GP 8.25
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Figure 2.4: GSM Synchronization Burst

GSM frequency correction burst

With the information in the burst all set to zeros, the burst essentially consists of a constant frequency carrier with no phase alteration.

T 3	All bits in Frequency correction burst 142	T 3	GP 8.25
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Figure 2.5: GSM Frequency correction Burst

GSM random access burst

This form of GSM burst used when accessing the network and it is shortened in terms of the data carried, having a much longer guard period. This GSM burst structure is used to ensure that it fits in the time slot regardless of any severe timing problems that may exist. Once the mobile has accessed the network and timing has been aligned, then there is no requirement for the long guard period.

T 7	Train 41	Data 36	T 3	GP 69.25
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Figure 2.6: GSM Random Access Burst

GSM discontinuous transmission (DTx)

A further power saving and interference reducing facility is the discontinuous transmission (DTx) capability that is incorporated within the specification. It is particularly useful because there are long pauses in speech. The most

important element of DTx is the Voice Activity Detector. It must correctly distinguish between voice and noise inputs, a task that is not trivial. If a voice signal is misinterpreted as noise, the transmitter is turned off an effect known as clipping results and this is particularly annoying to the person listening to the speech. However if noise is misinterpreted as a voice signal too often, the efficiency of DTX is dramatically decreased. The noise is controlled by the SID (silence indication descriptor).

2.1.7 GSM Frame Structure [2], [6]

The GSM system has a defined GSM frame structure to enable the orderly passage of information. The GSM frame structure establishes schedules for the predetermined use of timeslots.

By establishing these schedules and by the use of a frame structure, both the mobile and the base station are able to communicate not only over the voice data, but also signaling information without the various types of data becoming intermixed and both ends of the transmission knowing exactly what types of information are being transmitted.

The GSM frame structure provides the basis for the various physical channels used within GSM, and accordingly it is at the heart of the overall system

Basic GSM frame structure

The basic element in the GSM frame structure is the frame itself. This comprises the eight slots, each used for different users within the TDMA system. As mentioned in another page of the tutorial, the slots for transmission and reception for a given mobile are offset in time so that the mobile does not transmit and receive at the same time.

The basic GSM frame defines the structure upon which all the timing and structure of the GSM messaging and signaling is based. The fundamental unit of time is called a burst period and it lasts for approximately 0.577 ms (15/26 ms).

In simplified terms the base station transmits in two types of channel, namely traffic and control. Accordingly the channel structure is organized into two different types of frame, one for the traffic on the main traffic carrier frequency, and the other for the control on the beacon frequency.

GSM Multiframe

The GSM frames are grouped together to form multiframes and in this way it is possible to establish a time schedule for their operation and the network can be synchronized. There are several GSM multiframe structures:

- **Traffic multiframe:** The Traffic Channel frames are organized into multiframes consisting of 26 bursts and taking 120 ms. in a traffic multiframe, 24 bursts are used for traffic. These are numbered 0 to 11 and 13 to 24. One of the remaining bursts is then used to accommodate the SACCH, the remaining frame remaining free. The actual position used alternates between position 12 and 25.
- **Control multiframe:** the Control Channel multiframe that comprises 51 bursts and occupies 235.4 msec. This always occurs on the beacon frequency in time slot zero and it may also occur within slots 2, 4 and 6 of the beacon frequency as well. This multiframe is subdivided into logical channels which are time-scheduled. These logical channels and functions include the following:
 - Frequency correction burst
 - Synchronization burst
 - Broadcast channel (BCH)
 - Paging and Access Grant Channel (PACCH)
 - Stand Alone Dedicated Control Channel (SDCCH)

GSM Superframe

Multiframes are then constructed into superframes taking 6.12 seconds. These consist of 51 traffic multiframes or 26 control multiframes. As the traffic multiframes are 26 bursts long and the control multiframes are 51 bursts long, the different number of traffic and control multiframes within the super frame, brings them back into line again taking exactly the same interval.

GSM Hyperframe

Above this 2048 superframes (i.e. 2 to the power 11) are grouped to form one hyperframe which repeats every 3 hours 28 minutes 53.76 seconds. It is the largest time interval within the GSM frame structure.

Within the GSM hyperframe there is a counter and every time slot has a unique sequential number comprising the frame number and time slot number. This is used to maintain synchronization of the different scheduled operations with the GSM frame structure. These include functions such as:

- **Frequency hopping:** Frequency hopping is a feature that is optional within the GSM system. It can help reduce interference and fading issues, but for it to work, the transmitter and receiver must be synchronized so they hop to the same frequencies at the same time.
- **Encryption:** The encryption process is synchronized over the GSM hyperframe period where a counter is used and the encryption process will repeat with each hyperframe. However, it is unlikely that the cell phone conversation will be over 3 hours and accordingly it is unlikely that security will be compromised as a result.

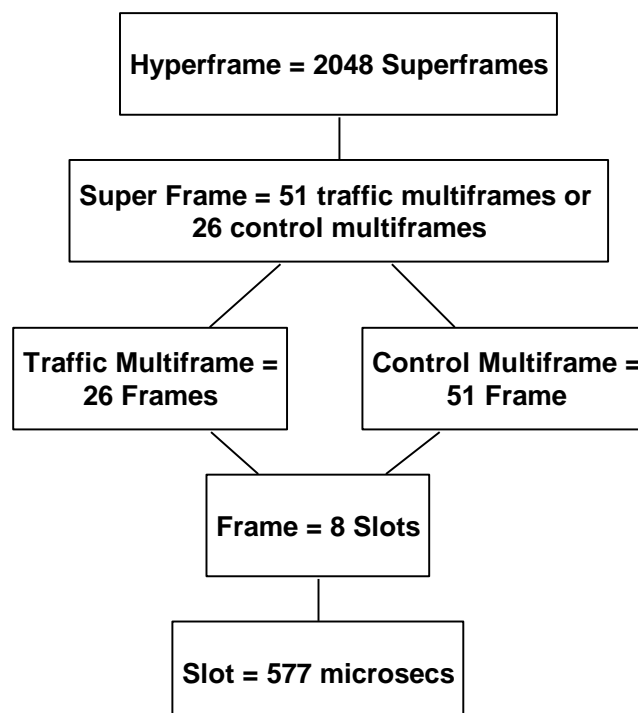


Figure 2.7: GSM Frame Structure Summary

GSM frame structure

By structuring the GSM signaling into frames, multiframes, superframes and hyperframes, the timing and organization is set into an orderly format that enables both the GSM mobile and base station to communicate in a reliable and efficient manner. The GSM frame structure forms the basis onto which the other forms of frame and hence the various GSM channels are built.

2.1.8 GSM Frequencies and Frequency Bands [7]

Although it is possible for the GSM cellular system to work on a variety of frequencies, the GSM standard defines GSM frequency bands and frequencies for the different spectrum allocations that are in use around the globe. For most applications the GSM frequency allocations fall into three or four bands, and therefore it is possible for phones to be used for global roaming.

While the majority of GSM activity falls into just a few bands, for some specialist applications, or in countries where spectrum allocation requirements mean that the standard bands cannot be used, different allocations may be required. Accordingly for most global roaming dual band, tri-band or quad-band phones will operate in most countries, although in some instances phones using other frequencies may be required.

GSM frequency band usage

The usage of the different frequency bands varies around the globe although there is a large degree of standardization. The GSM frequencies available depend upon the regulatory requirements for the particular country and the ITU (International Telecommunications Union) region in which the country is located.

As a rough guide Europe tends to use the GSM 900 and 1800 bands as standard. These bands are also generally used in the Middle East, Africa, Asia and Oceania.

For North America the USA uses both 850 and 1900 MHz bands, the actual band used is determined by the regulatory authorities and is dependent upon

the area. For Canada the 1900 MHz band is the primary one used, particularly for urban areas with 850 MHz used as a backup in rural areas. For Central and South America, the GSM 850 and 1900 MHz frequency bands are the most widely used although there are some areas where other frequencies are used.

GSM band allocations

There are total of fourteen different recognized GSM frequency bands. These are defined in 3GPP TS 45.005.

Table 2.1: GSM frequency bands

Band	Uplink (MHz)	Downlink (MHz)	Comments
380	380.2 - 389.8	390.2 - 399.8	
410	410.2 - 419.8	420.2 - 429.8	
450	450.4 - 457.6	460.4 - 467.6	
480	478.8 - 486.0	488.8 - 496.0	
710	698.0 - 716.0	728.0 - 746.0	
750	747.0 - 762.0	777.0 - 792.0	
810	806.0 - 821.0	851.0 - 866.0	
850	824.0 - 849.0	869.0 - 894.0	
900	890.0 - 915.0	935.0 - 960.0	P-GSM, i.e. Primary or standard GSM allocation
900	880.0 - 915.0	925.0 - 960.0	E-GSM, i.e. Extended GSM allocation
900	876.0 - 915	921.0 - 960.0	R-GSM, i.e. Railway GSM allocation
900	870.4 - 876.0	915.4 - 921.0	T-GSM
1800	1710 – 1785	1805 - 1880	
1900	1850 - 1910	1930 - 1990	

2.1.9 GSM logical and physical channels

GSM uses a variety of channels in which the data is carried. In GSM, these channels are separated into physical channels and logical channels. The Physical channels are determined by the timeslot, whereas the logical channels are determined by the information carried within the physical channel. It can be further optimized by saying that several recurring timeslots on a carrier constitute a physical channel. These are then used by different logical channels to transfer information. These channels may either be used for user data (payload) or for optimizing to enable the system to operate correctly.

Common and dedicated channels

The channels may also be divided into common and dedicated channels. The forward common channels are used for paging to inform a mobile of an incoming call, responding to channel requests, and broadcasting bulletin board information. The return common channel is a random access channel used by the mobile to request channel resources before timing information is conveyed by the BSS.

The dedicated channels are main of two types: those used for optimizing and those used for traffic. The optimizing channels are used for maintenance of the call and for enabling call set up, providing facilities such as handover when the call is in progress, and finally terminating the call. The traffic channels handle the actual payload.

TCHf	Full rate traffic channel.
TCH h	Half rate traffic channel.
BCCH	Broadcast Network information, e.g. for describing the current control channel structure. The BCCH is a point-to-multipoint channel (BSS-to-MS).
SCH	Synchronization of the MSs.
FCHMS	Frequency correction.
AGCH	Acknowledge channel requests from MS and allocate a SDCCH.
PCHMS	Terminating call announcement.

RACHMS	access requests, response to call announcement, location update
FACCHt	For time critical optimizing over the TCH (e.g. for handover optimizing). Traffic burst is stolen for a full optimizing burst.
SACCHt	TCH in-band optimizing, e.g. for link monitoring.
SDCCH	For optimizing exchanges, e.g. during call setup, registration / location updates.
FACCHs	FACCH for the SDCCH. The SDCCH burst is stolen for a full optimizing burst. Function not clear in the present version of GSM (could be used for e.g. handover of an eight-rate channel, i.e. using a “SDCCH-like” channel for other purposes than optimizing).
SACCHs	SDCCH in-band optimizing, e.g. for link monitoring.

2.1.10 GSM handover or handoff [2], [8]

One of the key elements of a mobile phone or cellular telecommunications system is that the system is split into many small cells to provide good frequency re-use and coverage. However as the mobile moves out of one cell to another it must be possible to retain the connection. The process by which this occurs is known as handover or handoff. The term handover is more widely used within Europe, whereas handoff tends to be use more in North America. Either way, handover and handoff are the same process.

Requirements for GSM handover

The process of handover or handoff within any cellular system is of great importance. It is a critical process and if performed incorrectly handover can result in the loss of the call. Dropped calls are particularly annoying to users and if the number of dropped calls rises, customer dissatisfaction increases and they are likely to change to another network. Accordingly GSM handover was an area to which particular attention was paid when developing the standard.

Types of GSM handover

Within the GSM system there are four types of handover that can be performed for GSM only systems:

- **Intra-BTS handover:** This form of GSM handover occurs if it is required to change the frequency or slot being used by a mobile

because of interference, or other reasons. In this form of GSM handover, the mobile remains attached to the same base station transceiver, but change the channel or slot.

- **Inter-BTS Intra BSC handover:** This form of GSM handover or GSM handoff occurs when the mobile moves out of the coverage area of one BTS but into another controlled by the same BSC. In this instance the BSC is able to perform the handover and it assigns a new channel and slot to the mobile, before releasing the old BTS from communicating with the mobile.
- **Inter-BSC handover:** When the mobile moves out of the range of cells controlled by one BSC, a more involved form of handover has to be performed, handing over not only from one BTS to another but one BSC to another. For this the handover is controlled by the MSC.
- **Inter-MSC handover:** This form of handover occurs when there is changing between networks. The two MSCs involved negotiate to control the handover.

2.2 General Packet Radio Service Technology

2.2.1 Introduction

The General Packet Radio Service (GPRS) is a new service that provides actual packet radio access for Global System for Mobile Communications (GSM) and Time-Division Multiple Access (TDMA) users. It provides transmission of IP packets over existing cellular networks, bringing the Internet to the mobile phone [8]. Anything the Internet offers, from web browsing to chat and email, will be available from GSM and TDMA service providers via GPRS-enabled devices. [9]

The main benefits of GPRS are : It reserves radio resources only when there is data to send and it reduces reliance on traditional circuit-switched network elements. The increased functionality of GPRS will decrease the incremental cost to provide data services, an occurrence that will, in turn, increase the penetration of data services among consumer and business users. In addition, GPRS will allow improved quality of data services as measured in terms of reliability, response time, and features supported. The unique

applications that will be developed with GPRS will appeal to a broad base of mobile subscribers and allow operators to differentiate their services.

GPRS is a non-voice, value added, packet-switched, mobile communication system. GPRS is implemented over the existing GSM network. So it shares GSM frequency bands and makes use of many properties of physical layer of the original GSM system, most importantly time-division multiple access frame structure, modulation techniques, and structure of GSM time slots.

From a high level, GPRS can be thought of as an overlay network onto a second-generation GSM network. This data overlay network provides packet data transport at rates from 9.6 to 171 kbps [9] [10]. Additionally, multiple users can share the same air-interface resources. GPRS offers the flexibility and throughput of packet switching. At the same time, because it is designed to work on the existing GSM network, it is relatively easy and cost-effective to implement. It uses the same GSM radio frequencies and base stations that are already in place.

2.2.2 Data communication needs

Before examining GPRS technology in detail, let's review some basic terms of data communications. Data communication applications [11] generally are divided into two categories:

- Real time applications involve small data transactions such as sending or receiving a quick e-mail, performing a financial transaction, getting a sports or news update from the web, or chatting on line.
- Data access applications are bulkier and involve sending or receiving large amounts of data. Examples are downloading web pages and files from the Internet or transferring large files to other users. Two techniques are available for moving data across communication networks:

Circuit switching is a mode in which a connection (or circuit) is established from the point of origin of a data transfer to the destination. Network resources are dedicated for the duration of the call until the user breaks the connection. Using these resources, data can be transmitted or received either continuously or in bursts, depending on the application. Since resources

remain dedicated for the entire duration of a data call, the number of subscribers that the network can support is limited.

Packet switching is a mode in which resources are assigned to a user only when data needs to be sent or received. Data is sent in packets, which are routed across the network along with other user traffic. This technique allows multiple users to share the same resources, thus increasing capacity on the network and managing resources quite effectively. However, the technique does place some limitations on data throughput.

Experience has shown that most data communication applications do not require continuous data transfer. Users may need to be connected to a data communication network (such as a LAN, WAN, the Internet, or a corporate Intranet), but that does not mean they are sending and receiving data at all times. Furthermore, data transfer needs generally are not symmetrical. In most cases users send out small messages but receive large downloads. At any given time, most of the data transfer is in one direction.

General packet radio service (GPRS) [11][12] gives GSM subscribers access to data communication applications such as e-mail, corporate networks, and the Internet using their mobile phones. The GPRS service uses the existing GSM network and adds new packet-switching network equipment. See Figure 3.4. Existing GSM networks use circuit-switched technology to transfer information (voice or data) between users. However, GPRS uses packet switching, which means there is no dedicated circuit assigned to the GPRS mobile phone.

A physical channel is established dynamically, only when data is being transferred. Once the data has been sent, the resource (a timeslot on the air interface) can be re-allocated to other users for more efficient use of the network.

Today's mobile phones will not work with GPRS technology, and so the industry is working on a new generation of mobiles that can handle both GSM and packet-switched communication. In the future, GPRS phones may be integrated into devices such as laptop computers or personal digital

assistants. GPRS also has the ability to support short message service (SMS).

To support high data rates, GPRS employs new air interface error coding schemes and multiple timeslots, in a way similar to HSCSD (high-speed circuit-switched data). Theoretically we can get a maximum data rate of 171.2 kbps by using eight timeslots. However, today this seems unlikely due to challenges of designing the mobile phones and to inadequate air interface quality. Because packet-switched communication allows non continuous assignment of resources to a user, GPRS billing will not be based on connection time, but rather on resource usage [12] [13].

2.2.3 GPRS Specifications

- ▶ Modulation : GMSK
- ▶ Symbol Rate : 270ksym/s
- ▶ Radio data rate per time slot : 228kb/s
- ▶ User data rate per time slot : 228kb/s
- ▶ User data rate per time slot : 20kb/s(CS4)
- ▶ User data rate(8 time slots) : 160kb/s

2.2.4 GPRS network architecture [13], [14]

GPRS technology brings many changes to the existing GSM network. Most of the changes are amendments made by adding new blocks rather than by modifying existing resources. A simplified view of this new hybrid network shows the elements introduced by GPRS.

The gateway GPRS support node (GGSN) is similar to the GSM gateway mobile switching center (GMSC) and provides a gateway between the GPRS network and the public packet data network (PDN) or other GPRS networks. The GGSN provides authentication and location management functions, connects to the home location register (HLR) by means of the Gc interface, and counts the number of packets transmitted for accurate subscriber billing.

The serving GPRS support node (SGSN), like the GSM mobile switching center and visitor location register (MSC/VLR), controls the connection between the network and the mobile station (MS). The SGSN provides

session management and GPRS mobility management functions such as handovers and paging. Functions of the packet control unit (PCU) include converting packet data into a format that can be transferred over the air interface, managing radio resources, and implementing quality of service (QoS) measurements.

PCU	Packet control unit
SGSN:	Serving GPRS support node
CGSN:	Gateway GPRS support node
Gs, Gr, Gc:	SS7 signaling protocol
Gb, Gn:	GPRS data and signaling interfaces

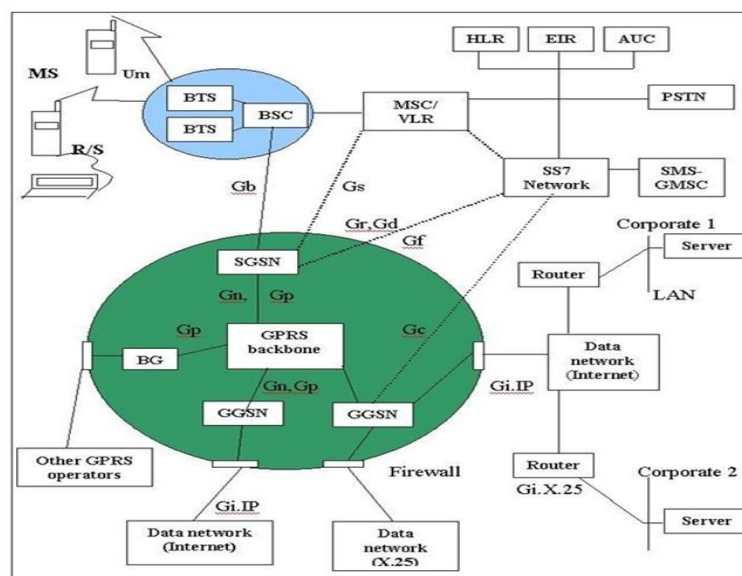


Figure 2.8: GPRS Network Architecture

The signaling links between the GPRS nodes and the GSM blocks will be SS7 MAP interfaces. The signaling between GPRS nodes is defined by the GPRS specifications. New physical interfaces include the Gb interface, which connects the SGSN to the PCU and is usually located in the base station subsystem (BSS); the Gn interface, which connects the GGSN and SGSN; and the Gc, Gr, and Gs interfaces, which carry SS7-based protocols.

2.2.5 GPRS mobile phone operation states

Mobile phones go through different states of communication. For example, when a GSM phone camps onto a network, the phone enters an idle state in which it uses very few network resources. When the user makes a call request or receives a call, however, the phone goes into the dedicated state in which it is assigned a continuous resource until the connection is terminated.

The GPRS mobile phones will also have defined states, which are described below.

- GPRS idle is the state in which the mobile phone camps onto the GSM network. The phone receives circuit-switched paging and behaves as a GSM phone. Although it does not interact with the GPRS network in this state, it still possesses GPRS functionality.
- *GPRS ready is the state achieved when the GPRS mobile attached itself to the network. In this state the mobile phone can activate a packet data protocol (PDP) context, which allows the phone to establish a packet transfer session with external data networks to transmit and receive data packets. Once a PDP context is activated, resource blocks are assigned to the session until data transfer ceases for a specified period and the mobile phone moves into the standby state.
- GPRS standby is a state in which the mobile is connected to the GPRS network, but no data transmission occurs. If a data packet for the mobile arrives, the network will page the mobile, which in turn activates a PDP context session to bring the mobile back to the ready state.

2.2.6 GPRS/GSM mobile classes

ETSI defines three different classes of mobiles for the hybrid GPRS / GSM network:

Class A (GSM/GPRS)

Class A mobiles can attach to the GPRS and GSM network simultaneously. They can receive GSM voice/data/SMS calls and GPRS data calls. For this to happen, the mobiles must monitor both the GSM and GPRS networks for incoming calls. Class A mobiles also can make and

receive GPRS and GSM calls simultaneously. Operational requirements of this class include an additional receiver in the mobile phone for Neighbour cell measurements.

Class B (GSM/GPRS)

This class is similar to class A with the exception that Class B mobile phones will not support simultaneous traffic. If a GPRS call is ON, the phone cannot receive GSM calls and vice versa.

Class C (GSM or GPRS)

This class of mobile phones will have both GSM and GPRS functionality but will attach to only one network at a time. Thus, if the phone is attached to the GPRS network, it will be detached from the GSM network and will not be able to make or receive GSM calls. Conversely, if it is attached to the GSM network, it will not be able to make or receive GPRS calls. Today most manufacturers are building Class B phones.

A GPRS attach is a GPRS mobility management (GMM) process that is always initiated by the mobile phone. Depending on the settings of the mobile phone, the GPRS attach may be performed every time the phone is powered on, or it may be initiated manually by the user.

The request for a GPRS attach is made to the SGSN in a process that is transparent to the BSS. First the mobile notifies the SGSN of its identity as an IMSI (international mobile subscriber identity) or P-TMSI (packet temporary mobile subscriber identity). Then it sends its old routing area identification (RAI), class mark, CKSN, and desired attach type. The latter indicates to the SGSN whether the mobile wants to attach as a GPRS device, a GSM device, or both. The SGSN will attach the mobile and inform the HLR if there has been a change in the RAI. If the desired attach type is both GPRS and GSM, the SGSN will also update the location with the VLR, provided that the Gs interface exists.

Note that a GPRS attach does not enable the mobile phone to transmit and receive data. For this to occur, the mobile has to activate a communication session using PDP context.

2.2.7 Features, Applications & Challenges

Features

- **Speed:** Theoretical maximum speeds of up to 171.2 kilobits per second (kbps) are achievable with GPRS using all eight timeslots at the same time.
- **Immediacy:** GPRS facilitates instant connections whereby information can be sent or received immediately as the need arises, subject to radio coverage.
- **New and better applications:** GPRS facilitates several new applications that have not previously been available over GSM networks due to the limitations in speed of Circuit Switched Data (9.6 kbps) and message length of the Short Message Service (160 characters).

Applications [15]

- **Chat:** Chat can be distinguished from general information services because the source of the information is a person with chat whereas it tends to be from an Internet site for information services.
- **Textual and visual Information:** A wide range of content can be delivered to mobile phone users ranging from share prices, sports scores, weather, flight information, news headlines, prayer reminders, lottery results, jokes, horoscopes, traffic, location sensitive services and so on.
- **Still Images:** Still images such as photographs, pictures, postcards, greeting cards and presentations, static web pages can be sent and received over the mobile network using GPRS.
- **Moving Images:** The wireless industry is moving from text messages to icons and picture messages to photographs and blueprints to video messages and movie previews being downloaded and on to full blown movie watching via data streaming on a mobile device using GPRS.
- **Web Browsing:** Using Circuit Switched Data for web browsing has never been an enduring application for mobile users. Because of the slow speed of Circuit Switched Data, it takes a long time for data to arrive from the Internet server to the browser.
- **Corporate Email**
- **Internet Email**
- **File Transfer**

2.3 Universal Mobile Telecommunication System (UMTS)

2.3.1 Introduction

UMTS is one of the major new 'third generation' (3G) mobile communications systems being developed within the framework defined by the ITU and known as IMT-2000. UMTS will enable the wireless Information Society, delivering high-value broadband information, commerce and entertainment services to mobile users via fixed, wireless and satellite networks. UMTS will speed convergence between telecommunications, IT, media and content industries to deliver new services and create fresh revenue-generating opportunities. UMTS is the European vision of 3G. UMTS is an upgrade from GSM via GPRS or EDGE. The standardization work for UMTS is carried out by Third Generation Partnership Project (3GPP) [13]. UMTS provides variety of data rates: 144 kbps for rural, 384 kbps for urban outdoor, 2048 kbps for indoor and low range outdoor.

The Universal Mobile Telecommunication System (UMTS) is a third generation (3G) mobile communication system that provides a range of broadband wireless and mobile communication services. UMTS maintains the global roaming capability of the second generation (2G) GSM system and its packet-switch mode enhancement (GPRS system) and provides enhanced capabilities. Compared with 2G telecommunication systems, UMTS is able to support multimedia services including graphics, pictures, and video communications, as well as voice and data at a higher data rate and with better quality of service.

UMTS targets to build an all-IP network by extending the second generation GSM/GPRS system and using complex technologies including Code Division Multiple Access (CDMA), Asynchronous Transfer Mode (ATM), and Internet Protocol (IP). GPRS is the convergence point between the 2G technologies and the packet-switch domain of UMTS. According to the GSM association, UMTS will offer a wide range of voice, data and multimedia services. It provides high data rates will reach from 114 to 2000 kbps (or 2 Mbps) depending on whether the user is stationary or in motion. It will also provide

large capacity in order to achieve high data-rate multimedia services in wireless environments.

UMTS is the name given to a totally new performance dimension in mobile radio [16]. UMTS is the cornerstone of what is called the third mobile radio generation (3G) for voice and data communication, both packet and circuit-switched. UMTS employs separate frequency bands so is free from the bottlenecks of GSM systems.

Once UMTS is implemented, it would have the path for HSDPA (High Speed Downlink Packet Access). HSDPA provides a smooth evolutionary path for the UMTS networks to higher data rates and higher capacities, in the same way as Enhanced Data rates for GSM Evolution (EDGE) does in the Global System for Mobile communication (GSM) world. HSDPA is the European 3rd generation wireless standard. [17]

2.3.2 UMTS Architecture

UMTS Generic Architecture The architecture for a typical third generation telecommunication system is illustrated in UMTS architecture in figure 2.9. There are three major categories of network elements:

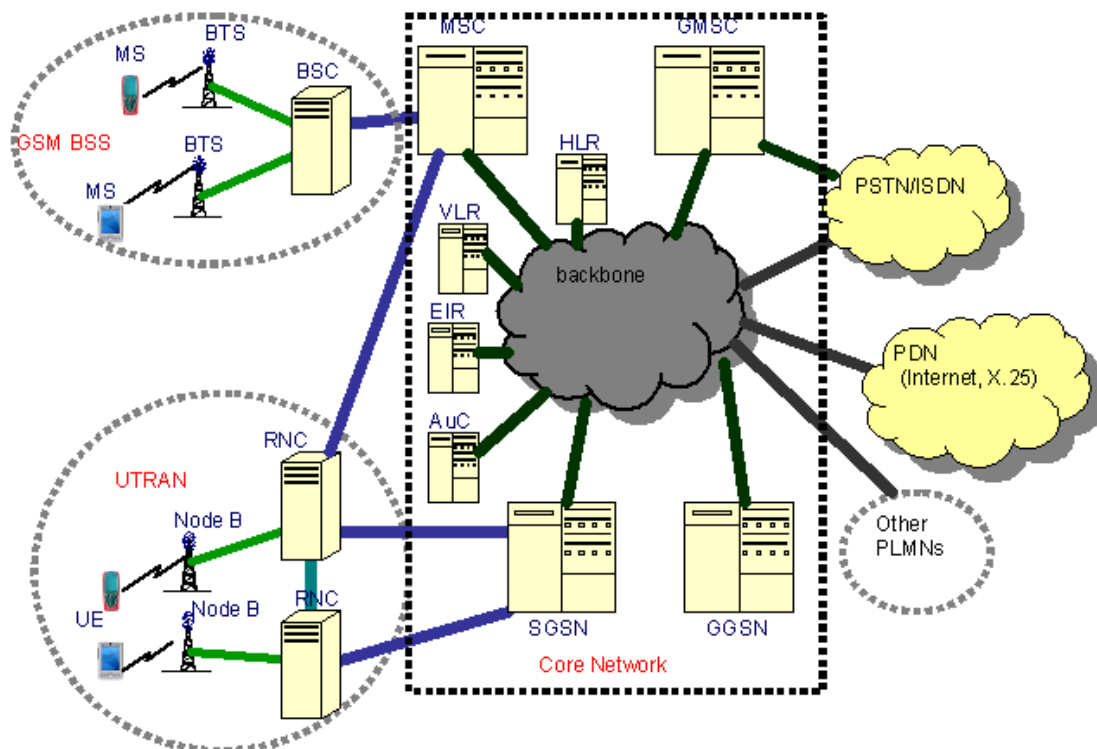


Figure 2.9: UMTS Generic Architecture

- **GSM Core Network Elements:** Mobile Service Center (MSC), Visitor Location Register (VLR), Home Location Register (HLR), Authentication Center (AuC), and Equipment Identity Register (EIR).
- **GPRS Network Elements:** Serving GPRS Support Node (SGSN), and Gateway GPRS Support Node (GGSN).
- **UMTS-specific Network Elements:** User equipment (UE), and UMTS Terrestrial Radio Access Network (UTRAN) elements.

The core network is based on GSM/GPRS, but uses ATM or IP as the transport network. The ATM-based UMTS network is more popular since it ensures various QoS and classes-of-service to the end users. The functions of core networks include switching, routing, transporting, and maintaining a database for user traffic. It contains the circuit-switch domain that includes MSCs, VLRs, and GMSCs, and the packet-switch domain that includes SGSNs and GGSNs. The EIR, HLR, and AuC are part of both domains [16]. In an ATM-based UMTS network, ATM adaptation layer type 2 (ALL2) can handle circuit-switch connections, while ALL5 can handle packet-switched connections.

Architecture of the *QualNet* UMTS Model

The *QualNet* UMTS model is intended to model the network architecture illustrated as in figure 2.10. The Public Land Mobile Network (PLMN) contains different node types, such as UE, Node B, RNC, SGSN, GGSN, and HLR nodes. The SGSN, GGSN, and HLR nodes form the Core Network (CN). It is assumed that the SGSN and GGSN have the capability to handle both circuit switched services and packet switched services. That is, the SGSN also implements the capability of a MSC and the GGSN also implements the capability of a GMSC. Such a SGSN is also called UMTS MSC (UMSC).

Each Node B is connected via a single-hop connection to a RNC and each RNC is connected via a single-hop connection to a SGSN. The RNCs can be connected to each other via single-hop connections. The connections among SGSNs, GGSNs, and HLRs can be any type of backbone network. No special connections are required among them (i.e., they need not be one hop away from each other) [18]. It is assumed that each SGSN has one Visitor Location

Register (VLR) co-located with it. In the *QualNet* UMTS model, the SGSN node also implements the functionality of the VLR.

The GGSN node is a special SGSN node, which acts as a gateway node to interconnect the PLMN with other type of networks such as PSTN, ISDN, or Packet Data Networks (PDNs) such as the Internet. It is also the gateway node that interconnects different PLMNs. One PLMN can have multiple GGSNs to interconnect with different networks. However, it is assumed that one PLMN can only have one Home Location Register (HLR).

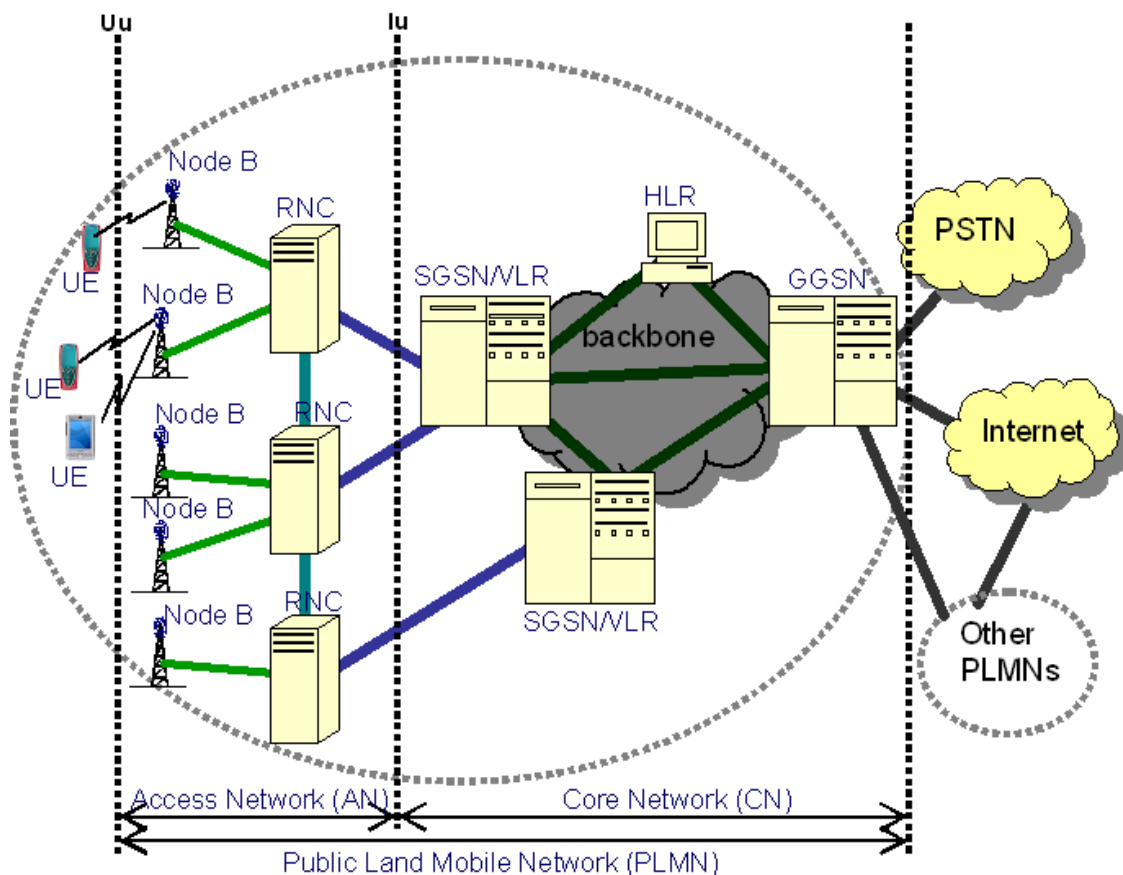


Figure 2.10: Architecture of the *QualNet* UMTS Model

As illustrated in architecture of the *QualNet* UMTS Model, the PLMN can be divided into three parts, namely User Equipment (UE), Access Network (AN), and Core Network (CN). The Access Network can more precisely be called the UMTS Terrestrial Radio Access Network (UTRAN). A UE most commonly refers to a user handset. The access network provides radio access to UEs. The core network implements functions such as location registration, handover, session management, call management, etc.

UMTS Frequency Spectrum

- UMTS Band: 1900-2025 MHz and 2110-2200 MHz for 3G transmission.
- Terrestrial UMTS (UTRAN): 1900-1980 MHz, 2010-2025 MHz, and 2110-2170 MHz bands [19].
- Figure 2.11 shows UMTS frequency spectrum.

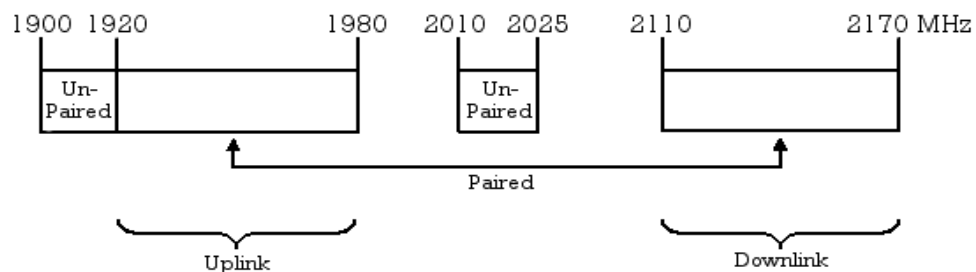


Figure 2.11: UMTS frequency spectrum

2.3.3 UMTS advantages

- Always-on
- Personalized
- Location aware
- Real-time and flexible
- Greater range of enriched multimedia services
- Higher data rates for a greater number of users
- Lower costs in long-term because of network efficiencies
- IP transport in access and core networks
- Separation of control and transport functionalities
- IP multimedia services for mobile devices

2.3.4 UMTS Applications

- Multimedia Messaging Service
- Mobile Intranet/Extranet Access
- Location-based Services
- Wireless Advertising
- Mobile Information
- Business Solutions
- Mobile Transactions

- Radio and Television
- Person-to-Person Communications
- Email and Internet Access
- Real-time image transfer
- Telecommunications
- Video on demand
- Interactive video services
- Entertainment services
- Location based services

2.4 Wireless Local Area Network (WLAN)

2.4.1 Introduction

- 802.11 refers to a family of specifications developed by the IEEE for wireless LAN technology. 802.11 specifies an over-the-air interface between a wireless client and a base station or between two wireless clients.
- **WLAN** is more than just cable replacement, it provides hassle-free broadband Internet access everywhere. Wireless LANs based on the IEEE 802.11 standards allow wire- free networking in the local area network environment using the unlicensed 2.4 or 5 GHz unlicensed radio band [20].
- WLAN is Suitable for local short-distance networking (access point coverage area normally max. ~100m).
- WLAN is compatible with existing LANs.
- Flexible data communication systems and implemented as an extension to the wired networks (LAN).
- Realize on networking in business & meteoric growth of the Internet & online services are strong testimonies to the benefits of shared data & shared resources.
- Minimizes the need for wired connections.
- Combines data connectivity with user mobility and provides general purpose connectivity alternative for a broad range of business customers.

- Users can access shared information without looking for a place to plug in.
- Network managers can set up or augment networks without installing or moving wires.
- Electromagnetic waves (radio or infrared) are used to transmit & receive data over the air.

2.4.2 Overview of 802.11

- An 802.11 LAN is based on a cellular architecture where the system is subdivided into cells. Each cell (called **Basic Service Set**, or **BSS**, in the 802.11 nomenclature) is controlled by a Base Station (called **Access Point** or, in short, **AP**).
- Although a wireless LAN may be formed by a single cell, with a single Access Point, (and as will be described later, it can also work without an Access Point), most installations will be formed by several cells, where the Access Points are connected through some kind of backbone (called **Distribution System** or **DS**). This backbone is typically Ethernet and, in some cases, is wireless itself.
- The whole interconnected Wireless LAN, including the different cells, their respective Access Points and the Distribution System, is seen as a single 802 network to the upper layers of the OSI model and is known in the Standard as **Extended Service Set (ESS)**.

The following figure 2.12 and 2.13 shows a typical 802.11 LAN including the components described above:

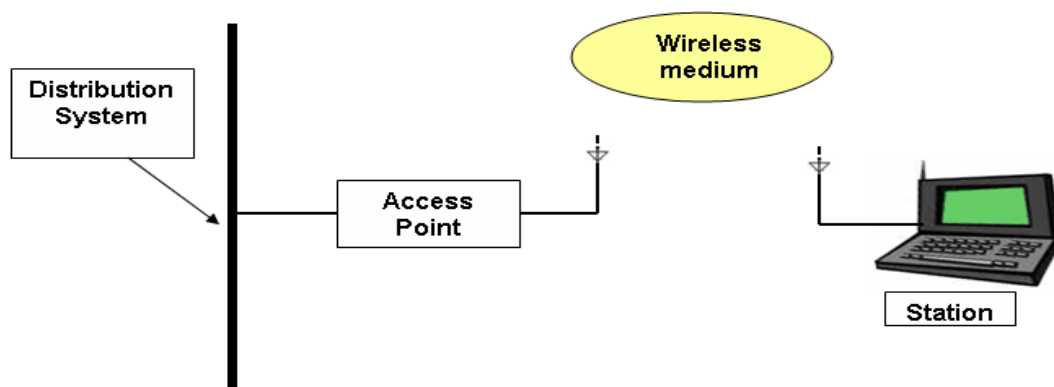


Figure 2.12: Wireless LAN Network

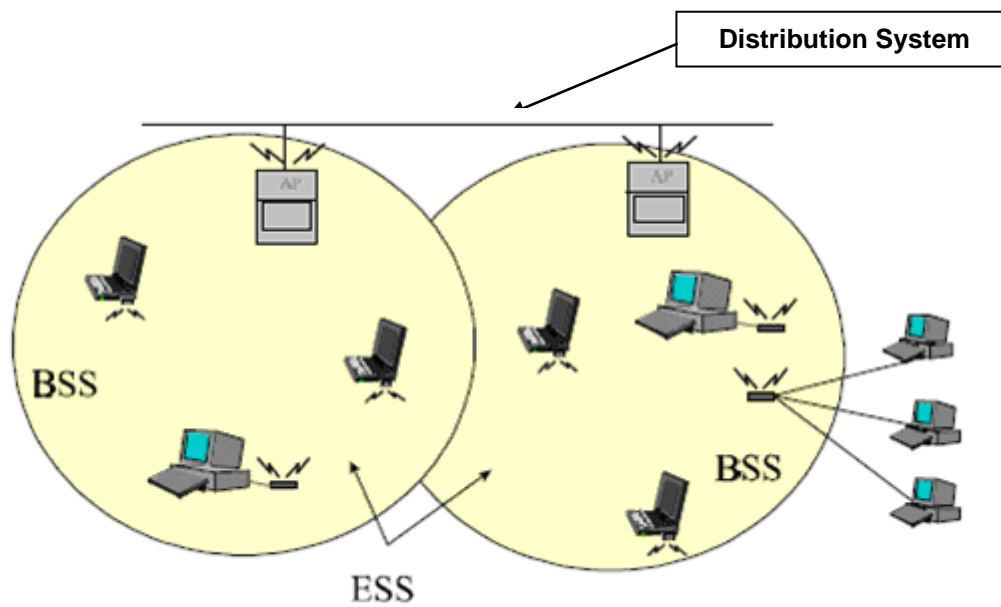


Figure 2.13: A Typical 802.11 LAN

- This standard also defines the concept of a **Portal**. A portal is a device that interconnects between an 802.11 and another 802 LAN. This concept is an abstract description of part of the functionality of a “translation bridge”. Figure 2.14 shows 802.11 architecture.

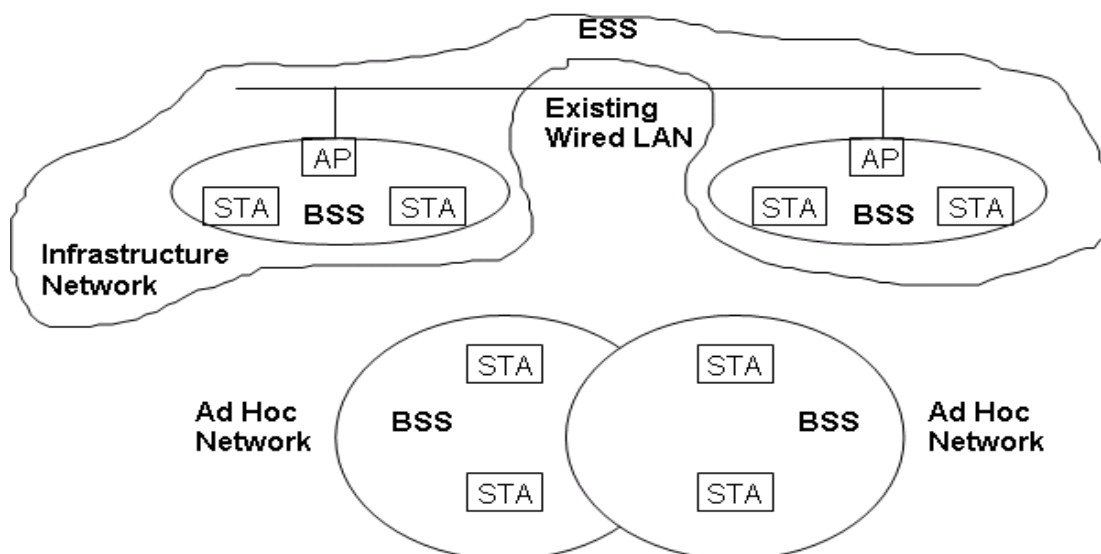


Figure 2.14: 802.11 Architecture

2.4.3 802.11 PHY and MAC Protocol

The IEEE 802.11 standard defines a set of MAC and PHY specifications for wireless LAN, also known as WiFi. It was developed by the IEEE 802.11 working group. The original standard was developed in 1997. Later, several amendments have been proposed to extend 802.11 at both the MAC and physical layers to support various features such as higher bandwidth, QoS, security, and so on.

- **802.11a/g PHY Model**

802.11a PHY is an extension to IEEE 802.11 PHY that applies to wireless LANs and provides up to 54 Mbps in the 2.4 GHz or 5 GHz band. 802.11a PHY uses an orthogonal frequency division multiplexing (OFDM) encoding scheme rather than FHSS or DSSS [21]. **802.11a** supports up to 54 Mbps using the 5 GHz ISM and UNII bands. **802.11g** [22] supports up to 54 Mbps using the 2.4 GHz ISM band.

- **802.11 MAC Model**

IEEE 802.11 defines two different architectures, BSS (Basic Service Set) and IBSS (Independent Basic Service Set). In BSS (also known as Infrastructure mode), wireless stations (STAs) are associated with an Access Point (AP). All communications take place through the AP [29,30]. In IBSS (also known as Ad Hoc mode) stations can communicate directly to each other provided, they are within each other's transmission range.

WLAN Architecture--Ad-Hoc mode

Peer-to-peer setup where clients can connect to each other directly. Generally not used for business networks.



Figure 2.15: Example of WLAN – Adhoc mode

Mobile stations communicate to each other directly.

- It's set up for a special purpose and for a short period of time. For example, the participants of a meeting in a conference room may create an ad hoc network at the beginning of the meeting and dissolve it when the meeting ends.

WLAN Architecture—Mesh

- **Mesh:** Every client in the network also acts as an access or relay point, creating a “self-healing” and (in theory) infinitely extensible network. Not yet in widespread use, unlikely to be in homes.

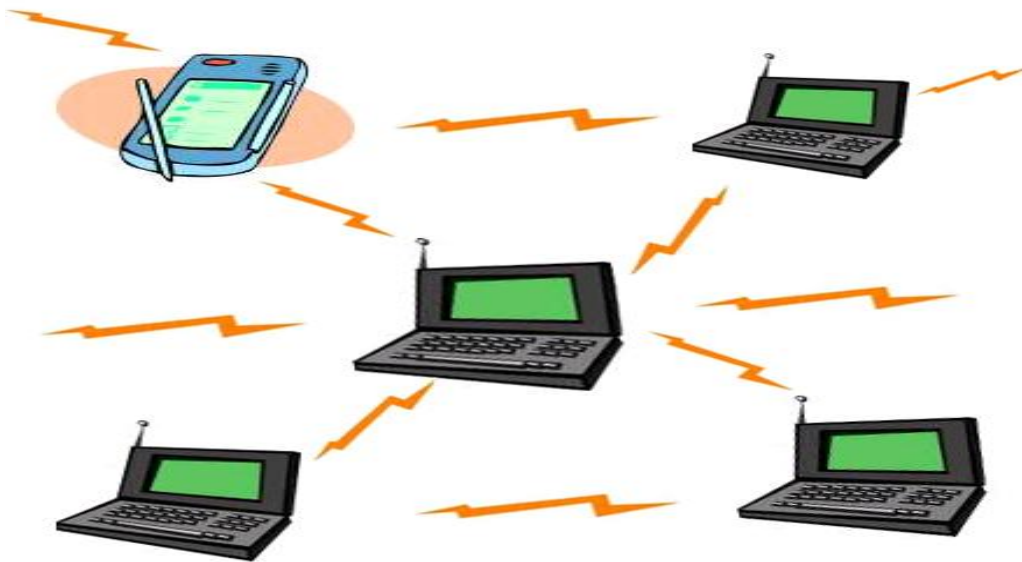


Figure 2.16: Example of WLAN – Mesh mode

WLAN Architecture—Infrastructure Mode

- There is an Access Point (AP), which becomes the hub of a “star topology.”
- Any communication has to go through AP. If a Mobile Station (MS), like a computer, a PDA, or a phone, wants to communicate with another MS, it needs to send the information to AP first, then AP sends it to the destination MS
- Multiple APs can be connected together and handle a large number of clients.
- Used by the majority of WLANs in homes and businesses.

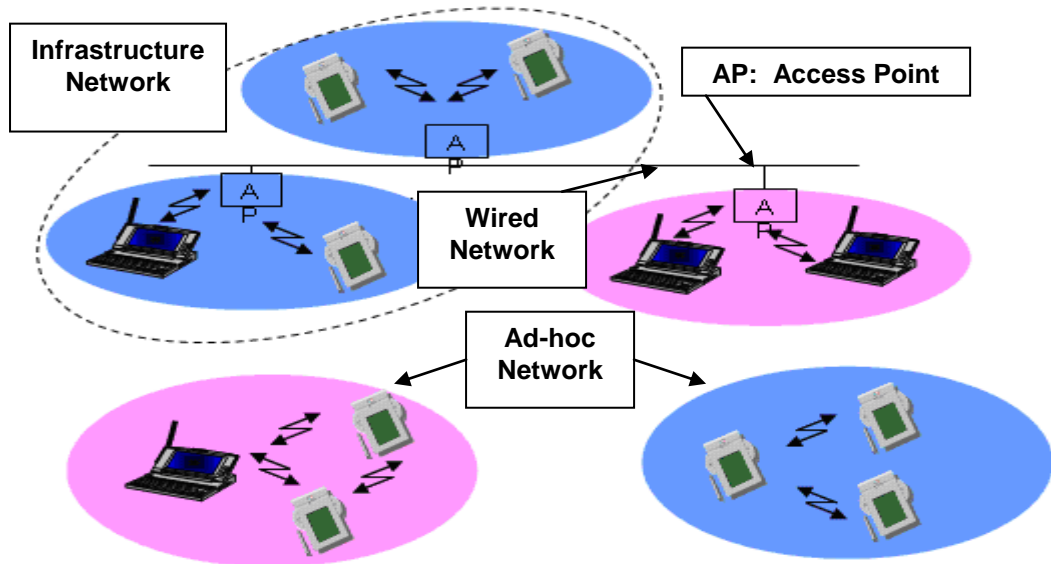


Figure 2.17: Example of WLAN – Infrastructure mode

- Wireless LAN is typically deployed as an extension of an existing wired network as shown below.

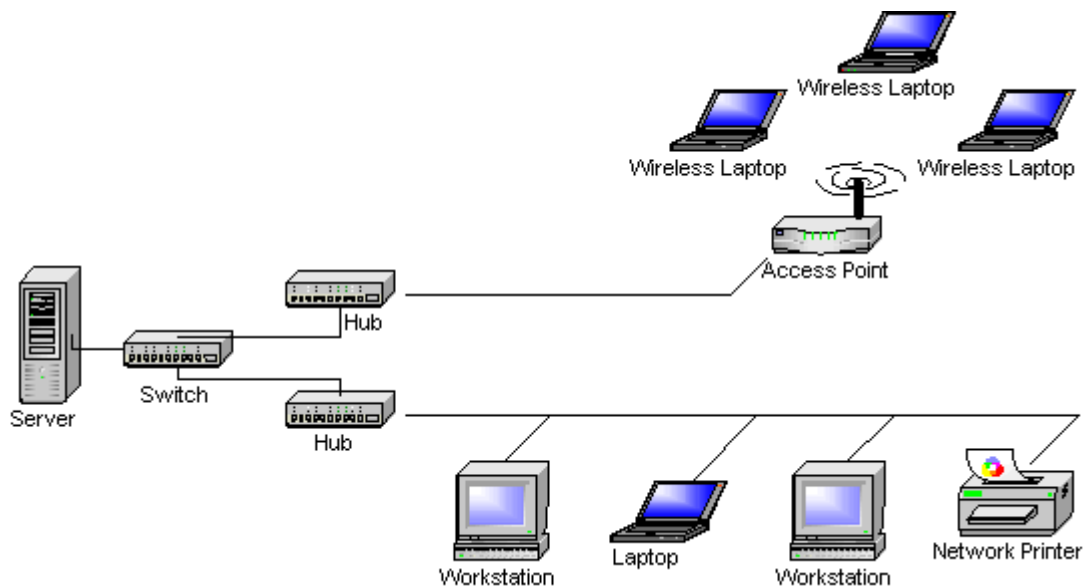


Figure 2.18: Example of Wireless LAN Topologies

- IEEE 802.11 MAC defines two access mechanisms:
 - Distributed Coordination Function (DCF): DCF provides distributed channel access based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). This mechanism is mandatory.
 - Point Coordination Function (PCF): PCF provides centrally controlled channel access through polling. This mechanism is optional.

IEEE 802.11 standard also defines the Power Saving (PS) Mode for reducing the energy consumption at stations.

DCF Procedure

The fundamental access method of the IEEE 802.11 MAC is DCF. The DCF shall be implemented in all STAs, for use within both ad hoc and infrastructure network configurations. For a STA to transmit, it shall sense the medium to determine, if another STA is transmitting. If the medium is not determined to be busy, then the transmission may proceed. If the medium is determined to be busy, the STA shall defer until the end of the current transmission. The CSMA/CA distributed algorithm mandates that a gap of a minimum specified duration exist between contiguous frame sequences. A transmitting STA shall ensure that the medium is idle for this required duration before attempting to transmit again.

After deferral to an ongoing transmission or prior to attempting to transmit again immediately after a successful transmission, the STA shall select a random backoff interval and shall decrement the backoff interval counter while the medium is idle. A refinement of the method may be used under various circumstances to further minimize collisions. Here, the transmitting and receiving STA exchange short control frames (Request-To-Send (RTS) and Clear-To-Send (CTS) frames) after determining that the medium is idle and after any deferrals or backoffs, prior to data transmission.

PCF Procedure

In the PCF procedure, the access to the channel is centralized by using a poll-based protocol controlled by the Point Coordinator. The access points generally serve as PCs. The PCF mode provides contention free service to the stations. In PCF mode, a frame is divided into two parts: contention-free period (CFP) and contention period (CP). The PC indicates the start of the contention free period by sending a beacon frame which contains the PCF related information (for example, the CFP parameter set). The CFP is repeated after a fixed interval that is contention-free repetition interval.

After sending the beacon, the PC starts polling stations one by one in the order of their association IDs. If the PC has a data packet to send to the station, it sends the polling packet piggy-backed on the data packet. If the PC does not have any data to send, it sends only a polling packet.

Power Saving Mode

Power saving mode is used to reduce the energy consumption at the station nodes. Three distinct building blocks are provided to support power savings: a Wakeup Procedure, a Sleep Procedure, and a Power Save Poll (PS-Poll) Procedure. A station can combine these power management building blocks in various manners for different applications.

2.4.4 Wireless LAN: Characteristics

- Types
 - Infrastructure based
 - Adhoc
- Advantages
 - Flexible deployment
 - Minimal wiring difficulties
 - More robust against disasters (earthquake etc)
 - Historic buildings, conferences, trade shows,
- Disadvantages
 - Low bandwidth compared to wired networks (1-10 Mbit/s)
 - Proprietary solutions
 - Need to follow wireless spectrum regulations
- Features
 - Compatible with existing LANs
 - Suitable for local short-distance networking (access point coverage area normally max. ~300m).
 - WLAN uses unlicensed radio frequencies : 2.4 GHz band and 5 GHz band
 - ISM band (band for the **I**ndustrial, **S**cientific and **M**edical use : 2.4 GHz) : Available worldwide (with some exceptions) and 5 GHz band : No worldwide support.

- The ISM bands are license-free, provided that devices are low power. In this band, one doesn't need a license to set up and operate a wireless network.

Table 2.2 shows different IEEE 802.11 WLAN Standards[26][27], Spectrum occupied, Maximum physical rate, Transmission scheme, Advantages and Disadvantages by each 802.11 standard.

Table 2.2 IEEE 802.11 WLAN Standards and its characteristics

Standard	Spectrum	Maximum physical rate	Trans- mission	Major Dis-advantages	Major Advantages
802.11	2.4 GHz	2 Mbps	FHSS/ DSSS	Limited bit rate	Higher range
802.11a	5 GHz	54 Mbps	OFDM	Smallest range of all 802.11 standards	Higher bit rate in less-crowded spectrum
802.11b	2.4 GHz	11 Mbps	DSSS	Bit rate too low for many emerging applications	Widely deployed; Higher range
802.11g	2.4 GHz	54 Mbps	OFDM	Limited number of collocated WLANs higher range than 802.11a	Higher bit rate in 2.4 GHz spectrum

2.5. Wireless Fidelity (Wi-Fi) [23]

The position that wireless technologies will replace the PSTN is met with a number of objections. Primarily, these objections are focused on quality of service (QoS) issues, the security of the wireless network, limitations in the range of the delivery of the service, and the availability of bandwidth.

2.5.1 Overview of Wi-Fi [24][25]

- Wi-Fi ("Wireless Fidelity") is the popular term for a high-frequency wireless local area network (WLAN)
- The IEEE 802.11 standard defines a set of MAC and PHY specifications for wireless LAN, also known as WiFi. It was developed by the IEEE 802.11 working group.

- *Wi-Fi follows **IEEE 802.11b** standard and supports up to 11 Mbps using the 2.4 GHz ISM band.*
- The original standard was developed in 1997 and it is promoted by the Wi-Fi Alliance (Formerly WECA - Wireless Ethernet Carriers Association)
- The Wireless Ethernet Compatibility Alliance started the Wi-Fi--wireless fidelity--certification program to ensure that equipment claiming 802.11 compliance was genuinely interoperable.
- It is a wireless technology that uses radio frequency to transmit data through the air.
- Wi-Fi refers to the technology surrounding the radio transmission of internet protocol data from an internet connection wirelessly to a host computer.
- Wi-Fi is meant to be used generically when referring to any type of 802.11 network, whether 802.11b, 802.11a, 802.11g [26], dual-band, etc.
- Wi-Fi standards use the Ethernet protocol and CSMA/CA (carrier sense multiple access with collision avoidance) for path sharing [27].
- Modulation used in 802.11 has historically been phase-shift keying (PSK).

2.5.2 802.11 Standard

- 802.11 is primarily concerned with the lower layers of the OSI model.
- Data Link Layer
 - Logical Link Control (LLC).
 - Medium Access Control (MAC).
- Physical Layer
 - Physical Layer Convergence Procedure (PLCP).
 - Physical Medium Dependent (PMD).
- ✓ Wireless networks are standardized by IEEE.
- ✓ Under 802 LAN MAN standards committee.

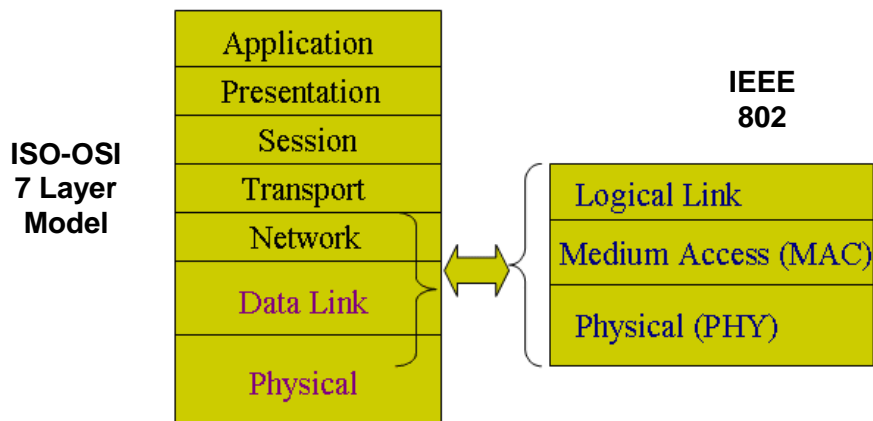


Figure 2.19 Standardization of Wireless Networks

802.11b Standard

- Limits the number of access points in range of each other to three.
- Widely available
- Greater range, lower power needs
- Uses direct-sequence spread-spectrum technology.
- Has 11 channels, with 3 non-overlapping, and supports rates from 1 to 11 Mbps, but realistically about 4-5 Mbps max.
- Well-supported, stable, and cost effective, but runs in the 2.4 GHz range that makes it prone to interference from other devices (microwave ovens, cordless phones, etc) and also has security disadvantages.

802.11b PHY Model

802.11b PHY is an extension to IEEE 802.11 PHY that applies to wireless LANS and provides 11 Mbps transmission (with a fallback to 5.5, 2 and 1 Mbps) in the 2.4 GHz band [32]. 802.11b PHY uses only Direct-Sequence Spread-Spectrum (DSSS) modulation. 802.11b PHY was a 1999 ratification to the original 802.11 PHY standard, allowing wireless functionality comparable to Ethernet.

802.11b is a direct extension of the DSSS modulation technique. As with other spread-spectrum technologies, the signal transmitted using DSSS takes up more bandwidth than the information signal that is being modulated. The carrier signals occur over the full bandwidth (spectrum) of a device

transmitting frequency. DSSS modulates the signal by multiplying the data being transmitted by a "noise" signal. This noise signal is a pseudorandom sequence of 1 and -1 values, at a frequency much higher than that of the original signal, thereby spreading the energy of the original signal into a much wider band.

The 802.11b standard uses Complementary code keying (CCK) as its modulation technique, which is a variation on CDMA . Complementary codes are sets of finite sequences of equal length, such that the number of pairs of identical elements with any given separation in one sequence is equal to the number of pairs of unlike elements having the same separation in the other sequences. CCK is a variation and improvement on, M-ary Orthogonal Keying and uses "poly phase complementary codes".

802.11g Standard

- Extension of 802.11b, with the same disadvantages (security and interference).
- Has a shorter range than 802.11b.
- Faster than 802.11b (24Mb vs 11Mb)
- Is backwards compatible with 802.11b so it allows for a smooth transition from 11b to 11g.
- Flexible because multiple channels can be combined for faster throughput, but limited to one access point.
- Runs at 54 Mbps, but realistically about 20-25 Mbps and about 14 Mbps when b associated
- Uses frequency division multiplexing

802.11a Standard

- Completely different from 11b and 11g.
- Greater bandwidth (54Mb)
- Less potential interference (5GHz)
- More non-overlapping channels
- Flexible because multiple channels can be combined for faster throughput and more access points can be co-located.
- Shorter range than 11b and 11g.

- Runs in the 5 GHz range, so less interference from other devices.
- Has 12 channels, 8 non-overlapping, and supports rates from 6 to 54 Mbps, but realistically about 27 Mbps max
- Uses frequency division multiplexing

IEEE 802.11 defines two different architectures, BSS (Basic Service Set) and IBSS (Independent Basic Service Set). In BSS (also known as Infrastructure mode), wireless stations (STAs) are associated with an Access Point (AP). All communications take place through the AP. In IBSS (also known as Ad Hoc mode) stations can communicate directly to each other provided, they are within each other's transmission range.

2.5.3 Wi-Fi Models

IEEE 802.11 defines two different architectures, BSS (Basic Service Set) and IBSS (Independent Basic Service Set). In BSS (also known as Infrastructure mode), wireless stations (STAs) are associated with an Access Point (AP). All communications take place through the AP [In IBSS (also known as Ad Hoc mode) stations can communicate directly to each other provided, they are within each other's transmission range.

WiFi Adhoc Model

Peer-to-peer setup where clients can connect to each other directly. Generally not used for business networks.



Figure 2.20 WiFi Adhoc Model

In adhoc model mobile stations communicate to each other directly. It's set up for a special purpose and for a short period of time. For example, the participants of a meeting in a conference room may create an ad hoc network at the beginning of the meeting and dissolve it when the meeting ends.

Wi-Fi Infrastructure Model

Wi-Fi Infrastructure model includes (most common):

- Stations (STA) – any wireless device[29]
- Access Point (AP) – connects BSS to DS, controls access by STA's
- Basic Service Set (BSS) – a region controlled by an AP, mobility is supported within a single BSS
- Extended Service Set (ESS) – a set of BSS's forming a virtual BSS, mobility is supported between BSS's in an ESS
- Distribution Service (DS) – connection between BSS's

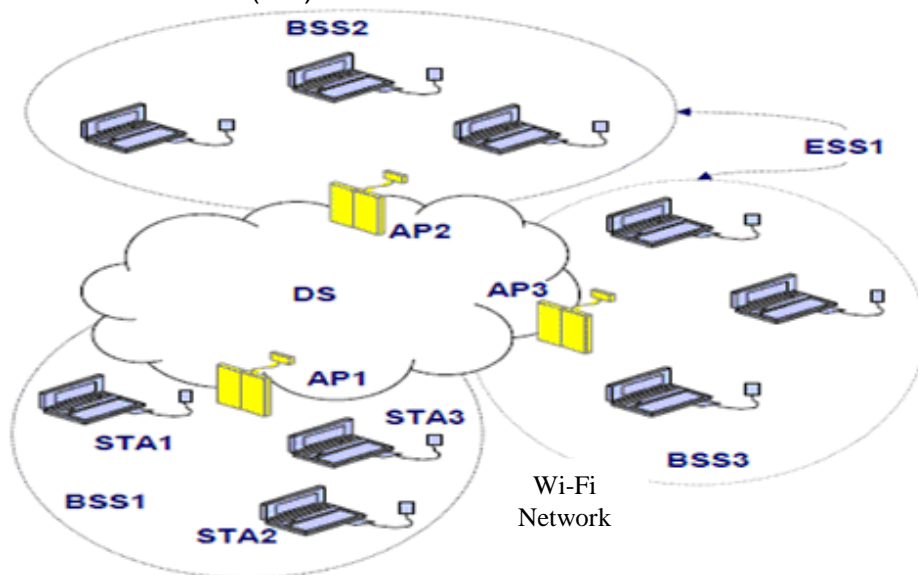


Figure 2.21 WiFi Infrastructure Model

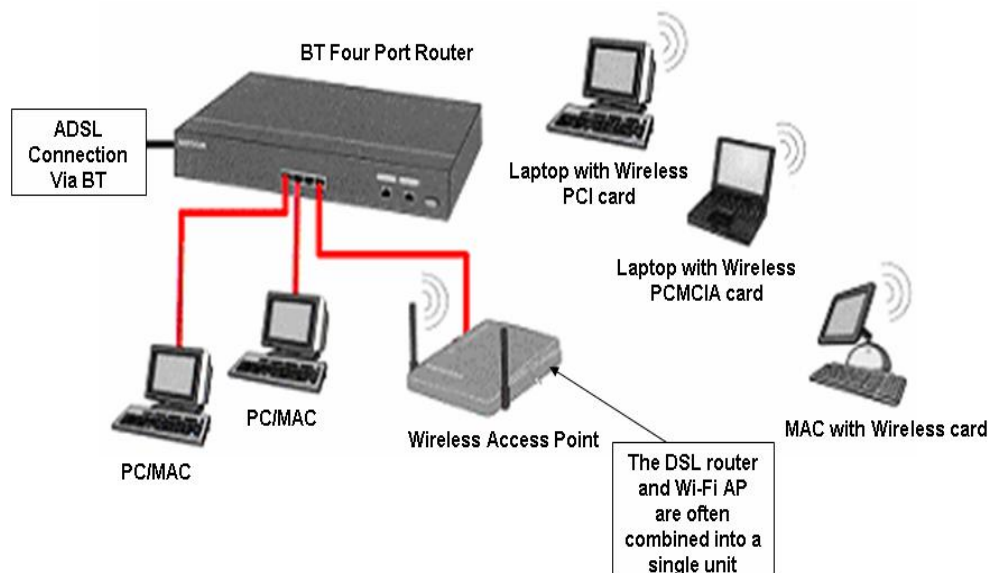


Figure 2.22 Example of small business usage of Wi-Fi Network

2.5.4 The Need for QoS in Wireless Networks [30]

An additional network requirement must be supported if the user experience in wireless broadband is to be similar to the user experience in wired broadband (for example, T1 access). The IEEE has been grappling with the issue of QoS in wireless networks and has recently approved 802.11e, which is backward compatible with other variants of 802.11. That means that improvements in QoS [31] contained in 802.11e can be applied to 802.11 or 802.11a. This section outlines the mechanisms used to ensure the QoS contained in both 802.11 and 802.11e.

Challenges to Wireless QoS

Many previous attempts at WLAN QoS (and non-QoS channel access schemes) show that the strategies that work well in a wired environment do not translate to WLAN. Several factors break possible assumptions: The packet error rate can be in the range of 10 to 20 percent, bit rates vary according to channel conditions, and the "rubber pipe problem" arises where bandwidth managers do not know how much bandwidth they have to manage because a neighbouring, unrelated bandwidth manager can take some of it at any time. In addition, if a wireless network is to bypass or substitute for the PSTN, it must be able to prioritize voice and video packets over data packets.

Latency in Wireless Networks

Latency is defined as the time it takes for the network to respond to a user command. If latency is high, causing noticeable delays in downloading web pages, then the experience feels nothing at all like broadband, no matter how high the data rates are. Low latency (less than 50 ms) is a requirement for the successful mass-market adoption of wireless services and devices.

The latency experienced by wireless users has a number of contributing sources, including the air link processing, propagation, network processing and transport, the far-end server (if applicable), the application, and the user device. The sum of these latencies must be minimized to ensure a positive end-user experience. Because of the many contributing sources in wired

networks, there is little room for latency contributed by the wireless system. Table 2.3 describes the types of delay encountered on an 802.11 network.

Table 2.3: Types of delay encountered on an 802.11 network

Delay	Definition
Air link processing	The time necessary to convert user data to air link packets (code, modulate, and frame user data) and transmit it
Propagation	The time necessary for a signal to travel the distance between the base station and the subscriber device, and vice versa
Network transmission	The time necessary to send the packet across the backhaul and backbone networks, including routing and protocol processing delays and transmission time
Far-end processing	The time required for processing by the far-end servers and other devices

The processing delay leads to another very unique disadvantage of systems that are not built on an all-IP basis. Many networks cannot transmit native IP packets and require IP assistance through either a protocol change (transcoding and encapsulation) or the addition of equipment in the network to simulate IP performance. Those measures introduce complexity and packet delays, further impacting the latency of a given system and driving up cost.

Through put and latency are two essentials for measuring network performance. When taken together, these elements define the speed of a network. Whereas throughput is the quantity of data that can pass from source to destination in a specific time, round-trip latency is the time it takes for a single data transaction to occur (that is, the time between requesting data and receiving it). Latency can also be thought of as the time it takes for data to be sent on one end to be retrieved on the other end (from one user to the other).

Latency is crucial to the broadband experience because the Internet is based on the Transmission Control Protocol (TCP). TCP requires the recipient of a

packet to acknowledge its receipt. If the sender does not receive a receipt in a certain amount of time (ms), then TCP assumes that the connection is congested and slows down the rate at which it sends packets. TCP is very effective in dealing with congestion on the wired networks.

A system's ability to efficiently handle a large user population depends significantly on its ability to serve many small TCP/IP messages per unit time and multiplex many active data users within a given cell. Hence, high latency translates directly into lower system capacity for serving data users, which equates to higher cost

2.5.5 Wi-Fi Services, advantages and disadvantages [32]

Wi-Fi network services

- Distribution and integration
- Association, re-association, and disassociation
- Authentication and deauthentication
- Providing privacy

Advantages

- Freedom – You can work from any location that you can get a signal.
- Setup Cost – No cabling required.
- Flexibility – Quick and easy to setup in temp or permanent space.
- Scalable – Can be expanded with growth.
- Mobile Access – Can access the network on the move.

Disadvantages

- Speed – Slower than cable.
- Range – Affected by various medium.
 - Travels best through open space.
 - Reduced by walls, glass, water, etc
- Security – Greater exposure to risks.
 - Unauthorized access.
 - Compromising data.

2.6 Worldwide Interoperability for Microwave Access (WiMAX)

2.6.1 Introduction

WiMAX is a telecommunication technology that provides wireless transmission of data. WiMAX is wireless broadband technology, and a great alternative that fixed broadband connections such as cable or DSL. The technology is based on the IEEE 802.16 standard (called Broadband Wireless Access) [33]. WiMAX is led by the WiMAX Forum, a global organization of manufacturers and operators, who share knowledge and developments to ensure compliance and international compatibility in WiMAX technology as per the IEEE 802.16 standard. The name "WiMAX" was created by the Forum, which was formed in June 2001.

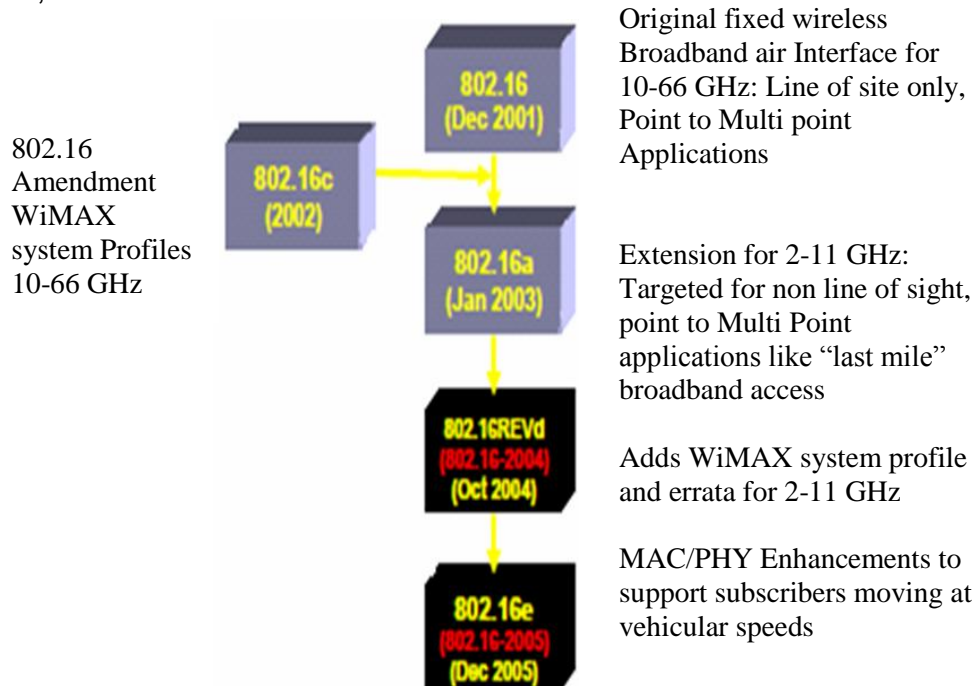


Figure 2.23: IEEE 802.16 Standard gradual development

2.6.2 802.16 Standards History [34], [35]

WiMAX is the first standard based on proprietary implementations of DOCSIS/HFC architecture in wireless domain. Figure 2.23 shows gradual development of IEEE 802.16 standard.

2.6.3 WiMAX Architecture

- Figure 2.23 shows IEEE 802.16 Network Architecture and figure 2.24 shows example of WMAN. IEEE 802.16 consists of the access point, BS (Base Station) and SSs (Subscriber Stations).

- All data traffic goes through the BS, and the BS control the allocation of bandwidth on the radio channel.

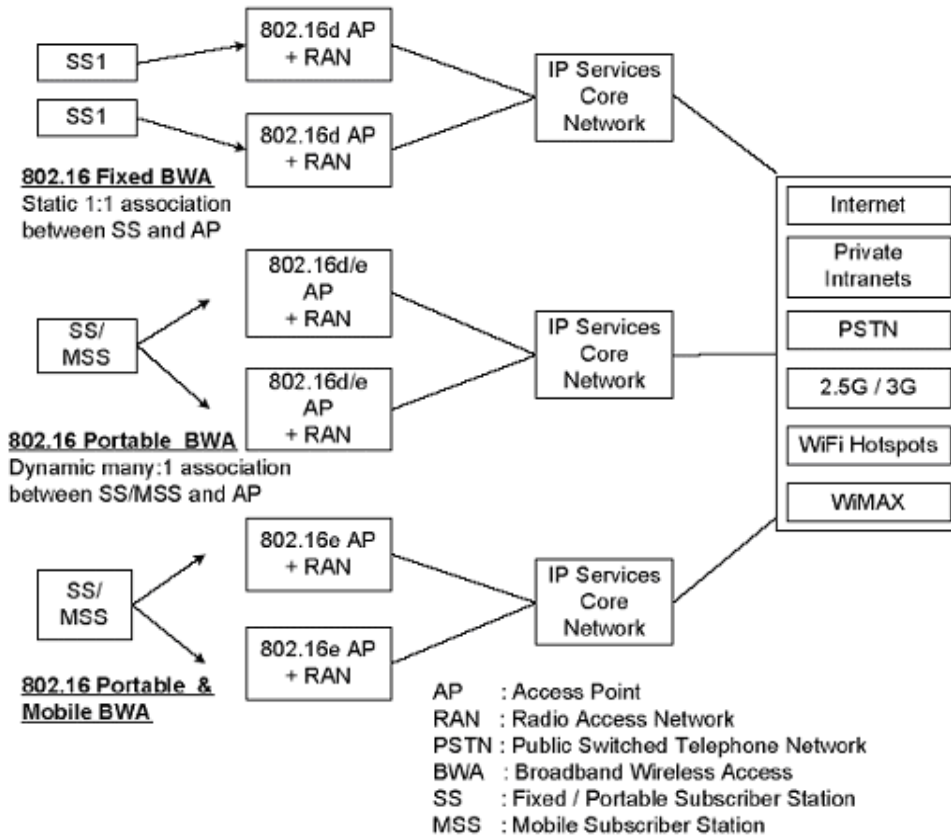


Figure 2.24: IEEE 802.16 Network Architecture

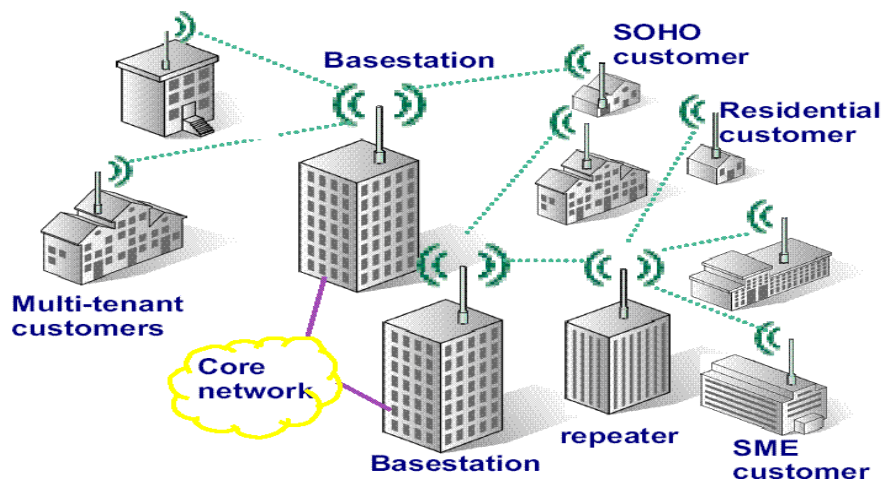


Figure 2.25: Example of Wireless Metropolitan Area Network (WMAN)

- During the communication, all the information coming from a SS goes to the BS and are retransmitted to the right SS.
- Base stations (BS) can handle thousands of subscriber stations (SS).

- Two type of link are defined:
 - The downlink: From the BS to the SS.
 - The uplink: From the SS to the BS.

❖ **WiMAX actually can provide two forms of wireless service:**

- There is the **non-line-of-sight** - Wi-Fi sort of service, where a small antenna on the computer connects to the tower. In this mode, WiMAX uses a **lower frequency range** -- 2 GHz to 11 GHz (similar to Wi-Fi). Lower-wavelength transmissions are not as easily disrupted by physical obstructions -- they are better able to diffract, or bend, around obstacles.
- There is **line-of-sight** service, where a fixed dish antenna points straight at the WiMAX tower from a rooftop or pole. The line-of-sight connection is stronger and more stable, so it's able to send a lot of data with fewer errors. Line-of-sight transmissions use **higher frequencies**. At higher frequencies, there is less interference and lots more bandwidth.

2.6.4 802.16 PHY, 802.16 MAC and 802.16e MAC Protocol

802.16 PHY [37]

IEEE 802.16 specifies multiple physical specifications including SC, OFDM and OFDMA. OFDMA is similar to OFDM [38] [39] using multiple sub carriers to transmit data. However, while OFDM uses all available sub carriers in each transmission, different sub carriers could be arranged to different subscribers in downlink and each transmission could use a subset of the available sub carriers in uplink in OFDMA.

The mandatory features are implemented in current implementation. It supports variable channel bandwidth, different FFT sizes, multiple cyclic prefix time, and different modulation schemes such as QPSK, 16QAM, and 64QAM with convolutional encoding at variety encoding rates.

The raw data rates of the OFDMA are depends on several parameters such as channel bandwidths, FFT size, sampling factor, cyclic prefix time, modulation scheme, encoding scheme and encoding rate. It can be up to 70 Mbps by using high grade modulation scheme with other suitable parameters.

802.16 MAC and 802.16e MAC

The IEEE 802.16 standard, including MAC layer [40] and PHY layer specifications, defines the air interface and associated functions of the broadband wireless access system supporting multimedia services. It is designed for high-range and high-bandwidth wireless access, or Wireless Metropolitan Area Network (Wireless MAN) [41] [42]. The bandwidth is up to 70 Mbps and radio range can go up to 50 kilometers (31 miles). Its major advantages include:

- ▶ High bandwidth and large coverage range
- ▶ Multiple service with different QoS guarantees
- ▶ Built-in security
- ▶ Cost-effective and fast-to-deploy first mile access to public networking
- ▶ A cost effective alternative that replaces WiFi and 3G/4G

The basic components of an 802.16 network are Base Stations (BS) and Subscriber Stations (SS) (or Mobile Stations (MS) in 802.16e). The BS connect to the public networks and serve their registered subscriber stations. The SS typically serve a building (commercial or residential, or WiFi hot spots). Both BS and SS are assumed to be static in an 802.16 network (mobility support is added in 802.16e standard). The basic operation mode of an 802.16 network is called Point to Multi-Point (PMP) where SS is only one-hop away from BS and can only communicate with its BS, not other neighbouring SS.

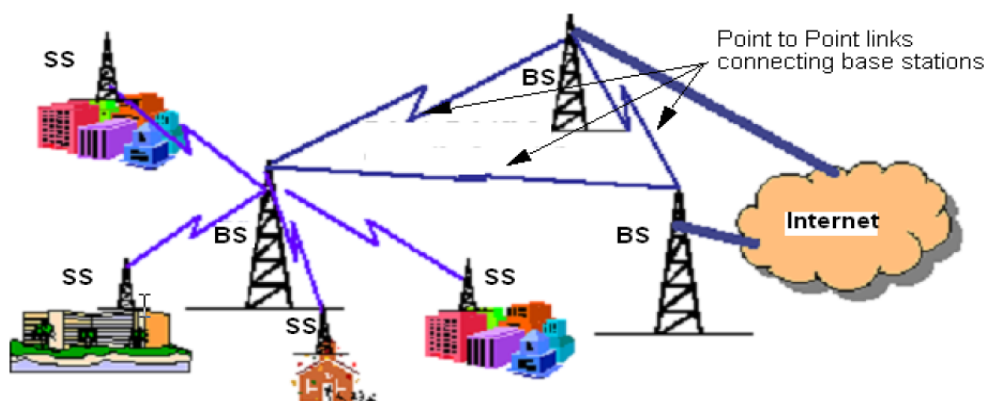


Figure 2.26: IEEE 802.16 MAC with PMP Mode

An optional operational mode called Mesh mode, has no clear distinction between SS and BS. Stations can talk directly to each other and be more than one-hop away from the BS, and the BS is defined as the station that provides access to the public network, such as the Internet. Figure 4.26 shows an illustration of an 802.16 network running under the basic PMP mode [37].

IEEE 802.16e added mobility support to IEEE 802.16. It can support mixed fixed and mobile broadcast wireless access networks. In the 802.16e specification, Subscriber Stations (SS) are also referred to as Mobile Stations (MS). Under 802.16e, the MS can handover from one BS to another BS.

1. Neighbour BS information advertisement: The serving BS periodically broadcasts information about neighbouring BSs. This information is then used by MS to guide the Neighbour BS scanning. In addition, the BS also indicates to MS the thresholds that will trigger Neighbour BS scan or handover actions.
2. Neighbour BS scanning: When the signal quality/QoS of the serving BS is below a certain threshold, the MS starts the Neighbour BS scanning procedure, seeking available BS and determining their suitability as targets for handover. During Neighbour BS scanning, the MS may also associate with neighbouring BSs to reduce delay in handover.
3. Handover: An MS may perform handover under two conditions, a) when the signal quality of the serving BS is too low, and b) when the QoS capability of the serving BS cannot fulfill requirements. Both MS and BS can initiate the handover.
4. Sleep mode: When MS is inactive, it can go to sleep mode in order to save power.
5. Paging: paging is used to reach an MS in idle or sleep mode.
6. Idle mode: An MS can go into idle mode where it periodically listens to DL broadcast traffic without ranging and registration. This can save overhead on handover when the MS traverses an air-link environment populated by multiple BS.
7. Authentication and Service Authorization (ASA) server: The access control of MS.

8. Backbone functionalities: The BSs can use the backbone to communicate with each other to exchange some information for services such as network/BS assisted handovers.

Figure 4.27 shows the IEEE 802.16e Access Network supporting mobility.

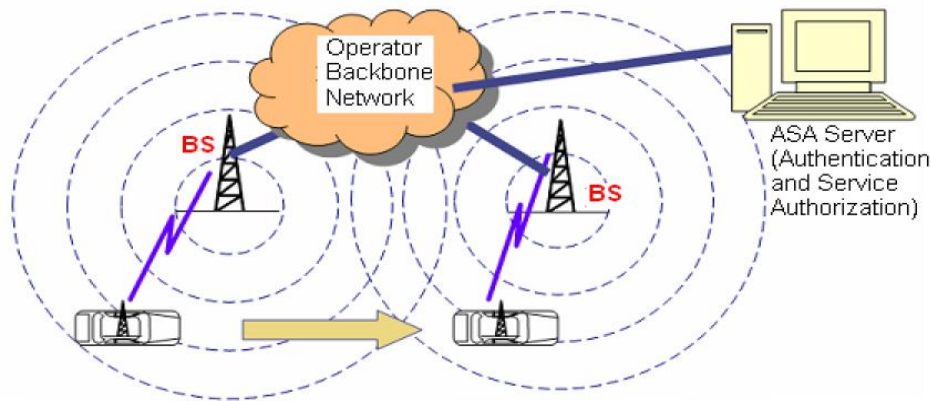


Figure 2.27: IEEE 802.16e Access Network with Mobility Support

The IEEE 802.16 MAC [40] is basically a TDMA type of medium access control protocol. The medium is first divided into MAC frames, then each MAC frame is divided into a downlink subframe and an uplink subframe. In the downlink subframe, the BS transmits different bursts to different SSs in TDD way. For the uplink, different SSs transmit in different uplink bursts that are primarily TDMA. The scheduling of downlink and uplink bursts is controlled by the BS. SS needs to request bandwidth based on its need. Thus, the uplink access is usually referred to as TDMA

IEEE 802.16 MAC supports 3 duplex modes. They are TDD, FDD Half-Duplex, and FDD Full-Duplex. The IEEE 802.16 also defines 4 PHY types including SC, SCa, OFDM, and OFDMA.

2.6.5 WiMAX Operation

WiMAX could be used to set up a back-up or even primary communications system that would be difficult to destroy with a single, pinpoint attack. Figure 2.28 shows WiMAX operation and gives idea about how WiMAX works. A cluster of WiMAX transmitters would be set up in range of a key command center but as far from each other as possible. Each transmitter would be in a bunker hardened against bombs and other attacks. No single attack could

destroy all of the transmitters, so the officials in the command center would remain in communication at all times. WiMAX system consists of two parts:

- ▶ **WiMAX Base Station or WiMAX Tower** : Typically, a base station can cover up to 10 km radius. It is similar in concept of a cell-phone tower. A single WiMAX tower can provide coverage to a very large area -- as big as 3,000 square miles (~8,000 square km). It can also connect to another WiMAX tower using a line-of-sight, microwave link. This connection to a second tower (often referred to as a **backhaul**), along with the ability of a single tower to cover up to 3,000 square miles, is what allows WiMAX to provide coverage to remote rural areas.
- ▶ **WiMAX receiver** : The receiver and antenna could be a small box or PCMCIA card , or they could be built into a laptop the way WiFi access is today.

WiMAX could also Boost Government Security. In an emergency, communication is crucial, for government officials as they try to determine the cause of the problem, find out who may be injured and coordinate rescue efforts or cleanup operations. A gas-line explosion or terrorist attack could destroy the cables that connect leaders and officials with their vital information networks. Several base stations can be connected with one another by backhaul microwave links.

1. Wire line backhauling
2. Microwave Point-to-Point connection

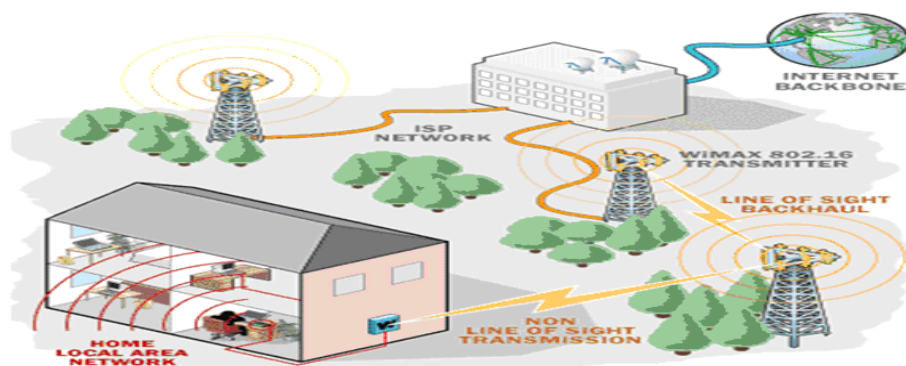


Figure 2.28: WiMAX Operation

In practical terms, WiMAX would operate similar to Wi-Fi but at higher speeds, over greater distances and for a greater number of users. WiMAX could potentially erase the suburban and rural blackout areas that currently have no

broadband Internet access, as the phone and cable companies have not yet run the necessary wires to those remote locations.

2.6.6 IEEE 802.16 Features

- Frequency range:10-66 GHz
- Connectivity at speeds up to 70 Mbps
- Use wireless links with microwave or millimeter wave radios
- Use licensed spectrum
- WiMax covers metropolitan area in scale
- Provide public network service to fee-paying customers
- Use point-to-multipoint architecture with stationary rooftop or tower-mounted antennas
- Antenna with a variety of radiation patterns are used (e.g., directional or Omni-directional)
- Provide broadband and QoS guarantee data Transmissions
- Another significant feature of WiMax technology is the connectivity on move
- WiMax adopts Orthogonal Frequency Division Multiplexing (OFDM) (carriers of width of 5MHz or greater can be used)
- Provide high speed access to about 60 businesses at T1 speeds.
- It serves up to a thousand homes in term of DSL speed
- Protocol of communication network without wire, based on the standard IEEE 802.16
- Allows communications over long distances than WiFi, and a greater bandwidth means it provides wide coverage and high speed compared to Wi-Fi. Theoretically Cover approximately 40 ~ 50 Km (30 miles)
- Goal is to Provide high-speed Internet access to home and business subscribers, without wires

2.6.7 IEEE 802.16 Applications

- Provide broadband Internet access with transmission rates over >2 Mb/s
- Replace DSL or cable
- DSL can deliver up to 6 Mb/s at distances up to 18,000 feet

- IEEE 802.16 can deliver up to 120 Mb/s at distances up to 30 km
 - Provide local multipoint distributed services (LMDS)
 - Better price points for both home and business customers
 - WiMAX allow competitors joint access to any subscriber in areas without preexisting physical cable or telephone networks
 - It would allow gamers access to adhoc local networks of other players with the same gear- without any internet access.
 - These are most common applications of WiMAX which can be used for Broadband Wireless Access (BWA).Figure 2.29 shows WiMAX applications.
1. For residential or home Broadband Internet Access
 2. For medium and small size business
 3. Backhaul networks for cellular base stations

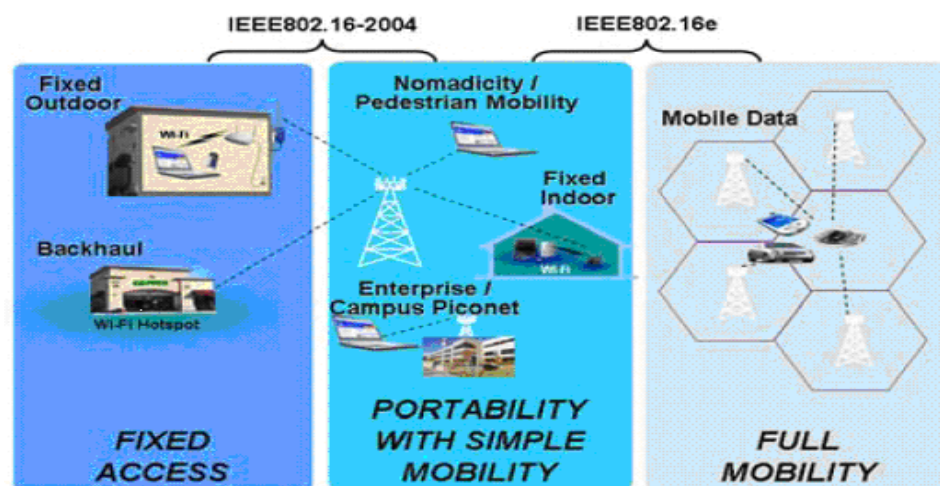


Figure 2.29: WiMAX Applications

2.6.8 Quality of Service (QoS)

The IEEE 802.16 standard has been designed to fully support multiple network layer protocols, either ATM or packets (IP, Ethernet...). Thus, Quality of Service is a key feature of the standard, as multiple types of traffic may be carried through the network. Achieving a QoS on the whole system scale is made possible by the standard through the combination of multiple features:

1. Connection allocation, modification and deletion on either Subscriber or Base Station request,

2. Fragmentation of MAC Service Data Units (SDUs) in order to fit in allocated time slots. This parameter is set on a per-connection basis,
3. Packing of MAC SDUs in one allocated time slot. This parameter is set on a per connection basis,
4. Dynamic setting of the uplink map,
5. Dynamic setting of the downlink map,

The standard does not describe how to implement a particular QoS, but specifies the tools available to achieve such a goal, which allows competition and vendor specific implementations.

