CHAPTER-4

Network design of WiMAX

4.1 Infrastructure Equipment of WiMAX:

4.1.1 HiperMAX

HiperMAX Base Station is optimised to support the IEEE 802.16e specification, and will also support 802.16-2004 for fixed and nomadic applications. This means that both 256 OFDM and SOFDMA PHYs are supported within the overall design.

The HiperMAX base station is designed to deliver the best link budget, with highest capacity and net throughput. The system is typically deployed from macro-cell sites, used in typical wireless rollout. HiperMAX implements an eight element array for 3.5 and 2.5GHz systems and a two or four element antenna array for systems below 2 GHz.All HiperMAX Base Stations support and MIMO and are platform-ready for SDMA. The SDMA implementation of the HiperMAX uses the antenna array to enhance capacity and improve frequency re-use. The HiperMAX base station can be configured to provide TDM voice applications; otherwise the system is optimized to support VoIP applications, using a standard gateway to PSTN.

Fig:4.1.1HiperMAX

4. 1.2 Macro MAX

The MacroMAX product is a highly upgradeable macro base station, which utilizes software defined radio (SDR) technology to enable complete upgradeability of the MAC and PHY layers.MacroMAX uses a indoor radio unit, with external feeders to appropriate mast installed antennae. The use of separate antennae enables space time coding (STC) and maximum radio combining (MRC) techniques to be utilized, which increases the link budget. The MacroMAX supports the IEEE802.16-2004 standard, and is ready for soft upgrade to IEEE 802.16e for portable and mobile applications.

Fig:4.1.2 MacroMAX

MicroMAX is designed to support low-density, rural broadband access, enterprise applications, in both licensed and unlicensed bands as the base station radiates within recognized EiRP limits. One of the key features of the MicroMAX BSR is that it requires less than 28W power which makes it ideally suited for line powering by using DSL lines thus enabling the economic delivery of broadband wireless services to communities beyond the reach of DSL.

4.1.3 RF Repeater

The Single-Band RF Repeater (RFR) is the kind of repeater used most frequently. It has a simple structure to transparently convey and amplify the wireless signal (at the same frequency) between the BTS (Base Transceiver Station) and mobiles.

As per operator's requirement for working frequency, two types of Single-Band RFR are available:

- Band-Selective Single-Band RF Repeater: to amplify all signals in the whole band (bandwidth is customized);
- Channel-Selective Single-Band RF Repeater: to amplify only the signals transmitted in the customized 1 (2 or 4) channel.

Fig:4.1.3 RF Repeater

4.2 Backhaul

Backhaul is actually a connection system from the Access Point (AP) back to the provider and to the connection from the provider to the network. A backhaul can set out any technology and media provided; it connects the system to the backbone. In most of the WiMAX deployments circumstances, it is also possible to connect several base stations with one another by use of high speed backhaul microware links. This would also allow for roaming by a WiMAX subscriber from one base station coverage area to another, similar to roaming enabled by cellular phone companies.

4.2.1 Cellular Backhaul

The market for cellular services is becoming more and more competitive. To stay in the business, cellular operators are constantly looking for ways to reduce operating costs.Backhaul costs for cellular operators represent a significant portion of their recurring costs.

WiMAX can provide Point-to-Point links of up to 30 miles (50 km), with data rates capable of supporting multiple E1/T1s Cellular operators can therefore use WiMAX equipment to backhaul Base Station traffic to their Network Operation and Switching

Centers, as shown below:

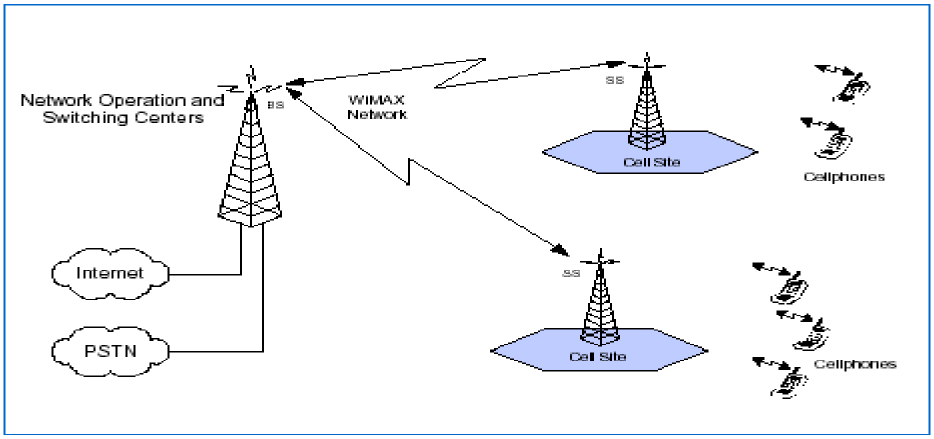

Fig: 4.2.1 Cellular Backhaul

Based on the availability of spectrum for WiMAX in different countries, the cellular backhaul application may or may not be able to handle nationwide networks. Cellular traffic is a mix of voice and data, for which the built-in QoS feature of WiMAX is highly suited. Leasing backhaul facilities from local telephone companies can be cost prohibitive, and deploying a fiber solution, which is both costly and time consuming, could negatively impact rollout of service. Wired solutions for providing cellular backhaul are seldom cost-effective in rural or suburban areas, and most versions of DSL

4.2.2 Wireless Metro WiMAX Backhaul:

There are typically a number of layers to be considered in any metropolitan network design. In many cases, these networks will often rely on existing metro fiber for the central metro-core layer, building out new [wireless] layers for the access and metro backhaul segments. Within the backhaul layer, perceived spectrum scarcity can make the use of unlicensed technology an attractive alternative to licensed technology. This paper examines the wireless backhaul layer with a view to illuminate desirable performance attributes and how these can be realized with either licensed or unlicensed technologies.

Typical Metropolitan WiMAX Network Topologies:

Focusing on wireless networking, there are a number of general topologies. These include:

The typical configurations of this topology are illustrated below in Figure The key difference in these topologies are that daisy-chaining reduces overall path availability performance and increased delay and delay variability. The daisy chain, however, allows the effective reach of the metro fiber PoP to be considerably extended.

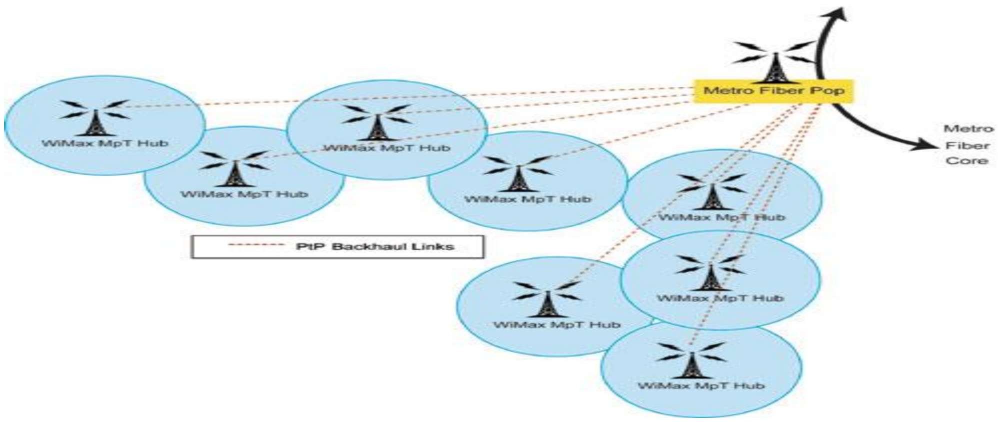

Fig:.4.2.2 WiMAX MpT Access+PtPBackhaul

As a general goal, a key design objective of the network design is the minimization of delay and delay variability. Delay performance directly impacts the operation of time-sensitive applications. These include things like VoIP and VIDoIP, TDMoIP services. Delay variability affects the operation of hand-off processing applicable to mobile applications

Many Ethernet network deployments are undertaken without proper consideration of delay and delay variability and as a result present the operators with performance difficulties when high-value, delay-sensitive services/applications are deployed.