2.7 WIBRO

2.7.1 Introduction

WIBRO stands for **W**ireless **B**roadband Internet [45]. It can work on lower cost, higher speed than mobile phone Internet and add mobility. Using WiBro, we can enjoy high speed Internet even when we moving. Many people believe that WiBro can realize Ubiquitous society. It is 3.5G Wireless Mobile Communication System High-speed Portable Internet. It is based on TTA PG302 and IEEE802.16e Standard.

This technology is the latest advancement in Wireless Communication which presents drastic change in Wireless Internet and helpful to connect each and every person globally. It is the most advanced and upcoming technology now a days. WiBro is the Portable Internet Service to provide a high data rate and wireless internet access with PSS (Personal Subscriber Station) under the stationary or mobile environment, anytime and anywhere. It is part of the IEEE 802.16 family such as WiMAX. With the help of WiBro, it is possible to expand the bandwidth and to accommodate a plenty of user to access the wireless internet. Because of large frequency band of 2.3 to 2.4 GHz and channel bandwidth of 9 MHz, it can cover of large coverage area of hundreds and thousands of km. It adopts TDM multiplexing , TDD duplexing technique and OFDMA multiple access technique. Due to OFDMA all the carriers are orthogonal to each other,it minimizes the self-interference.

WiBro is a 2.3 GHz based Mobile WiMAX system. [46] The Mobile WiMAX/WiBro system distinguishes itself by the three distinctive features,

namely, broadband, IP and mobility. It provides high-speed data services over 19/5Mbps downlink/uplink in its initial stage, which is likely to be doubled in the second stage. It fully employs the IP technology, differently from the existing circuit-mode cellular systems such as WCDMA/HSDPA and cdma2000/EV-DO. In addition, it can provide high-rate data services to the mobile users moving over 120 km/h. In this aspect, the Mobile WiMAX/WiBro system is viewed to be on the path towards the 4th generation wireless systems. Figure 2.30 shows versatility of WiBro.

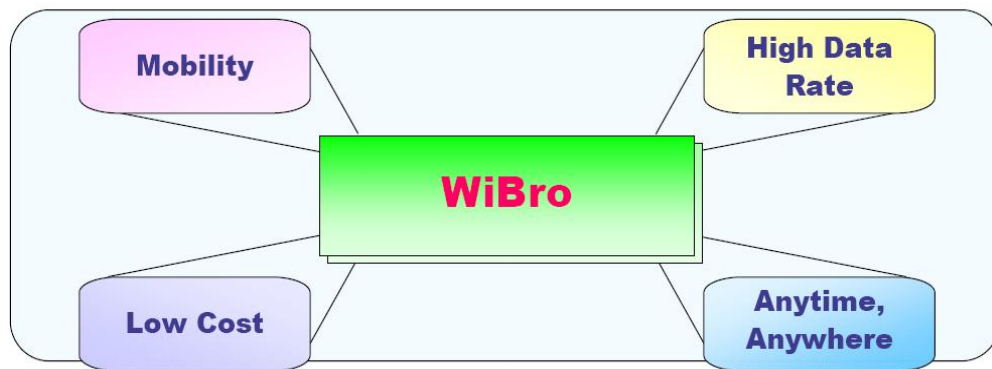


Figure 2.30: Versatility of WiBro

2.7.2 Network Architecture of WiBro or Indoor WiBro network model

The network architecture of WiBro in the phase I standardization is shown in Figure 2.31. Basically, the network architecture of WiBro is the same as other IP-based networks but there is difference at the radio access network. A new RAN has been designed to enable the requirements of high data rate with mobility [47]. RAS have the responsibility to interface between mobile and core network at the physical layer and it also controls the radio resource at the data link layer in conjunction with ACR. RAS and ACR also support link layer handoff.

Indoor WiBro system is supposed to be deployed in home and office. In this case, each indoor RAS can construct its own private network (Femto cell). Usually, indoor WiBro network in home environment does not even contain ACR. The RAS of indoor WiBro takes over some essential functions of ACR instead. Also, there can exist an simplified ACR in the indoor WiBro network,

namely pico-ACR, in office area. However, the functions of a pico-ACR are very different from those of the existing ACR in outdoor WiBro system.

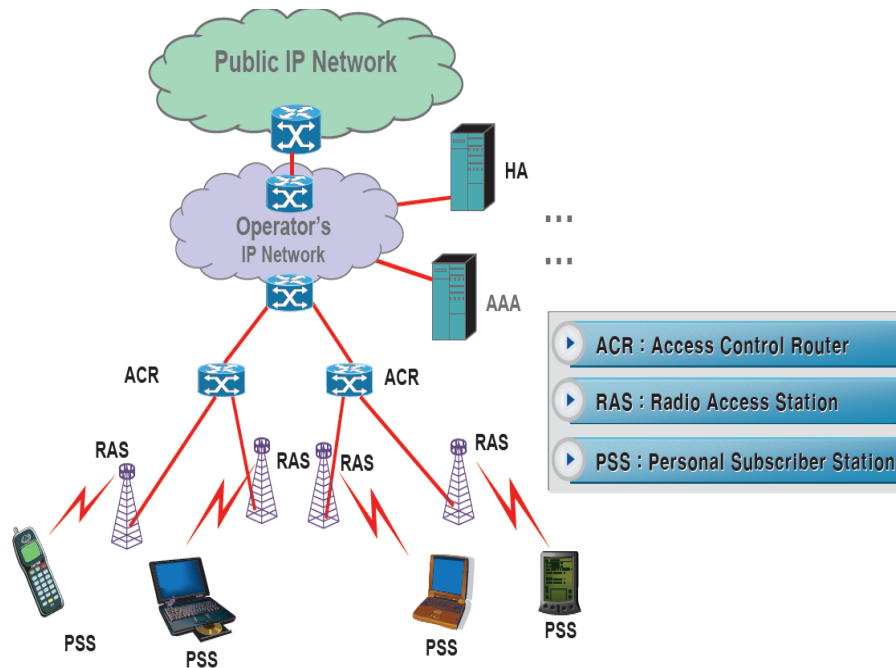


Figure 2.31: Network Architecture of WiBro (Phase I standardization)

Therefore, if we directly apply the existing layered architecture for network management to indoor WiBro system, each RAS in home and each ACR in office should have their own WiBro [48] [49]. Figure 2.32 shows WiBro system architecture.

Functionality of ACR and RAS

- | | |
|---|--|
| <ul style="list-style-type: none"> ➤ ACR – Access Control Router <ul style="list-style-type: none"> • Packet classification & header suppression • Service flow management • Traffic switching & Integration point • Handover management • Session information maintenance • RAS interface • Core network interface | <ul style="list-style-type: none"> ➤ RAS – Radio Access Station <ul style="list-style-type: none"> • PHY Processing and air resource scheduling • MAC management message processing • MAC PDU processing • CID management • Encryption & Decryption • ACR interface |
|---|--|

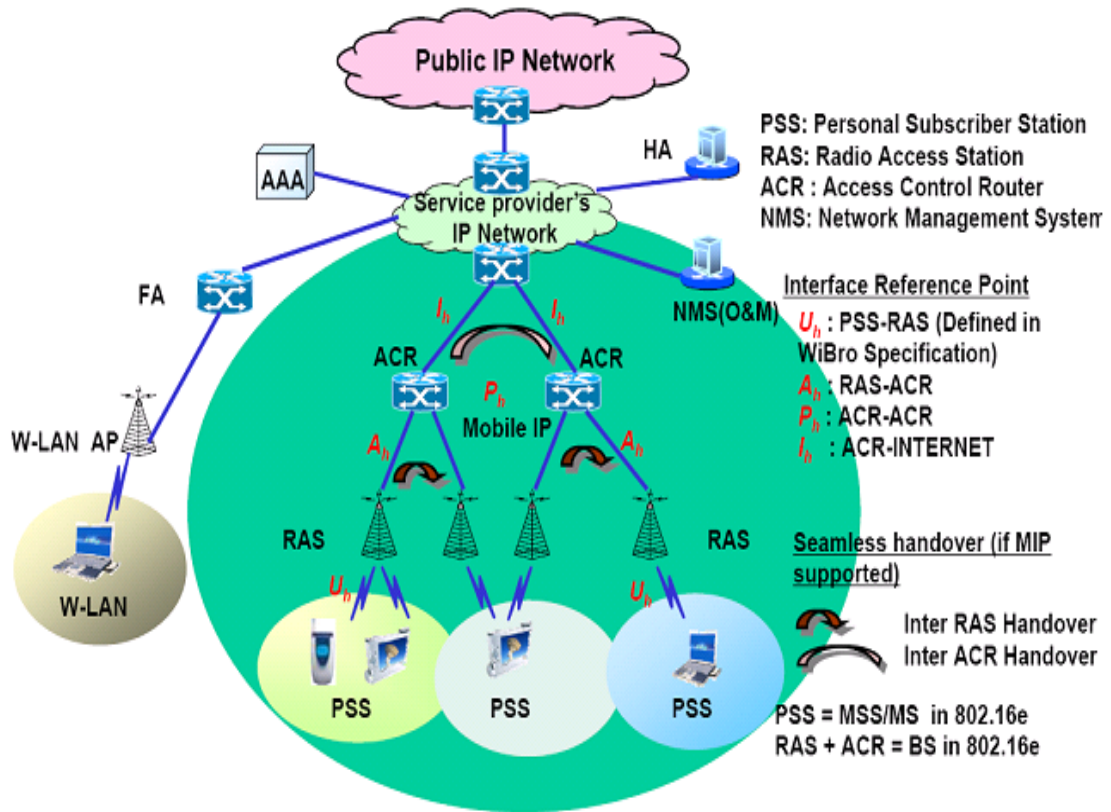


Figure 2.32: WiBro System Architecture

2.7.3 WiBro system specifications

- Multiple Access/Duplexing : OFDMA/TDD
- Frequency band: 2.3 GHz ~ 2.4 GHz
- Frequency reuse factor: 1
- Number of used tones: 864 out of 1,024
- Number of data tones: 768
- Number of pilot tones: 96
- Tone spacing: 9.765625 kHz
- Signal bandwidth: 8.447 MHz
- Ratio of cyclic prefix time to the basic OFDM symbol time: 1/8
- Basic OFDMA symbol time: 102.4 ms
- Cyclic prefix time: 12.8 ms
- OFDMA symbol time: 115.2 ms
- TDD frame length: 5 ms

- Number of symbols in a frame: 42
- Channel BW: 8.75 (~9) MHz
- Modulation: QPSK,16QAM,64QAM
- Mobility: ≤ 60 km/h
- Handoff: ≤ 150 ms
- Throughput (per user): Download 512 Kbps to 3 Mbps, Upload 128 Kbps to 1 Mbps
- Service coverage : 1~2 km
- Spectral Efficiency[bps/Hz/Cell(Sector)] : Download 2-6, Upload 1-2
- Bandwidth : 10 MHz sampling BW or Frequency with 1024 FFT with 9 MHz carrier spacing Synchronized transmission
- Modulation level: QPSK(DL/UL), 16QAM(DL/UL), 64QAM(DL only)
- User Data Rate : > 1 Mbps/user

2.7.4 Key features of WiBro

- High speed internet service (indoor & outdoor)
- Maximize the usage over the allocated spectrum
- Maximize the spectral efficiency
- Extend the service coverage
- Reduce the cost per bit
- Low power consumption
- Faster handoff
- Easy cell planning
- Roaming with cellular and WLAN
- Much lower service charges than EV-DO
- Much higher-speed Internet access than EV-DO
- Mobile Internet access in high-speed mobile environment
- Much wider coverage than wireless LAN-based services
- Flexible sub channelization for band selection and diversity
- Full diversity sub channel by multiple symbol grouping
- Preamble for Cell differentiation with different Random sequences
- Pilot tone based DL and UL and Pilot-assist transmission in DL and UL
- OFDM symbol timing and frequency

- WiBro is for the wireless high-speed broadband service able to deliver data, video and voice at speeds of up to 120 km/h.
- WiBro (Mobile WiMAX) provides true mobile connectivity by giving users seamless broadband connections anytime, anywhere.
- Portable and mobile applications include WiBro will provide broadband services to metropolitan areas not accessible by current technology as well as create broadband "hot zones" in more densely populated areas.
- WiBro service is being provided in Korea using 100 MHz of frequency spectrum in the 2.3GHz band.
- WiBro technology can become one of the strong candidates for the 4G (4th Generation) wireless standard and WiBro in aperture between 3G and 4G.
- WiBro services can have potential applications in various fields e.g.,
 - Interactive services: Web Browsing, Game interface, Interactive information, Wireless Internet access, Network Game etc
 - Streaming services: VoD, MPEG, etc.
 - Back Ground services: FTP, E-MAIL, SMS, multicast/broadcast, MMS, Push To Talk, Real time broadcasting, Conferencing etc.
 - Information service : Voice over Internet Protocol (VoIP), Video telephony
- Figure 2.33 shows WiBro positioning in Wireless Technology Roadmap

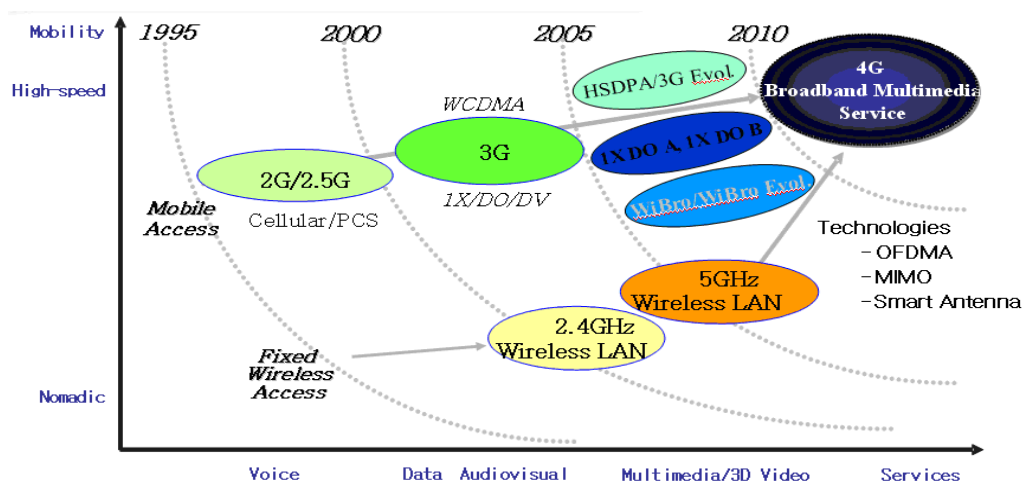


Figure 2.33: Wireless technology roadmap: WiBro Positioning

2.7.5 Advantages of WiBro

- Provides high data rate and high speed internet service (indoor & outdoor)
- Maximize the usage over the allocated spectrum
- Maximize the spectral efficiency
- Extend the service coverage
- Reduce the cost per bit
- Low power consumption
- Faster handoff
- Easy cell planning
- Roaming with cellular and WLAN
- Frequency reuse is possible

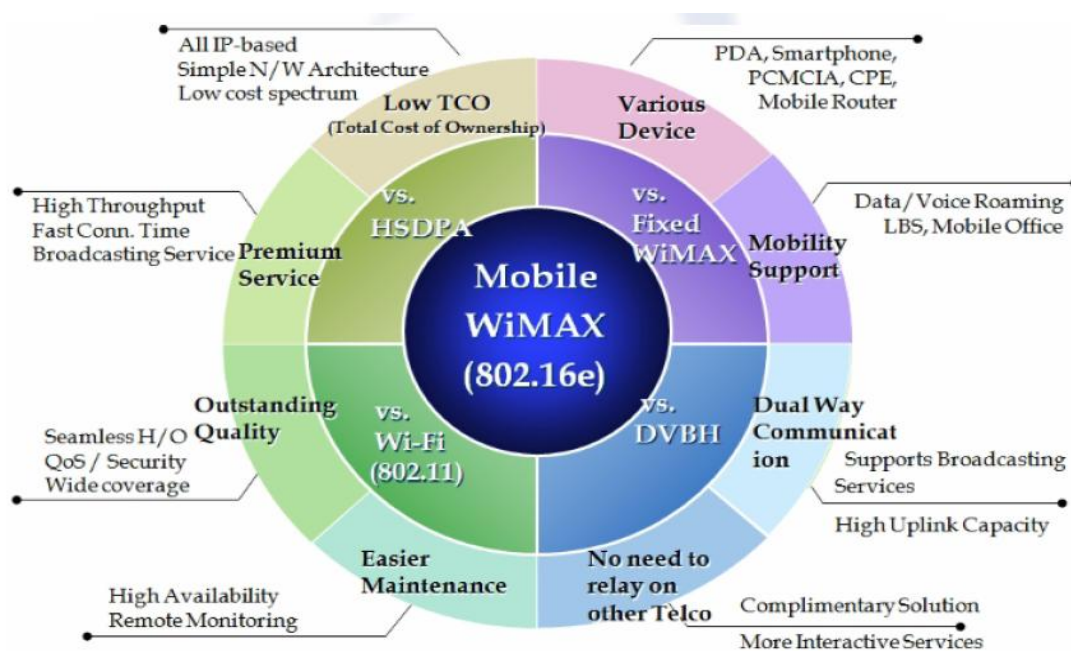


Figure 2.34: Advantages of WiBro Technology

2.8 Comparison of Different Wireless Communication Technologies with respect to Various Aspects for MARS Application .

This chapter includes theoretical comparison of different wireless communication technologies with reference to various aspects like Power, Number of users accommodated, Mobility, Data rate, Frequency, IEEE Standard, Coverage area etc.

2.8.1 Theoretical Comparison

This includes comparison of various wireless communication technologies with respect to various aspects as shown in Table 2.4 and Table 2.5.

*Table 2.4 Comparison of Wireless Communication Technologies
[GSM/GPRS&UMTS]*

Aspects	GSM/GPRS	UMTS
IEEE Standard	-	-
Data rate	171.2 Kbps	8 kbps, 144 Kbps, 384 Kbps, 2 Mbps (2 Mbps - 10 Mbps)
Frequency range (BW)	890-915 MHz: Uplink , 935-960 MHz: Downlink	1920 - 1980 MHz: Uplink , 2110 - 2170 MHz: Downlink
Mobility	80 - 150 Km/h (Approx.)	300 - 350 Km/h (Approx.)
Range (Coverage)	1000+ meter (Approx. 20-22 Km)	1000+ meter (Approx. 35-40 Km)
Channel Condition (LOS,NLOS)	LOS	NLOS
Modulation	GMSK	QPSK,BPSK
Multiple Access	TDMA	CDMA
Duplexing	FDD	TDD/FDD
Generation	2G/2.5G	3G
No. of user accommodated	Large (Approx. 120 user)	Large (Approx. 250 user)
Mode supported	TCP/IP	Asynchronous Transfer Mode (ATM), Internet Protocol (IP)
Devices/ Elements used	BTS, BSC, MSC, HLR,EIR, VLR, AuC, MS, SGSN, GGSN	UMTS – UE, Node-B, SGSN, GGSN, RNC, UTRAN
Infrastructure Cost	High	High
Application	Wide Area Voice and Data, Low speed internet access	Audio and video streaming (movies etc.), video-conferencing, Moderate to high speed internet access
Advantages	Existing Infrastructure	Better QoS, More user control
Access	Point to Multipoint	Point to Multipoint

*Table 2.5 Comparison of Wireless Communication Technologies
[WLAN, WiFi, WiMax, WiBro]*

Aspects	WLAN	WiFi	WiMAX	WiBro
IEEE Standard	802.11x(a/g)	802.11b	802.16d	802.16e
Data rate	6 to 54 Mbps	5.5 to 11 Mbps	70 Mbps	8.75-9 Mbps
Frequency range (BW)	5/2.4 GHz	2.4 GHz	10-66 GHz	2.3—2.4 GHz
Mobility	Pedestrian	Pedestrian	Pedestrian	60-120 Km/h
Range (Coverage)	10-20m (Up to 100m)	1-100m 32m (indoors) & 95m (Outdoors)	40-50 Km (Large)	1-2 Km (Medium)
Channel Condition (LOS,NLOS)	NLOS	NLOS	LOS/ NLOS	NLOS
Modulation	OFDM, BPSK, QPSK	complementary code keying (CCK)	QPSK,16QAM, 64QAM	QPSK,16QAM, 64QAM
Multiple Access	CSMA-CA	FHSS,DSSS	OFDMA	OFDMA
Duplexing	TDD	TDD	OFDM/TDD	TDD
Generation	-	-	3.5G	Between 3.5-4G
No. of user accommodated	4 – 8 user	40 – 50 user	1000+ user	1000+ user
Mode supported	Adhoc mode, Infrastructure mode	Adhoc mode, Infrastructure mode	-	-
Devices/ Elements used	Access point, Nodes(PC, Laptop, Mobile etc)	Access point, Nodes(PC, Laptop, Mobile etc)	Subscriber station, Base station	Subscriber station, Base station
Infrastructure Cost	Low	Moderate	High	High
Application	High Speed Internet Access, PC networking, File transfers	Internet browsing, PC networking, File transfers	Wireless stationary, cable TV, telephony and heavy-duty multimedia	High Speed Wireless Internet Access with Mobility
Advantages	Speed, Ubiquity, Data & Voice Access Points, Ad-Hoc Networking, Cable Replacement	Speed, Flexibility, Ad-hoc networks easy to establish, No cables, Robustness	High speed wireless broadband access	High speed, Mobility, Wide coverage area
Access	Point to Point	Point to Point	Point to Multipoint	Point to Multipoint

1.4 Organization of thesis

Chapter 2 It gives Overview of Various Wireless Communication Technologies. GSM (Global System for Mobile Communication), GPRS (General Packet Radio Service), UMTS (Universal Mobile Telephone System), WLAN (Wireless Local Area Network), Wi-Fi(Wireless Fidelity),Wi-MAX (Worldwide Interoperability for Microwave Access) and WiBro (Wireless Broadband)

Chapter 3 It gives Overview of Mobile Augmented Reality System with new Layered Architecture concept and Applications.

Chapter 4 It gives Overview of QualNET simulator. It throws lights on various tools available in QualNET. It also shows how it differs from other simulators and It explains how to design a scenario, how to run it and analyze results.

Chapter 5 It gives details of different Simulation results of Wireless Technologies. GSM (Global System for Mobile Communication)/GPRS (General Packet Radio Service), UMTS (Universal Mobile Telephone System), WLAN (Wireless Local Area Network), Wi-Fi (Wireless Fidelity),Wi-MAX (Worldwide Interoperability for Microwave Access) and WiBro (Wireless Broadband) Using QualNET 5.0 Simulator.

Chapter 6 It gives details of Development and Implementation of Mobile Augmentation Reality System Application.

Chapter 7 It contains Conclusion and Future Aspects.

Chapter 2: Overview of Various Wireless Communication Technologies

2.1 GSM Technology

2.1.1 Introduction to GSM

During early 1980s, analog cellular telephone systems were experiencing rapid growth in Europe, particularly in Scandinavia and the United Kingdom, and also in France and Germany. Each country developed its own system, which was incompatible with everyone else's in equipment and operation. This was an undesirable situation, because not only were the mobile equipment limited to operation within national boundaries, which in a unified Europe were increasingly unimportant, but there was also a very limited market for each type of equipment, so scale of economy and the subsequent savings could not be realized.

The Europeans realized this early on, and in 1982 the Conference of European Posts and Telegraphs (CEPT) formed a study group called the Global System for Mobile Communication (GSM) to study and to develop a pan-European public land mobile system. [1] The proposed system had to meet certain criteria:

- Good subjective speech quality
- Low terminal and service cost
- Support for international roaming
- Ability to support handheld terminals
- Support for range of new services and facilities
- Spectral efficiency
- ISDN compatibility

In 1989, GSM responsibility was transferred to the European Telecommunication Standards Institute (ETSI), and phase I of the GSM specifications were published in 1990. Commercial service was started in mid-1991, and by 1993 there were 36 GSM networks in 22 countries. Although standardized in Europe, GSM was not only a European standard. Over 200

GSM networks (including DCS1800 and PCS1900) are operational in 110 countries around the world. In the beginning of 1994, there were 1.3 million subscribers worldwide, which had grown to more than 55 million by October 1997. With North America making a delayed entry into the GSM field with a derivative of GSM called PCS1900, GSM systems exist on every continent, and the acronym GSM now aptly stands for Global System for Mobile communications.

The developers of GSM choose an unproven (at the time) digital system, as opposed to the then-standard analog cellular systems like AMPS in the United States and TACS in the United Kingdom. They had faith that advancements in compression algorithms and digital signal processors would allow the fulfillment of the original criteria and the continual improvement of the system in terms of quality and cost. Over 8000 pages of GSM recommendations tried to allow flexibility and competitive innovation among suppliers, but provide enough standardization that guarantee proper interworking between the components of the system. This was done by providing functional and interface descriptions for each of the functional entities defined in the system.

2.1.2 GSM Specifications [2] [3]

Specification Summary for GSM Cellular System

Multiple access technology	FDMA / TDMA
Duplex technique	FDD
Uplink frequency band	933 -960 MHz (basic 900 MHz band only)
Downlink frequency band	890 - 915 MHz (basic 900 MHz band only)
Channel spacing	200 kHz
Modulation	GMSK
Speech coding	Various - original was RPE-LTP/13
Speech channels per RF channel	8
Channel data rate	270.833 kbps
Frame duration	4.615 ms

2.1.3 GSM Subscriber Services [4]

There are two basic types of services offered through GSM: telephony (also referred to as teleservices) and data (also referred to as bearer services). Telephony services are mainly voice services that provide subscribers with the complete capability (including necessary terminal equipment) to communicate with other subscribers. Data services provide the capacity necessary to transmit appropriate data signals between two access points creating an interface to the network. In addition to normal telephony and emergency calling, the following subscriber services are supported by GSM:

Dual-tone Multi-Frequency	Cell broadcast
Facsimile group III	Voice mail
Short message services	Fax mail

Supplementary Services

GSM supports a comprehensive set of supplementary services that can complement and support both telephony and data services. Supplementary services are defined by GSM and are characterized as revenue-generating features. A partial listing of supplementary services are as follows.

- Call forwarding
- Barring of outgoing calls
- Barring of incoming calls
- Advice of charge (AoC)
- Call hold
- Call waiting
- Multiparty service
- Calling line identification presentation/restriction
- Closed user groups (CUGs)

2.1.4 GSM Network Architecture [5]

The GSM technical specifications define the different elements within the GSM network architecture. It defines the different elements and the ways in which they interact to enable the overall network operation to be maintained. The GSM network architecture is now well established and with the other later cellular systems now established and other new ones being deployed, the basic GSM network architecture has been updated to interface to the network elements required by these systems. Despite the developments of the newer systems, the basic GSM network architecture has been maintained, and the elements described below perform the same functions as they did when the original GSM system was launched in the early 1990s.

GSM network architecture elements

The GSM network architecture as defined in the GSM specifications can be grouped into four main areas:

- Mobile station (MS)
- Base-station subsystem (BSS)
- Network and Switching Subsystem (NSS)
- Operation and Support Subsystem (OSS)

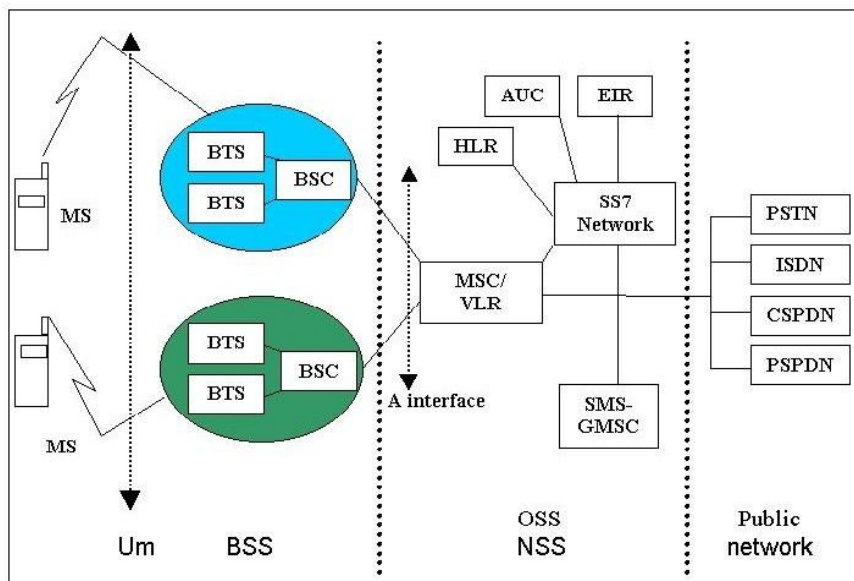


Figure 2.1: GSM network architecture

Mobile station

Mobile stations (MS), mobile equipment (ME) or as they are most widely known, cell or mobile phones are the section of a GSM cellular network that the user sees and operates. In recent years their size has fallen dramatically while the level of functionality has greatly increased. A further advantage is that the charges between the time limits reduced.

Base Station Subsystem (BSS)

The Base Station Subsystem (BSS) section of the GSM network architecture that is fundamentally associated with communicating with the mobiles on the network. It consists of two elements:

- **Base Transceiver Station (BTS):** The BTS used in a GSM network comprises of the radio transmitter receivers, and their associated antennas that transmit and receive to directly communicate with the mobiles.
- **Base Station Controller (BSC):** It controls a group of BTSs, and is often co-located with one of the BTSs in its group. It manages the radio resources and controls items such as handover within the group of BTSs, allocates channels and the like, It communicates with the BTSs over what is termed the Abis interface.

Network Switching Subsystem (NSS)

The GSM network subsystem contains a variety of different elements, and is often termed as the core network. It provides the main control and interfacing for the whole mobile network. The major elements within the core network include:

- **Mobile Switching services Centre (MSC):** The main element within the core network area of the overall GSM network architecture is the Mobile switching Services Centre (MSC). Functions include registration, authentication, call location, inter-MSC handovers and call routing to a mobile subscriber.
- **Home Location Register (HLR):** This database contains all the administrative information about each subscriber along with their last

known location. In this way, the GSM network is able to route calls to the relevant base station for the MS.

- **Visitor Location Register (VLR):** This contains selected information from the HLR that enables the selected services for the individual subscriber to be provided.
- **Equipment Identity Register (EIR):** The EIR is the entity that decides whether given mobile equipment may be allowed onto the network. Dependent upon the information held in the EIR, the mobile may be allocated one of three states - allowed onto the network, barred access, or monitored in case of problems.
- **Authentication Centre (AuC):** The AuC is a protected database that contains the secret key also contained in the user's SIM card. It is used for authentication and for ciphering on the radio channel.
- **Gateway Mobile Switching Centre (GMSC):** The GMSC is the point to which a ME terminating call is initially routed, without any knowledge of the MS's location. The GMSC is thus in charge of obtaining the MSRN (Mobile Station Roaming Number) from the HLR based on the MSISDN (Mobile Station ISDN number, the "directory number" of a MS) and routing the call to the correct visited MSC.
- **SMS Gateway (SMS-G):** The two gateways handle messages directed in different directions. The SMS-GMSC (Short Message Service Gateway Mobile Switching Centre) is for short messages being sent to an ME. The SMS-IW MSC (Short Message Service Inter-Working Mobile Switching Centre) is used for short messages originated with a mobile on that network.

Operation and Support Subsystem (OSS)

It is used to control and monitor the overall GSM network and it is also used to control the traffic load of the BSS.

2.1.5 GSM Network Interfaces [2]

The network structure is defined within the GSM standards. Additionally each interface between the different elements of the GSM network is also defined. It enables to a large degree that network elements from different manufacturers can be used.

1. **Um interface** The "air" or radio interface standard that is used for exchanges between a mobile (ME) and a base station (BTS / BSC). For signaling, a modified version of the ISDN LAPD, known as LAPDm is used.
2. **Abis interface** This is a BSS internal interface linking the BSC and a BTS. The Abis interface allows control of the radio equipment and radio frequency allocation in the BTS.
3. **A interface** The A interface is used to provide communication between the BSS and the MSC. The interface carries information to enable the channels, timeslots and the like to be allocated to the mobile equipments being serviced by the BSSs. The messaging required within the network to enable handover etc to be undertaken is carried over the interface.
4. **B interface** The B interface exists between the MSC and the VLR. It uses a protocol known as the MAP/B protocol. The interface is used whenever the MSC needs access to data regarding a MS located in its area.
5. **C interface** The C interface is located between the HLR and a GMSC or a SMS-G. When a call originates from outside the network it has to pass through the gateway so that routing information required to complete the call may be gained. The protocol used for communication is MAP/C.
6. **D interface** The D interface is situated between the VLR and HLR. It uses the MAP/D protocol to exchange the data related to the location of the ME and for the management of the subscriber.
7. **E interface** The E interface provides communication between two MSCs. The E interface exchanges data related to handover between the anchor and relay MSCs using the MAP/E protocol.
8. **F interface** The F interface is used between an MSC and EIR. It uses the MAP/F protocol. The communications along this interface are used to confirm the status of IMEI of the ME about gaining access to the network.
9. **G interface** The G interface interconnects two VLRs of different MSCs and uses the MAP/G protocol to transfer subscriber information, during e.g. a location update procedure.

10.H interface The H interface exists between the MSC and the SMS-G. It transfers short messages and uses the MAP/H protocol.

11.I interface: This interface can be found between the MSC and the ME. Messages exchanged over I interface are relayed transparently through the BSS.

Although the interfaces for the GSM cellular system may not be as rigorously defined as many might like, but they at least provide a large element of the definition required, enabling the functionality of GSM network entities to be defined sufficiently

2.1.6 GSM Radio Air Interface, GSM Slot and Burst

One of the key elements of the development of the GSM was the development of the GSM air interface. There were many requirements that were placed on the system, and many of these had a direct impact on the air interface. Elements including the modulation, GSM slot structure, burst structure and the like were all devised to provide the optimum performance.

GSM signal and GMSK modulation characteristics

The core of any radio based system is the format of the radio signal itself. The carrier is modulated using a form of phase shift keying known as Gaussian Minimum Shift Keying (GMSK). GMSK was used for the GSM system for a variety of reasons:

- It is resistant to noise when compared to many other forms of modulation.
- Radiation outside the accepted bandwidth is lower than other forms of phase shift keying.
- It has a constant power level which allows higher efficiency RF power amplifiers to be used in the handset, thereby reducing current consumption and conserving battery life.

GMSK has advantages in terms of spectral efficiency as well as having almost constant amplitude which allows the use of more efficient transmitter power amplifiers, thereby saving on current consumption. The nominal bandwidth for the GSM signal using GMSK is 200 kHz. The unwanted or spurious emissions

outside the nominal bandwidth are sufficiently low to enable adjacent channels to be used from the same base station.

The basic carrier is able to support the data throughput of approximately 270 kbps, but as some of this supports the management overhead, the data rate allotted to each time slot out of eight is only 24.8 kbps. In addition to this error correction is required to overcome the problems of interference, fading and general data errors that may occur. This means that the available data rate for transporting the digitally encoded speech is 13 kbps for the basic vocoders

GSM slot structure and multiple access scheme

GSM uses a combination of both TDMA and FDMA techniques. The FDMA element involves the division by frequency of the (maximum) 25 MHz bandwidth into 124 carrier frequencies spaced 200 kHz apart as already described.

The carriers are then divided in time, using a TDMA scheme. This enables the different users of the single radio frequency channel to be allocated different times slots. They are then able to use the same RF channel without mutual interference. The slot is then the time that is allocated to the particular user, and the GSM burst is the transmission that is made in this time.

Each GSM slot, and hence each GSM burst lasts for 0.577 mS ($15/26$ mS). Eight of these burst periods are grouped into what is known as a TDMA frame. This lasts for approximately 4.615 ms (i.e. $120/26$ ms) and it forms the basic unit for the definition of logical channels. One physical channel has one burst period allocated in each TDMA frame.

There are different types of frame that are carry different data, and also the frames are organized into what are termed multiframes and superframes to provide overall synchronization.

GSM slot structure

This GSM slot is the smallest individual time period that is available to each mobile. It has a defined format because a variety of different types of data are required to be transmitted.

Although there are shortened transmission bursts, the slot is normally used for transmitting 148 bits of information. This data can be used for carrying voice data, control and synchronization data.

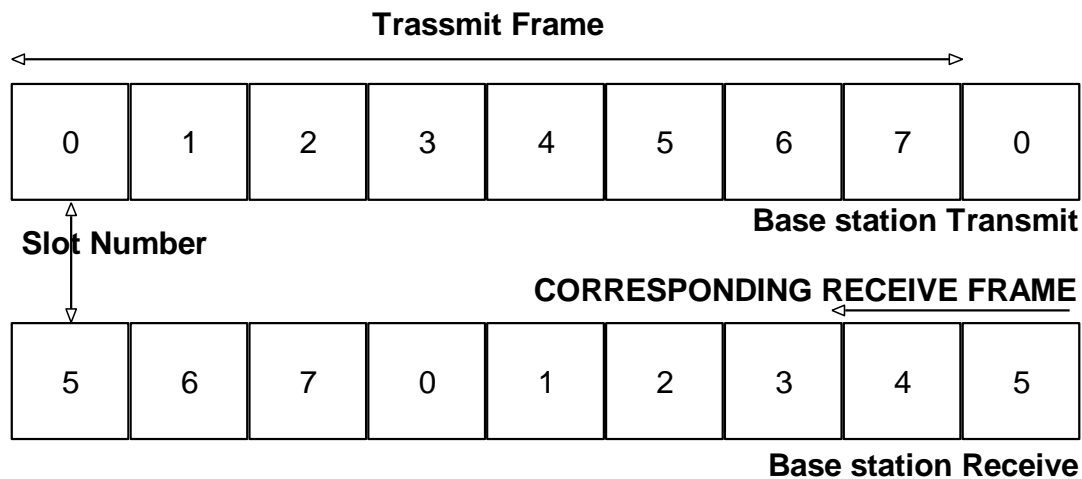


Figure 2.2: GSM Slot offset between transmit and receive frame

It can be seen from the GSM slot structure that the timing of the slots in the uplink and the downlink are not simultaneous, and there is a time offset between transmit and receive. This offset in the GSM slot timing is deliberate and it means that a mobile that which is allocated the same slot in both directions does not transmit and receive at the same time. This considerably reduces the need for expensive filters to isolate the transmitter from the receiver. It also provides a space saving

GSM burst

The GSM burst, or transmission can fulfill a variety of functions. Some GSM bursts are used for carrying data while others are used for control information.

Normal burst *uplink and downlink*

- Synchronization burst *downlink*
- Frequency correction burst *downlink*
- Random Access (Shortened Burst) *uplink*

GSM normal burst

This GSM burst is used for the standard communications between the base station and the mobile, and typically transfers the digitized voice data. The structure of the normal GSM burst is exactly defined and follows a common format. It contains data that provides a number of different functions

T 3	Info 57	F 1	Training 26	F 1	Info 57	T 3	GP 8.25
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Figure 2.3: GSM Normal Burst

GSM synchronization burst

The purpose of this form of GSM burst is to provide synchronization for the mobiles on the network.

T 3	Info 39	Long Training sequence 64	Info 39	T 1	GP 8.25
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Figure 2.4: GSM Synchronization Burst

GSM frequency correction burst

With the information in the burst all set to zeros, the burst essentially consists of a constant frequency carrier with no phase alteration.

T 3	All bits in Frequency correction burst 142	T 3	GP 8.25
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Figure 2.5: GSM Frequency correction Burst

GSM random access burst

This form of GSM burst used when accessing the network and it is shortened in terms of the data carried, having a much longer guard period. This GSM burst structure is used to ensure that it fits in the time slot regardless of any severe timing problems that may exist. Once the mobile has accessed the network and timing has been aligned, then there is no requirement for the long guard period.

T 7	Train 41	Data 36	T 3	GP 69.25
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Figure 2.6: GSM Random Access Burst

GSM discontinuous transmission (DTx)

A further power saving and interference reducing facility is the discontinuous transmission (DTx) capability that is incorporated within the specification. It is particularly useful because there are long pauses in speech. The most

important element of DTx is the Voice Activity Detector. It must correctly distinguish between voice and noise inputs, a task that is not trivial. If a voice signal is misinterpreted as noise, the transmitter is turned off an effect known as clipping results and this is particularly annoying to the person listening to the speech. However if noise is misinterpreted as a voice signal too often, the efficiency of DTX is dramatically decreased. The noise is controlled by the SID (silence indication descriptor).

2.1.7 GSM Frame Structure [2], [6]

The GSM system has a defined GSM frame structure to enable the orderly passage of information. The GSM frame structure establishes schedules for the predetermined use of timeslots.

By establishing these schedules and by the use of a frame structure, both the mobile and the base station are able to communicate not only over the voice data, but also signaling information without the various types of data becoming intermixed and both ends of the transmission knowing exactly what types of information are being transmitted.

The GSM frame structure provides the basis for the various physical channels used within GSM, and accordingly it is at the heart of the overall system

Basic GSM frame structure

The basic element in the GSM frame structure is the frame itself. This comprises the eight slots, each used for different users within the TDMA system. As mentioned in another page of the tutorial, the slots for transmission and reception for a given mobile are offset in time so that the mobile does not transmit and receive at the same time.

The basic GSM frame defines the structure upon which all the timing and structure of the GSM messaging and signaling is based. The fundamental unit of time is called a burst period and it lasts for approximately 0.577 ms (15/26 ms).

In simplified terms the base station transmits in two types of channel, namely traffic and control. Accordingly the channel structure is organized into two different types of frame, one for the traffic on the main traffic carrier frequency, and the other for the control on the beacon frequency.

GSM Multiframe

The GSM frames are grouped together to form multiframes and in this way it is possible to establish a time schedule for their operation and the network can be synchronized. There are several GSM multiframe structures:

- **Traffic multiframe:** The Traffic Channel frames are organized into multiframes consisting of 26 bursts and taking 120 ms. in a traffic multiframe, 24 bursts are used for traffic. These are numbered 0 to 11 and 13 to 24. One of the remaining bursts is then used to accommodate the SACCH, the remaining frame remaining free. The actual position used alternates between position 12 and 25.
- **Control multiframe:** the Control Channel multiframe that comprises 51 bursts and occupies 235.4 msec. This always occurs on the beacon frequency in time slot zero and it may also occur within slots 2, 4 and 6 of the beacon frequency as well. This multiframe is subdivided into logical channels which are time-scheduled. These logical channels and functions include the following:
 - Frequency correction burst
 - Synchronization burst
 - Broadcast channel (BCH)
 - Paging and Access Grant Channel (PACCH)
 - Stand Alone Dedicated Control Channel (SDCCH)

GSM Superframe

Multiframes are then constructed into superframes taking 6.12 seconds. These consist of 51 traffic multiframes or 26 control multiframes. As the traffic multiframes are 26 bursts long and the control multiframes are 51 bursts long, the different number of traffic and control multiframes within the super frame, brings them back into line again taking exactly the same interval.

GSM Hyperframe

Above this 2048 superframes (i.e. 2 to the power 11) are grouped to form one hyperframe which repeats every 3 hours 28 minutes 53.76 seconds. It is the largest time interval within the GSM frame structure.

Within the GSM hyperframe there is a counter and every time slot has a unique sequential number comprising the frame number and time slot number. This is used to maintain synchronization of the different scheduled operations with the GSM frame structure. These include functions such as:

- **Frequency hopping:** Frequency hopping is a feature that is optional within the GSM system. It can help reduce interference and fading issues, but for it to work, the transmitter and receiver must be synchronized so they hop to the same frequencies at the same time.
- **Encryption:** The encryption process is synchronized over the GSM hyperframe period where a counter is used and the encryption process will repeat with each hyperframe. However, it is unlikely that the cell phone conversation will be over 3 hours and accordingly it is unlikely that security will be compromised as a result.

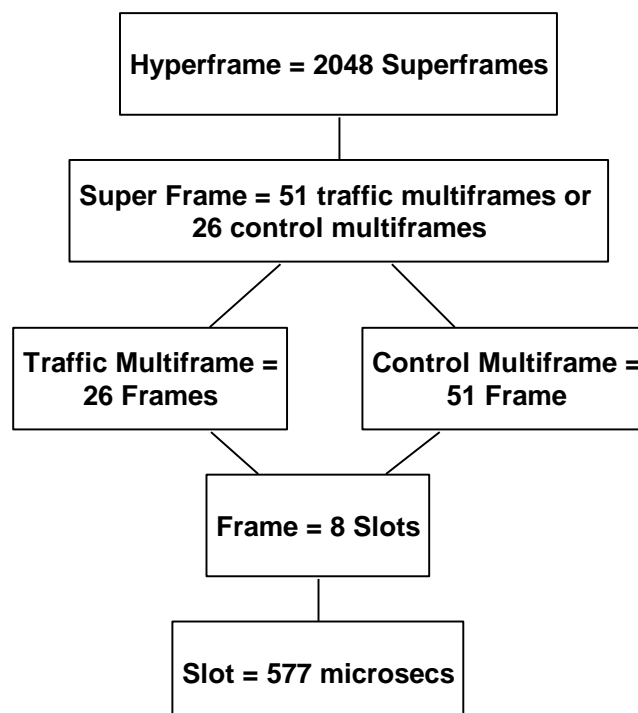


Figure 2.7: GSM Frame Structure Summary

GSM frame structure

By structuring the GSM signaling into frames, multiframes, superframes and hyperframes, the timing and organization is set into an orderly format that enables both the GSM mobile and base station to communicate in a reliable and efficient manner. The GSM frame structure forms the basis onto which the other forms of frame and hence the various GSM channels are built.

2.1.8 GSM Frequencies and Frequency Bands [7]

Although it is possible for the GSM cellular system to work on a variety of frequencies, the GSM standard defines GSM frequency bands and frequencies for the different spectrum allocations that are in use around the globe. For most applications the GSM frequency allocations fall into three or four bands, and therefore it is possible for phones to be used for global roaming.

While the majority of GSM activity falls into just a few bands, for some specialist applications, or in countries where spectrum allocation requirements mean that the standard bands cannot be used, different allocations may be required. Accordingly for most global roaming dual band, tri-band or quad-band phones will operate in most countries, although in some instances phones using other frequencies may be required.

GSM frequency band usage

The usage of the different frequency bands varies around the globe although there is a large degree of standardization. The GSM frequencies available depend upon the regulatory requirements for the particular country and the ITU (International Telecommunications Union) region in which the country is located.

As a rough guide Europe tends to use the GSM 900 and 1800 bands as standard. These bands are also generally used in the Middle East, Africa, Asia and Oceania.

For North America the USA uses both 850 and 1900 MHz bands, the actual band used is determined by the regulatory authorities and is dependent upon

the area. For Canada the 1900 MHz band is the primary one used, particularly for urban areas with 850 MHz used as a backup in rural areas. For Central and South America, the GSM 850 and 1900 MHz frequency bands are the most widely used although there are some areas where other frequencies are used.

GSM band allocations

There are total of fourteen different recognized GSM frequency bands. These are defined in 3GPP TS 45.005.

Table 2.1: GSM frequency bands

Band	Uplink (MHz)	Downlink (MHz)	Comments
380	380.2 - 389.8	390.2 - 399.8	
410	410.2 - 419.8	420.2 - 429.8	
450	450.4 - 457.6	460.4 - 467.6	
480	478.8 - 486.0	488.8 - 496.0	
710	698.0 - 716.0	728.0 - 746.0	
750	747.0 - 762.0	777.0 - 792.0	
810	806.0 - 821.0	851.0 - 866.0	
850	824.0 - 849.0	869.0 - 894.0	
900	890.0 - 915.0	935.0 - 960.0	P-GSM, i.e. Primary or standard GSM allocation
900	880.0 - 915.0	925.0 - 960.0	E-GSM, i.e. Extended GSM allocation
900	876.0 - 915	921.0 - 960.0	R-GSM, i.e. Railway GSM allocation
900	870.4 - 876.0	915.4 - 921.0	T-GSM
1800	1710 – 1785	1805 - 1880	
1900	1850 - 1910	1930 - 1990	

2.1.9 GSM logical and physical channels

GSM uses a variety of channels in which the data is carried. In GSM, these channels are separated into physical channels and logical channels. The Physical channels are determined by the timeslot, whereas the logical channels are determined by the information carried within the physical channel. It can be further optimized by saying that several recurring timeslots on a carrier constitute a physical channel. These are then used by different logical channels to transfer information. These channels may either be used for user data (payload) or for optimizing to enable the system to operate correctly.

Common and dedicated channels

The channels may also be divided into common and dedicated channels. The forward common channels are used for paging to inform a mobile of an incoming call, responding to channel requests, and broadcasting bulletin board information. The return common channel is a random access channel used by the mobile to request channel resources before timing information is conveyed by the BSS.

The dedicated channels are main of two types: those used for optimizing and those used for traffic. The optimizing channels are used for maintenance of the call and for enabling call set up, providing facilities such as handover when the call is in progress, and finally terminating the call. The traffic channels handle the actual payload.

TCHf	Full rate traffic channel.
TCH h	Half rate traffic channel.
BCCH	Broadcast Network information, e.g. for describing the current control channel structure. The BCCH is a point-to-multipoint channel (BSS-to-MS).
SCH	Synchronization of the MSs.
FCHMS	Frequency correction.
AGCH	Acknowledge channel requests from MS and allocate a SDCCH.
PCHMS	Terminating call announcement.

RACHMS	access requests, response to call announcement, location update
FACCHt	For time critical optimizing over the TCH (e.g. for handover optimizing). Traffic burst is stolen for a full optimizing burst.
SACCHt	TCH in-band optimizing, e.g. for link monitoring.
SDCCH	For optimizing exchanges, e.g. during call setup, registration / location updates.
FACCHs	FACCH for the SDCCH. The SDCCH burst is stolen for a full optimizing burst. Function not clear in the present version of GSM (could be used for e.g. handover of an eight-rate channel, i.e. using a “SDCCH-like” channel for other purposes than optimizing).
SACCHs	SDCCH in-band optimizing, e.g. for link monitoring.

2.1.10 GSM handover or handoff [2], [8]

One of the key elements of a mobile phone or cellular telecommunications system is that the system is split into many small cells to provide good frequency re-use and coverage. However as the mobile moves out of one cell to another it must be possible to retain the connection. The process by which this occurs is known as handover or handoff. The term handover is more widely used within Europe, whereas handoff tends to be use more in North America. Either way, handover and handoff are the same process.

Requirements for GSM handover

The process of handover or handoff within any cellular system is of great importance. It is a critical process and if performed incorrectly handover can result in the loss of the call. Dropped calls are particularly annoying to users and if the number of dropped calls rises, customer dissatisfaction increases and they are likely to change to another network. Accordingly GSM handover was an area to which particular attention was paid when developing the standard.

Types of GSM handover

Within the GSM system there are four types of handover that can be performed for GSM only systems:

- **Intra-BTS handover:** This form of GSM handover occurs if it is required to change the frequency or slot being used by a mobile

because of interference, or other reasons. In this form of GSM handover, the mobile remains attached to the same base station transceiver, but change the channel or slot.

- **Inter-BTS Intra BSC handover:** This form of GSM handover or GSM handoff occurs when the mobile moves out of the coverage area of one BTS but into another controlled by the same BSC. In this instance the BSC is able to perform the handover and it assigns a new channel and slot to the mobile, before releasing the old BTS from communicating with the mobile.
- **Inter-BSC handover:** When the mobile moves out of the range of cells controlled by one BSC, a more involved form of handover has to be performed, handing over not only from one BTS to another but one BSC to another. For this the handover is controlled by the MSC.
- **Inter-MSC handover:** This form of handover occurs when there is changing between networks. The two MSCs involved negotiate to control the handover.

2.2 General Packet Radio Service Technology

2.2.1 Introduction

The General Packet Radio Service (GPRS) is a new service that provides actual packet radio access for Global System for Mobile Communications (GSM) and Time-Division Multiple Access (TDMA) users. It provides transmission of IP packets over existing cellular networks, bringing the Internet to the mobile phone [8]. Anything the Internet offers, from web browsing to chat and email, will be available from GSM and TDMA service providers via GPRS-enabled devices. [9]

The main benefits of GPRS are : It reserves radio resources only when there is data to send and it reduces reliance on traditional circuit-switched network elements. The increased functionality of GPRS will decrease the incremental cost to provide data services, an occurrence that will, in turn, increase the penetration of data services among consumer and business users. In addition, GPRS will allow improved quality of data services as measured in terms of reliability, response time, and features supported. The unique

applications that will be developed with GPRS will appeal to a broad base of mobile subscribers and allow operators to differentiate their services.

GPRS is a non-voice, value added, packet-switched, mobile communication system. GPRS is implemented over the existing GSM network. So it shares GSM frequency bands and makes use of many properties of physical layer of the original GSM system, most importantly time-division multiple access frame structure, modulation techniques, and structure of GSM time slots.

From a high level, GPRS can be thought of as an overlay network onto a second-generation GSM network. This data overlay network provides packet data transport at rates from 9.6 to 171 kbps [9] [10]. Additionally, multiple users can share the same air-interface resources. GPRS offers the flexibility and throughput of packet switching. At the same time, because it is designed to work on the existing GSM network, it is relatively easy and cost-effective to implement. It uses the same GSM radio frequencies and base stations that are already in place.

2.2.2 Data communication needs

Before examining GPRS technology in detail, let's review some basic terms of data communications. Data communication applications [11] generally are divided in two categories:

- Real time applications involve small data transactions such as sending or receiving a quick e-mail, performing a financial transaction, getting a sports or news update from the web, or chatting on line.
- Data access applications are bulkier and involve sending or receiving large amounts of data. Examples are downloading web pages and files from the Internet or transferring large files to other users. Two techniques are available for moving data across communication networks:

Circuit switching is a mode in which a connection (or circuit) is established from the point of origin of a data transfer to the destination. Network resources are dedicated for the duration of the call until the user breaks the connection. Using these resources, data can be transmitted or received either continuously or in bursts, depending on the application. Since resources

remain dedicated for the entire duration of a data call, the number of subscribers that the network can support is limited.

Packet switching is a mode in which resources are assigned to a user only when data needs to be sent or received. Data is sent in packets, which are routed across the network along with other user traffic. This technique allows multiple users to share the same resources, thus increasing capacity on the network and managing resources quite effectively. However, the technique does place some limitations on data throughput.

Experience has shown that most data communication applications do not require continuous data transfer. Users may need to be connected to a data communication network (such as a LAN, WAN, the Internet, or a corporate Intranet), but that does not mean they are sending and receiving data at all times. Furthermore, data transfer needs generally are not symmetrical. In most cases users send out small messages but receive large downloads. At any given time, most of the data transfer is in one direction.

General packet radio service (GPRS) [11][12] gives GSM subscribers access to data communication applications such as e-mail, corporate networks, and the Internet using their mobile phones. The GPRS service uses the existing GSM network and adds new packet-switching network equipment. See Figure 3.4. Existing GSM networks use circuit-switched technology to transfer information (voice or data) between users. However, GPRS uses packet switching, which means there is no dedicated circuit assigned to the GPRS mobile phone.

A physical channel is established dynamically, only when data is being transferred. Once the data has been sent, the resource (a timeslot on the air interface) can be re-allocated to other users for more efficient use of the network.

Today's mobile phones will not work with GPRS technology, and so the industry is working on a new generation of mobiles that can handle both GSM and packet-switched communication. In the future, GPRS phones may be integrated into devices such as laptop computers or personal digital

assistants. GPRS also has the ability to support short message service (SMS).

To support high data rates, GPRS employs new air interface error coding schemes and multiple timeslots, in a way similar to HSCSD (high-speed circuit-switched data). Theoretically we can get a maximum data rate of 171.2 kbps by using eight timeslots. However, today this seems unlikely due to challenges of designing the mobile phones and to inadequate air interface quality. Because packet-switched communication allows non continuous assignment of resources to a user, GPRS billing will not be based on connection time, but rather on resource usage [12] [13].

2.2.3 GPRS Specifications

- ▶ Modulation : GMSK
- ▶ Symbol Rate : 270ksym/s
- ▶ Radio data rate per time slot : 228kb/s
- ▶ User data rate per time slot : 228kb/s
- ▶ User data rate per time slot : 20kb/s(CS4)
- ▶ User data rate(8 time slots) : 160kb/s

2.2.4 GPRS network architecture [13], [14]

GPRS technology brings many changes to the existing GSM network. Most of the changes are amendments made by adding new blocks rather than by modifying existing resources. A simplified view of this new hybrid network shows the elements introduced by GPRS.

The gateway GPRS support node (GGSN) is similar to the GSM gateway mobile switching center (GMSC) and provides a gateway between the GPRS network and the public packet data network (PDN) or other GPRS networks. The GGSN provides authentication and location management functions, connects to the home location register (HLR) by means of the Gc interface, and counts the number of packets transmitted for accurate subscriber billing.

The serving GPRS support node (SGSN), like the GSM mobile switching center and visitor location register (MSC/VLR), controls the connection between the network and the mobile station (MS). The SGSN provides

session management and GPRS mobility management functions such as handovers and paging. Functions of the packet control unit (PCU) include converting packet data into a format that can be transferred over the air interface, managing radio resources, and implementing quality of service (QoS) measurements.

PCU	Packet control unit
SGSN:	Serving GPRS support node
CGSN:	Gateway GPRS support node
Gs, Gr, Gc:	SS7 signaling protocol
Gb, Gn:	GPRS data and signaling interfaces

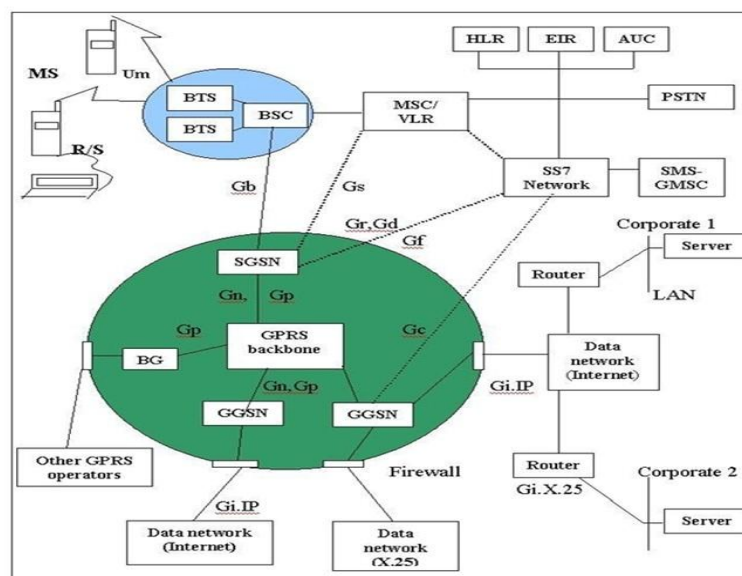


Figure 2.8: GPRS Network Architecture

The signaling links between the GPRS nodes and the GSM blocks will be SS7 MAP interfaces. The signaling between GPRS nodes is defined by the GPRS specifications. New physical interfaces include the Gb interface, which connects the SGSN to the PCU and is usually located in the base station subsystem (BSS); the Gn interface, which connects the GGSN and SGSN; and the Gc, Gr, and Gs interfaces, which carry SS7-based protocols.

2.2.5 GPRS mobile phone operation states

Mobile phones go through different states of communication. For example, when a GSM phone camps onto a network, the phone enters an idle state in which it uses very few network resources. When the user makes a call request or receives a call, however, the phone goes into the dedicated state in which it is assigned a continuous resource until the connection is terminated.

The GPRS mobile phones will also have defined states, which are described below.

- GPRS idle is the state in which the mobile phone camps onto the GSM network. The phone receives circuit-switched paging and behaves as a GSM phone. Although it does not interact with the GPRS network in this state, it still possesses GPRS functionality.
- *GPRS ready is the state achieved when the GPRS mobile attached itself to the network. In this state the mobile phone can activate a packet data protocol (PDP) context, which allows the phone to establish a packet transfer session with external data networks to transmit and receive data packets. Once a PDP context is activated, resource blocks are assigned to the session until data transfer ceases for a specified period and the mobile phone moves into the standby state.
- GPRS standby is a state in which the mobile is connected to the GPRS network, but no data transmission occurs. If a data packet for the mobile arrives, the network will page the mobile, which in turn activates a PDP context session to bring the mobile back to the ready state.

2.2.6 GPRS/GSM mobile classes

ETSI defines three different classes of mobiles for the hybrid GPRS / GSM network:

Class A (GSM/GPRS)

Class A mobiles can attach to the GPRS and GSM network simultaneously. They can receive GSM voice/data/SMS calls and GPRS data calls. For this to happen, the mobiles must monitor both the GSM and GPRS networks for incoming calls. Class A mobiles also can make and

receive GPRS and GSM calls simultaneously. Operational requirements of this class include an additional receiver in the mobile phone for Neighbour cell measurements.

Class B (GSM/GPRS)

This class is similar to class A with the exception that Class B mobile phones will not support simultaneous traffic. If a GPRS call is ON, the phone cannot receive GSM calls and vice versa.

Class C (GSM or GPRS)

This class of mobile phones will have both GSM and GPRS functionality but will attach to only one network at a time. Thus, if the phone is attached to the GPRS network, it will be detached from the GSM network and will not be able to make or receive GSM calls. Conversely, if it is attached to the GSM network, it will not be able to make or receive GPRS calls. Today most manufacturers are building Class B phones.

A GPRS attach is a GPRS mobility management (GMM) process that is always initiated by the mobile phone. Depending on the settings of the mobile phone, the GPRS attach may be performed every time the phone is powered on, or it may be initiated manually by the user.

The request for a GPRS attach is made to the SGSN in a process that is transparent to the BSS. First the mobile notifies the SGSN of its identity as an IMSI (international mobile subscriber identity) or P-TMSI (packet temporary mobile subscriber identity). Then it sends its old routing area identification (RAI), class mark, CKSN, and desired attach type. The latter indicates to the SGSN whether the mobile wants to attach as a GPRS device, a GSM device, or both. The SGSN will attach the mobile and inform the HLR if there has been a change in the RAI. If the desired attach type is both GPRS and GSM, the SGSN will also update the location with the VLR, provided that the Gs interface exists.

Note that a GPRS attach does not enable the mobile phone to transmit and receive data. For this to occur, the mobile has to activate a communication session using PDP context.

2.2.7 Features, Applications & Challenges

Features

- **Speed:** Theoretical maximum speeds of up to 171.2 kilobits per second (kbps) are achievable with GPRS using all eight timeslots at the same time.
- **Immediacy:** GPRS facilitates instant connections whereby information can be sent or received immediately as the need arises, subject to radio coverage.
- **New and better applications:** GPRS facilitates several new applications that have not previously been available over GSM networks due to the limitations in speed of Circuit Switched Data (9.6 kbps) and message length of the Short Message Service (160 characters).

Applications [15]

- **Chat:** Chat can be distinguished from general information services because the source of the information is a person with chat whereas it tends to be from an Internet site for information services.
- **Textual and visual Information:** A wide range of content can be delivered to mobile phone users ranging from share prices, sports scores, weather, flight information, news headlines, prayer reminders, lottery results, jokes, horoscopes, traffic, location sensitive services and so on.
- **Still Images:** Still images such as photographs, pictures, postcards, greeting cards and presentations, static web pages can be sent and received over the mobile network using GPRS.
- **Moving Images:** The wireless industry is moving from text messages to icons and picture messages to photographs and blueprints to video messages and movie previews being downloaded and on to full blown movie watching via data streaming on a mobile device using GPRS.
- **Web Browsing:** Using Circuit Switched Data for web browsing has never been an enduring application for mobile users. Because of the slow speed of Circuit Switched Data, it takes a long time for data to arrive from the Internet server to the browser.
- **Corporate Email**
- **Internet Email**
- **File Transfer**

2.3 Universal Mobile Telecommunication System (UMTS)

2.3.1 Introduction

UMTS is one of the major new 'third generation' (3G) mobile communications systems being developed within the framework defined by the ITU and known as IMT-2000. UMTS will enable the wireless Information Society, delivering high-value broadband information, commerce and entertainment services to mobile users via fixed, wireless and satellite networks. UMTS will speed convergence between telecommunications, IT, media and content industries to deliver new services and create fresh revenue-generating opportunities. UMTS is the European vision of 3G. UMTS is an upgrade from GSM via GPRS or EDGE. The standardization work for UMTS is carried out by Third Generation Partnership Project (3GPP) [13]. UMTS provides variety of data rates: 144 kbps for rural, 384 kbps for urban outdoor, 2048 kbps for indoor and low range outdoor.

The Universal Mobile Telecommunication System (UMTS) is a third generation (3G) mobile communication system that provides a range of broadband wireless and mobile communication services. UMTS maintains the global roaming capability of the second generation (2G) GSM system and its packet-switch mode enhancement (GPRS system) and provides enhanced capabilities. Compared with 2G telecommunication systems, UMTS is able to support multimedia services including graphics, pictures, and video communications, as well as voice and data at a higher data rate and with better quality of service.

UMTS targets to build an all-IP network by extending the second generation GSM/GPRS system and using complex technologies including Code Division Multiple Access (CDMA), Asynchronous Transfer Mode (ATM), and Internet Protocol (IP). GPRS is the convergence point between the 2G technologies and the packet-switch domain of UMTS. According to the GSM association, UMTS will offer a wide range of voice, data and multimedia services. It provides high data rates will reach from 114 to 2000 kbps (or 2 Mbps) depending on whether the user is stationary or in motion. It will also provide

large capacity in order to achieve high data-rate multimedia services in wireless environments.

UMTS is the name given to a totally new performance dimension in mobile radio [16]. UMTS is the cornerstone of what is called the third mobile radio generation (3G) for voice and data communication, both packet and circuit-switched. UMTS employs separate frequency bands so is free from the bottlenecks of GSM systems.

Once UMTS is implemented, it would have the path for HSDPA (High Speed Downlink Packet Access). HSDPA provides a smooth evolutionary path for the UMTS networks to higher data rates and higher capacities, in the same way as Enhanced Data rates for GSM Evolution (EDGE) does in the Global System for Mobile communication (GSM) world. HSDPA is the European 3rd generation wireless standard. [17]

2.3.2 UMTS Architecture

UMTS Generic Architecture The architecture for a typical third generation telecommunication system is illustrated in UMTS architecture in figure 2.9. There are three major categories of network elements:

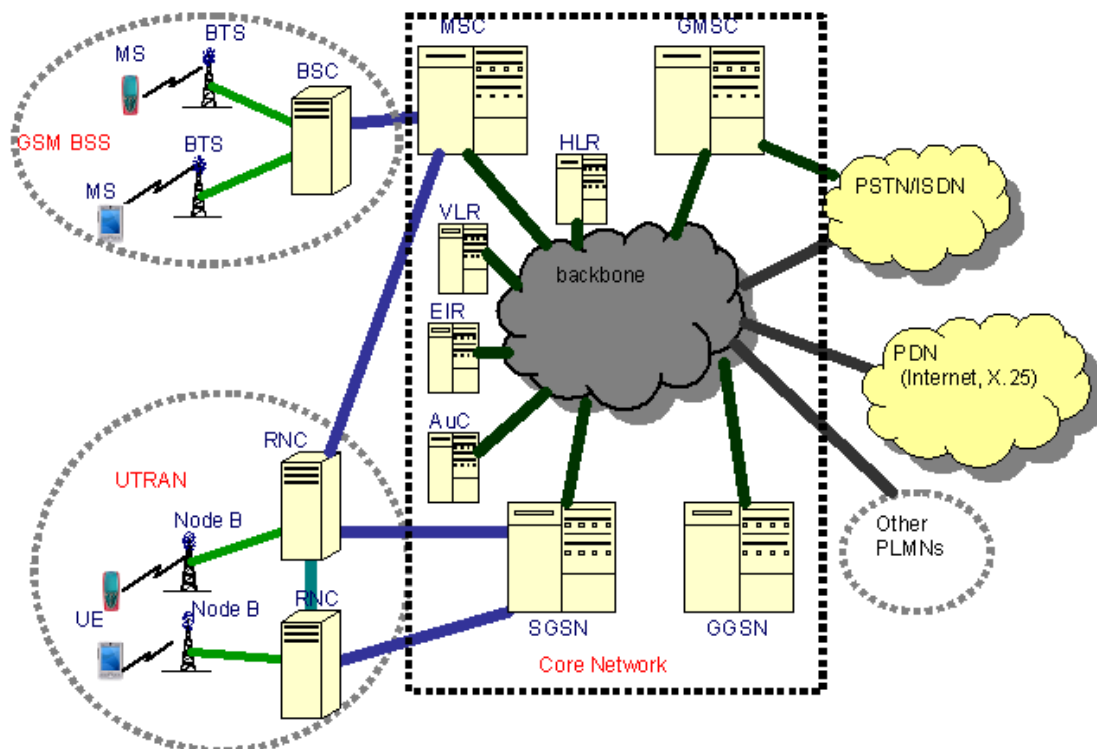


Figure 2.9: UMTS Generic Architecture

- **GSM Core Network Elements:** Mobile Service Center (MSC), Visitor Location Register (VLR), Home Location Register (HLR), Authentication Center (AuC), and Equipment Identity Register (EIR).
- **GPRS Network Elements:** Serving GPRS Support Node (SGSN), and Gateway GPRS Support Node (GGSN).
- **UMTS-specific Network Elements:** User equipment (UE), and UMTS Terrestrial Radio Access Network (UTRAN) elements.

The core network is based on GSM/GPRS, but uses ATM or IP as the transport network. The ATM-based UMTS network is more popular since it ensures various QoS and classes-of-service to the end users. The functions of core networks include switching, routing, transporting, and maintaining a database for user traffic. It contains the circuit-switch domain that includes MSCs, VLRs, and GMSCs, and the packet-switch domain that includes SGSNs and GGSNs. The EIR, HLR, and AuC are part of both domains [16]. In an ATM-based UMTS network, ATM adaptation layer type 2 (ALL2) can handle circuit-switch connections, while ALL5 can handle packet-switched connections.

Architecture of the *QualNet* UMTS Model

The *QualNet* UMTS model is intended to model the network architecture illustrated as in figure 2.10. The Public Land Mobile Network (PLMN) contains different node types, such as UE, Node B, RNC, SGSN, GGSN, and HLR nodes. The SGSN, GGSN, and HLR nodes form the Core Network (CN). It is assumed that the SGSN and GGSN have the capability to handle both circuit switched services and packet switched services. That is, the SGSN also implements the capability of a MSC and the GGSN also implements the capability of a GMSC. Such a SGSN is also called UMTS MSC (UMSC).

Each Node B is connected via a single-hop connection to a RNC and each RNC is connected via a single-hop connection to a SGSN. The RNCs can be connected to each other via single-hop connections. The connections among SGSNs, GGSNs, and HLRs can be any type of backbone network. No special connections are required among them (i.e., they need not be one hop away from each other) [18]. It is assumed that each SGSN has one Visitor Location

Register (VLR) co-located with it. In the *QualNet* UMTS model, the SGSN node also implements the functionality of the VLR.

The GGSN node is a special SGSN node, which acts as a gateway node to interconnect the PLMN with other type of networks such as PSTN, ISDN, or Packet Data Networks (PDNs) such as the Internet. It is also the gateway node that interconnects different PLMNs. One PLMN can have multiple GGSNs to interconnect with different networks. However, it is assumed that one PLMN can only have one Home Location Register (HLR).

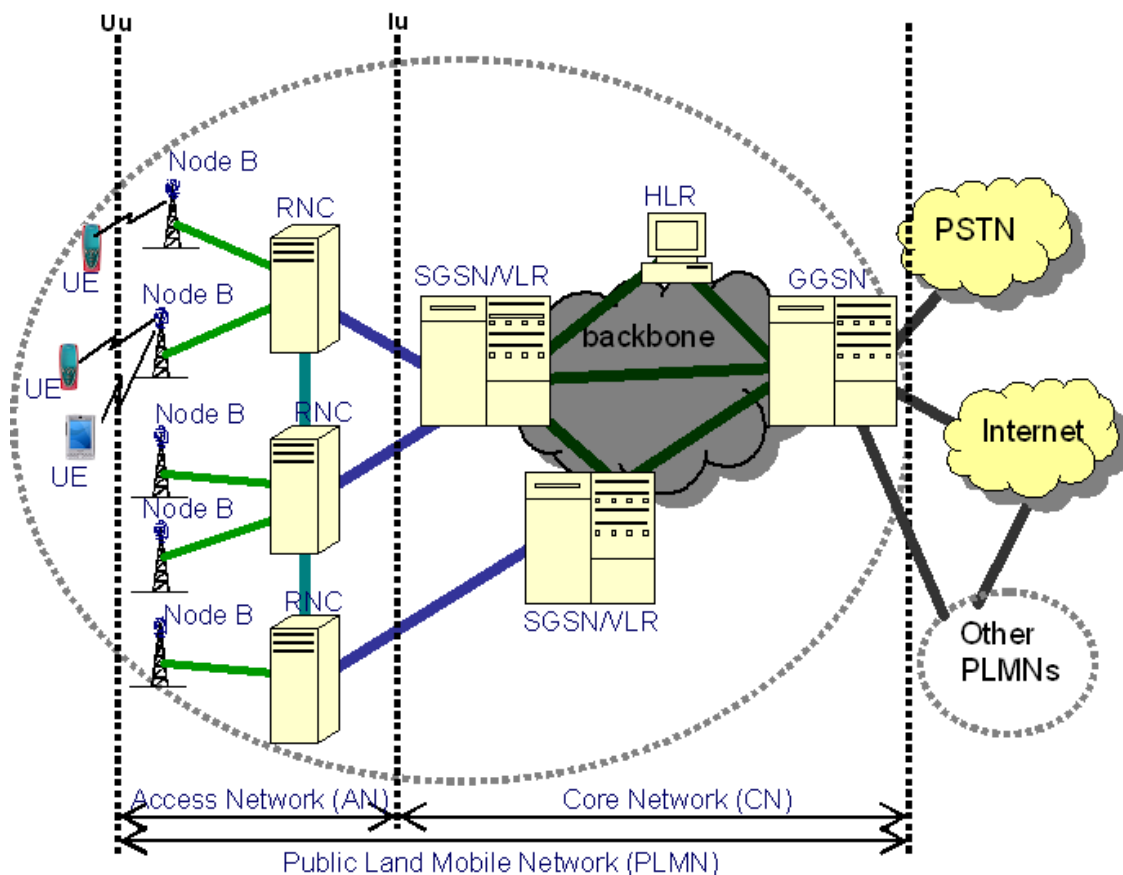


Figure 2.10: Architecture of the QualNet UMTS Model

As illustrated in architecture of the QualNet UMTS Model, the PLMN can be divided into three parts, namely User Equipment (UE), Access Network (AN), and Core Network (CN). The Access Network can more precisely be called the UMTS Terrestrial Radio Access Network (UTRAN). A UE most commonly refers to a user handset. The access network provides radio access to UEs. The core network implements functions such as location registration, handover, session management, call management, etc.

UMTS Frequency Spectrum

- UMTS Band: 1900-2025 MHz and 2110-2200 MHz for 3G transmission.
- Terrestrial UMTS (UTRAN): 1900-1980 MHz, 2010-2025 MHz, and 2110-2170 MHz bands [19].
- Figure 2.11 shows UMTS frequency spectrum.

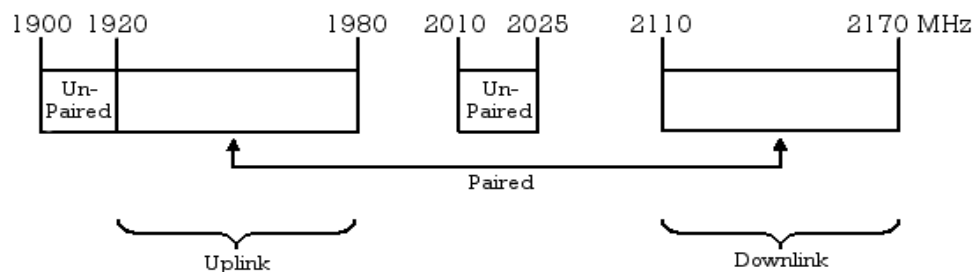


Figure 2.11: UMTS frequency spectrum

2.3.3 UMTS advantages

- Always-on
- Personalized
- Location aware
- Real-time and flexible
- Greater range of enriched multimedia services
- Higher data rates for a greater number of users
- Lower costs in long-term because of network efficiencies
- IP transport in access and core networks
- Separation of control and transport functionalities
- IP multimedia services for mobile devices

2.3.4 UMTS Applications

- Multimedia Messaging Service
- Mobile Intranet/Extranet Access
- Location-based Services
- Wireless Advertising
- Mobile Information
- Business Solutions
- Mobile Transactions

- Radio and Television
- Person-to-Person Communications
- Email and Internet Access
- Real-time image transfer
- Telecommunications
- Video on demand
- Interactive video services
- Entertainment services
- Location based services

2.4 Wireless Local Area Network (WLAN)

2.4.1 Introduction

- 802.11 refers to a family of specifications developed by the IEEE for wireless LAN technology. 802.11 specifies an over-the-air interface between a wireless client and a base station or between two wireless clients.
- **WLAN** is more than just cable replacement, it provides hassle-free broadband Internet access everywhere. Wireless LANs based on the IEEE 802.11 standards allow wire- free networking in the local area network environment using the unlicensed 2.4 or 5 GHz unlicensed radio band [20].
- WLAN is Suitable for local short-distance networking (access point coverage area normally max. ~100m).
- WLAN is compatible with existing LANs.
- Flexible data communication systems and implemented as an extension to the wired networks (LAN).
- Realize on networking in business & meteoric growth of the Internet & online services are strong testimonies to the benefits of shared data & shared resources.
- Minimizes the need for wired connections.
- Combines data connectivity with user mobility and provides general purpose connectivity alternative for a broad range of business customers.

- Users can access shared information without looking for a place to plug in.
- Network managers can set up or augment networks without installing or moving wires.
- Electromagnetic waves (radio or infrared) are used to transmit & receive data over the air.

2.4.2 Overview of 802.11

- An 802.11 LAN is based on a cellular architecture where the system is subdivided into cells. Each cell (called **Basic Service Set**, or **BSS**, in the 802.11 nomenclature) is controlled by a Base Station (called **Access Point** or, in short, **AP**).
- Although a wireless LAN may be formed by a single cell, with a single Access Point, (and as will be described later, it can also work without an Access Point), most installations will be formed by several cells, where the Access Points are connected through some kind of backbone (called **Distribution System** or **DS**). This backbone is typically Ethernet and, in some cases, is wireless itself.
- The whole interconnected Wireless LAN, including the different cells, their respective Access Points and the Distribution System, is seen as a single 802 network to the upper layers of the OSI model and is known in the Standard as **Extended Service Set (ESS)**.

The following figure 2.12 and 2.13 shows a typical 802.11 LAN including the components described above:

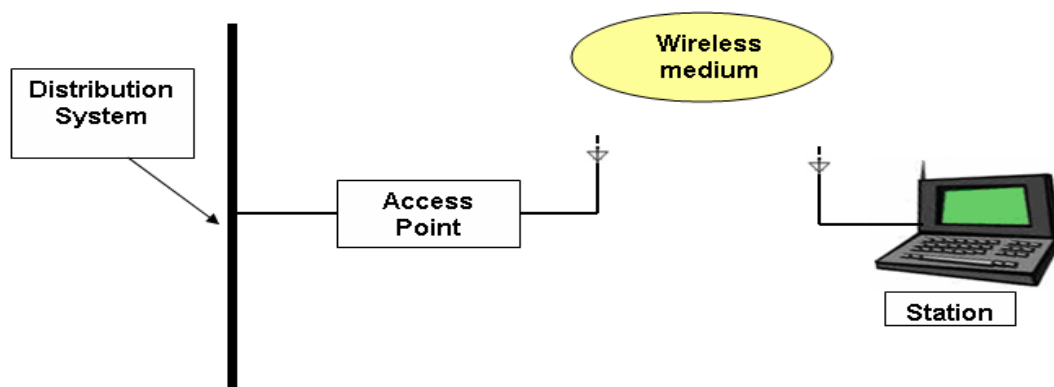


Figure 2.12: Wireless LAN Network

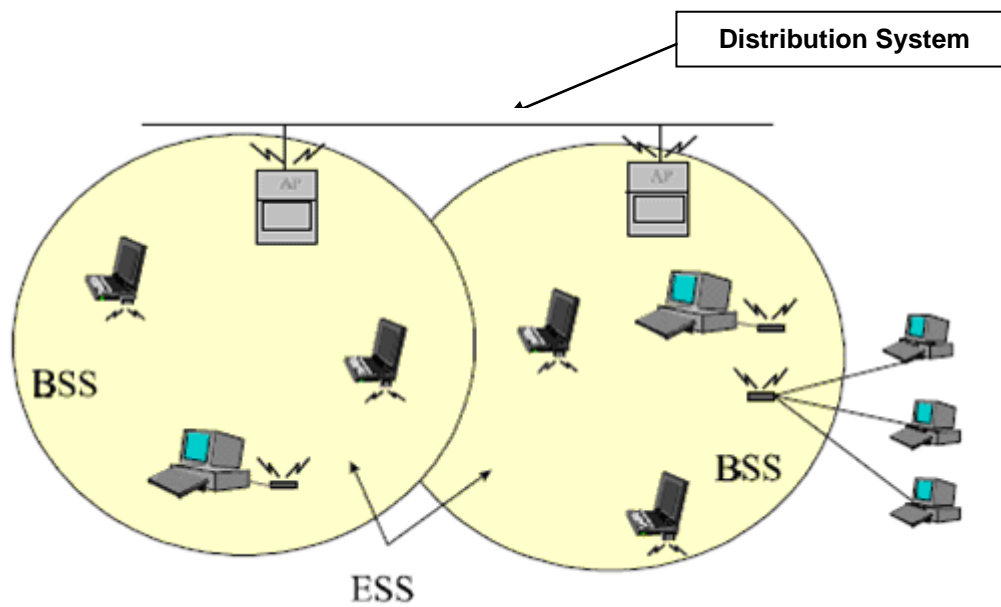


Figure 2.13: A Typical 802.11 LAN

- This standard also defines the concept of a **Portal**. A portal is a device that interconnects between an 802.11 and another 802 LAN. This concept is an abstract description of part of the functionality of a “translation bridge”. Figure 2.14 shows 802.11 architecture.

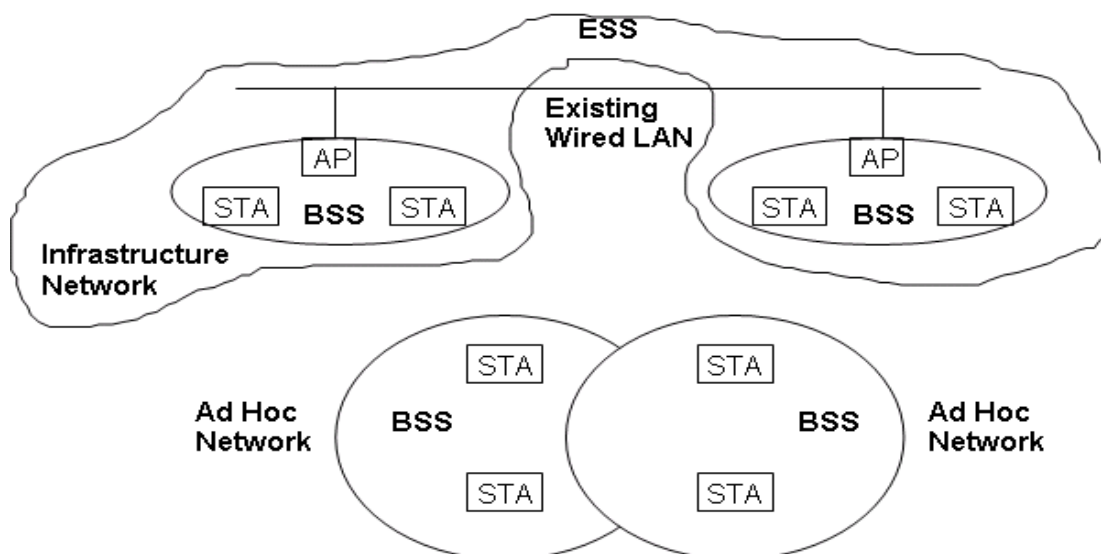


Figure 2.14: 802.11 Architecture

2.4.3 802.11 PHY and MAC Protocol

The IEEE 802.11 standard defines a set of MAC and PHY specifications for wireless LAN, also known as WiFi. It was developed by the IEEE 802.11 working group. The original standard was developed in 1997. Later, several amendments have been proposed to extend 802.11 at both the MAC and physical layers to support various features such as higher bandwidth, QoS, security, and so on.

- **802.11a/g PHY Model**

802.11a PHY is an extension to IEEE 802.11 PHY that applies to wireless LANs and provides up to 54 Mbps in the 2.4 GHz or 5 GHz band. 802.11a PHY uses an orthogonal frequency division multiplexing (OFDM) encoding scheme rather than FHSS or DSSS [21]. **802.11a** supports up to 54 Mbps using the 5 GHz ISM and UNII bands. **802.11g** [22] supports up to 54 Mbps using the 2.4 GHz ISM band.

- **802.11 MAC Model**

IEEE 802.11 defines two different architectures, BSS (Basic Service Set) and IBSS (Independent Basic Service Set). In BSS (also known as Infrastructure mode), wireless stations (STAs) are associated with an Access Point (AP). All communications take place through the AP [29,30]. In IBSS (also known as Ad Hoc mode) stations can communicate directly to each other provided, they are within each other's transmission range.

WLAN Architecture--Ad-Hoc mode

Peer-to-peer setup where clients can connect to each other directly. Generally not used for business networks.



Figure 2.15: Example of WLAN – Adhoc mode

Mobile stations communicate to each other directly.

- It's set up for a special purpose and for a short period of time. For example, the participants of a meeting in a conference room may create an ad hoc network at the beginning of the meeting and dissolve it when the meeting ends.

WLAN Architecture—Mesh

- **Mesh:** Every client in the network also acts as an access or relay point, creating a “self-healing” and (in theory) infinitely extensible network. Not yet in widespread use, unlikely to be in homes.

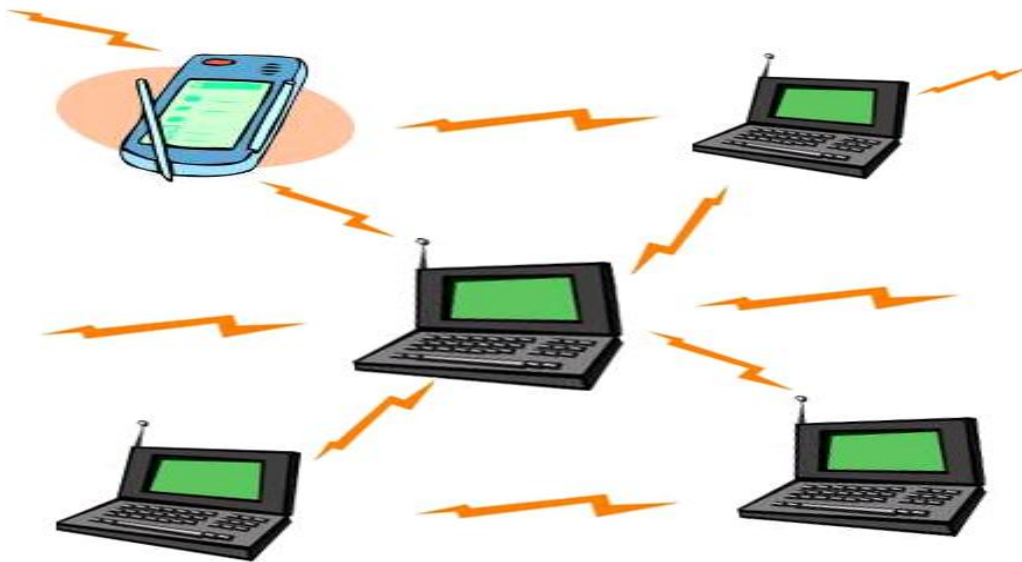


Figure 2.16: Example of WLAN – Mesh mode

WLAN Architecture—Infrastructure Mode

- There is an Access Point (AP), which becomes the hub of a “star topology.”
- Any communication has to go through AP. If a Mobile Station (MS), like a computer, a PDA, or a phone, wants to communicate with another MS, it needs to send the information to AP first, then AP sends it to the destination MS
- Multiple APs can be connected together and handle a large number of clients.
- Used by the majority of WLANs in homes and businesses.

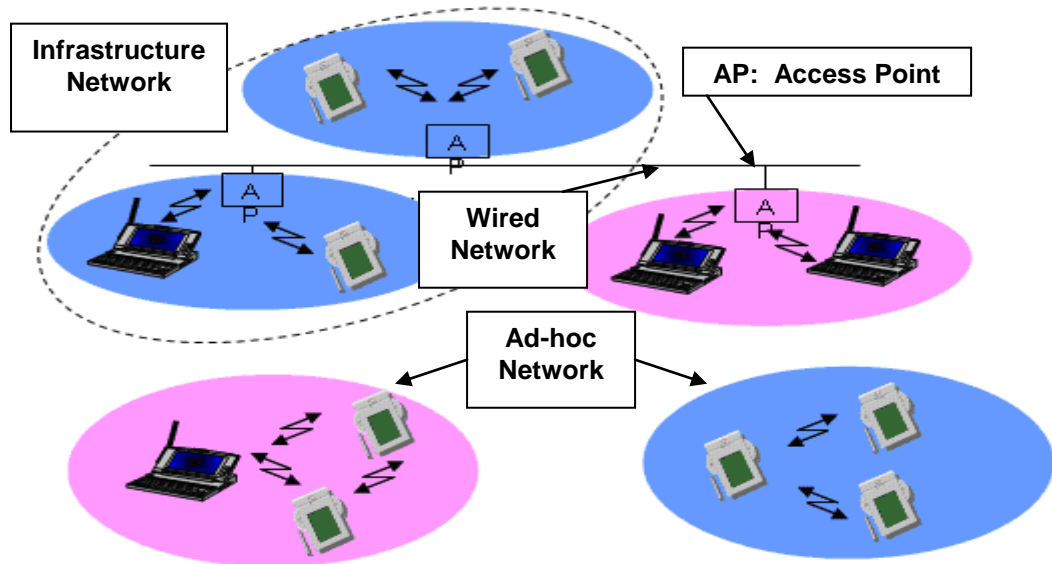


Figure 2.17: Example of WLAN – Infrastructure mode

- Wireless LAN is typically deployed as an extension of an existing wired network as shown below.

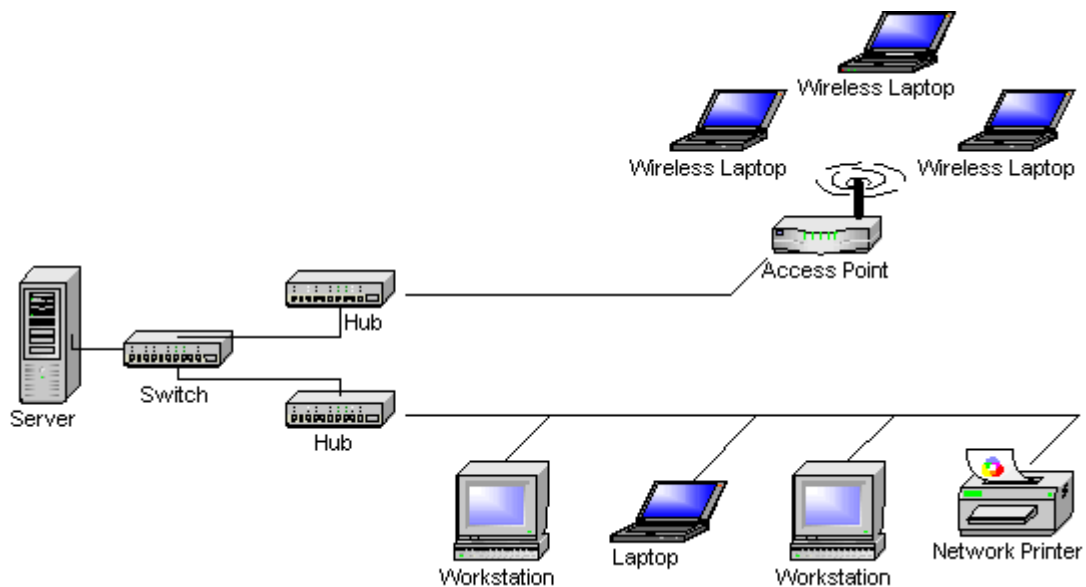


Figure 2.18: Example of Wireless LAN Topologies

- IEEE 802.11 MAC defines two access mechanisms:
 - Distributed Coordination Function (DCF): DCF provides distributed channel access based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). This mechanism is mandatory.
 - Point Coordination Function (PCF): PCF provides centrally controlled channel access through polling. This mechanism is optional.

IEEE 802.11 standard also defines the Power Saving (PS) Mode for reducing the energy consumption at stations.

DCF Procedure

The fundamental access method of the IEEE 802.11 MAC is DCF. The DCF shall be implemented in all STAs, for use within both ad hoc and infrastructure network configurations. For a STA to transmit, it shall sense the medium to determine, if another STA is transmitting. If the medium is not determined to be busy, then the transmission may proceed. If the medium is determined to be busy, the STA shall defer until the end of the current transmission. The CSMA/CA distributed algorithm mandates that a gap of a minimum specified duration exist between contiguous frame sequences. A transmitting STA shall ensure that the medium is idle for this required duration before attempting to transmit again.

After deferral to an ongoing transmission or prior to attempting to transmit again immediately after a successful transmission, the STA shall select a random backoff interval and shall decrement the backoff interval counter while the medium is idle. A refinement of the method may be used under various circumstances to further minimize collisions. Here, the transmitting and receiving STA exchange short control frames (Request-To-Send (RTS) and Clear-To-Send (CTS) frames) after determining that the medium is idle and after any deferrals or backoffs, prior to data transmission.

PCF Procedure

In the PCF procedure, the access to the channel is centralized by using a poll-based protocol controlled by the Point Coordinator. The access points generally serve as PCs. The PCF mode provides contention free service to the stations. In PCF mode, a frame is divided into two parts: contention-free period (CFP) and contention period (CP). The PC indicates the start of the contention free period by sending a beacon frame which contains the PCF related information (for example, the CFP parameter set). The CFP is repeated after a fixed interval that is contention-free repetition interval.

After sending the beacon, the PC starts polling stations one by one in the order of their association IDs. If the PC has a data packet to send to the station, it sends the polling packet piggy-backed on the data packet. If the PC does not have any data to send, it sends only a polling packet.