4.2.3 The Wireless Backhaul Layer:

The metro WiMAX backhaul layer generally needs to extend the attributes of the metro fiber PoP to which it is typically backhauling traffic to. The general function of the backhaul layer is to extend the metropolitan geographic reach of the metro core network since WiMAX access is all about getting the wireless signals to within close proximity of the end-sites. As such, the key Ethernet backhaul layer attributes are:

- **High performance traffic policing**
- **Bandwidth scalability**
- **Low delay and low delay-variability**
- **Availability**

4.3 802.16 WiMAX Backhaul Access Network Applications:

WiMAX is a possible replacement candidate for cellular phone technologies such as GSM and CDMA, or can be used as a layover to increase capacity. It has also been considered as a wireless backhaul technology for 2G, 3G, and 4G networks in both developed and developing nations.

"Backhaul" for remote cellular operations is typically provided via satellite, and in urban areas via one or several T1 connections. WiMAX is mobile broadband and as such has much more substantial backhaul needed. Therefore traditional backhaul solutions are not appropriate. Consequently the role of very high capacity wireless microwave point-to-point backhaul (200 or more Mbit/s with typically 1 ms or less delay) is on the rise. Also fiber backhaul is more appropriate. Deploying WiMAX in rural areas with limited or no internet backbone will be challenging as additional methods and hardware will be required to procure sufficient bandwidth from the nearest sources — the difficulty being in proportion to the distance between the end-user and the nearest sufficient internet backbone.

Given the limited wired infrastructure in some developing countries, the costs to install a WiMAX station in conjunction with an existing cellular tower or even as a solitary hub are likely to be small in comparison to developing a wired solution. Areas of low population density and flat terrain are particularly suited to WiMAX and its range. For countries that have skipped wired infrastructure as a result of prohibitive costs and unsympathetic geography, WiMAX can enhance wireless infrastructure in an inexpensive, decentralized, deployment-friendly and effective manner.

4.4 Technology: WiMAX Design

The design of the WiMAX is ideal for challenges related with earlier versions of wired and wireless access networks. At the same time the backhaul connects the WiMAX system to the network, it is not an integrated part of WiMAX system. Normally a WiMAX network consists of two parts, a WiMAX Base Station (BS) and a WiMAX receiver also referred as Customer Premise Equipment (CPE).