Power Saving Mode

Power saving mode is used to reduce the energy consumption at the station nodes. Three distinct building blocks are provided to support power savings: a Wakeup Procedure, a Sleep Procedure, and a Power Save Poll (PS-Poll) Procedure. A station can combine these power management building blocks in various manners for different applications.

2.4.4 Wireless LAN: Characteristics

- Types
 - Infrastructure based
 - Adhoc
- Advantages
 - Flexible deployment
 - Minimal wiring difficulties
 - More robust against disasters (earthquake etc)
 - Historic buildings, conferences, trade shows,
- Disadvantages
 - Low bandwidth compared to wired networks (1-10 Mbit/s)
 - Proprietary solutions
 - Need to follow wireless spectrum regulations
- Features
 - Compatible with existing LANs
 - Suitable for local short-distance networking (access point coverage area normally max. ~300m).
 - WLAN uses unlicensed radio frequencies : 2.4 GHz band and 5 GHz band
 - ISM band (band for the **I**ndustrial, **S**cientific and **M**edical use : 2.4 GHz) : Available worldwide (with some exceptions) and 5 GHz band : No worldwide support.

- The ISM bands are license-free, provided that devices are low power. In this band, one doesn't need a license to set up and operate a wireless network.

Table 2.2 shows different IEEE 802.11 WLAN Standards[26][27], Spectrum occupied, Maximum physical rate, Transmission scheme, Advantages and Disadvantages by each 802.11 standard.

Table 2.2 IEEE 802.11 WLAN Standards and its characteristics

Standard	Spectrum	Maximum physical rate	Trans-mission	Major Dis-advantages	Major Advantages
802.11	2.4 GHz	2 Mbps	FHSS/DSSS	Limited bit rate	Higher range
802.11a	5 GHz	54 Mbps	OFDM	Smallest range of all 802.11 standards	Higher bit rate in less-crowded spectrum
802.11b	2.4 GHz	11 Mbps	DSSS	Bit rate too low for many emerging applications	Widely deployed; Higher range
802.11g	2.4 GHz	54 Mbps	OFDM	Limited number of collocated WLANs higher range than 802.11a	Higher bit rate in 2.4 GHz spectrum

2.5. Wireless Fidelity (Wi-Fi) [23]

The position that wireless technologies will replace the PSTN is met with a number of objections. Primarily, these objections are focused on quality of service (QoS) issues, the security of the wireless network, limitations in the range of the delivery of the service, and the availability of bandwidth.

2.5.1 Overview of Wi-Fi [24][25]

- Wi-Fi ("Wireless Fidelity") is the popular term for a high-frequency wireless local area network (WLAN)
- The IEEE 802.11 standard defines a set of MAC and PHY specifications for wireless LAN, also known as WiFi. It was developed by the IEEE 802.11 working group.

- *Wi-Fi follows **IEEE 802.11b** standard and supports up to 11 Mbps using the 2.4 GHz ISM band.*
- The original standard was developed in 1997 and it is promoted by the Wi-Fi Alliance (Formerly WECA - Wireless Ethernet Carriers Association)
- The Wireless Ethernet Compatibility Alliance started the Wi-Fi--wireless fidelity--certification program to ensure that equipment claiming 802.11 compliance was genuinely interoperable.
- It is a wireless technology that uses radio frequency to transmit data through the air.
- Wi-Fi refers to the technology surrounding the radio transmission of internet protocol data from an internet connection wirelessly to a host computer.
- Wi-Fi is meant to be used generically when referring to any type of 802.11 network, whether 802.11b, 802.11a, 802.11g [26], dual-band, etc.
- Wi-Fi standards use the Ethernet protocol and CSMA/CA (carrier sense multiple access with collision avoidance) for path sharing [27].
- Modulation used in 802.11 has historically been phase-shift keying (PSK).

2.5.2 802.11 Standard

- 802.11 is primarily concerned with the lower layers of the OSI model.
- Data Link Layer
 - Logical Link Control (LLC).
 - Medium Access Control (MAC).
- Physical Layer
 - Physical Layer Convergence Procedure (PLCP).
 - Physical Medium Dependent (PMD).
- ✓ Wireless networks are standardized by IEEE.
- ✓ Under 802 LAN MAN standards committee.

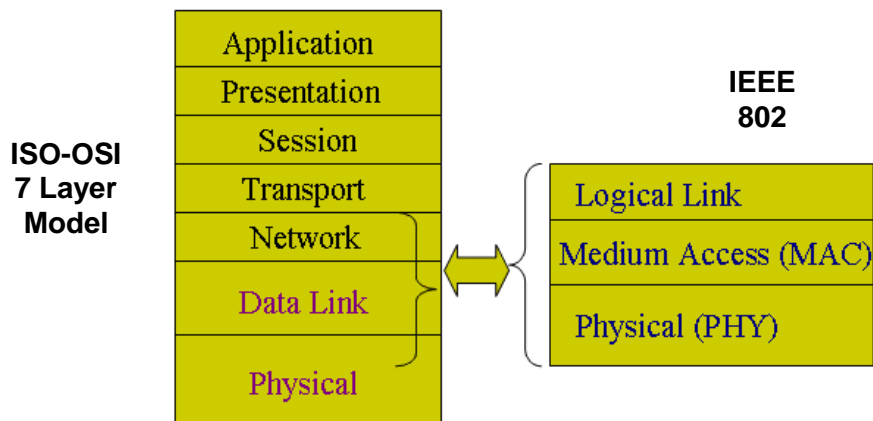


Figure 2.19 Standardization of Wireless Networks

802.11b Standard

- Limits the number of access points in range of each other to three.
- Widely available
- Greater range, lower power needs
- Uses direct-sequence spread-spectrum technology.
- Has 11 channels, with 3 non-overlapping, and supports rates from 1 to 11 Mbps, but realistically about 4-5 Mbps max.
- Well-supported, stable, and cost effective, but runs in the 2.4 GHz range that makes it prone to interference from other devices (microwave ovens, cordless phones, etc) and also has security disadvantages.

802.11b PHY Model

802.11b PHY is an extension to IEEE 802.11 PHY that applies to wireless LANS and provides 11 Mbps transmission (with a fallback to 5.5, 2 and 1 Mbps) in the 2.4 GHz band [32]. 802.11b PHY uses only Direct-Sequence Spread-Spectrum (DSSS) modulation. 802.11b PHY was a 1999 ratification to the original 802.11 PHY standard, allowing wireless functionality comparable to Ethernet.

802.11b is a direct extension of the DSSS modulation technique. As with other spread-spectrum technologies, the signal transmitted using DSSS takes up more bandwidth than the information signal that is being modulated. The carrier signals occur over the full bandwidth (spectrum) of a device

transmitting frequency. DSSS modulates the signal by multiplying the data being transmitted by a "noise" signal. This noise signal is a pseudorandom sequence of 1 and -1 values, at a frequency much higher than that of the original signal, thereby spreading the energy of the original signal into a much wider band.

The 802.11b standard uses Complementary code keying (CCK) as its modulation technique, which is a variation on CDMA . Complementary codes are sets of finite sequences of equal length, such that the number of pairs of identical elements with any given separation in one sequence is equal to the number of pairs of unlike elements having the same separation in the other sequences. CCK is a variation and improvement on, M-ary Orthogonal Keying and uses "poly phase complementary codes".

802.11g Standard

- Extension of 802.11b, with the same disadvantages (security and interference).
- Has a shorter range than 802.11b.
- Faster than 802.11b (24Mb vs 11Mb)
- Is backwards compatible with 802.11b so it allows for a smooth transition from 11b to 11g.
- Flexible because multiple channels can be combined for faster throughput, but limited to one access point.
- Runs at 54 Mbps, but realistically about 20-25 Mbps and about 14 Mbps when b associated
- Uses frequency division multiplexing

802.11a Standard

- Completely different from 11b and 11g.
- Greater bandwidth (54Mb)
- Less potential interference (5GHz)
- More non-overlapping channels
- Flexible because multiple channels can be combined for faster throughput and more access points can be co-located.
- Shorter range than 11b and 11g.

- Runs in the 5 GHz range, so less interference from other devices.
- Has 12 channels, 8 non-overlapping, and supports rates from 6 to 54 Mbps, but realistically about 27 Mbps max
- Uses frequency division multiplexing

IEEE 802.11 defines two different architectures, BSS (Basic Service Set) and IBSS (Independent Basic Service Set). In BSS (also known as Infrastructure mode), wireless stations (STAs) are associated with an Access Point (AP). All communications take place through the AP. In IBSS (also known as Ad Hoc mode) stations can communicate directly to each other provided, they are within each other's transmission range.

2.5.3 Wi-Fi Models

IEEE 802.11 defines two different architectures, BSS (Basic Service Set) and IBSS (Independent Basic Service Set). In BSS (also known as Infrastructure mode), wireless stations (STAs) are associated with an Access Point (AP). All communications take place through the AP [In IBSS (also known as Ad Hoc mode) stations can communicate directly to each other provided, they are within each other's transmission range.

WiFi Adhoc Model

Peer-to-peer setup where clients can connect to each other directly. Generally not used for business networks.



Figure 2.20 WiFi Adhoc Model

In adhoc model mobile stations communicate to each other directly. It's set up for a special purpose and for a short period of time. For example, the participants of a meeting in a conference room may create an ad hoc network at the beginning of the meeting and dissolve it when the meeting ends.

Wi-Fi Infrastructure Model

Wi-Fi Infrastructure model includes (most common):

- Stations (STA) – any wireless device[29]
- Access Point (AP) – connects BSS to DS, controls access by STA's
- Basic Service Set (BSS) – a region controlled by an AP, mobility is supported within a single BSS
- Extended Service Set (ESS) – a set of BSS's forming a virtual BSS, mobility is supported between BSS's in an ESS
- Distribution Service (DS) – connection between BSS's

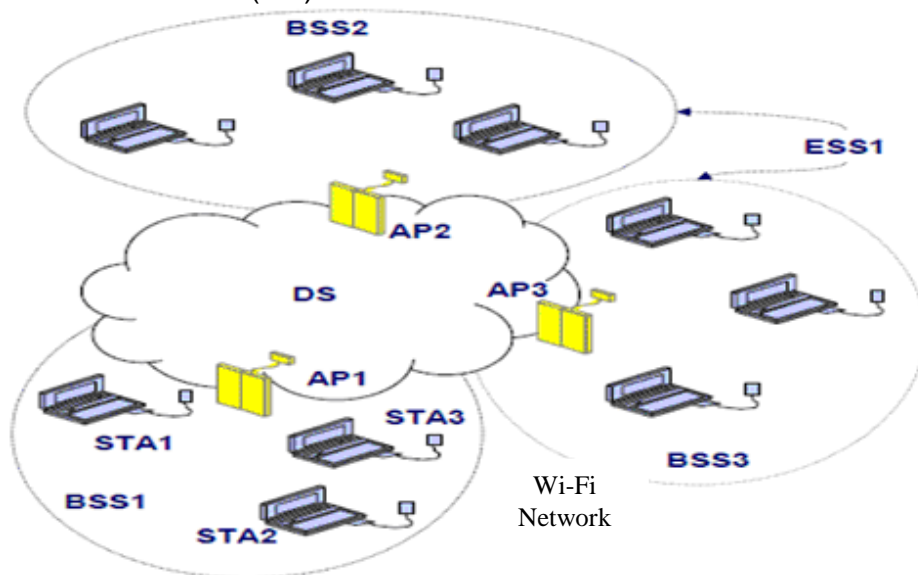


Figure 2.21 WiFi Infrastructure Model

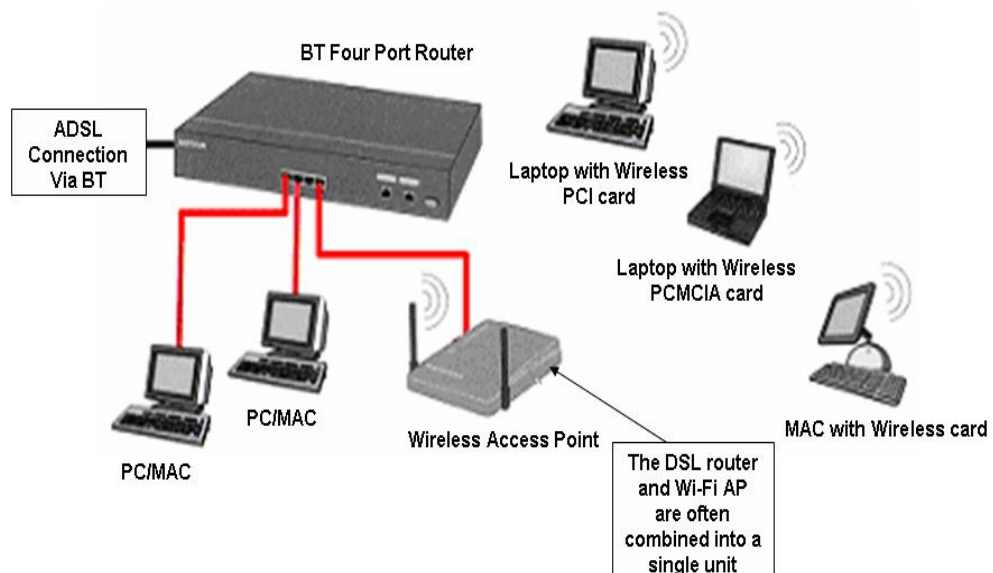


Figure 2.22 Example of small business usage of Wi-Fi Network

2.5.4 The Need for QoS in Wireless Networks [30]

An additional network requirement must be supported if the user experience in wireless broadband is to be similar to the user experience in wired broadband (for example, T1 access). The IEEE has been grappling with the issue of QoS in wireless networks and has recently approved 802.11e, which is backward compatible with other variants of 802.11. That means that improvements in QoS [31] contained in 802.11e can be applied to 802.11 or 802.11a. This section outlines the mechanisms used to ensure the QoS contained in both 802.11 and 802.11e.

Challenges to Wireless QoS

Many previous attempts at WLAN QoS (and non-QoS channel access schemes) show that the strategies that work well in a wired environment do not translate to WLAN. Several factors break possible assumptions: The packet error rate can be in the range of 10 to 20 percent, bit rates vary according to channel conditions, and the "rubber pipe problem" arises where bandwidth managers do not know how much bandwidth they have to manage because a neighbouring, unrelated bandwidth manager can take some of it at any time. In addition, if a wireless network is to bypass or substitute for the PSTN, it must be able to prioritize voice and video packets over data packets.

Latency in Wireless Networks

Latency is defined as the time it takes for the network to respond to a user command. If latency is high, causing noticeable delays in downloading web pages, then the experience feels nothing at all like broadband, no matter how high the data rates are. Low latency (less than 50 ms) is a requirement for the successful mass-market adoption of wireless services and devices.

The latency experienced by wireless users has a number of contributing sources, including the air link processing, propagation, network processing and transport, the far-end server (if applicable), the application, and the user device. The sum of these latencies must be minimized to ensure a positive end-user experience. Because of the many contributing sources in wired

networks, there is little room for latency contributed by the wireless system. Table 2.3 describes the types of delay encountered on an 802.11 network.

Table 2.3: Types of delay encountered on an 802.11 network

Delay	Definition
Air link processing	The time necessary to convert user data to air link packets (code, modulate, and frame user data) and transmit it
Propagation	The time necessary for a signal to travel the distance between the base station and the subscriber device, and vice versa
Network transmission	The time necessary to send the packet across the backhaul and backbone networks, including routing and protocol processing delays and transmission time
Far-end processing	The time required for processing by the far-end servers and other devices

The processing delay leads to another very unique disadvantage of systems that are not built on an all-IP basis. Many networks cannot transmit native IP packets and require IP assistance through either a protocol change (transcoding and encapsulation) or the addition of equipment in the network to simulate IP performance. Those measures introduce complexity and packet delays, further impacting the latency of a given system and driving up cost.

Through put and latency are two essentials for measuring network performance. When taken together, these elements define the speed of a network. Whereas throughput is the quantity of data that can pass from source to destination in a specific time, round-trip latency is the time it takes for a single data transaction to occur (that is, the time between requesting data and receiving it). Latency can also be thought of as the time it takes for data to be sent on one end to be retrieved on the other end (from one user to the other).

Latency is crucial to the broadband experience because the Internet is based on the Transmission Control Protocol (TCP). TCP requires the recipient of a

packet to acknowledge its receipt. If the sender does not receive a receipt in a certain amount of time (ms), then TCP assumes that the connection is congested and slows down the rate at which it sends packets. TCP is very effective in dealing with congestion on the wired networks.

A system's ability to efficiently handle a large user population depends significantly on its ability to serve many small TCP/IP messages per unit time and multiplex many active data users within a given cell. Hence, high latency translates directly into lower system capacity for serving data users, which equates to higher cost

2.5.5 Wi-Fi Services, advantages and disadvantages [32]

Wi-Fi network services

- Distribution and integration
- Association, re-association, and disassociation
- Authentication and deauthentication
- Providing privacy

Advantages

- Freedom – You can work from any location that you can get a signal.
- Setup Cost – No cabling required.
- Flexibility – Quick and easy to setup in temp or permanent space.
- Scalable – Can be expanded with growth.
- Mobile Access – Can access the network on the move.

Disadvantages

- Speed – Slower than cable.
- Range – Affected by various medium.
 - Travels best through open space.
 - Reduced by walls, glass, water, etc
- Security – Greater exposure to risks.
 - Unauthorized access.
 - Compromising data.

2.6 Worldwide Interoperability for Microwave Access (WiMAX)

2.6.1 Introduction

WiMAX is a telecommunication technology that provides wireless transmission of data. WiMAX is wireless broadband technology, and a great alternative that fixed broadband connections such as cable or DSL. The technology is based on the IEEE 802.16 standard (called Broadband Wireless Access) [33]. WiMAX is led by the WiMAX Forum, a global organization of manufacturers and operators, who share knowledge and developments to ensure compliance and international compatibility in WiMAX technology as per the IEEE 802.16 standard. The name "WiMAX" was created by the Forum, which was formed in June 2001.

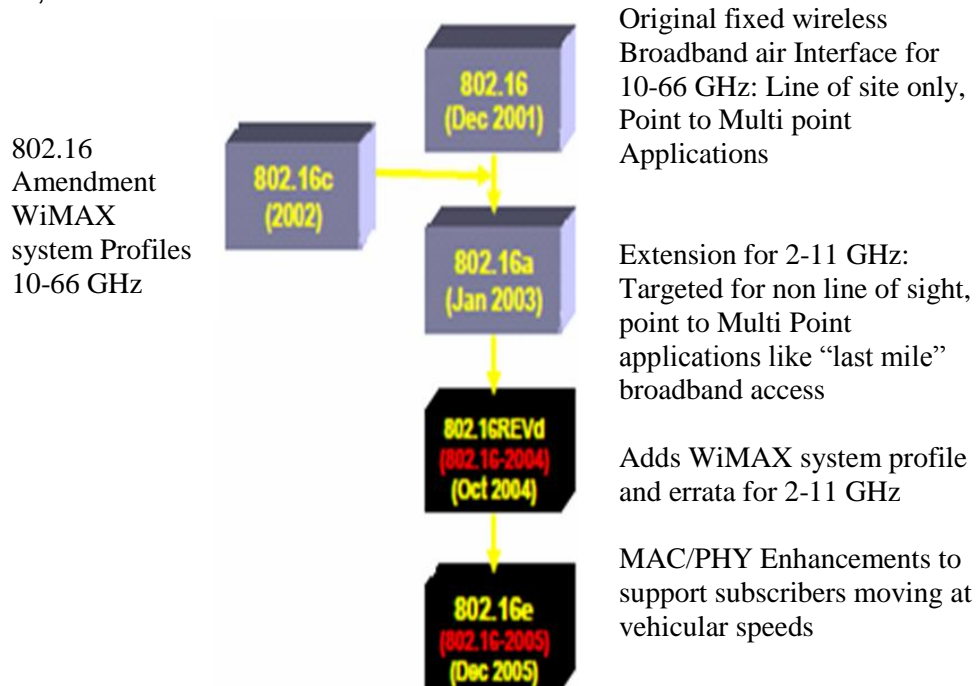


Figure 2.23: IEEE 802.16 Standard gradual development

2.6.2 802.16 Standards History [34], [35]

WiMAX is the first standard based on proprietary implementations of DOCSIS/HFC architecture in wireless domain. Figure 2.23 shows gradual development of IEEE 802.16 standard.

2.6.3 WiMAX Architecture

- Figure 2.23 shows IEEE 802.16 Network Architecture and figure 2.24 shows example of WMAN. IEEE 802.16 consists of the access point, BS (Base Station) and SSs (Subscriber Stations).

- All data traffic goes through the BS, and the BS control the allocation of bandwidth on the radio channel.

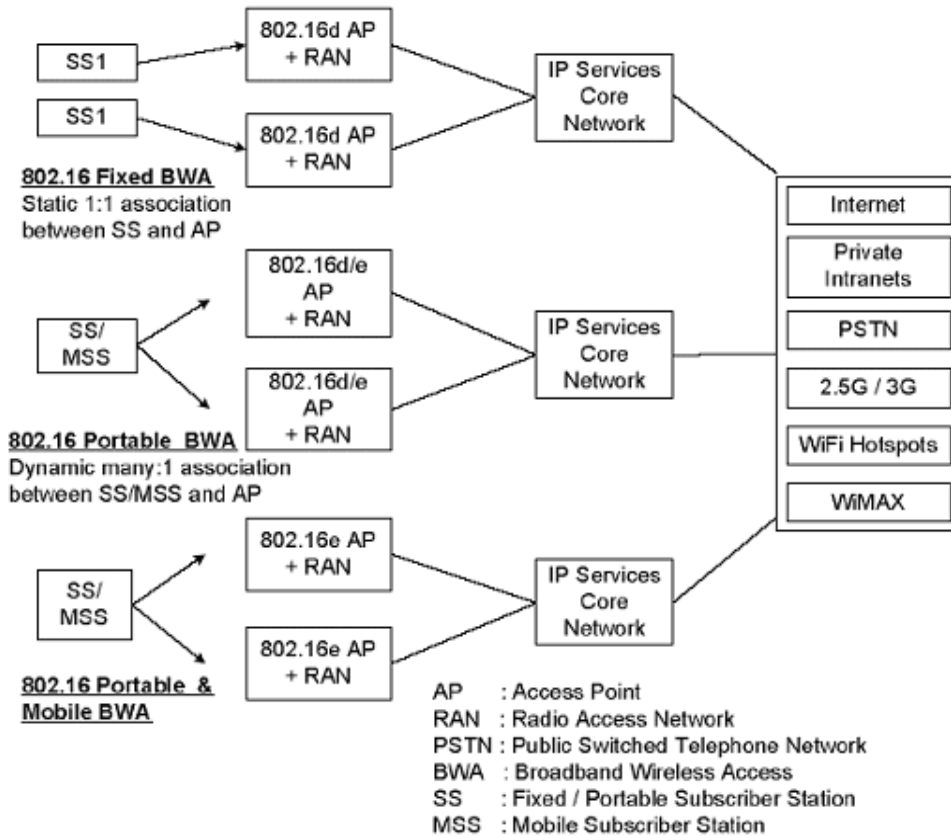


Figure 2.24: IEEE 802.16 Network Architecture

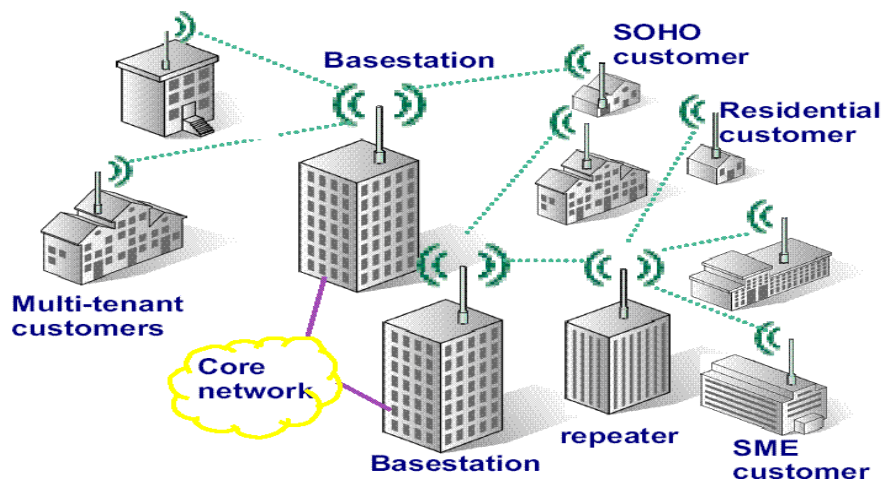


Figure 2.25: Example of Wireless Metropolitan Area Network (WMAN)

- During the communication, all the information coming from a SS goes to the BS and are retransmitted to the right SS.
- Base stations (BS) can handle thousands of subscriber stations (SS).

- Two type of link are defined:
 - The downlink: From the BS to the SS.
 - The uplink: From the SS to the BS.

❖ **WiMAX actually can provide two forms of wireless service:**

- There is the **non-line-of-sight** - Wi-Fi sort of service, where a small antenna on the computer connects to the tower. In this mode, WiMAX uses a **lower frequency range** -- 2 GHz to 11 GHz (similar to Wi-Fi). Lower-wavelength transmissions are not as easily disrupted by physical obstructions -- they are better able to diffract, or bend, around obstacles.
- There is **line-of-sight** service, where a fixed dish antenna points straight at the WiMAX tower from a rooftop or pole. The line-of-sight connection is stronger and more stable, so it's able to send a lot of data with fewer errors. Line-of-sight transmissions use **higher frequencies**. At higher frequencies, there is less interference and lots more bandwidth.

2.6.4 802.16 PHY, 802.16 MAC and 802.16e MAC Protocol

802.16 PHY [37]

IEEE 802.16 specifies multiple physical specifications including SC, OFDM and OFDMA. OFDMA is similar to OFDM [38] [39] using multiple sub carriers to transmit data. However, while OFDM uses all available sub carriers in each transmission, different sub carriers could be arranged to different subscribers in downlink and each transmission could use a subset of the available sub carriers in uplink in OFDMA.

The mandatory features are implemented in current implementation. It supports variable channel bandwidth, different FFT sizes, multiple cyclic prefix time, and different modulation schemes such as QPSK, 16QAM, and 64QAM with convolutional encoding at variety encoding rates.

The raw data rates of the OFDMA are depends on several parameters such as channel bandwidths, FFT size, sampling factor, cyclic prefix time, modulation scheme, encoding scheme and encoding rate. It can be up to 70 Mbps by using high grade modulation scheme with other suitable parameters.

802.16 MAC and 802.16e MAC

The IEEE 802.16 standard, including MAC layer [40] and PHY layer specifications, defines the air interface and associated functions of the broadband wireless access system supporting multimedia services. It is designed for high-range and high-bandwidth wireless access, or Wireless Metropolitan Area Network (Wireless MAN) [41] [42]. The bandwidth is up to 70 Mbps and radio range can go up to 50 kilometers (31 miles). Its major advantages include:

- ▶ High bandwidth and large coverage range
- ▶ Multiple service with different QoS guarantees
- ▶ Built-in security
- ▶ Cost-effective and fast-to-deploy first mile access to public networking
- ▶ A cost effective alternative that replaces WiFi and 3G/4G

The basic components of an 802.16 network are Base Stations (BS) and Subscriber Stations (SS) (or Mobile Stations (MS) in 802.16e). The BS connect to the public networks and serve their registered subscriber stations. The SS typically serve a building (commercial or residential, or WiFi hot spots). Both BS and SS are assumed to be static in an 802.16 network (mobility support is added in 802.16e standard). The basic operation mode of an 802.16 network is called Point to Multi-Point (PMP) where SS is only one-hop away from BS and can only communicate with its BS, not other neighbouring SS.

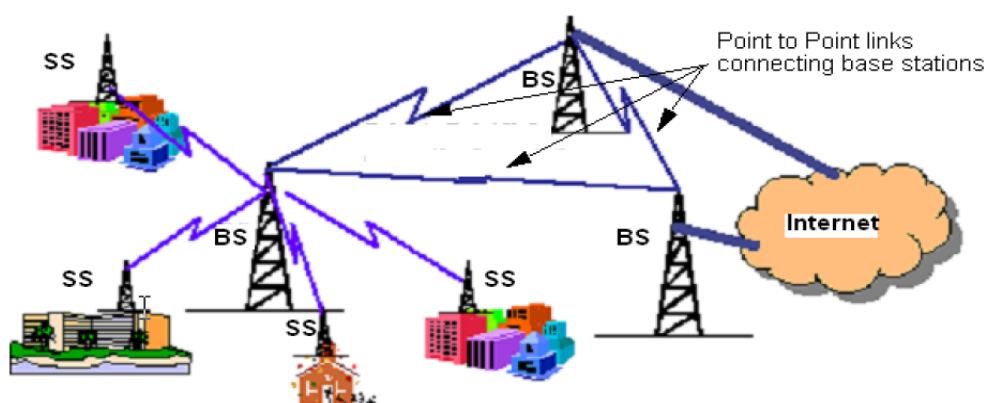


Figure 2.26: IEEE 802.16 MAC with PMP Mode

An optional operational mode called Mesh mode, has no clear distinction between SS and BS. Stations can talk directly to each other and be more than one-hop away from the BS, and the BS is defined as the station that provides access to the public network, such as the Internet. Figure 4.26 shows an illustration of an 802.16 network running under the basic PMP mode [37].

IEEE 802.16e added mobility support to IEEE 802.16. It can support mixed fixed and mobile broadcast wireless access networks. In the 802.16e specification, Subscriber Stations (SS) are also referred to as Mobile Stations (MS). Under 802.16e, the MS can handover from one BS to another BS.

1. Neighbour BS information advertisement: The serving BS periodically broadcasts information about neighbouring BSs. This information is then used by MS to guide the Neighbour BS scanning. In addition, the BS also indicates to MS the thresholds that will trigger Neighbour BS scan or handover actions.
2. Neighbour BS scanning: When the signal quality/QoS of the serving BS is below a certain threshold, the MS starts the Neighbour BS scanning procedure, seeking available BS and determining their suitability as targets for handover. During Neighbour BS scanning, the MS may also associate with neighbouring BSs to reduce delay in handover.
3. Handover: An MS may perform handover under two conditions, a) when the signal quality of the serving BS is too low, and b) when the QoS capability of the serving BS cannot fulfill requirements. Both MS and BS can initiate the handover.
4. Sleep mode: When MS is inactive, it can go to sleep mode in order to save power.
5. Paging: paging is used to reach an MS in idle or sleep mode.
6. Idle mode: An MS can go into idle mode where it periodically listens to DL broadcast traffic without ranging and registration. This can save overhead on handover when the MS traverses an air-link environment populated by multiple BS.
7. Authentication and Service Authorization (ASA) server: The access control of MS.

8. Backbone functionalities: The BSs can use the backbone to communicate with each other to exchange some information for services such as network/BS assisted handovers.

Figure 4.27 shows the IEEE 802.16e Access Network supporting mobility.

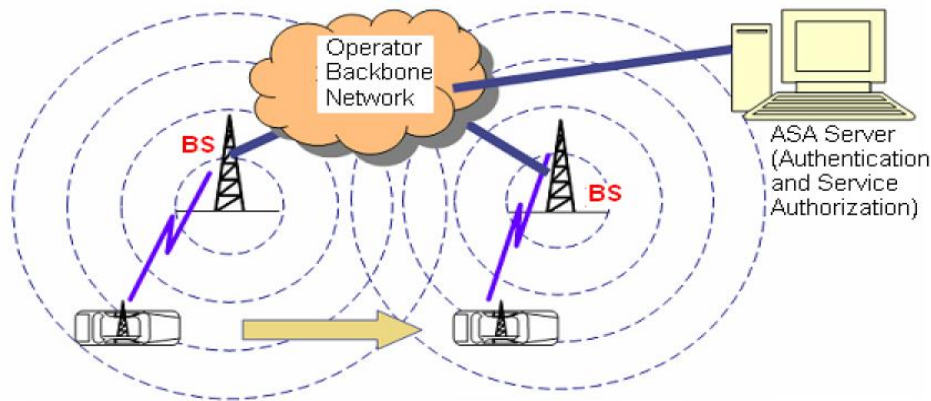


Figure 2.27: IEEE 802.16e Access Network with Mobility Support

The IEEE 802.16 MAC [40] is basically a TDMA type of medium access control protocol. The medium is first divided into MAC frames, then each MAC frame is divided into a downlink subframe and an uplink subframe. In the downlink subframe, the BS transmits different bursts to different SSs in TDD way. For the uplink, different SSs transmit in different uplink bursts that are primarily TDMA. The scheduling of downlink and uplink bursts is controlled by the BS. SS needs to request bandwidth based on its need. Thus, the uplink access is usually referred to as TDMA

IEEE 802.16 MAC supports 3 duplex modes. They are TDD, FDD Half-Duplex, and FDD Full-Duplex. The IEEE 802.16 also defines 4 PHY types including SC, SCa, OFDM, and OFDMA.

2.6.5 WiMAX Operation

WiMAX could be used to set up a back-up or even primary communications system that would be difficult to destroy with a single, pinpoint attack. Figure 2.28 shows WiMAX operation and gives idea about how WiMAX works. A cluster of WiMAX transmitters would be set up in range of a key command center but as far from each other as possible. Each transmitter would be in a bunker hardened against bombs and other attacks. No single attack could

destroy all of the transmitters, so the officials in the command center would remain in communication at all times. WiMAX system consists of two parts:

- ▶ **WiMAX Base Station or WiMAX Tower** : Typically, a base station can cover up to 10 km radius. It is similar in concept of a cell-phone tower. A single WiMAX tower can provide coverage to a very large area -- as big as 3,000 square miles (~8,000 square km). It can also connect to another WiMAX tower using a line-of-sight, microwave link. This connection to a second tower (often referred to as a **backhaul**), along with the ability of a single tower to cover up to 3,000 square miles, is what allows WiMAX to provide coverage to remote rural areas.
- ▶ **WiMAX receiver** : The receiver and antenna could be a small box or PCMCIA card , or they could be built into a laptop the way WiFi access is today.

WiMAX could also Boost Government Security. In an emergency, communication is crucial, for government officials as they try to determine the cause of the problem, find out who may be injured and coordinate rescue efforts or cleanup operations. A gas-line explosion or terrorist attack could destroy the cables that connect leaders and officials with their vital information networks. Several base stations can be connected with one another by backhaul microwave links.

1. Wire line backhauling
2. Microwave Point-to-Point connection

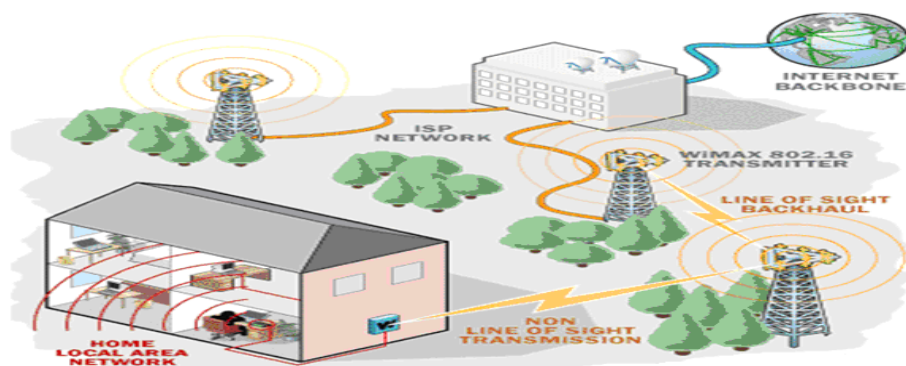


Figure 2.28: WiMAX Operation

In practical terms, WiMAX would operate similar to Wi-Fi but at higher speeds, over greater distances and for a greater number of users. WiMAX could potentially erase the suburban and rural blackout areas that currently have no

broadband Internet access, as the phone and cable companies have not yet run the necessary wires to those remote locations.

2.6.6 IEEE 802.16 Features

- Frequency range:10-66 GHz
- Connectivity at speeds up to 70 Mbps
- Use wireless links with microwave or millimeter wave radios
- Use licensed spectrum
- WiMax covers metropolitan area in scale
- Provide public network service to fee-paying customers
- Use point-to-multipoint architecture with stationary rooftop or tower-mounted antennas
- Antenna with a variety of radiation patterns are used (e.g., directional or Omni-directional)
- Provide broadband and QoS guarantee data Transmissions
- Another significant feature of WiMax technology is the connectivity on move
- WiMax adopts Orthogonal Frequency Division Multiplexing (OFDM) (carriers of width of 5MHz or greater can be used)
- Provide high speed access to about 60 businesses at T1 speeds.
- It serves up to a thousand homes in term of DSL speed
- Protocol of communication network without wire, based on the standard IEEE 802.16
- Allows communications over long distances than WiFi, and a greater bandwidth means it provides wide coverage and high speed compared to Wi-Fi. Theoretically Cover approximately 40 ~ 50 Km (30 miles)
- Goal is to Provide high-speed Internet access to home and business subscribers, without wires

2.6.7 IEEE 802.16 Applications

- Provide broadband Internet access with transmission rates over >2 Mb/s
- Replace DSL or cable
- DSL can deliver up to 6 Mb/s at distances up to 18,000 feet

- IEEE 802.16 can deliver up to 120 Mb/s at distances up to 30 km
 - Provide local multipoint distributed services (LMDS)
 - Better price points for both home and business customers
 - WiMAX allow competitors joint access to any subscriber in areas without preexisting physical cable or telephone networks
 - It would allow gamers access to adhoc local networks of other players with the same gear- without any internet access.
 - These are most common applications of WiMAX which can be used for Broadband Wireless Access (BWA). Figure 2.29 shows WiMAX applications.
1. For residential or home Broadband Internet Access
 2. For medium and small size business
 3. Backhaul networks for cellular base stations

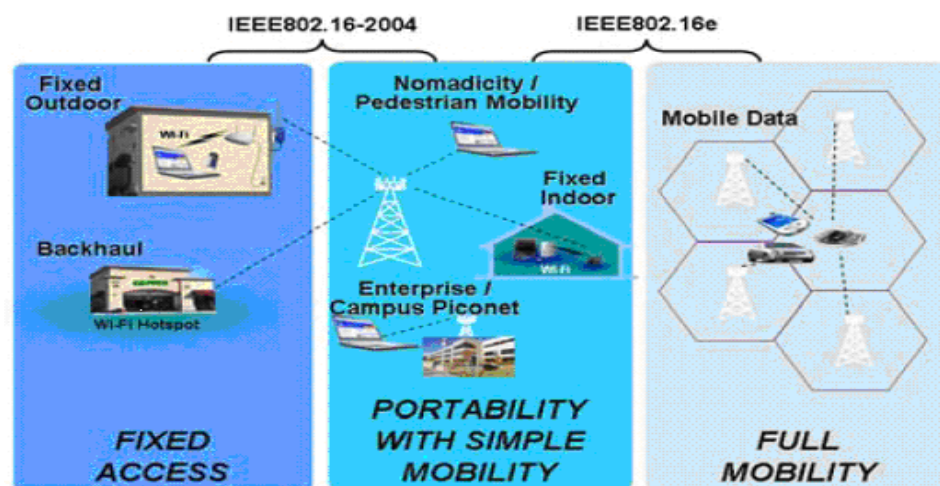


Figure 2.29: WiMAX Applications

2.6.8 Quality of Service (QoS)

The IEEE 802.16 standard has been designed to fully support multiple network layer protocols, either ATM or packets (IP, Ethernet...). Thus, Quality of Service is a key feature of the standard, as multiple types of traffic may be carried through the network. Achieving a QoS on the whole system scale is made possible by the standard through the combination of multiple features:

1. Connection allocation, modification and deletion on either Subscriber or Base Station request,

2. Fragmentation of MAC Service Data Units (SDUs) in order to fit in allocated time slots. This parameter is set on a per-connection basis,
3. Packing of MAC SDUs in one allocated time slot. This parameter is set on a per connection basis,
4. Dynamic setting of the uplink map,
5. Dynamic setting of the downlink map,

The standard does not describe how to implement a particular QoS, but specifies the tools available to achieve such a goal, which allows competition and vendor specific implementations.

2.7 WIBRO

2.7.1 Introduction

WIBRO stands for **W**ireless **B**roadband Internet [45]. It can work on lower cost, higher speed than mobile phone Internet and add mobility. Using WiBro, we can enjoy high speed Internet even when we moving. Many people believe that WiBro can realize Ubiquitous society. It is 3.5G Wireless Mobile Communication System High-speed Portable Internet. It is based on TTA PG302 and IEEE802.16e Standard.

This technology is the latest advancement in Wireless Communication which presents drastic change in Wireless Internet and helpful to connect each and every person globally. It is the most advanced and upcoming technology now a days. WiBro is the Portable Internet Service to provide a high data rate and wireless internet access with PSS (Personal Subscriber Station) under the stationary or mobile environment, anytime and anywhere. It is part of the IEEE 802.16 family such as WiMAX. With the help of WiBro, it is possible to expand the bandwidth and to accommodate a plenty of user to access the wireless internet. Because of large frequency band of 2.3 to 2.4 GHz and channel bandwidth of 9 MHz, it can cover of large coverage area of hundreds and thousands of km. It adopts TDM multiplexing , TDD duplexing technique and OFDMA multiple access technique. Due to OFDMA all the carriers are orthogonal to each other, it minimizes the self-interference.

WiBro is a 2.3 GHz based Mobile WiMAX system. [46] The Mobile WiMAX/WiBro system distinguishes itself by the three distinctive features,

namely, broadband, IP and mobility. It provides high-speed data services over 19/5Mbps downlink/uplink in its initial stage, which is likely to be doubled in the second stage. It fully employs the IP technology, differently from the existing circuit-mode cellular systems such as WCDMA/HSDPA and cdma2000/EV-DO. In addition, it can provide high-rate data services to the mobile users moving over 120 km/h. In this aspect, the Mobile WiMAX/WiBro system is viewed to be on the path towards the 4th generation wireless systems. Figure 2.30 shows versatility of WiBro.

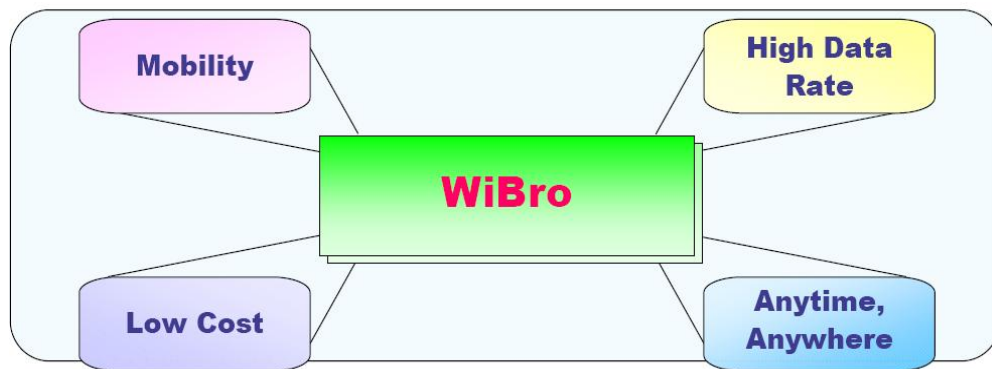


Figure 2.30: Versatility of WiBro

2.7.2 Network Architecture of WiBro or Indoor WiBro network model

The network architecture of WiBro in the phase I standardization is shown in Figure 2.31. Basically, the network architecture of WiBro is the same as other IP-based networks but there is difference at the radio access network. A new RAN has been designed to enable the requirements of high data rate with mobility [47]. RAS have the responsibility to interface between mobile and core network at the physical layer and it also controls the radio resource at the data link layer in conjunction with ACR. RAS and ACR also support link layer handoff.

Indoor WiBro system is supposed to be deployed in home and office. In this case, each indoor RAS can construct its own private network (Femto cell). Usually, indoor WiBro network in home environment does not even contain ACR. The RAS of indoor WiBro takes over some essential functions of ACR instead. Also, there can exist an simplified ACR in the indoor WiBro network,

namely pico-ACR, in office area. However, the functions of a pico-ACR are very different from those of the existing ACR in outdoor WiBro system.

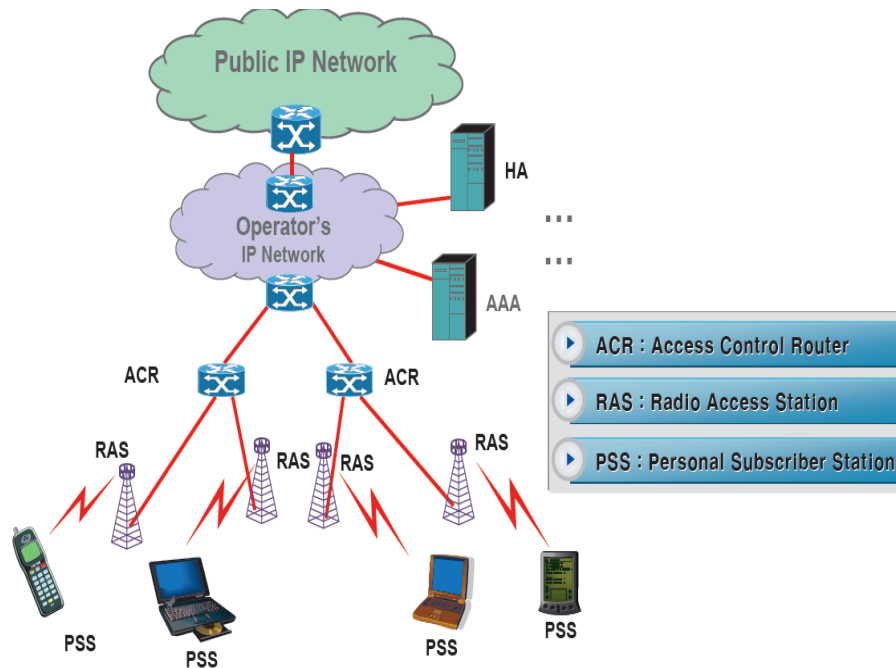


Figure 2.31: Network Architecture of WiBro (Phase I standardization)

Therefore, if we directly apply the existing layered architecture for network management to indoor WiBro system, each RAS in home and each ACR in office should have their own WiBro [48] [49]. Figure 2.32 shows WiBro system architecture.

Functionality of ACR and RAS

- | | |
|---|--|
| <ul style="list-style-type: none"> ➤ ACR – Access Control Router <ul style="list-style-type: none"> • Packet classification & header suppression • Service flow management • Traffic switching & Integration point • Handover management • Session information maintenance • RAS interface • Core network interface | <ul style="list-style-type: none"> ➤ RAS – Radio Access Station <ul style="list-style-type: none"> • PHY Processing and air resource scheduling • MAC management message processing • MAC PDU processing • CID management • Encryption & Decryption • ACR interface |
|---|--|

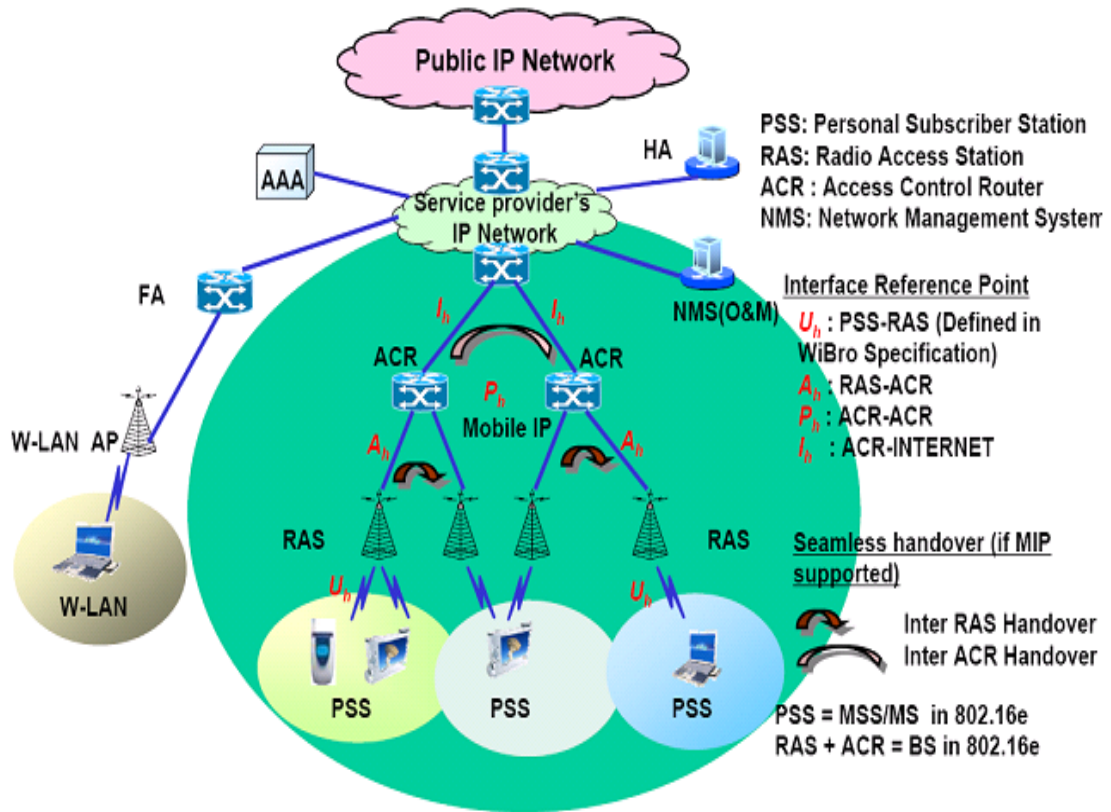


Figure 2.32: WiBro System Architecture

2.7.3 WiBro system specifications

- Multiple Access/Duplexing : OFDMA/TDD
- Frequency band: 2.3 GHz ~ 2.4 GHz
- Frequency reuse factor: 1
- Number of used tones: 864 out of 1,024
- Number of data tones: 768
- Number of pilot tones: 96
- Tone spacing: 9.765625 kHz
- Signal bandwidth: 8.447 MHz
- Ratio of cyclic prefix time to the basic OFDM symbol time: 1/8
- Basic OFDMA symbol time: 102.4 ms
- Cyclic prefix time: 12.8 ms
- OFDMA symbol time: 115.2 ms
- TDD frame length: 5 ms

- Number of symbols in a frame: 42
- Channel BW: 8.75 (~9) MHz
- Modulation: QPSK,16QAM,64QAM
- Mobility: ≤ 60 km/h
- Handoff: ≤ 150 ms
- Throughput (per user): Download 512 Kbps to 3 Mbps, Upload 128 Kbps to 1 Mbps
- Service coverage : 1~2 km
- Spectral Efficiency[bps/Hz/Cell(Sector)] : Download 2-6, Upload 1-2
- Bandwidth : 10 MHz sampling BW or Frequency with 1024 FFT with 9 MHz carrier spacing Synchronized transmission
- Modulation level: QPSK(DL/UL), 16QAM(DL/UL), 64QAM(DL only)
- User Data Rate : > 1 Mbps/user

2.7.4 Key features of WiBro

- High speed internet service (indoor & outdoor)
- Maximize the usage over the allocated spectrum
- Maximize the spectral efficiency
- Extend the service coverage
- Reduce the cost per bit
- Low power consumption
- Faster handoff
- Easy cell planning
- Roaming with cellular and WLAN
- Much lower service charges than EV-DO
- Much higher-speed Internet access than EV-DO
- Mobile Internet access in high-speed mobile environment
- Much wider coverage than wireless LAN-based services
- Flexible sub channelization for band selection and diversity
- Full diversity sub channel by multiple symbol grouping
- Preamble for Cell differentiation with different Random sequences
- Pilot tone based DL and UL and Pilot-assist transmission in DL and UL
- OFDM symbol timing and frequency

- WiBro is for the wireless high-speed broadband service able to deliver data, video and voice at speeds of up to 120 km/h.
- WiBro (Mobile WiMAX) provides true mobile connectivity by giving users seamless broadband connections anytime, anywhere.
- Portable and mobile applications include WiBro will provide broadband services to metropolitan areas not accessible by current technology as well as create broadband "hot zones" in more densely populated areas.
- WiBro service is being provided in Korea using 100 MHz of frequency spectrum in the 2.3GHz band.
- WiBro technology can become one of the strong candidates for the 4G (4th Generation) wireless standard and WiBro in aperture between 3G and 4G.
- WiBro services can have potential applications in various fields e.g.,
 - Interactive services: Web Browsing, Game interface, Interactive information, Wireless Internet access, Network Game etc
 - Streaming services: VoD, MPEG, etc.
 - Back Ground services: FTP, E-MAIL, SMS, multicast/broadcast, MMS, Push To Talk, Real time broadcasting, Conferencing etc.
 - Information service : Voice over Internet Protocol (VoIP), Video telephony
- Figure 2.33 shows WiBro positioning in Wireless Technology Roadmap

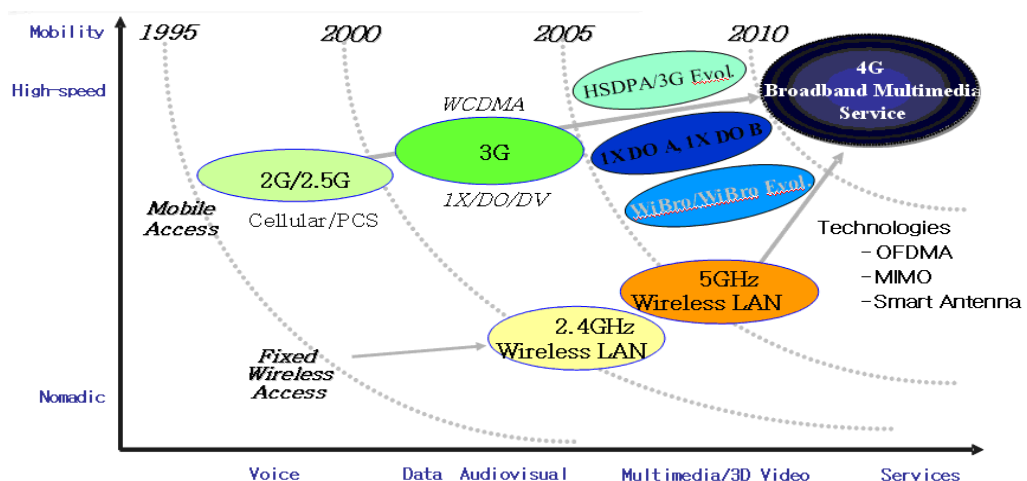


Figure 2.33: Wireless technology roadmap: WiBro Positioning

2.7.5 Advantages of WiBro

- Provides high data rate and high speed internet service (indoor & outdoor)
- Maximize the usage over the allocated spectrum
- Maximize the spectral efficiency
- Extend the service coverage
- Reduce the cost per bit
- Low power consumption
- Faster handoff
- Easy cell planning
- Roaming with cellular and WLAN
- Frequency reuse is possible

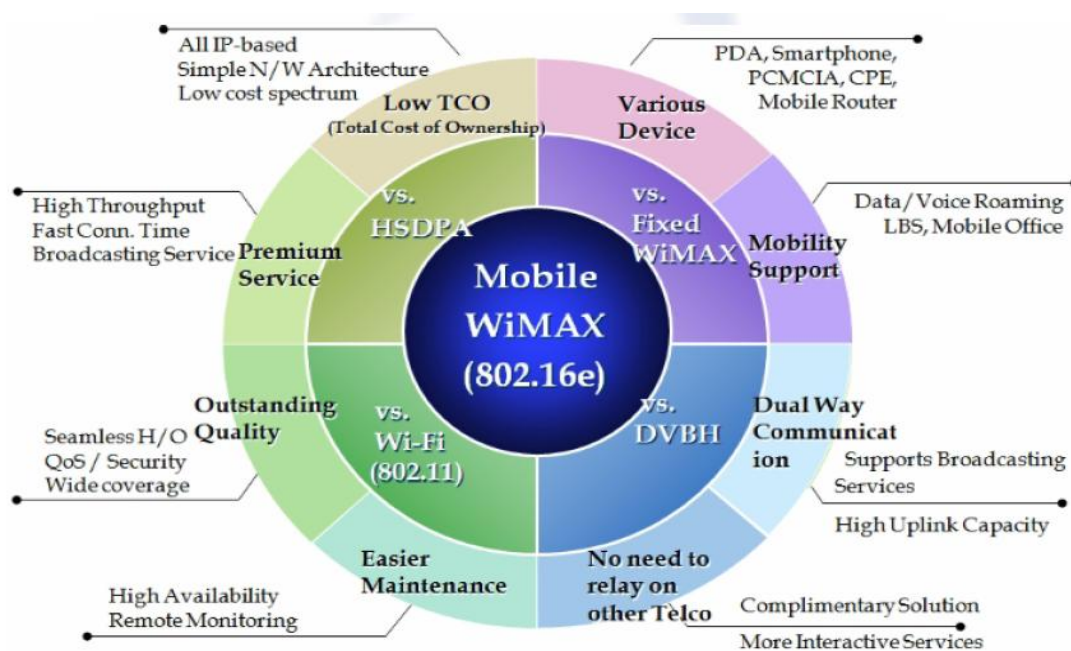


Figure 2.34: Advantages of WiBro Technology

2.8 Comparison of Different Wireless Communication Technologies with respect to Various Aspects for MARS Application .

This chapter includes theoretical comparison of different wireless communication technologies with reference to various aspects like Power, Number of users accommodated, Mobility, Data rate, Frequency, IEEE Standard, Coverage area etc.

2.8.1 Theoretical Comparison

This includes comparison of various wireless communication technologies with respect to various aspects as shown in Table 2.4 and Table 2.5.

*Table 2.4 Comparison of Wireless Communication Technologies
[GSM/GPRS&UMTS]*

Aspects	GSM/GPRS	UMTS
IEEE Standard	-	-
Data rate	171.2 Kbps	8 kbps, 144 Kbps, 384 Kbps, 2 Mbps (2 Mbps - 10 Mbps)
Frequency range (BW)	890-915 MHz: Uplink , 935-960 MHz: Downlink	1920 - 1980 MHz: Uplink , 2110 - 2170 MHz: Downlink
Mobility	80 - 150 Km/h (Approx.)	300 - 350 Km/h (Approx.)
Range (Coverage)	1000+ meter (Approx. 20-22 Km)	1000+ meter (Approx. 35-40 Km)
Channel Condition (LOS,NLOS)	LOS	NLOS
Modulation	GMSK	QPSK,BPSK
Multiple Access	TDMA	CDMA
Duplexing	FDD	TDD/FDD
Generation	2G/2.5G	3G
No. of user accommodated	Large (Approx. 120 user)	Large (Approx. 250 user)
Mode supported	TCP/IP	Asynchronous Transfer Mode (ATM), Internet Protocol (IP)
Devices/ Elements used	BTS, BSC, MSC, HLR,EIR, VLR, AuC, MS, SGSN, GGSN	UMTS – UE, Node-B, SGSN, GGSN, RNC, UTRAN
Infrastructure Cost	High	High
Application	Wide Area Voice and Data, Low speed internet access	Audio and video streaming (movies etc.), video-conferencing, Moderate to high speed internet access
Advantages	Existing Infrastructure	Better QoS, More user control
Access	Point to Multipoint	Point to Multipoint

*Table 2.5 Comparison of Wireless Communication Technologies
[WLAN, WiFi, WiMax, WiBro]*

Aspects	WLAN	WiFi	WiMAX	WiBro
IEEE Standard	802.11x(a/g)	802.11b	802.16d	802.16e
Data rate	6 to 54 Mbps	5.5 to 11 Mbps	70 Mbps	8.75-9 Mbps
Frequency range (BW)	5/2.4 GHz	2.4 GHz	10-66 GHz	2.3—2.4 GHz
Mobility	Pedestrian	Pedestrian	Pedestrian	60-120 Km/h
Range (Coverage)	10-20m (Up to 100m)	1-100m 32m (indoors) & 95m (Outdoors)	40-50 Km (Large)	1-2 Km (Medium)
Channel Condition (LOS,NLOS)	NLOS	NLOS	LOS/ NLOS	NLOS
Modulation	OFDM, BPSK, QPSK	complementary code keying (CCK)	QPSK,16QAM, 64QAM	QPSK,16QAM, 64QAM
Multiple Access	CSMA-CA	FHSS,DSSS	OFDMA	OFDMA
Duplexing	TDD	TDD	OFDM/TDD	TDD
Generation	-	-	3.5G	Between 3.5-4G
No. of user accommodated	4 – 8 user	40 – 50 user	1000+ user	1000+ user
Mode supported	Adhoc mode, Infrastructure mode	Adhoc mode, Infrastructure mode	-	-
Devices/ Elements used	Access point, Nodes(PC, Laptop, Mobile etc)	Access point, Nodes(PC, Laptop, Mobile etc)	Subscriber station, Base station	Subscriber station, Base station
Infrastructure Cost	Low	Moderate	High	High
Application	High Speed Internet Access, PC networking, File transfers	Internet browsing, PC networking, File transfers	Wireless stationary, cable TV, telephony and heavy-duty multimedia	High Speed Wireless Internet Access with Mobility
Advantages	Speed, Ubiquity, Data & Voice Access Points, Ad-Hoc Networking, Cable Replacement	Speed, Flexibility, Ad-hoc networks easy to establish, No cables, Robustness	High speed wireless broadband access	High speed, Mobility, Wide coverage area
Access	Point to Point	Point to Point	Point to Multipoint	Point to Multipoint

Chapter 4: Overview of QualNet 5.0

4.1 History

QualNet 5.0 is a commercial spin-off from the GloMoSim simulator, which was developed at the University of California, Los Angeles, UCLA, and is distributed by Scalable Network Technologies. The simulator itself is C++ based. All protocols are implemented in a series of C++ files, and called by the simulation kernel. One of the major selling points of QualNet 5.0 is that it is very scalable [64]. No efficiency is lost in running large simulations of many thousands of nodes with heavy traffic.

Whilst it is possible to run simulations completely from the command line, QualNet 5.0 comes with a java based graphical user interface. This allows for easy, more intuitive setup of simulations as well as allowing easy observation of results. During simulation runtime, it allows the user to observe the signals being transmitted and received at each node, which aids in the understanding of what is physically happening.

The three main programs used in QualNet 5.0 are the simulator, the analyzer and the packet tracer. The simulator runs the given simulation, the analyzer displays the results and the packet tracer allows us to follow the path of a packet through the network. There is also a protocol developer in the GUI; however, it is much more powerful to develop protocols from C++ coding.

4.2 Overview

QualNet 5.0 is a comprehensive suite of tools for modeling large wired and wireless networks. It uses simulation and emulation to predict the behavior and performance of networks to improve their design, operation and management. QualNet 5.0 provides a comprehensive environment for designing protocols, creating and animating network scenarios, and analyzing their performance. QualNet 5.0 is composed of the following tools:

- **QualNet 5.0 Architect** -- A graphical experiment design and visualization tool. Architect has two modes: Design mode, for designing experiments, and Visualize mode, for running and visualizing experiments.
- **QualNet 5.0 Analyzer** -- A graphical statistics analyzing tool.
- **Packet Tracer** -- A graphical tool to display and analyze packet traces.
- **File Editor** -- A text editing tool.
- **QualNet 5.0 Command Line Interface** -- Command line access to the simulator.

4.2.1 QualNet 5.0 Functions:

- Design new protocol models.
- Optimize new and existing models.
- Design large wired and wireless networks using pre-configured or user-designed models.
- Analyze the performance of networks and perform what-if analysis to optimize them.

4.2.2 Key Features of QualNet 5.0

The key features of *QualNet 5.0* that enable creating a virtual network environment are :

➤ **Speed**

QualNet 5.0 can support real-time speed to enable software-in-the-loop, network emulation, and hardware-in-the-loop modeling. Faster speed enables model developers and network designers to run multiple “what-if” analyses by varying model, network, and traffic parameters in a short time.

➤ **Scalability**

QualNet 5.0 can model thousands of nodes by taking advantage of the latest hardware and parallel computing techniques. *QualNet 5.0* can run on cluster, multi-core, and multi-processor systems to model large networks with high fidelity.

➤ **Model Fidelity**

QualNet 5.0 uses highly detailed standards-based implementation of protocol models. It also includes advanced models for the wireless environment to enable more accurate modeling of real-world networks.

➤ **Portability**

QualNet 5.0 and its library of models run on a vast array of platforms, including Windows XP, Mac OS X, and Linux operating systems, distributed and cluster parallel architectures, and both 32- and 64-bit computing platforms.

➤ **Extensibility**

QualNet 5.0 can connect to other hardware and software applications, such as OTB, real networks, and third party visualization software, to greatly enhancing the value of the network model.

4.3 QualNet 5.0 Architecture

Figure 4.1 (a) illustrates the QualNet 5.0 architecture Figure 4.1 (b) shows QualNet 5.0 layered model. A high-level description of the various components is provided below [64][65]. QualNet 5.0 architecture is similar to the Physical Networks. It is having well defined API for the protocols to interact with each other.

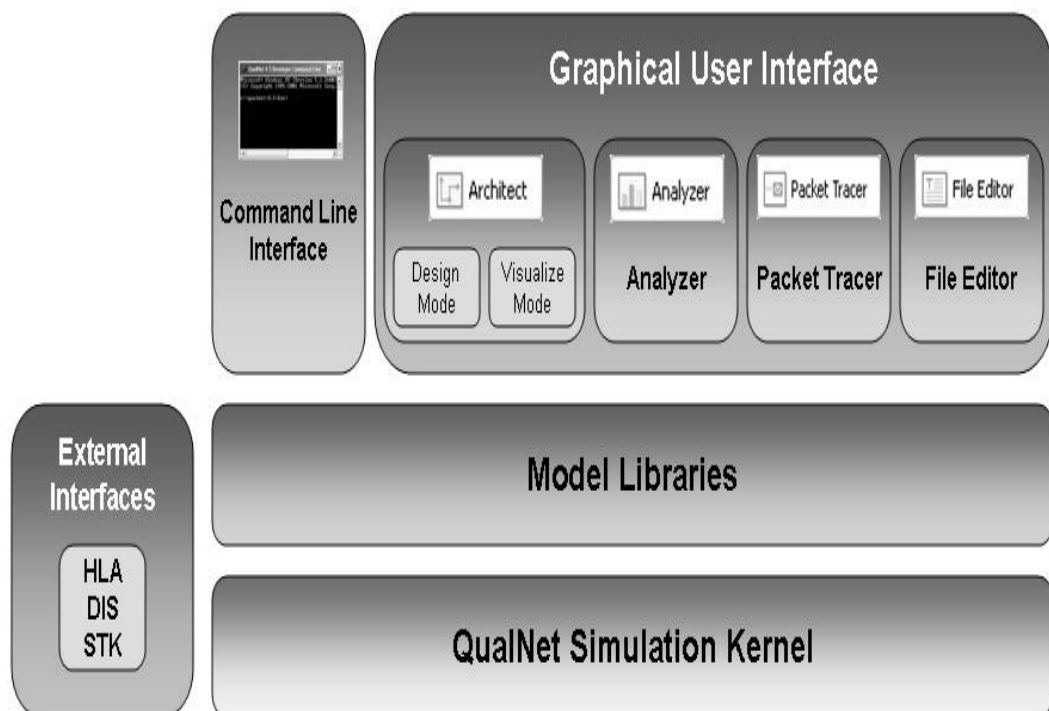


Figure 4.1 (a) QualNet 5.0 Architecture

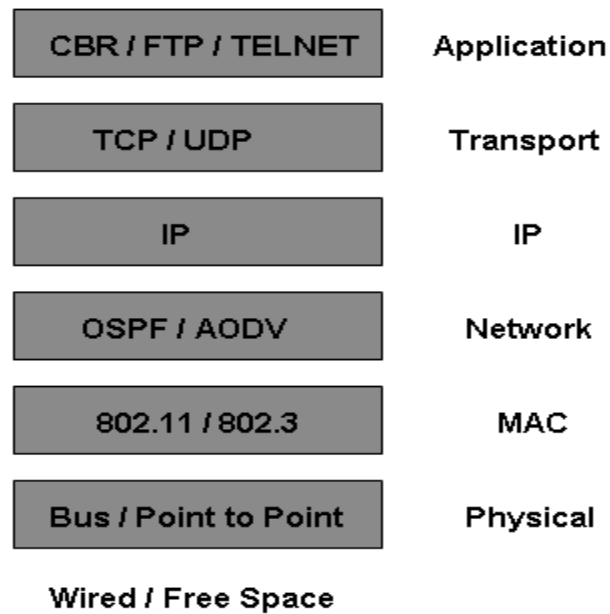


Figure 4.1 (b) QualNet 5.0 Layered Model

QualNet 5.0 Kernel

The kernel of QualNet 5.0 is a, SNT-proprietary, parallel discrete-event scheduler. It provides the scalability and portability to run hundreds and thousands of nodes with high-fidelity models on a variety of platforms, from laptops and desktops to high performance computing systems. Users do not directly interact with the kernel, but use the QualNet 5.0 API to develop their protocol models.

QualNet 5.0 Model Libraries

QualNet 5.0 includes support for a number of model libraries that enable you to design networks using SNT-developed protocol models. Purchase of QualNet 5.0 includes the Developer Model Library; additional libraries for modeling WiFi networks, mobile ad-hoc networks (MANET), military radios, WiMAX and cellular models are also available. Refer to the *QualNet 5.0 Model Libraries* in Appendix- A and Appendix-B.

QualNet 5.0 Graphical User Interface (GUI)

QualNet 5.0 GUI consists of Architect, Analyzer, Packet Tracer, and File Editor. These modes are accessible from the Components Toolbar.

◆ **Architect**

Architect is a network design and visualization tool. It has two modes: **Design mode** and **Visualize mode**. In **Design mode**, you can set up terrain, network connections, subnets, mobility patterns of wireless users, and other functional parameters of network nodes. In **Visualize mode**, you can perform in-depth visualization and analysis of a network scenario designed in Design mode. As simulations are running, users can watch packets at various layers flow through the network and view dynamic graphs of critical performance metrics. Real-time statistics are also an option, where you can view dynamic graphs while a network scenario simulation is running.

◆ **Analyzer**

Analyzer is a statistical graphing tool that displays the metrics collected during the simulation of a network scenario in a graphical format. You can customize the graph display. All statistics are exportable to spreadsheets in CSV format.

◆ **Packet Tracer**

Packet Tracer provides a visual representation of packet trace files generated during the simulation of a network scenario. Trace files are text files in XML format that contain information about packets as they move up and down the protocol stack.

◆ **File Editor**

File Editor is a text editing tool that displays the contents of the selected file in text format and allows the user to edit files.

QualNet 5.0 Command Line Interface

The QualNet 5.0 command line interface enables a user to run QualNet 5.0 from a DOS prompt (in Windows) or from a command window (in Linux or Mac OS X). When QualNet 5.0 is run from the command line, input to QualNet 5.0 is in the form of text files which can be created and modified using any text editor. Building and running scenarios with the command line interface takes less memory and scenarios typically run faster than with the GUI. With the command line interface the users have the flexibility to interface with visualization and analysis tools of their choice.

4.4 Scenario-based Network Simulation

In QualNet 5.0, a specific network topology is referred to as a scenario. A scenario allows the user to specify all the network components and conditions under which the network will operate. This includes: terrain details, channel propagation effects including path loss, fading, and shadowing, wired and wireless subnets, network devices such as switches, hubs and routers, the entire protocol stack of a variety of standard or user-configured network components, and applications running on the network. Most of these are optional; you can start with a basic network scenario and specify as much detail as necessary to improve the accuracy of your network model.

General Approach

In general, a simulation study comprises the following phases:

- The first phase is to create and prepare the simulation scenario based on the system description and metrics of interest.
- The next step is to execute, visualize, and analyze the created scenario and collect simulation results. Simulation results can include scenario animations, runtime statistics, final statistics, and output traces.
- The last phase is to analyze the simulation results. Typically, users may need to adjust the scenarios based on the collected simulation results. This general procedure is illustrated in Figure 4.2.

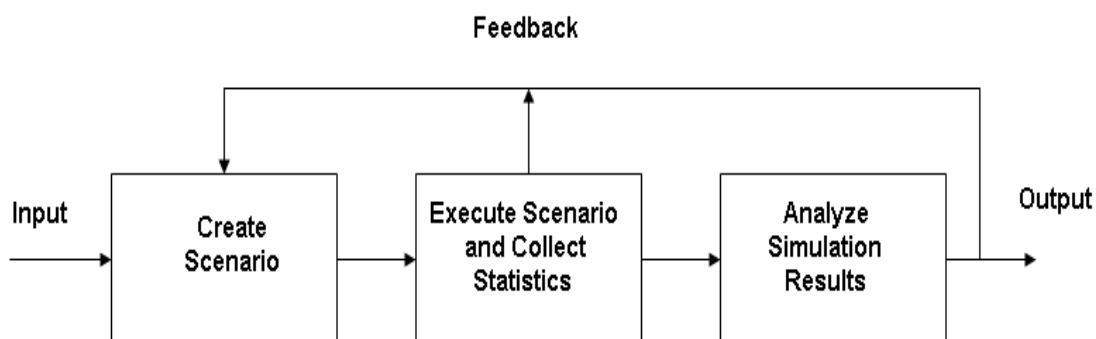


Figure 4.2 Scenario-based Simulation

Creating Scenarios

Creating a scenario can be divided into several steps focusing on different aspects. The key steps in creating a simulation scenario for QualNet 5.0 are illustrated in Figure 4.3.

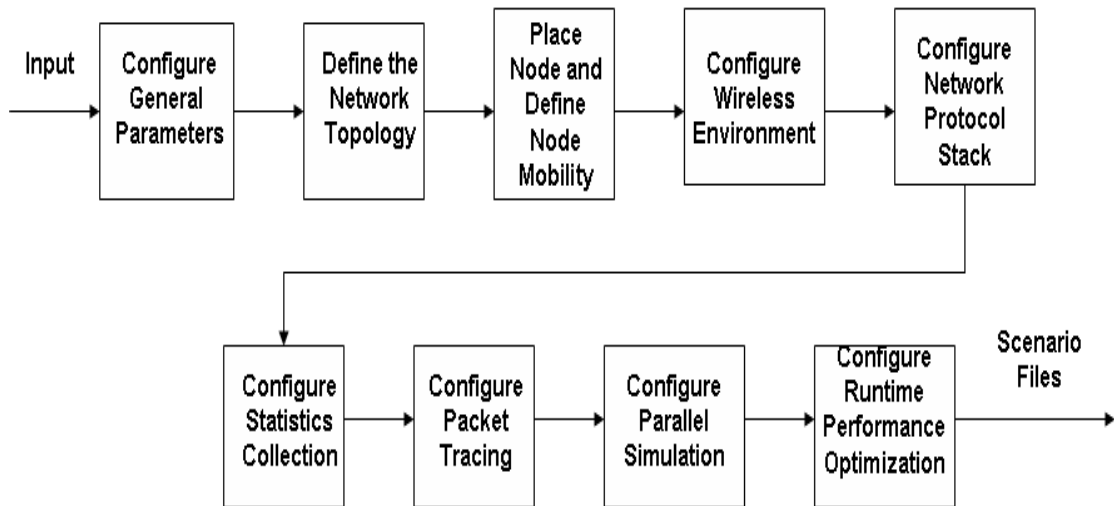


Figure 4.3 Creating a Scenario

The general approach is to first configure the general properties which are applicable to the whole scenario. Next, specify the network topology by creating subnets, placing nodes, and defining node mobility. Then one needs to configure the protocol stack for individual nodes or groups of nodes as necessary. The last step is to configure parameters for collecting simulation results and controlling runtime performance.

Files Associated with a Scenario

Input to the QualNet 5.0 simulator consists of several files. For the command line interface, the input files are text files. The main input files for command line are:

- **Scenario configuration file:** This is the primary input file for QualNet 5.0 and specifies the network scenario and parameters for the simulation. This file usually has the extension “.config”.
- **Node placement file:** This file is referenced by the scenario configuration file and specifies the initial position of nodes in the scenario. (The node

placement file may also contain the future positions of nodes.) This file usually has the extension “.nodes”.

- **Application configuration file:** This file is referenced by the scenario configuration file and specifies the applications running on the nodes in the scenario. This file usually has the extension “.app”.

In addition to the above three files, QualNet 5.0 may use other input files. These additional files depend upon the models specified in the configuration file and are referenced by the configuration file. These input files are text files which can be created using any text editor. When using the command line interface, the user has to create these files manually. When the user creates a scenario in Architect, the major input files representing the scenario (scenario configuration, node placement, and application configuration files) are automatically created by Architect [64][65]. The primary output file generated by a QualNet 5.0 simulation run is a statistics file, which has the extension “.stat”. This file contains the statistics collected during the simulation run. Other output files that may be generated by QualNet 5.0 include the trace file (which has the extension “.trace”) which records packet traces, and the animation file (which has the extension “.anim”) which records the animation trace of a scenario when the scenario is run in Architect. Both the statistics and trace files are text files which can be viewed using any text editor. In addition, Analyzer can be used to view the contents of the statistics file in a graphical, easy to analyze manner.

4.5 QualNet 5.0 Requirements

System Requirements

QualNet 5.0 is supported on the following platforms :

- Microsoft Windows XP (Home and Professional) with service pack 3 (SP3)
- Microsoft Windows XP Professional Edition x64 Edition
- Windows Vista (Home Basic and Business) 32-bit and 64-bit editions

Table 4.1 Minimum platform requirements to run QualNet 5.0 on a Windows system

Item	Requirements
CPU	32-bit (x86 compatible) processor (including Core Duo, Pentium, Xeon, and Athlon) Or 64-bit (x86-64 compatible) processor (including AMD Opteron, Athlon 64, Intel Core 2 Duo, and Pentium/Xeon EM64T).
Memory	128 MB free for LAN-size simulations without GUI 512 MB free for LAN-size simulations with GUI 2 - 4 GB free for a large network (1000+ nodes)
Disk	600 MB free disk space

In the addition to the above, the following are recommended when running the QualNet 5.0 GUI on Windows:

- Discrete graphics card with at least 128 MB memory supporting hardware 3D acceleration
- Display with 1024 x 768 or better resolution

Executable Files

The QualNet 5.0 distribution includes one or more executable files that have been compiled with the model libraries that are part of the base QualNet 5.0 distribution and QualNet 5.0 Model Libraries [67] consist of the following:

- Multimedia and Enterprise Model Library
- Propagation Library: ALE/ASAPS
- Propagation Library: TIREM
- Standard Interfaces Library
- Advanced Wireless Model Library
- Wireless Model Library
- Developer Model Library
- Cellular Model Library
- Network Security Model Library
- Military Radios Library
- Network Emulation Model Library
- Satellite Model Library
- Sensor Networks Model Library

- UMTS Model Library
- Urban Propagation Model Library

4.6 Designing the scenario

Given QualNet has been started successfully; a new empty scenario has to be created using a wizard which can be started via File->New. After it has finished a workspace with an empty scenario can be seen as shown in figure 4.4

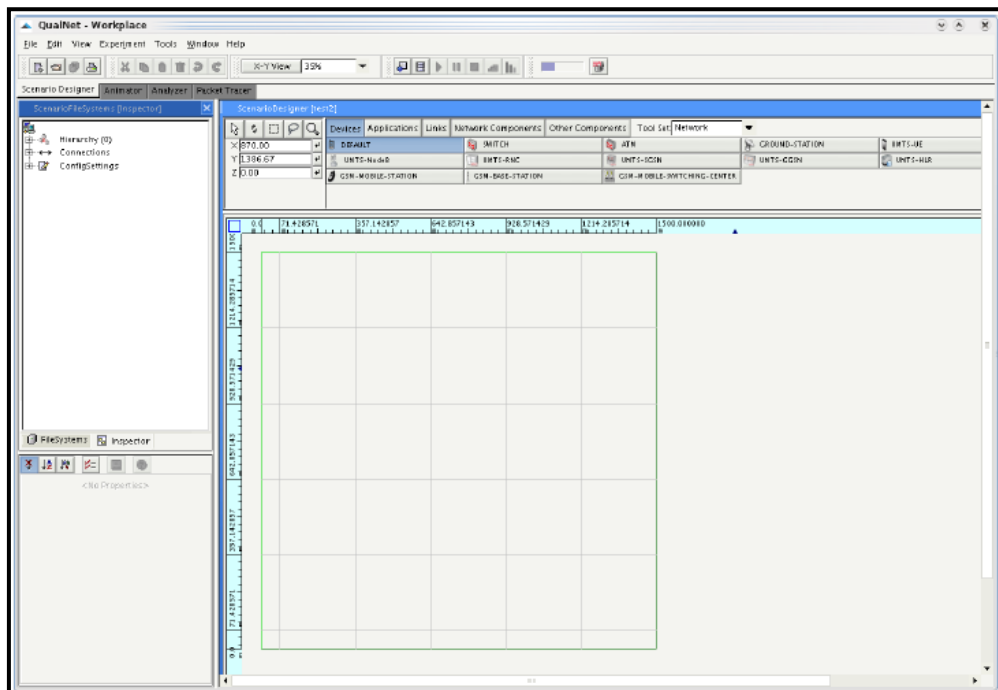


Figure 4.4: Screen for to design a scenario

All properties of the scenario can be viewed and changed using the Inspector on the left side. There's an amazing amount of properties, sub properties and parameters that can be altered although we only need to touch a very few of them. For not having to change common properties for each node there's a possibility to set global properties below ConfigSettings[66]. In particular only some of the items are of interest in the following. The changes as listed below were made to configure the nodes according to the requirements:

- Wireless Settings->Radio/Physical Layer->Radio Type: 802.15.4 Radio
- Wireless Settings->MAC Protocol->MAC Protocol : 802.15.4
- Network Protocols->Routing Protocol->Routing Policy->Routing Protocol for IPv4 : AODV

- Network Protocols->Network Protocol->IP Fragmentation Unit: 70
- Node Positioning->Mobility->Mobility Model : Random Waypoint
- General->Terrain->Coordinate-System->Dimensions: 100 100

Now we can start adding nodes by selecting Devices->DEFAULT in the toolbar and clicking in the workspace. This is merely useful in scenarios with only a few nodes. A vast number of nodes can be created easily utilizing Experiment->Place Nodes. In the dialog the number of nodes to be created can be set – in our case 11 nodes. Keeping the placement strategy Uniform works quite well. After clicking Finish, 11 new nodes should appear on the workspace. The first node (which will be our data sink) should be dragged to the center of the workspace (make sure to select the move-tool before) so the average distance to all the other mobile nodes will be minimal.

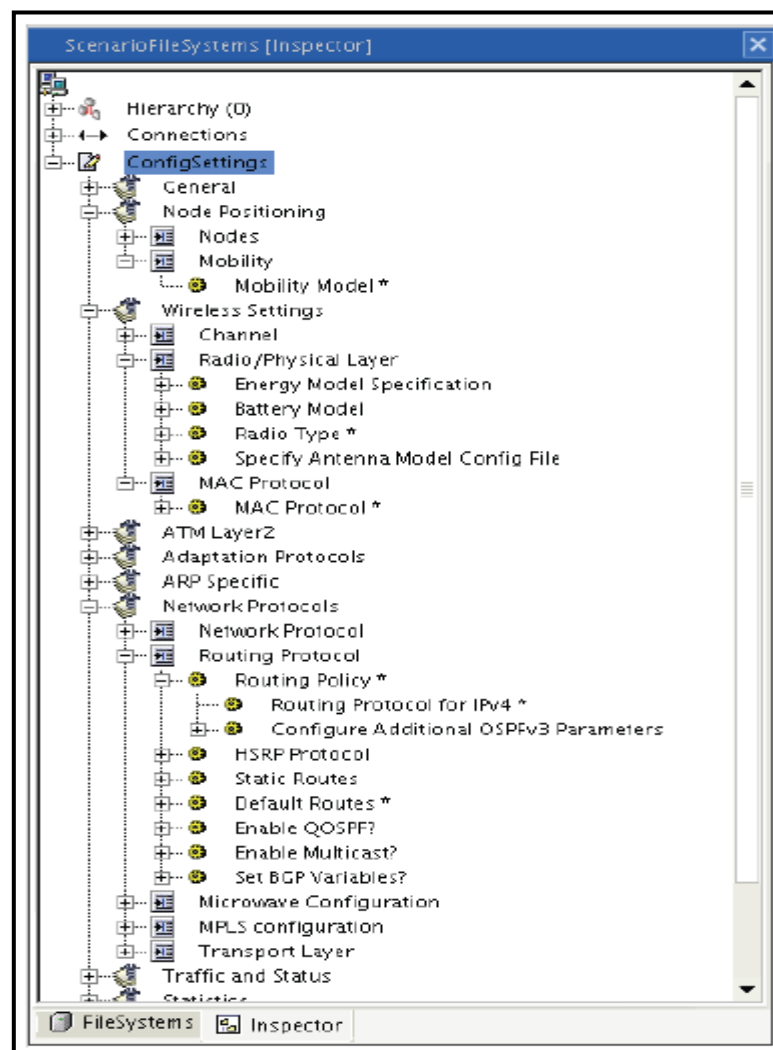


Figure 4.5: Configuring Nodes in scenario

Data sink

The data sink differs from the other (sensor) nodes only regarding mobility and its role in the 802.15.4 network. Therefore the following properties below Hierarchy (0) -> Nodes -> host1 -> Node Configuration explicitly have to be overridden:

- Mobility -> Mobility Model : None
- MAC Protocol -> MAC Protocol : 802.15.4
- MAC Protocol -> MAC Protocol -> Device Type: Full Function Device

The latter two settings are required to make the root node act as PAN Coordinator which is required in every 802.15.4 wireless network. The other nodes act as so called Reduced Function Devices (RFD).

Mobile sensor nodes

No further changes have to be made for mobile sensor nodes although it's possible to tune various interesting parameters in later experiments, for example transmission power or energy model specifications.

Wireless subnet

Until now all the nodes will only communicate on PHY and MAC layer. Therefore a wireless subnet has to be added to the scenario. The most convenient way to achieve this is selecting all hosts either using the rectangular- or the lasso selection tool. Then enable Network Components->Wireless Network in the toolbar and click somewhere into the selected region. This will add a new wireless subnet and automatically attach all hosts to it.

Now the PHY and MAC layer need to be configured by modifying some items below Hierarchy (0) -> Nodes -> Wireless Subnet N8-192.0.0.0:

- Wireless Subnet Properties->Radio Type->Radio Type: 802.15.4 Radio
- Wireless Subnet Properties->MAC Protocol->MAC Protocol : 802.15.4

As a last tweak the simulation time (ConfigSettings->General->Simulation Time) should be altered to 300 seconds as per default the simulation runs faster than real time and thus would be finished just after a few seconds.

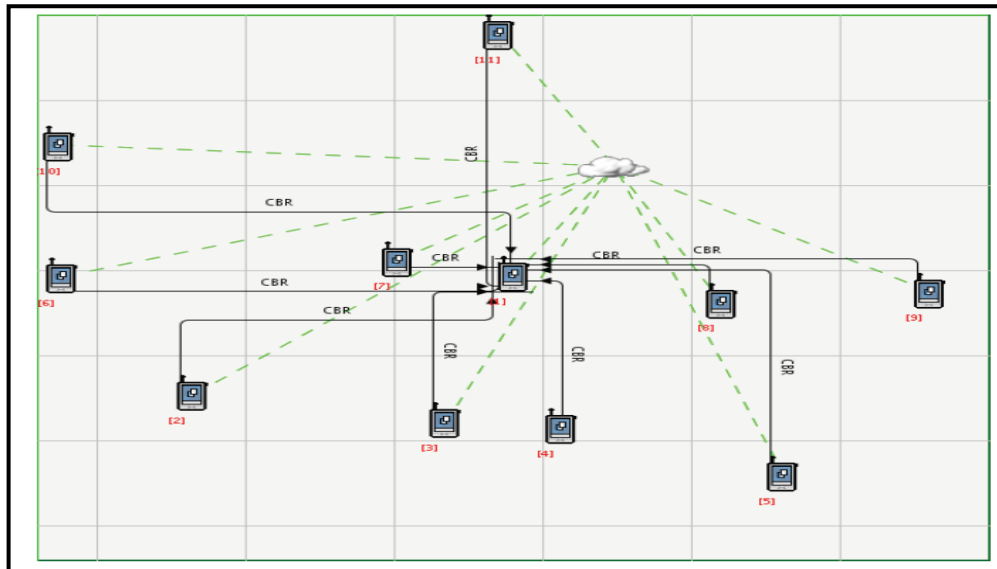


Figure 4.6: Nodes placed in Scenario

4.7 Running the scenario

There are various ways of running the scenario depending on the results you want to have. Every procedure has its own advantages and disadvantages.

Graphical animation

To give an idea of how (in terms of quantitative) the scenario performs it can be run using the QualNet Animator.

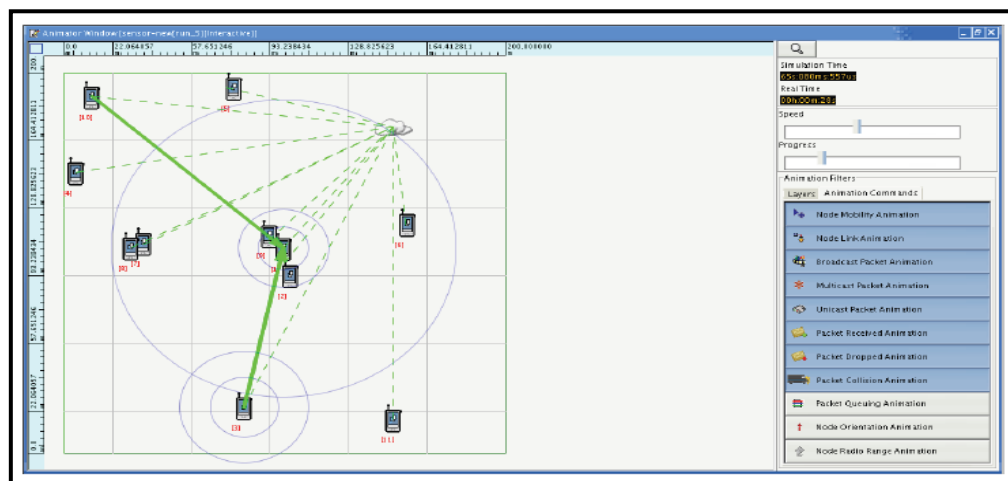


Figure 4.7: Qualnet Animator

Figure 4.7 shows the Animator with the previously designed scenario in action. On the right side you can enable or disable various types of animations. In the Layers tab animations for each of the 7 OSI layers can be enabled or disabled individually. The worst drawback of the QualNet animator is its extreme high CPU utilization and its implementation in Java which makes it run very slowly on most machines.

QualNet 3D Visualizer

To bypass the performance limitations of the Animator you can use the QualNet 3D Visualizer which makes use of OpenGL accelerated graphic cards. It also allows various three-dimensional views at the running scenario. In figure 4.8 and 4.9 typical 3D Visualizer sessions are shown.

While offering a lot of easy-to-use graphical frontends, QualNet also brings a command line interface which is mainly useful if you're only interested in the actual statistical data of a simulation. When creating a scenario using the Designer, besides the project file a subdirectory with the same name is being created and contains various other files related to simulation.

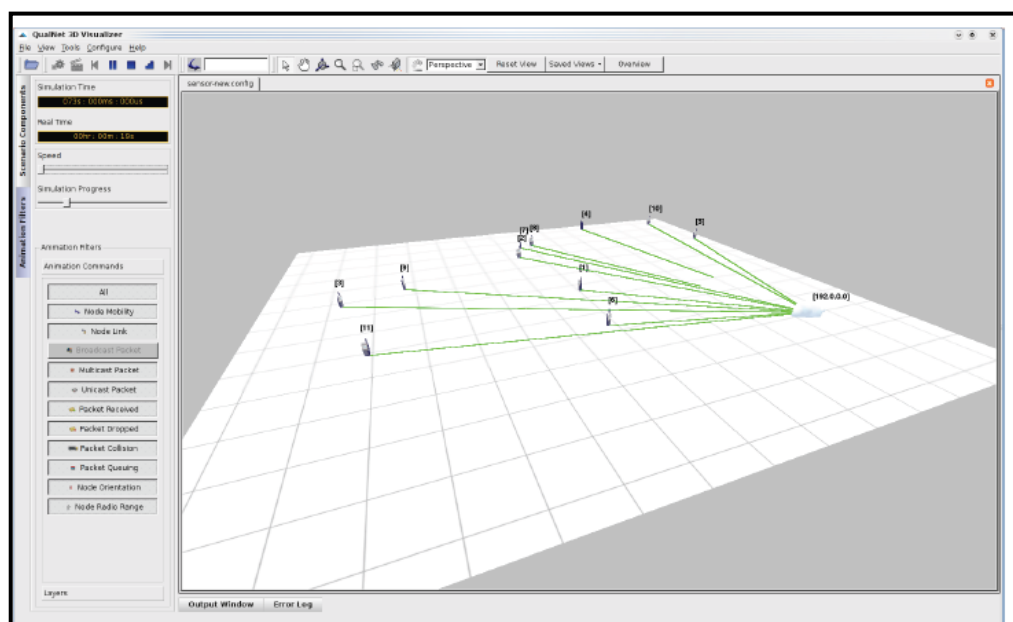


Figure 4.8: Qualnet 3D Visualizer

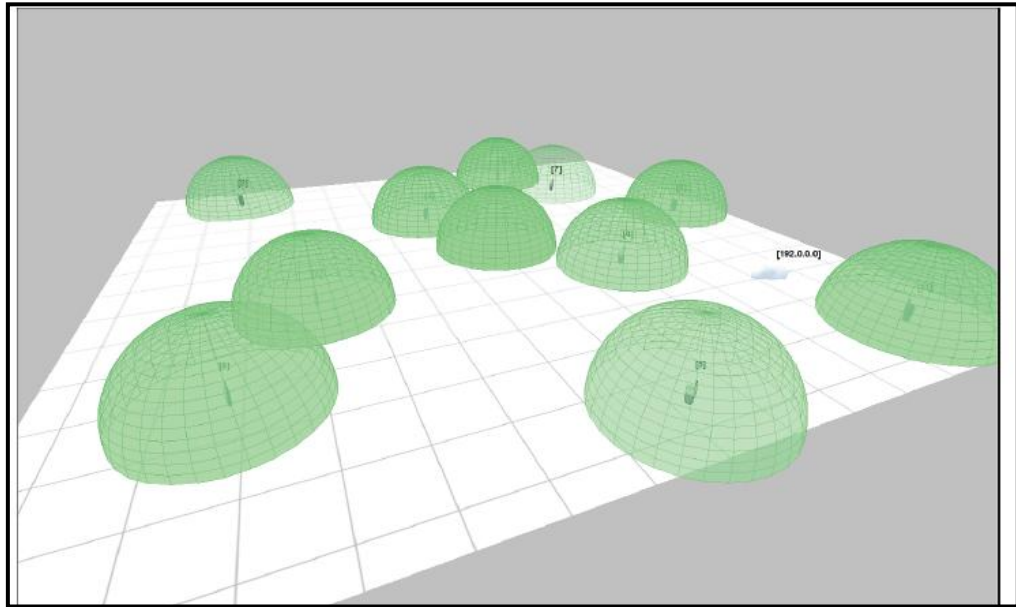


Figure 4.9: Qualnet 3D Visualizer with broadcasting

For using the command line interface the file `<project name>.config` is of importance. This config file is a standard text file and settings can be changed easily by just editing this file. To run the scenario described in a config file, the QualNet CLI can be run as follows: `cd <path to scenario folder >/< project name > <path to Qualnet >/ bin / Qualnet <project name >. Config` . If not specified differently, this will generate a file called `Qualnet.stat` which contains all statistical data related to the simulation. It can be viewed using the QualNet Analyzer as described in the next point.