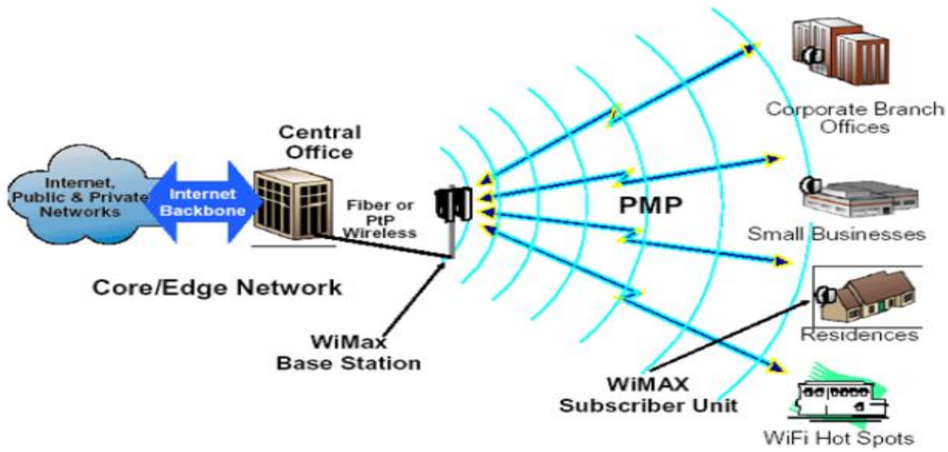

Fig: 4.4 Technology: WiMAX Design

4.4.1 Base Station (BS)

A WiMAX base station comprises of internal devices and a WiMAX tower. A base station can normally covers the area of about 50 kilometers or 30 miles radius, but some other and environmental issues bound the limits of WiMAX range to 10 km or 6 miles. Any wireless user within the coverage area would be able to access the WiMAX services. The WiMAX base stations would use the media access control layer defines in the standard and would allocate uplink and downlink bandwidth to subscribers according to their requirements on real time basis.

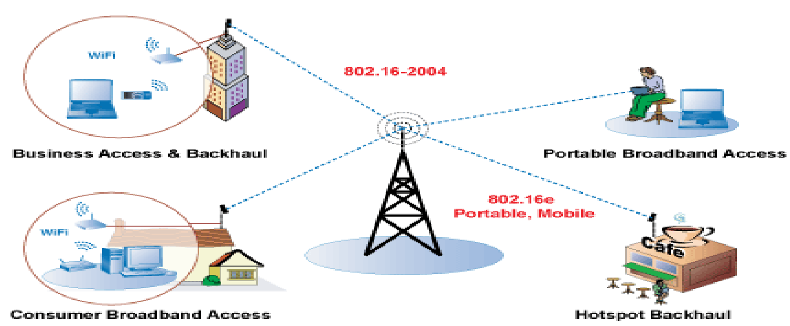

Fig: 4.4.1. Diagram of WiMAX Base station

WiMAX base stations transmit up to 30 miles, but because it is a cell-based topology, would yield a more typical range of 3 to 5 miles. WiMAX systems can deliver a capacity of up to 75 Mbps per channel, for fixed and portable access applications. This is enough bandwidth to simultaneously support hundreds of businesses with T-1 speed connectivity and thousands of residences with DSL speed connectivity.

4.5 WiMAX Networks

All WiMAX networks share similar characteristics and necessary components. These components consist of an air interface, base station, subscriber station and network management. WiMAX networks, regardless if they are fixed or nomadic, need a physical wireless air link. From the 802.16 specifications, this can be any frequency from 2 GHz to 66 GHz and channel bandwidth can be from 1.25 MHz to 20 MHz wide.