4.8 Analyzing the Simulation results

The most interesting part probably is analyzing the statistical data generated during simulation. Depending on the configuration scenario statistics for all OSI layers can be viewed separately. Clicking the Analyzer tab at the top will bring up the QualNet Analyzer. Inside the subdirectory belonging to the current scenario there should be some files called "Qualnet.stat" - if not, the scenario hasn't been run before. Double clicking the according statistic file will open the Analyzer which allows you to browse through the statistics of the different OSI layers. Selecting items will show informative graphs such as shown in figure 4.10 and figure 4.11.

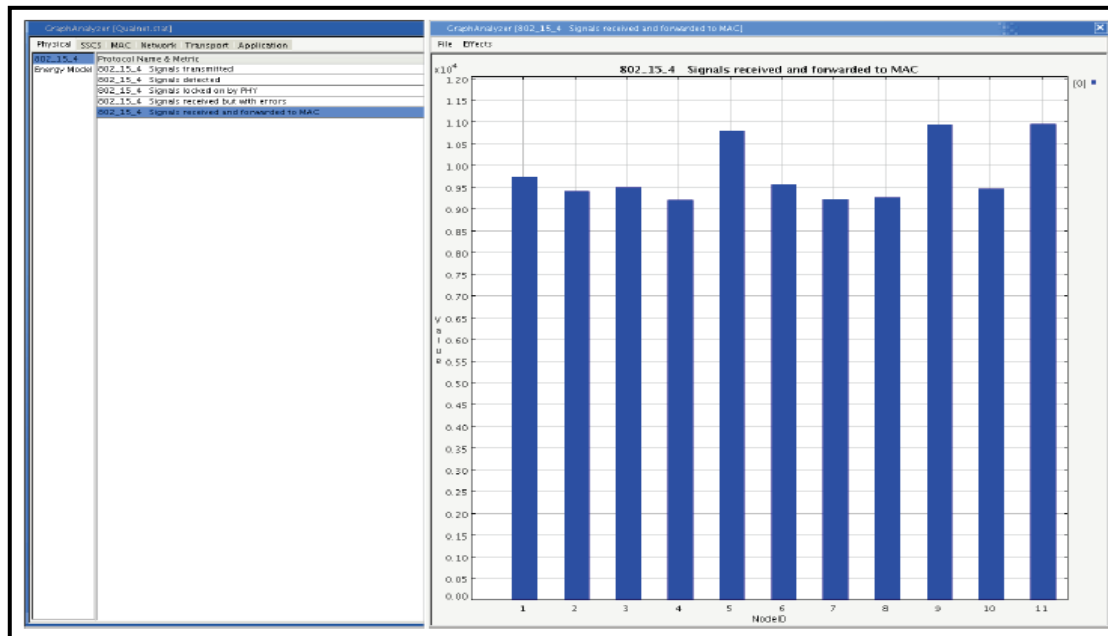


Figure 4.10: Analyzing result 1

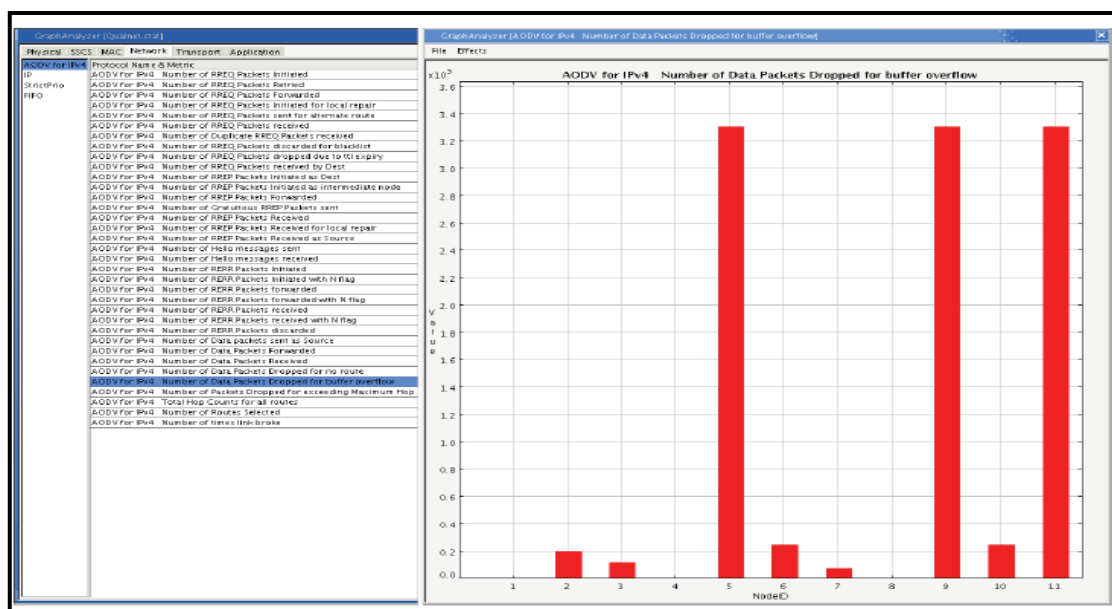


Figure 4.11: Analyzing result 2

4.9 QualNet 5.0 Model Libraries [67]

QualNet 5.0 Model Libraries greatly extend the base capabilities of QualNet 5.0. They support specialized networks, such as WiFi, sensor networks, cellular, MANET, WiMAX, military radios, and satellite. Model libraries also

enable hardware-in-the-loop and powerful 3-D visualization. The QualNet 5.0 Model Libraries consist of the following:

- **Developer Library**, included with QualNet 5.0 Developer, for modeling a large variety of networks, including WANs, LANs, IPv6, abstract satellite, etc.,
- **Wireless Library**, included with QualNet 5.0 Developer, for 802.11a/b/g and mobile ad-hoc networks,
- **Multimedia and Enterprise Library**, included with QualNet 5.0 Developer, for modeling VOIP, queueing, scheduling, MPLS, and other Quality of Service capabilities,
- **Advanced Wireless Library** for Fixed and Mobile WiMAX, based on IEEE 802.16d and 802.16e standards, respectively,
- **Cellular Library** for modeling GSM cellular networks ,
- **Network Emulation Library** for hardware, software, and human in the loop,
- **Network Security Library** for modeling networks with encryption, authentication, security keys, certificates, as well as attackers and eavesdroppers,
- **Military Radios Library**† for Link-11, Link-16, surrogate JTRS (WNW) radios, and other standards and models,
- **Propagation Library: TIREM**‡ for terrain and propagation effects based on the Terrain Integrated Rough Earth Model,
- **Propagation Library: Urban** for urban path loss and terrain effects,
- **Standard Interfaces Library** for integrating QualNet 5.0 to a number of complimentary simulators via HLA or DIS,
- **Satellite Library** for satellite and ground station communication,
- **Sensor Networks Library** for IEEE 802.15.4 (ZigBee) and sensor networks, and **UMTS Library** for third Generation (3G) mobile broadband networks

4.10 Comments

Without having compared QualNet to other similar solutions various advantages became apparent while using it. The most important ones are:

- Easy-to-use and clear User Interface
- Wide range of possible applications (even WIMAX mac layer is supported)
- Support for multiprocessor systems and distributed computing
- Sophisticated animation capabilities
- Extensive possibilities for analyzing scenario
- Shipped with a lot helpful documentation and tons of example scenarios

There're some disadvantages as well:

- Difficult installation on Linux
- Slow Java-based UI
- Very expensive (couldn't find any specific figure) { however there's a special QualNet University Program which - according to 5 - allows to get a license for less costing

Chapter-3: Overview of Mobile Augmented Reality System and applications

3.1 Augmented Reality (AR):

Mobile augmented reality [50],[51] is a relatively new and intriguing concept. The ability of augmented reality [52] to present information superimposed on our view on the world opens up many interesting opportunities for graphical interaction with our direct environment. Combining this with mobility further increases the potential usage of this technology for direct daily use. However, the technical problems with mobile augmented reality are just as great.

The computer systems that combine the real and the virtual in order to assist users in interacting with their physical environments are called Augmented Reality systems. Augmented Reality and mobile computing are often mentioned together, as many mobile computing platforms rely on some kind of head-up or head-mounted display to provide continuous access to information, often coupled with hands-free operation. The ultimate goal is to make the mobile computer a part of the user's normal daily life. Augmented Reality as a user interface for mobile computing is particularly powerful when the computer has access to information on location and situation, so it can provide contextual information

3.1.1 Definition

There are two commonly accepted definitions of Augmented Reality today. One was given by Ronald Azuma in 1997. [53] Augmented Reality

- combines real and virtual
- is interactive in real time
- is registered in 3D

Additionally Paul Milgram and Fumio Kishino defined Milgram's Reality-Virtuality Continuum in 1994. [54] They describe a continuum that spans from the real environment to a pure virtual environment. In between there are

Augmented Reality (closer to the real environment) and Augmented Virtuality (is closer to the virtual environment).



Figure 3.1: Simplified representation of a "virtuality continuum".

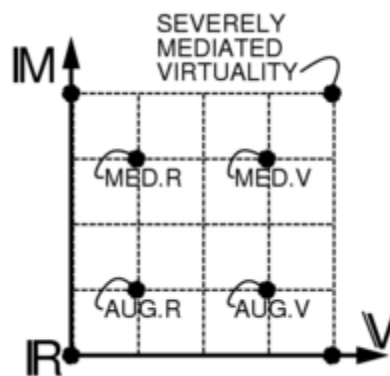


Figure 3.2 Milligram's Continuum

Mediated Reality continuum showing four points: Augmented Reality, Augmented Virtuality, Mediated Reality, and Mediated Virtuality on the Virtuality and Mediality axes. This continuum has been extended into a two-dimensional plane of "Virtuality" and "Mediality". Taxonomy of Reality, Virtuality, Mediality. The origin R denotes unmodified reality. A continuum across the Virtuality axis V includes reality augmented with graphics (Augmented Reality), as well as graphics augmented by reality (Augmented Virtuality). However, the taxonomy also includes modification of reality or virtuality or any combination of these. The modification is denoted by moving up the mediality axis. Further up this axis, for example, we can find mediated reality, mediated virtuality, or any combination of these. Further up and to the right we have virtual worlds that are responsive to a severely modified version of reality. (at right) Mediated reality generalizes the concepts of mixed reality, etc.. It includes the virtuality reality continuum (mixing) but also, in addition to

additive effects, also includes multiplicative effects (modulation) of (sometimes deliberately) diminished reality. Moreover, it considers, more generally, that reality may be modified in various ways. The mediated reality framework describes devices that deliberately modify reality, as well as devices that accidentally modify it. More recently, the term augmented reality has been blurred a bit due to the increased interest of the general public in AR.

3.2 A R Technology

Hardware

The main hardware components for augmented reality are: display, tracking, input devices, and computer. Combination of powerful CPU, camera, accelerometers, GPS and solid state compass are often present in modern Smartphone's, which make them prospective platforms for augmented reality.

Display

There are three major display techniques for Augmented Reality:

Head Mounted Displays

Handheld Displays

Spatial Displays

Head Mounted Displays

A Head Mounted Display (HMD) places images of both the physical world and registered virtual graphical objects over the user's view of the world. The HMD's are either optical see-through or video see-through in nature. An optical see-through display employs half-silver mirror technology to allow views of physical world to pass through the lens and graphical overlay information to be reflected into the user's eyes. The HMD must be tracked with a six degree of freedom sensor. This tracking allows for the computing system to register the virtual information to the physical world. The main advantage of HMD AR is the immersive experience for the user. The graphical information is slaved to the view of the user. The most common

products employed are as follows: Micro Vision Nomad, Sony Glasstron, and I/O Displays.

Handheld Displays

Handheld Augment Reality employs a small computing device with a display that fits in a user's hand. All handheld AR solutions to date have employed video see-through techniques to overlay the graphical information to the physical world. Initially handheld AR employed sensors such as digital compasses and GPS units for its six degree of freedom tracking sensors. This moved onto the use of fiducial marker systems such as the AR Tool Kit for tracking. Today vision systems such as SLAM or PTAM are being employed for tracking. Handheld display AR promises to be the first commercial success for AR technologies. The two main advantages of handheld AR is the portable nature of handheld devices and ubiquitous nature of camera phones.

Spatial Displays

Instead of the user wearing or carrying the display such as with head mounted displays or handheld devices; Spatial Augmented Reality (SAR) makes use of digital projectors to display graphical information onto physical objects. The key difference in SAR is that the display is separated from the users of the system. Because the displays are not associated with each user, SAR scales naturally up to groups of users, thus allowing for collocated collaboration between users. SAR has several advantages over traditional head mounted displays and handheld devices. The user is not required to carry equipment or wear the display over their eyes. This makes spatial AR a good candidate for collaborative work, as the users can see each other's faces. A system can be used by multiple people at the same time without each having to wear a head mounted display. Spatial AR does not suffer from the limited display resolution of current head mounted displays and portable devices. A projector based display system can simply incorporate more projectors to expand the display area. Where portable devices have a small window into the world for drawing, a SAR system can display on any number of surfaces of an indoor setting at once. The tangible nature of SAR makes this an ideal technology to support design, as SAR supports both a graphical visualization and passive haptic

sensation for the end users. People are able to touch physical objects, and it is this process that provides the passive haptic sensation. ^{[2] [8] [9] [10]}

Tracking

Modern mobile augmented reality systems use one or more of the following tracking technologies: digital cameras and/or other optical sensors, accelerometers, GPS, gyroscopes, solid state compasses, RFID, wireless sensors. Each of these technologies have different levels of accuracy and precision. Most important is the tracking of the pose and position of the user's head for the augmentation of the user's view. The user's hand(s) can tracked or a handheld input device could be tracked to provide a 6DOF interaction technique. Stationary systems can employ 6DOF track systems such as Polhemus, ViCON, A.R.T, or Ascension.

Input devices

This is a current open research question. Some systems, such as the Tinmith system, employ pinch glove techniques. Another common technique is a wand with a button on it. In case of smart phone, phone itself could be used as 3D pointing device, with 3D position of the phone restored from the camera images.

Computer

Camera based systems require powerful CPU and considerable amount of RAM for processing camera images. Wearable computing systems employ a laptop in a backpack configuration. For stationary systems a traditional workstation with a powerful graphics card. Sound processing hardware could be included in augmented reality systems.

Software

For consistent merging real-world images from camera and virtual 3D images, virtual images should be attached to real-world locations in visually realistic way. That means a real world coordinate system, independent from the camera, should be restored from camera images. That process is called Image registration and is part of Azuma's definition of Augmented Reality.

Augmented reality image registration uses different methods of computer vision, mostly related to video tracking. Many computer vision methods of augmented reality are inherited from similar visual odometry methods.

3.3 Applications of AR [55]

Advertising: Marketers started to use AR to promote products via interactive AR applications.

Entertainment and education: AR can be used in the fields of entertainment and education to create virtual objects in museums and exhibitions, theme park attractions (such as Cadbury World)

Military and emergency services: AR can be applied to military and emergency services as wearable systems to provide information such as instructions, maps, enemy locations, and fire cells.

Navigation devices: AR can augment the effectiveness of navigation devices for a variety of applications.

Industrial Applications: AR can be used to compare the data of digital mock-ups with physical mock-ups for efficiently finding discrepancies between the two sources. It can further be employed to safeguard digital data in combination with existing real prototypes, and thus save or minimize the building of real prototypes and improve the quality of the final product.

Architecture: AR can be employed to simulate planned construction projects.

Sightseeing: Models may be created to include labels or text related to the objects/places visited. With AR, users can rebuild ruins, buildings, or even landscapes as they previously existed.

Support with complex tasks: Complex tasks such as assembly, maintenance, and surgery can be simplified by inserting additional information into the field of view.

Prospecting: In the fields of hydrology, ecology, and geology, AR can be used to display an interactive analysis of terrain characteristics. Users could use, and collaboratively modify and analyze, interactive three-dimensional maps.

Art: AR can be incorporated into artistic applications that allow artists to create art in real time over reality such as painting, drawing, modeling, etc.

Collaboration: AR can help facilitate collaboration among distributed team members via conferences with real and virtual participants. The Hand of God is a good example of a collaboration system.

Music: Pop group Duran Duran included interactive AR projections into their stage show during their 2000 *Pop Trash* concert tour.

3.4 Augmented Reality and Ubiquitous Computing

By definition, the goal of augmented reality is to make computational devices ubiquitous in the everyday world. Although oft described as making these devices "invisible," most efforts have focused on replication and dissemination. The vision is something like "Computing devices will be everywhere. They will be smaller so that we can carry them around with us and they will be able to communicate back and forth with each other." [56] The end result is that although computational devices are more likely to be seen as ubiquitous, they are far from invisible. Our world is now cluttered with various computational things that vie for our attention. Augmented reality and ubiquitous computing is an inevitably evolving topic in computing. Many devices, which are already equipped with computers, can be found in our homes or offices.

Nevertheless people still use their washing machines and telephones not considering them as a computer. Additionally, growing communication possibilities and the advent of small computers like Personal-Digital-Assistance (PDA) let Mark Weiser's vision come true [57]. In the ubiquitous computing research we consider technology and applications, using PDAs, other mobile devices and extended "dump" machines (like TV) to set up prototypes for the demonstration of ubiquitous computing scenarios.

A common focus shared by researchers in mobile, ubiquitous and wearable computing is the attempt to break away from the traditional desktop computing paradigm. Computational services need to become as mobile as their users. Whether that service mobility is achieved by equipping the user with computational power or by instrumenting the environment, all services

need to be extended to take advantage of the constantly changing context in which they are accessed.

Attaining the goals of augmented reality and ubiquitous computing will require a highly sophisticated infrastructure. In the ideal system, a real-time tracking mechanism will derive the locations and operational status of many system components and will use that context to deliver messages more intelligently. Users will be able to choose from among a variety of devices to gain mobile, high-bandwidth access to data and computational resources anywhere on the network. These devices will be intuitive, attractive and responsive. They will automatically adapt their behavior to suit the current user and context.

The wireless communication revolution is bringing fundamental changes to telecommunication and computing. Wide-area cellular systems and wireless LANs promise to make integrated networks a reality and provide fully distributed and ubiquitous mobile computing and communications, thus bringing an end to the tyranny of geography. Furthermore, services for the mobile user are maturing and are poised to change the nature and scope of communication

Recent advances in wireless networks and computer down-sizing technologies have led to the development of the concept of mobile computing. In the near future, millions of mobile users will be equipped with small, powerful and battery-operated palmtops. Through the wireless networks, this portable equipment will become an integrated part of existing distributed computing environments, and mobile users can access to data stored at information servers located at the static portion of the network even while they are on the move. In our increasingly mobile world, the ability to access information on demand at any location can satisfy people's information needs as well as conferring on them a competitive advantage. As such, the potential market for mobile computing applications is estimated to be billions of dollars annually. For example, passengers will access airline schedules, investors will access stock activities, travelers will access weather or traffic conditions.

For wireless computing to be widely accepted, there are two obstacles to be cleared. First, for palmtops that operate on AA batteries, power conservation is a key issue. For an 'average user', the power source is expected to last 2 to 3 hours before replacing or recharging becomes necessary. What makes it worse is the predictions by battery experts of the modest improvement in battery capacity of only 20%-30% over the next 5-10 years. Second, the bandwidth of the wireless channel is also very limited. The bandwidth of a wireless channel can vary from 1.2 Kbps for slow paging channels, through 19.2 Kbps (e.g. Cellular Digital Packet Data) to about 2Mbps for the wireless LAN. Therefore, mobile computers would frequently be disconnected from the network or be kept in a weak connection status to conserve energy, and transmission be kept at a minimum to avoid channel contention. These two issues pose a great challenge to researchers in the community.

3.4.1 Handheld Devices

Handheld devices like PDAs are a key technology and build the base for many mobile computing and ubiquitous computing projects [58][59].

3.4.2 Location

Knowledge about the location of a person or device is useful for many applications in ubiquitous computing. An examples is the routing of phone calls; to provide this service a user has to be located all around a building or area (absolute location). But even relative location, where only devices and persons in the direct proximity are detected (e.g. in a room), could be useful. One example is the ad-hoc meeting, supported by PDAs, where social communication is supported by PDAs. The research in this area focuses on how to get this location information and how to present this information in the background computer system.

3.4.3 Context of use

There is more to context than location - For example, context is also the social situation the user actually was in. In this research area it is worthwhile to find out what sensor information could be useful to detect situations and how applications could profit from this information.

3.4.4 Information Access

The relation between direct and indirect information access is one of the most exciting areas of research in ubiquitous computing. Ubiquitous computing environments give a lot of possibilities to retrieve, to input and to output information, so combining only these possibilities leads to a lot of new challenges for new applications. Different information access scenarios are built to find out how information access works in ubiquitous computing scenarios.

3.4.5 Privacy

When building global communication and network infrastructures and "computerizing" the user as described in ubiquitous computing the question of privacy arises. Technologies like active badges or even GSM mobile phones enable computer systems to track any person using such technologies. These issue of privacy and security as well as individualism is underestimated by current ubiquitous computing proposals and collides with the real world. As a solution we suggest a concept that integrates a personal device (PD) into ubiquitous computing to overcome these problems.

3.4.6 Encryption

New network technologies like infrared or wireless radio communication need encryption technology to ensure security to its users. But available bandwidth of these networks is small and therefore a precious resource. The ongoing research tries to find solutions, based on available and well introduced technologies.

3.5 Mobile Use Contexts are the Challenge

"The coherence of situated action is tied in essential ways not to individual predispositions or conventional rules but to local interactions contingent on the actor's particular circumstances." Suchman

The characteristic feature of interaction with context-aware computers is that it typically takes place while being away from the desktop. Some researchers call the paradigm "technology beyond the desktop" (Bellotti & Bly, 1996). The

hypothesis advocated here is that the core of the problem of context-aware HCI has been that use contexts of the desktop based computing are radically different from the use context of context-aware computers. The concepts and theories we talk about HCI [60] have been conceptually inadequate; in other words, weak from the point of view of explanatory power. Mobile contexts differ from desktop-contexts: internal factors such as tasks, needs, and goals are different, as are external factors such as social resources and present objects and events. Indeed, when data from our mobility data (Paper II, Kankainen & Oulasvirta, 2002; Oulasvirta, 2004) were classified, shopping, evaluating people, selecting routes, ad hoc meetings, SMS messaging, relaxing, waiting, surprising and delighting others, rendezvousing, being late, safety, acquiring information, collecting memories, and gags were among the most frequent, in contrast to “desktop contexts”. Moreover, mobile contexts encompass larger geographical area for movement, involve many unidentifiable users and devices, loosely defined leisure oriented tasks, dynamic environment and objects, more interruptions and disrupting stimuli etc. Therefore, new conceptual approaches are needed for describing, explaining, and predicting human behavior in mobile contexts.

What, then, are the characteristic features of “the mobile context”, becomes the overarching question for researchers. Three closely related questions emerge from the interests of the three main stakeholders in this research enterprise:

- *Social science*: What are the relevant (for the user) contextual factors and resources in mobile use situations and user activities?
- *Psychology*: How can the context be used to support the user, without distracting the original on-going tasks and activities?
- *Computer science*: What are the context sensors that can recognize these meaningful contexts and, moreover, help discriminating among them?

To date, hardly anyone seems to have paid attention to the two first vital questions, although millions of euros have been spent every year for the

technology side of the enterprise (Thackara, 2001). A recent meta-review of empirical work in mobile HCI echoes this claim (Kjeldskov & Graham, 2003)

3.6 Mobile Augmented Reality System

The Mobile AR System can be defined as; “A mobile AR system is one in which augmentation of the data occurs through available knowledge of where the user is (the user's location and therefore the surrounding environment)”.

A prominent example that served cause us to study the role of wireless technology issues in MARS is Columbia’s ”Touring Machine”, which is used as a mobile multimedia information system and journalistic tool [61].

3.6.1 Features of MARS: A mobile AR system combines the following features:

- Application and data sharing between a mobile and a stationary user or two mobile users
- 3D stereographic display of computer generated images. This enhances the sensation of seeing virtual objects.
- Direct manipulation and interaction with the virtual objects.
- Instant collaboration with another user wearing another mobile kit.

3.6.2 Applications of MARS: There are numerous applications of MARS, few important application areas out of them are listed bellow.

- Disaster management
- Virtual classroom
- Computer Assisted Surgery
- Situated documentary
- Battlefield
- Entertainment

3.6.3 Architecture of MARS - The Layered Approach [62] : The architecture of MARS can be depicted in many ways .There can be no restriction on which of the basic unit lies at which end. But broadly based on the functional requirement the we propose following MARS can have following layer model modules..

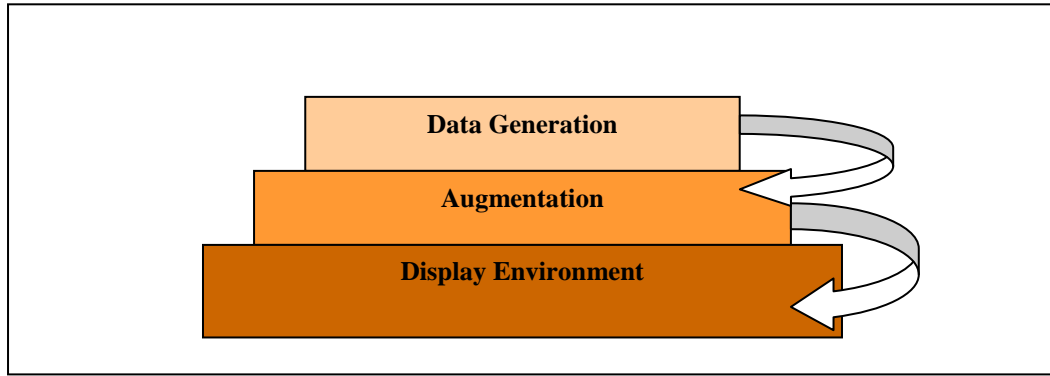


Figure 3.3 Layered Architecture of MARS

Although it is not mandatory that each MARS should have strict distinction among this layers we propose this approach since distinct layers can be studied and explores independently to enhance the capabilities of the MARS

3.6.4 Operation of MARS: In the architecture that we have proposed the data generation module tracks the position of the scene/object using various tracking devices, it also involves human operator to enter the data using sophisticated devices such as touch pad, graphic tablet gloves and sensor. Then the recorded data is temporarily stored in the buffer and forwarded to augmentation Unit. In case of the mixed Reality Systems This unit may be responsible to mix the virtual and augmented environment. The mobile computing device within the Data generation Unit then Sends the data to the augmentation unit (In case if the Augmentation Unit is not within the data generation unit itself) which after augmentation Send the data to the display unit (again if it is different from other two units).Each layer communicates with the layer down using wired Connection Or Wireless connection

Wired Connection: Generally when the two layers do not have strict distinction at that time such connections can be used. For example in case of the situated documentaries as shown in Figure 3.3 the augmentation unit may be within the Data generation unit.

Wireless Connection: But wired connection is not wise approach in the sensitive application like ones in the battlefield where the data generation unit(The soldier carrying Data Tracking Mobile devices)should be loaded with

minimum weight and even the units can be hidden easily. So in such applications there is a strict distinction in all the layers described above. So each layer communicates with each other via GPRS ,UMTS, WLAN ,Wi-Fi , Wimax and WiBro wireless technology

3.7 Wireless technology in MARS

Generally in the MARS system of today uses both above said approach but the ultimate goal of the MARS system are

- 1) Maximum Mobility
- 2) Optimum Augmentation
- 3) Better Display
- 4) Real time environment

Unfortunately some of these goals are contradictory. For example we are having now computers that can process in GHZ but there are not so mobile .We are having mobile and wireless devices that can operated from all most any place in the world but their computing power is limited. More over the requirement to use bulky tracking device such as 3D camera, Gloves, graphic tablet etc also imposes restriction on the mobility.

In addition to that in case of the MARS which has cleared distinction in layers we need to send the augmented data to the display system the can immerse the user in real like environment. Again such a systems are available up to somewhat extent (Walk through Displays).But their size again becomes the limiting factor in mobility A solution to that may be devices like HMD .But we need to have the devices that enable us to communicate data in two ways that means the a single unit should play a role of DATA generation and display ensuring the mobility as well This gives rise to following model.

Answer to all this questions may be the mobiles of next generation that have such capabilities. Now let's see whether the mobile generations are capable of fulfilling our requirements or not.

We are now living in the 2.5 generation of the Mobile and using GPRS,GSM Technology .The UTMS 3G mobiles will change the scenario. The following

graph [63] shows how the rapid change in the wireless transmission technology are going to take place.

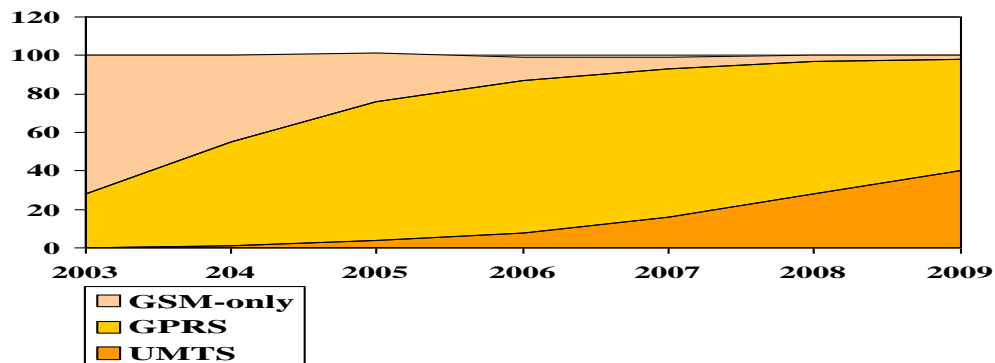


Figure3.4 : Rapid change in wireless communication

The UMTS Third Generation Cellular Networks will cover following objectives.

- The ability to speak to another user, face-to-face, by videophone
- Impressive high data rates for data transmission
- Simultaneous communication by voice and packet transmission
- The capacity to download and e-mail multimedia content
- Videoconferencing for up to eight participants
- Secure purchasing thanks to high levels of confidentiality and authentication
- I-mode mobile internet service
- Following graphs shows the How the data rates are likely to change with the upcoming generations.

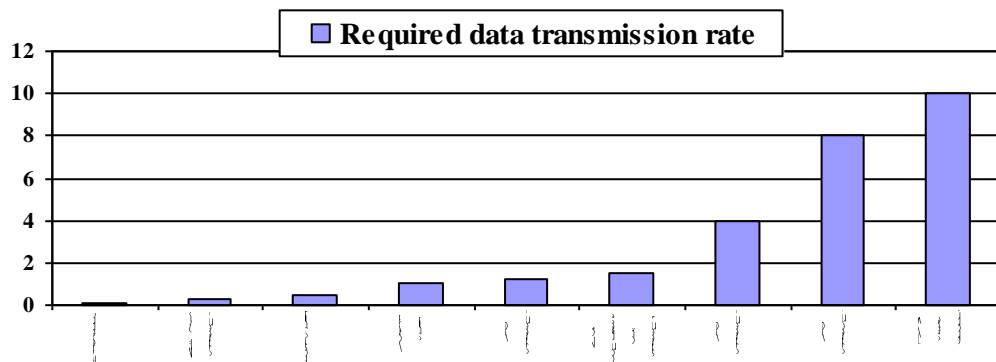


Figure 3.5 Various Data Rates for Different Applications

Chapter 5: Simulation of Wireless Technologies using QualNet5.0

5.1 GSM/GPRS (General Packet Radio Service)

The *QualNet* GSM model is based on 3GPP standards.

5.1.1 Features and assumptions

Implemented Features

The *QualNet* GSM model allows calls between Mobile Stations over the radio interface. Features include:

- The configuration allowed is: one MSC, multiple Base Stations and multiple Mobile Stations.
- Standard band is supported (900 MHz Mobile Stations and Base Stations)
- Cell selection and re-selection
- Dynamic channel assignment and release
- Location update
- Call setup and tear-down
- Handover (intra-MSC and inter-cell/Base Station)

Assumptions and Limitations

When creating a new GSM scenario, the following must be considered:

- In QualNet-5.0, the GSM model requires three node types to be defined.
 1. Mobile Station – MS
 2. Base Station – BS
 3. Mobile Switching Center – MSC
- Add multiple wireless channels for BSs.
- The listening channel mask should be zero for all MSs.
- All BSs must be connected with a wireless subnet.
- All BSs must be connected with MSC through a point to point connection or wireless networks.
- Configured neighboring BSs information for each BS.
- All MSs must be able to listen each broadcast channel.
- Use GSM link to establish the call between two MSs.

- MSC needs only GSM Layer3 protocol at the network layer.
- Set GSM protocol at network layer, MAC layer and physical layer for each BS and MS.
- Each BS has its own cell identity and location area code. But if end user defines the same area code for multiple BS's, then *QualNet* will not throw any exception.
- Originating and Terminating MS's, after releasing the Traffic channel, again select the cell.
- The paging broadcast packet is transmitted only in the BS in which terminating MS is currently present.
- Value of C2 Cell Reselection parameter is assumed to be 2.0 dB.
- After every call completion, Location Update procedure is initialized for originating as well as terminating MS.
- If there are more than 100 MSs in a single BS, no exception is thrown by *QualNet*.
- If an MS is busy, and there is a call request for the MS, *QualNet* doesn't throw any exception and silently drops the new call.
- *QualNet* GSM Model doesn't throw any exception if user gives erroneous input. It silently rejects the call request.

5.1.2 Sample Scenario

Scenario topology description

The sample scenario consists of one PLMN. There are 10 nodes in the GSM PLMN: one MSC, two Base Stations and seven mobile stations. Two BSs are connected to MSC via wired links. Also, both BSs are connected to a wireless network. All MSs are connected to another wireless network topology. Figure 5.1 shows the topology of the sample scenario.

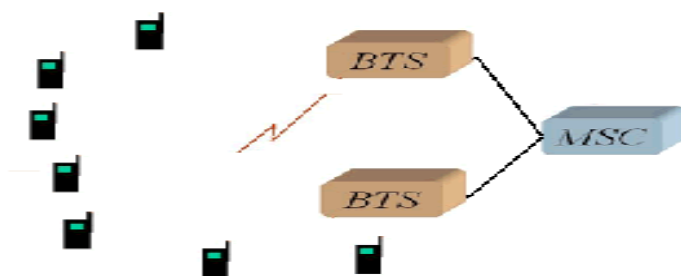


Figure 5.1: GSM/GPRS Sample Scenario Topology

GSM/GPRS Scenario developed using QualNet

Figure 5.2 shows GSM Scenario developed with coverage area 1000m X 1000m using QualNet. It contains 10 nodes out of which, nodes 4 through 10 are Mobile Stations (MS), 1 and 2 are Base Stations (BS), and node 3 is a Mobile Switch Center (MSC). The MS nodes are placed in a random fashion in the covered area and move as specified in the mobility trace file.

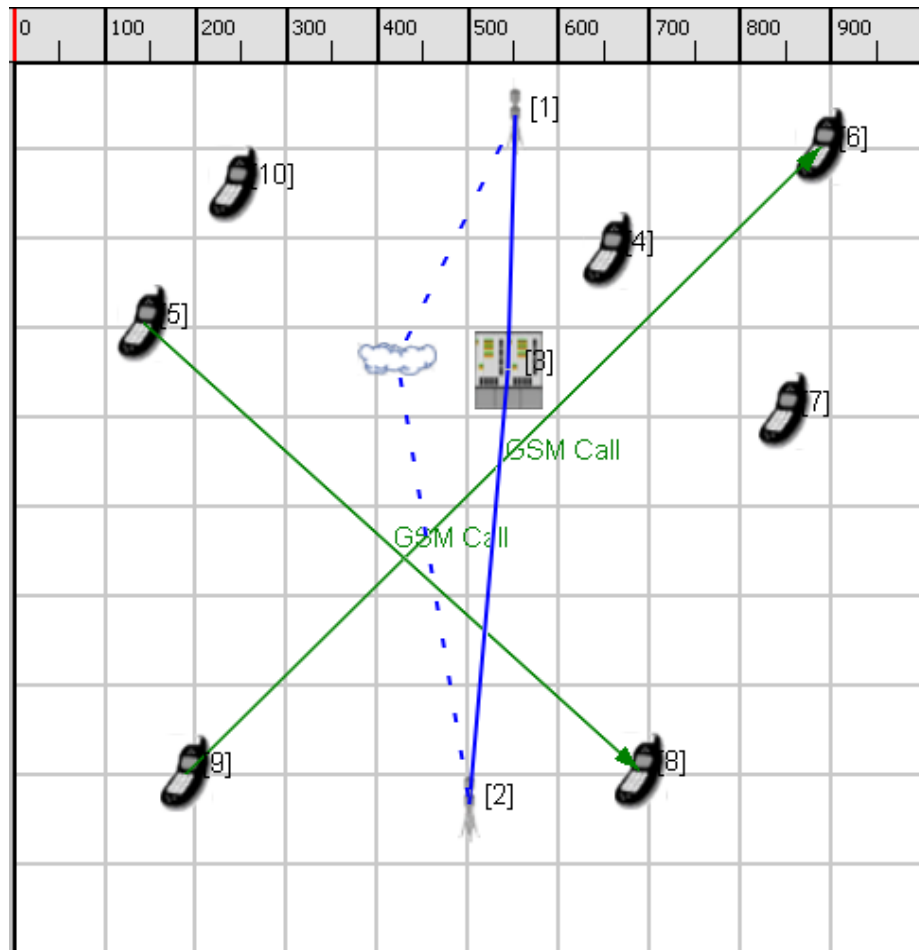


Figure 5.2: GSM Scenario developed using QualNet

The BS nodes are placed to cover the desired area and are fixed in location, as the MSC has been placed. The BS's are connected via wired links to the MSC and a default route file needs to be specified to ensure messaging between them is sent on the correct interface. The figure 5.2 shows GSM/GPRS scenario made using QualNet-5.0 as per architecture.

Below figures show how the various GUI parameters have been set for above scenario in figure 5.2.

Property	Value
Version	5.0
Experiment Name	GSMExample
Experiment Comment	none
Simulation Time	150 seconds
Seed	1
Scenario Background Image File	[Optional]

Figure 5.3 GSM Scenario Properties (a) General Properties

Property	Value
[-] Coordinate System	Cartesian
Scenario Dimensions (meters)	X: 1000 Y: 1000
Altitude Range (meters)	Above Sea Level: 1500 Below Sea Level: 1500
Terrain Data Format	None
Specify Urban Terrain Features	No
Weather Mobility Interval	100 milliseconds

(b) Terrain Properties

Property	Value
[-] Number of Channels	8
Channel Frequency [0]	935 MHz
Pathloss Model [0]	Two Ray
[-] Shadowing Model [0]	Constant
Shadowing Mean (dB) [0]	4.0
Fading Model [0]	None
Propagation Limit (dBm) [0]	-111.0
Maximum Propagation Distance [0]	0
Propagation Communication Proximity [0]	400
Propagation Profile Update Ratio [0]	0.0
Channel Frequency [1]	890 MHz
Pathloss Model [1]	Two Ray
[-] Shadowing Model [1]	Constant
Shadowing Mean (dB) [1]	4.0
Fading Model [1]	None
Propagation Limit (dBm) [1]	-111.0
Maximum Propagation Distance [1]	0
Propagation Communication Proximity [1]	400
Propagation Profile Update Ratio [1]	0.0
Channel Frequency [2]	935.2 MHz
Pathloss Model [2]	Two Ray

(c) Channel Properties

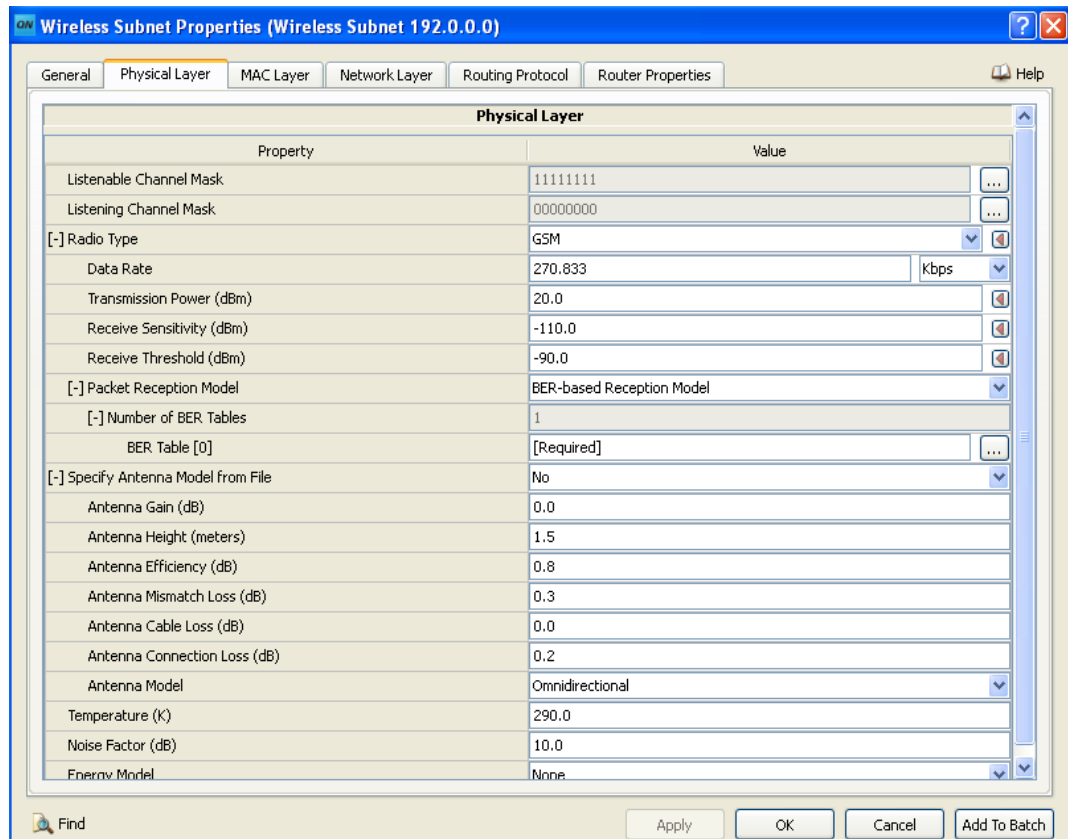
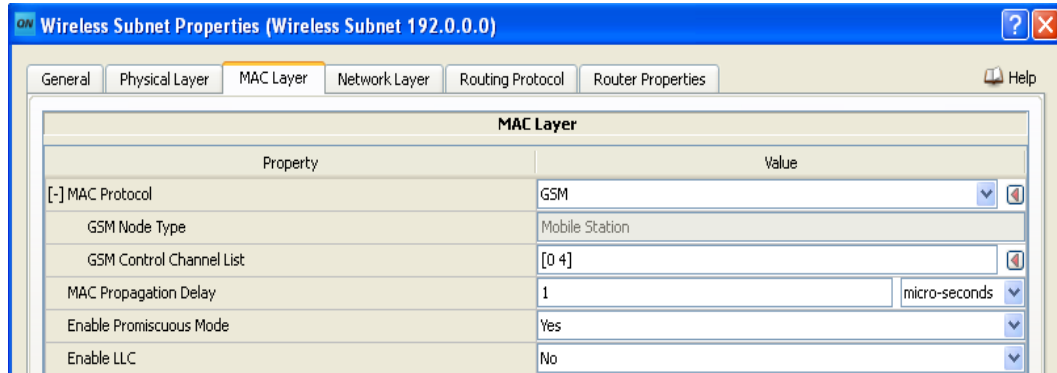
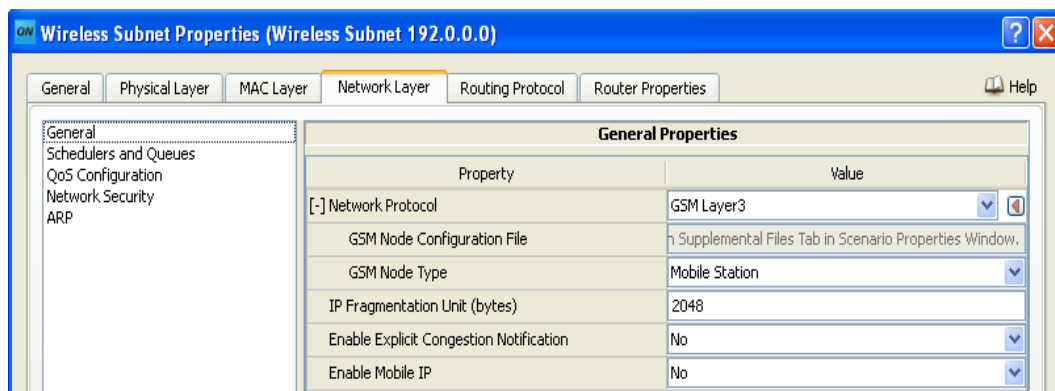


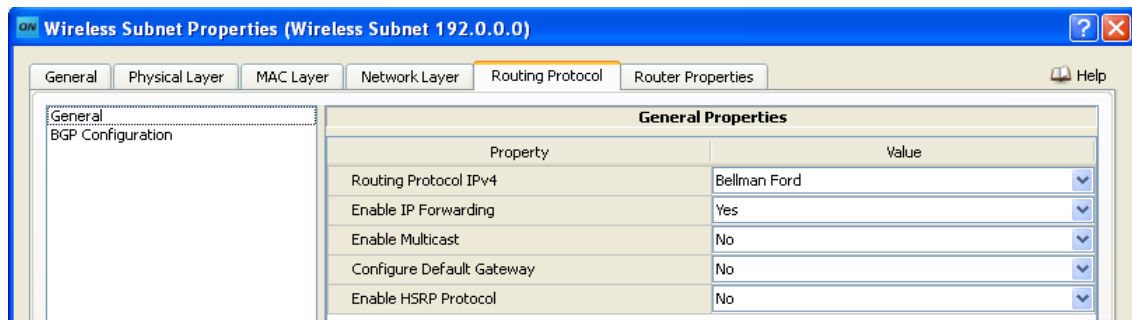
Figure 5.4: GSM/GPRS Scenario -- Wireless Subnet Properties (a) Physical Layer



(b) MAC Layer



(c) Network Layer



(d) Routing Protocol

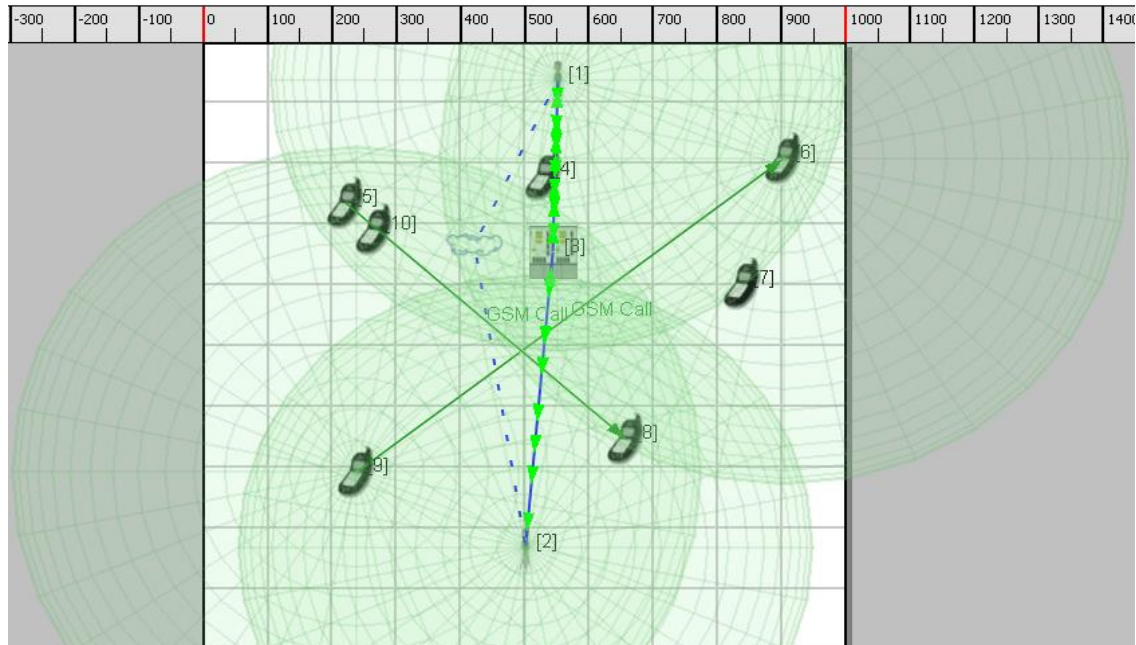


Figure 5.5: GSM/GPRS Scenario: Live Simulation

5.1.3 Simulation Results of GSM/GPRS Scenario

Below figures show the various results of above scenario after simulation using QualNet Analyzer.

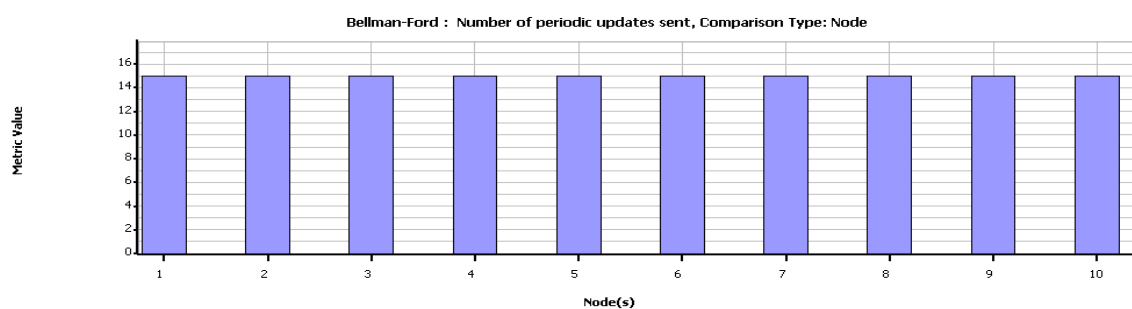
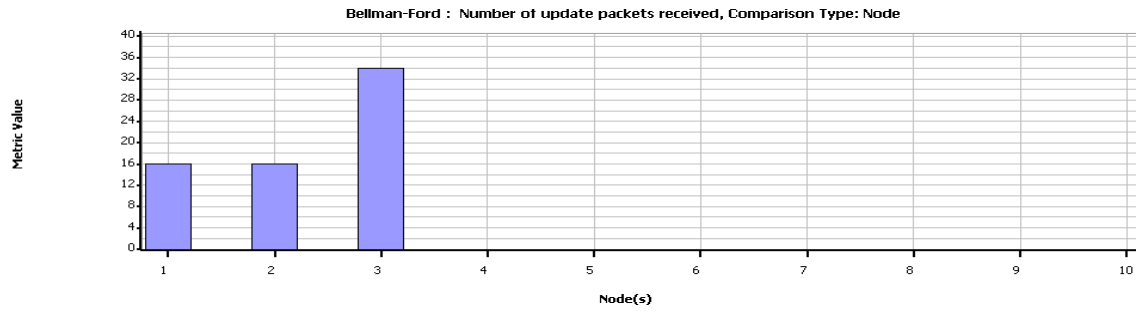
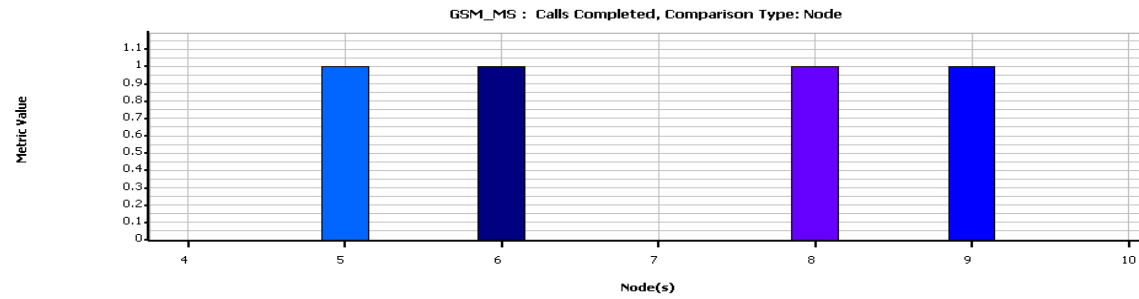


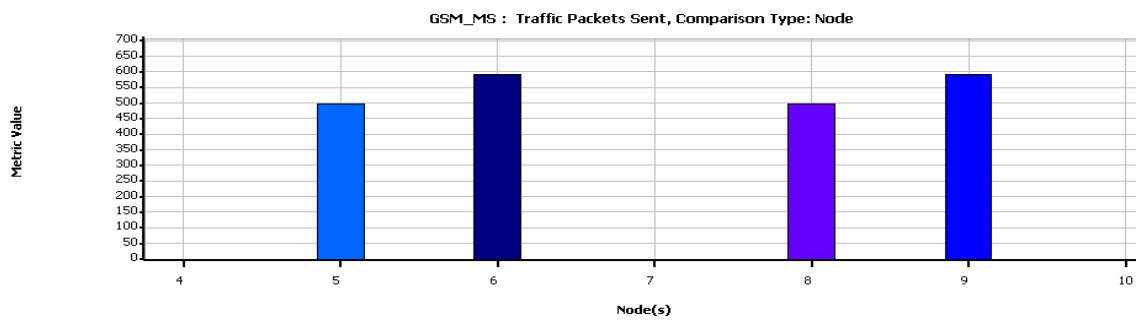
Figure 5.6: GSM/GPRS Scenario: Analyzer Results (a) Bellman-Ford: Number of periodic updates sent



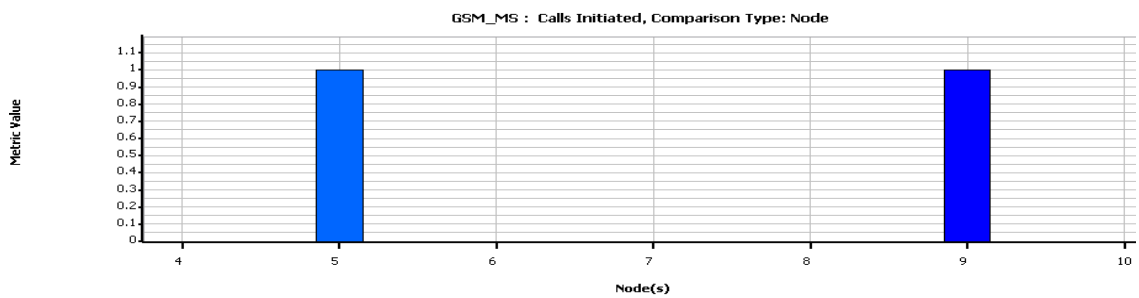
(b) Bellman-Ford: Number of periodic updates received



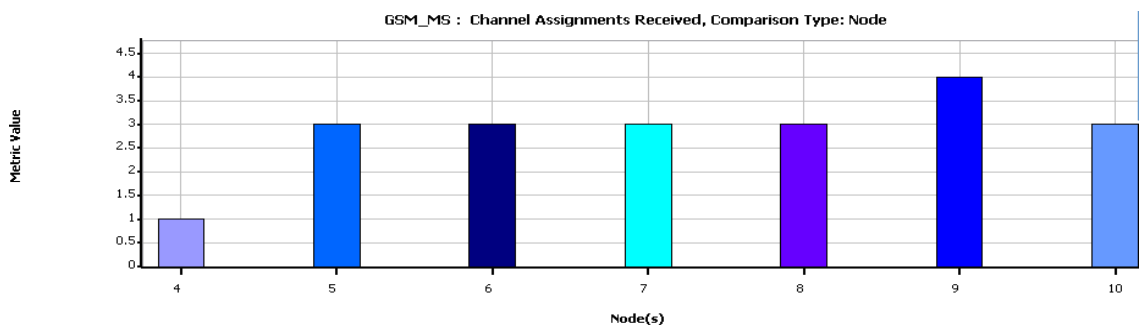
(c) GSM MS: Number of calls completed



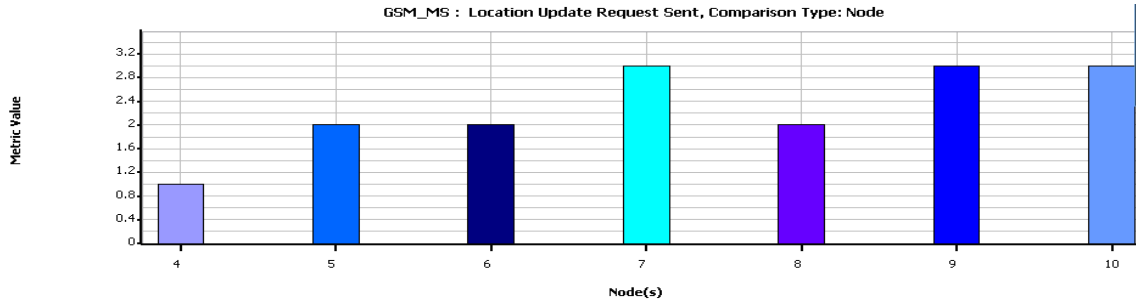
(d) GSM MS: Number of traffic packets sent



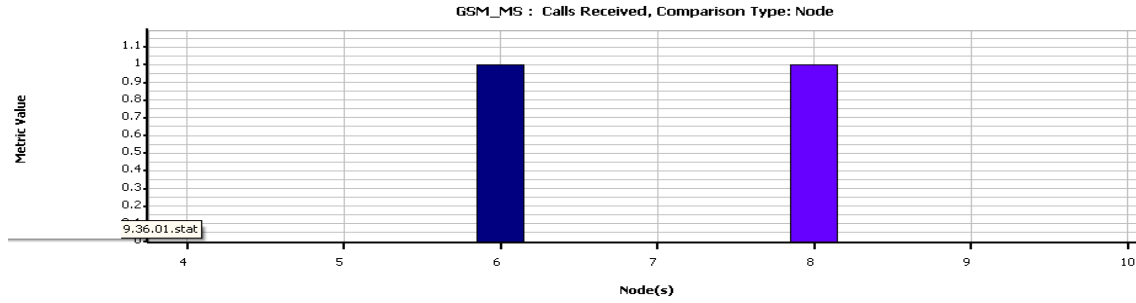
(e) GSM MS: Number of calls initiated



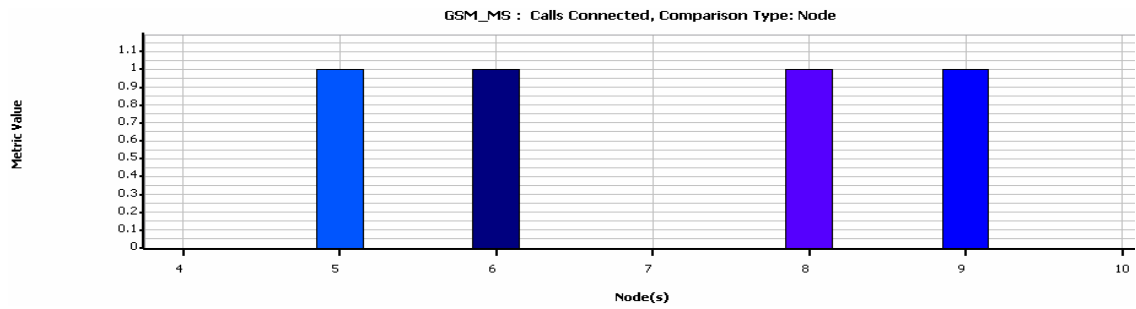
(f) GSM MS: Number of channel assignments received



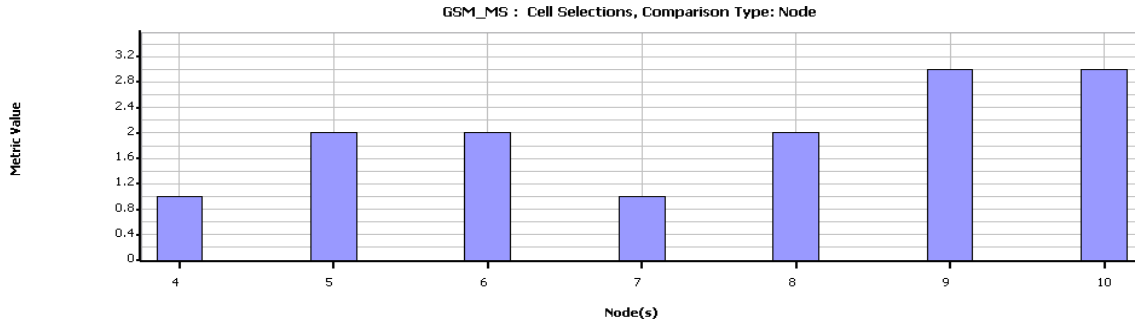
(g) GSM MS: Number of location update request sent



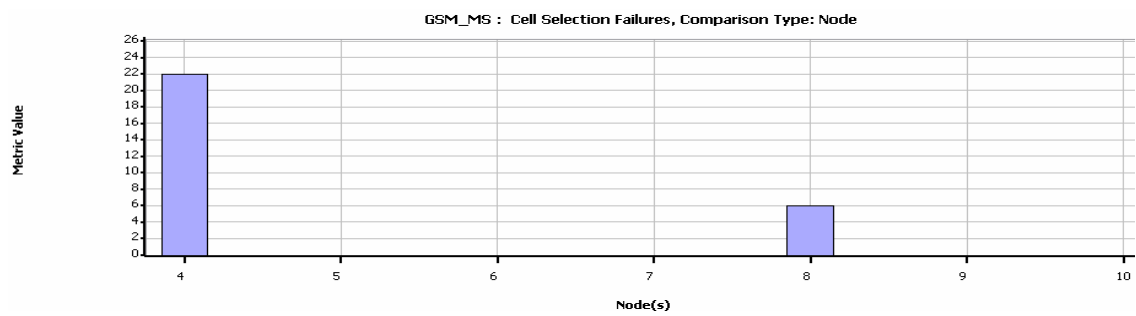
(h) GSM MS: Number of calls received



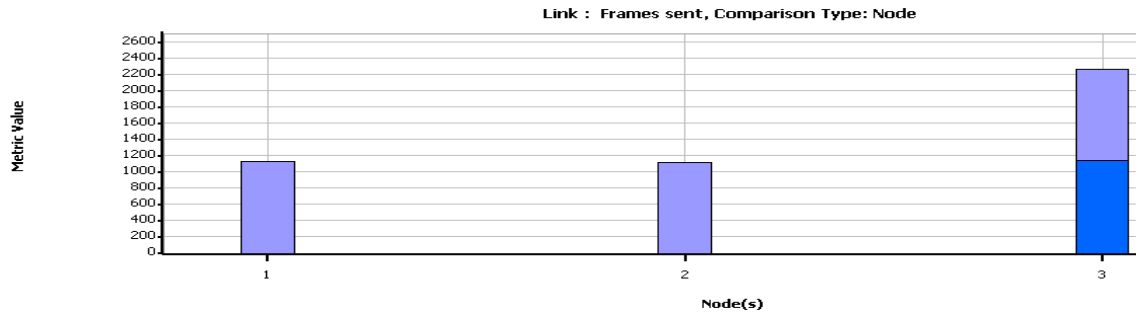
(i) GSM MS: Number of calls connected



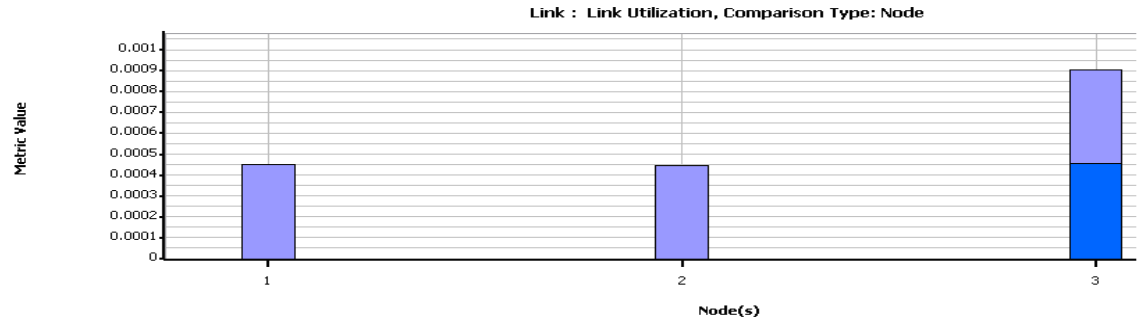
(j) GSM MS: Cell selections



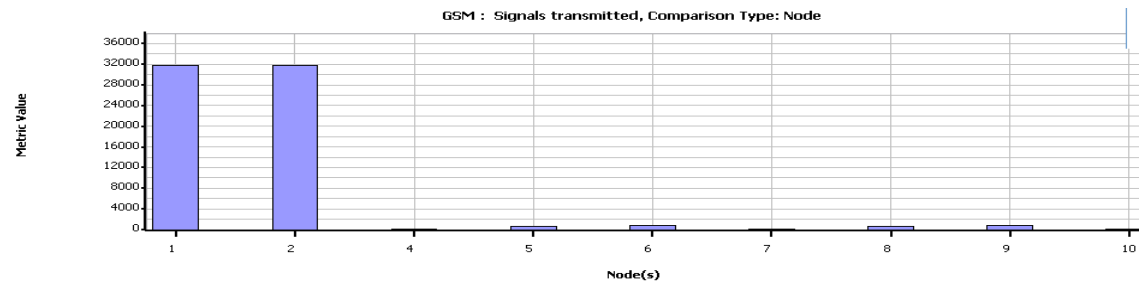
(k) GSM MS: Cell selection failures



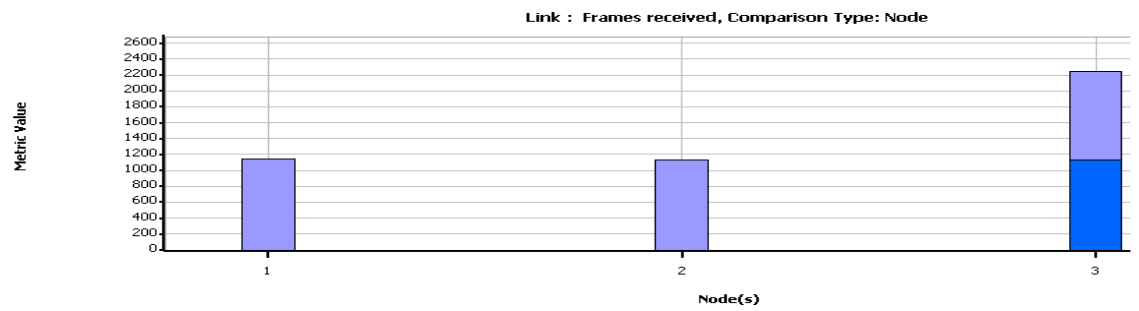
(l) Link: Frames sent



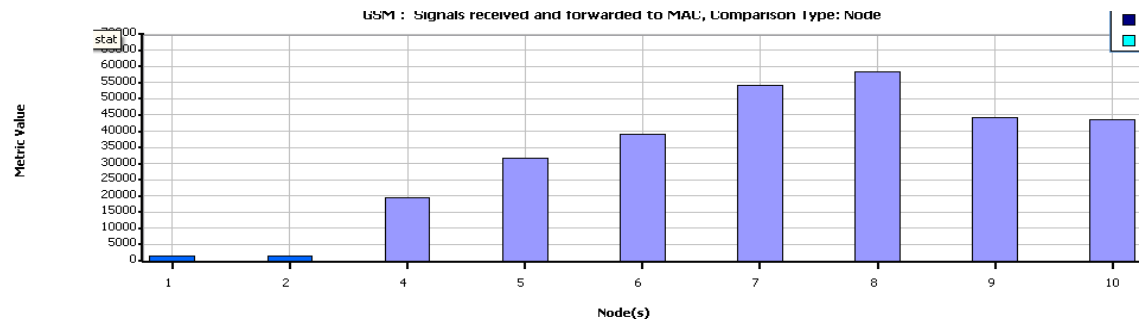
(m) Link: Link utilization



(n) GSM: Signals transmitted



(o) Link: Frames received



(p) GSM: Signals received and forwarded to MAC

5.1.4 GSM/GPRS Scenario Specifications for Case studies

1) Base Transceiver Station

- Mobility Model : None
- Radio Type : 802.11b
- Transmitted Power: 15 dbm
- Receiver sensitivity: -83 dbm to -93 dbm
- MAC Protocol: GSM
- Routing Policy: Dynamic
- Routing Protocol for IPV4: Bellman Ford
- Channel Range: 0 – 3
- Network protocol : IPv4

2) Mobile Station Controller

- Mobility Model : None
- Radio Type : 802.11b
- Transmitted Power: 15 dbm
- Receiver sensitivity: -83 dbm to -93 dbm
- MAC Protocol: GSM
- Routing Policy: Dynamic
- Routing Protocol for IPV4: Bellman Ford
- Network protocol : IPv4

3) Mobile

- Mobility Model : Random Waypoint
- Radio Type : 802.11b
- Transmitted Power: 15 dbm
- Receiver sensitivity: -83 dbm to -93 dbm
- MAC Protocol: GSM
- Routing Policy: Dynamic
- Routing Protocol for IPV4: Bellman Ford
- Network protocol : IPv4

4) Wireless Subnet

- Radio Type : GSM
- Transmitted Power: 20 dbm

- Receiver sensitivity: -110 dbm
- MAC Protocol: GSM
- Network Protocol: GSM Layer 3

5) GSM Link Properties

- Call start time : 18s
- Call Duration : 10s

6) Point to Point Link Properties

- MAC Protocol : Abstract Link MAC
- Link Type: Wired
- Network Protocol : GSM Layer 3

7) Wireless Subnet Link

- No properties to set by user

8) Configuration settings

- Simulation time : 30s
- Seed : 1
- Coordinate system : Cartesian
- Dimensions : 1000 x 1400
- Channel Frequency(MHz) : 890, 890.2, 890.4, 890.6, 935, 935.2, 935.4, 935.6
- Propagation Model: Statistical
- Propagation Limit: -111 dbm
- Pathloss Model : Two Ray
- Shadowing Model : Constant
- Fading Model : None
- Radio Type : GSM
- Data Rate : 270.33 kbps
- Transmission Power : 20 dbm
- Receive sensitivity : -110 dbm
- Receive threshold : -90 dbm
- Packet Reception model : Bit Error Rate
- MAC Protocol: GSM
- GSM Control Channel : [0 4]

- Network Protocol : GSM Layer 3
- Routing Policy : Dynamic

All these settings are default settings. And all case study simulations are carried out on the base of all above parameters. In all case studies power, data rate, path propagation model and microwave configuration is done

Case study1: To study the effect of change of Power Level on GSM Network

Settings: As given above

Experiment setup: As in fig.5.2

Details: In this experiment, power is varied of general settings – GSM signal from 5dbm to 20 dbm. For each power level various simulation results are generated and among them they are compared on base of GSM power transmitted, received, no of calls successfully connected, no of traffic packets sent.

Effect on the GSM signal power transmitted by all nodes

As in figure 5.7, as we vary the power of GSM signal transmitted, power transmitted by all nodes varies. As in above figure 5.7. Four different power levels are used 5dbm, 10dbm ,15dbm and 20 dbm. It is clearly seen from the bar graph that as we vary power from 5 dbm to 20 dbm, power transmitted by all nodes increases. It proves that as we vary power level, power transmitted by all nodes increases.

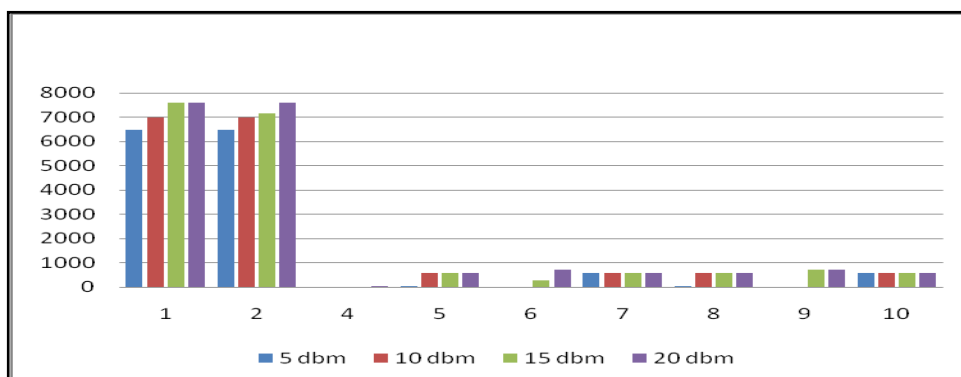


Figure 5.7: Effect on GSM Signal transmitted by variation in Power level

Effect on the GSM signal power received by all nodes

As in figure 5.8 power level is varied from 5 dbm to 20 dbm. As we increase GSM signal power level, it increases signal level transmitted by all nodes

which in turn give rise to the signal level received by all nodes. It is clearly visible that signal level received by nodes particularly 4 to 10 increases substantially. It proves that GSM power transmitted, increases signal received by all nodes.

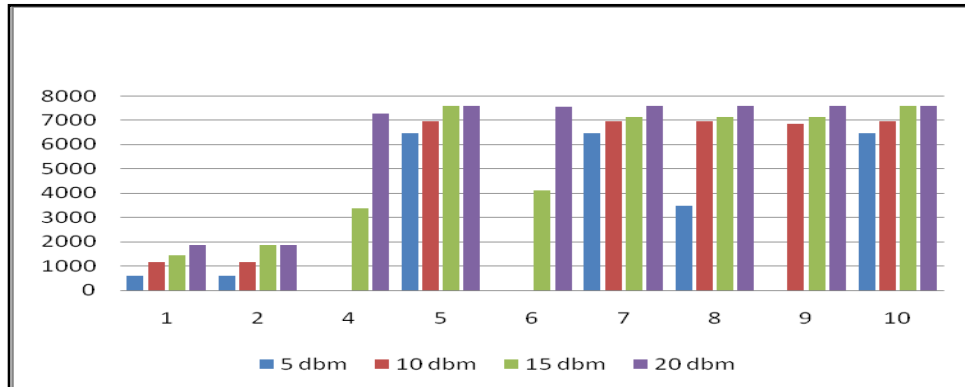


Figure 5.8: Effect on GSM Signal received by variation in Power level

Effect of variation of Power on Calls

As there is increase in GSM signal strength, power transmitted and received by all nodes increases, now let's see the effect on calls also. Figure 5.8 below shows bar chart comparing effect of variation in GSM signal on calls. Here power is varied from 5dbm to 20dbm.

As in figure 5.9 for 5 dbm power, 2 call is initiated, 1 call is received but one call is connected or completed. For 10 dbm power, 2 call is initiated, 2 call is received, connected and completed. For 15 dbm power, 3 calls are initiated, 3 call is received, connected and 2 call completed. For 20 dbm power, 3 calls are initiated, 3 calls are received, connected, completed. It proves that increases no of successful call completions.

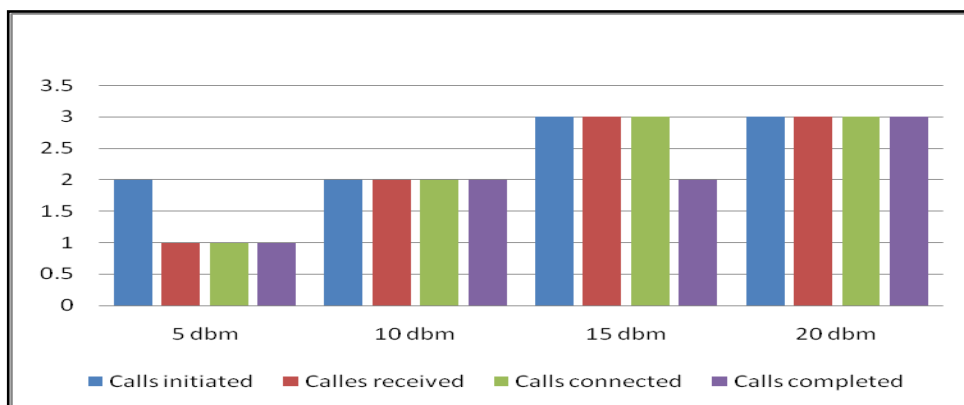


Figure 5.9: Effect on Calls by variation in Power level

Effects on Traffic Packets sent by all nodes

Now let's check effect on no of traffic packets sent by all nodes by variation in GSM signal power from 5 dbm to 20 dbm.

It is clearly shown in figure 5.10 that when the power level is 5dbm, no packets are sent any node except node 10. It means that this power is not sufficient to complete any call. Then power is increased to 10 dbm, about 500 packets are sent by node 5 ,7,8 and 10, but by 4,6 and 9 no packets are sent. If power level is raised to 15dbm, 500 packets are sent by node5, 7,8 and 9, while 150 of packets sent by node 6. Now it is still raised to 20dbm, no of packets sent by node 5,7and 9 is 500 while by node 6 and 9 are 590 each.

It proves that as we increase the signal power no of packets sent by all nodes also increases. So in turn it allows more users to accommodate.

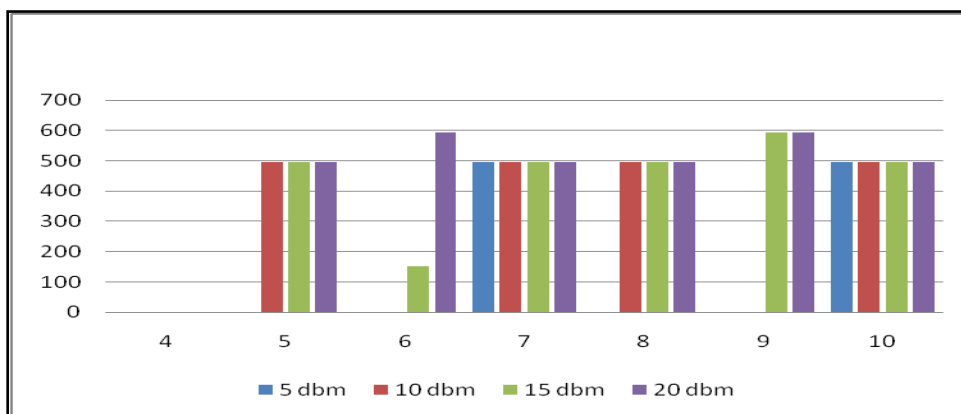


Figure 5.10: Effect on no. of Traffic Packets sent by variation in Power level

Conclusion:

- Power Level affect on transmitted GSM signal level and also received GSM signal level by all nodes
- As power level increases no. of calls successfully completed also increases
- Traffic packets sent are also increases as power level increases
- Power to operate sufficiently in this network is 20dbm

Case study 2: To study the effect of Propagation Model on GSM Network

Settings: As given above, power level of GSM signal will be 20dbm

Experiment setup: As in figure 5.2

Details: In this experiment we have varied path propagation model which is affecting fading of the various network. Variation in path propagation model has a huge effect on the performance of GSM Network on power transmitted, received, calls, traffic packets etc. In this experiment we will also check effect of variation in traffic from low traffic to heavy traffic condition.

We have varied path propagation models i.e., two ray model, free space model, Okumura-hata (urban), street microcell (LOS) and street microcell (NLOS).

Effect on GSM signal transmitted by all nodes

From figure 5.11, we can visualize that GSM signal transmitted drastically affected by variation in path propagation model. As it is clear from the figure 5.11 that two ray model gives more amount of power transmitted respect to other models by all nodes. Power transmitted by street microcell (NLOS) is less and only transmitted by node 1 and 2 in this model. Free space model also fails to give power transmitted by all nodes. Only two ray model, Okumura- hata model and Street microcell model gives power transmitted by all nodes. Among them power transmitted by okumura and street microcell are less compared to two ray model.

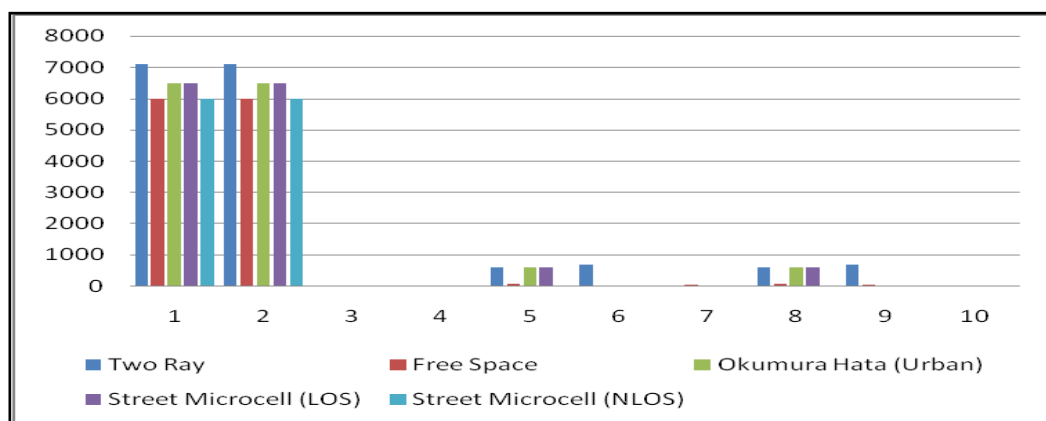


Figure 5.11: Effect on GSM Signal transmitted by variation in Propagation Model

So, it proves that two ray model gives better power transmission capability to all nodes.

Effect on GSM Signal received by all nodes

From figure 5.12, we can see the effect of variation of the path propagation model in GSM signal received by all nodes. As in figure 5.12, street microcell (NLOS) model many nodes fails to receive power. Same is the case with free space, okumura and street microcell (LOS) model.

Free space model delivers more amount of power to mobile nodes but it fails to deliver power to BTS. While two ray model delivers power to all nodes, it provides less amount of power to mobile nodes respect to free space. But it provides sufficient amount of power to successful completion of calls.

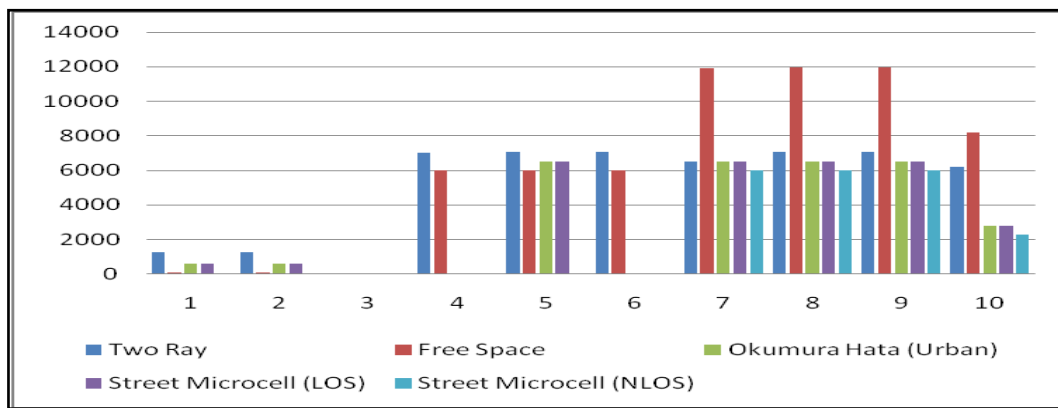


Figure 5.12: Effect on GSM Signal received by variation in Path Propagation Model

So, it proves that two ray model is better also in receiving power by all nodes.

Effect on Calls

Now let's examine the effect of variation in path propagation model to calls. As it is shown in figure 5.13. Comparison is done on basis of calls initiated, received, connected and completed.

In street microcell (NLOS), initiates one call but fails to receive, connect and complete by any node. Street microcell (LOS) and Okumura model initiates two calls but it succeeds to receive, connect and complete only one call. Free space model succeeds to initiate, receive, connect and complete one call only. But two ray model initiates two calls and receive, connect and complete two calls.

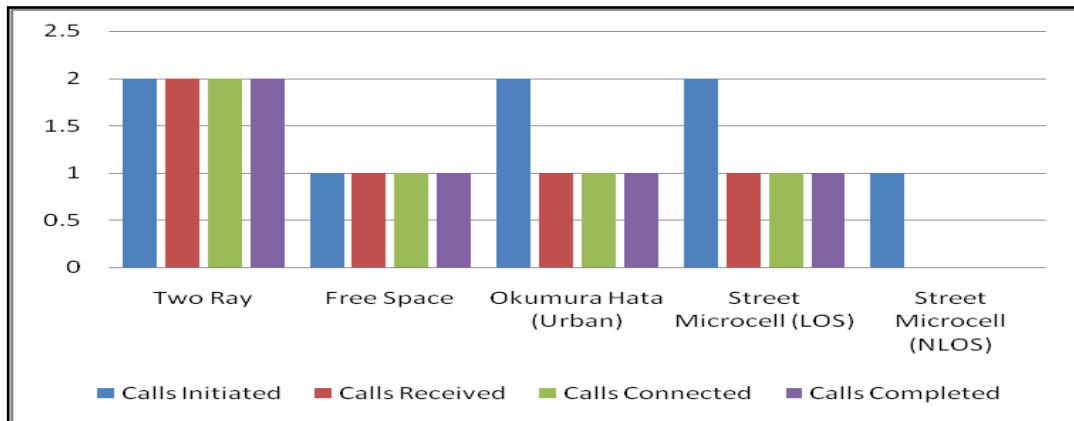


Figure 5.13: Effect on Calls by variation in Path Propagation Model

So, it proves that two ray model gives more number of successful call initiations to completions and Two ray model is better than other models.

Effect on traffic packets sent

Here we have compared the performance of various models on bases of no of traffic packets sent by all nodes. It is shown in figure 5.14 that free space model and street microcell (NLOS) fails to send traffic packets at all. While Okumura and street microcell (LOS) sends successfully traffic packets on node 5 and 8 but fails to send packets by node 6 and 9. In case of two ray model, it sends successfully packets from all nodes.

So, even with this 20dbm power, two ray model can send packet from all nodes, while other all model fails to provide. It means that they require more amount of power to transmit packets from all nodes.

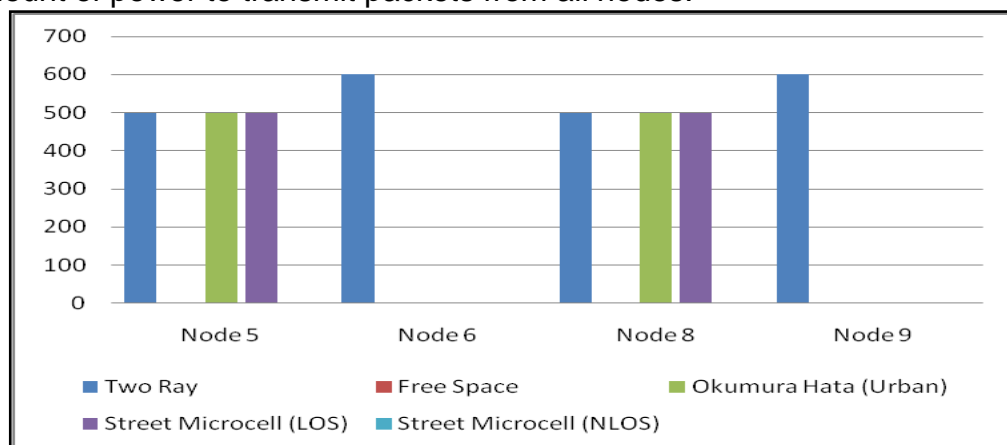


Figure 5.14: Effect on Traffic Packets sent by variation in Path Propagation Model

Effect of variation in traffic intensity on channel assignment

Here we have varied traffic intensity of our experiment set up and compared the performance on the base of the number of channels assigned by BTS. Two cases are considered, low traffic means that 7 mobile nodes and high traffic means 27 mobile nodes.

In case of low traffic conditions, two ray, free space, okumura, street microcell (LOS) and street microcell (NLOS) provides 100%, 50%, 100%, 100% and 100% respectively but in heavy traffic condition it is 45%, 40%, 40%, 37% and 30% respectively. It says that max channel assignment in both conditions is provided by two ray conditions. But the performance of two ray model is vastly affected by variation in traffic i.e. 100% to 45% while free space model is less affected by variation in traffic i.e. 50% to 40%.

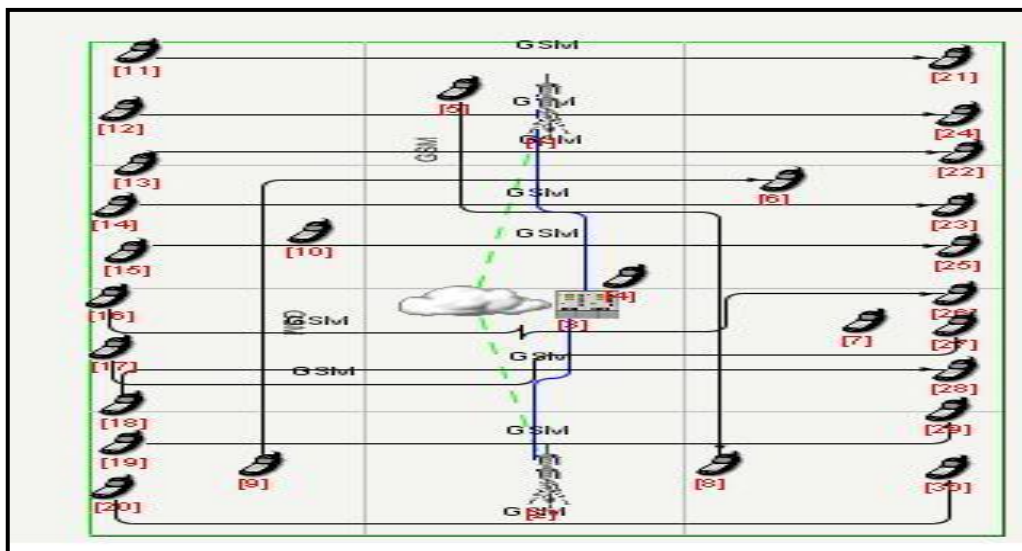


Figure 5.15: High Traffic Condition

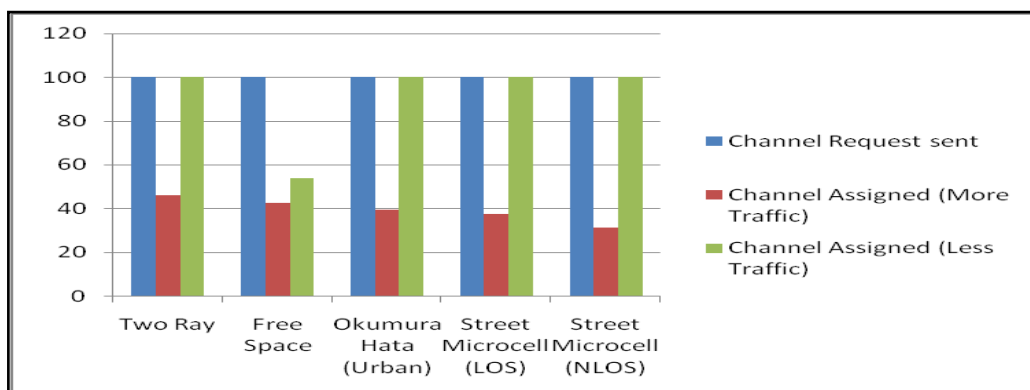


Figure 5.16: Effect on Channel Assignment by variation in Path Propagation Mode

It proves that, performance of two ray model is prone to change in traffic. So, in this condition free space model is better.

Conclusion:

- Best Path Propagation model proved here is Two Ray Model
- It gives more no of call completions at min power level than other models
- It sends more no of traffic packets
- It gives 100% channel assignment at less traffic
- But its performances are affected by change in traffic

Case study 3: To study the effect of change in data rate on GSM Network

Settings: As given above, power level of GSM signal will be 20dbm

Experiment setup: As in figure 5.15

Details: In this experiment we have varied the data rate of GSM signal. We have varied data rate from 240 kbps to 2000 kbps. Basic default data rate of any GSM signal is always 270.33 kbps.

Here we have compared the performance on the basis of the channel requests and assigned, also on the base of calls initiated and completed. Here we have compared all with reference power level kept as 20 dbm. We have also kept two ray model as path propagation model. Because this power level and path propagation model is sufficient enough to carry out successful call completions as it is proved in previous section.

Now we have changed traffic to three times as it is shown in figure 5.15. So no of nodes are changed from 7 to 27. It means traffic intensity is increased and we have increased the data rate by maintaining power level and other parameter which were sufficient to operate in the low traffic conditions.

Effect on Channel requests and channel assigned

As it is shown in figure 5.17, we have taken four different data rate 240, 270, 1000 and 2000 kbps. So, we have taken one data rate less than reference 270 kbps and two data rates higher than reference levels.

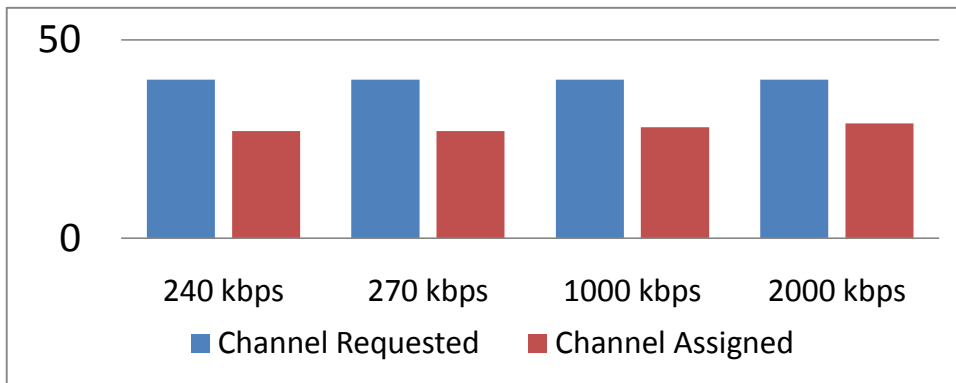


Figure 5.17: Effect on Channel Requested and Assigned by variation in data rate

As in figure 5.17, for all data rates channel is requested for 40 times and channel is assigned 26 times for 240 and 270 kbps while 28 times 1000 kbps and 29 times for 2000 kbps. It means that as we are increasing data rate no of times channels assigned is also increased not substantially but a bit only. It proves that change in data rate increases channel assignment by all nodes.

Effect on Call Initiation and Completion

Here we are going to compare the effect of change in data rate on Calls. We have maintained same power 20 dbm, path propagation model two ray and other parameters as default values. We have just varied data rate from 240 to 2000 kbps. Effect on calls is shown in figure 5.18. Here we can see that as data rate increases no of call completions and initiations increases.