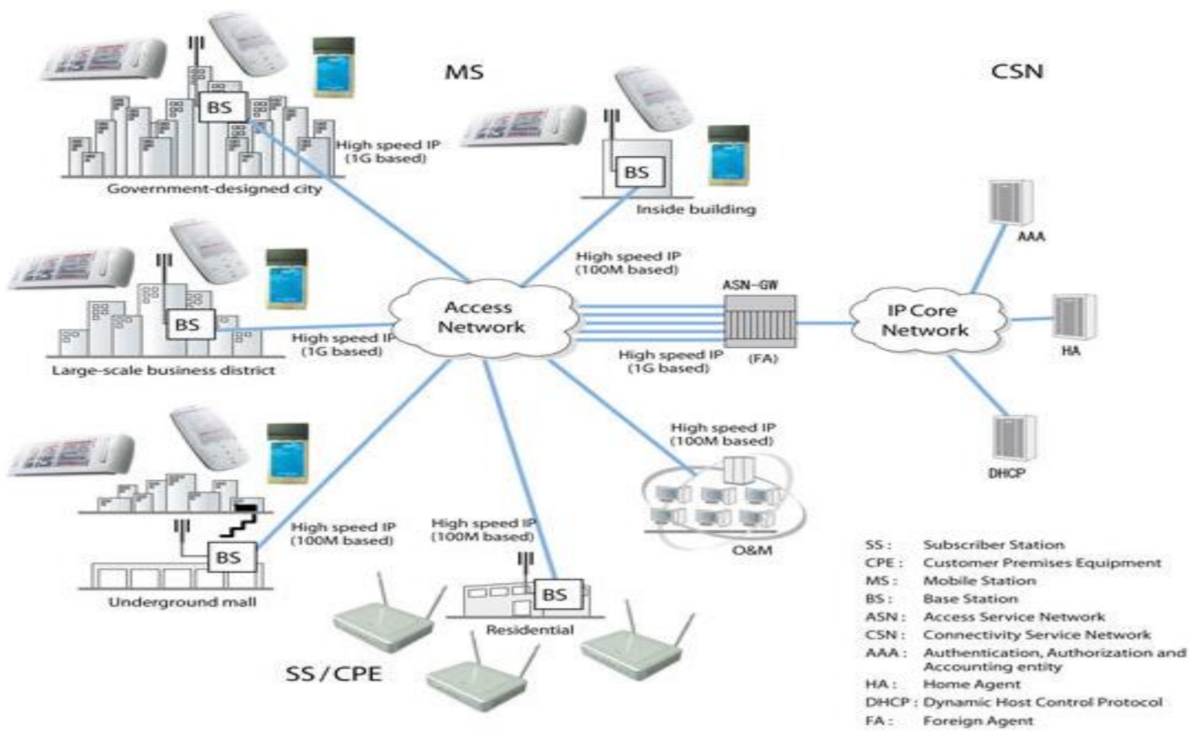

Fig: 4.5 WiMAX Networks

However, the WiMAX Forum, an international, industry-lead standards organization, has claimed that they are willing to work with any frequencies that become available. In fact, the WiMAX Forum recently announced that it is adding the 700 MHz band to its technology roadmap and work on the certification of the frequency range has already started in the Forum's working groups. Based on the regulations and laws of e each country, a WiMAX network can use either licensed or unlicensed frequencies .

Each WiMAX network needs a network or Internet connection, which can be supplied by a traditional land line service or can even be provided by another WiMAX link or other wireless technology.A centralized base station is required to manage the WiMAX network. WiMAX is a scheduled protocol and the base station manages access point entry into the network and it also controls the dedicated bandwidth, signal power levels, and prioritized traffic. Base stations can handle hundreds of access points and they can interface with the internal network. A well-designed WiMAX network strategically places each base station in order to maximize coverage areas.

Access points, or subscriber stations, are needed to provide users with access to the network. Each access point has an RF interface to connect to the physical wireless air link. Wireless devices can access the network, such as a cell phone that is equipped for WiMAX connectivity, or via an Ethernet interface. Access points can be mobile or mounted to poles, towers or buildings.

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4.6 Sectorization

Sectorization scheme divides a cell into several sectorized cells and use two types of frequency reuse Schemes:

1. Each sector in a cell uses all the system channel band-width allocated to the cell.(fig:1a)

2. Channel band-width is divided into several sub-channels and each sub-channel is allocated in only one sector. (Fig: 1b)

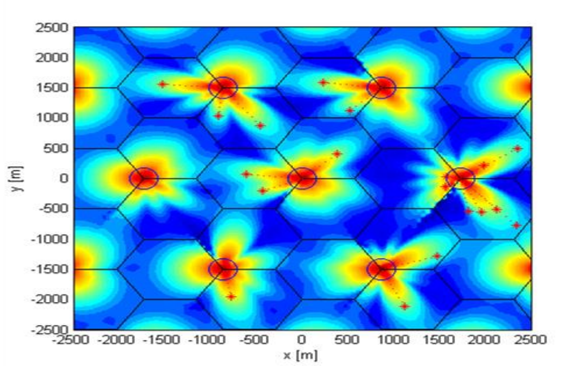

Fig: 4: 6 Sectorization Scheme.