As in figure 5.18, if 240 kbps and 270 kbps are there, four calls are initiated and two calls are received while if data rate is 1000 kbps and 2000 kbps is there, then five calls are initiated and two calls are completed. It means that it requires more power.

So, it proves that increase in data rate increases call initiations and if power is increased then also call completions

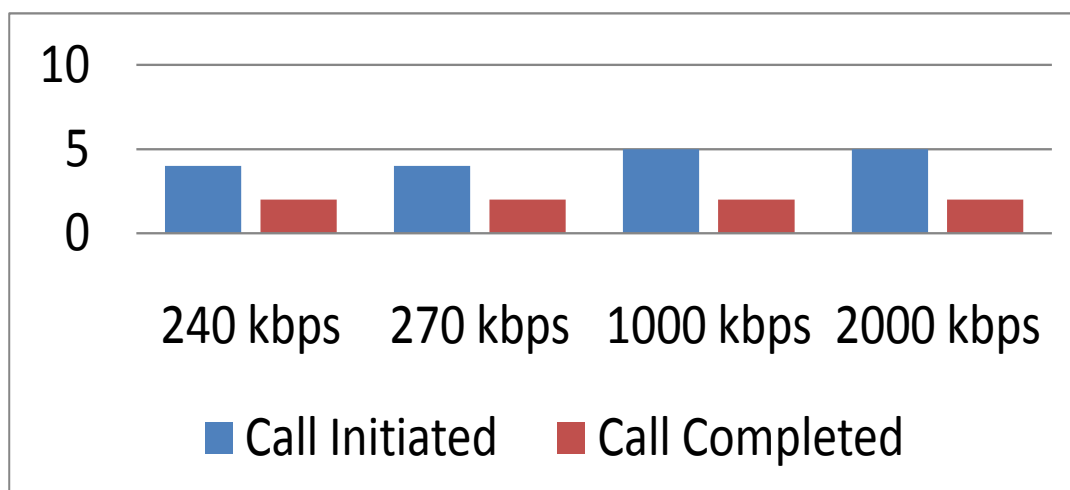


Figure 5.18: Effect on Calls by variation in data rate

.Conclusion:

- By change in data rate we can increase no of call initiation to completion
- It also increases the no of channel assignment
- It allows more users to be accommodated at a time

It can be concluded from all above comparative analysis that even if the size of cell is increased performance of GSM network does not deteriorate at all. So, we can say that this network is better in providing coverage than the previous one

5.1.5 Analysis of GSM/GPRS

The above GSM/GPRS examples have been experimented in various ways by changing various aspects as given below

1. Comparison is based on Number of users accommodated Vs Power

Table 5.1 Different values of Number of users accommodated and Power for GSM/GPRS

Power (dBm)	No. of users accommodated
5	30
10	66
15	100
20	146
25	200
30	320

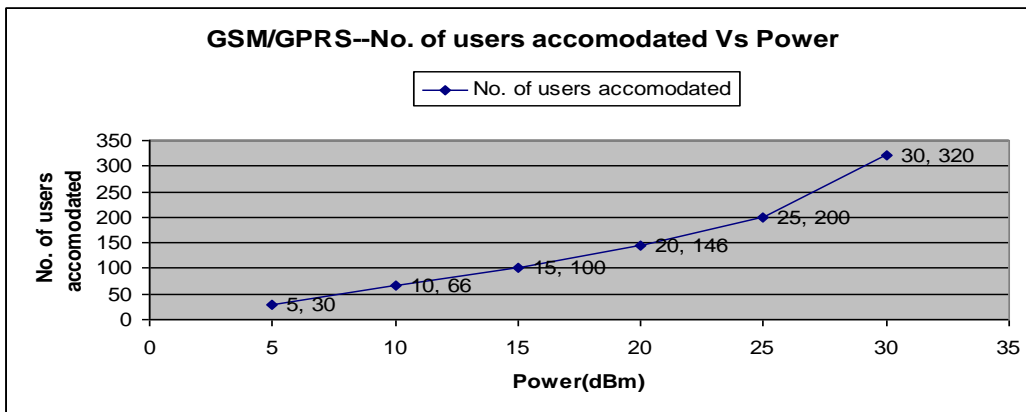


Figure 5.19 Graph shows analysis of no. of users accommodated Vs Power for GSM/GPRS

2. Comparison is based on Range (Coverage area) Vs Power

Table 5.2 Different values of Range and Power for GSM/GPRS

Power (dBm)	Range (Meter)
5	60
10	130
15	250
20	500
25	1000
30	1600

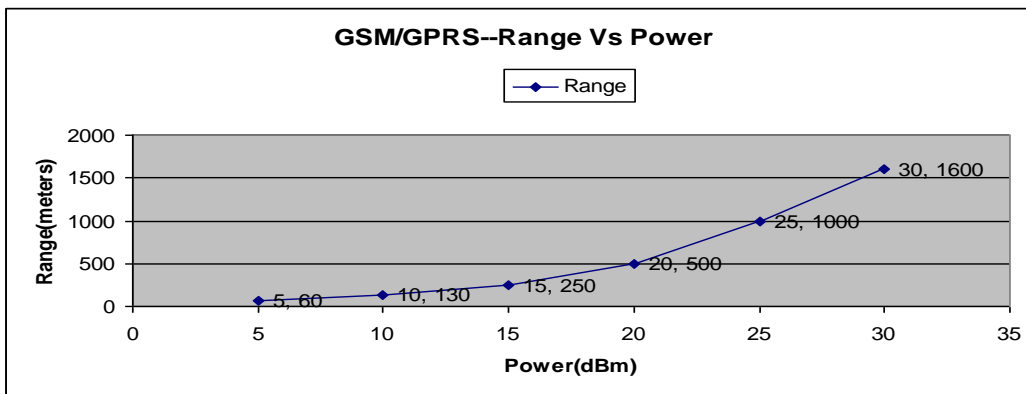


Figure5.20 Graph shows analysis of Range Vs Power for GSM/GPRS

3. Comparison is based on Data rate Vs Power

Table 5.3 Different values of Data rate and Power for GSM/GPRS

Power(dBm)	Data rate (Kbps)
5	180.43
10	240.27
15	270.833
20	350.66
25	966.56
30	1389.52

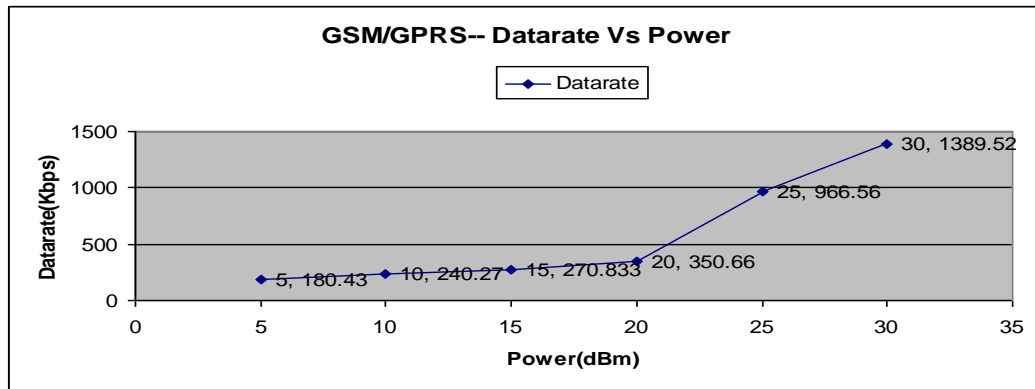


Figure 5.21 Graph shows analysis of Data rate Vs Power for GSM/GPRS

5.2 UMTS (Universal Mobile Telecommunication System)

The *QualNet* UMTS model is based on 3GPP standards.

5.2.1 Features and Assumptions

Implemented Features

- ◆ UMTS FDD (Frequency Division Duplex)
- ◆ UE, Node B, RNC, SGSN, GGSN, and HLR node types
- ◆ Support for four QoS classes: Background, Interactive, Streaming, and Conversational
- ◆ Open source admission control

Assumptions and Limitations

- Each carrier network has only one HLR.
- The VLR is co-located with the SGSN node.
- A SGSN node has both the SGSN module and MSC module. Thus, effectively it acts as a UMSC node.
- A GGSN node has both the GGSN module and GMSC module.
- A RNC can connect to only one SGSN.
- The mobile node (UE) is assumed to be a fully functional UMTS terminal. There is no modeling of different classes.
- Cordless Telephony Service (CTS) related services/functions/protocols are not supported.
- Only UTRAN radio access network is supported. Support for GSM BSS radio access network is not implemented.

5.2.2 Sample Scenario

The QualNet GUI provides preconfigured device types for the different UMTS nodes. The preconfigured UMTS device types can be selected from the Devices tab. These device types are as in figure 5.22: UMTS-UE, UMTS-RNC, UMTS-Node B, UMTS-SGSN, UMTS-GGSN, and UMTS-HLR.



Figure 5.22: UMTS Devices

Figure 5.23 shows the icons placed on the canvas for the different UMTS devices.

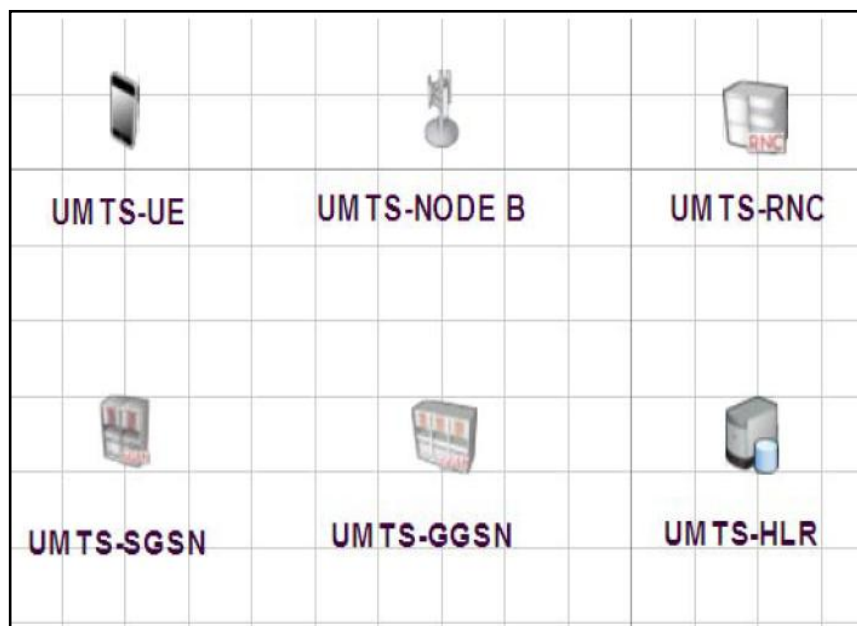


Figure 5.23 Icons for UMTS Devices

Scenario Description

The scenario shown in figure 5.24 is developed based on UMTS architecture. The sample scenario consists of one PLMN connected to a small IP network. There are 54 nodes in the UMTS PLMN: 47 UEs, three Node Bs, one RNC, one SGSN, one GGSN, and one HLR server. All three Node Bs are connected to the RNC. The SGSN, GGSN, and HLR are connected by point-to-point links and form the core network or RNC. All the UMTS UE are connected using wireless link with the help of wireless subnet. The IP network

consists of six nodes, two of which is connected to the GGSN and the other four IP nodes. Node B is a main device which radiates signal like BTS in GSM and it covers area depending on the transmission power of the Node B antenna. In QualNet-5.0, I have made various experiments by setting Number of users accommodated, Coverage area, Data rate and Power levels. Figure 5.24 is one of the best scenario of UMTS developed using QualNet-5.0.

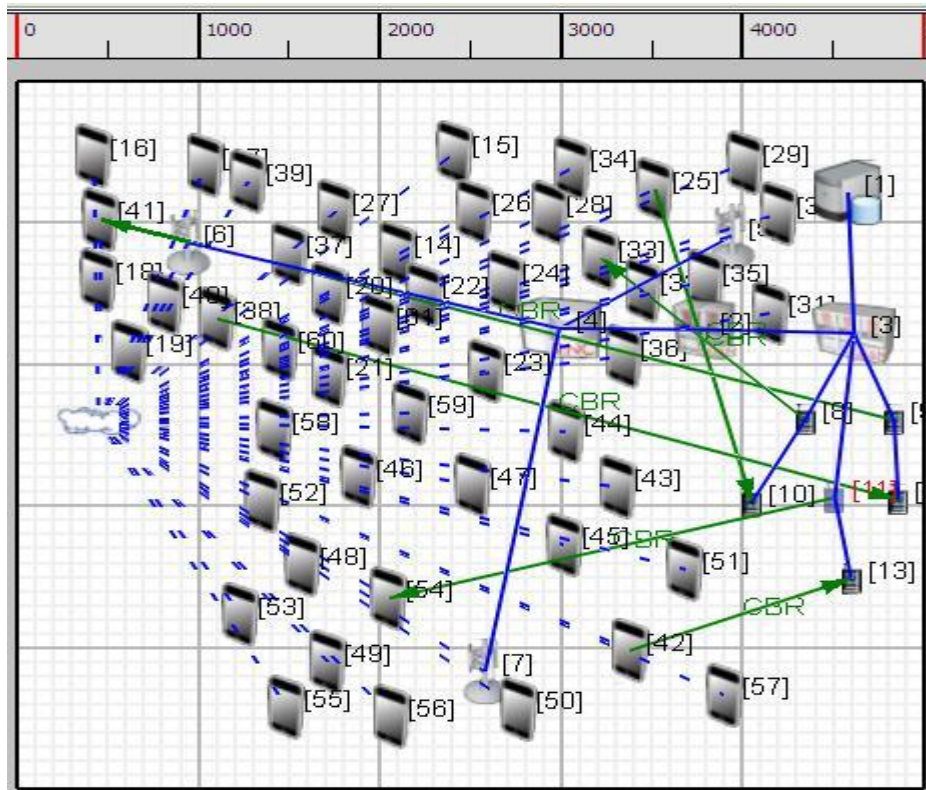


Figure 5.24: UMTS Scenario with coverage area 5000 sq. m developed using QualNet

This section describes sample scenario developed using QualNet-5.0 and how to configure sample scenario of UMTS in the QualNet GUI. It also includes analyzer results after simulating the scenario as shown in figure 5.24.

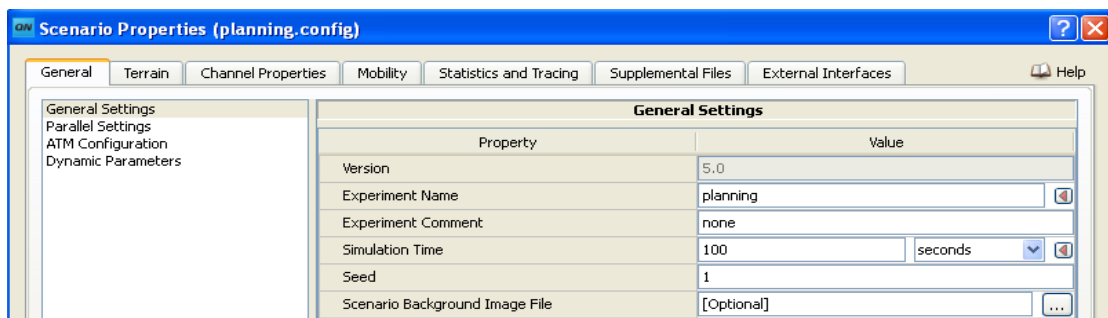
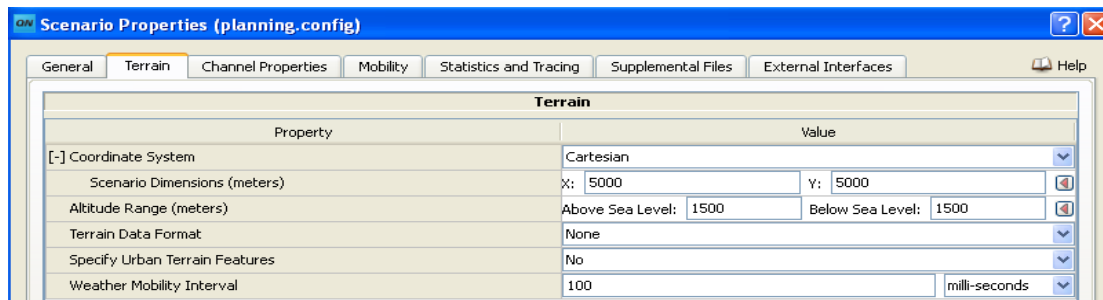


Figure 5.25: UMTS Scenario Properties (a) General Properties

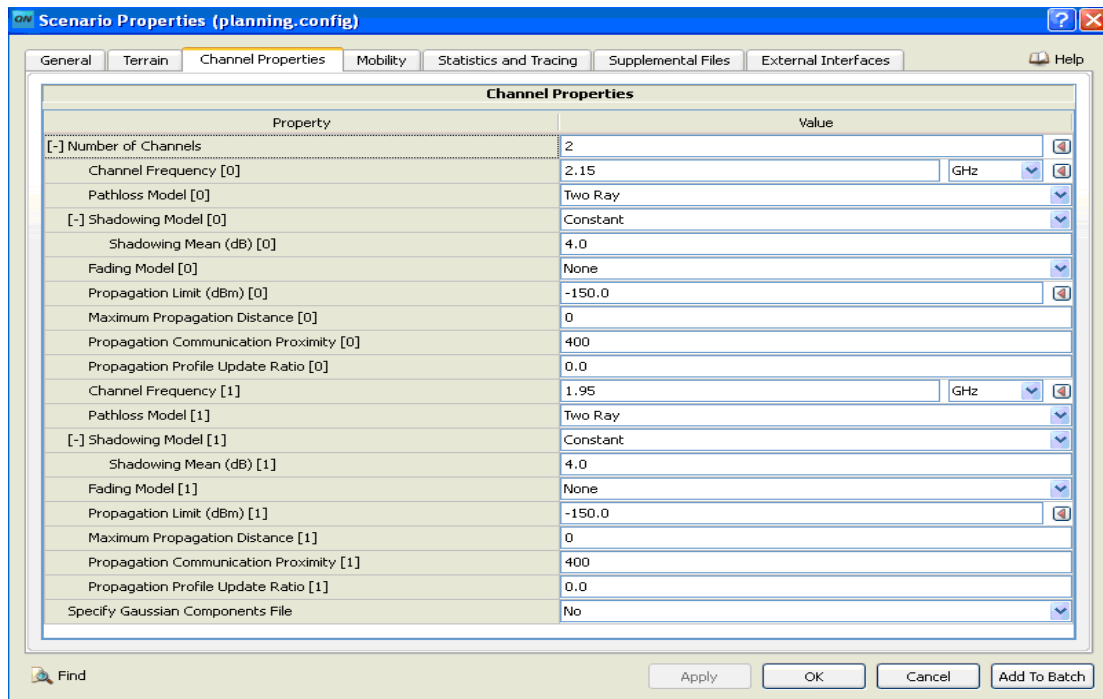


Scenario Properties (planning.config)

General **Terrain** Channel Properties Mobility Statistics and Tracing Supplemental Files External Interfaces Help

Property	Value
[...] Coordinate System	Cartesian
Scenario Dimensions (meters)	X: 5000 Y: 5000
Altitude Range (meters)	Above Sea Level: 1500 Below Sea Level: 1500
Terrain Data Format	None
Specify Urban Terrain Features	No
Weather Mobility Interval	100 milli-seconds

(b) Terrain Properties



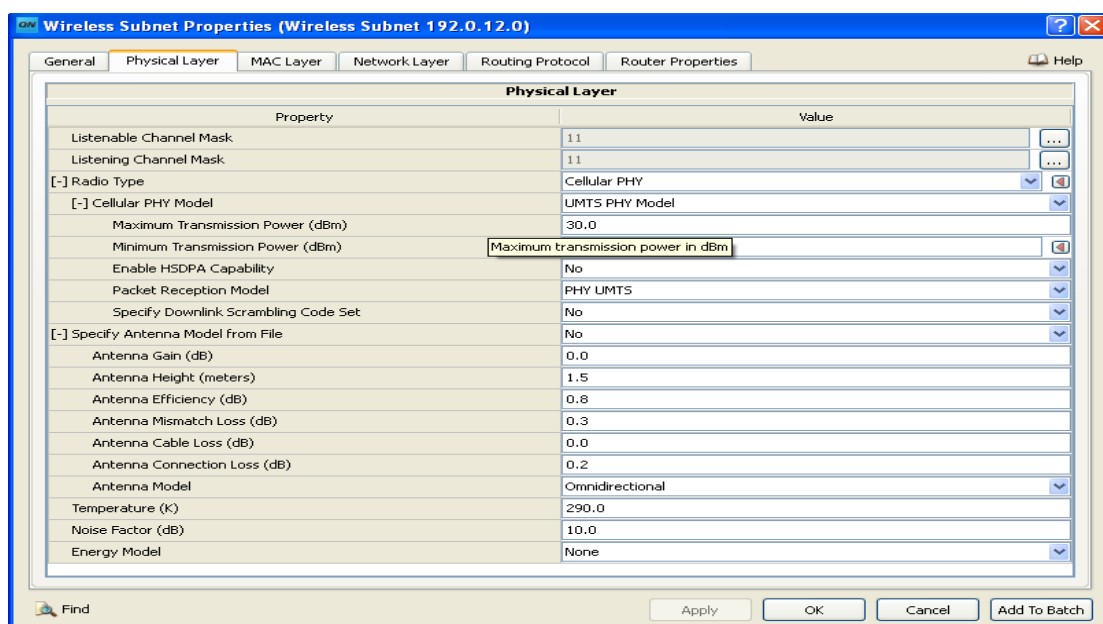
Scenario Properties (planning.config)

General Terrain **Channel Properties** Mobility Statistics and Tracing Supplemental Files External Interfaces Help

Property	Value
[...] Number of Channels	2
Channel Frequency [0]	2.15 GHz
Pathloss Model [0]	Two Ray
[...] Shadowing Model [0]	Constant
Shadowing Mean (dB) [0]	4.0
Fading Model [0]	None
Propagation Limit (dBm) [0]	-150.0
Maximum Propagation Distance [0]	0
Propagation Communication Proximity [0]	400
Propagation Profile Update Ratio [0]	0.0
Channel Frequency [1]	1.95 GHz
Pathloss Model [1]	Two Ray
[...] Shadowing Model [1]	Constant
Shadowing Mean (dB) [1]	4.0
Fading Model [1]	None
Propagation Limit (dBm) [1]	-150.0
Maximum Propagation Distance [1]	0
Propagation Communication Proximity [1]	400
Propagation Profile Update Ratio [1]	0.0
Specify Gaussian Components File	No

Find Apply OK Cancel Add To Batch

(c) Channel properties



Wireless Subnet Properties (Wireless Subnet 192.0.12.0)

General **Physical Layer** MAC Layer Network Layer Routing Protocol Router Properties Help

Property	Value
Listenable Channel Mask	11
Listening Channel Mask	11
[...] Radio Type	Cellular PHY
[...] Cellular PHY Model	UMTS PHY Model
Maximum Transmission Power (dBm)	30.0
Minimum Transmission Power (dBm)	Maximum transmission power in dBm
Enable HSDPA Capability	No
Packet Reception Model	PHY UMTS
Specify Downlink Scrambling Code Set	No
[...] Specify Antenna Model from File	No
Antenna Gain (dB)	0.0
Antenna Height (meters)	1.5
Antenna Efficiency (dB)	0.8
Antenna Mismatch Loss (dB)	0.3
Antenna Cable Loss (dB)	0.0
Antenna Connection Loss (dB)	0.2
Antenna Model	Omnidirectional
Temperature (K)	290.0
Noise Factor (dB)	10.0
Energy Model	None

Find Apply OK Cancel Add To Batch

Figure 5.26 UMTS Scenario -- Wireless Subnet Properties (a) Physical Layer

Wireless Subnet Properties (Wireless Subnet 192.0.12.0)

General Physical Layer **MAC Layer** Network Layer Routing Protocol Router Properties Help

Property	Value
[-] MAC Protocol	Cellular MAC
Cellular MAC Protocol	UMTS Layer 2
MAC Propagation Delay	1 micro-seconds
Enable Promiscuous Mode	Yes
Enable LLC	No

(b) MAC Layer

Wireless Subnet Properties (Wireless Subnet 192.0.12.0)

General Physical Layer MAC Layer **Network Layer** Routing Protocol Router Properties Help

General
Schedulers and Queues
QoS Configuration
Network Security
ARP

Property	Value
[-] Network Protocol	Cellular Layer3
IP Fragmentation Unit (bytes)	2048
Enable Explicit Congestion Notification	No
Enable Mobile IP	No

(c) Network Layer

Wireless Subnet Properties (Wireless Subnet 192.0.12.0)

General Physical Layer MAC Layer Network Layer **Routing Protocol** Router Properties Help

General
BGP Configuration

Property	Value
[-] Routing Protocol IPv4	AODV
Network Diameter (hops)	35
Node Traversal Time	40 milli-seconds
Active Route Timeout Interval	3 seconds
My Route Timeout Interval	6 seconds
Maximum RREQ Retries	2
Route Deletion Constant	5
Enable Hello Messages	No
Enable Local Repair	No
Enable Better Route Search	No
Enable Acknowledgement Processing	No
Maximum Number of Buffered Packets	100
Maximum Buffer Size (bytes)	0
Open Bi-directional Connection	No
TTL Start	1
TTL Increment	2
TTL Threshold	7
RREQs Replied by Destination Only	No
Enable IP Forwarding	Yes
Enable Multicast	No
Configure Default Gateway	No

Find Apply OK Cancel Add To Batch

(d) Routing Protocol

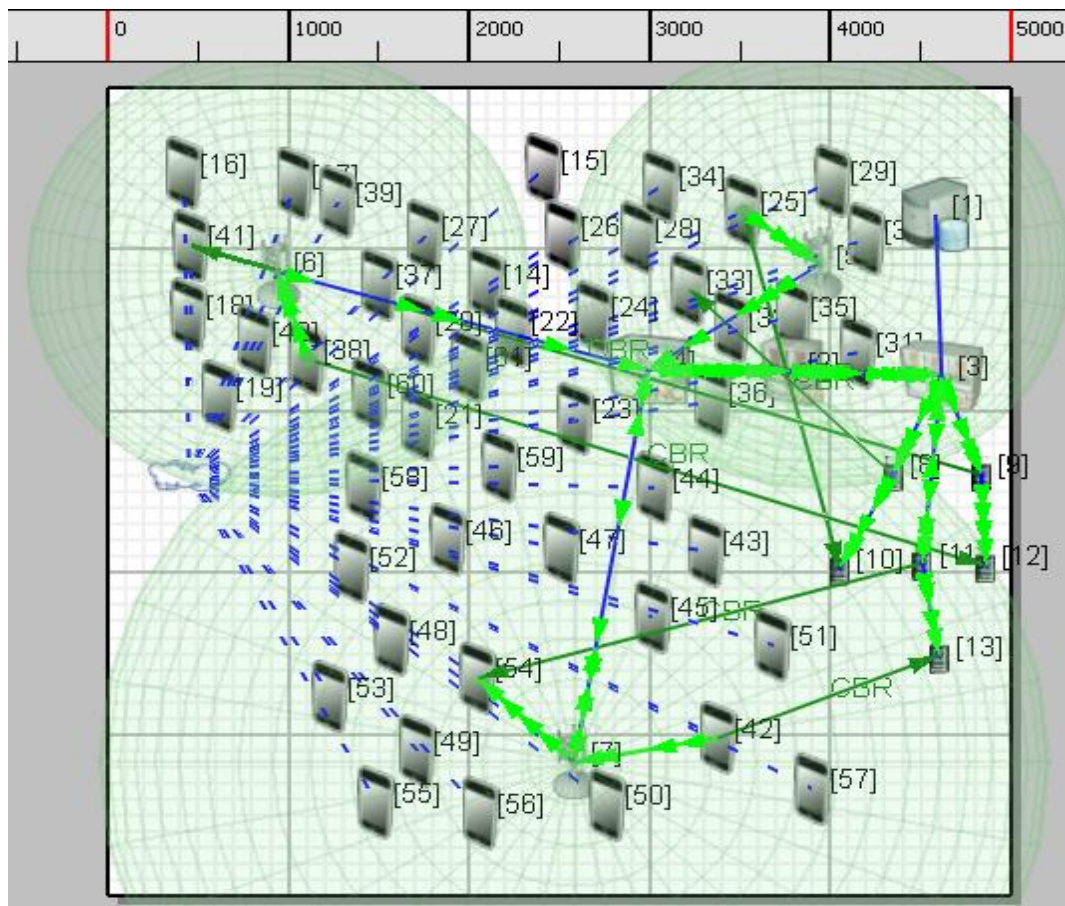
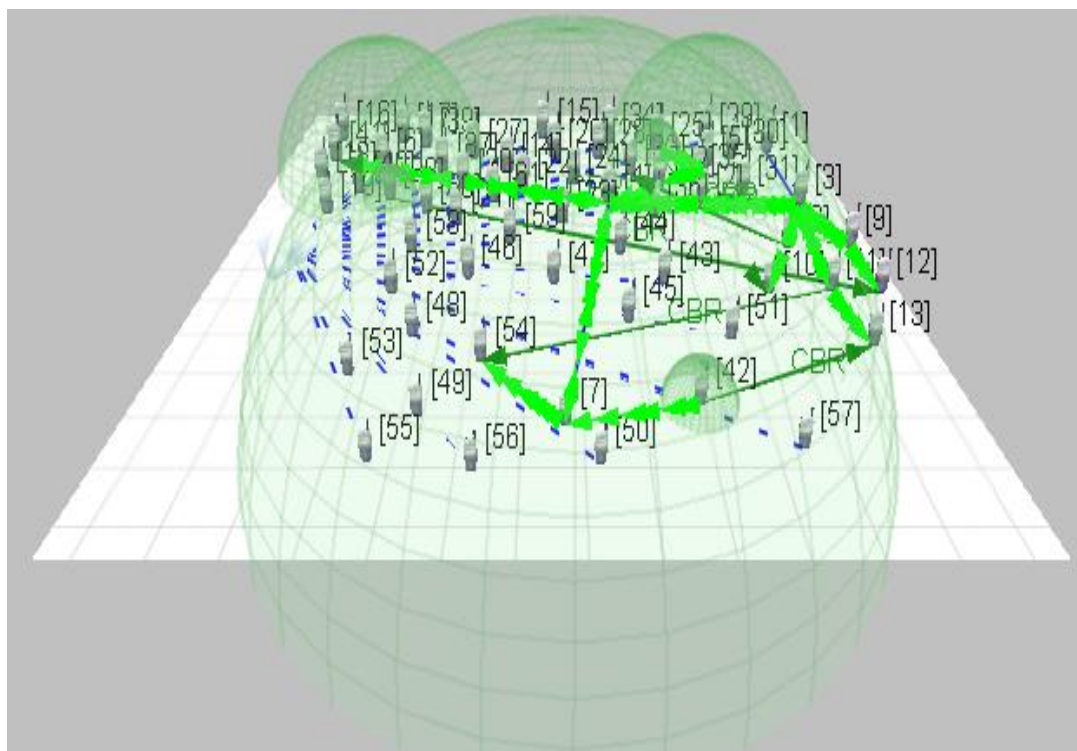


Figure 5.27 Live Simulation of UMTS model (a) X-Y mode



(b) 3D mode

5.2.3 Simulation results of UMTS scenario

Below figures show the various results of above scenario after simulation using QualNet Analyzer.

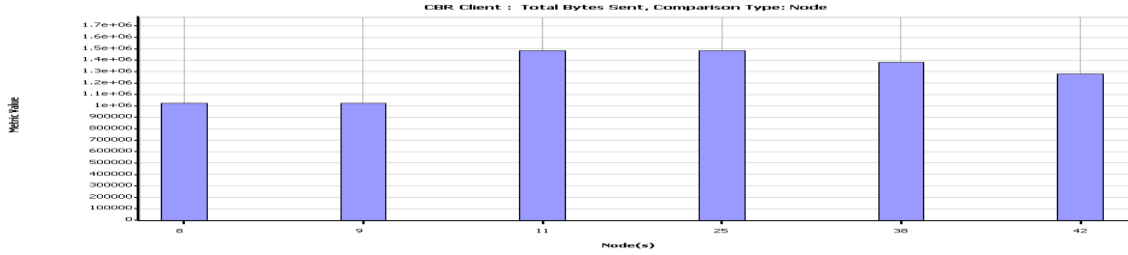
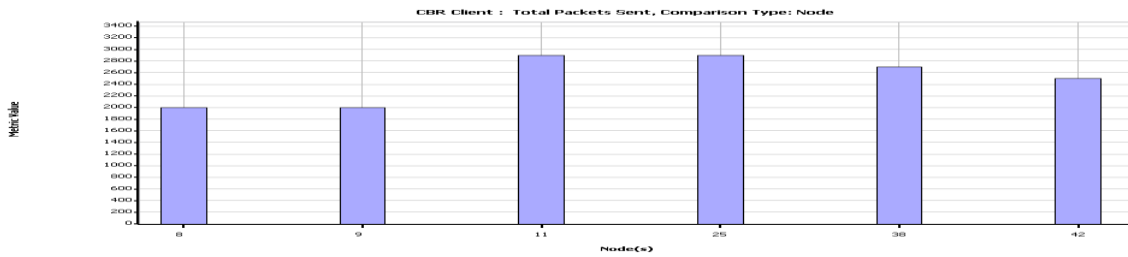
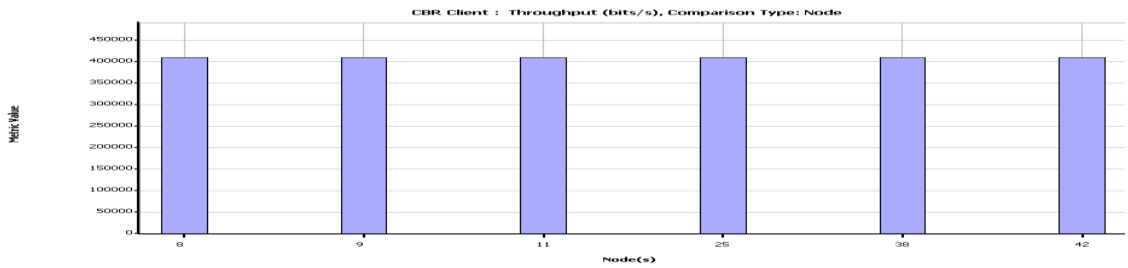


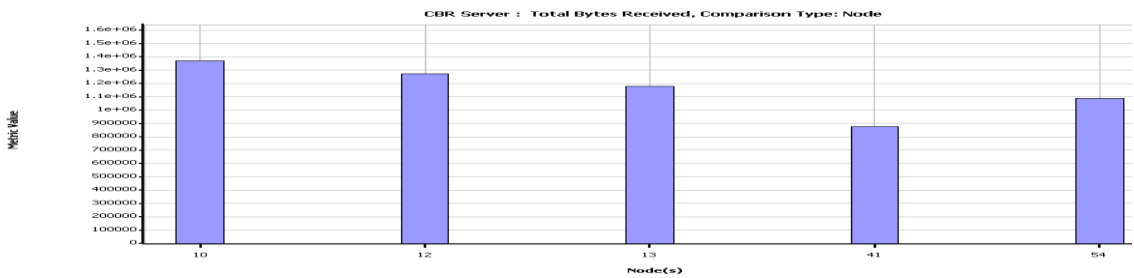
Figure 5.28 UMTS Scenario : Analysis results (a) CBR Client: Total Bytes Sent



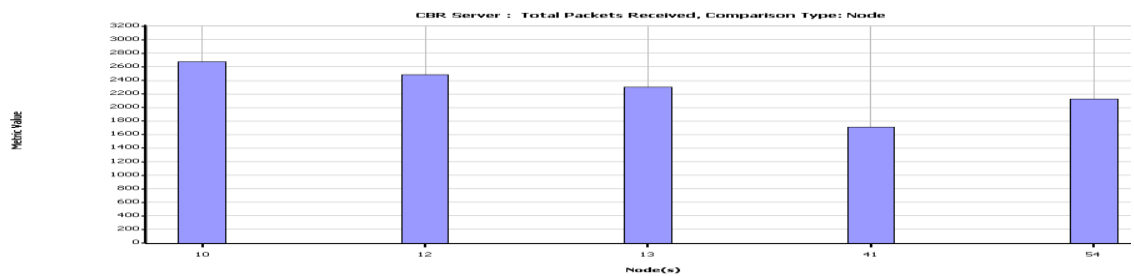
(b) CBR Client : Total packets sent



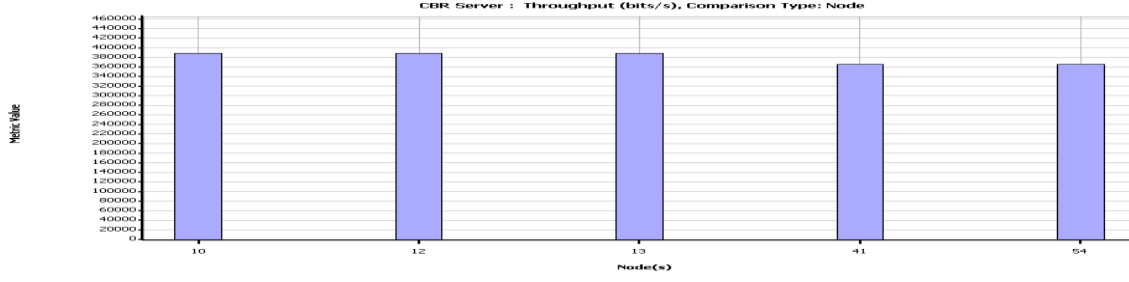
(c) CBR Client: Throughput (bits/s)



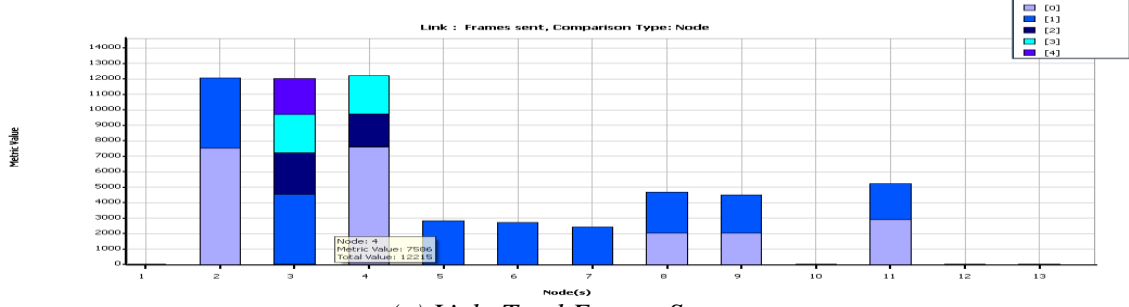
(d) CBR Server: Total Bytes Received



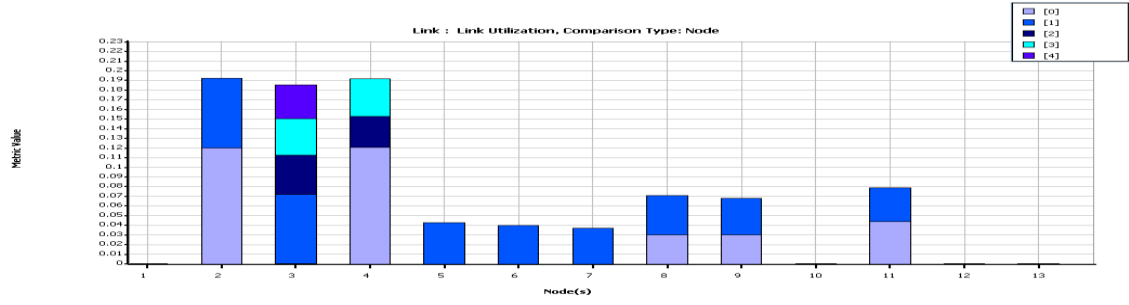
(e) CBR Server: Total Packets Received



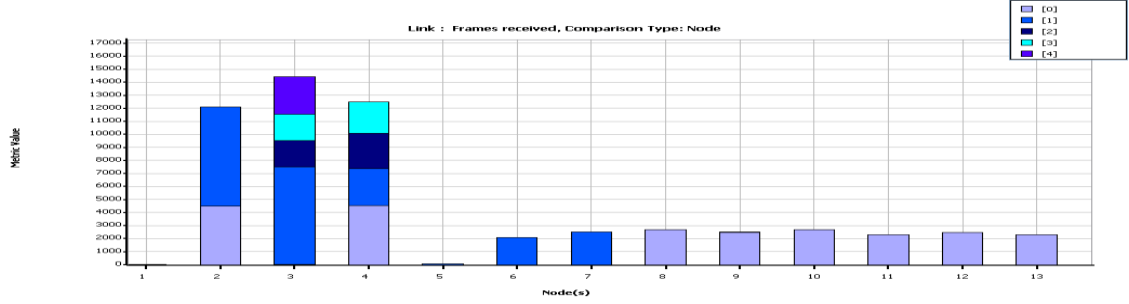
(f) CBR Server: Throughput (bits/s)



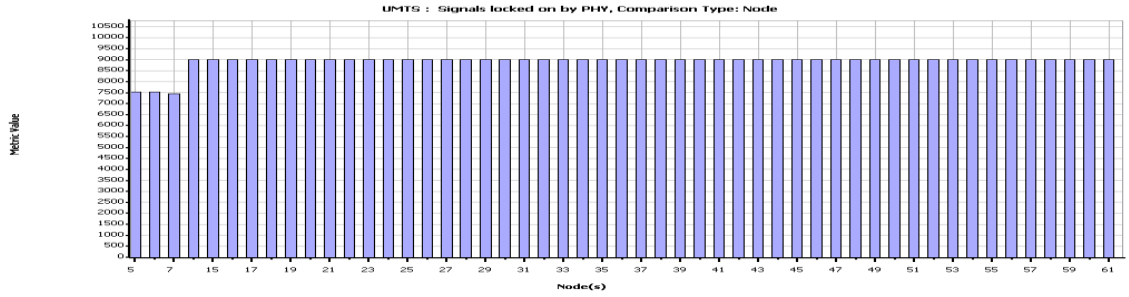
(g) Link: Total Frames Sent



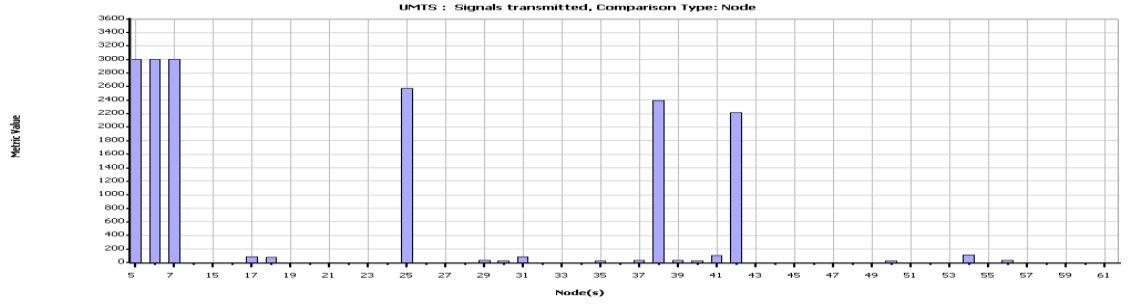
(h) Link: Link Utilization



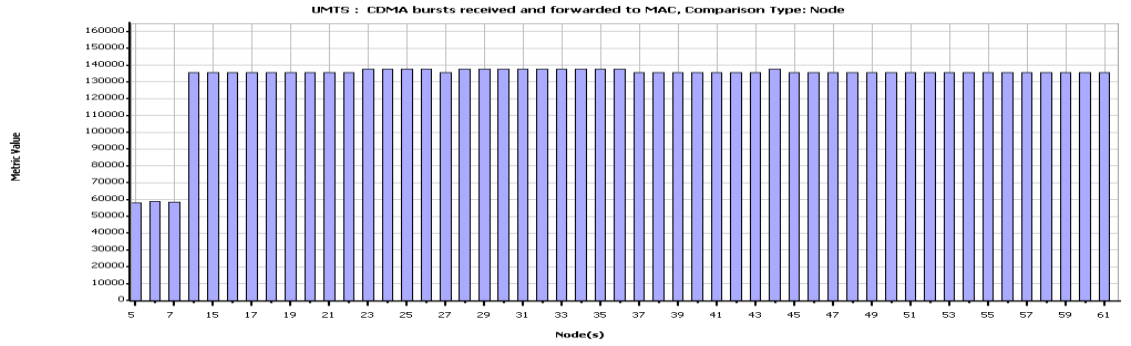
(i) Link: Total Frames Received



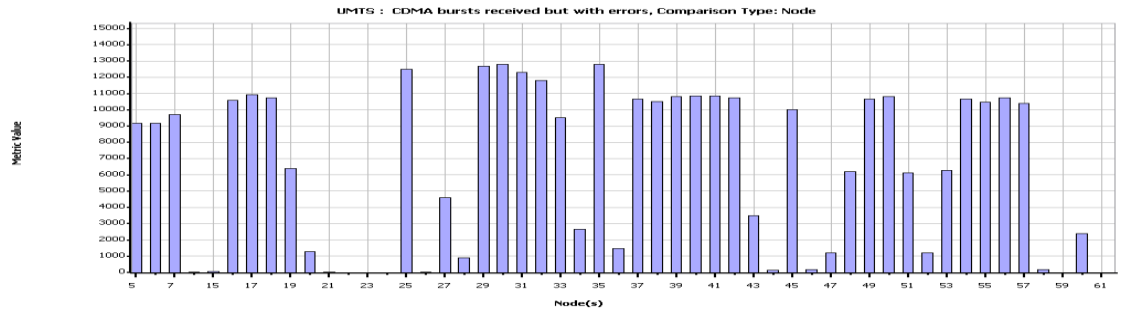
(j) UMTS: Signals locked on by PHY layer



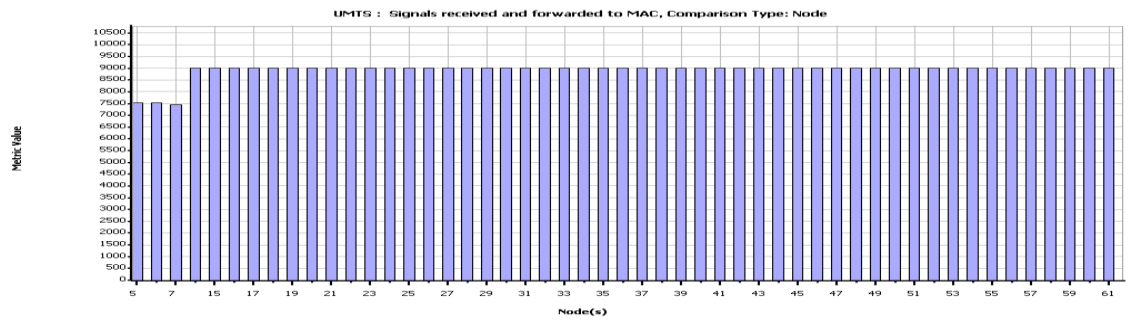
(k) UMTS: Signals transmitted



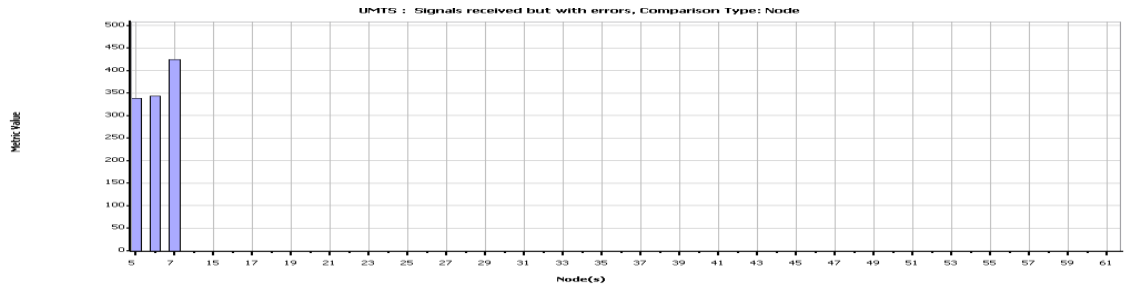
(l) UMTS: CDMA Bursts received and forwarded to MAC



(n) UMTS: CDMA Bursts received but with errors



(o) UMTS: Signals received and forwarded to MAC



(p) UMTS: Signals received but with errors

5.2.4 UMTS Network Specifications for Case studies

1) UMTS –UE

- Mobility Model : Random Waypoint
- Radio Type : Cellular PHY
- Transmitted Power: 30 dbm
- Receiver sensitivity: -84dbm
- MAC Protocol: Cellular MAC
- Routing Policy: Dynamic
- Routing Protocol for IPV4: Bellman Ford
- Network protocol : IPv4

2) UMTS-NODE B

- Mobility Model : None
- Radio Type : Cellular PHY
- Transmitted Power: 30 dbm
- Receiver sensitivity: -84 dbm
- MAC Protocol: Cellular MAC
- Routing Policy: Dynamic
- Routing Protocol for IPV4: Bellman Ford
- Network protocol : IPv4

3) UMTS-RNC

- Mobility Model : None
- Radio Type : Cellular PHY
- Transmitted Power: 30 dbm
- Receiver sensitivity: -84 dbm
- MAC Protocol: Cellular MAC
- Routing Policy: Dynamic
- Routing Protocol for IPV4: Bellman Ford
- Network protocol : IPv4

4) UMTS-SGSN , UMTS-GGSN

- Mobility Model : None
- Radio Type : Cellular PHY

- Transmitted Power: 30 dbm
- Receiver sensitivity: -84 dbm
- MAC Protocol: Cellular MAC
- Routing Policy: Dynamic
- Routing Protocol for IPV4: Bellman Ford
- Network protocol : IPv4

Wireless Subnet

- Radio Type : Cellular PHY
- Transmitted Power: 30 dbm
- Receiver sensitivity: -110 dbm
- MAC Protocol: Cellular MAC
- Network Protocol: Cellular Layer 3

5) CBR Link Properties

- Call start time : 1s
- Call Duration : 100s

6) Point to Point Link Properties

- MAC Protocol : Abstract Link MAC
- Link Type: Wired
- Network Protocol : Cellular Layer 3

7) Wireless Subnet Link

- No properties to set by user

All this settings are default settings. For above case study simulations are carried out on the base of all above parameters.

Case study1: To study the effect of Propagation Model on UMTS Network.

Settings: As given above

Experiment setup: As in figure 5.24.

Details: In this experiment we have varied path propagation model which is affecting fading of the various network. Variation in path propagation model has a huge effect on the performance of UMTS Network .In this Experiment we see how Different propagation models gives Throughputs, Jitter, Delay effects and Signals Received with Errors for UMTS Network

As shown in figure 5.29 node 10,12,13 throughput is in the range of 397000 for Free space model and Two ray model, while node 33 in free space model gives throughput 365000 and for Free space no throughput is getting. for node 41 and 54 throughput is 365000 which is less then compared to node 10,12,and 13

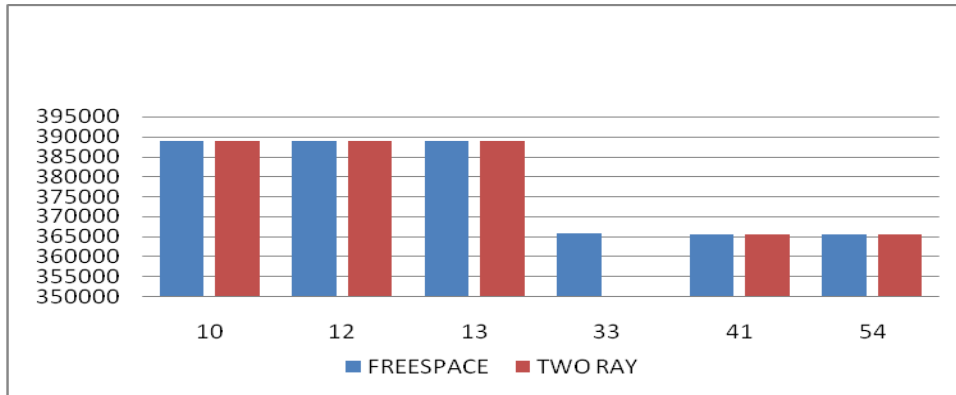


Figure 5.29: Effect of throughput on Propagation Model

As Jitter increase it means that transmission delay increase ,we can see that normally when power is increased, Jitter decreases and Network performance increases .As shown in figure 5.30 mentioned effect of Jitter on node 10,12,13,33,41 and 54 ,For Free space and two ray model effect of Jitter is normally same in most of nodes except node 33

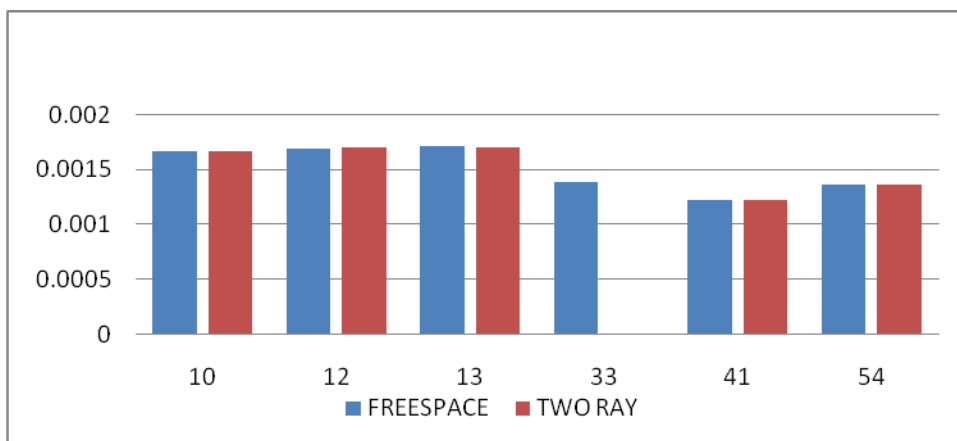


Figure 5.30: Effect of Jitter on Propagation Model

As shown in Figure 5.30 for node 10,12 and 13 effect of Delay for Free space and Two ray model is similar but node 33 in Free space model have more delay then Two ray model ,for node 41 and 54 Delay is increased in the range of 1.75 and 2.15 which is higher than other nodes .

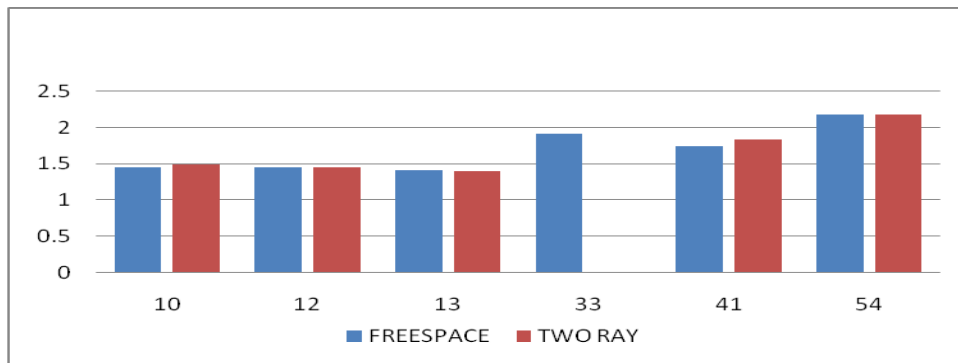


Figure 5.31: Effect of Delay on Propagation Model

As per figure 5.32 In Two ray model signals received with more errors compared to free space model.

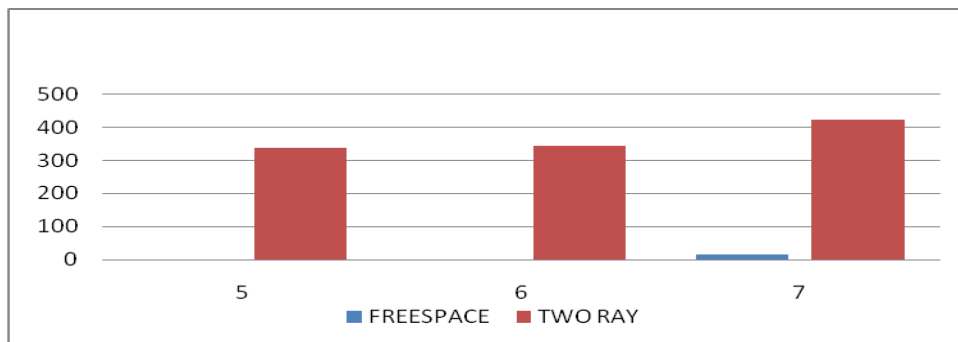


Figure 5.32: signal received with errors in Propagation Model

Conclusion : From above experiment performance show that Two ray model is better than Free space model with respect to Throughput, Jitter, Delay and Signal received with errors .

Case study2: To study the effect of variation of Routing protocol models on UMTS Network

Settings: As given above

Experiment setup: As in figure 5.24

Details: In this experiment we have to see the effect of ANODV, AODV, BELLMAN FORD and DYMO Routing Model on UMTS Network. Routing protocol is responsible for discovering the routes and successful delivery of packets from source to destination node.

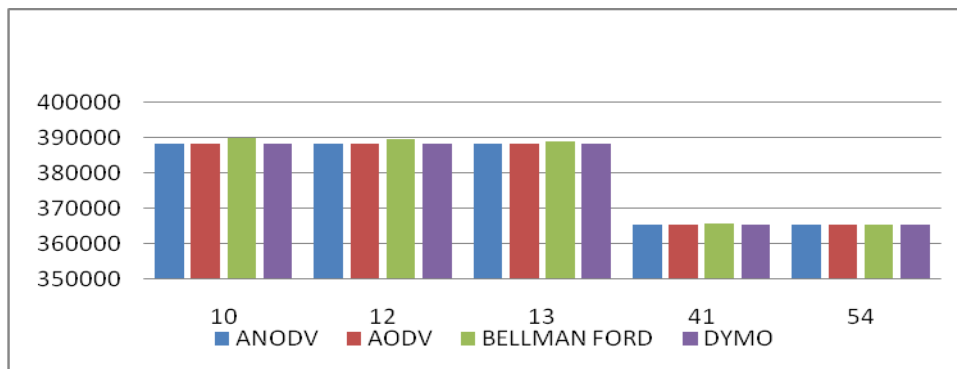


Figure 5.33 Effect of throughput on Routing protocol models

As shown in above figure 5.33 Bellman ford routing protocol gives slightly higher throughput than other routing protocols and node 41 & 54 gives less throughput compared to node 10, 12 and 13.

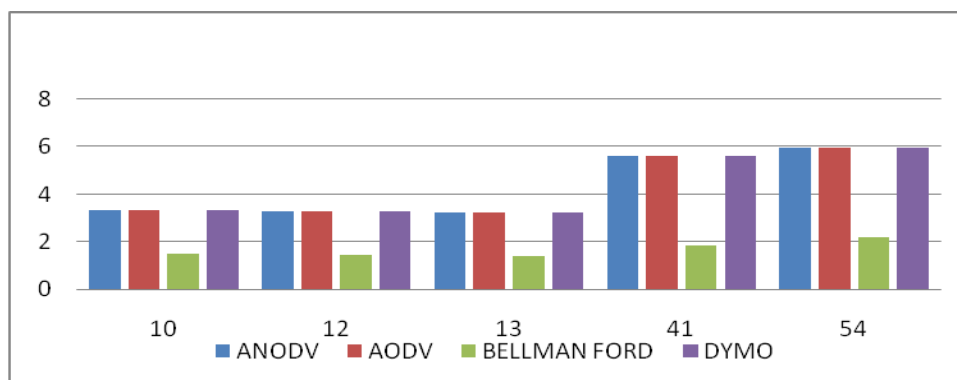


Figure 5.34 Effect of Delay on Routing protocol models

As shown in above figure 5.34 Bellman ford gives less amount of end to end Delay for almost all nodes while ANODV and AODV gives similar delay and DYMO gives more delay compared to other routing models.

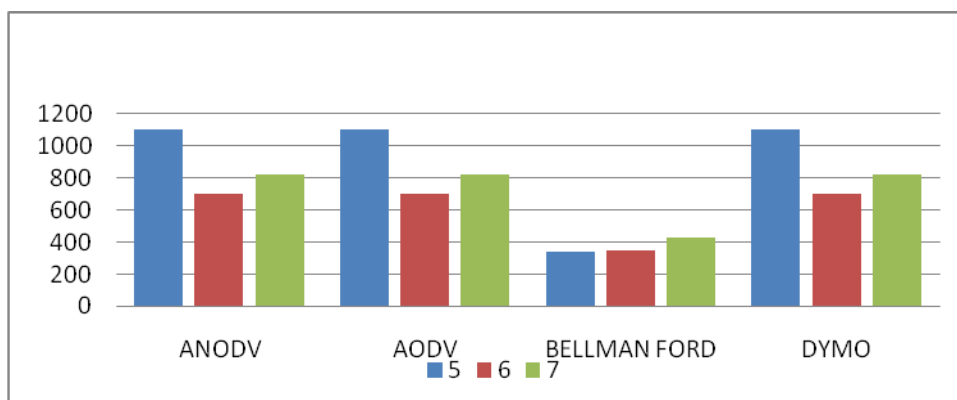


Figure 5.35: signal received with errors in Routing protocol models

As shown in figure 5.35 Bellman ford routing model receives signals with very less errors. ANODV and AODV routing protocol model perform similar for most of nodes which receives signal with somehow more errors compared to Bellman ford and DYMO receives signal with more errors .

Conclusion: From above experiment performance show that Bell man Ford Routing model is more suitable routing protocol model for UMTS network .

5.2.5 Analysis of UMTS Networks

The above UMTS example has been experimented in various ways by changing various aspects as given below

1. Comparison is based on Number of users accommodated Vs Power

Table 5.4 Different values of Number of users accommodated and Power for UMTS

Power (dBm)	No. of users accommodated
10	20
15	50
20	80
25	200
28	260
32	340

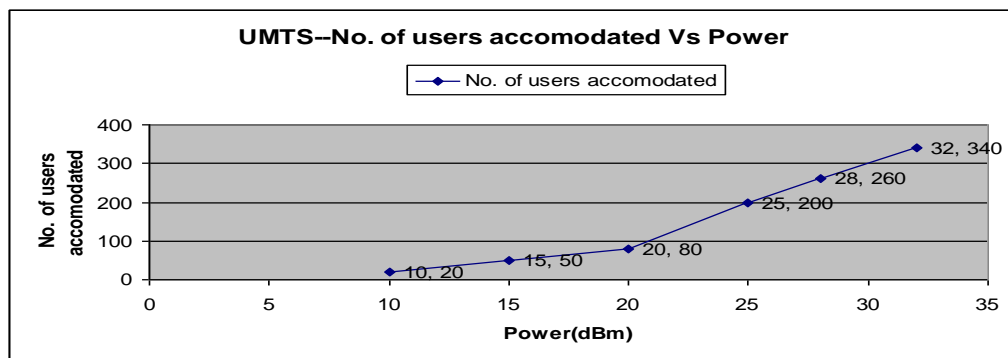


Figure 5.36 Graph shows analysis of no. of users accommodated Vs Power for UMTS

2. Comparison is based on Range (Coverage area) Vs Power

Table 5.5 Different values of Range and Power for UMTS

Power(dBm)	Range(Meter)
10	200
15	500
20	1000
25	1400
28	1700
32	2200

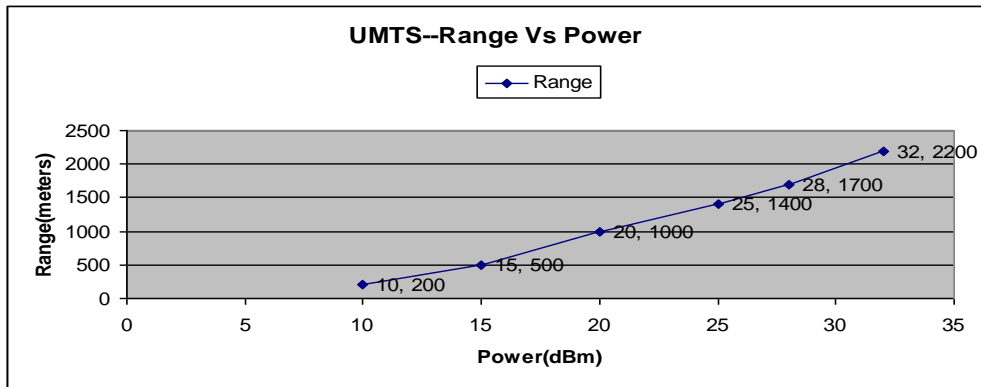


Figure 5.37 Graph shows analysis of Range Vs Power for UMTS

3. Comparison is based on Data rate Vs Power

Table 5.6 Different values of Data rate and Power for UMTS

Power(dBm)	Data rate(Mbps)
10	2
15	4
20	5
25	7
28	9
32	10

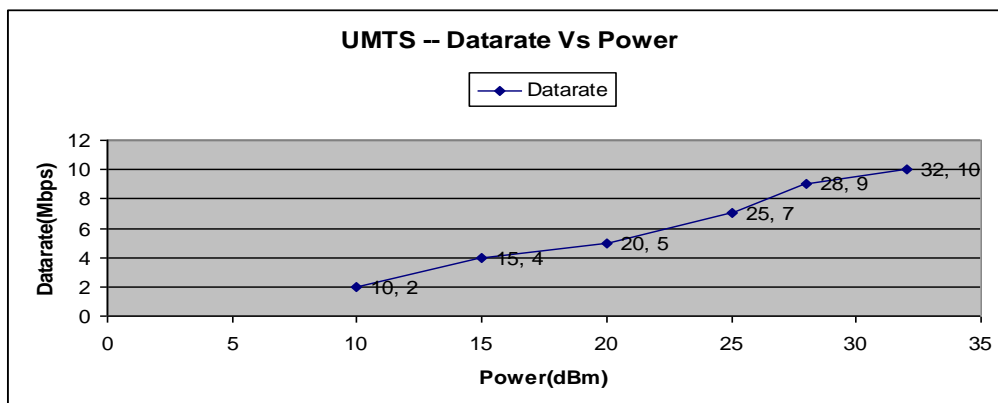


Figure 5.38: Graph shows analysis of Data rate Vs Power for UMTS

5.3 WLAN (Wireless Local Area Network)

802.11a PHY is an extension to IEEE 802.11 PHY that applies to wireless LANs and provides up to 54 Mbps in the 5 GHz band. 802.11a PHY uses an orthogonal frequency division multiplexing encoding scheme rather than FHSS or DSSS.

5.3.1 Features and assumptions

Implemented Features

DCF Mode

- Active and passive scanning.
- Dynamic association.
- Authentication procedure.
- Association procedure.
- De-authentication procedure.
- DCF procedure.
- Power save mode

PCF Mode

- PCF is working in three Modes as POLL & DELIVER, DELIVER ONLY and POLL ONLY.
- Poll save by count procedure.
- Operation with overlapping point-coordinated BSSs.

Assumptions and Limitations

- The routing of packets is assumed to be network layer based. (IEEE 802.11 does not constrain the DS to be either data link or network layer based.). A user configuration may allow or prevent an AP or PC from relaying packets outside the BSS.

Infrastructure/AP Mode

- In Sleep mode, if STA receive packet from network layer, it immediately changes the state from doze to active state.

Ad hoc/IBSS Mode

- All the nodes are in single IBSS to support ad hoc mode.
- Scan and join is not required for a node at the time of joining, for default IBSS.
- For ad hoc mode, Beacon interval and ATIM window, interval needs to be configured at subnet level.
- For an IBSS, PS Mode should be either enabled or disabled for all nodes.

5.3.2 Sample Scenarios

This section describes two sample scenarios:

- Ad hoc mode
- Infrastructure mode

Sample Scenario Topology for Adhoc Mode

As Shown in the figure 5.39, there are six nodes in WLAN adhoc mode topology. In adhoc mode, there is no any access point available. Each node acting separately and communicate with one another. The ad hoc mode can be selected at both the interface and subnet levels. The power save mode in ad hoc mode can be configured only at the subnet level.

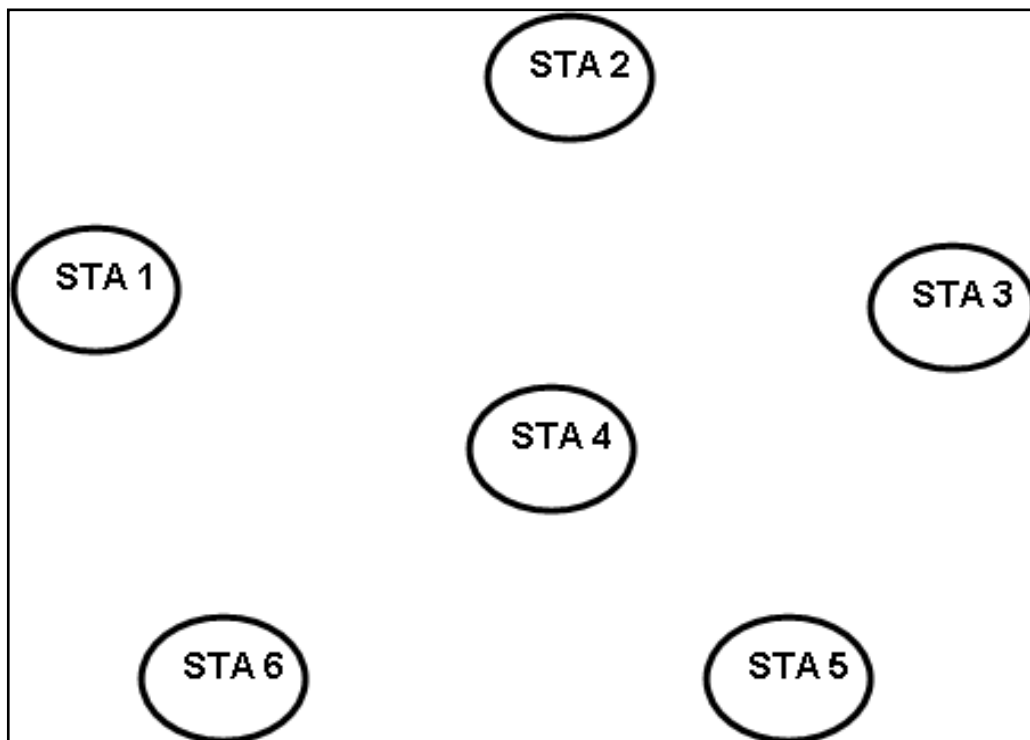


Figure 5.39: Adhoc Mode Sample Scenario Topology

According to the topology WLAN Adhoc mode scenario has been developed in QualNet-5.0 in as shown in figure 5.40. Place six nodes of the Default device type and a wireless subnet on the canvas. Connect all six nodes to the wireless subnet so that each node can communicate with one another.

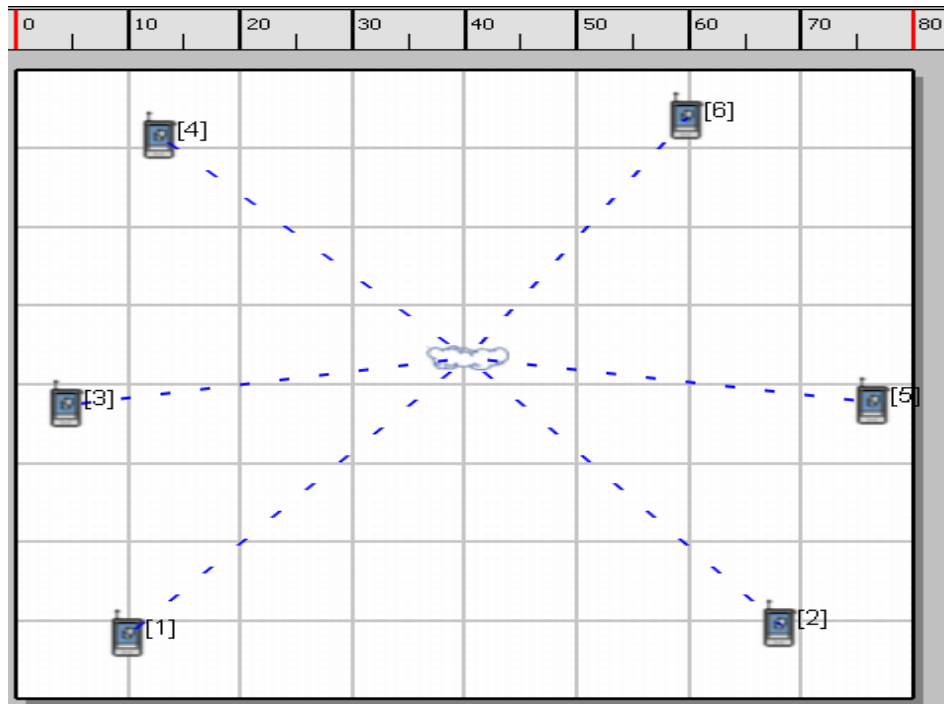


Figure 5.40: WLAN (Adhoc mode) Scenario developed with coverage area 80m X 100m using QualNet-5.0

Sample Scenario Topology for Infrastructure Mode

The sample scenario topology for infrastructure mode is shown in figure 5.41. The below scenario topology contains six nodes, in which one node is acting as an access point and other nodes are acting as a simple node or station. The infrastructure mode of WLAN must contain one access point. Here, nodes are not communicating directly; instead, all the communication takes place through the access point.

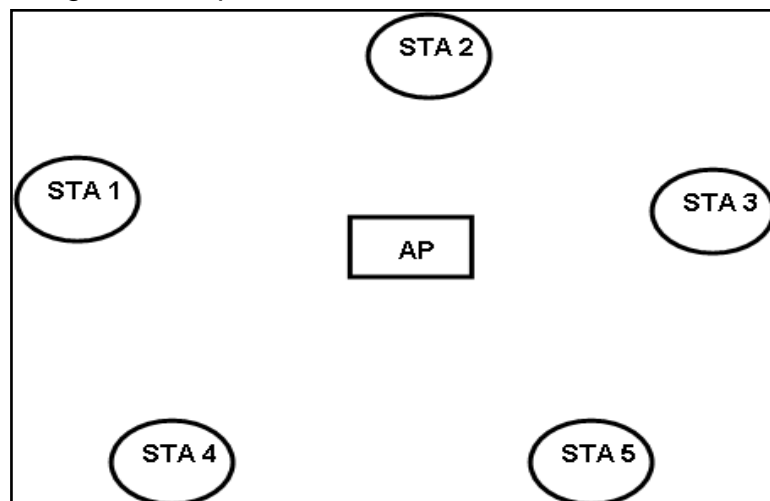


Figure 5.41 : Infrastructure Mode Scenario Topology

GUI Configuration

The figure 5.42 shows WLAN (Infrastructure mode) scenario made using QualNet-5.0 as per architecture. Place six nodes of default device type and a wireless subnet on the canvas. Connect all six nodes to the wireless subnet. This scenario contains 6 nodes out of which Node 1 is an access point and nodes 2 to 6 are stations. Nodes 1, 2, 3, and 4 have power saving enabled. The infrastructure mode can be selected at both the interface and subnet levels. The access point can be configured only at the interface level.

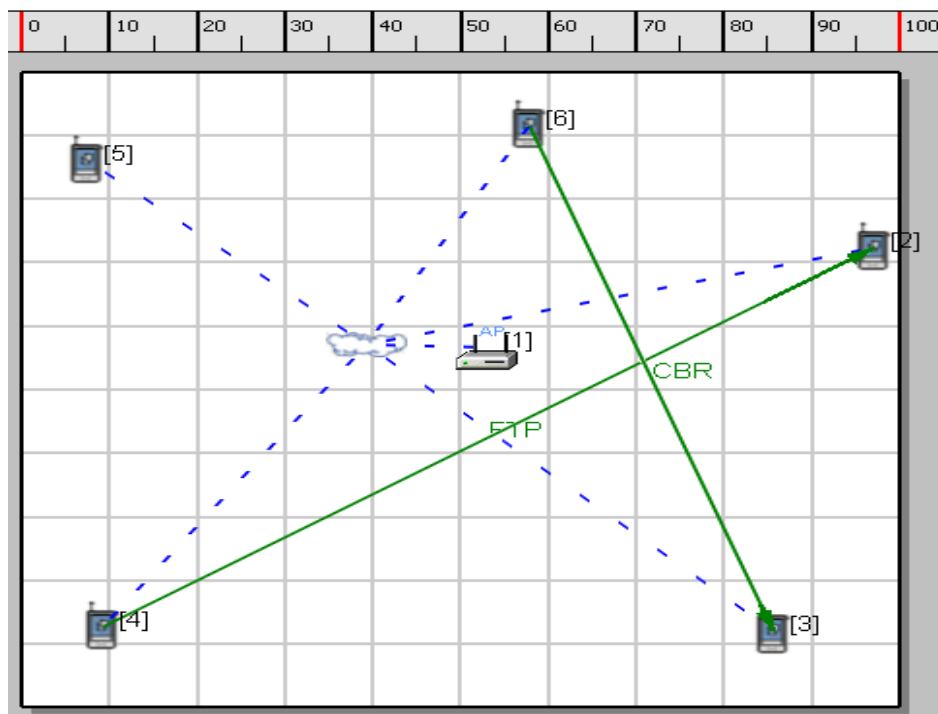


Figure 5.42 WLAN (Infrastructure mode) Scenario developed with coverage area 100m X 100m using QualNet-5.0.

Below figures show how the various GUI parameters have been set for above scenario in figure 5.42.

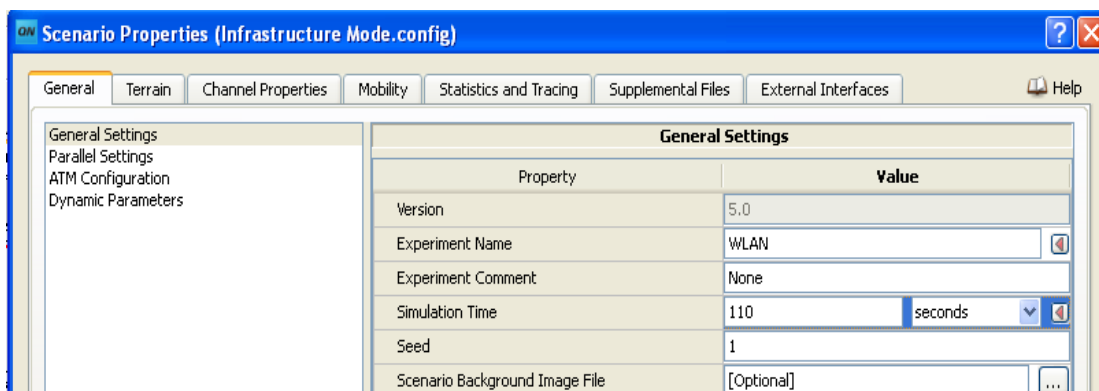
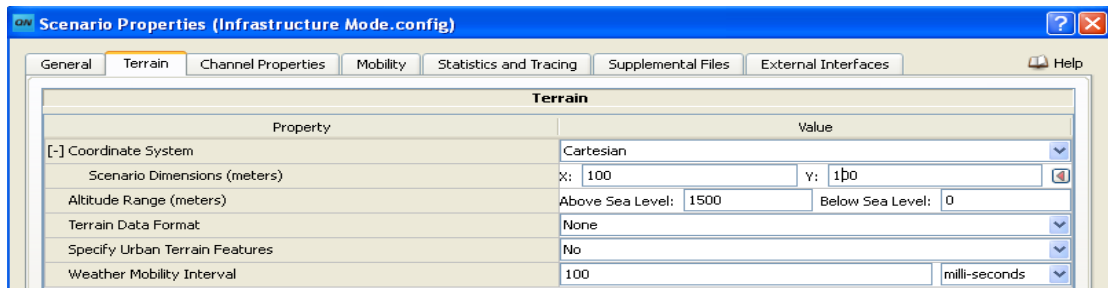


Figure 5.43 WLAN Scenario Properties (a) General Properties

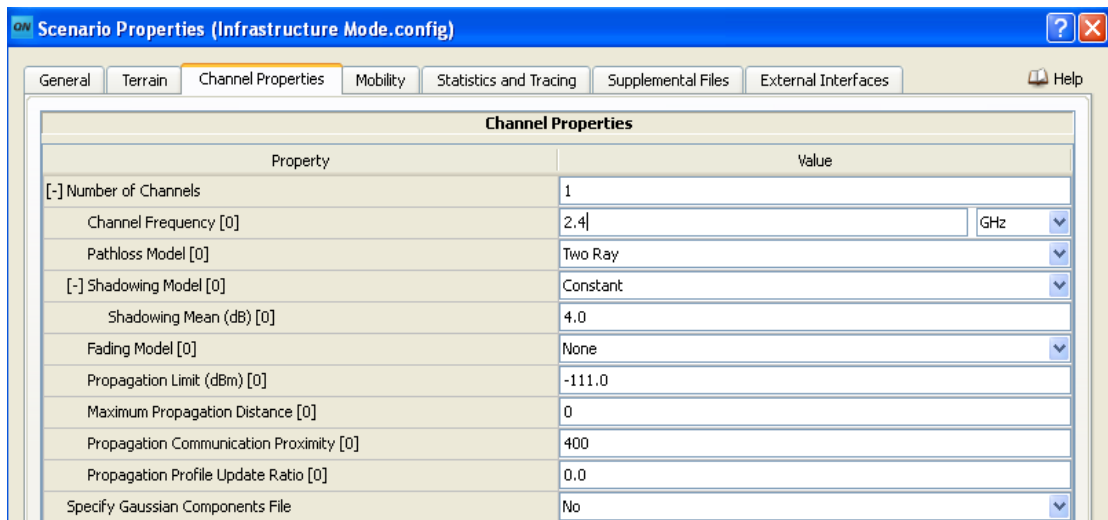


Scenario Properties (Infrastructure Mode.config)

General Terrain Channel Properties Mobility Statistics and Tracing Supplemental Files External Interfaces Help

Property	Value
[...] Coordinate System	Cartesian
Scenario Dimensions (meters)	X: 100 Y: 100
Altitude Range (meters)	Above Sea Level: 1500 Below Sea Level: 0
Terrain Data Format	None
Specify Urban Terrain Features	No
Weather Mobility Interval	100 milli-seconds

(b) Terrain Properties

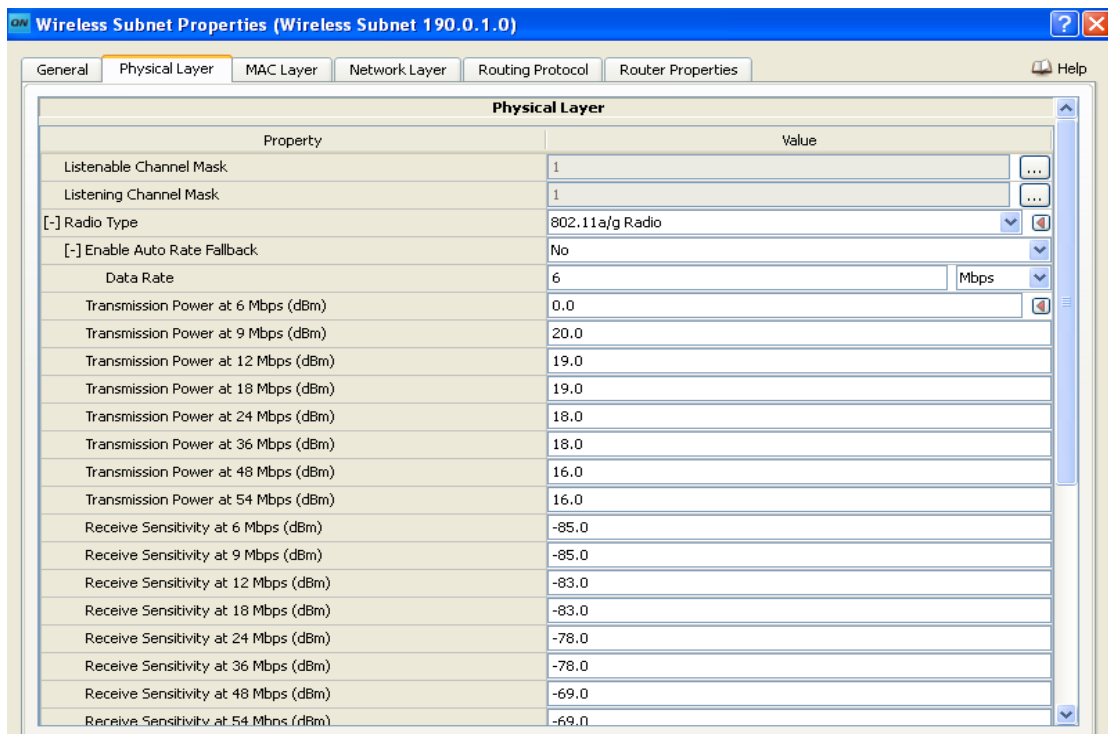


Scenario Properties (Infrastructure Mode.config)

General Terrain Channel Properties Mobility Statistics and Tracing Supplemental Files External Interfaces Help

Property	Value
[...] Number of Channels	1
Channel Frequency [0]	2.4 GHz
Pathloss Model [0]	Two Ray
[...] Shadowing Model [0]	Constant
Shadowing Mean (dB) [0]	4.0
Fading Model [0]	None
Propagation Limit (dBm) [0]	-111.0
Maximum Propagation Distance [0]	0
Propagation Communication Proximity [0]	400
Propagation Profile Update Ratio [0]	0.0
Specify Gaussian Components File	No

(c) Channel Properties

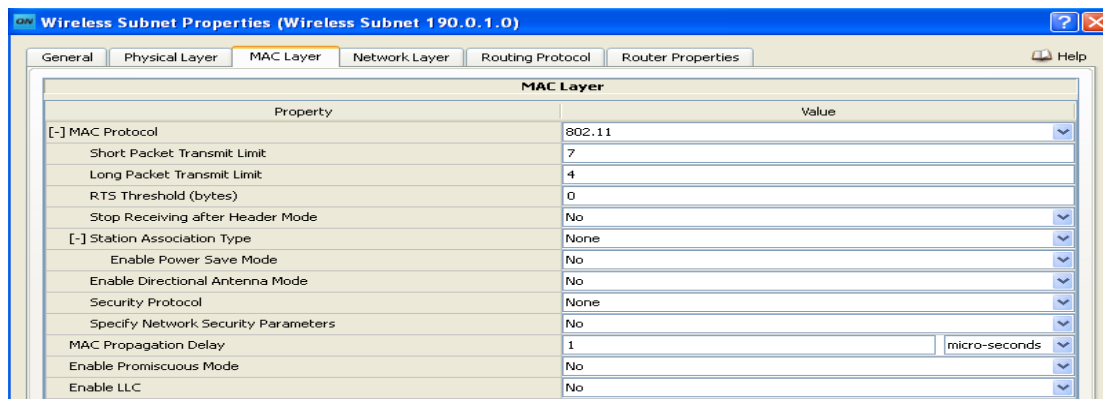


Wireless Subnet Properties (Wireless Subnet 190.0.1.0)

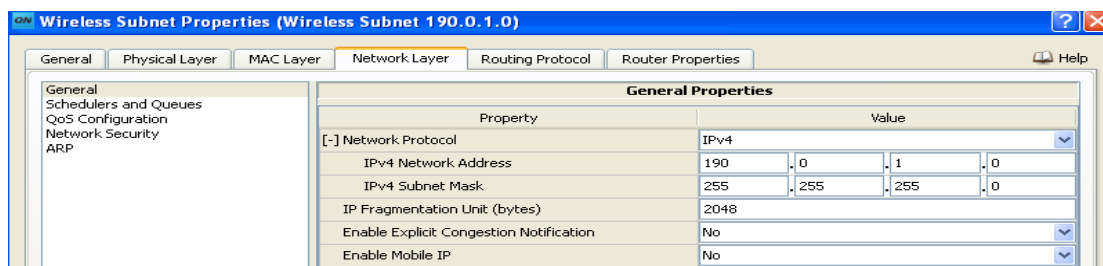
General Physical Layer MAC Layer Network Layer Routing Protocol Router Properties Help

Property	Value
Listenable Channel Mask	1
Listening Channel Mask	1
[...] Radio Type	802.11a/g Radio
[...] Enable Auto Rate Fallback	No
Data Rate	6 Mbps
Transmission Power at 6 Mbps (dBm)	0.0
Transmission Power at 9 Mbps (dBm)	20.0
Transmission Power at 12 Mbps (dBm)	19.0
Transmission Power at 18 Mbps (dBm)	19.0
Transmission Power at 24 Mbps (dBm)	18.0
Transmission Power at 36 Mbps (dBm)	18.0
Transmission Power at 48 Mbps (dBm)	16.0
Transmission Power at 54 Mbps (dBm)	16.0
Receive Sensitivity at 6 Mbps (dBm)	-85.0
Receive Sensitivity at 9 Mbps (dBm)	-85.0
Receive Sensitivity at 12 Mbps (dBm)	-83.0
Receive Sensitivity at 18 Mbps (dBm)	-83.0
Receive Sensitivity at 24 Mbps (dBm)	-78.0
Receive Sensitivity at 36 Mbps (dBm)	-78.0
Receive Sensitivity at 48 Mbps (dBm)	-69.0
Receive Sensitivity at 54 Mbps (dBm)	-69.0

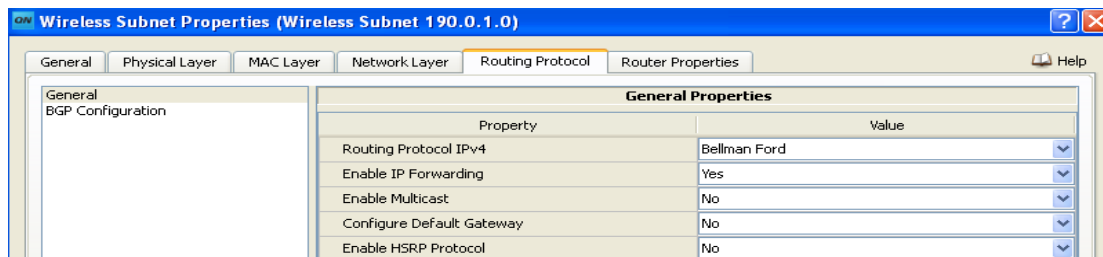
Figure 5.44: WLAN Scenario -- Wireless Subnet Properties (a) Physical Layer



(b) MAC Layer



(c) Network Layer



(d) Routing Protocol

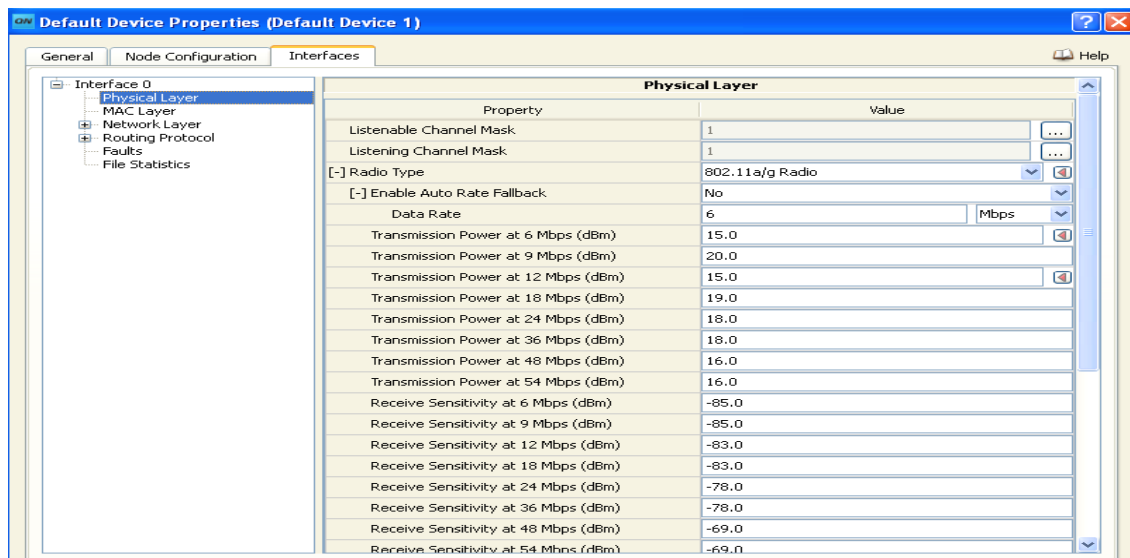
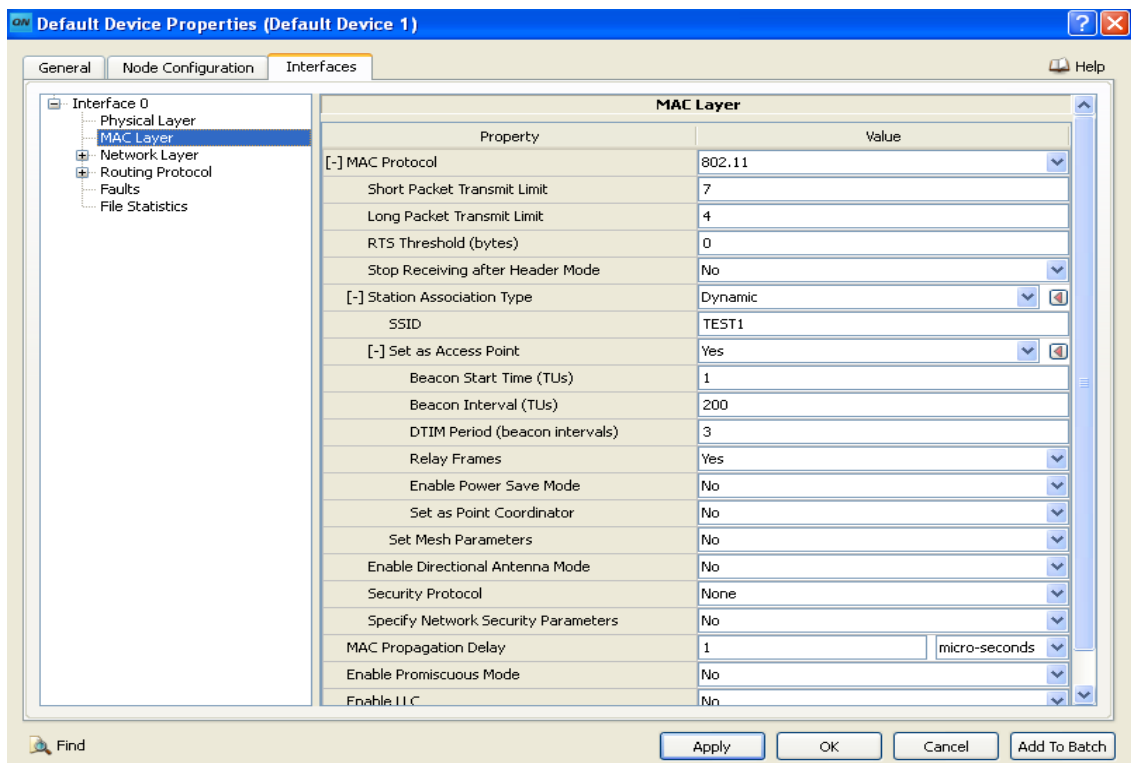


Figure 5.45: WLAN Scenario – Default Device-1 Properties (a) Physical Layer



(b) MAC Layer

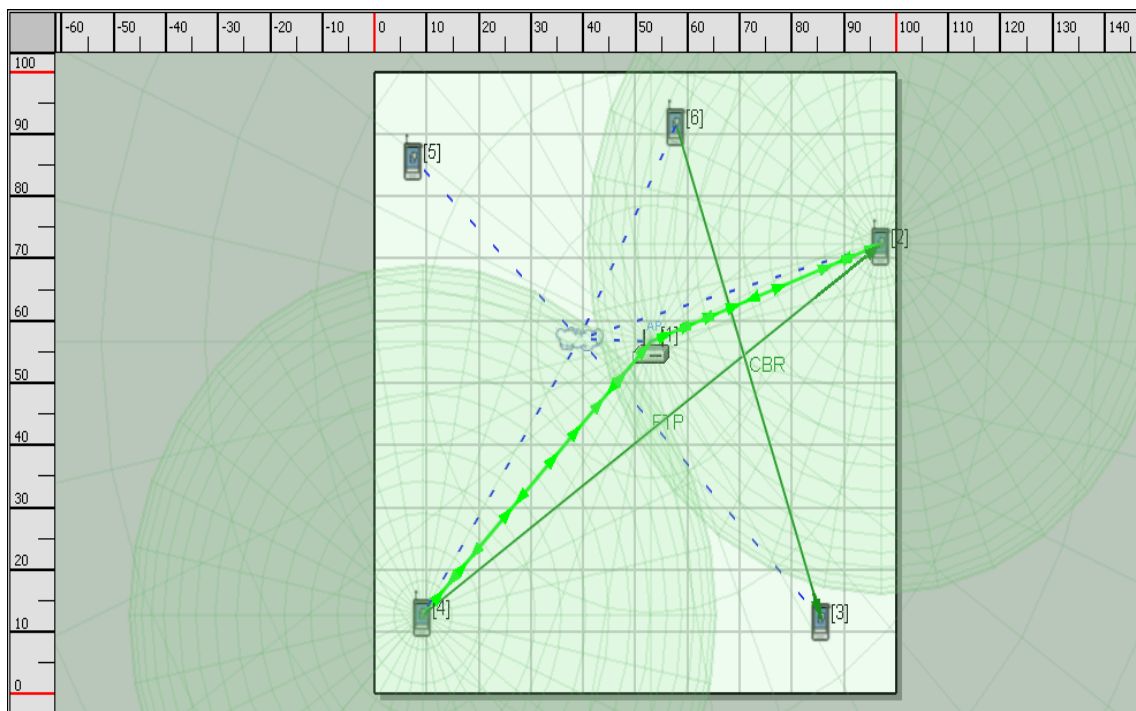


Figure 5.46: WLAN Scenario, Live Simulation

5.3.3 Simulation results of WLAN scenario

Below figures show the various results of above scenario after simulation using QualNet Analyzer.