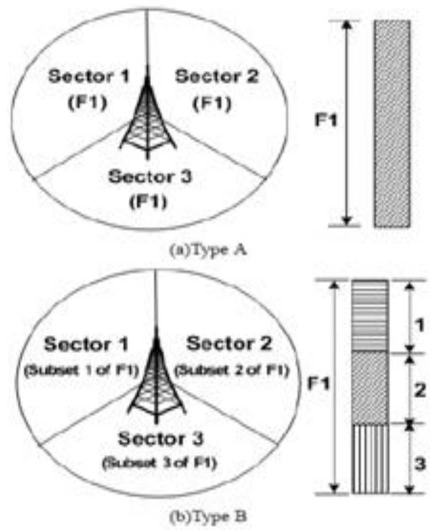

Fig: 4.6.a Example of Sectorization scheme in that a cell is divided into three sectorized cells

In type A of fig 1(a): Each sectorized cell uses the entire channel band width F1. This can improves system capacity and spectrum efficiency, but users can suffer not only inter-cell interference but also intra-cell interference.

In type B of fig 1(b): The available band-width for each sector is a part of entire channel band-width F1. Subsets 1, 2, and 3 in F1 are allocated to sectors. This can reduce inter-cell interference as well as intra-cell one, compared with the previous one. However users located in cell boundary experienced degradation of SINR.

- Without Sectorization adjacent cells will interfere with one another and the frequency reuse factor will be one.
- An overly sectorized cell will interfere with itself and will not efficiently reduce the interference into adjacent cells.
- The optimal Sectorization from an interference stand point is one that balances the effects of the cells self interference with the interference from adjacent cells.
- Adding more sectors increases the system cost.. However, site acquisition and infrastructure normally out weigh the antenna and RF equipment cost.

4.7 Polarization

The use of dual polarization antennas tends to be the most cost effective solution for diversity. Where a technique such as maximum ratio combining is used, slant 45 degree dual polarized antennas have been shown to have the most desirable performance. Generally the C /I ratios are similar for each of the ports. This works out to be beneficial for maximum ratio combining. However, in situation where a space-time combining technique is used, vertical-horizontal dual polarized antennas tend to be optimal. Most scatterers tend to be horizontally oriented; the decorrelation the scattering environment of the two polarizations has less con elation and thus enhances the diversity gam.

4.8 Selecting Network Topology:

4.8.1 Point-to-Point Network :

A point-to-point wireless network is a direct link between two distinct locations. In the diagram, point-to-point connections are represented by the red lines. These connections are commonly used in cellular backhaul and for building-to-building extensions of IP and circuit-switched services Fiber optics and leased copper connections are examples of "wired" point-to-point networks.

Advantages of point-to-point networks include a dedicated link to a specific location and offering higher data capacities than on a shared topology like multipoint or mesh. Point-to-point networks typically include a matched pair of radios, which can be installed professionally or by a seasoned IT technician. For cellular backhaul, microwave point-to-point radios have been called into action during several natural disasters, such as wildfires, where cabled copper and fiber optics are inoperable.

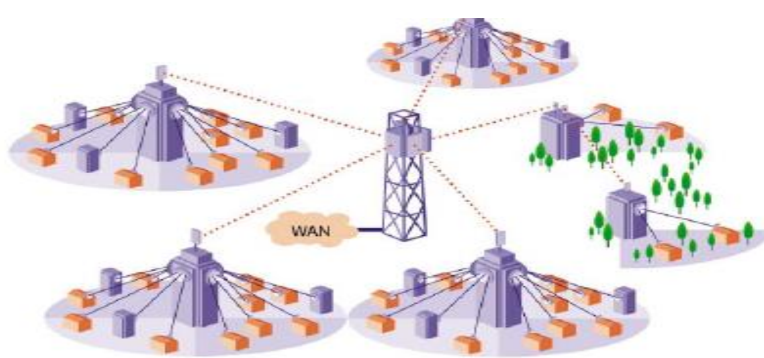

Fig: 4.8.1 Point-to-point network

4.8.2 Point-to-Multipoint Network:

WiMAX is most often associated with the point-to-multipoint topology. Multipoint networks can be thought of as a hub and spoke combination. Multipoint networks use a base station as the "hub" and subscriber units as the connection points at the other end of the spokes connecting to the base station. In the diagram, a multipoint base station would be the red circles and the subscriber units are the black circles attached via black lines. Cellular phone networks are another example of a multipoint network, where the subscriber stations are the mobile phones. A multipoint network can address broadband access requirements to more users than can be afforded with a point-to-point solution. Broadband capacities are shared amongst all of the subscribers connected to that base station.