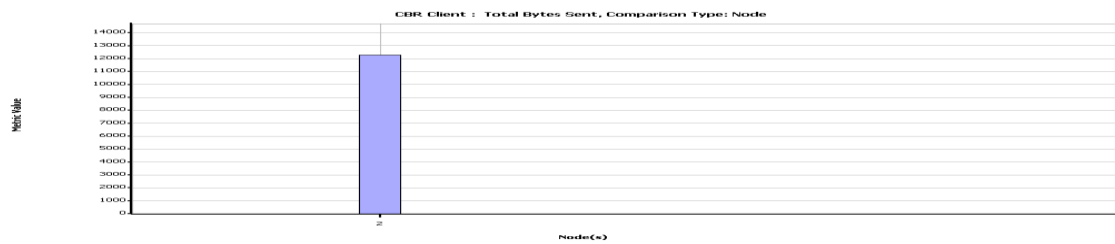
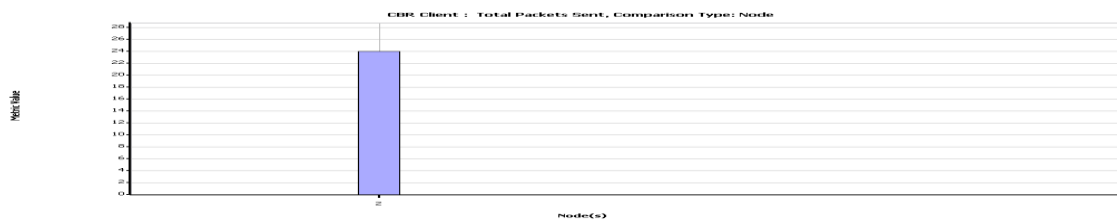
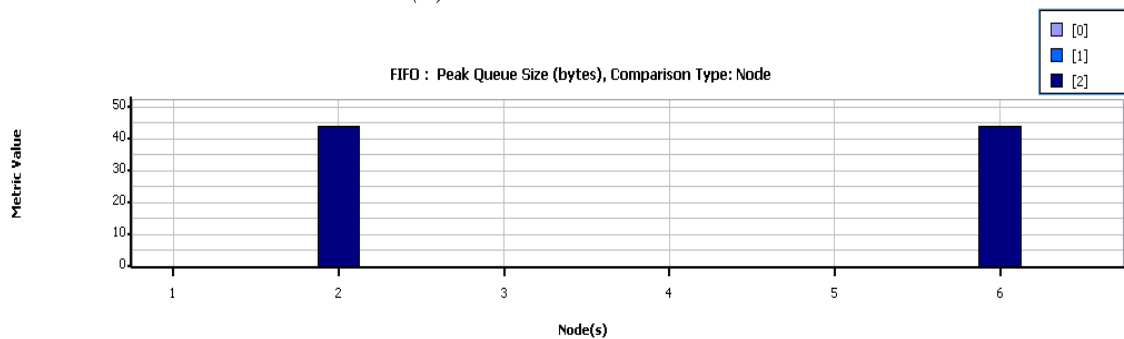


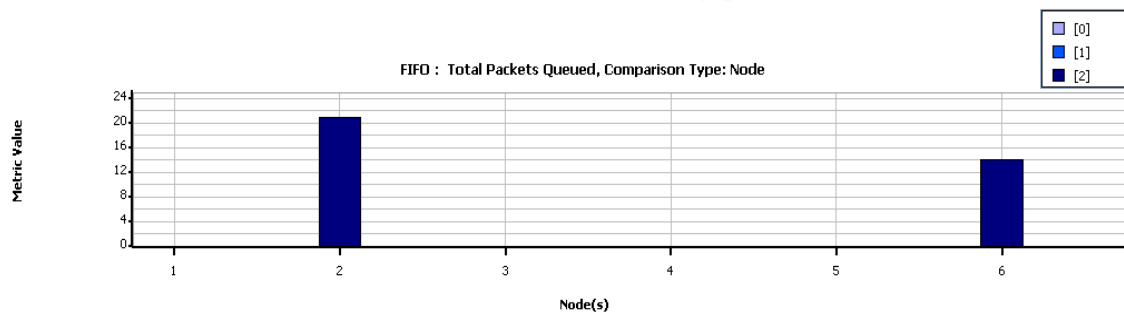
Figure 5.47: WLAN Scenario: Analyzer Results (a) CBR Client: Total Bytes Sent



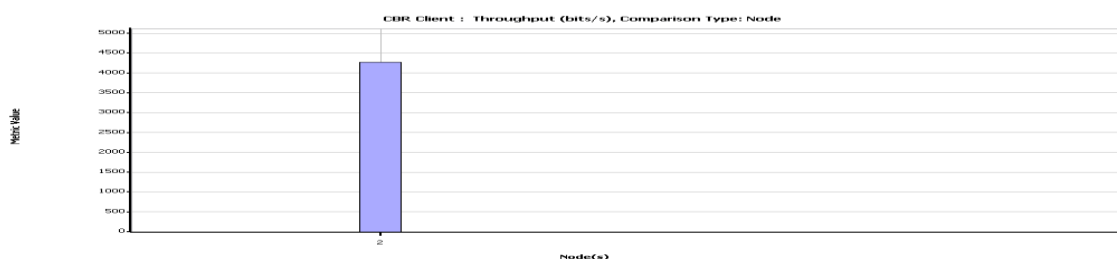
(b) CBR Client: Total Packets Sent



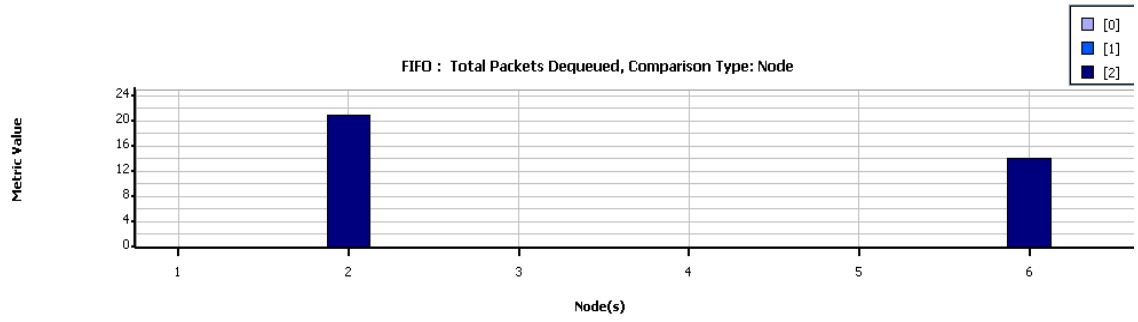
(c) CBR Client: Throughput (bits/s)



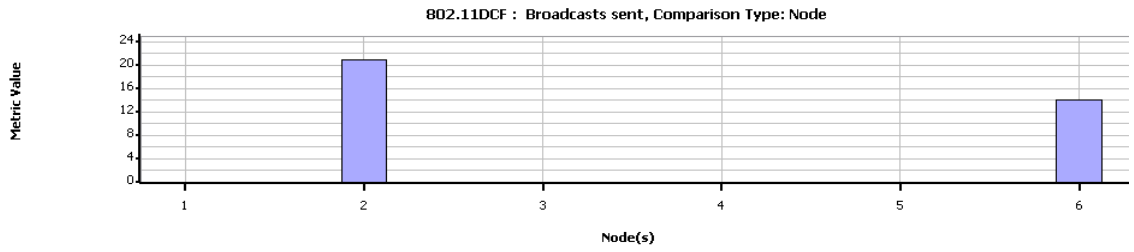
(d) FIFO: Peak Queue Size (bytes)



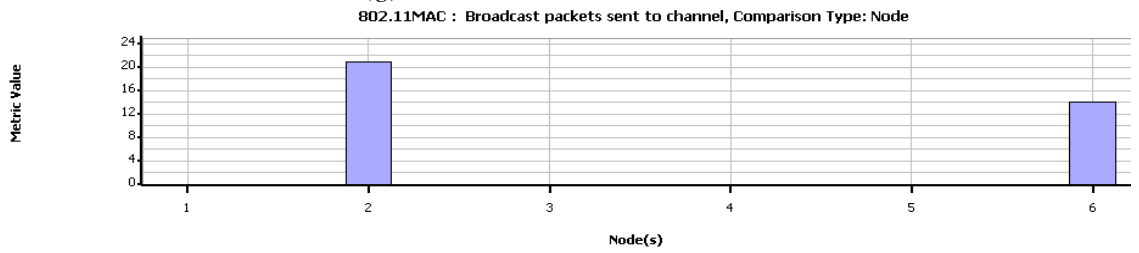
(e) FIFO: Total Packets Queued



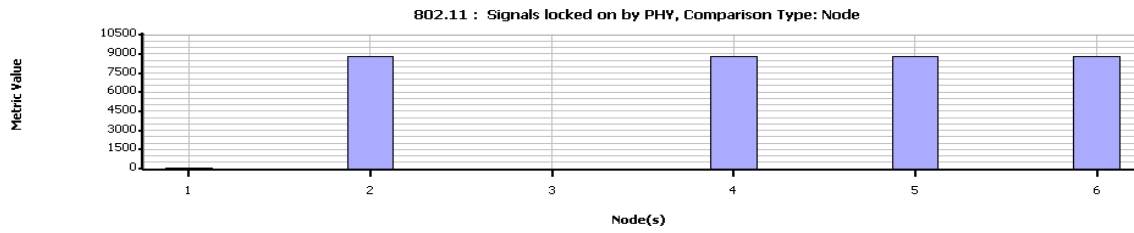
(f) FIFO: Total Packets Dequeued



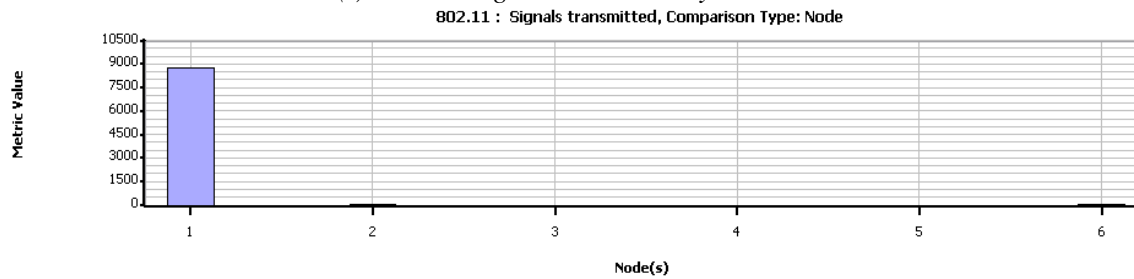
(g) 802.11 DCF: Broadcasts sent



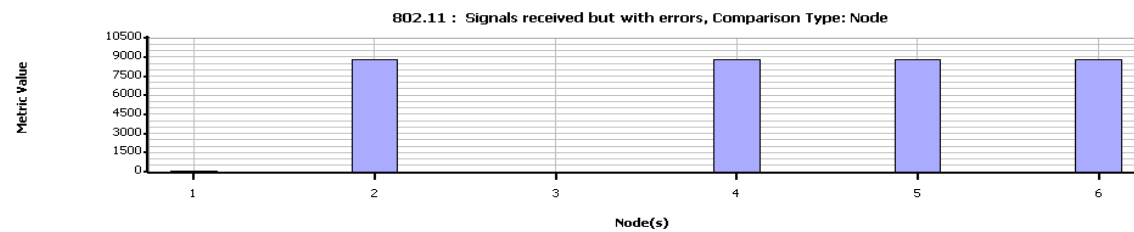
(h) 802.11 MAC: Broadcasts packets sent to the channel



(i) 802.11: Signals locked on by PHY



(j) 802.11: Signals transmitted



(k) 802.11: Signals received with errors

5.3.4 Analysis of WLAN

The above WLAN example has been experimented in various ways by changing various aspects as given below

1. Comparison is based on Number of users accommodated Vs Power

Table 5.7: Different values of Number of users accommodated and Power for WLAN

Power (dBm)	No. of users accommodated
10	4
14	9
18	17
20	22
22	32
25	44

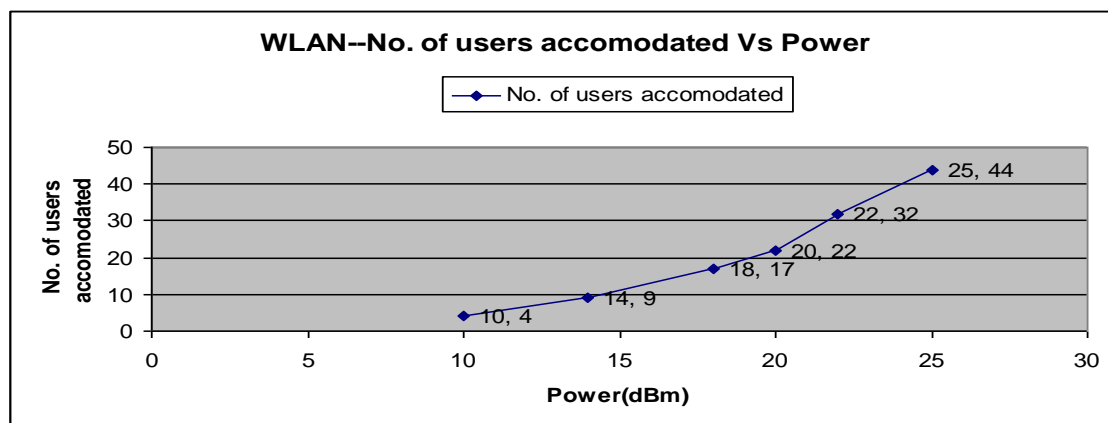


Figure 5.48 Graph shows analysis of no. of users accommodated Vs Power for WLAN

2. Comparison is based on Range (Coverage area) Vs Power

Table 5.8: Different values of Range and Power for WLAN

Power (dBm)	Rang (Meter)
10	50
14	85
18	150
20	200
25	320
30	500

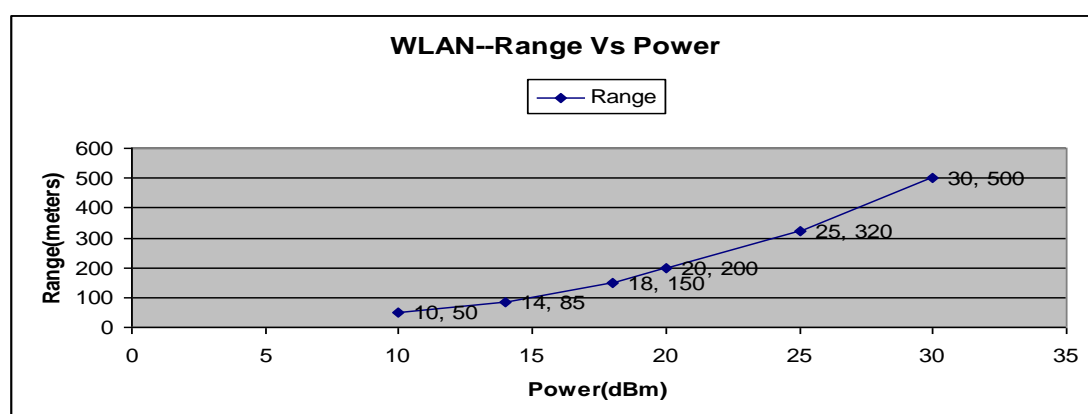


Figure 5.49: Graph shows analysis of Range Vs Power for WLAN

5.4 Wi-Fi (Wireless Fidelity)

802.11b PHY is an extension to IEEE 802.11 PHY that applies to wireless LANs and also known as Wi-Fi. It provides up to 11 Mbps in the 2.4-GHz band. 802.11b PHY uses FHSS or DSSS multiple access scheme and Complementary Code Keying (CCK) modulation.

5.4.1 Features and assumptions

Implemented Features

DCF Mode

- Active and passive scanning.
- Dynamic association.
- Authentication procedure.
- Association procedure.
- De-authentication procedure.
- DCF procedure.
- Power save mode

PCF Mode

- PCF is working in three Modes as POLL & DELIVER, DELIVER ONLY and POLL ONLY.
- Poll saves by count procedure.
- Operation with overlapping point-coordinated BSSs.

Assumptions and Limitations

802.11 Model

- The routing of packets is assumed to be network layer based. (IEEE 802.11 does not constrain the DS to be either data link or network layer based.). A user configuration may allow or prevent an AP or PC from relaying packets outside the BSS.

Infrastructure/AP Mode

- In Sleep mode, if STA receive packet from network layer, it immediately changes the state from doze to active state.

Ad hoc/IBSS Mode

- All the nodes are in single IBSS to support ad hoc mode.
- Scan and join is not required for a node at the time of joining, for default IBSS.
- For ad hoc mode, Beacon interval and ATIM window, interval needs to be configured at subnet level.
- For an IBSS, PS Mode should be either enabled or disabled for all nodes.

5.4.2. Wi-Fi Network Scenario1 with One access point

Figure 5.50 shows the network with only one access point. It has 60 nodes already and 9 FTP applications. Here, we have assumed that we have two ray pathloss model. As per 802.11 b FCC regulations max transmit out power can be 30 dbm and antenna gain can be 6dbi for Omni-directional antenna. So we have set max value of transmit power and antenna gain.

We have analyzed above network on base of data rate, path loss model and traffic intensity. First we assume that we have two ray model and results for 1 Mbps and 11 Mbps is compared for both server and client nodes.

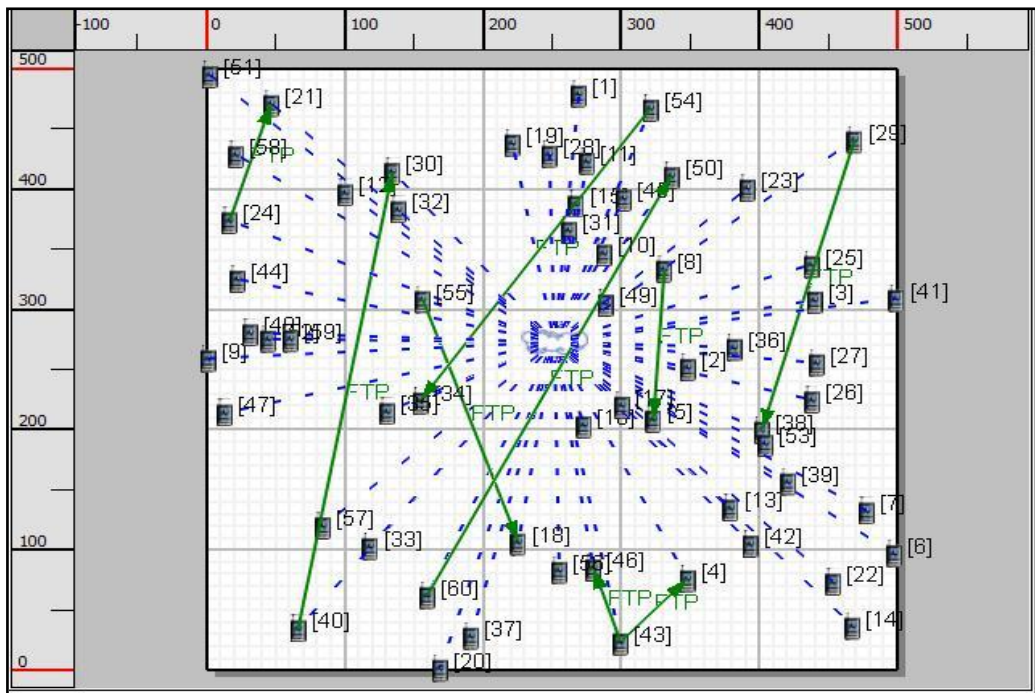


Figure 5.50: New Wi-Fi Network with only one access point

This network is designed so as to minimize number of access point, in the ground floor analysis of C.U.Shah College of Engineering and Technology. Aim is to optimize network and find out some other ways to reach out same area with only one access point.

Wi-Fi Scenario1 Specifications

Terrain:

<i>Co ordinate system</i>	Cartesian
<i>Dimensions</i>	500 meters x 500 meters
<i>Altitude</i>	Above sea level 1500 meters

Channel:

<i>No. of Channels</i>	1
<i>Channel Frequency</i>	2.4 GHz
<i>Pathloss Model</i>	Two Ray and Free Space model
<i>Shadowing model</i>	Constant
<i>Shadowing mean</i>	22 dbm
<i>Fading model</i>	None
<i>Propagation limit</i>	-111.0 dbm

Wireless Subnet

Physical Layer

<i>Radio Type</i>	802.11 b
<i>Data rate</i>	1 Mbps, 2 Mbps, 5.5 Mbps, 11 Mbps
<i>Transmit Power</i>	30 dbm
<i>Receive sensitivity</i>	-94dbm to -87 dbm
<i>Packet reception model</i>	PHY802.11b Reception model, BER based Reception model
<i>Specify Antenna from file</i>	No
<i>Antenna Gain</i>	6 dbi
<i>Antenna Height</i>	1.5 meters`

MAC Layer

<i>MAC Protocol</i>	802.11
---------------------	--------

<i>Station association type</i>	Dynamic
<i>Set as access point</i>	Yes
<i>Security Protocol</i>	None
<i>Enable Promiscuous mode</i>	Yes
Network Layer	
<i>Network Layer Protocol</i>	IPv4
<i>IP fragmentation unit</i>	2048 bytes
Routing Protocol	
<i>Routing Protocol IPv4</i>	Bellman – Ford
<i>Enable IP forwarding</i>	Yes

Mobile Station

Mobility and Placement

<i>Node Placement strategy</i>	File
<i>Mobility Model</i>	Random Waypoint

Network Layer

<i>Network Protocol</i>	IPv4
-------------------------	------

Routing Protocol

<i>Routing Protocol for IPv4</i>	Bellman Ford
<i>Enable IP forwarding</i>	Yes

Mobile station to Wireless Subnet Interface

Physical Layer

<i>Radio Type</i>	802.11 b
<i>Data rate</i>	1 Mbps, 2 Mbps, 5.5 Mbps, 11 Mbps
<i>Transmit Power</i>	30 dbm
<i>Receive sensitivity</i>	-94dbm to -87 dbm
<i>Packet reception model</i>	PHY802.11b Reception model BER based Reception model
<i>Specify Antenna from file</i>	No
<i>Antenna Gain</i>	6 dbi
<i>Antenna Height</i>	1.5 meters

MAC Layer

MAC Protocol	802.11
Station association type	Dynamic
Set as access point	Yes
Security Protocol	None
Enable Promiscuous mode	Yes

Network Layer

Network Layer Protocol	IPv4
IP fragmentation unit	2048 bytes

Routing Protocol

Routing Protocol IPv4	Bellman – Ford
Enable IP forwarding	Yes

(Modified Settings as per FCC regulatory requirements)

5.4.3 Wi-Fi Case studies for scenario 1

All this settings are default settings, all case study simulations are carried out on the base of all above parameters

Case study 1: To study effect of data rate on throughput of Wi-Fi network

Experimental Setup: As per figure 5.50

Settings: As per section 5.4.2.

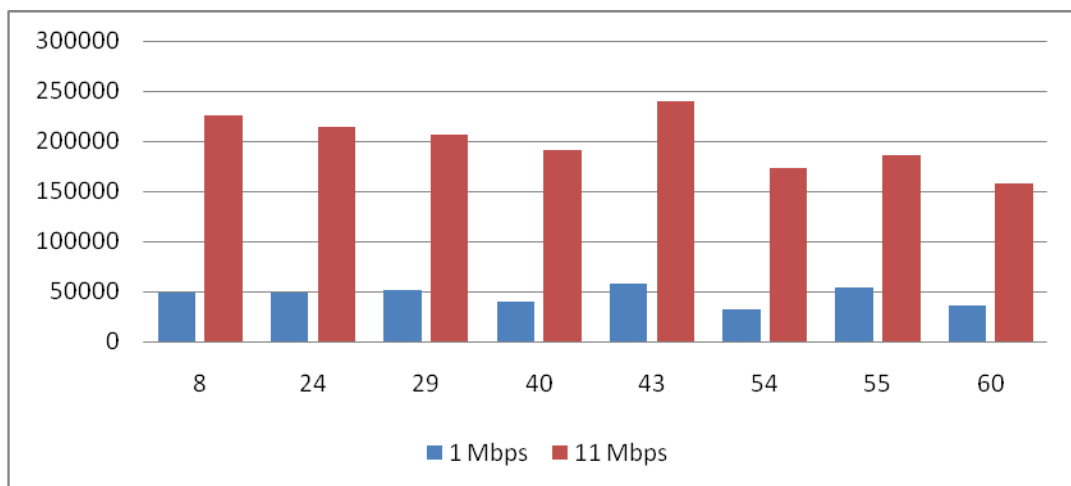


Figure 5.51: Effect of data rate on throughput of FTP client of modified network

It is clearly visible from figure 5.51 that as we vary data rate from 1 Mbps to 11 Mbps, with power of 30 dbm and antenna gain of 6 dbi, throughput of client nodes increases substantially. It is as the previous network was giving. So, by using only access point does not affect on throughput of network.

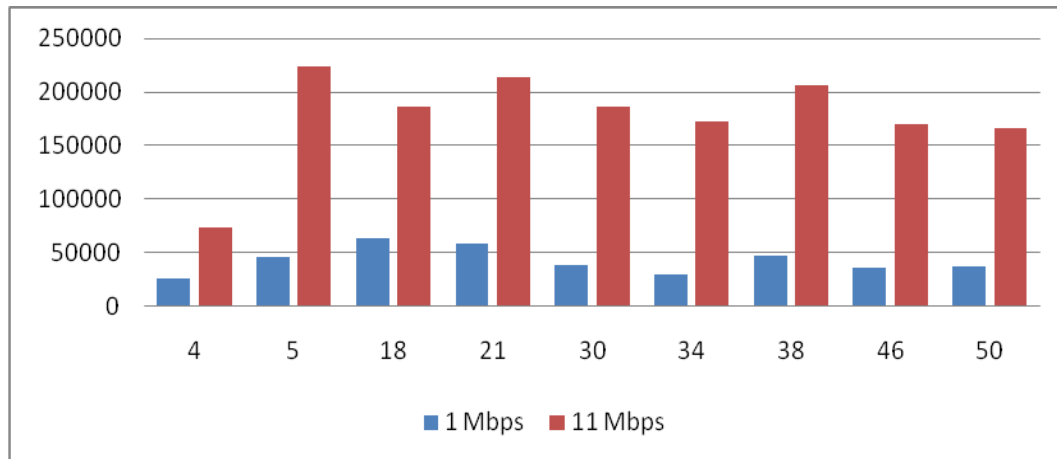


Figure 5.52: Effect of data rate on throughput of FTP server of modified network

It is clearly visible from figure 5.52 that as we vary data rate from 1 Mbps to 11 Mbps, with power of 30 dbm and antenna gain of 6 dbm, throughput of server nodes increases substantially. It is as the previous network was giving. So, by using only access point does not affect on throughput of network. But one thing to mark here in compared with previous result is that no node has less throughput compared to 1 Mbps. And the reason behind that is higher power compared to previous version. It happens for both client and server nodes. So this model seems better.

Case study 2: To study effect of Pathloss model on throughput of Wi-Fi network

Experimental Setup: As per figure 5.49

Settings: As per section 5.4.2.

Now we need to compare our model on base of pathloss model. As we know that various pathloss models are available. But among that okumura hata and Costa hata models cannot be used because of limitation of frequency use for them. They can work only for frequency less than 1.5 GHz or less. While Wi-Fi works for more than 2.4GHz.

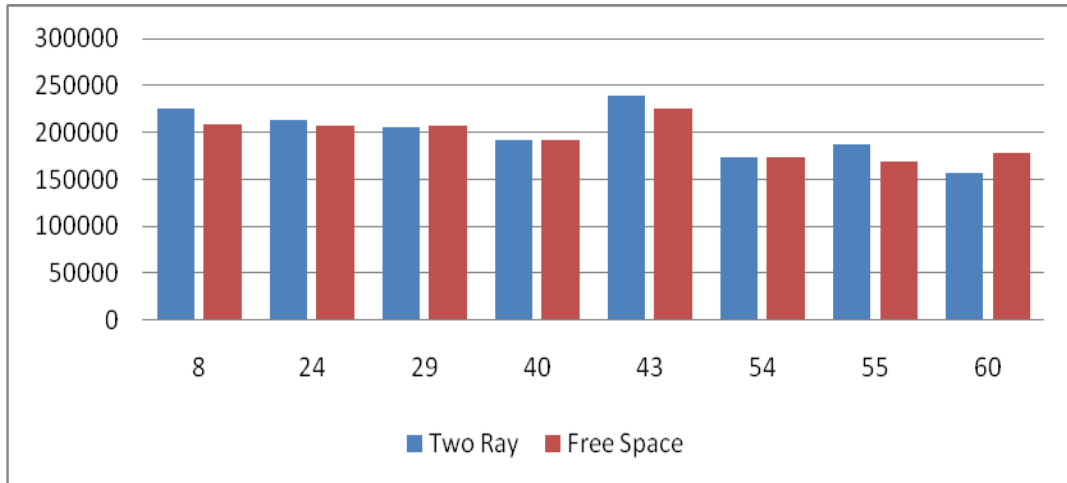


Figure 5.53: Effect of Pathloss model on FTP Client throughput of modified network

In this comparison we have assumed data rate which is better 11 Mbps. And we have varied pathloss models from two ray to free space model. Graphs of comparison for both client and server nodes are shown in figure 5.53 & 5.54. It is easily visualized from the graphs that there is not a lot change in throughput almost.

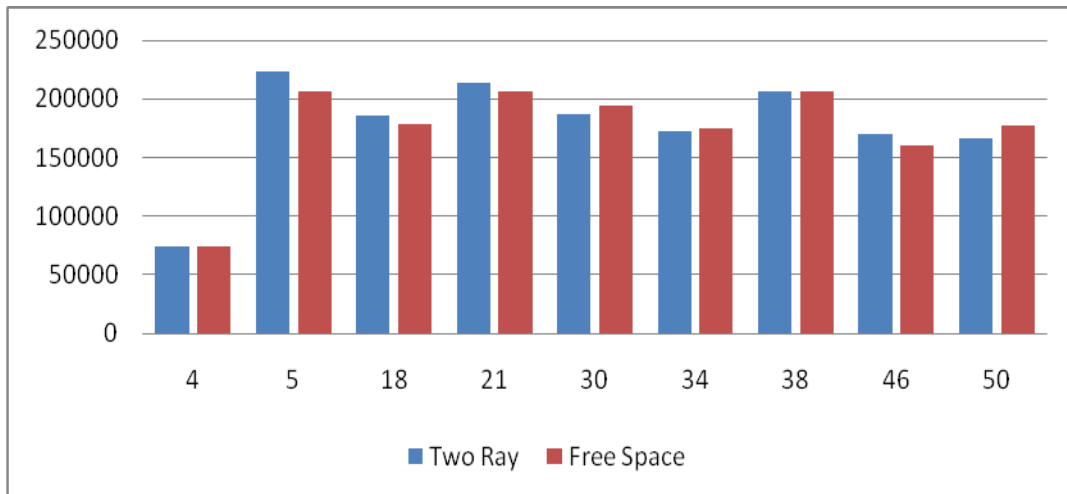


Figure 5.54: Effect of Pathloss model on FTP Server throughput of modified network

But two ray model seems better than free space model. As already mentioned there is not drastic but even if we can say that two ray is better. If we observe figure 5.53, we can see that variation of throughput for two ray model to free space model, does not give any drastic change in throughput, but they remain almost same. In case of almost all nodes, two ray model gives throughput higher, while in some nodes free space model gives throughput higher. But if

we see overall two ray model gives higher throughput. Similar is the case with the figure 5.54, we can see that variation of throughput for two ray model does not give a large change in throughput. But throughput of majority nodes remains higher for two ray model as compared to free space model. So, we can conclude that two ray model is better than free space model.

But the point to mark is that in our previous network with two access point, when we change path loss model, it fails to give throughput in case of some nodes. But this new network is prone to variation in throughput. So, this model seems to be better.

Case study 3: To study effect of traffic on throughput of Wi-Fi network

Experimental Setup: As per figure 5.50

Settings: As per section 5.4.2.

As we have seen previous network with more than one access point, it was giving us large variation in throughput when we increase the traffic. But when we increase the traffic to our modified network which by default has 60 nodes and we are going to make it 120 nodes, let's check what happens?

Now it is shown in figure 5.55 and 5.56 that as we vary traffic from less to high what is the change in throughput. It seems that almost all nodes have same throughput as it was having for less traffic in high traffic condition. It means that this network is less affected by variation in traffic.

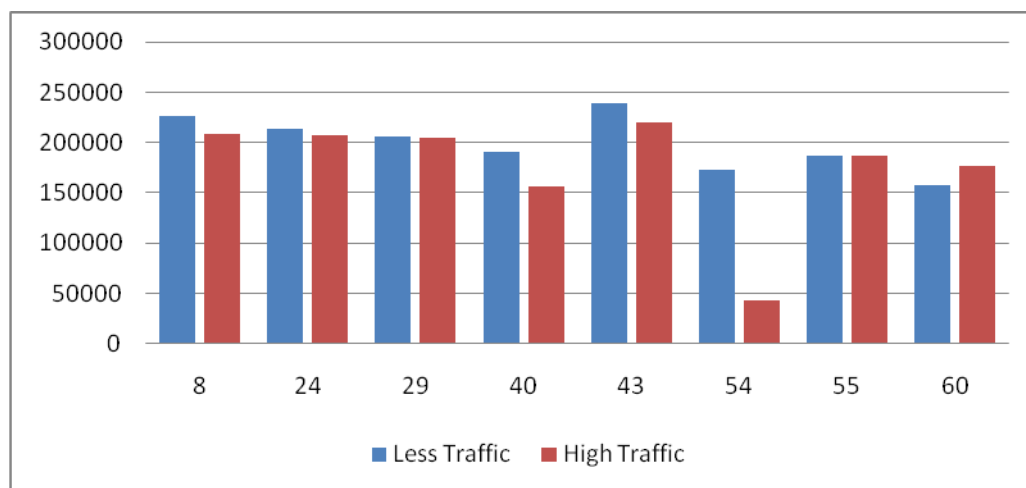


Figure 5.55: Effect of traffic on FTP client throughput of modified network

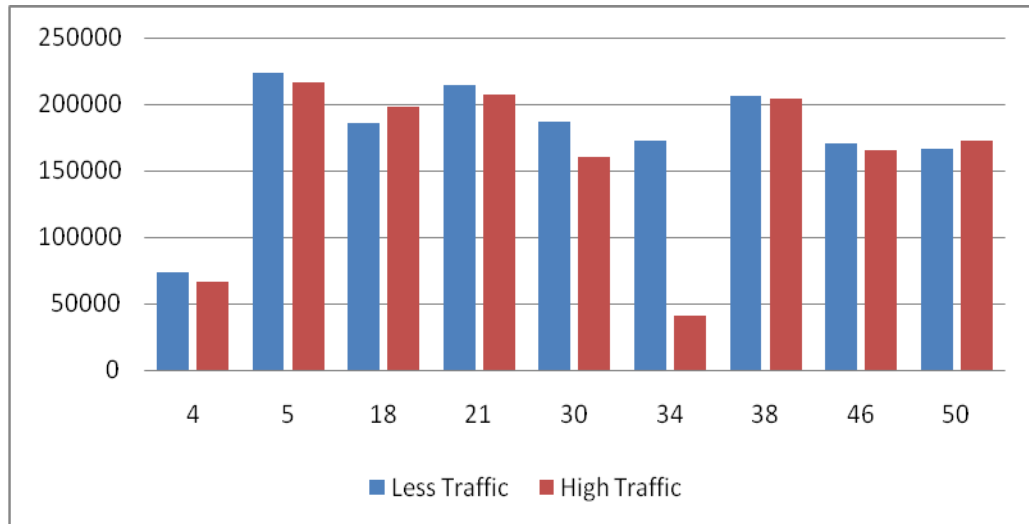


Figure 5.56: Effect of traffic on FTP server throughput of modified network

As it was the case with the old network that when we vary traffic, throughput was decreasing sharply, but in our new network it does not decrease sharply. It changes minutely. So it is clear from above figure and facts of communication that as traffic increases always performance decreases. But due to high power level maintained in all nodes this situation is not occurred in our network. No doubt, performance decreases but it is not that much to worry except at node 54 and 34. So, even if suddenly traffic doubles it does not affect vastly to our network. So, we can say that this new network is better than the previous one.

Case study 4: To study effect of traffic on throughput of Wi-Fi network

Experimental Setup: As per figure 5.49

Settings: As per section 5.4.2.

Figure 5.56 shows the comparison of throughput on the basis of the first three modulation schemes, DPSK, DQPSK and FSK2. Fig. 5.54 shows comparison of throughput as compared on basis of FSK8, GMSK and QAM64. From all graphs we can say that better throughput is achieved almost every whereby either the use of GMSK or by QAM64 technique

Similarly we have compared the throughput on sever side nodes. And finally from above charts we can conclude that throughput we achieve is better from the QAM 64, GMSK and also by FSK2 techniques. In next section we have

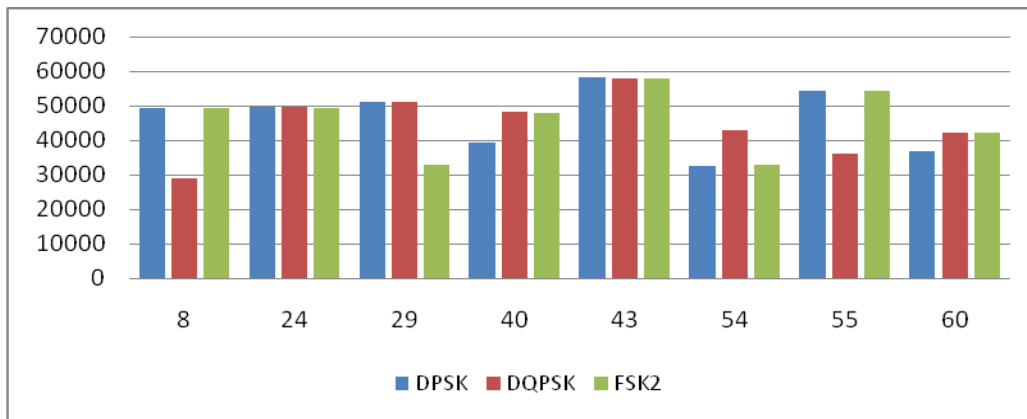


Figure 5.57: FTP client throughput of modified network

compared server throughput of all server nodes with respect to same modulation techniques

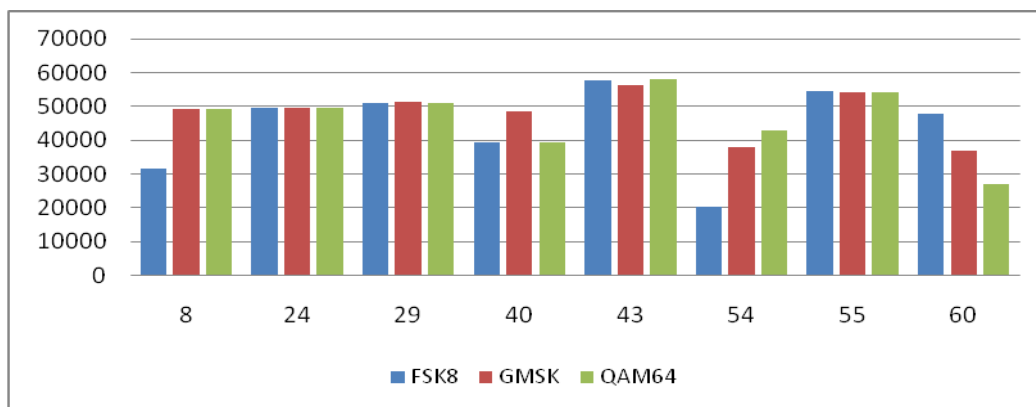


Figure 5.58: FTP client throughput of modified network

Effect on FTP Server throughput

Figure 5.59 shows the comparison of all server nodes for DPSK, DQPSK and FSK2. While Figure 5.60 shows the comparison of all server nodes for FSK8, GMSK and QAM64.

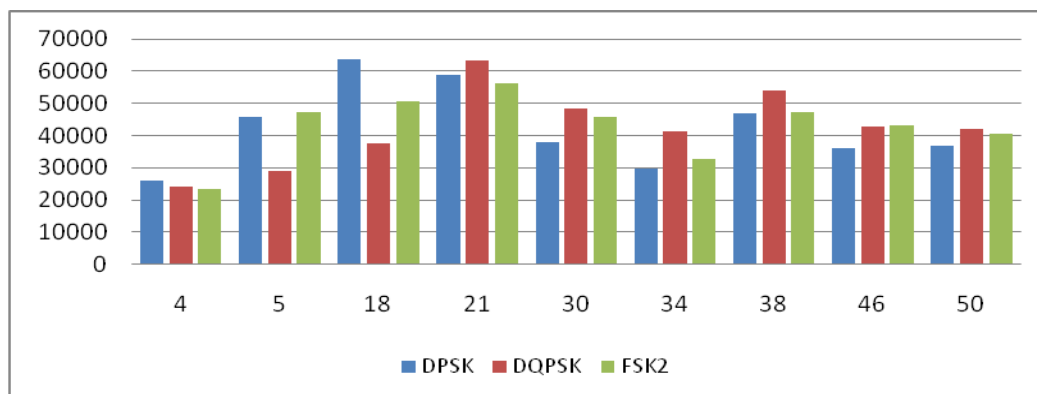


Figure 5.59: FTP server throughput of modified network

From above figure we can see that almost better throughput is given by FSK2 but DQPSK also gives better throughput but it has problem that for some nodes its throughput decreases drastically.

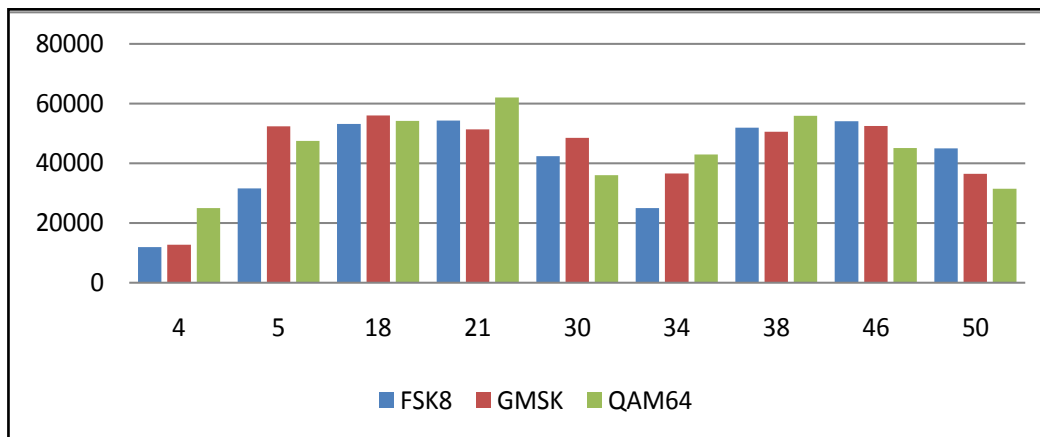


Figure 5.60: FTP server throughput of modified network

From above figure we can say that better performance is given by QAM64. So, QAM 64 is better than GMSK. GMSK gives better throughput but it lags in throughput in some nodes.

Effect on signal received with errors

Figure 5.61 shows the comparison of signals received with errors in case of all nodes compared with various modulation schemes. It proves that among DPSK, DQPSK and FSK2, DQPSK gives more signals with errors while DPSK gives fewer signals with error. So, it is better to use DQPSK for less error signals.

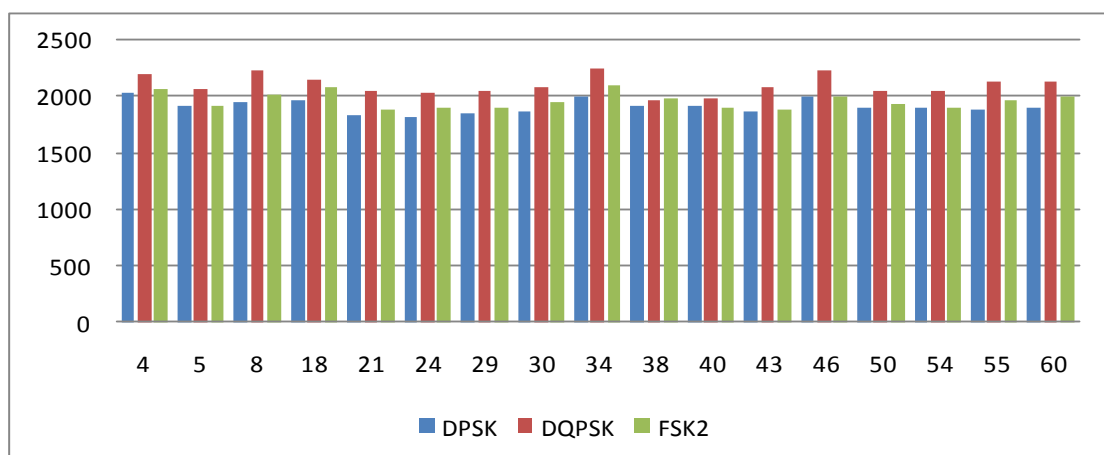


Figure 5.61: Signals received with errors

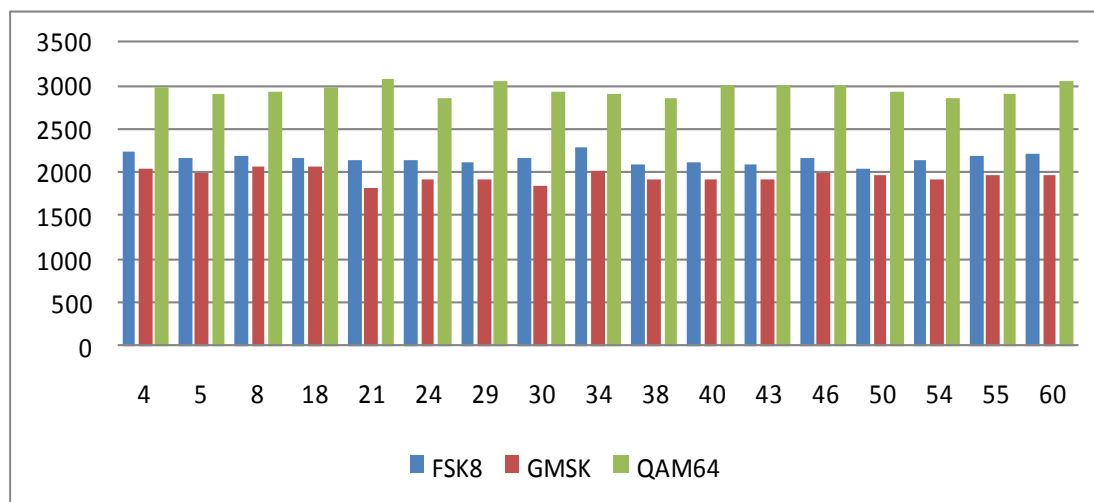


Figure 5.62: Signals received with errors

Figure 5.62 shows the comparison of FSK8, GMSK and QAM64. This shows that QAM64 gives more signals with errors compared to all modulation schemes. While for GMSK, it produces fewer signals with errors. So, GMSK is better for giving fewer signals with errors. All above analysis says that even if QAM64 gives better throughput compared to GMSK, GMSK is better because it gives fewer amounts of signals with errors. So, for our CCET College, GMSK is better than all other modulation schemes.

5.4.4 Wi-Fi Network Scenario2 with multiple access point

Figure 5.63 shows the case study Wi-Fi network under consideration for the evaluation. This network is actually modified version of Wi-Fi network at CU Shah College. On Ground floor we have established Wi-Fi network with three access points in college and one at diploma wing & hostel each. So we have tried to establish a network with just one wifi access point which can reach out 500 meters x 500 meters.

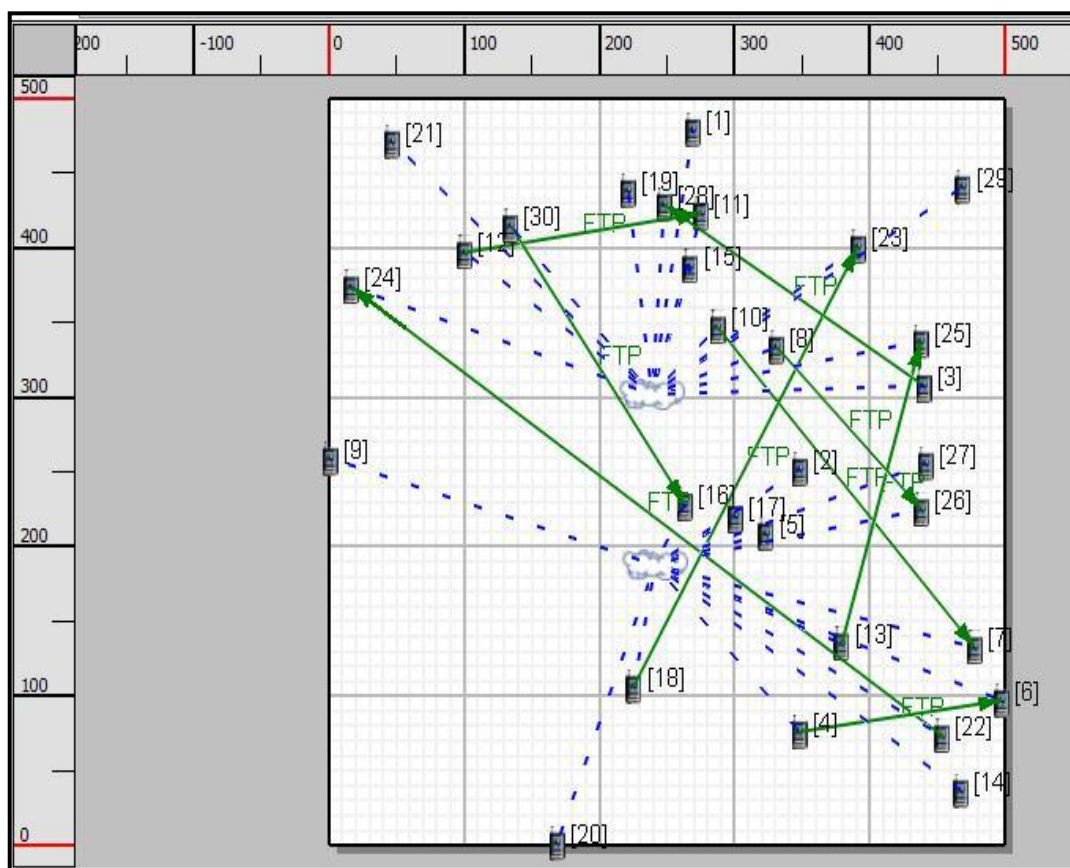


Figure5.63: Case Study Wi-Fi Network

WiFi Scenario2 Specifications:

Terrain:

<i>Co ordinate system</i>	Cartesian
<i>Dimensions</i>	500 meters x 500 meters
<i>Altitude</i>	Above sea level 1500 meters

Channel:

<i>No. of Channels</i>	1
<i>Channel Frequency</i>	2.4 GHz
<i>Pathloss Model</i>	Two Ray and Free Space model
<i>Shadowing model</i>	Constant
<i>Shadowing mean</i>	22 dbm
<i>Fading model</i>	None
<i>Propagation limit</i>	-111.0 dbm

Wireless Subnet

Physical Layer

<i>Radio Type</i>	802.11 b
<i>Data rate</i>	1 Mbps, 2 Mbps, 5.5 Mbps, 11 Mbps
<i>Transmit Power</i>	18.5 dbm
<i>Receive sensitivity</i>	-94dbm to -87 dbm
<i>Packet reception model</i>	PHY802.11b Reception model BER based Reception model
<i>Specify Antenna from file</i>	No
<i>Antenna Gain</i>	0 db
<i>Antenna Height</i>	1.5 meters

MAC Layer

<i>MAC Protocol</i>	802.11
<i>Station association type</i>	Dynamic
<i>Set as access point</i>	Yes
<i>Security Protocol</i>	None
<i>Enable Promiscuous mode</i>	Yes

Network Layer

<i>Network Layer Protocol</i>	IPv4
<i>IP fragmentation unit</i>	2048 bytes

Routing Protocol

<i>Routing Protocol IPv4</i>	Bellman – Ford
<i>Enable IP forwarding</i>	Yes

Mobile Station

Mobility and Placement

<i>Node Placement strategy</i>	File
<i>Mobility Model</i>	Random Waypoint

Network Layer

<i>Network Protocol</i>	IPv4
-------------------------	------

Routing Protocol

<i>Routing Protocol for IPv4</i>	Bellman Ford
<i>Enable IP forwarding</i>	Yes

Mobile station to Wireless Subnet Interface

Physical Layer

<i>Radio Type</i>	802.11 b
<i>Data rate</i>	1 Mbps, 2 Mbps, 5.5 Mbps, 11 Mbps
<i>Transmit Power</i>	18.5 dbm
<i>Receive sensitivity</i>	-94dbm to -87 dbm
<i>Packet reception model</i>	PHY802.11b Reception model BER based Reception model
<i>Specify Antenna from file</i>	No
<i>Antenna Gain</i>	0 db
<i>Antenna Height</i>	1.5 meters

MAC Layer

<i>MAC Protocol</i>	802.11
<i>Station association type</i>	Dynamic
<i>Set as access point</i>	Yes
<i>Security Protocol</i>	None
<i>Enable Promiscuous mode</i>	Yes

Network Layer

<i>Network Layer Protocol</i>	IPv4
<i>IP fragmentation unit</i>	2048 bytes

Routing Protocol

<i>Routing Protocol IPv4</i>	Bellman – Ford
<i>Enable IP forwarding</i>	Yes

(Default Settings as per IEEE 802.11b standard)

5.4.5 Wi-Fi Case studies for scenario 2

Researcher have experimented different case studies based on various ways by changing various aspects

Case study 1: To study effect of data rate on throughput of Wi-Fi network

Experimental Setup: As per figure 5.63

Settings: As per section 5.4.4.

After establishing network, we have established eight FTP connections. These eight FTP connections connect total 18 nodes out of 30 by FTP link. After these data rate of access point working on 802.11b is varied from 1Mbps,

2mbps, 5.5mbps and 11 mbps with constant power of 18.5 dbm and constant loss of 11db in path.

For each of case we have derived results for throughput and then summarized it. After this we have made traffic double that is 60 nodes in same network. Then again all tests as above are conducted and results are derived for FTP client and server throughput for connecting nodes. FTP with 100,1000,10000 or more packets is sent. Figure 5.64 and 5.65 shows the throughput for data rate of 1Mbps, power level of 18.5 dbm.

As seen in figure at every node which is FTP client, is tested in form of throughput for different data rates i.e., 1Mbps, 2Mbps, 5.5Mbps, 11 Mbps. It is clearly visible from figure that as out data rate increases throughput also increases. But nodes which are far away from the access points are getting lower throughput at higher data rates. It is fact as per the datasheet of Linksys that as data rate increases the spread of Wi-Fi network, i.e. area it covers decreases. So, it is proved from above figure5.64 that as we increase data rate throughput

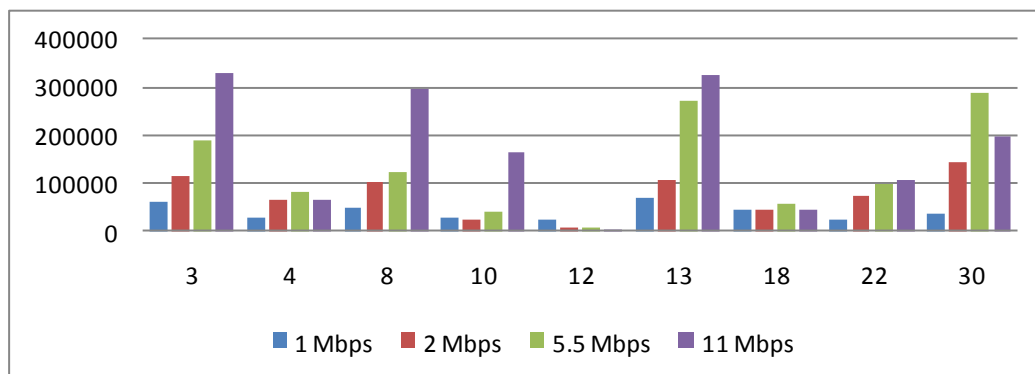


Figure 5.64: FTP Client Throughput for variation in data rate

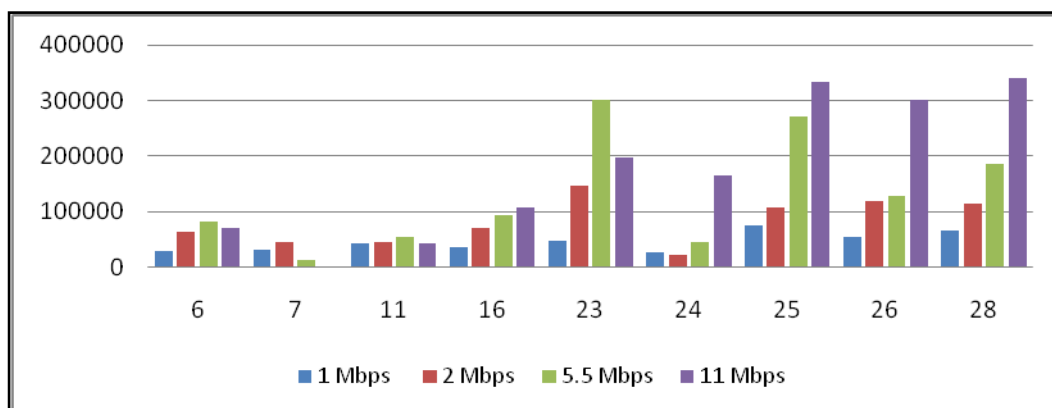


Figure 5.65: FTP Server Throughput for variation in data rate

As seen in above figure 5.64, throughput of various FTP client nodes are compared with respect to data rates. It once again says that throughput increases if nodes are in nearby region of the access points and decreases in far region. But one important point to consider is that this network provides sufficient coverage to all nodes in so region of 500mtrs x 500mtrs. While currently if we see in our college which requires 4-5 access point for the same. So, it shows an improvement if we shift from 802.11 g to 802.11 b.

Case study 2: To study effect of variation in traffic on throughput of Wi-Fi network

Experimental Setup: As per figure 5.63

Settings: As per section 5.4.4.

Now if we double traffic let's check effect on throughput for all nodes for just two data rates 1 Mbps and 11 Mbps. Also let's observe effect of change in traffic.

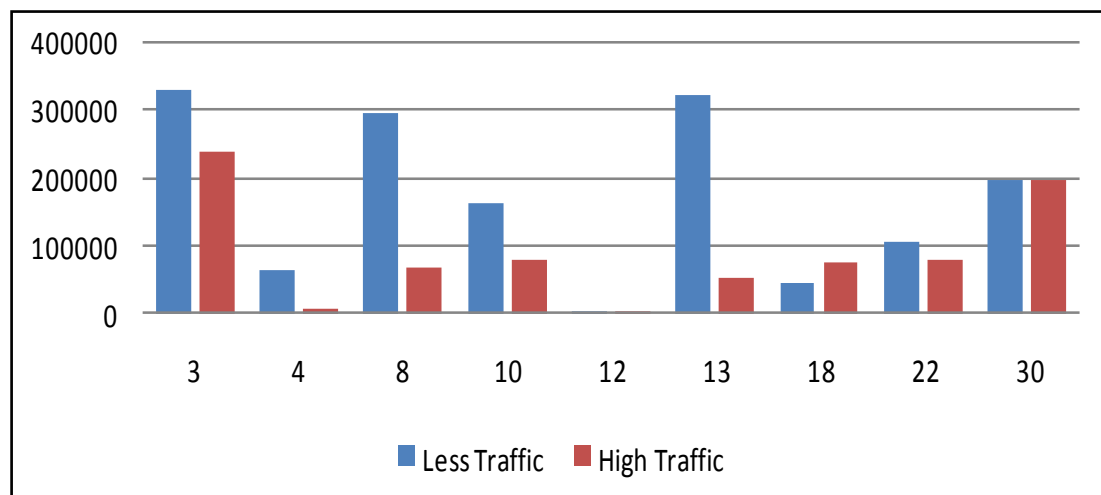


Figure 5.66: Effect on FTP client throughput by change in traffic (1 Mbps)

So from figure 5.66 we can definitely say that throughput which measure of any system is vastly affected by traffic. Whether we work at low data rate or high data rate, we can easily visualize in figure that drop in throughput for change in traffic.

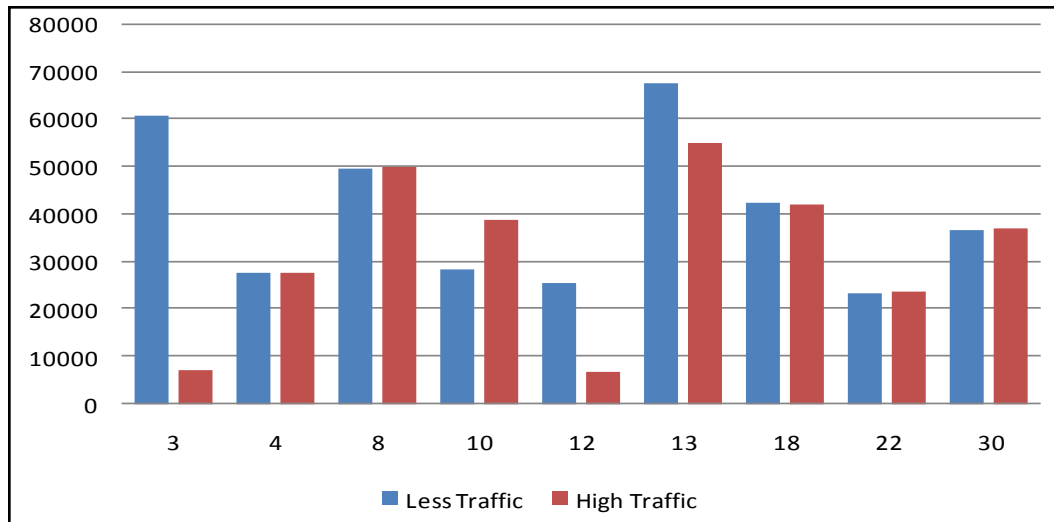


Figure 5.67: Effect on FTP client throughput by change in traffic (11 Mbps)

So, we can conclude that performance of Wi-Fi network is vastly affected by traffic. But the throughput at high data rate is less affected compared to less data rate.

Case study 3: To study effect of variation in Pathloss model on throughput of Wi-Fi network

Experimental Setup: As per figure 5.63

Settings: As per section 5.4.4

Now let's compare on the base of pathloss models. Here okumura hata or Costa hata models are not applicable because the fact that they can be used for frequency less than 1.5GHz. So, we have considered only two models two ray model and free space model. Comparison is given in below figure5.68. From both graphs it is revealed that the free space model behaves well and gives better performance for the all nodes. So, for a wifi network of small area free space model is better than all other models.

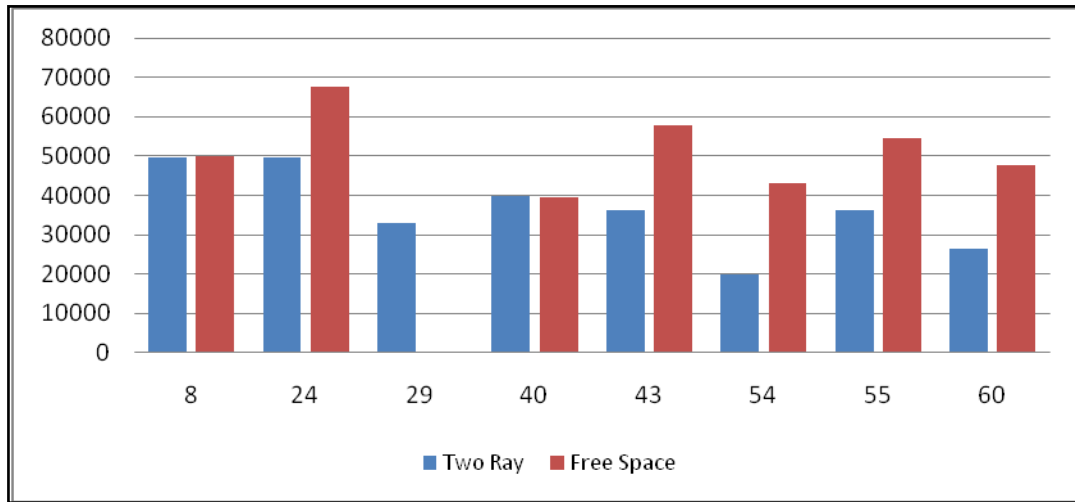


Figure 5.68: Effect of Pathloss model on FTP client throughput

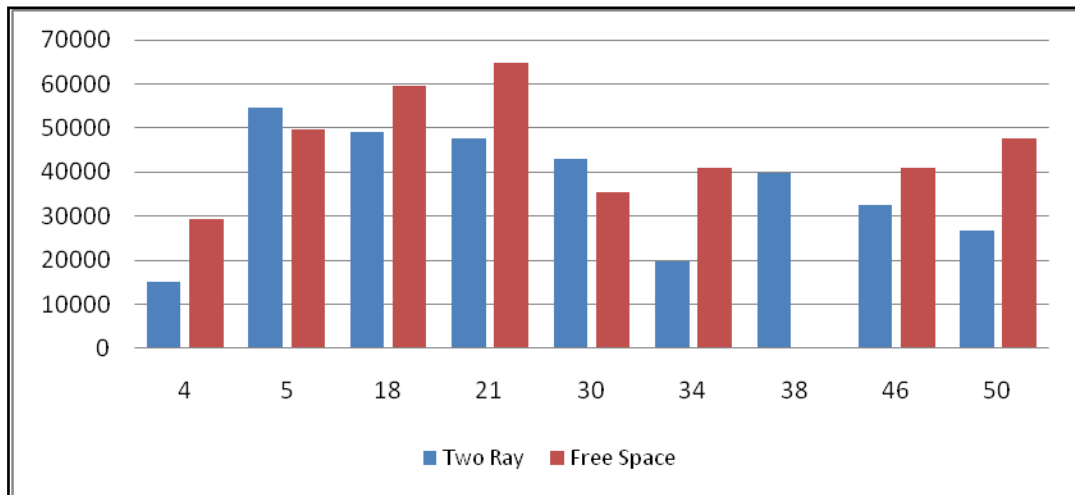


Figure 5.69: Effect of Pathloss model on FTP server throughput

From above graphs it is proved that free space model is better in giving throughput but it fails to give throughput in certain cases like node 38. So, if we neglect it, free space is better else two ray model is better.

5.4.6 Analysis of Wi-Fi Network

The above Wi-Fi example has been experimented in various ways by changing various aspects as given below

1. Comparison is based on Number of users accommodated Vs Power

Table 5.9 Different values of Number of users accommodated and Power for Wi-Fi

Power (dBm)	No. of users accommodated
4	5
6	11
9	19
11	36
14	65
18	84

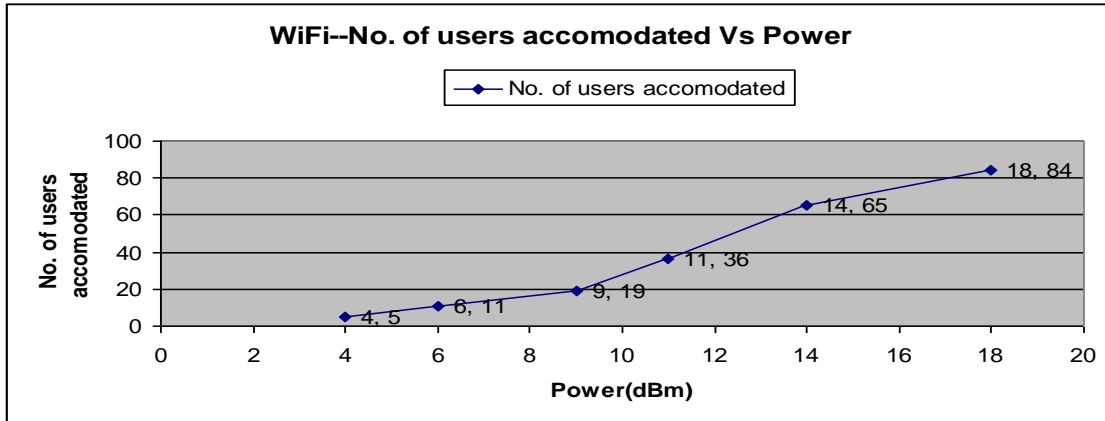


Figure 5.70 Graph shows analysis of no. of users accommodated Vs Power for Wi-Fi

2. Comparison is based on Range (Coverage area) Vs Power

Table 5.10 Different values of Range and Power for Wi-Fi

Power (dBm)	Range (Meter)
4	10
6	25
9	46
11	60
14	70
18	96

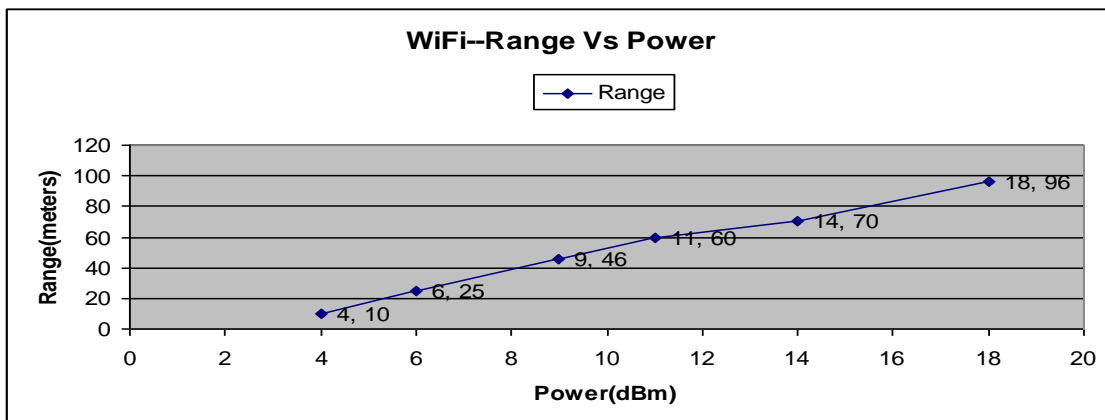


Figure 5.71 Graph shows analysis of Range Vs Power for Wi-Fi

3. Comparison is based on Data rate Vs Power

Table 5.11 Different values of Data rate and Power for Wi-Fi

Power(dBm)	Data rate (Kbps)
4	1
6	2
9	4
11	6
14	8
18	11

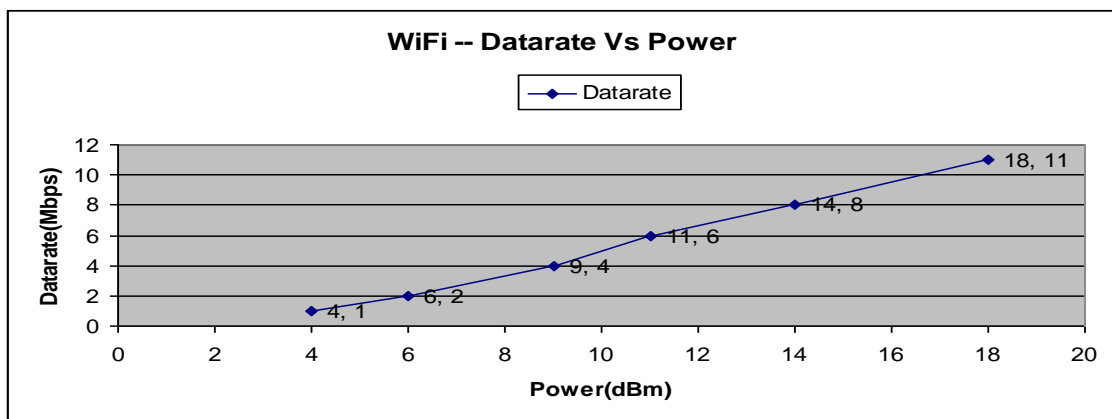


Figure 5.72: Graph shows analysis of Data rate Vs Power for Wi-Fi

5.5 WiMAX (Worldwide Interoperability for Microwave Access)

WiMAX follows the IEEE 802.16d standard. The various features of WiMAX can be implemented using QualNet-5.0 mentioned as below.

5.5.1 Implemented Features

The PHY802.16 and MAC802.16 models of QualNet-5.0 have implemented features defined in IEEE 802.16d. The detailed list of implemented features is:

- OFDMA physical model.
- Variety channel bandwidth support.
- Multiple FFT size support.
- Multiple cyclic prefix time support.
- Multiple data rates support.
- BER-based reception quality estimation.
- Sub-channel SINR representation.
- Data rate and transmission range estimation.

- Point to Multi-Point (PMP) mode.
- Time Division Duplex (TDD) mode:
 - MAC frame is divided into downlink sub frame and uplink sub frame.
 - DL-MAP and UL-MAP supporting sub channels of OFDMA PHY.
- Network entry and initialization:
 - Channel scan and synchronization with DL channel. Channel lost detection and network re-entry.
 - DCD and UCD messages for obtaining and maintaining DL/UL parameters.
 - Initial (contention) ranging and periodical ranging.
 - Negotiation of basic capability and registration.
 - CDMA-based ranging.
- Dynamic flow management including service flow addition, deletion and change.
- Bandwidth management:
 - Polling-based bandwidth requests.
 - Contention-based bandwidth requests.
 - CDMA-based bandwidth requests.
- Scheduling service at the base station:
- MAC frame construction:
 - Downlink (DL) sub frame construction.
 - Uplink (UL) burst construction.
 - PDU concatenation, fragmentation, packing, and CRC.
- Adaptive Modulation and Coding (AMC):
 - Signal strength monitoring (UL/DL) and reporting (DL).
 - Seven burst profiles for both downlink and uplink transmissions using different coding and modulation combinations.
 - Dynamic switch of burst profiles based on CINR.
 - Support for broadcast and multicast flows.

- Convergence Sub layer (CS):
 - Classify flows to different service types based on their priority.
 - Retrieve accurate QoS parameters of UGS flows.
 - Support both IPv4 and IPv6.
- Interface other networks such as ATM, 802.3, 802.11 at network layer.
- Support 802.16 OFDMA PHY.
- Simple admission control.
- ARQ.

5.5.2 Sample Scenario

Sample Scenario Topology

Assume the scenario contains two subnets. Subnet 1 contains node 1 to node 10 and subnet 2 contains node 11 to node 20. Both subnets run 802.16 MAC with node 1 as the BS of subnet 1 and node 15 as the BS of subnet 2. The two base stations, node 1 and node 15, are connected via a wired point-to-point link, as shown in figure 5.73.

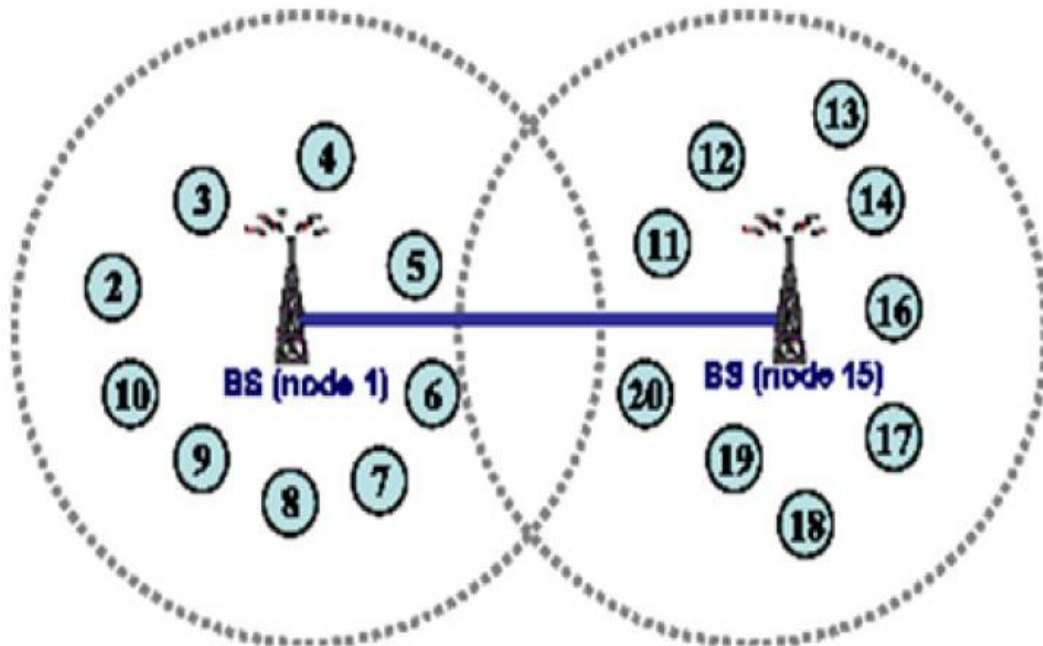


Figure 5.73: Topology of Sample Scenario

GUI Configuration

In this section, we use an example to show how to configure a scenario and Wireless Subnet Properties editor with 802.16 PHY and 802.16 MAC in GUI.

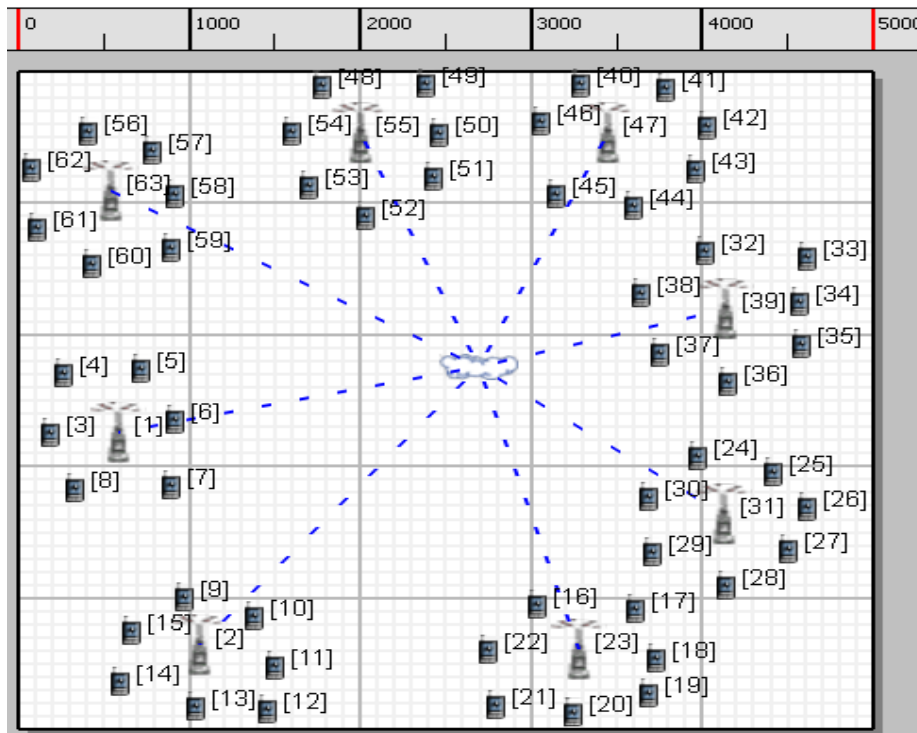
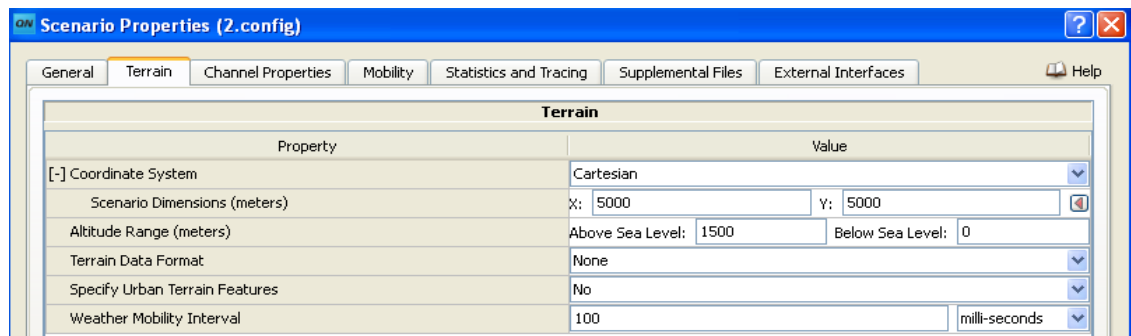


Figure 5.74: WiMAX Scenario developed with coverage area 5000m X 5000m using QualNet

Parameters can be set in the Interface Properties editor and default Device Properties Editor in a similar way. Figure 5.74 shows WiMAX Scenario developed with coverage area 5000m X 5000m using QualNet-5.0 as per WiMAX architecture. Place 63 nodes of default device type and a wireless subnet on the canvas. Nodes 1, 2, 23, 31, 39, 47, 55, 63 are acting as a Base station and other nodes are acting as a Subscriber station. Connect all Base stations to the wireless subnet. Connect other nodes to the default wireless subnet.

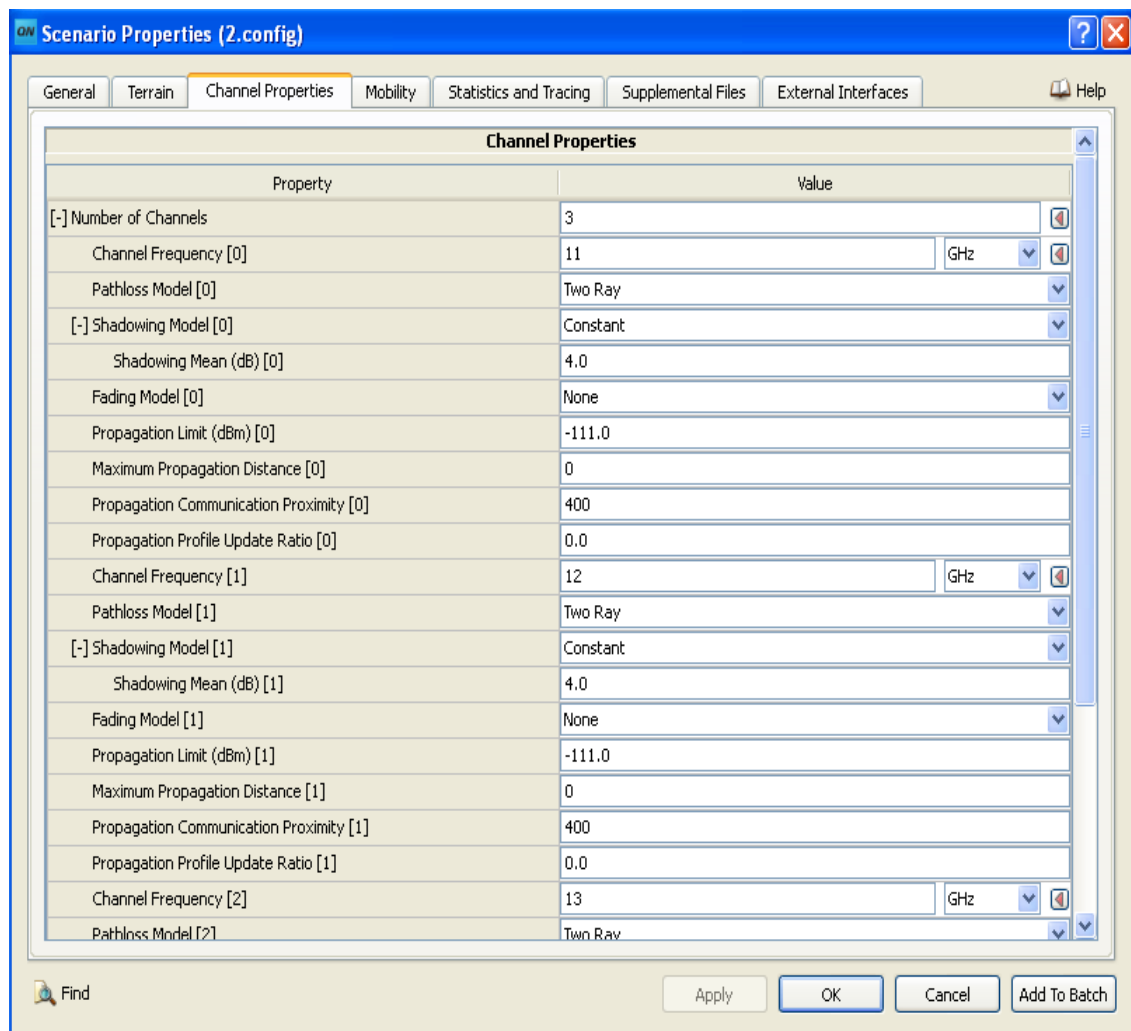
Below figures show how the various GUI parameters have been set for above scenario in figure 5.74



The screenshot shows the 'Terrain' tab of the 'Scenario Properties (2.config)' window. The window has a blue title bar and a menu bar with 'General', 'Terrain', 'Channel Properties', 'Mobility', 'Statistics and Tracing', 'Supplemental Files', 'External Interfaces', and 'Help'. The 'Terrain' tab is selected, and the 'Terrain' section is active. The table below lists the properties and their values.

Property	Value
[-] Coordinate System	Cartesian
Scenario Dimensions (meters)	X: 5000 Y: 5000
Altitude Range (meters)	Above Sea Level: 1500 Below Sea Level: 0
Terrain Data Format	None
Specify Urban Terrain Features	No
Weather Mobility Interval	100 milli-seconds

Figure 5.75 WiMAX Scenario Properties (a) Terrain Properties



The screenshot shows the 'Channel Properties' tab of the 'Scenario Properties (2.config)' window. The window has a blue title bar and a menu bar with 'General', 'Terrain', 'Channel Properties', 'Mobility', 'Statistics and Tracing', 'Supplemental Files', 'External Interfaces', and 'Help'. The 'Channel Properties' tab is selected, and the 'Channel Properties' section is active. The table below lists the properties and their values.

Property	Value
[-] Number of Channels	3
Channel Frequency [0]	11 GHz
Pathloss Model [0]	Two Ray
[-] Shadowing Model [0]	Constant
Shadowing Mean (dB) [0]	4.0
Fading Model [0]	None
Propagation Limit (dBm) [0]	-111.0
Maximum Propagation Distance [0]	0
Propagation Communication Proximity [0]	400
Propagation Profile Update Ratio [0]	0.0
Channel Frequency [1]	12 GHz
Pathloss Model [1]	Two Ray
[-] Shadowing Model [1]	Constant
Shadowing Mean (dB) [1]	4.0
Fading Model [1]	None
Propagation Limit (dBm) [1]	-111.0
Maximum Propagation Distance [1]	0
Propagation Communication Proximity [1]	400
Propagation Profile Update Ratio [1]	0.0
Channel Frequency [2]	13 GHz
Pathloss Model [2]	Two Ray

At the bottom of the window, there is a 'Find' button, an 'Apply' button, and 'OK', 'Cancel', and 'Add To Batch' buttons.

(b) Channel properties

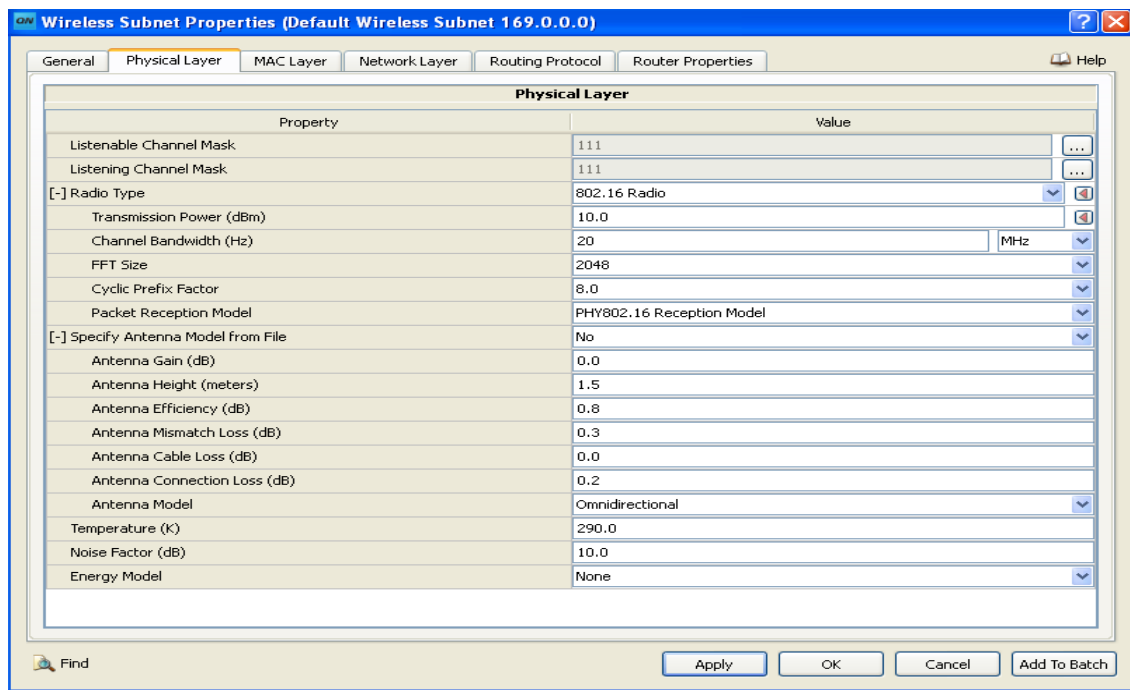
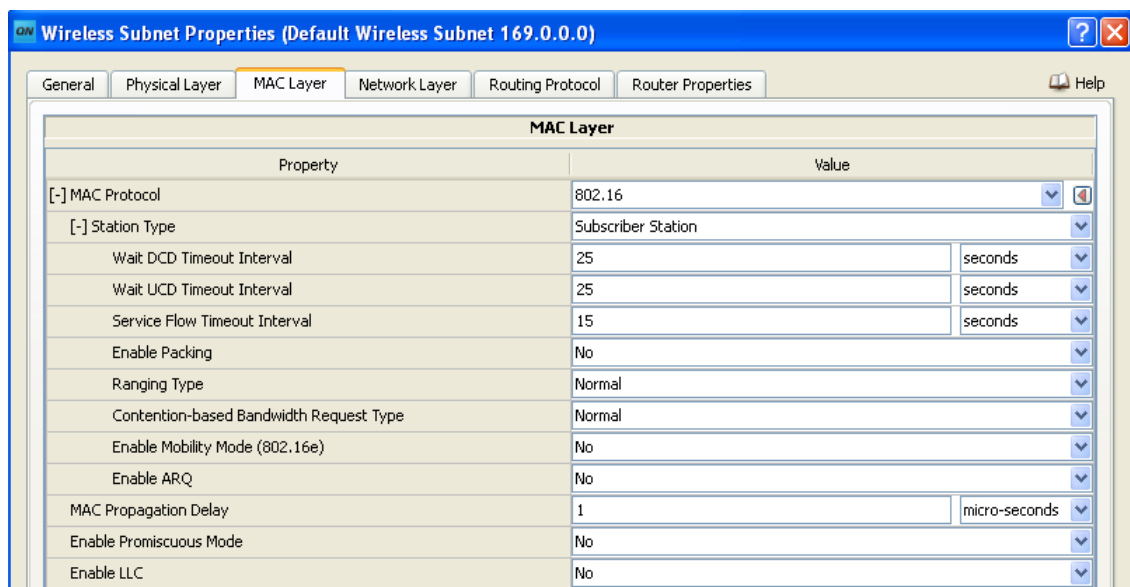
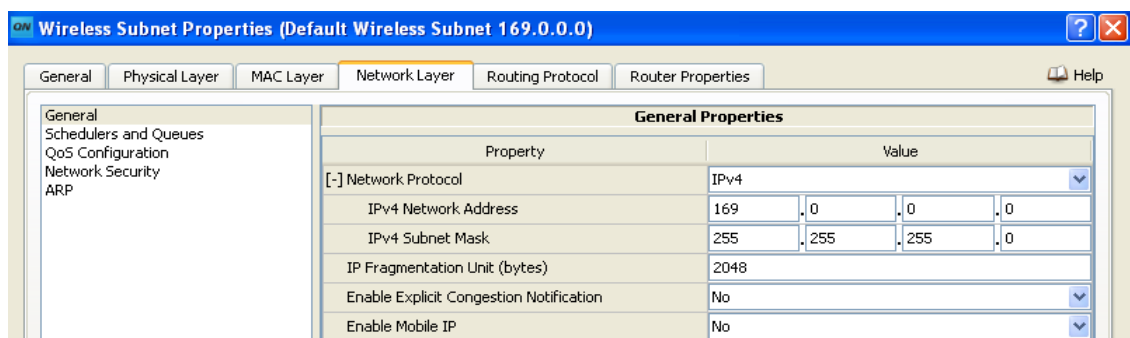


Figure 5.76 WiMAX Scenario–Default Wireless Subnet Properties (a) Physical Layer



(b) MAC Layer



(c) Network Layer

Wireless Subnet Properties (Wireless Subnet 190.0.1.0)

General Physical Layer MAC Layer Network Layer Routing Protocol Router Properties Help

Physical Layer

Property	Value
Listenable Channel Mask	111
Listening Channel Mask	111
[-] Radio Type	802.16 Radio
Transmission Power (dBm)	50.0
Channel Bandwidth (Hz)	20 MHz
FFT Size	2048
Cyclic Prefix Factor	8.0
Packet Reception Model	PHY802.16 Reception Model
[-] Specify Antenna Model from File	No
Antenna Gain (dB)	0.0
Antenna Height (meters)	1.5
Antenna Efficiency (dB)	0.8
Antenna Mismatch Loss (dB)	0.3
Antenna Cable Loss (dB)	0.0
Antenna Connection Loss (dB)	0.2
Antenna Model	Omnidirectional
Temperature (K)	290.0
Noise Factor (dB)	10.0
Energy Model	None

Figure 5.77 WiMAX Scenario – Wireless Subnet Properties (a) Physical Layer

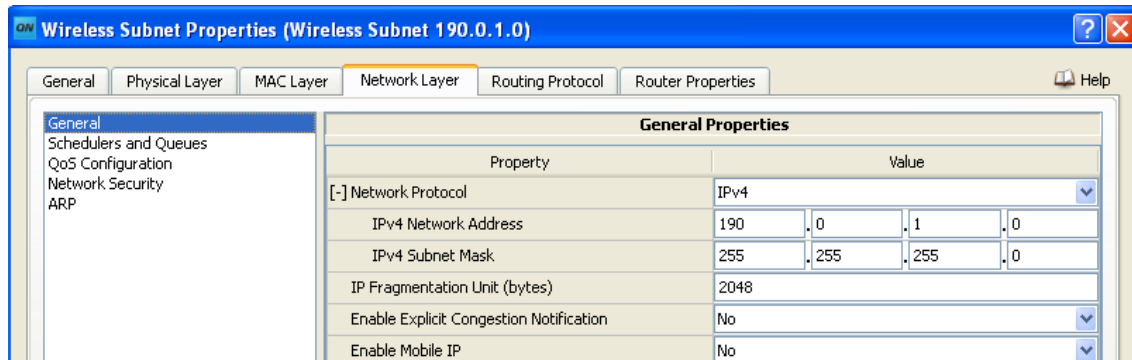
Wireless Subnet Properties (Wireless Subnet 190.0.1.0)

General Physical Layer MAC Layer Network Layer Routing Protocol Router Properties Help

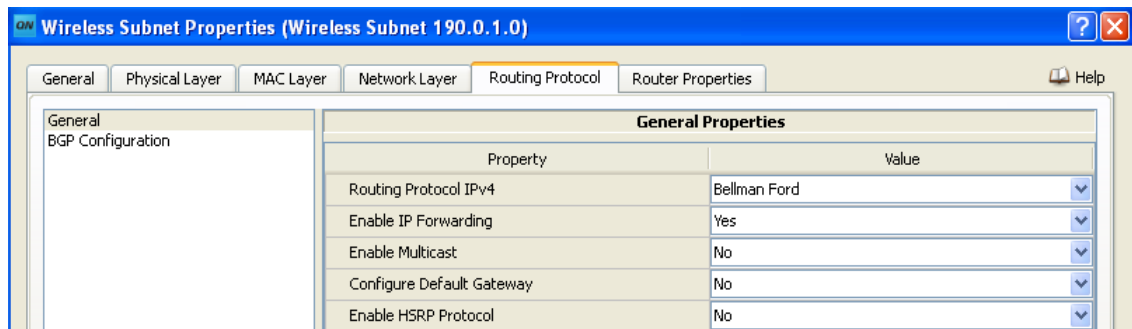
MAC Layer

Property	Value
[-] MAC Protocol	802.16
[-] Station Type	Base Station
MAC Frame Duration	20 milli-seconds
TDD Downlink Duration	10 milli-seconds
DCD Broadcast Interval	5 seconds
UCD Broadcast Interval	5 seconds
Ranging Minimal Backoff Value	3
Ranging Maximal Backoff Value	15
Bandwidth Request Minimal Backoff Value	3
Bandwidth Request Maximal Backoff Value	15
Service Flow Timeout Interval	15 seconds
Transmit/Receive Transition Gap(TTG)	10 micro-seconds
Receive/Transmit Transition Gap(RTG)	10 micro-seconds
SS Transition Gap(SSTG)	4 micro-seconds
Maximum Allowed Uplink Load Level	0.7
Maximum Allowed Downlink Load Level	0.7
Enable Packing	No
Admission Control Scheme	None
Ranging Type	Normal
Contention-based Bandwidth Request Type	Normal
Enable Mobility Mode (802.16e)	No

(b) MAC Layer



(c) Network Layer



(d) Routing protocol

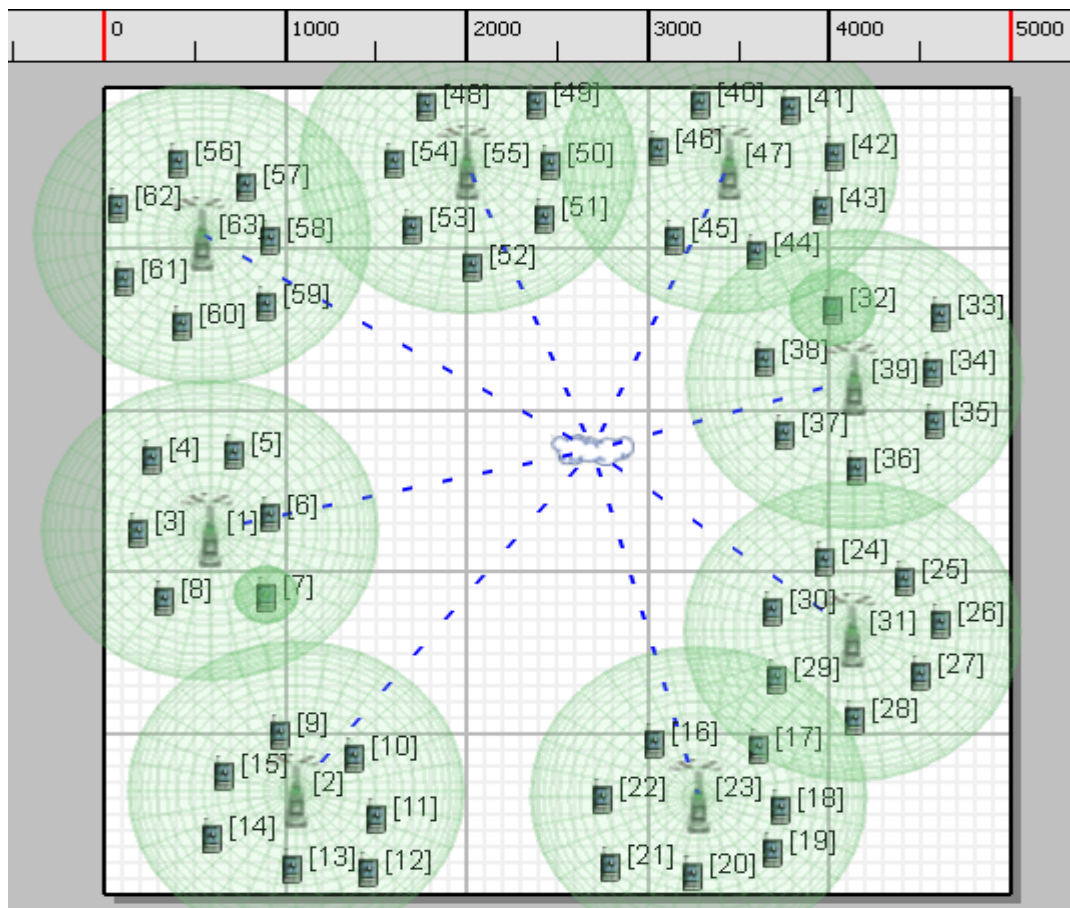


Figure 5.78 WiMAX Scenario: Live Simulation

5.5.3 Simulation Results of WiMAX Scenario

Below figures show the various results of above scenario after simulation using QualNet Analyzer.

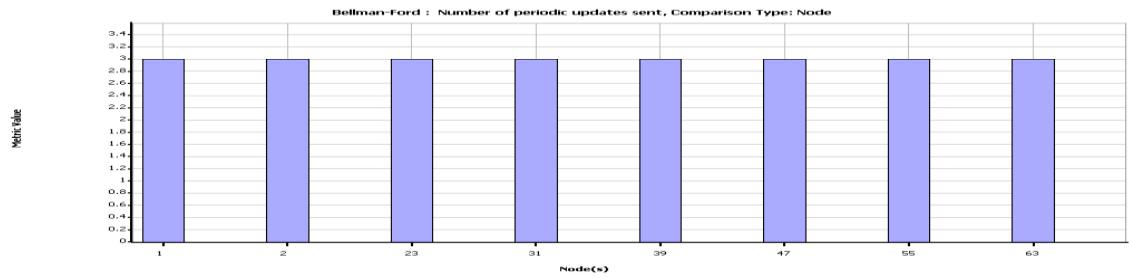
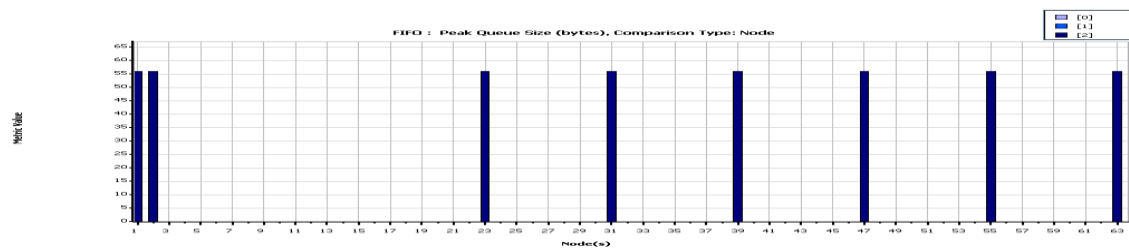
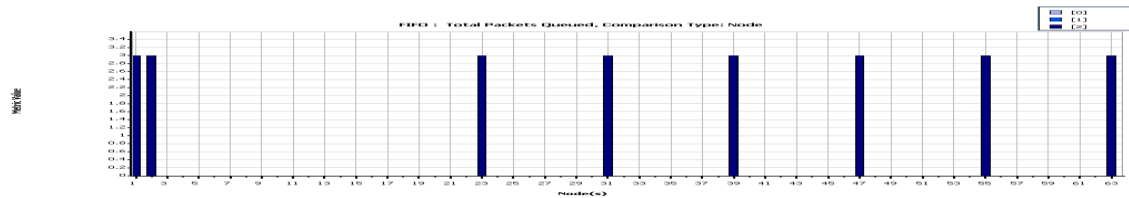


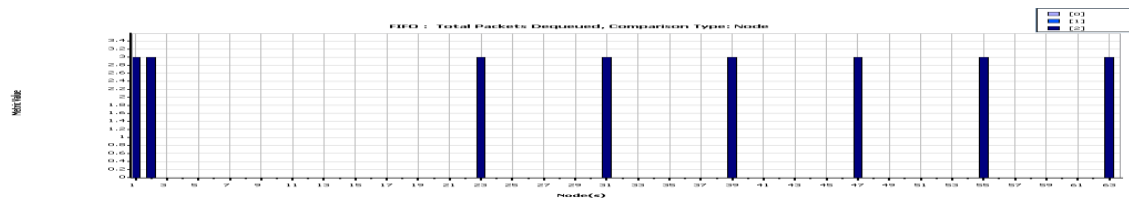
Figure 5.79 WiMAX Scenario : Analyzer Results (a) Bellman-Ford: Number of periodic updates sent



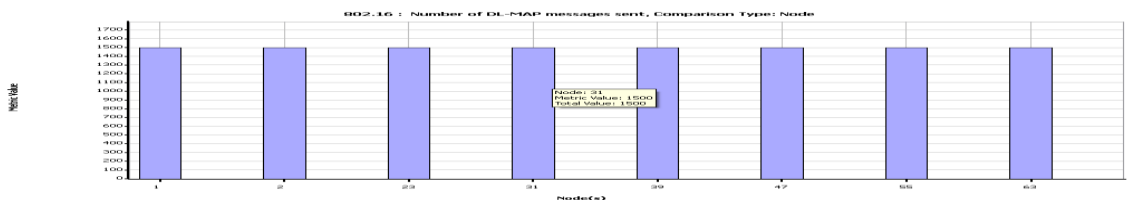
(c) FIFO: Peak Queue Size (bytes)



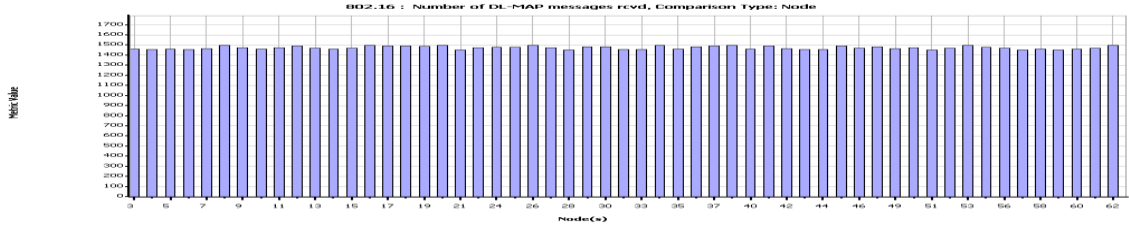
(c) FIFO: Total Packets Queued



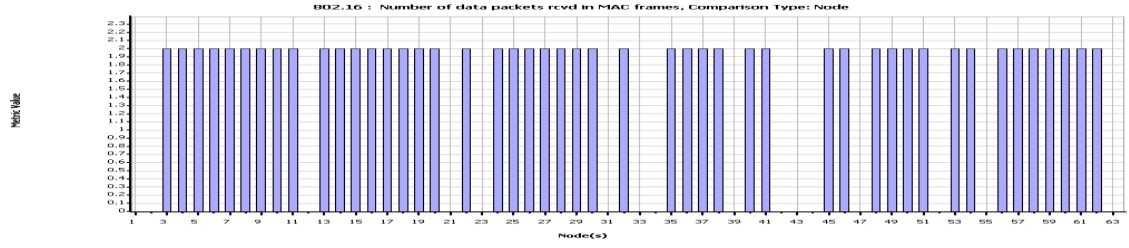
(c) FIFO: Total Packets Dequeued



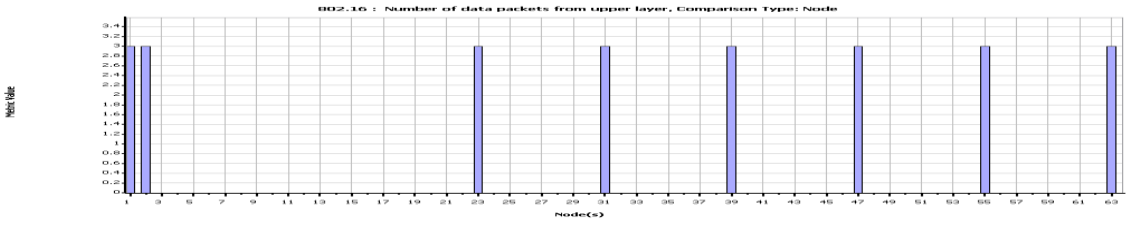
(d) 802.16: Number of DL-MAP messages sent



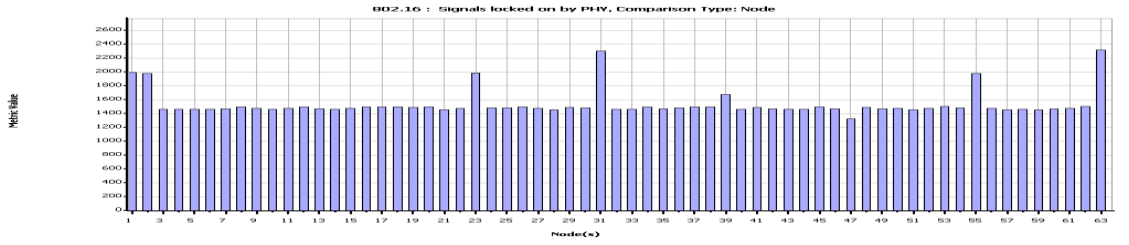
(e) 802.16: Number of DL-MAP messages received



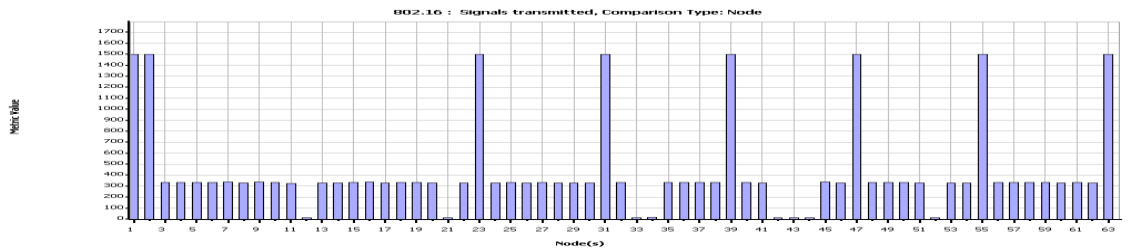
(f) 802.16: Number of data packets received in MAC frames



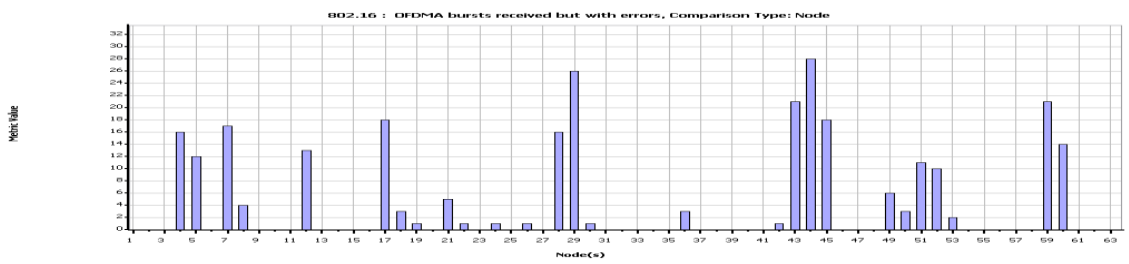
(g) 802.16: Number of data packets from upper layer



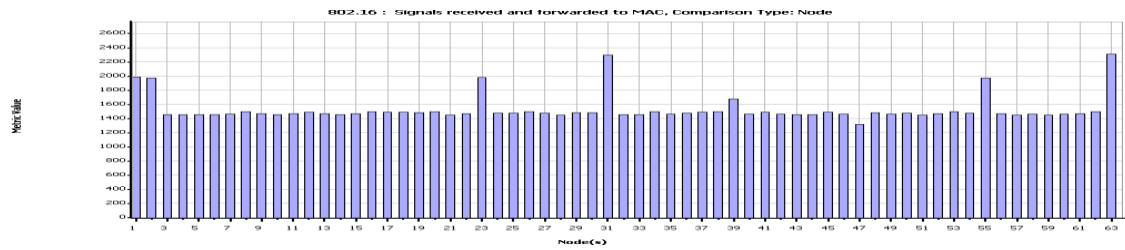
(h) 802.16: Signals locked on by PHY



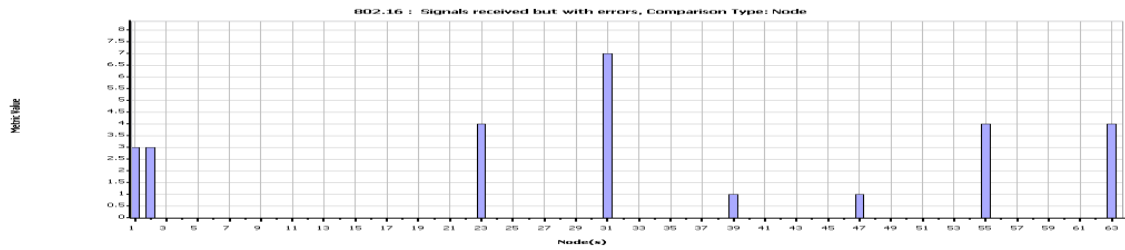
(i) 802.16: Signals transmitted



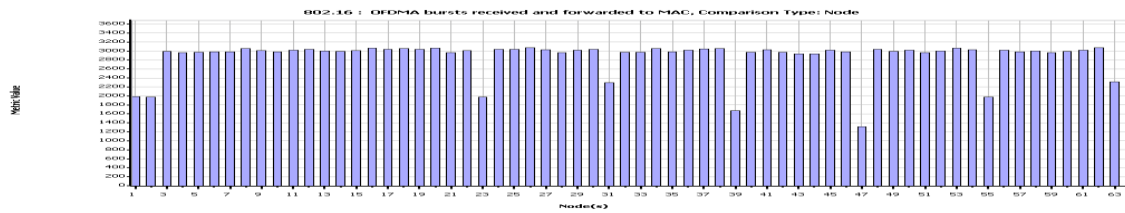
(j) 802.16: OFDMA bursts received but with errors



(k) 802.16: Signals received and forwarded to MAC



(l) 802.16: Signals received but with errors



(m) 802.16: OFDMA burst received and forwarded to MAC

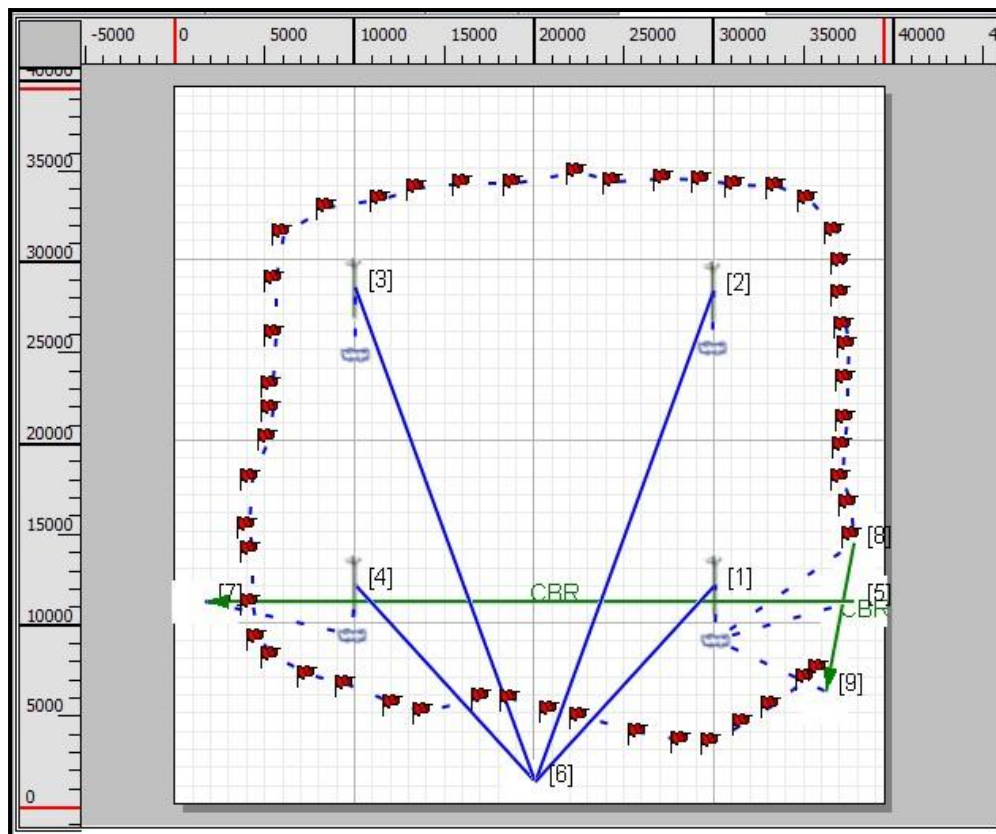


Figure 5.80: Case Study WiMAX Network

5.5.4 WiMAX Scenario Specifications for Case studies

Here we are considering a network of WiMAX as shown in figure 5.80. This network is having two applications of WiMAX. One is Fixed WiMAX connection while another is Mobile WiMAX.

This network is 40 kms x 40 kms. It has 4 base stations. There are four subscriber stations. There are two CBR applications under considerations. Node 5 and 7 are fixed nodes while 8 is a mobile node and 9 are fixed. Node 8 travels path from node 8 to node 9 as static path shown by flags. This path is taken such that node has to take hand off from base station 1, 2, 3, 4 and last back to 1.

This network is analyzed on the base of variation of transmit power level of base stations, path-loss models and routing models. Results are analyzed on based of the throughput of server, jitter at server and also end to end delay of packets.

As per IEEE 802.16 power level is 20dbm. But as per FCC norms any wireless network can have power level up to 30dbm and antenna gain up to 6db. So in this network we have varied power level from 15 dbm to 25 dbm to find out optimum level required to reach out every corner of above network.

Path loss model for any wireless network is preferred to be free space model. But we have taken free space and two ray model and performance of variation in path loss model is analyzed on base of CBR server throughput, server jitter and server end-to-end delay.

Unicast routing protocol means the finding of route to travel from one subscriber path to destination subscriber station. Generally preferred is bellman-ford protocol. But nowadays ad-hoc on demand distance vector (AODV) is used. So, we have also included it for our analysis. We have also considered Dynamic MANET on-demand routing protocol (DYMO). Once again performance is analyzed on CBR Server throughput, jitter and end-to-end delay.

Specifications

Terrain:

<i>Co ordinate system</i>	Cartesian
<i>Dimensions</i>	40 km x 40 km
<i>Altitude</i>	Above sea level 1500 meters

Channel:

<i>No. of Channels</i>	5
<i>Channel Frequency</i>	2.4 GHz
<i>Pathloss Model</i>	Two Ray and Free Space model
<i>Shadowing model</i>	Constant
<i>Shadowing mean</i>	4 dbm
<i>Fading model</i>	None
<i>Propagation limit</i>	-111.0 dbm

Wireless Subnet

Physical Layer

<i>Radio Type</i>	802.16
<i>Transmit Power</i>	25 dbm
<i>Channel Bandwidth</i>	5,10,15,20,25 MHz
<i>FFT Size</i>	128, 512, 1024, 2048
<i>Packet reception model</i>	PHY802.16 Reception model
<i>Cyclic prefix factor</i>	4,8,16,32
<i>Antenna Gain</i>	12 db
<i>Antenna Height</i>	10 meters

MAC Layer

<i>MAC Protocol</i>	802.16
<i>Station type</i>	Subscriber station
<i>Enable 802.16e mode</i>	Yes
<i>Neighbors BS Scanning RSS</i>	-76 dbm
<i>Trigger</i>	
<i>Handover RSS Margin</i>	-78 dbm
<i>Handover RSS Margin</i>	1 db
<i>Enable Promiscuous Mode</i>	Yes

Network Layer

<i>Network Layer Protocol</i>	IPv4
<i>IP fragmentation unit</i>	2048 bytes

Routing Protocol

<i>Routing Protocol IPv4</i>	Bellman – Ford
<i>Enable IP forwarding</i>	Yes

Mobile Station**Mobility and Placement**

<i>Node Placement strategy</i>	File
<i>Mobility Model</i>	File

Network Layer

<i>Network Protocol</i>	IPv4
-------------------------	------

Routing Protocol

<i>Routing Protocol for IPv4</i>	Bellman Ford
<i>Enable IP forwarding</i>	Yes

Mobile station to Wireless Subnet Interface**Physical Layer**

<i>Radio Type</i>	802.16
<i>Transmit Power</i>	25 dbm
<i>Channel Bandwidth</i>	5,10,15,20,25 MHz
<i>FFT Size</i>	128, 512, 1024, 2048
<i>Packet reception model</i>	PHY802.16 Reception model
<i>Cyclic prefix factor</i>	4,8,16,32
<i>Antenna Gain</i>	12 db
<i>Antenna Height</i>	10 meters

MAC Layer

<i>MAC Protocol</i>	802.16
<i>Station type</i>	Subscriber station
<i>Enable 802.16e mode</i>	Yes

<i>Neighbors BS Scanning RSS Trigger</i>	-76 dbm
<i>Handover RSS Margin</i>	-78 dbm
<i>Handover RSS Margin</i>	1 db
<i>Enable Promiscuous Mode</i>	Yes

Network Layer

<i>Network Layer Protocol</i>	IPv4
<i>IP fragmentation unit</i>	2048 bytes

Routing Protocol

<i>Routing Protocol IPv4</i>	Bellman – Ford
<i>Enable IP forwarding</i>	Yes

Base Station

Mobility and Placement

<i>Node Placement strategy</i>	File
<i>Mobility Model</i>	None

Network Layer

<i>Network Protocol</i>	IPv4
-------------------------	------

Routing Protocol

<i>Routing Protocol for IPv4</i>	Bellman Ford
<i>Enable IP forwarding</i>	Yes

Base station to Wireless subnet Interface

Physical Layer

<i>Radio Type</i>	802.16
<i>Transmit Power</i>	25 dbm
<i>Channel Bandwidth</i>	5,10,15,20,25 MHz
<i>FFT Size</i>	128, 512, 1024, 2048
<i>Packet reception model</i>	PHY802.16 Reception model
<i>Cyclic prefix factor</i>	4,8,16,32
<i>Antenna Gain</i>	12 db
<i>Antenna Height</i>	10 meters

MAC Layer

<i>MAC Protocol</i>	802.16
<i>Station type</i>	Base station
<i>Enable 802.16e mode</i>	Yes
<i>Neighbors BS Scanning RSS Trigger</i>	-76 dbm
<i>Handover RSS Margin</i>	-78 dbm
<i>Handover RSS Margin</i>	1 db
<i>Neighbor BS List</i>	2,3,4
<i>Enable Promiscuous Mode</i>	Yes
Network Layer	
<i>Network Layer Protocol</i>	IPv4
<i>IP fragmentation unit</i>	2048 bytes
Routing Protocol	
<i>Routing Protocol IPv4</i>	Bellman – Ford
<i>Enable IP forwarding</i>	Yes
Base station to Master Base station Interface	
MAC Layer	
<i>MAC Protocol</i>	Abstract Link MAC
<i>Enable Promiscuous Mode</i>	Yes
Network Layer	
<i>Network Layer Protocol</i>	IPv4
<i>IP fragmentation unit</i>	2048 bytes
Routing Protocol	
<i>Routing Protocol IPv4</i>	Bellman – Ford
<i>Enable IP forwarding</i>	Yes

Case study1: To study effect of variation of power level on WiMAX network

Experimental Setup: As per figure 5.80

Settings: As per section 5.5.3

We are going to vary power level from 15dbm to 25 dbm. We will take 15dbm, 20dbm, 22 dbm and then 25dbm. After taking all power levels all reading are tabulated and then comparative graph is generated for CBR Server throughput, jitter and end-to-end delay.

The throughput at the client is calculated as follows:

- If the session is complete, i.e., if all packets have been sent before the simulation ends, $\text{throughput} = (\text{total bytes sent} * 8) / (\text{time last packet sent} - \text{time first packet sent})$, where the times are in seconds.
- If the session is incomplete, i.e., if all packets have not been sent before the simulation ends, $\text{throughput} = (\text{total bytes sent} * 8) / (\text{simulation time} - \text{time first packet sent})$, where the times are in seconds.

The throughput at the server is calculated as follows:

If the session is complete, $\text{throughput} = (\text{total bytes sent} * 8) / (\text{time last packet received} - \text{time first packet received})$, where the times are in seconds.

If the session is incomplete, $\text{throughput} = (\text{total bytes sent} * 8) / (\text{simulation time} - \text{time first packet received})$, where the times are in seconds.

Average end-to-end delay = (total of transmission delays of all received packets) / (number of packets received), where, transmission delay of a packet = time packet received at server – time packet transmitted at client, where the times are in seconds.

Average jitter = (total packet jitter for all received packets) / (number of packets received – 1) where, packet jitter = transmission delay of the current packet – transmission delay of the previous packet. Jitter can be calculated only if at least two packets have been received.

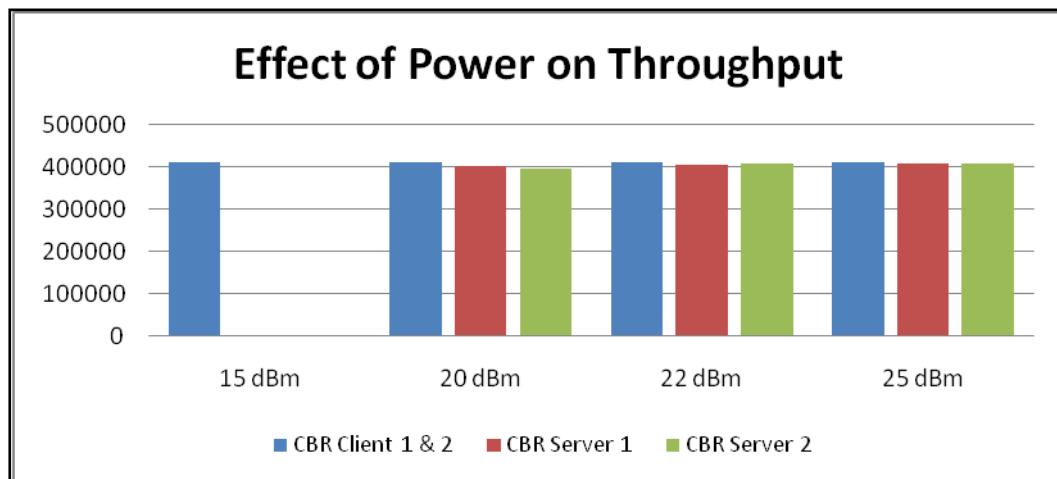


Figure 5.81: Effect of power on throughput

Figure 5.81 above shows that as power is 15 dbm, only CBR client gives throughput, but server 1 or 2 does not give any throughput. Then as power

increases from 20 dbm to 25 dbm, throughput gets rising for all nodes. It means that by change in power level gives more throughputs.

From figure 5.81 we can see that for 15dbm power we cannot get server throughput. It means that this power is not sufficient for this base station to provide coverage to all subscriber nodes.

So we have varied it to 20dbm, but when we simulate, it does not provide hand off at all base stations so throughput achieved is less compared to 22 dbm and 25 dbm. It means that 20 dbm is also not enough to provide complete coverage and hand -offs when required.

So, we have taken next level as 22dbm, but same problem is there that base station fails to provide hand off at all base stations. This power level is also not sufficient.

Next taken is 25 dbm which provided handoff at all base stations and also gives best throughput. So, optimum power level is 25 dbm.

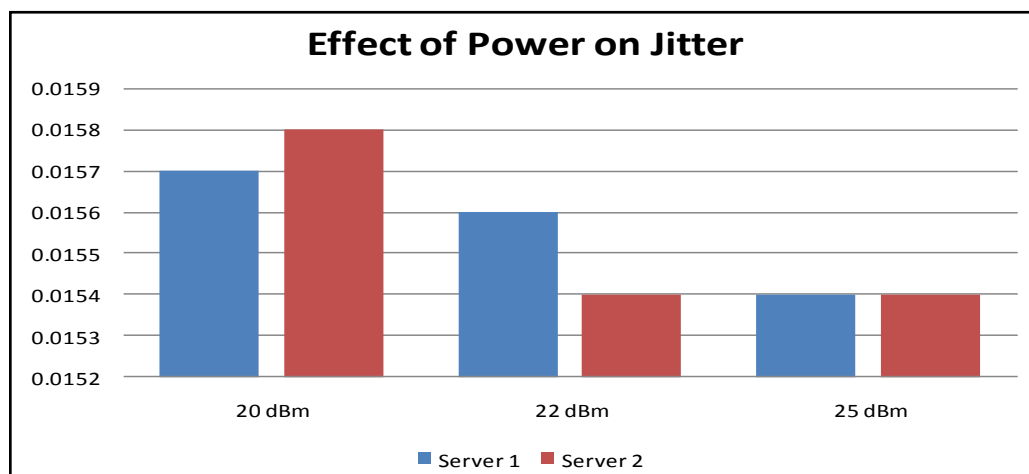


Figure 5.82: Effect of power on Jitter

As jitter increases it means that transmission delay increases. We can see that as power is increased jitter decreases, it means that increase in power level improves performance of network. We get least jitter at 25 dbm, so it is better compared to other power level. So, increase in power level decreases transmission delay.

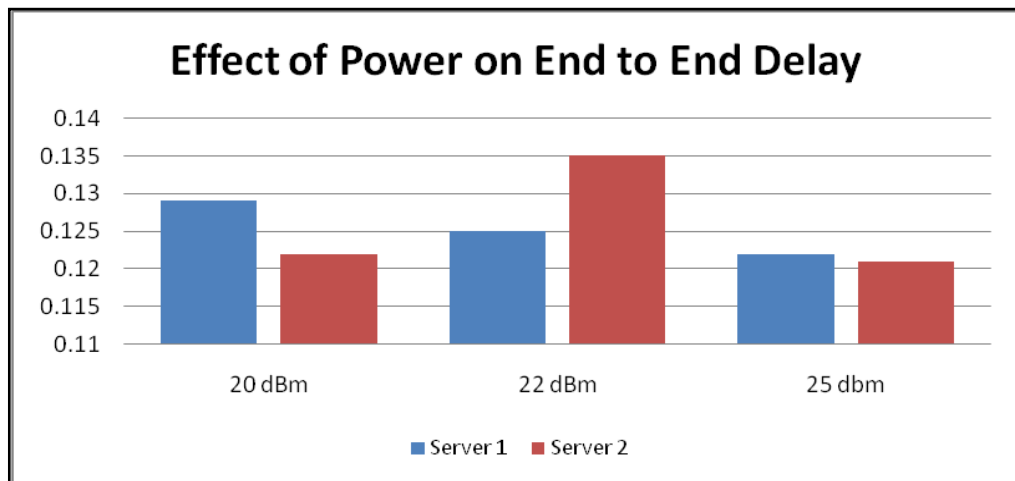


Figure 5.83: Effect of power on End to End delay

Figure 5.83 shows the end to end delay affected by power level; it is clear from above graph that power level increase decreases delay. So we get less delay for 25 dbm. Once again it is proved better.

So from all above three comparisons, we can say that 25 dbm is optimum power level and also we can say that rise in power level increases throughput and decreases jitter and end to end delay both.

Case study2: To study effect of variation of path loss model on WiMAX network

Experimental Setup: As per figure 5.80

Settings: As per section 5.5.3

In previous experiment we derived that optimum power level is 25 dbm, so we keep power level for this experiment 25 dbm.

Two path loss models are considered here. Two-Ray model and Free space model, because okumura hata and others can't work beyond 1.6Ghz frequency. So, we are limited to above two models only. Effect is analyzed on the base of the CBR throughput, jitter and end to end delay.

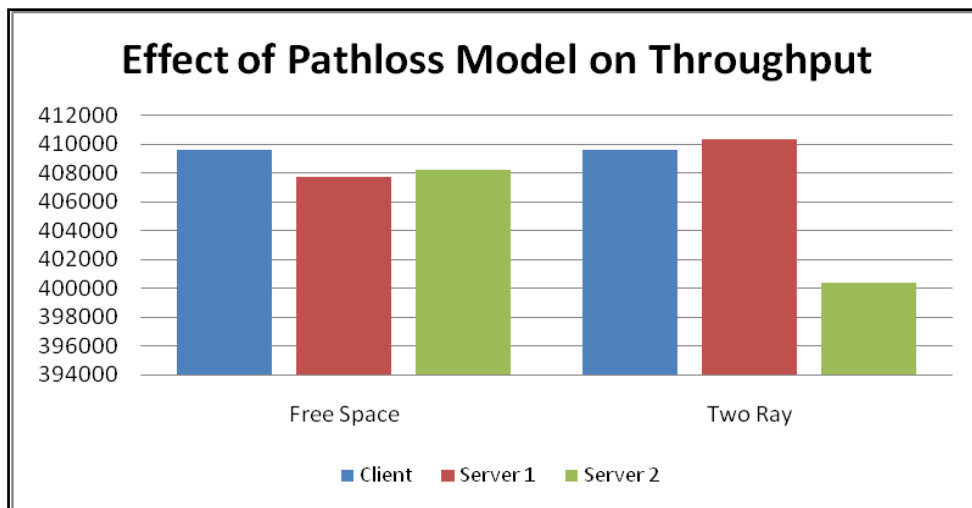


Figure 5.84: Effect of Pathloss model on throughput

Blue bars in figure 5.84 shows; client throughput which is fixed 419600 bits/sec, corresponding to this client throughput effect is analyzed for path loss model variation. Here we can see that server 1 which is having fixed

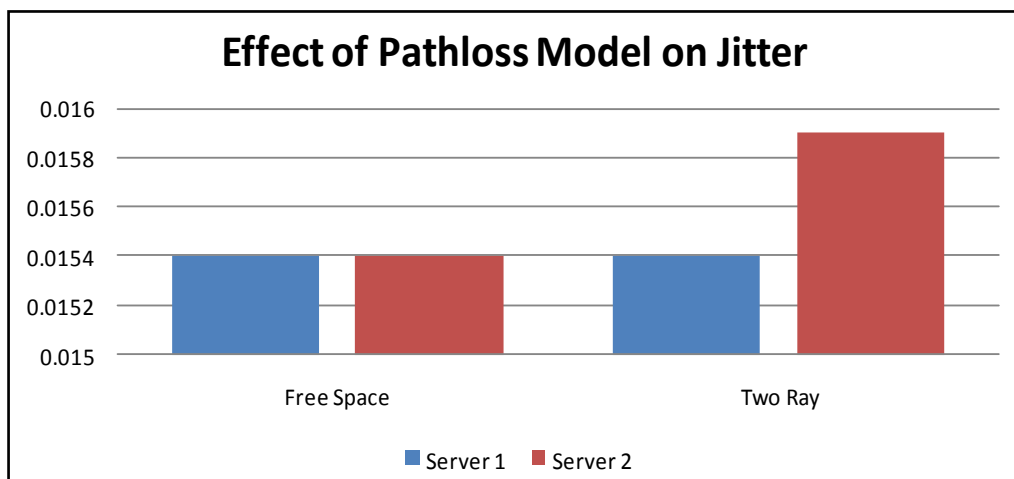


Figure 5.85: Effect of Pathloss model on Jitter

WiMAX application gives almost same throughput in both models, but mobile WiMAX server 2 is vastly affected in throughput. So, it is proved here that for mobile WiMAX free space model performs better than two ray model. As clearly shown in above figure 5.85, jitter of fixed WiMAX server 1 remains unchanged even if it is two ray or free space model. So, it means that performance of fixed WiMAX remains same. But jitter of mobile WiMAX is

affected by path loss model variation. Jitter in case of two ray model is more compared to free space, which is not desirable. So, we can see that performance in case of free space model is better compared to two ray model.

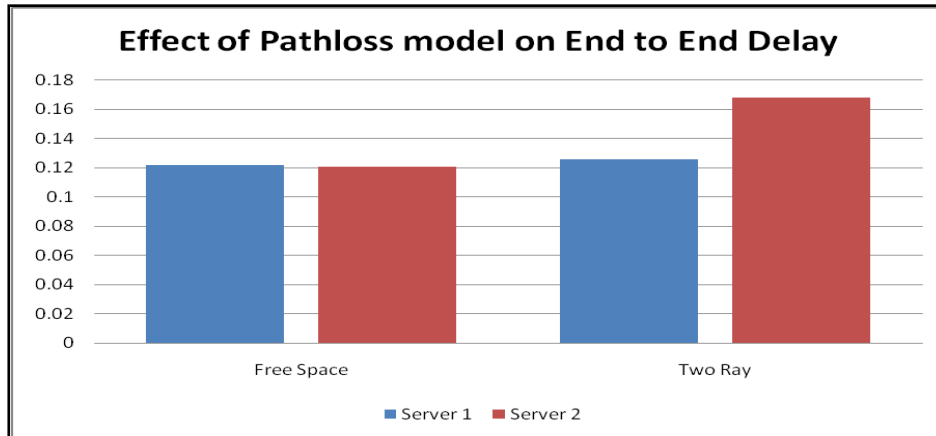


Figure 5.86: Effect of Pathloss model on end to end delay

It is clearly visible from the above figure 5.86 that free space model gives same amount of end to end delay as compared to two ray model. It gives same delay to server 1 and 2 both. Delay of server 1 of two ray model is higher than free space and delay of server 2 is also higher than that of free space model. So, we can say that free space gives less delay compared

Case study3: To study effect of variation of routing model on WiMAX network

Experimental Setup: As per figure 5.80

Settings: As per section 5.5.3

Routing protocol is responsible for discovering the routes and successful delivery of packet from source node to destination node. We have three protocols Bellman ford, AODV and DYMO protocols.

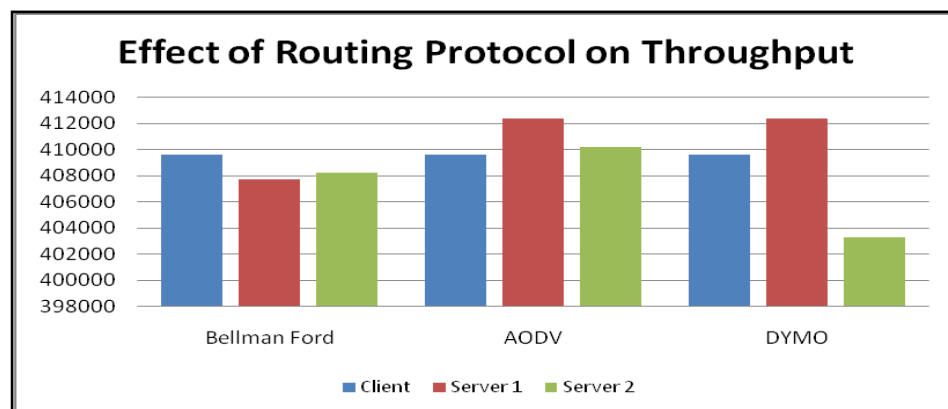


Figure 5.87: Effect of Routing Protocol on throughput

As above figure 5.87 says, throughput achieved is analyzed on base of routing protocols. Bellman ford gives almost same throughput for both servers. But DYMO gives higher throughput for server 1 and very less throughput for server 2, so its performance is affected. AODV gives higher throughput for both server 1 and 2, which higher than bellman and DYMO. So, we can say that AODV gives better throughput than others.

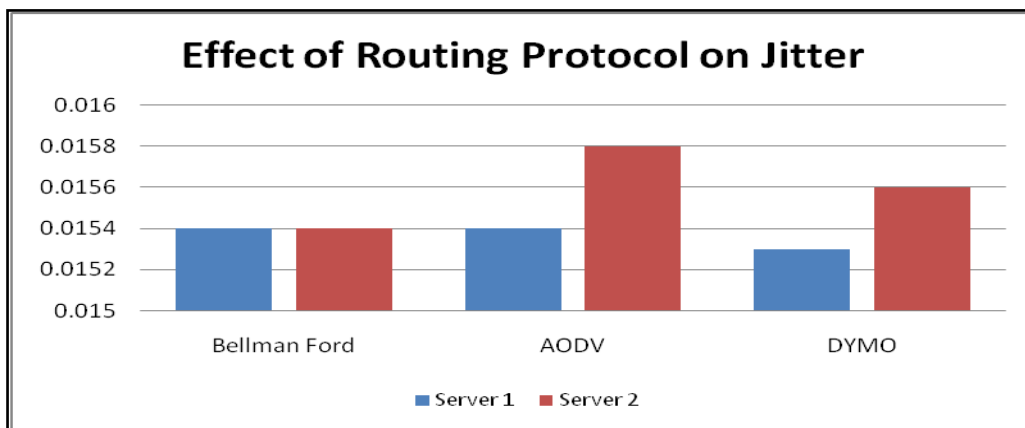


Figure5.88: Effect of routing protocol on jitter

Figure 5.88 shows effect on jitter. It is visualized from figure that bellman ford gives less jitter in both server 1 and 2 i.e., fixed and mobile. While DYMO and AODV gives less jitter for fixed node server1 but it gives higher amount of jitter for mobile node server 2. We can say that Bellman gives less jitter compared to others.

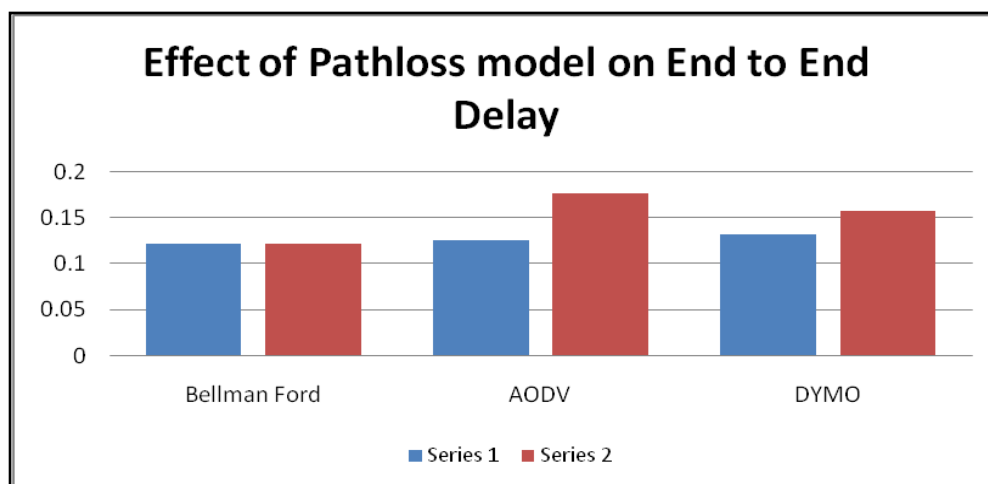


Figure 5.89: Effect of Pathloss model on end to end delay

As per above figure 5.89, bellman ford gives less amount of end to end delay for both server1 and server 2. While AODV and DYMO gives higher delay for

server 2 compared to server 1. It means that bellman ford gives very less end to end delay compared to all other model in both fixed and mobile WiMAX environment. So, bellman ford is better compared to AODV and DYMO in giving less delay.

Case study 4: To study effect of variation of FFT size on WiMAX network

Experimental Setup: As per figure 5.80

Settings: As per section 5.5.3

This parameter specifies the FFT size used in the device. Four FFT sizes are supported here: 2048, 1024, 512, and 128. The FFT size determines the number of available subcarriers and OFDM symbol duration. In general, for a given bandwidth, a larger FFT size results in a greater number of available subcarriers and a longer OFDM symbol duration.

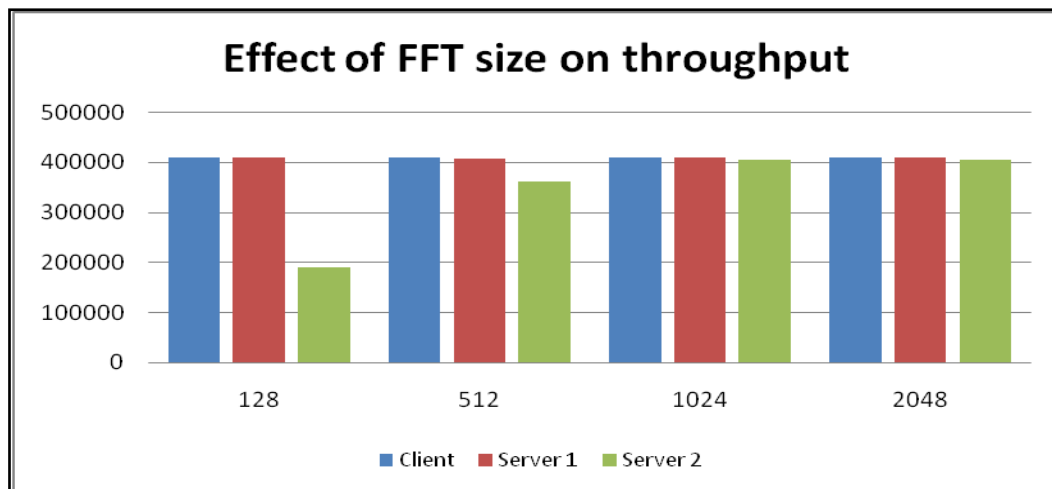


Figure 5.90: Effect of FFT size on throughput

Above figure 5.90 shows the comparison of throughput of various nodes for 128, 512, 1024 and 2048 FFT size. It is clear from above figure that client node throughput remains constant for any FFT size. Throughput of server 1 – fixed WiMAX remains also almost same, less affected by the FFT size. But throughput of mobile WiMAX node increases appreciably by increasing FFT size.

Figure 5.91 shows effect on jitter by increasing the FFT size. In comparison we have two server nodes. One is fixed WiMAX node, whose jitter almost remains same for any value of FFT size. But when we talk about mobile

WiMAX node, its jitter decreases appreciably as we increase FFT size. So, we can say that increasing FFT size decreases jitter of mobile WiMAX.

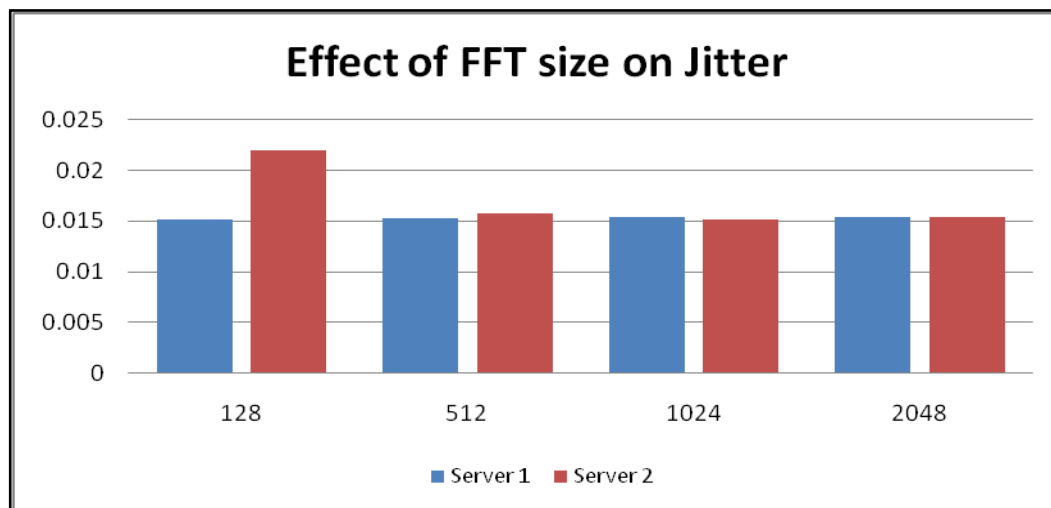


Figure 5.91: Effect of FFT size on Jitter

Effect on End to End delay by change in FFT size is shown in figure 5.91. It is clear from figure 5.92 that end to end delay of fixed WiMAX almost remains same for all size of FFT. But mobile WiMAX decreases very much when FFT size is increased. So, we can say that increasing FFT size, we can decrease end to end delay.

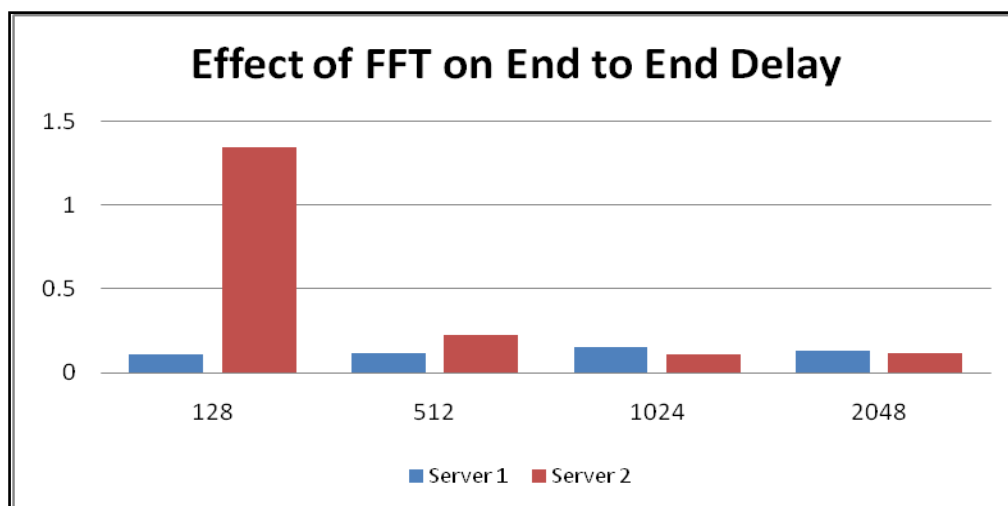


Figure 5.92: Effect of FFT size on end to end delay

Case study 5: To study effect of variation of band width on WiMAX network

Experimental Setup: As per figure 5.80

Settings: As per section 5.5.3

Now we will check effect of variation of bandwidth on throughput, jitter and end to end delay. It is known to us that increase in bandwidth increases ability to include more no of subscribers nodes.

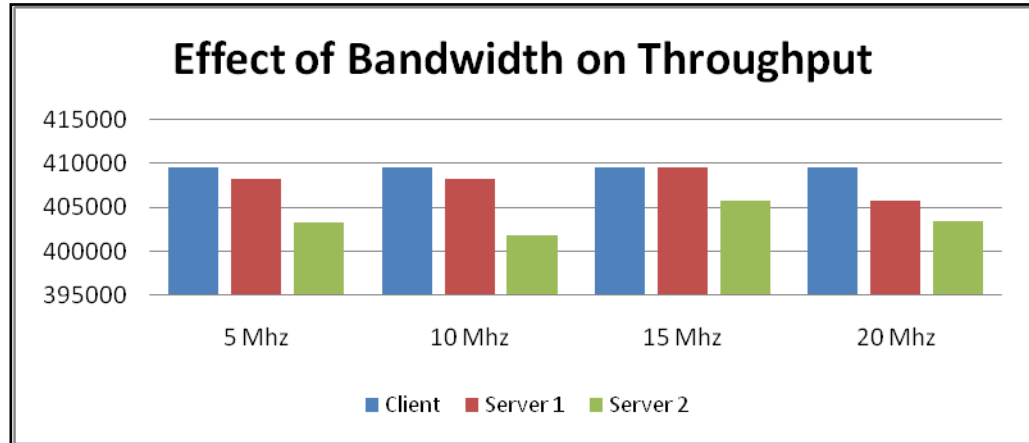


Figure 5.93: Effect of Bandwidth on throughput

From figure 5.93 we can say that we have varied bandwidth to 5, 10, 15 and 20 Mhz. And as we vary client node throughput remains same. So, it is node affected at all. Now when we see server nodes, fixed WiMAX node's throughput increases as we increase bandwidth and achieves max value for 15 Mhz. But it decreases for 20 Mhz. Similar is the case for the mobile WiMAX node that its throughput increases to higher value for 15 MHz and falls for 20 Mhz. It means that for this network, 15 MHz bandwidth is optimum for our network.

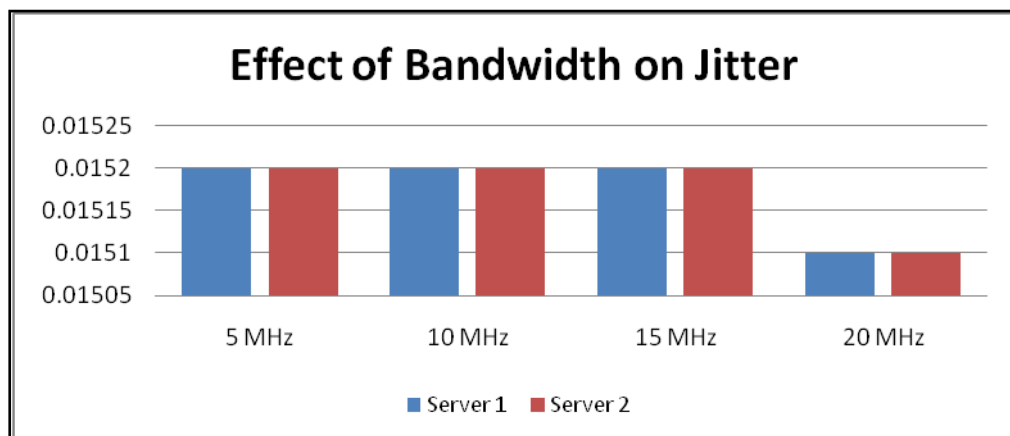


Figure 5.94: Effect of Bandwidth on jitter

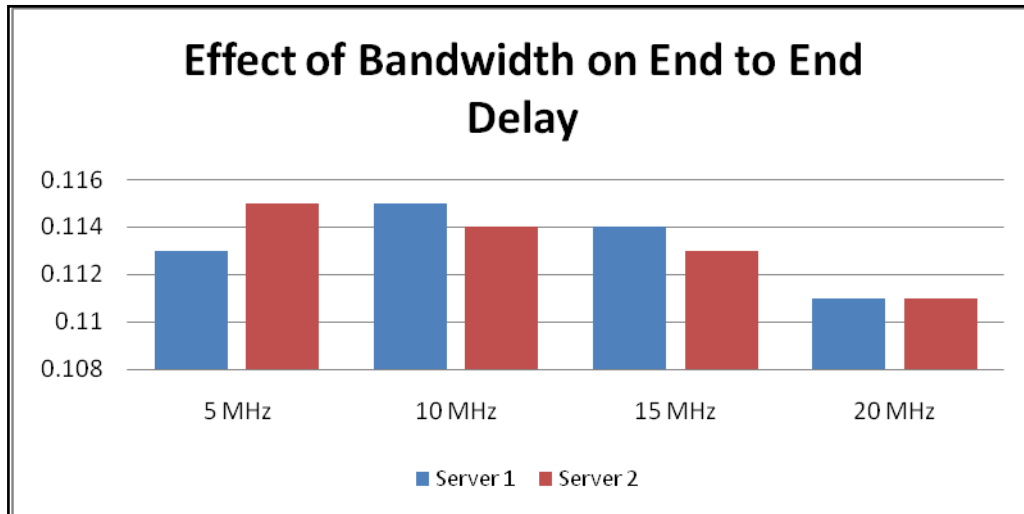


Figure 5.95: Effect of Bandwidth on end to end delay

From above figure 5.94 we can say that jitter is also affected by change in bandwidth. Jitter of server 1 and 2 both remains almost constant for 5 to 15 MHz bandwidth. But it decreases sharply for 20 MHz bandwidth. It means that jitter decreases as we increase bandwidth. So increase in bandwidth improves the jitter, which is desirable.

From figure 5.95 we can see that end to end delay is also affected by change in bandwidth. End to end delay of fixed WiMAX is less value for 5 MHz but it increases for 10 MHz and then it decreases sharply for higher values of bandwidth. It achieves minimum value for 20 MHz bandwidth.

End to end delay of mobile WiMAX nodes decreases as we increase the bandwidth. It has maximum value for 5 MHz bandwidth, and which in turn decreases to minimum value for 20 MHz. So, we can say that increase in bandwidth decreases end to end delay of both mobile and fixed WiMAX nodes.

5.5.5 Analysis of WiMAX

The above WiMAX example has been experimented in various ways by changing various aspects as given below

1. Comparison is based on Number of users accommodated Vs Power

Table 5.12 Different values of Number of users accommodated and Power for WiMAX

Power (dBm)	No. of users accommodated
20	30
25	62
30	88
35	135
40	182
48	252

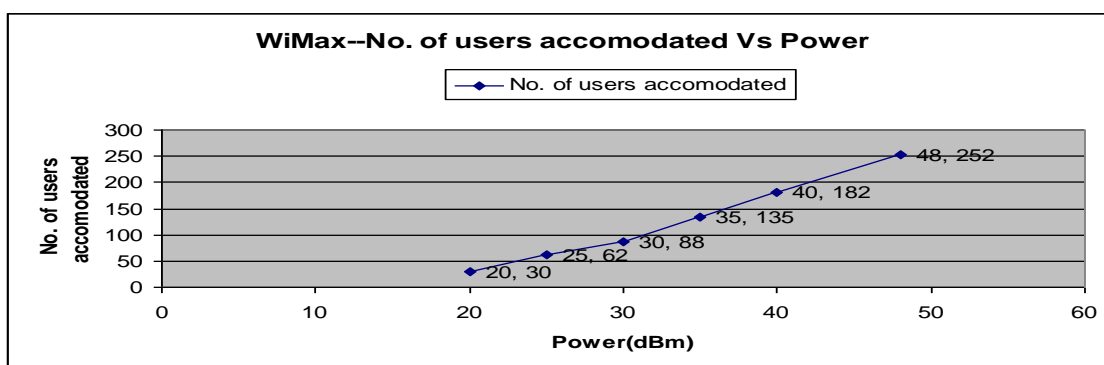


Figure 5.96: Graph shows analysis of no. of users accommodated Vs Power for WiMAX

2. Comparison is based on Range (Coverage area) Vs Power

Table 5.13 Different values of Range and Power for WiMAX

Power (dBm)	Range (Meter)
20	110
25	225
30	350
35	500
40	1000
48	1400

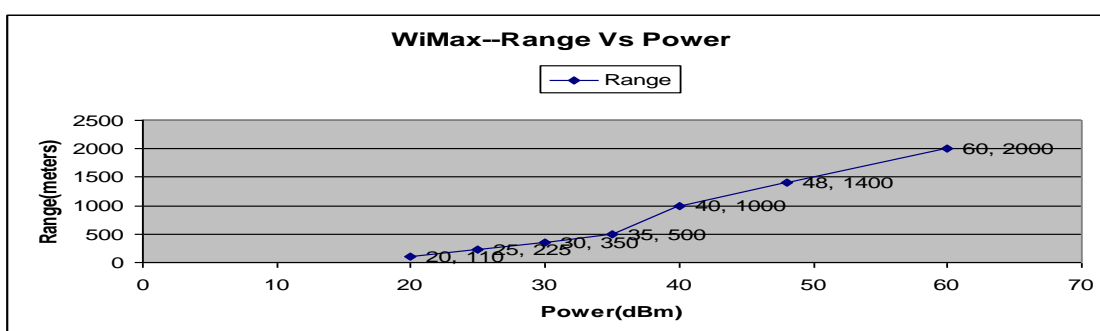


Figure 5.97: Graph shows analysis of Range Vs Power for WiMAX

3. Comparison is based on Data rate Vs Power

Table 5.14 Different values of Data rate and Power for WiMAX

Power(dBm)	Data rate (Kbps)
20	38
25	45
30	52
35	58
40	62
48	65
60	70

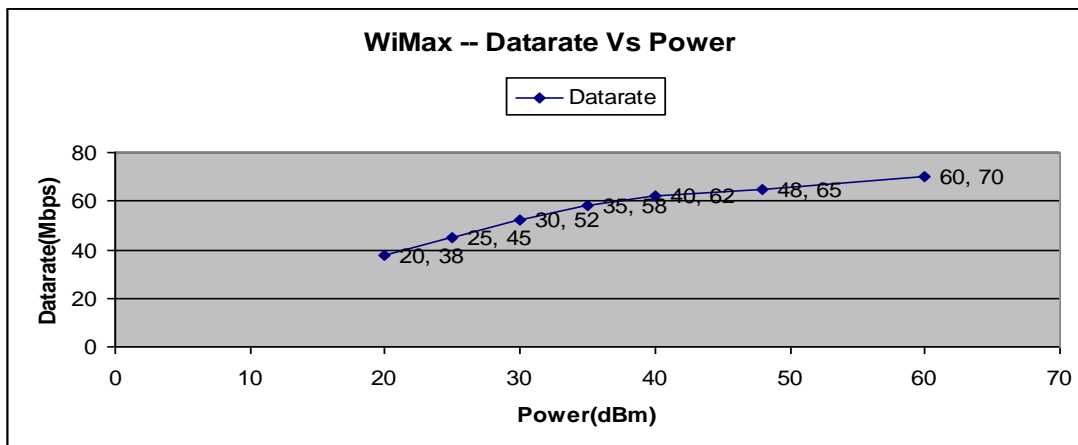


Figure 5.98: Graph shows analysis of Data rate Vs Power for WiMAX

5.6 WiBro (Wireless Broadband)

WiBro follows the IEEE 802.16e standard. The various features of WiBro can be implemented using QualNet-5.0 mentioned as below.

5.6.1 Implemented Features

The PHY802.16 and MAC802.16 models of QualNet-5.0 have implemented features defined in IEEE 802.16e. The detailed list of implemented features is:

- OFDMA physical model.
- Variety channel bandwidth support.
- Multiple FFT size support.
- Multiple cyclic prefix time support.
- Multiple data rates support.
- BER-based reception quality estimation.
- Sub-channel SINR representation.
- Data rate and transmission range estimation.

- Point to Multi-Point (PMP) mode.
- Time Division Duplex (TDD) mode:
 - MAC frame is divided into downlink sub frame and uplink sub frame.
 - DL-MAP and UL-MAP supporting sub channels of OFDMA PHY.
- Network entry and initialization:
 - Channel scan and synchronization with DL channel. Channel lost detection and network re-entry.
 - DCD and UCD messages for obtaining and maintaining DL/UL parameters.
 - Initial (contention) ranging and periodical ranging.
 - Negotiation of basic capability and registration.
 - CDMA-based ranging.
- Dynamic flow management including service flow addition, deletion and change.
- Bandwidth management:
 - Polling-based bandwidth requests.
 - Contention-based bandwidth requests.
 - CDMA-based bandwidth requests.
- Scheduling service at the base station:
- MAC frame construction:
 - Downlink (DL) subframe construction.
 - Uplink (UL) burst construction.
 - PDU concatenation, fragmentation, packing, and CRC.
- Adaptive Modulation and Coding (AMC):
 - Signal strength monitoring (UL/DL) and reporting (DL).
 - Seven burst profiles for both downlink and uplink transmissions using different coding and modulation combinations.
 - Dynamic switch of burst profiles based on CINR.
 - Support for broadcast and multicast flows.
- Convergence Sub layer (CS):

- Classify flows to different service types based on their priority.
- Support both IPv4 and IPv6.
- IEEE 802.16e Mobility Support:
 - Neighbor information exchange among configured BSs.
 - Neighbor BS scanning at SS.
 - MS initiated and BS initiated hard handoff.
 - Flow disconnection and reconnection.
 - Idle mode and paging.
 - Sleep mode.
- Interface other networks such as ATM, 802.3, 802.11 at network layer.
- Support 802.16 OFDMA PHY.
- Simple admission control.
- ARQ.

5.6.2 Sample Scenario

Sample Scenario Topology

Assume the scenario contains two subnets. Subnet 1 contains node 1 to node 10 and subnet 2 contains node 11 to node 20. Both subnets run 802.16 MAC with node 1 as the BS of subnet 1 and node 15 as the BS of subnet 2. The two base stations, node 1 and node 15, are connected via a wired point-to-point link, as shown in figure 5.99.

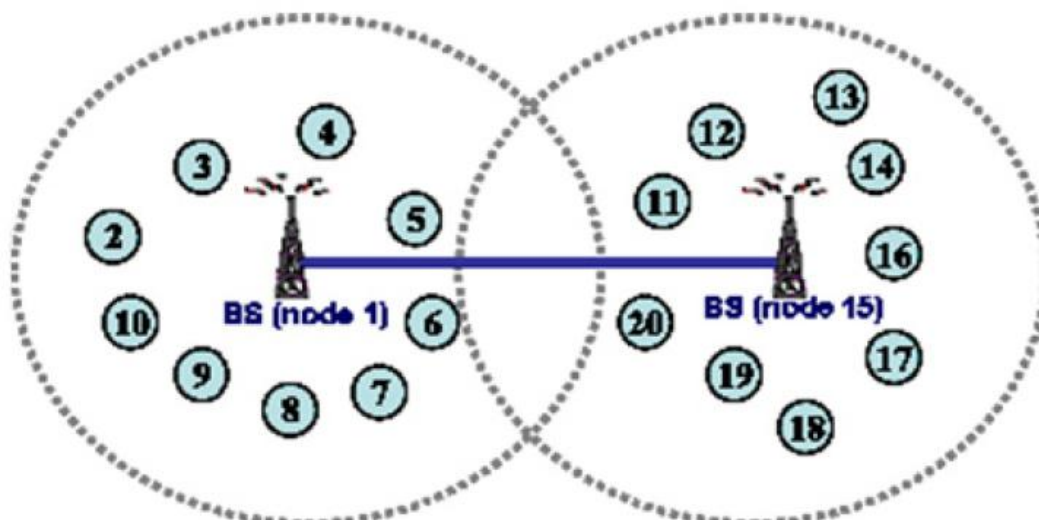


Figure 5.99 Topology of Sample Scenario

GUI Configuration

In this section, we use an example to show how to configure a scenario. I also show how to configure the 802.16 and 802.16e MAC parameters in the Wireless Subnet Properties editor. Parameters can be set in the Interface Properties editor and Default Device Properties editor in a similar way. For *WiBro Enable Mobility Mode (802.16e)* is set to Yes in Wireless Subnet Properties editor then set the dependent parameters.

Figure 5.100 shows WiMAX Scenario developed with coverage area 5000m X 5000m using QualNet-5.0 as per WiBro architecture. Place 110 nodes of default device type and a wireless subnet on the canvas. Nodes 1, 11, 21, 31, 41, 51, 61, 71, 81, 91, 101 are acting as a Base station and other nodes are acting as a Subscriber station. Connect all Base stations to the wireless subnet. Connect other nodes to the default wireless subnet.

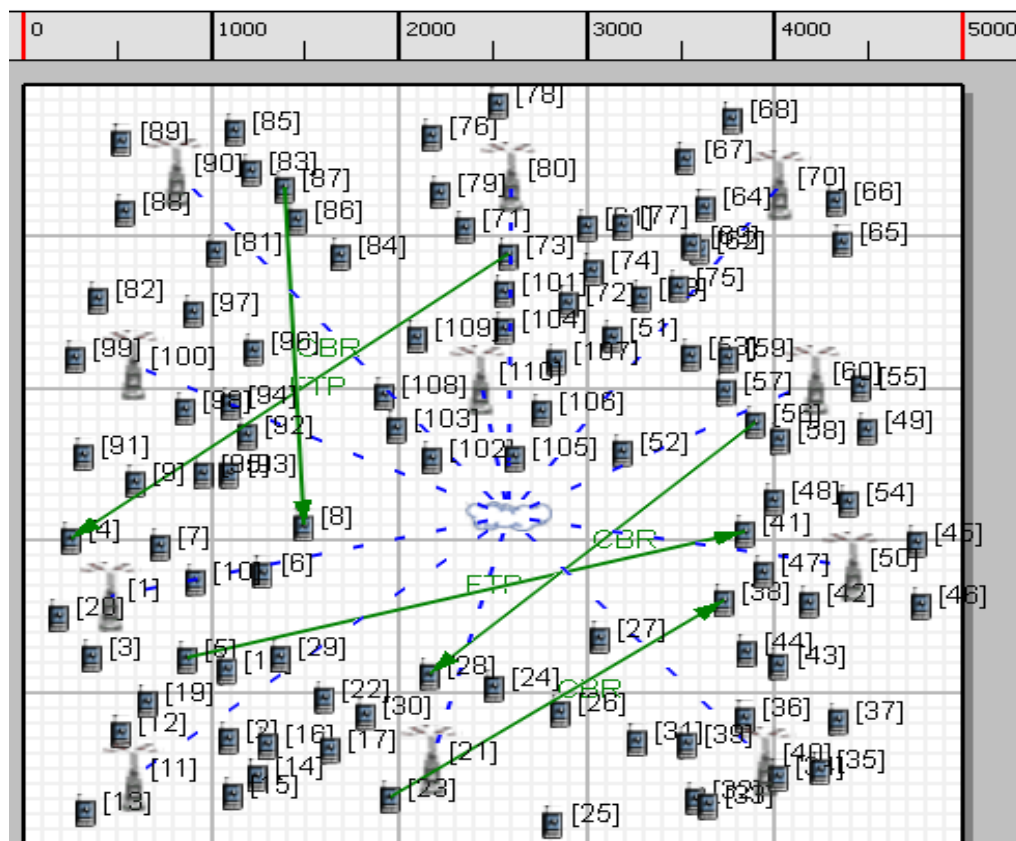
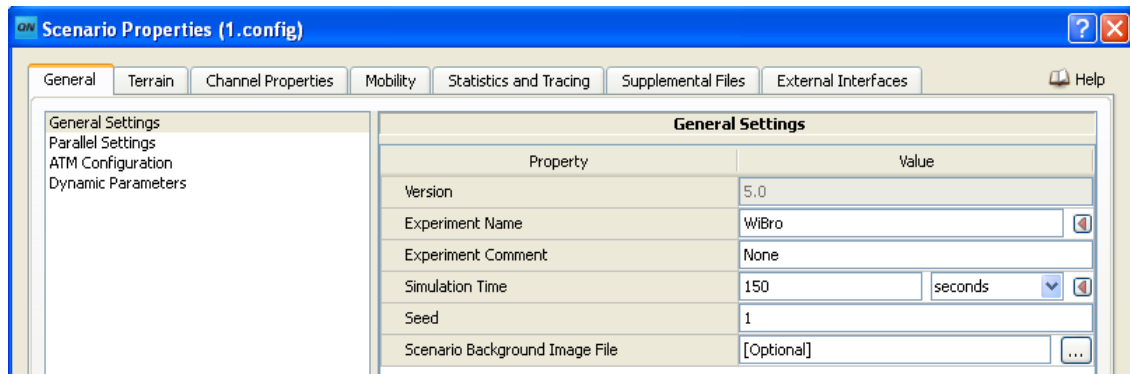


Figure 5.100 WiBro Scenario developed with coverage area 5000m X 5000m

Below figures show how the various GUI parameters have been set for above scenario in figure 5.100.



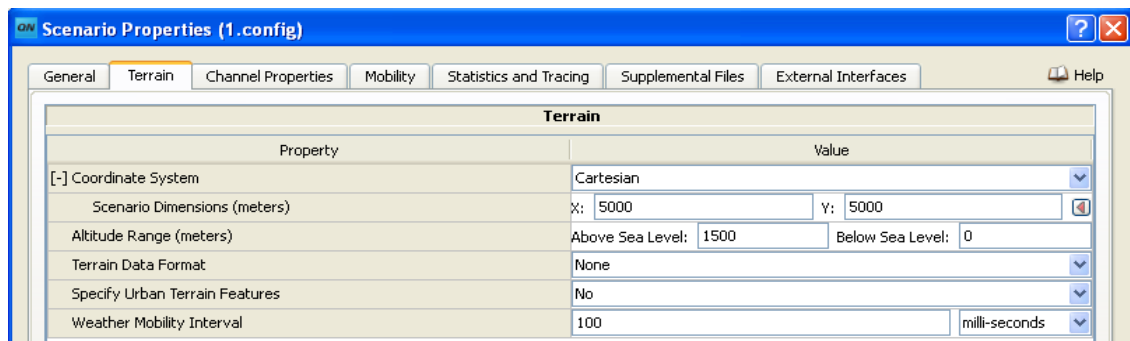
Scenario Properties (1.config)

General | Terrain | Channel Properties | Mobility | Statistics and Tracing | Supplemental Files | External Interfaces | Help

General Settings
Parallel Settings
ATM Configuration
Dynamic Parameters

Property	Value
Version	5.0
Experiment Name	WiBro
Experiment Comment	None
Simulation Time	150 seconds
Seed	1
Scenario Background Image File	[Optional]

Figure 5.101 WiBro Scenario Properties (a) General Properties



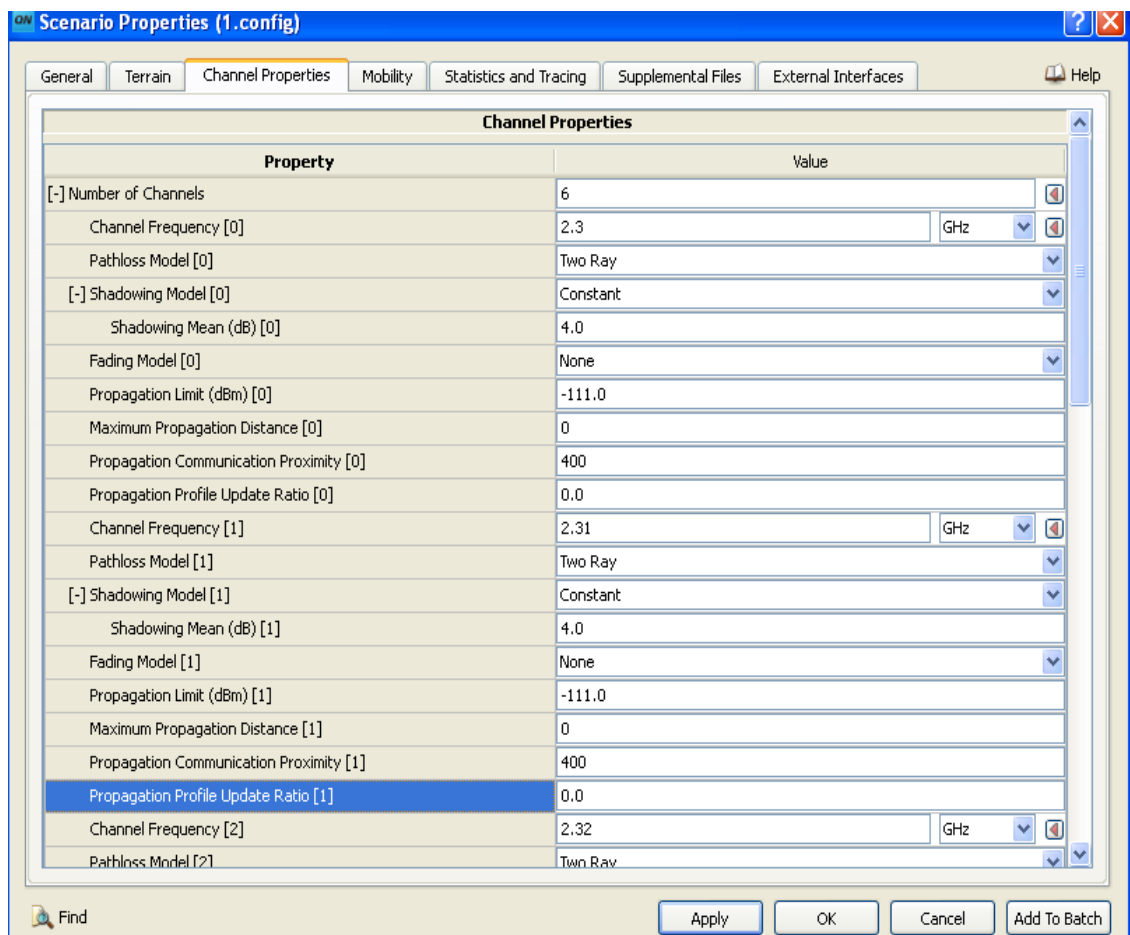
Scenario Properties (1.config)

General | Terrain | Channel Properties | Mobility | Statistics and Tracing | Supplemental Files | External Interfaces | Help

Terrain

Property	Value
[-] Coordinate System	Cartesian
Scenario Dimensions (meters)	X: 5000 Y: 5000
Altitude Range (meters)	Above Sea Level: 1500 Below Sea Level: 0
Terrain Data Format	None
Specify Urban Terrain Features	No
Weather Mobility Interval	100 milli-seconds

(b) Terrain Properties



Scenario Properties (1.config)

General | Terrain | Channel Properties | Mobility | Statistics and Tracing | Supplemental Files | External Interfaces | Help

Channel Properties

Property	Value
[-] Number of Channels	6
Channel Frequency [0]	2.3 GHz
Pathloss Model [0]	Two Ray
[-] Shadowing Model [0]	Constant
Shadowing Mean (dB) [0]	4.0
Fading Model [0]	None
Propagation Limit (dBm) [0]	-111.0
Maximum Propagation Distance [0]	0
Propagation Communication Proximity [0]	400
Propagation Profile Update Ratio [0]	0.0
Channel Frequency [1]	2.31 GHz
Pathloss Model [1]	Two Ray
[-] Shadowing Model [1]	Constant
Shadowing Mean (dB) [1]	4.0
Fading Model [1]	None
Propagation Limit (dBm) [1]	-111.0
Maximum Propagation Distance [1]	0
Propagation Communication Proximity [1]	400
Propagation Profile Update Ratio [1]	0.0
Channel Frequency [2]	2.32 GHz
Pathloss Model [2]	Two Ray

Find Apply OK Cancel Add To Batch

(c) Channel properties

Wireless Subnet Properties (Default Wireless Subnet 169.0.0.0)

General Physical Layer MAC Layer Network Layer Routing Protocol Router Properties Help

Physical Layer

Property	Value
Listenable Channel Mask	111111
Listening Channel Mask	111111
[-] Radio Type	802.16 Radio
Transmission Power (dBm)	8.0
Channel Bandwidth (Hz)	9 MHz
FFT Size	2048
Cyclic Prefix Factor	8.0
Packet Reception Model	PHY802.16 Reception Model
[-] Specify Antenna Model from File	No
Antenna Gain (dB)	0.0
Antenna Height (meters)	1.5
Antenna Efficiency (dB)	0.8
Antenna Mismatch Loss (dB)	0.3
Antenna Cable Loss (dB)	0.0
Antenna Connection Loss (dB)	0.2
Antenna Model	Omnidirectional
Temperature (K)	290.0
Noise Factor (dB)	10.0
Energy Model	None

Find Apply OK Cancel Add To Batch

Figure 5.102: WiBro Scenario – Default Wireless Subnet Properties (a) Physical Layer

Wireless Subnet Properties (Default Wireless Subnet 169.0.0.0)

General Physical Layer MAC Layer Network Layer Routing Protocol Router Properties Help

MAC Layer

Property	Value
[-] MAC Protocol	802.16
[-] Station Type	Subscriber Station
Wait DCD Timeout Interval	25 seconds
Wait UCD Timeout Interval	25 seconds
Service Flow Timeout Interval	15 seconds
Enable Packing	No
Ranging Type	Normal
Contention-based Bandwidth Request Type	Normal
[-] Enable Mobility Mode (802.16e)	Yes
Neighbor BS Scanning RSS Trigger (dBm)	-76.0
Handover RSS Trigger (dBm)	-78.0
Handover RSS Margin (dB)	1.0
Enable Sleep Mode	No
Enable Idle Mode	No
[-] Enable ARQ	Yes
ARQ Window Size	256
ARQ Retry Timeout (frames)	4
ARQ Retry Count	2
ARQ Sync Loss Interval (frames)	32
ARQ Receiving Purge Timeout Interval (frames)	28 seconds
ARO Block Size (bytes)	64

(b) MAC Layer

Wireless Subnet Properties (Default Wireless Subnet 169.0.0.0)

General Physical Layer MAC Layer **Network Layer** Routing Protocol Router Properties Help

General
Schedulers and Queues
QoS Configuration
Network Security
ARP

Property	Value
[-] Network Protocol	IPv4
IPv4 Network Address	169 . 0 . 0 . 0
IPv4 Subnet Mask	255 . 255 . 255 . 0
IP Fragmentation Unit (bytes)	2048
Enable Explicit Congestion Notification	No
Enable Mobile IP	No

(c) Network Layer

Wireless Subnet Properties (Default Wireless Subnet 169.0.0.0)

General Physical Layer MAC Layer Network Layer **Routing Protocol** Router Properties Help

General
BGP Configuration

Property	Value
[-] Routing Protocol IPv4	AODV
Network Diameter (hops)	35
Node Traversal Time	40
Active Route Timeout Interval	3
Maximum RREQ Retries	2
Route Deletion Constant	5
Enable Hello Messages	No
Enable Local Repair	No
Enable Better Route Search	No
Enable Acknowledgement Processing	No
Maximum Number of Buffered Packets	100
Maximum Buffer Size (bytes)	0
Open Bi-directional Connection	No
TTL Start	1
TTL Increment	2
TTL Threshold	7

a packet is received, the lifetime of that route is updated to this value. A default value of 10 seconds is suggested for error detection through MAC layer message (like

(d) Routing protocol

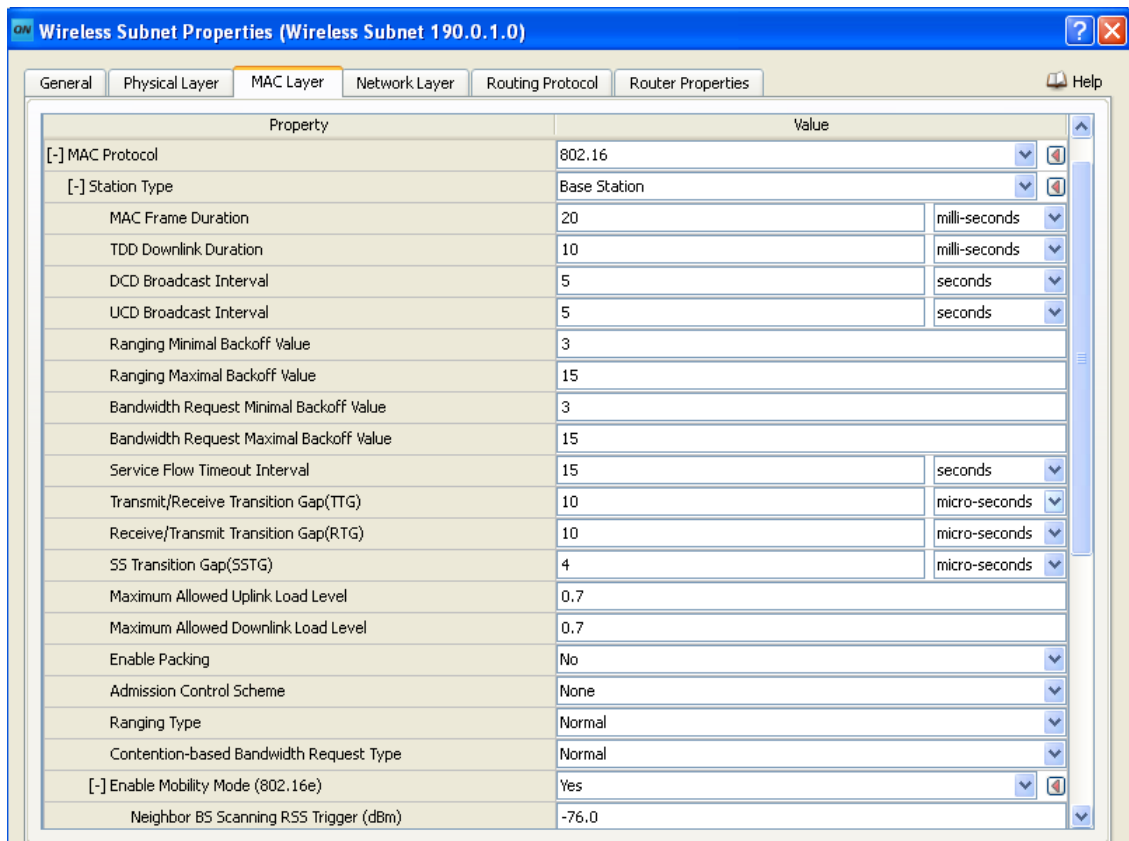
Wireless Subnet Properties (Wireless Subnet 190.0.1.0)

General **Physical Layer** MAC Layer Network Layer Routing Protocol Router Properties Help

Property	Value
Listenable Channel Mask	111111
Listening Channel Mask	111111
[-] Radio Type	802.16 Radio
Transmission Power (dBm)	35
Channel Bandwidth (Hz)	9
FFT Size	2048
Cyclic Prefix Factor	8.0
Packet Reception Model	PHY802.16 Reception Model
[-] Specify Antenna Model from File	No
Antenna Gain (dB)	0.0
Antenna Height (meters)	1.5
Antenna Efficiency (dB)	0.8
Antenna Mismatch Loss (dB)	0.3
Antenna Cable Loss (dB)	0.0
Antenna Connection Loss (dB)	0.2
Antenna Model	Omnidirectional
Temperature (K)	290.0
Noise Factor (dB)	10.0
Energy Model	None

Find Apply OK Cancel Add To Batch

Figure 5.103: WiBro Scenario – Wireless Subnet Properties (a) Physical Layer



(b) MAC Layer

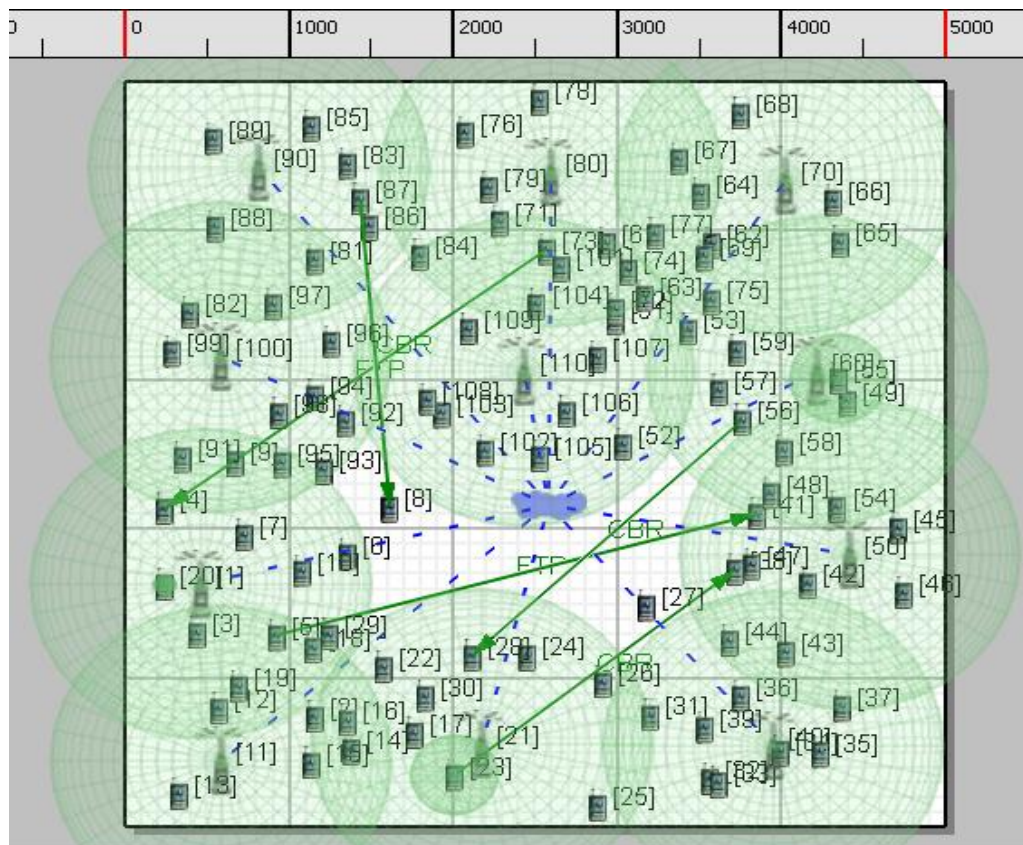
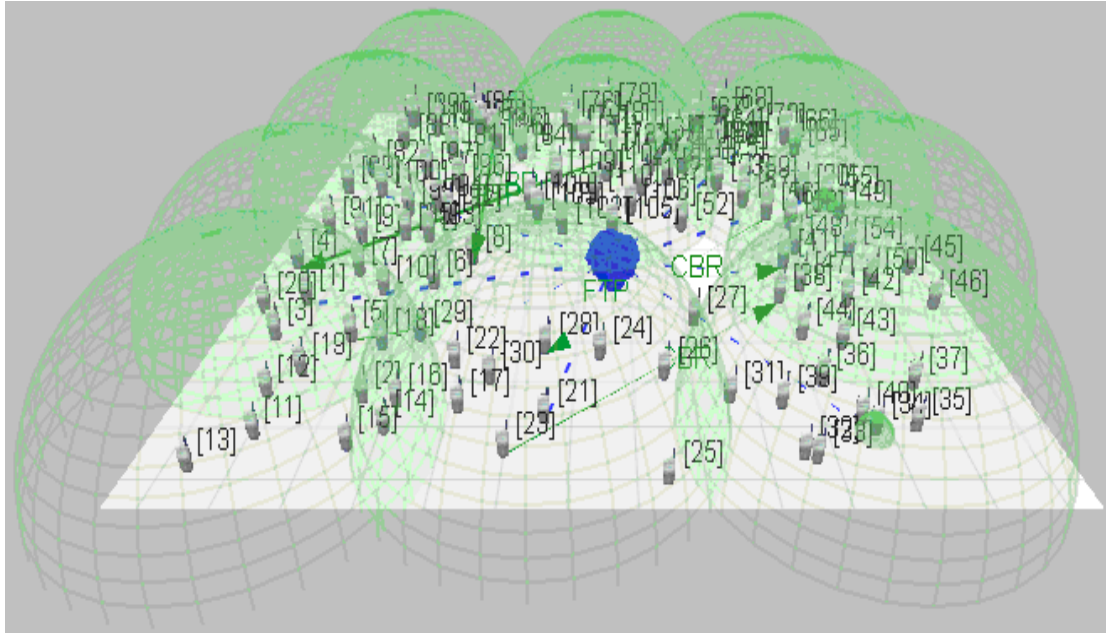


Figure 5.104: WiBro Scenario (a) Live Simulation with X-Y View



(b) Live Simulation with 3D View

5.6.3 Simulation results of WiBro scenario

Below figures show the various results of above scenario after simulation using QualNet Analyzer.