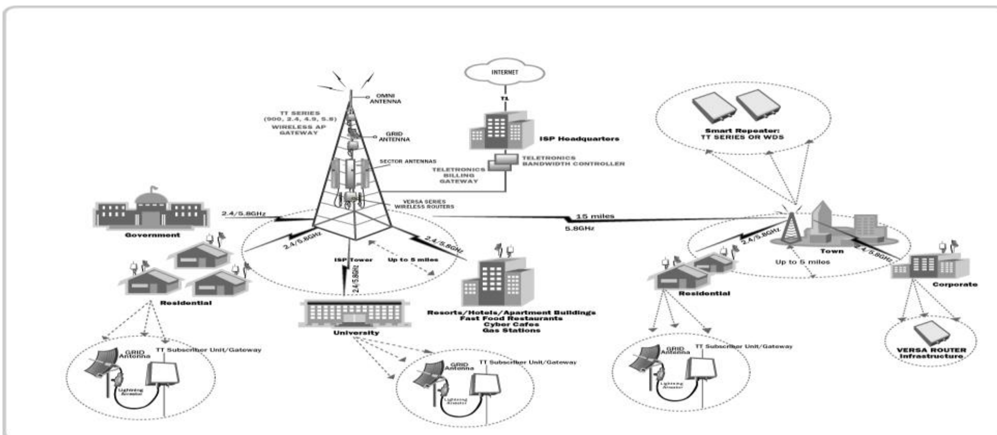

Fig: 4.8.2 Point to Multi point

4.8.3 Mesh Network :

A more recent wireless network topology that has been implemented for municipal Wi-Fi networks is mesh networking. Mesh offers a combination of point-to-point and point-to-multipoint capability by having each of the subscriber nodes able to communicate directly with other nodes. This obviates the base station element in the network, though one or more of the nodes are designated "off ramps" to connect the mesh with the Internet. The most successful implementations of mesh have been when a single entity has access to the nodes (i.e. an operator in a municipal network). Early mesh vendors discovered that providing broadband wireless access over mesh nodes were challenging because one user taking down his node would impact the performance and operation of other nodes relying on that device for connectivity.

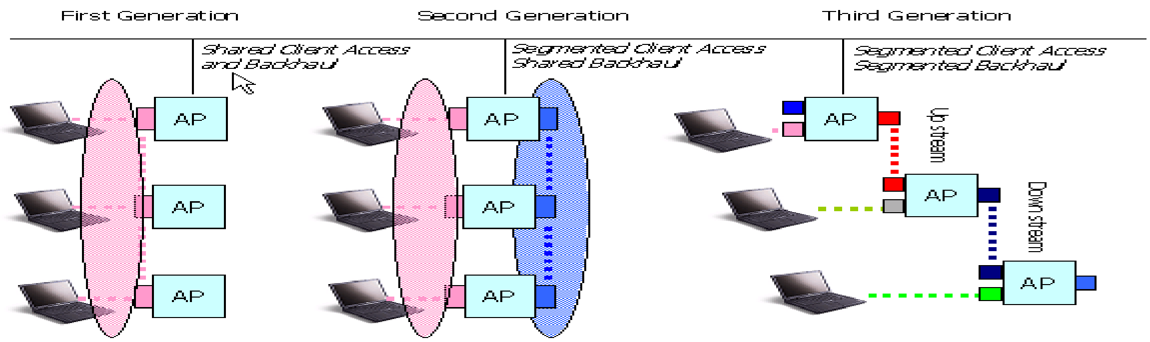

Fig: 4.8.3 Mesh Network

4.9 Uses of Repeater

The Single-Band RFR is working as a relay between the BTS and mobiles. It picks up the signal from the BTS via the Donor Antenna, linearly amplifies the signal and then retransmits it via the Coverage Antenna (or the Indoor Signal Distribution System) to the weak/blind coverage area. And the mobile signal is also amplified and retransmitted to the BTS via the opposite direction.