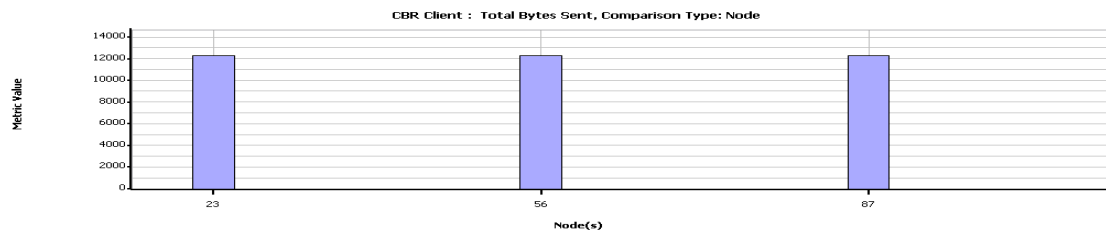
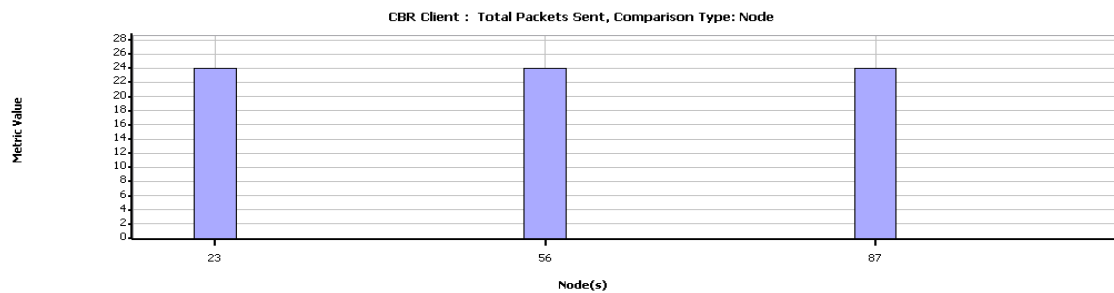
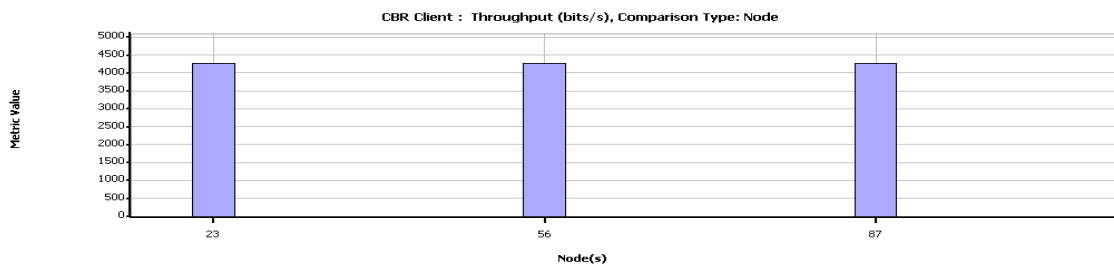


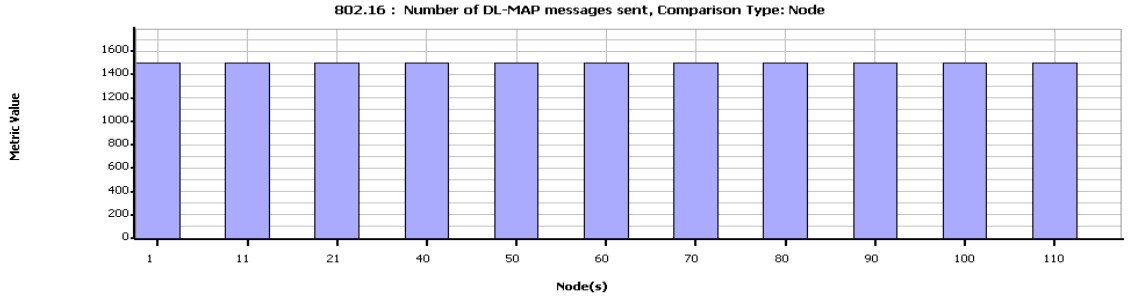
Figure 5.105: WiBro Scenario : Analyzer Results (a) CBR Client: Total Bytes Sent



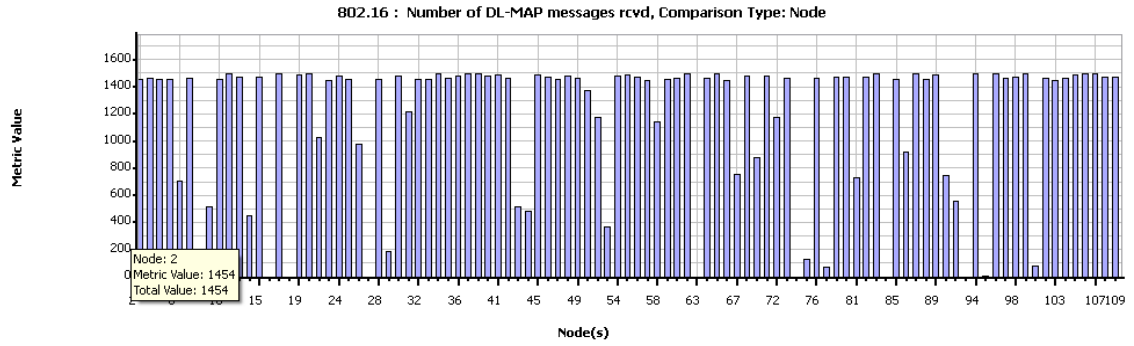
(b) CBR Client: Total Packetss Sent



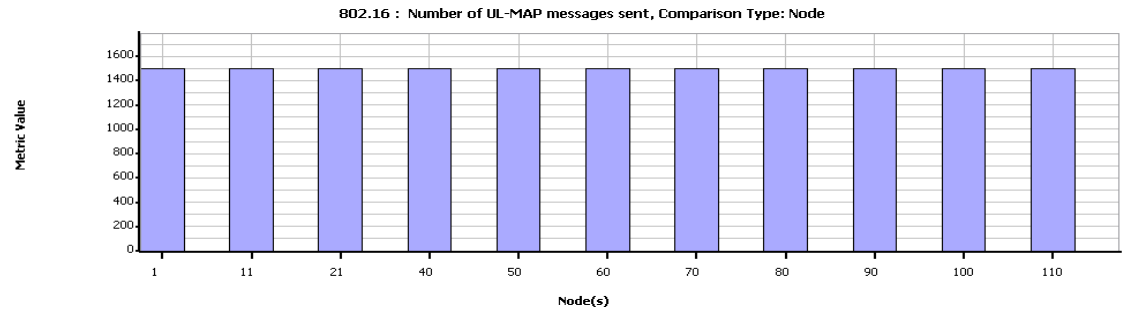
(c) CBR Client: Throughput (bits/s)



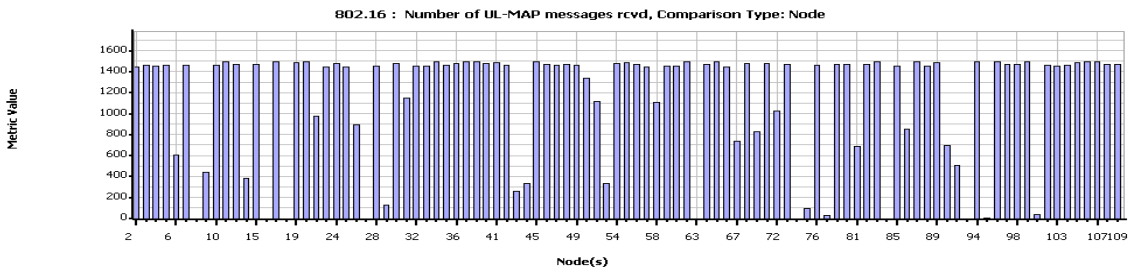
(d) 802.16: Number of DL-MAP messages sent



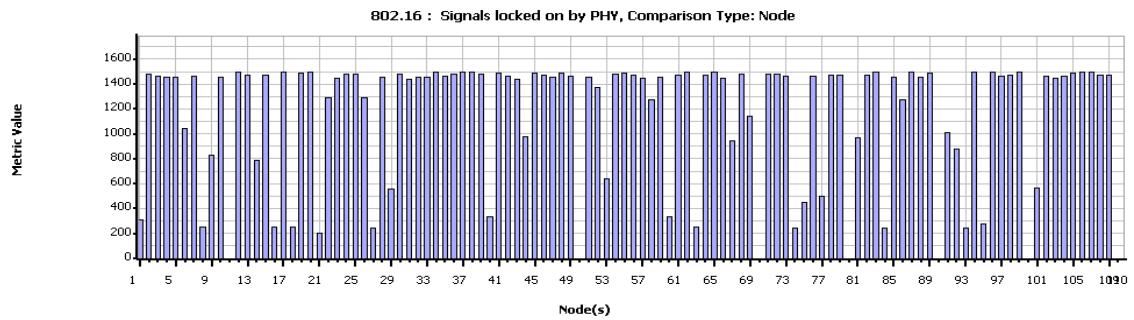
(e) 802.16: Number of DL-MAP messages received



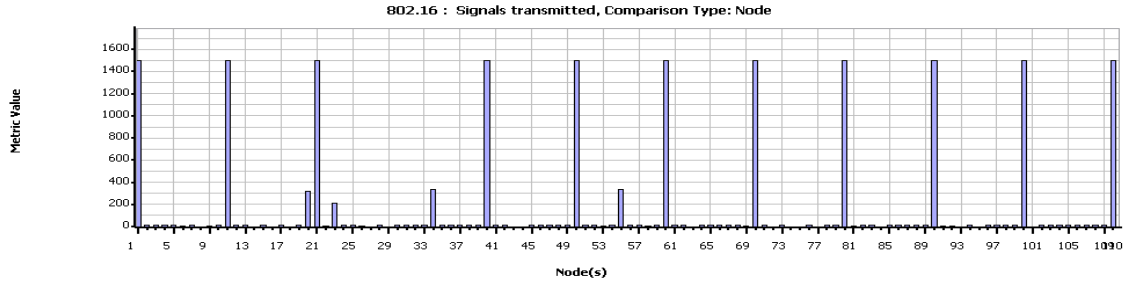
(f) 802.16: Number of UL-MAP messages sent



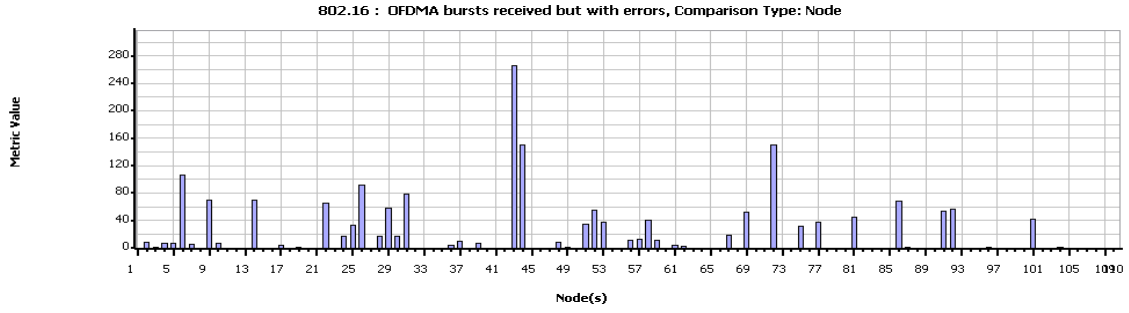
(g) 802.16: Number of UL-MAP messages received



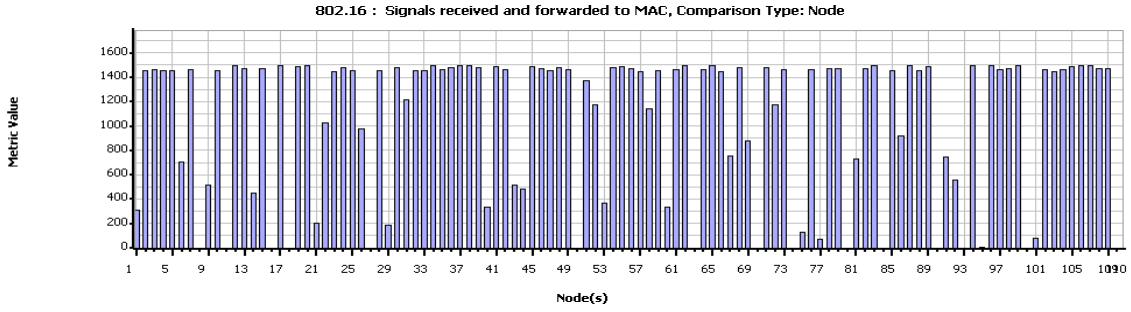
(h) 802.16: Signals locked on by PHY



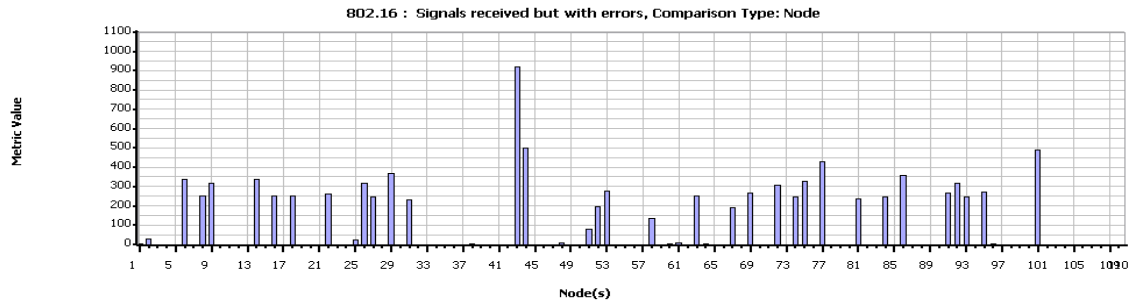
(i) 802.16: Signals transmitted



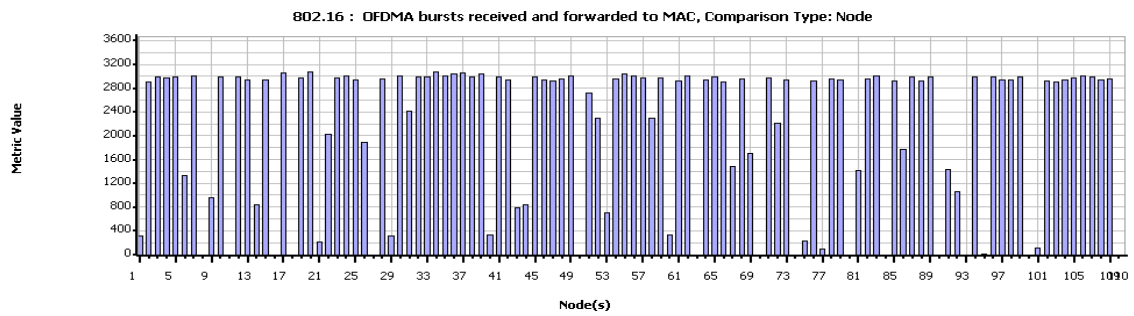
(j) 802.16: OFDMA bursts received but with errors



(k) 802.16: Signals received and forwarded to MAC



(l) 802.11: Signals received but with errors



(m) 802.16: OFDMA burst received and forwarded to MAC

5.6.4 Analysis of WiBro

The above WiBro example has been experimented in various ways by changing various aspects as given below.

1. Comparison is based on Number of users accommodated Vs Power

Table 5.15 Different values of Number of users accommodated and Power for WiBro

Power (dBm)	No. of users accommodated
16	40
25	78
30	150
38	180
48	320
56	480

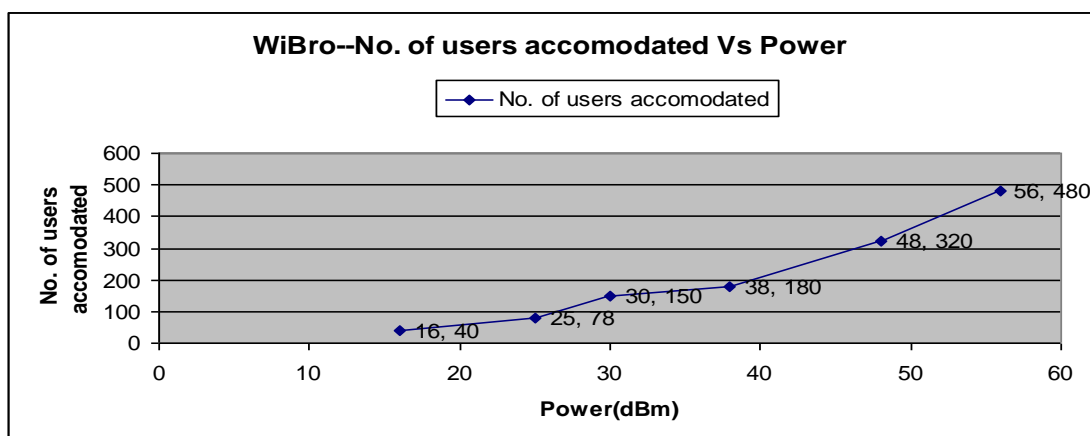


Figure 5.106: Graph shows analysis of no. of users accommodated Vs Power for WiBro

2. Comparison is based on Range (Coverage area) Vs Power

Table 5.16 Different values of Range and Power for WiBro

Power (dBm)	Range (Meter)
16	120
25	230
30	375
38	550
48	1200
56	1800

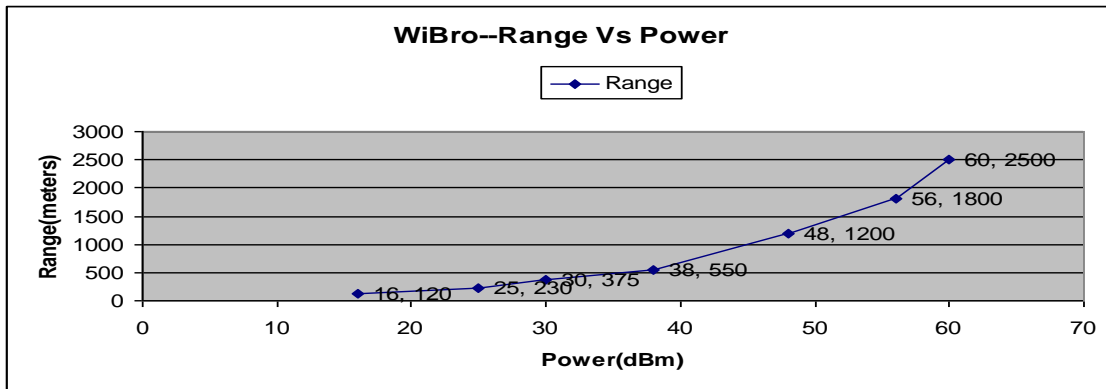


Figure 5.107: Graph shows analysis of Range Vs Power for WiBro

3. Comparison is based on Data rate Vs Power

Table 5.17 Different values of Data rate and Power for WiBro

Power(dBm)	Data rate (Kbps)
16	7.6
25	7.8
30	8
38	8.4
48	8.7
56	8.78

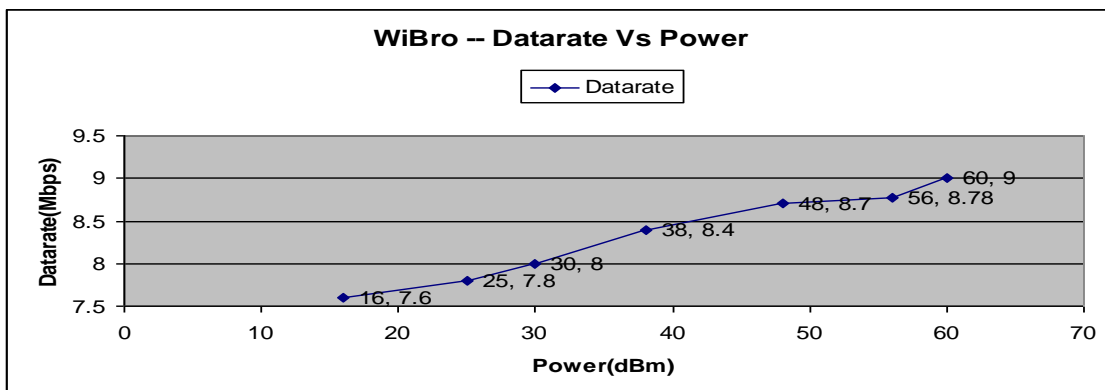


Figure 5.108 Graph shows analysis of Data rate Vs Power for WiBro

Chapter 6: Development and Implementation of Mobile Augmented Reality Systems Application (Live streaming through Mobile)

6.1 Introduction

The recent convergence of the Internet and mobile radio has also accelerated the demand for “Internet in the pocket” on light, low-cost terminals, as well as for wireless technologies like GSM/GPRS, UMTS, Wi-Fi and WiBro that boost data throughput and reduce cost per bit. Mobile networks are now going multimedia, potentially leading to an explosion in throughput from a few bytes for the Short Message Service (SMS) to a few Kbits/s for the Multimedia Messaging Service (MMS), to several 100 Kbits/s for video content.

Video has been an important media for communications and entertainment for many decades. Initially video was captured and transmitted in analog form. The advent of digital integrated circuits and computers led to the digitization of video, and digital video enabled a revolution in the compression and communication of video. Video compression became an important area of research in the late 1980’s and 1990’s and enabled a variety of applications including video storage on DVDs and Video-CDs, video broadcast over digital cable, satellite and terrestrial (over-the-air). Digital television (DTV), and video conferencing and videophone over circuit-switched networks. The growth and popularity of the Internet in the mid-1990’s motivated video communication over best-effort packet networks. Video over best-effort packet networks is complicated by a number of factors including unknown and time-varying bandwidth, delay, and losses, as well as many additional issues such as how to fairly share the network resources amongst many flows and how to efficiently perform one-to-many communication for popular content. The Mobile AR System can be defined as; “A mobile AR system is one in which augmentation of the data occurs through available knowledge of where the user is (the user’s location and therefore the surrounding environment)”, In this chapter, I have described

that how to develop an algorithm based on our designed Layered Architecture for MARS and implementation for MARS Application (Live streaming through Mobile) on mobile platform. Here we capture live stream through mobile ,augment it and uploading to web server and from web server any mobile or computer users can see live video streaming on their devices .To implement MARS Application (Live streaming through Mobile) on mobile platform we have used J2ME library : MIDP, (CLDC), Net Beans 6.0.1 & 6.8 and Mobile SDKs.

6.2 Architecture of MARS

6.2.1 The Layered Approach

The architecture of MARS can be depicted in many ways .There can be no restriction on which of the basic unit lies at which end. But broadly based on the functional requirement that, I propose following MARS can have following layer model modules. Although it is not mandatory that each MARS should have strict distinction among this layers. I propose this approach since distinct layers can be studied and explores independently to enhance the

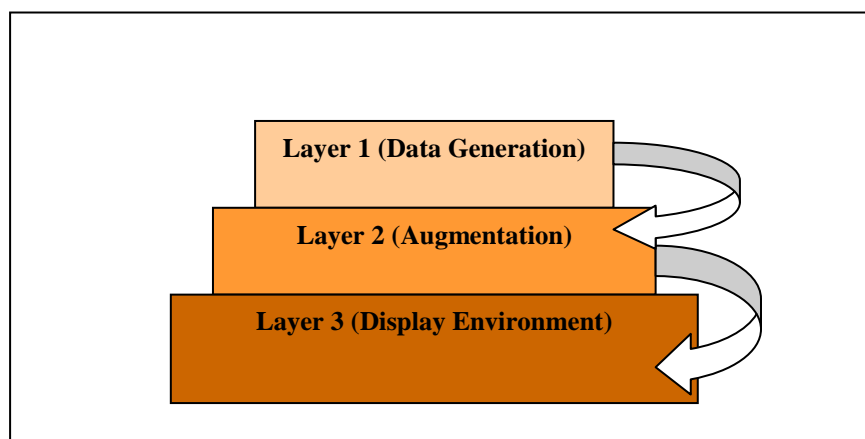


Figure 6.1 MARS Layered Architecture

Capabilities of the MARS. A prominent example that served cause us to study the role of wireless technology issues in MARS is Columbia's "Touring Machine", which is used as a mobile multimedia information system and journalistic tool[61] Features of MARS: A mobile AR system combines the following features: Application and data sharing between a mobile and a stationary user or two mobile users[68] 3D stereographic display of computer

generated images. This enhances the sensation of seeing virtual objects. Direct manipulation and interaction with the virtual objects. Instant collaboration with another user wearing another mobile kit.

6.2.2 Universal Network Architecture for MARS Application

Mobile Augmented Reality Systems Application (Live streaming through Mobile)[69][70] means that any mobile user with this application can capture live data (Image /Audio/Video) through mobile with available Wireless Technology like GSM/GPRS ,UMTS ,Wi-Fi ,WiMAX or WiBro and live data is converted in to byte stream which is stored in to web server. Now on other mobile users or on Computer systems can watch live uploaded data stream with this application.

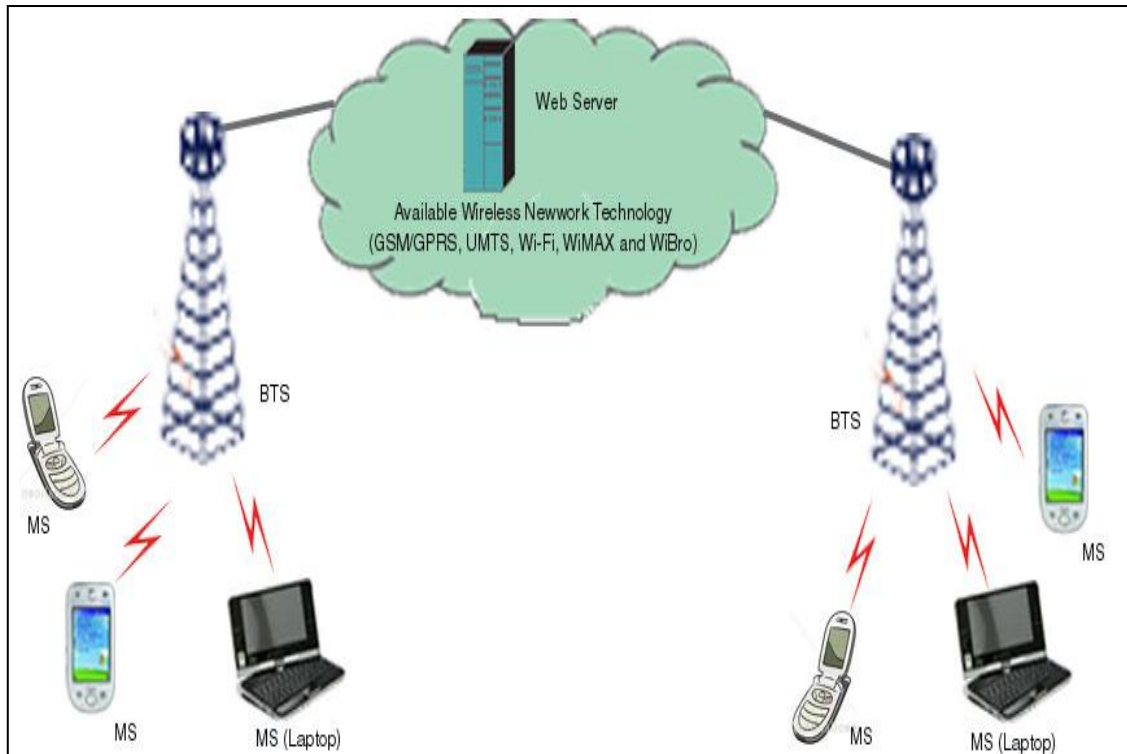
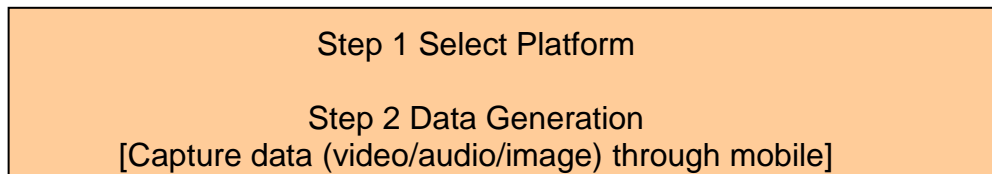


Figure 6.2: General Network Architecture for MARS (Live Streaming through Mobile)

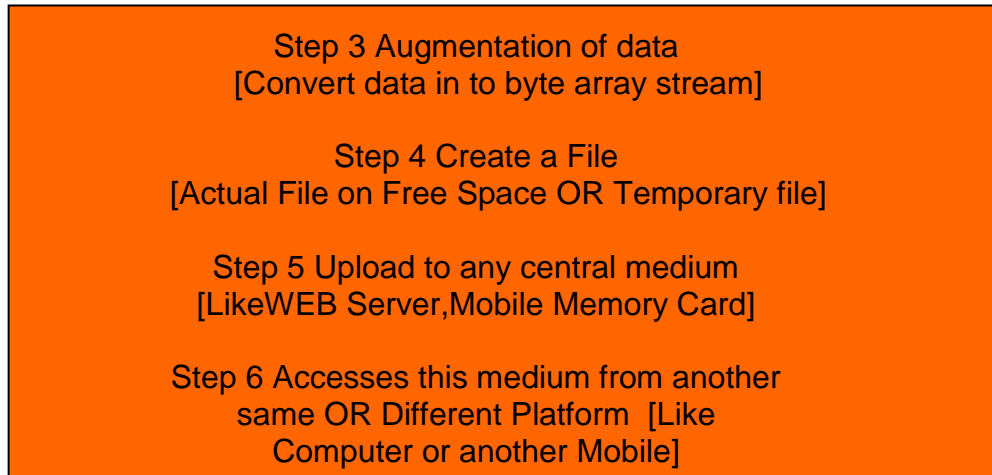
Figure 6.2 shows Universal Network Architecture for MARS Application. In chapter 2, I have explained about different Wireless Technologies Networks and in chapter 5, I have done simulation of different wireless technologies with the help of QualINET 5.0 and examine that how it gives better performance for this application

6.3 Developed an Algorithm for implementing Mobile Augmented Reality Systems Application (Live streaming through Mobile)

Layer 1 Approach



Layer 2 Approach



Layer 3 Approach

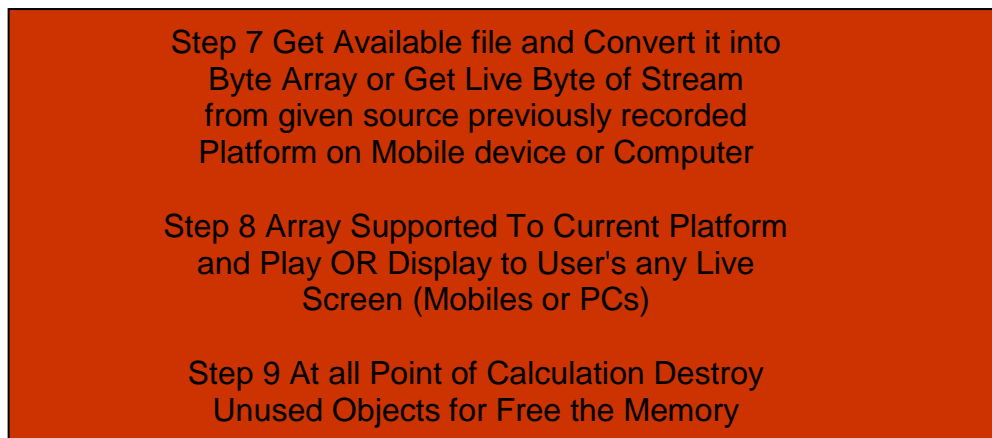


Figure 6.3 Algorithm for MARS Application (Live streaming through Mobile)

6.3.1 Layer 1 Approach

Step 1 Select Platform:

Here we select J2ME platform to develop application. Java Platform, Micro Edition (Java ME)[71] provides a robust, flexible environment for applications running on mobile and other embedded devices—mobile phones, personal digital assistants (PDAs), TV set-top boxes, and printers. Java ME includes flexible user interfaces, robust security, built-in network protocols, and support

for networked and offline applications that can be downloaded dynamically. Applications based on Java ME are portable across many devices, yet leverage each device's native capabilities.

At the heart of Java 2 Micro Edition (J2ME) are three core concepts: configurations, profiles, and optional packages. We can't write a J2ME application without understanding these concepts, because they determine the features of Java that we can use, which application programming interfaces (APIs) are available, and how our applications are packaged.

Configurations

A *configuration* is a complete Java runtime environment, consisting of three things:

A Java virtual machine (VM) to execute Java bytecode.

Native code to interface to the underlying system.

A set of core Java runtime classes.

To use a configuration, a device must meet certain minimum requirements as defined in the configuration's formal specification. Although a configuration does provide a complete Java environment, the set of core classes is normally quite small and must be enhanced with additional classes supplied by J2ME profiles or by configuration implementor. In particular, configurations do not define any user interface classes.

J2ME defines two configurations, the *Connected Limited Device Configuration* (CLDC)[72] and the *Connected Device Configuration* (CDC). The CLDC is for very constrained (limited) devices -- devices with small amounts of memory and/or slow processors. The VM used by the CLDC omits important features like finalization, while the set of core runtime classes is a tiny fraction of the J2SE core classes, just the basics from the `java.lang`, `java.io` and `java.util` packages, with a few additional classes from the new `javax.microedition.io` package. The CDC, on the other hand, includes a full Java VM and a much larger set of core classes, so it requires more memory than the CLDC and a faster processor. The CDC is in fact a superset of the CLDC.

Profiles

A *profile* adds domain-specific classes to a configuration to fill in missing functionality and to support specific uses of a device. For example, most profiles define user interface classes for building interactive applications. To use a profile, the device must meet all the minimum requirements of the underlying configuration as well as any additional requirements mandated by the profile's formal specification.

There are several profiles in various stages of development. The first profile to be released was the *Mobile Information Device Profile* (MIDP)[73][74], a CLDC-based profile for running applications on cellphones and interactive pagers with small screens, wireless HTTP connectivity, and limited memory. Another CLDC-based profile under development is the *Personal Digital Assistant Profile* (PDAP), which extends MIDP with additional classes and features for more powerful handheld devices. In terms of CDC-based profiles, the *Foundation Profile* (FP) extends the CDC with additional J2SE classes, the *Personal Basis Profile* (PBP) extends the FP with lightweight (AWT-derived) user interface classes and a new application model, and the *Personal Profile* extends the PBP with applet support and heavyweight UI classes. We'll also be discussing these profiles later on in this series.

Optional Packages

An *optional package* is a set of APIs in support of additional, common behaviors that don't really belong in one specific configuration or profile. Bluetooth support, for example, is defined as an optional package. Making it part of a profile wouldn't work, because none of the behaviors of a profile can be optional -- if a device supports a profile, it must support the entire profile -- and that would limit the profile to Bluetooth-enabled devices.

Optional packages have their own minimum requirements, of course, just like configurations and profiles. Optional packages also have specific dependencies on a particular configuration and/or one or more profiles -- they do not define a complete runtime environment, just sets of related APIs.

There are many optional packages in development, including the *RMI Optional Package*, which adds RMI support to CDC/FP-based profiles, the *Java APIs for Bluetooth*, which adds Bluetooth support to CLDC-based profiles, and the *JDBC Optional Package for CDC/Foundation Profile*, which defines a subset of JDBC (database access APIs) for use with CDC/FP-based profiles. Again, we'll be covering these later on in the series as the need arises.

The KVM and CVM

Two other terms you'll see mentioned in J2ME literature are *KVM* and *CVM*. These are the names of Java virtual machines for the CLDC (KVM) and the CDC (CVM), written specifically to work in the constrained environment of a handheld or embedded device and to be easily ported to different platforms. It should be noted, however, that the CLDC and CDC specifications do not require the use of the KVM or the CVM, only the use of a VM that adheres to the requirements of the specification in question. While many device manufacturers license the KVM or CVM from Sun Microsystems to serve as the core of their J2ME implementation, they are not required for J2ME compliance. It is a mistake, therefore, to consider the CLDC and KVM as synonymous, and similarly for the CDC and the CVM.

Step 2 Data Generation (Capture data (video/audio/image) through mobile) :

With some MIDP-enabled mobile phones implement the Mobile Media API [MMAPI], which allows MIDlets to have more powerful use of media types[75][76]. In particular, image capture via the device's camera may be supported.

Capture Using the Mobile Media API:

The Mobile Media API specification includes a code fragment that describes how to capture an image using the device's camera. The Camera MIDlet uses the same technique.

- 1) First, a Player must be created, which takes its input from the camera:
- 2) The player must be initialized
- 3) We must then get the visible"video control," which will show the live

viewfinder Image: The video control has two display modes: It can draw itself in a MIDP low-level UI Canvas object, or it can be added to a MIDP high-level UI Form as an Item. In this MIDlet, we will use the Canvas approach, but an alternative implementation using a Form also available.

- 4) Start the player, so that the user can see what the camera is pointing at:
- 5) Once the video control is active, we can take a snapshot Camera MIDlet Design.

User Interface Design:

The Camera MIDlet has two screens between which it alternates:



Figure 6.4: Capture data

The first screen shows a running video "viewfinder" image of the scene in front of the camera. When the user decides that the image is properly framed (and the subject is smiling nicely), he or she selects the option "Capture" or simply clicks the button mapped to "game action" FIRE.



Figure 6.5: Displaying the photo taken

The second screen then shows the photo that was taken. To keep this example MIDlet simple, nothing else can be done with the photo (it can't be saved or sent anywhere).

Software Design :

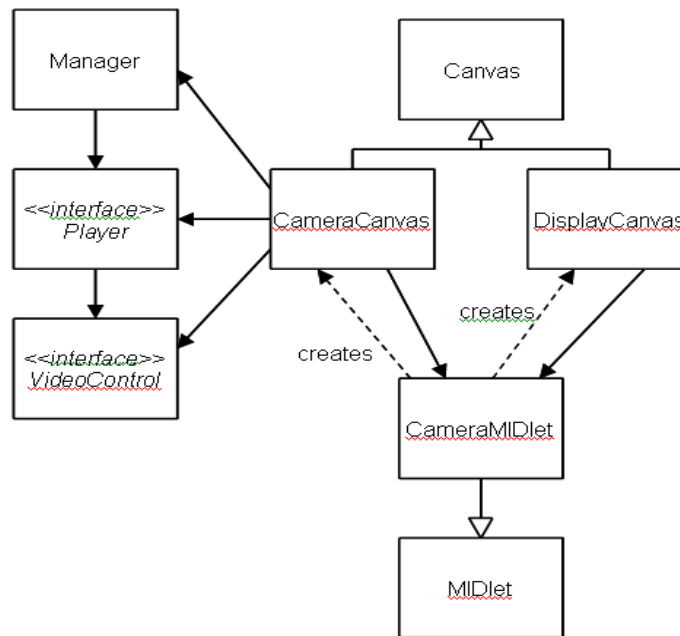


Figure 6.6 : Camera MIDlet class diagram

The CameraMIDlet creates both the CameraCanvas and the DisplayCanvas. The CameraCanvas requests a video capture player from the MMAPI Manager class, and receives an object implementing the Player interface. From this object it requests a video control, and receives an object implementing the VideoControl interface. We won't know (or need to know) the actual class of either of these objects, as we will interact with them only through those interfaces.

6.3.2 Layer 2 Approach

Step 3 Augmentation of data (Convert data in to byte array stream)

The Java library designers attacked this problem by creating lots of classes. In fact, there are so many classes for Java's I/O system that it can be intimidating at first. The list of classes which were used on this page you can find below:

```
java.io.InputStream
java.io.File
java.io.IOException
```

Step 4 Create a File (Actual File on Free Space OR Temporary file)

Although most of the classes are defined by java.io operate on streams, the File class does not. It deals directly with files and the file system. That is, the File class does not specify how information is retrieved from or stored in files; it describes the properties of a file itself. A File object is used to obtain or manipulate the information associated with a disk file, such as the permissions, time, date, and directory path, and to navigate subdirectory hierarchies. Files are primary source and destination for data within many programs. Although there are severe restrictions on their use within applets for security reasons, files are still a central resource for storing persistent and shared information.

Step 5 Upload to any central medium (Like WEB Server, Mobile Memory Card)

First get our data as a byte Array, then use Connection it may be http connection, https connection, or socket connection. Send this byte array to server using connection. At server side get this byte array then save it as you want means as a file or in database.

6.3.3 Layer 3 Approach

Step 6 Get Available file and Convert it into Byte Array or Get Live Byte of Stream from given source previously recorded Platform on Mobile device OR Computer and play

MIDP 2.0 offers a range of multimedia capabilities for mobile devices, including playback and recording of audio and video data from a variety of sources. Of course, not all mobile devices support all the options and MMAPI is designed in such a way that it takes full advantage of the capabilities that are available, while ignoring those that it cannot support. MIDP 2.0 comes with a subset of the MMAPI which ensures that if a device does not support MMAPI, you can still use a scaled down version. This scaled down version only supports audio (including tones) and excludes anything to do with video or images.

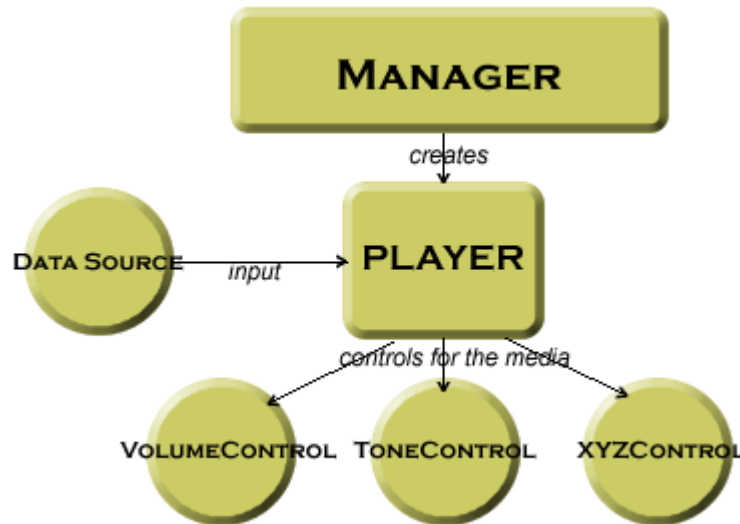


Figure 6.7: Player and Control interfaces

The MMAPI is built on a high-level abstraction of all the multimedia devices that are possible in a resource-limited device. This abstraction is manifest in three classes that form the bulk of operations that you do with this API. These classes are the Player and Control interfaces, and the Manager class. Another class, the Data Source abstract class, is used to locate resources, but unless you define a new way of reading data you will probably never need to use it directly.

In a nutshell, we use the Manager class to create Player instances for different media by specifying Data Source instances. The Player instances thus created are configurable by using Control instances. For example, almost all Player instances would theoretically support a Volume Control to control the volume of the Player.

Step 7 At all Point of Calculation Destroy Unused Objects for Free the Memory

The Java virtual machine's heap stores all objects created by a running Java application. Objects are created by the new instructions, but never freed explicitly by the code. Garbage collection is the process of automatically freeing objects that are no longer referenced by the program.

6.4 Tools used for Implementation of MARS Application Algorithm

JDK 1.6

Java Wireless tool Kit.

Net Beans IDE 6.0.1 Or 6.8[77]

6.4.1 The Java Development Kit:

The Java Development Kit (JDK) is a Sun Microsystems product aimed at Java developers. Since the introduction of Java, it has been by far the most widely used Java SDK. On 17 November 2006, Sun announced that it would be released under the GNU General Public License (GPL), thus making it free software. This happened in large part on 8 May 2007 ; Sun contributed the source code to the OpenJDK.

The JDK has as its primary components a selection of programming tools, including:

java – the *loader* for Java applications. This tool is an interpreter and can interpret the class files generated by the *javac* compiler. Now a single launcher is used for both development and deployment. The old deployment launcher, *jre*, no longer comes with Sun JDK.

javac – the *compiler*, which converts source code into *Java bytecode*

jar – the archiver, which packages related class *libraries* into a single *JAR file*. This tool also helps manage JAR files.

javadoc – the documentation generator, which automatically generates documentation from *source code* comments

jdb – the *debugger*

appletviewer – this tool can be used to run and debug Java applets without a web browser.

6.4.2 Java Wireless Tool Kit

The Sun Java Wireless Toolkit[75] (formerly known as Java 2 Platform, Micro Edition (J2ME) Wireless Toolkit) is a state-of-the-art toolbox for developing wireless applications that are based on J2ME's Connected Limited Device

Configuration (CLDC) and Mobile Information Device Profile (MIDP), and designed to run on cell phones, mainstream personal digital assistants, and other small mobile devices. The toolkit includes the emulation environments, performance optimization and tuning features, documentation, and examples that developers need to bring efficient and successful wireless applications to market quickly.

6.4.3 Net Beans IDE:

Using an Integrated Development Environment (IDE) for developing applications saves your time by managing windows, settings, and data. In addition, an IDE can store repetitive tasks through macros and abbreviations. Drag-and-drop features make creating graphical user interface (GUI) components or accessing databases easy, and highlighted code and debugging features alert you to errors in your code.

The NetBeans IDE is open source and is written in the Java programming language. It provides the services common to creating desktop applications -- such as window and menu management, settings storage -- and is also the first IDE to fully support JDK 6.0 features. The NetBeans platform and IDE are free for commercial and noncommercial use, and they are supported by Sun Microsystems.

It is aimed at those who are new to using IDEs, fairly new to programming, and new to the Java platform. We will learn to create a simple desktop application with a GUI interface and functionality that calculates overtime pay using basic features of the NetBeans IDE. It provides explanations for the code where appropriate, as well as links to the Java API and information about objects as they are introduced. Though the NetBeans environment also provides many rich features for the various Java platforms, such as Java Platform, Enterprise Edition (Java EE) and Java Platform, Micro Edition (Java ME)[78] covers only Java Platform, Standard Edition (Java SE) technology, which is generally the entry point for new developers and programmers.

6.5. Software Development of MARS (Live Streaming through Mobile) Application.

6.5.1 Design S/w for Broadcast:

This Application can Broadcast live video

Creating Camera Form:

```
mPlayer = Manager.createPlayer("capture://video");  
mPlayer.realize();  
mPlayer.start();
```



Figure 6.8 Camera Form



Figure 6.9 Record and broadcast Form

Creating Record and Broadcast Form:

```
mPlayer = Manager.createPlayer("capture://video");  
mPlayer.realize();  
rc = (RecordControl) mPlayer.getControl("RecordControl");  
ByteArrayOutputStream output = new ByteArrayOutputStream();  
rc.setRecordStream(output);  
mPlayer.start();  
rc.startRecord();
```

```
http = (HttpConnection) Connector.open(url + "?fname=" + ++i + ".3gp");  
http.setRequestMethod(HttpConnection.POST);  
http.setRequestProperty("Content-Type", "text/html");  
OutputStream oStrm = http.openOutputStream();  
oStrm.write(b);  
oStrm.flush();
```

6.5.2 Steps for Use of MARS (Live Broadcast Streaming Application through Mobile)

To use MARS (Live Broadcast Streaming Application through Mobile)

We have to follow following steps .As shown in figure 6.10

- Step 1: Open Broadcast Application
- Step 2: User have to select Camera Option then Select Yes to
“Allow Application videoCanvas to use Camera or audio
Application ?”
- Step 3: Start Live Recording
- Step 4: Select Available Wireless Technology for Live Broadcast Select
Access Point
- Step 5: Continue Live Recording and Broadcasting
- Step 6: Stop Live Recording
- Step 7: Close Open Broadcast Application

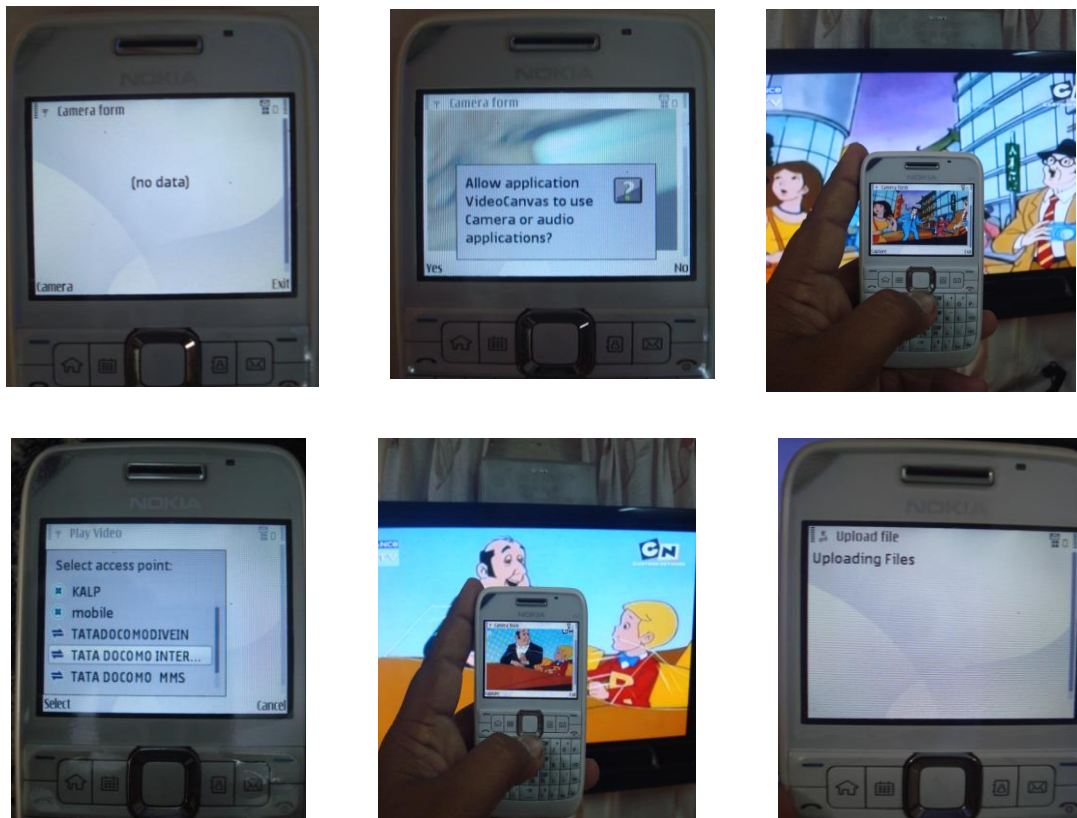


Figure 6.10: MARS (Live Broadcast Streaming Application through Mobile) Snap Shot

6.5.3 Steps for Use of MARS (Capture Image Streaming Application through Mobile)

To use MARS (Capture Image Streaming Application through Mobile) We have to follow following steps .As shown in figure 6.11

- Step 1: Open Capture Image Application
- Step 2: Select Camera option and Select Capture Option to take Image
- Step 3: User have to select Camera Option then Select “Allow Application videoCanvas to use Camera or audio application?”
- Step 4: User have to select Option YES for to “Allow application server Player to use Network and send or receive data?”
- Step 5: Select Access Point of Available Wireless Technology for Image Uploading on web server
- Step 6: received message image file uploaded successfully
- Step 7: Close Open Broadcast Application

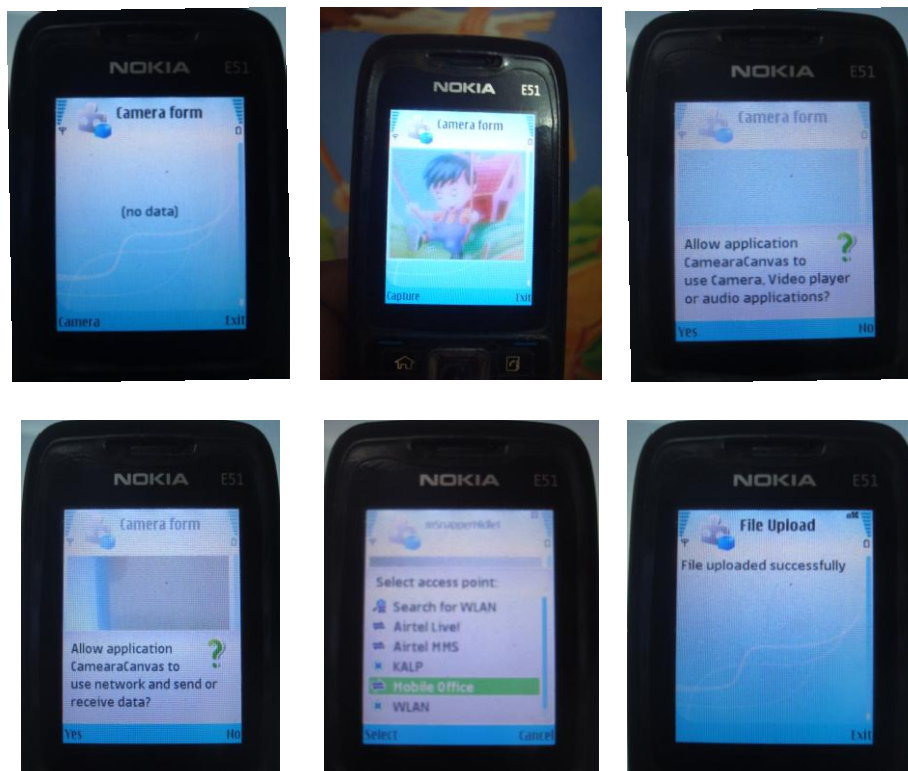


Figure 6.11: MARS (Capture Image Streaming Application through Mobile) Snap Shot

6.5.4 Design Software Application for Play Broadcast Media

Playing Broadcast Video:

```
mPlayer = Manager.createPlayer(url + i + ".3gp");
    Thread.sleep(time);
    mPlayer.realize();
    form.deleteAll();

    VideoControl video = (VideoControl)
mPlayer.getControl("VideoControl");
    //Get a GUI to display the video
    Item videoItem = (Item) video.initDisplayMode(
        VideoControl.USE_GUI_PRIMITIVE, null);
    video.setVisible(true);
    //Append the GUI to a form
    form.append(videoItem);
    //Start the video
    mPlayer.realize();
    mPlayer.start();
```



Figure 6.12: Mobile video Player application

6.5.5 Steps for Playing Broadcast Video through Mobile

To use MARS (Playing Live Broadcast Streaming Application through Mobile)

We have to follow following steps .As shown in figure 6.13

- Step 1: Open Play live Video Application
- Step 2: User have to select Option YES to “Allow application server Player to use Network and send or receive data?”
- Step 3: Select Access Point of Available Wireless Technology for Playing Live Video streams
- Step 4: Start live Video playing on mobile
- Step 5: Stop Live Playing
- Step 6: Close Play live Video Application

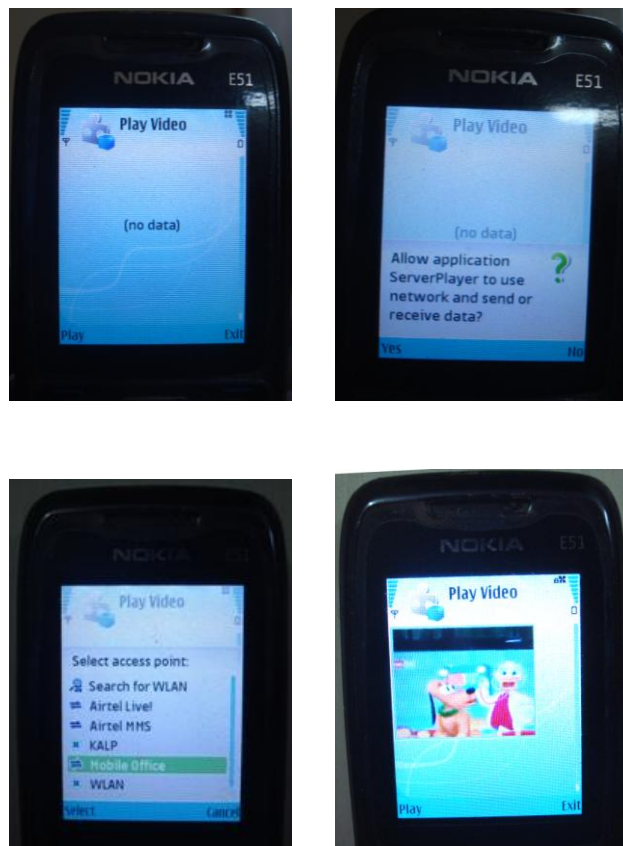


Figure 6.13 : MARS (Playing Broadcast Video application through Mobile) Snap Shot

6.5.6 Steps for Playing Broadcast Video in Computer/Laptop

To use MARS (Live Broadcast Streaming Application through Mobile), We have to follow following steps .As shown in figure 6.14 and 6.15

- Step 1: Open Internet connection on Computer/Laptop
- Step 2: Open website “www.khwandra.org “
- Step 3: In home page click Live Video link to Play live Video Application
- Step 4: Start live Video playing on Computer/Laptop
- Step 5: Stop Live video Playing application
- Step 6: Close web page

6.5.7 Steps for Watch Broadcasted Image in Computer/Laptop

To use MARS (Watch Broadcasted Application in Computer/ Laptop) We have to follow following steps .As shown in figure 6.14 and 6.16

- Step 1: Open Internet connection in Computer/Laptop
- Step 2: Open website “www.khwandra.org “
- Step 3: In home page click View Photo link to Watch Captured image through mobile
- Step 4: Watch last three Captured images on Computer /Laptop
- Step 5: Stop View photo application
- Step 6: Close web page



Figure 6.14: Website www.khwandra.org Home page

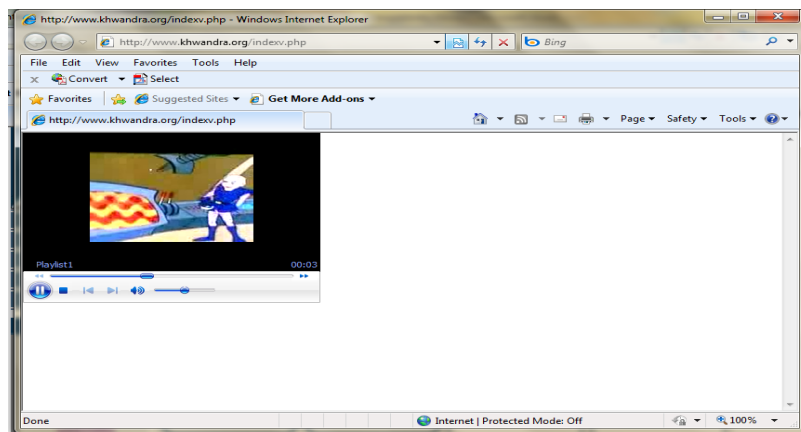


Figure 6.15: MARS (Playing Broadcast Video application on Computers)

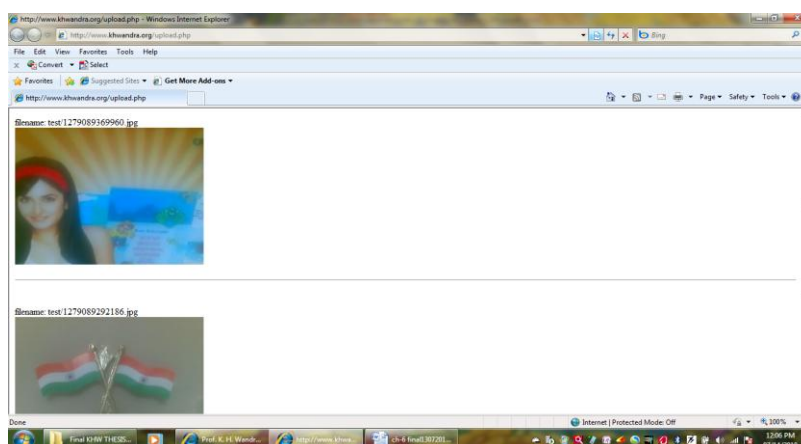


Figure 6.16 Watch Broadcasted Image in Computer/Laptop

6.6 Testing of MARS (Live Streaming through Mobile) Application

6.6.1 Specification to Run MARS (Live Streaming through Mobile) Application

Various practical experiment have been performed on different mobiles of Nokia and Sony Ericsson to run MARS (Live Streaming through Mobile) Application and finally concluded that following are minimum Specification required to run MARS (Live Streaming through Mobile) Application.

Specification: Symbian OS 6.1 onwards, S60 (for Nokia), Sony Ericsson Java Platform 7 (Java ME), JP-8 (8.0-8.2) (for Sony)
MIDP 2.0 and CLDC 1.0/1.1
16 MB Memory,
Camera with minimum VGA (280 by 320) Resolution,
GPRS / UMTS/ Wi-Fi Supported Handset.

6.6.2 Experimental Result Analysis of MARS (Live Streaming through Mobile) Application

Various Experiments have been carried out and run MARS (Live Streaming through Mobile) Application with following Nokia Mobiles E51 ,E61 ,E65 ,E66, E71, 6220, Navigator, 6680 ,6681,N70 ,N72 ,N92 ,N95 ,5630 ,5530 ,5730 music express,C5 and Sony Ericsson Mobiles G502, K550, K610, K660, K810, W800i, W910, C702, C902. Which have minimum specifications required as per topic 6.6.1 to run MARS (Live Streaming through Mobile) Application and It has been measured performance results in terms of delay for different GSM/GPRS Service providers (Vodafone , Airtel ,Tata Docomo ,Videocon and BSNL) because I wants to provide Live Video facility (Like 3G application) on currently available GSM/GPRS based Networks.

6.6.3 Experiment Using GSM/GPRS networks

In this experiment ,Using different GSM/GPRS Mobile Service Providers, Like Vodafone, Airtel, Tata Docomo, Videocon and BSNL. It has been executed MARS (Live Streaming through Mobile) Application with Nokia E63 mobile on Vodafone , Airtel ,Tata Docomo, Videocon and BSNL one by one and measure the Delay of GSM/GPRS network as shown in Figure 6.17 during High traffic (Day time) and during Low traffic (Night time).

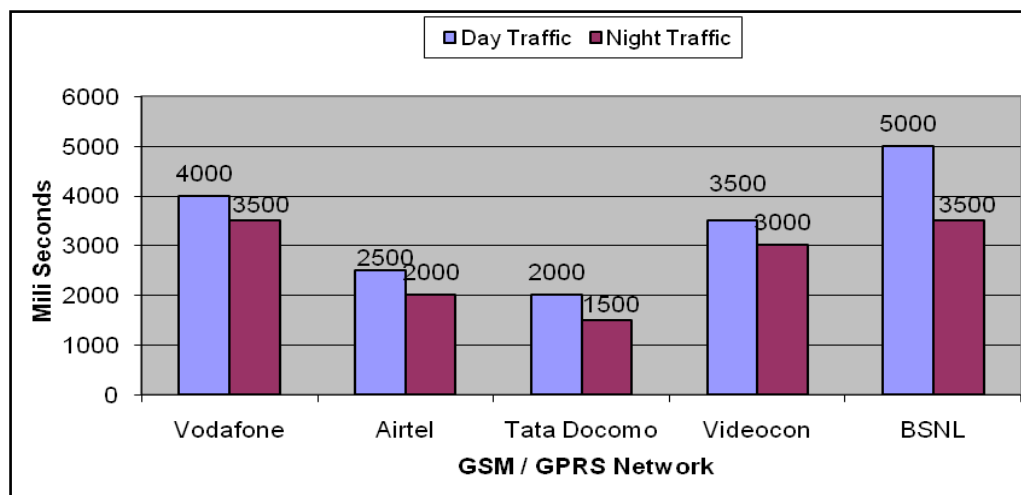


Figure 6.17: Delay of GSM/GPRS network

Figure 6.17 shows that Maximum delay in BSNL mobile network and Less delay in Tata Docomo and Airtel mobile network compared to other mobile network.

6.6.4 Experiment Using Wi-Fi networks

In another set up. It has been performed experiment of MARS (Live Streaming through Mobile) Application using different types of internet connections (GPRS, Dial Up, Broadband and Leased Line) in Wi-Fi networks to verify the performance of MARS (Live Streaming through Mobile) Application, In terms of Delay.

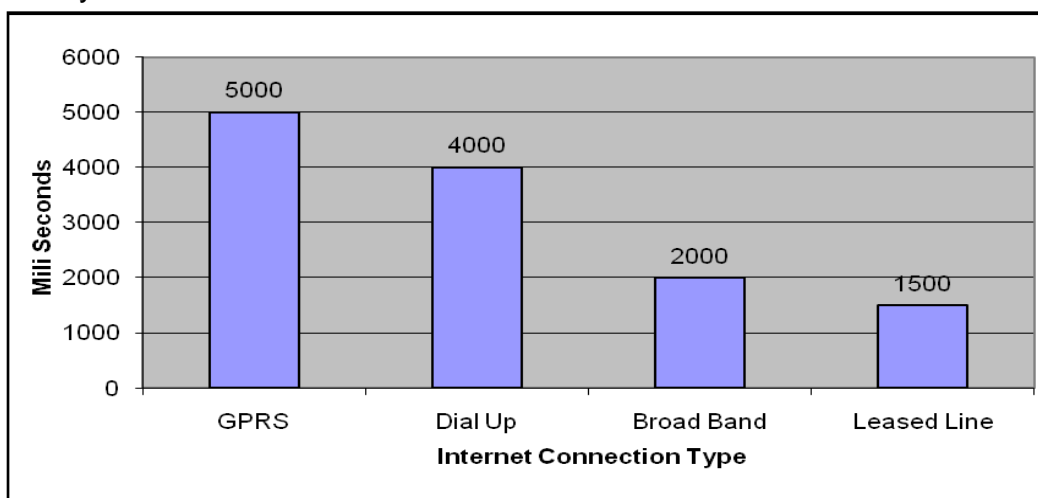


Figure 6.18: Delay in different internet connections type

As shown in figure 6.18 shows that GPRS Network based internet have a delay normally in the range of 1500 to 5000ms which is depends on mobile service provider. Broadband and Leased Line internet gives very good performance with delay of 2000 ms and 1500 ms respectively, while in Dial up connection is 4000 ms. From above experiments results it concludes that in Wi-Fi networks with Broadband and Leased Line internet connection gives very good performance with minimum delay for MARS (Live Streaming through Mobile) Application.

Finally, Experiments have been performed for MARS (Live Streaming through Mobile) Application on Wi-Fi networks in first case with Single Access Point and in second case with Multiple Access Points with Broadband internet connection.




Figure 6.19: Delay in Wi-Fi Network with Single AP & Multiple AP


Figure 6.19 shows the performance of both the case for normal and high traffic. With single AP delay of 1500 and 2000 ms observed for normal and high traffic and with multiple AP delay of 2000 and 3000 ms observed for normal and high traffic. It concludes that normal traffic in Wi-Fi networks gives very good performance with minimum delay for MARS (Live Streaming through Mobile) Application.


APPENDIX - C

Sr No	Device	Photo	Operating system	Screen resolution	Screen size (diagonal) (inches)	Free RAM (for running apps)	Stills camera/Flash	Video camera	Wi-Fi
1	Nokia E51		Symbian OS 9.2, S60 3rd Edition, Feature Pack 1	240 by 320	2.0"	44MB	1600 by 1200	320 by 240	Y
2	Nokia 5800 Xpress Music		Symbian OS 9.1, S60 3rd Edition	240 by 640	2.75"	128MB	3.2MP/LED Flash	2048 by 1538	N
3	Nokia E65		Symbian OS 9.1a, S60 3rd Edition	240 by 320	2.4"	20MB	1600 by 1200	352 by 288	Y
4	Nokia E66		Symbian OS 9.2, S60 3rd Edition, Feature Pack 1	240 by 320	2.4"	80MB	3.2 megapixel/LED	320 by 240	Y
5	Nokia E71		Symbian OS 9.2, S60 3rd Edition, Feature Pack 1	320 by 240	2.4"	80MB	3.2 megapixel/LED	320 by 240	Y
6	Nokia 6220 Classic		Symbian OS 9.3, S60 3rd Edition, Feature Pack 2	240 by 320	2.2"	80MB	5 megapixel/Xenon	640 by 480	N

7	Nokia 6710 Navigator		Symbian OS 9.3, S60 3rd Edition, Feature Pack 2	240 by 320	2.6"	Unknown	5 megapixel/Dual LED	640 by 480	Y
8	Nokia 6110 Navigator		Symbian OS 9.2, S60 3rd Edition, Feature Pack 1	240 by 320	2.2"	17MB	1600 by 1200/LED	320 by 240	No
9	Nokia 6210 Navigator		Symbian OS 9.3, S60 3rd Edition, Feature Pack 2	240 by 320	2.4"	20MB	3 megapixel/LED	640 by 480	N
10	Nokia 6680		Symbian OS 8.0a, S60 2nd Edition Feature Pack 2	176 by 208	2.1"	8MB	1280 by 960/LED	176 by 144	N
11	Nokia 6681		Symbian OS 8.0a, S60 2nd Edition Feature Pack 2	176 by 208	2.1"	8MB	1280 by 960/LED	176 by 144	N
12	Nokia N70		Symbian OS 8.1a, S60 2nd Edition Feature Pack 3	176 by 208	2.1"	32MB	1600 by 1200/LED	352 by 288	N
13	Nokia N72		Symbian OS 8.1a, S60 2nd Edition Feature Pack 3	176 by 208	2.1"	32MB	1600 by 1200/LED	352 by 288	N

14	Nokia N92		Symbian OS 9.1, S60 3rd Edition	320 by 240	2.8"	not known	1600 by 1200/LED	352 by 288	Y
15	Nokia N95		Symbian OS 9.2, S60 3rd Edition, Feature Pack 1	240 by 320	2.6"	20MB	2592 by 1944/LED	640 by 480	Y
16	Nokia 5630 Classic		Symbian OS 9.3, S60 3rd Edition, Feature Pack 2	240 by 320	2.2"	Unknown	3 megapixel/dual LED	640 by 480	Y
17	Nokia 5530 Xpress Music		Symbian OS 9.4, S60 5th Edition	360 by 640	2.9", resistive touch	53MB	3 megapixel/LED	640 by 480	Y
18	Nokia 5730 Xpress Music		Symbian OS 9.3, S60 3rd Edition, Feature Pack 2	240 by 320	2.4"	75MB	3 megapixel LED	640 by 480	Y
19	Nokia C5		Symbian OS 9.3, S60 3rd Edition, Feature Pack 2	240 by 320	2.2"	Unknown	3 megapixel EDof/LED	640 by 480	N

20	Sony Ericsson G502		Sony Ericsson Java Platform 7 (Java ME)	240 by 320	1.9"	32 MB	2.0 MP,	1600 x 1200	N
21	K550		Sony Ericsson Java Platform 7 (Java ME)	176 by 220	1.9"	77 MB	2 MP, LED flash	1632x1224	N
22	K610		Sony Ericsson Java Platform 7 (Java ME)	176 by 220	1.9"	16 MB	2 MP	1600x1200	N
23	K660		Sony Ericsson Java Platform 7 (Java ME)	240 by 320	2.0"	32 MB	2 MP,	1600x1200	N
24	K810		Sony Ericsson Java Platform 7 (Java ME)	240 by 320	2.0"	64 MB	3.15 MP, xenon	2048x1536	Y
25	W800i		Sony Ericsson Java Platform 7 (Java ME)	176 by 220	1.8"	34 MB	2 MP, LED flash	1632x1224	N
26	W910		Sony Ericsson Java Platform 7 (Java ME)	240 by 320	2.4"	40 MB	2 MP	1600x1200	N
27	C702		Sony Ericsson Java Platform 7 (Java ME)	240 by 320	2.2"	160 MB	3.15 MP, LED flash	2048x1536	N

28	C902		Sony Ericsson Java Platform 7 (Java ME)	240 by 320	2.0"	160 MB	5 MP, LED flash	2592x19 44	N
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APPENDIX - B

ALL2	ATM adaptation layer type 2
AN	Access Network
AoC	Advice of charge
APIs	application programming interfaces
APN	access point name
APs	one or more access points
ASA	Authentication and Service Authorization
AuC	Authentication Centre
BCH	Broadcast channel
BS	Base Station
BSC	Base Station Controller
BSS	Base-station subsystem
BSSGP	base station system GPRS protocol
BTS	Base Transceiver Station
BVCI	BSSGP virtual connection identifier
BWA	Broadband Wireless Access
CCCH	common control channel
CCK	complimentary code keying
CDC	Connected Device Configuration
CDMA	Code Division Multiple Access
CEPT	Conference of European Posts and Telegraphs
CFP	contention-free period
CLDC	Connected Limited Device Configuration
CN	Core Network

CP	contention period
CS	Convergence Sub layer
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CTS	Clear-To-Send
CTS	Cordless Telephony Service
CUGs	Closed user groups
CV	Countdown value
dB	Decibels
DCF	Distributed Coordination Function
DL	Downlink
DLCI	data link connection identifier
DPF	data path function
DPSK	differential phase-shift keying
DS	Distribution System
DSSS	direct sequence spread spectrum
DTV	Digital television
DTx	discontinuous transmission
EIR	Equipment Identity Register
ERP	Effective radiated power
ESS	Extended Service Set
ETSI	European Telecommunication Standards Institute
FBSS	Fast base station switching
FCC	Federal Communications Commission
FDD	Frequency Division Duplex
FHSS	Frequency-hopping spread spectrum
FP	Foundation Profile

2G	second generation
3G	Third Generation
GGSN	Gateway GPRS support node
GMM	GPRS mobility management
GMSC	GSM gateway mobile switching center
GMSK	Gaussian Minimum Shift Keying
GPL	GNU General Public License
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
GSNs	GSM Gateway support nodes
GTP	GPRS tunneling protocol
GUI	Graphical User Interface
HLR	Home location register
HMD	Head Mounted Display
HPAs	High-power amplifiers
HSCSD	High-speed circuit-switched data
HSDPA	High Speed Downlink Packet Access
IBSS	Independent Basic Service Set
IDE	Integrated Development Environment
IEEE	Institute of Electrical & Electronics Engineers
IMSI	international mobile subscriber identity
IP	Internet Protocol
ISO/IEC	Standardization/International Electrotechnical Commission
ITU	International Telecommunications Union
J2ME	Java 2 Micro Edition
Java EE	Java Platform, Enterprise Edition

Java SE	Java Platform, Standard Edition
JDK	Java Development Kit
kbps	kilobits per second
LLC	Logical link control
LMDS	Local multipoint distributed services
LNAs	Low-noise amplifiers
LSP	Link selection parameter
MAC	Medium Access Control
MAC CPS	MAC Common Part Sub layer
MAC SAP	MAC Service Access Point
MANET	Mobile ad-hoc networks
MDHO	Macro diversity handover
ME	Mobile equipment
MIDP	Mobile Information Device Profile
MMS	Multimedia Messaging Service
MS	Mobile station
MSC	Mobile Switch Center
MSC	Mobile switching center
MTU	Maximum transmission unit
NIC	Network interface card
N-PDUs	Network layer PDUs
NS	Network service
NSAPI	Network service access point identifier
NSEI	Network service entity identifier
NSPs	Between network service providers
NSS	Network and Switching Subsystem

OSS	Operation and Support Subsystem
PACCH	Paging and Access Grant Channel
PBP	Personal Basis Profile
PCF	Point Coordination Function
PCU	Packet control unit
PD	Personal device
PDAP	Personal Digital Assistant Profile
PDCH	Packet data channels
PDN	Packet data network
PDP	Packet data protocol
PHY	Physical
PHY SAP	PHY Service Access Point
PLMN	Public Land Mobile Network
PMP	Point to Multi-Point
PN	Pseudorandom numerical
PS	Power Saving
PS-Poll	Power Save Poll
PT	Payload type
P-TMSI	Packet temporary mobile subscriber identity
QoS	Quality of service
RAI	Routing area identification
RF	Radio frequency
RLC	Radio link control
RRBP	Relative reserved block period
RTS	Request-To-Send
SAR	Spatial Augmented Reality

SDCCH	Stand Alone Dedicated Control Channel
SDUs	Service Data Units
SGSN	Serving GPRS support node
SIM	Subscriber identity module
SMS	Short message service
SMS-G	SMS Gateway
SNDCP	Sub network dependent convergence protocol
SNR	Signal-to-noise ratio
SSs	Subscriber Stations
TBF	Temporary block flow
TCP	Transmission control protocol
TDD	Time Division Duplexing
TDMA	Time-Division Multiple Access
TEID	Tunnel Endpoint ID
UDP	User datagram protocol
UE	User equipment
UL	Uplink
UMSC	UMTS MSC
UMTS	Universal Mobile Telephone System
USF	Uplink status flag
UTRAN	UMTS Terrestrial Radio Access Network
VLR	Visitor Location Register
VM	Virtual machine
WiBro	Wireless Broadband
Wi-max	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network

APPENDIX-A

QualNet-5.0 Model Library Index

Library	Model
Advanced Wireless	802.16 MAC and 802.16e MAC
	802.16 PHY
ALE/ASAPS Advanced Propagation	Automatic Link Establishment (ALE)
	Automatic Link Establishment/Advanced Stand Alone Prediction System (ALE/ ASAPS)
Cellular	Abstract Cellular
	Global System for Mobile Communications (GSM) Model
	User Behavior Model
Developer	802.3 LAN/Ethernet
	Abstract Link MAC
	Abstract Satellite Model
	Abstract Transmission Control Protocol (Abstract TCP)
	Address Resolution Protocol (ARP)
	Asynchronous Transfer Mode (ATM)
	Bellman-Ford Routing Protocol
	Class-Based Queuing (CBQ)
	Constant Bit Rate (CBR) Traffic Generator
	Faults
	File Transfer Protocol (FTP)
	File Transfer Protocol/Generic (FTP/Generic)
	File-based Node Placement Model
	First-In First-Out (FIFO) Queue
	Grid Node Placement Model
	HyperText Transfer Protocol (HTTP)
	Internet Control Message Protocol (ICMP)
	Internet Control Message Protocol version 6 (ICMPv6)
	Internet Group Management Protocol (IGMP)
	Internet Protocol - Dual IP
	Internet Protocol Security (IPSec)
	Internet Protocol version 4 (IPv4)

	Internet Protocol version 6 (IPv6)
	Logical Link Control (LLC) Protocol
	Lookup Traffic Generator
	Multicast Constant Bit Rate (MCBR) Traffic Generator
	Neighbor Discovery Protocol
	Random Early Detection (RED) Queue
Developer (continued)	Random Early Detection with In/Out (RIO) Queue
	Random Node Placement Model
	Round Robin Scheduler
	Routing Information Protocol next generation (RIPng)
	Routing Information Protocol/Routing Information Protocol version 2 (RIP/ RIPv2)
	Satellite Toolkit (STK)
	Self-Clocked Fair Queueing (SCFQ) Scheduler
	Static and Default Routes
	Static Multicast Routes
	Strict Priority Scheduler
	Super Application Traffic Generator
	Telecommunications Network (TELNET)
	Trace File-based Traffic Generator (Traffic-Trace)
	Traffic Generator (Traffic-Gen)
	Transmission Control Protocol (TCP)
	Uniform Node Placement Model
	User Datagram Protocol (UDP)
	Variable Bit Rate (VBR)Traffic Generator
	Weighted Fair Queuing (WFQ) Scheduler
	Weighted RED (WRED) Queue
	Weighted Round Robin (WRR) Scheduler
Military Radios	Compact Terrain Database Format 7 (CTDB 7) and Format 8 (CTDB 8) Models* FCSC
	Enhanced Position Location Reporting System (EPLRS)*
	Radio Prototype*
	Link 11 Protocol*
	Link 16 Protocol*
	Multi-Generator (MGEN) Toolset*

	Single Channel Ground and Airborne Radio System (SINCGARS)*
	Surrogate Joint Tactical Radio System-Wideband Networking Waveform (JTRS-WNW)*
	Threaded App*
	Traffic Generator Extension for Military Radios (Traffic-Gen-Ext)*
	Unifying Slot Assignment Protocol (USAP)*
Multimedia and Enterprise	Border Gateway Protocol version 4 (BGPv4)
	Detailed Switch Model Differentiated Services (DiffServ)
	Distance Vector Multicast Routing Protocol (DVMRP)
	Enhanced Interior Gateway Routing Protocol (EIGRP)
	H323 and H225 Protocols
	Hot Standby Router Protocol (HSRP)
	Interior Gateway Routing Protocol (IGRP)
	Multicast Extensions to OSPF (MOSPF)
	Multi-Protocol Label Switching (MPLS)
	Open Shortest Path First version 2 (OSPFv2) Routing Protocol
Multimedia and Enterprise(continued)	Open Shortest Path First version 3 (OSPFv3) Routing
	Protocol Policy-based Routing
	Protocol Independent Multicast Protocol: Dense Mode (PIM-DM) and Sparse Mode(PIM-SM)
	Quality of Service Extensions to OSPF (QOSPF)
	Real-time Transport Protocol (RTP)
	Route Map
	Route Redistribution
	Router Access List
	Router Model
	Session Initiation Protocol (SIP)
	Switched Ethernet
	Virtual LAN (VLAN)
	Voice over Internet Protocol (VoIP)
Network Security	Adversary Model
Network Security	Anonymous On-demand Routing (ANODR) Protocol

(continued)	Credential Model: IFF Certificate
	ISAKMP Model
	Secure Neighbor Model
	WEP and CCMP Model
Satellite	Abstract Network Equation Satellite (ANESAT) Model
	Aloha Satellite Model with RSV Support (Satellite-RSV)
	Satellite Technology Support Module Physical Layer (SATTSM-PHY)
Sensor Networks	ZigBee MAC
	ZigBee PHY
Standard Interfaces	Distributed Interactive Simulation (DIS)
	Interface High Level Architecture (HLA) Interface
TIREM Propagation	Terrain Integrated Rough Earth Model (TIREM)
UMTS	Phone Call Traffic Generator
	Universal Mobile Telecommunication System (UMTS)
Urban Propagation	Automatic Model Selection
	COST 231-Hata Propagation Model
	COST 231-Walfish-Ikegami (COST-WI) Propagation Model
	Okumura-Hata Propagation Model
	Street Microcell Propagation Model
	Street Mobile-to-mobile Propagation Model
	Suburban Propagation Model
Wireless	802.11 MAC Protocol
	802.11a/g PHY Model
	802.11b PHY Model
	802.11e MAC Protocol
	802.11s MAC Protocol
	Abstract PHY Model
	Ad-hoc On-demand Distance Vector (AODV) Routing Protocol
	Aloha MAC Protocol
	Battery Models BER-based Reception Model
	Border cast Resolution Protocol (BRP)
	Carrier Sense Multiple Access (CSMA) MAC Protocol
Wireless (continued)	Cartesian Terrain Format

	Constant Shadowing Model
	Digital Elevation Model (DEM) Terrain Format
	Digital Terrain Elevation (DTED) Terrain Format
	Dynamic MANET On-demand (DYMO) Routing Protocol
	Dynamic Source Routing (DSR) Protocol
	ESRI Shapefile Terrain Format
	Fast Rayleigh Fading Model
	File-based Mobility Model
	Fisheye State Routing Protocol
	Free-space Pathloss Model
	Generic MAC Protocol Group Node Placement and Mobility Models
	Interzone Routing Protocol (IERP)
	Intrazone Routing Protocol (IARP)
	Irregular Terrain Model (ITM)
	Landmark Ad Hoc Routing (LANMAR) \
	Protocol Location-Aided Routing (LAR) Protocols
	Lognormal Shadowing Model
	Microwave Links
	Mobile IPv4
	Multiple Access Collision Avoidance (MACA) MAC Protocol
	Omni directional Antenna Model
	On-Demand Multicast Routing Protocol (ODMRP)
	Optimized Link State Routing Protocol - INRIA (OLSR-INRIA)
	Optimized Link State Routing Protocol version 2 (OLSRv2)
	Path loss Matrix Model
	Patterned Antenna Model
	Pedestrian Mobility Model
	Radio Energy Models
	Random Waypoint Mobility Model
	Rayleigh Fading Model
	Ricean Fading Model
	SNR-based Reception Model

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Chapter 7: Conclusion and Future Aspects

7.1 Conclusion

The role and performance of different wireless technology applicable to MARS live streaming application through mobile has been developed. The simulation has been carried out with the various parameter aspects like Bandwidth, Data rate, Frequency, Power requirement, Routing algorithm, Number of users, Coverage, Throughput, and Modulation technique, Jitter, Delay and Signal received with errors in QualNET5.0 simulator for various scenario models of Wireless Technology.

After performing simulation of GSM/GPRS, UMTS WLAN, Wi-Fi, WiMAX and WiBro on QualNET5.0 It has been concluded as below.

GSM/GPRS Network

After the various experiments have been carried out on GSM/GPRS models using QualNet-5.0, researcher has come to know that,

- ✓ Power Level affect on transmitted GSM/GPRS signal level and also received GSM signal level by all nodes. As power level increases no. of calls successfully completed also increases. Traffic packets sent also increases as power level increase. Power to operate sufficiently in this network is 20dbm
- ✓ Best Path Propagation model proved here is Two Ray Model. It gives more no of call completions at min power level than other models. It sends more no of traffic packets. It gives 100% channel assignment at less traffic. But its performance is affected by change in traffic
- ✓ By change in data rate, we can increase no of call initiation to completion. It also increases the no. of channel assignment. It allows more users to be accommodated at a time
- ✓ GSM/GPRS covers area up to 2 Km, providing good coverage with 20 dBm

transmission power. It accommodates approximately 120 users with 20 dBm.

It supports data rate, up to 270.83 Kbps.

- ✓ It provides mobility up to 140 Km/h with good coverage.

UMTS Networks

After the various experiments have been carried out on UMTS models using QualNet-5.0, It has been observed that,

- ✓ UMTS covers area up to 5 Km, providing good coverage with 30 dBm transmission power.
- ✓ It accommodates approximately 200 users with 30 dBm.
- ✓ It supports low data rate, up to 2 Mbps.
- ✓ It provides mobility up to 300 Km/h with good coverage.

WLAN Networks

After the various experiments have been carried out on WLAN models using QualNet-5.0, It has been noticed that,

- ✓ WLAN covers area up to 100 m, providing good coverage with 10 dBm transmission power.
- ✓ It accommodates approximately 8 users with 10 dBm.
- ✓ It supports data rate, up to 6 to 54 Mbps.
- ✓ It provides pedestrian mobility.

Wi-Fi Network

After the various experiment has been carried out on Wi-Fi models using QualNet-5.0, It has been observed that,

- ✓ As the data rate increases throughput increases appreciably. It decreases when network spread. If power is high, its effect can't be judged. We get higher throughput at 11 Mbps compared to other data rates.
- ✓ As traffic increases, throughput decreases. When data rate is higher, throughput is not that much affected as compared at lower data rate.
- ✓ We say that Free Space model gives better throughput compared to two ray model, but in some cases it fails to give throughput. While two ray model

gives average throughput to all nodes. So, we can say that better model is Two ray model

- ✓ We say that QAM 64 is best in giving throughput. But when we see the graphs of Signals received but with errors, then it also proves that QAM 64 gives most erroneous signals while GMSK gives least erroneous signals. So, we can conclude that GMSK is better than all other techniques because of giving better throughput and minimum errors.
- ✓ Wi-Fi covers area up to 150 m, providing good coverage with 15 dBm transmission power.
- ✓ It accommodates approximately 50 users with 15 dBm.
- ✓ It supports data rate up to 5.5 to 11 Mbps.
- ✓ It provides pedestrian mobility.

WiMAX Network

After the various experiments have been carried out on WiMAX models using QualNet-5.0, It has been known that,

- ✓ 25 dbm which provided handoff at all base stations and also gives the best throughput. So, optimum power level is 25 dbm. As power is increased jitter decreases, it means that increase in power level improves performance of network.
- ✓ Free space model gives better throughput, less delay and jitter as compared to other models. So, it is better in both fixed and mobile WiMAX both.
- ✓ Bellman ford gives fewer amounts of delay, jitter and better throughput, so it is better routing protocol compared to other protocols.
- ✓ Higher FFT, cyclic prefix factor and bandwidth size give better throughput, less jitter and delay.
- ✓ WiMAX covers area up to 5 Km, providing good coverage with 50 dBm transmission power.
- ✓ It accommodates approximately 260 users with 50 dBm.
- ✓ It supports data rate up to 70 Mbps

WiBRO Networks

After the various experiment has been carried out on WiBRO models using QualNet-5.0, It has been understood that,

- ✓ WiBro covers area up to 5 Km, providing good coverage with 60 dBm power.
- ✓ It accommodates approximately 500 users with 60 dBm.
- ✓ It supports data rate up to 9 Mbps with mobility.
- ✓ It provides mobile internet access with vehicular speed up to 120 Km/h.

Result Analysis of MARS (Live Streaming through Mobile) Application in real GSM/GPRS and Wi-Fi Networks.

Various Experiments have been performed and run MARS (Live Streaming through Mobile) Application with different Nokia Mobiles and Sony Ericsson Mobiles. All mobiles have minimum specification like Symbian OS 6.1 onwards, S60 (for Nokia), Sony Ericsson Java Platform 7 (Java ME), JP-8 (for Sony), supported MIDP 2.0 and CLDC 1.0/1.1, 16 MB Memory, Camera with minimum VGA (240 by 320) Resolution, GPRS / UMTS/ Wi-Fi supported Handset, Above said specifications are required to run MARS (Live Streaming through Mobile) Application and the results of performance have been measured in terms of delay in different GSM/GPRS Service providers (Vodafone, Airtel, Tata Docomo, Videocon and BSNL) and in Wi-Fi networks with different type of internet connectivity (GPRS, Dial Up, Broadband and Leased line) because I want to provide Live Video facility (Like 3G application) on currently available GSM/GPRS based Networks as well as in Wi-Fi based networks.

After the various experiments of MARS (Live Streaming through Mobile) Application have been carried out on real GSM/GPRS and Wi-Fi networks, It has been known that,

- ✓ Observed Maximum delay in BSNL mobile network and less delay in Tata Docomo and Airtel mobile network compared to other mobile network.
- ✓ Wi-Fi networks with Broadband and Leased Line internet connection gives very good performance with minimum delay for MARS (Live Streaming through Mobile) Application.
- ✓ In Wi-Fi networks, normal traffic in Wi-Fi networks gives very good performance with minimum delay for MARS (Live Streaming through Mobile) Application.
- ✓ MARS (Live Streaming through Mobile) Application gives very good performance in Docomo and Airtel mobile network and in Wi-Fi networks with Broadband Internet connection.

7.2 Future aspects

Work carried out as a part of thesis is just a small drop of sea. Still a lot work can be carried out by the virtue of Qualnet simulator. GSM/GPRS and UMTS network analyzed here and optimized is just on the base of call success. But it can be carried over to optimize on base of SNR, BER even with GPRS and EDGE with good rate also. GSM/GPRS network can even be tested with different set of specification may be in 1800 MHz or 1900 MHz band also. GSM network is very prone to traffic, so deep analysis can also be carried out performance such that we can have better performance network.

In case of Wi-Fi, we have analyzed on the base of various pathloss model, traffic, data rate etc. but we can still analyze and optimize wi-fi network such that it provides better throughput by decreasing BER, SNR and increasing throughput. Now required performance by wi-fi network can be varied from a network to another network. But still we can analyze on more parameters like routing protocol and others so that we can come up with some specification for a specific terrain or specific environmental conditions.

WiMAX is today's shining star and demand of present time and also of future.

WiMAX is just analyzed in this researchwork but still work of optimization can be carried out for both fixed and mobile WiMAX network. We can still analyze it on more set of parameters and finally we can design a network of WiMAX which gives better throughput and better performance.

As the QualNet-5.0 simulator itself is C++ based and all protocols have been implemented in a series of C++ files, it is possible to run simulations completely from the command line in QualNet-5.0. In future develop a various protocols (user defined) for each Wireless Communication Technology as mentioned above using C++ coding.

Performance of MARS (Live Streaming through Mobile) Application can be improved by designing or modifying wireless technology to achieve desired data rate and good coverage.

With the help of MARS (Live Streaming through Mobile) Application user can either send or receive live data ,so it can be modified in future so that user can send Live Video and can do text chatting simultaneously.

With the help of MARS (Live Streaming through Mobile) Application user can either send or receive live data ,so it can be modified in future so that user can send and receive simultaneous live data.

In future MARS (Live Streaming through Mobile) Application can be designed in such a way that it can work on almost brands and operating systems of mobile phones with available wireless technology.