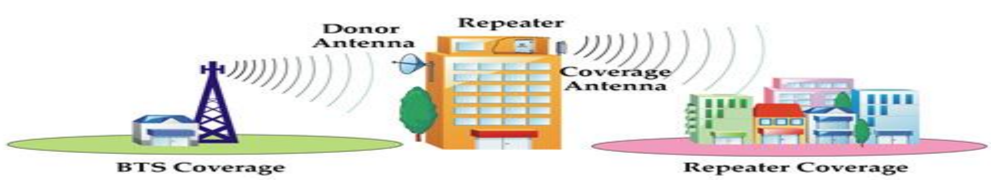

Fig:4.9.a Application Diagram of Outdoor Single-Band RF Repeater

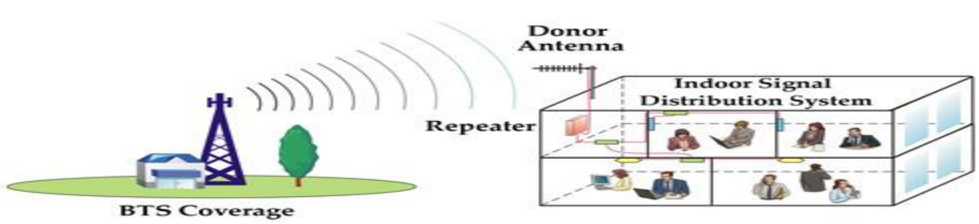

Fig:4.9.b Application Diagram of Indoor Single-Band RF Repeater

4.10 Modes of operation:

- Line of sight (LOS)
- Non-line of sight (NLOS)

Line of sight (LOS) or Non-line of sight (NLOS)

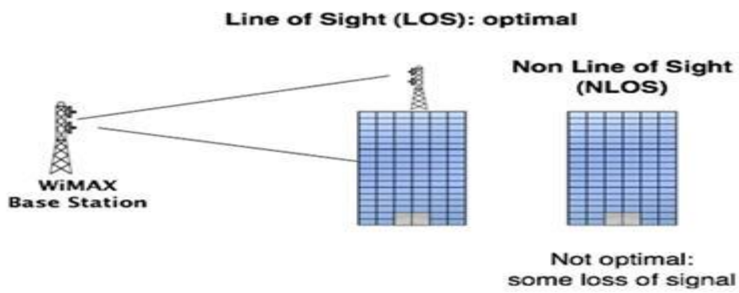

Figure : 3.10.aThe difference between line of sight and non-line of sight

Earlier wireless technologies (LMDS, MMDS for example) were unsuccessful in the mass market as they could not deliver services in non-line-of-sight scenarios. This limited the number of subscribers they could reach and, given the high cost of base stations and CPE, those business plans failed. WiMAX functions best in line of sight situations and, unlike those earlier technologies, offers acceptable range and throughput to subscribers who are not line of sight to the base station. Buildings between the base station and the subscriber diminish the range and throughput, but in an urban environment, the signal will still be strong enough to deliver adequate service. Given WiMAX's ability to deliver services non-line-of-sight, the WiMAX service provider can reach many customers in high-rise office buildings to achieve a low cost per subscriber because so many subscribers can be reached from one base station.

4.10.1 LOS versus NLOS

Line-of-sight (LOS) is a condition where a signal travels over the air directly from a wireless transmitter to a wireless receiver without passing an obstruction. LOS is an ideal condition for a wireless transmission because the propagation challenge only comes from weather or atmospheric parameters and the characteristic of its operating frequency. In LOS environment, signal can reach longer distance with better signal strength and higher throughput.

Conversely, non-line-of-sight (NLOS) is a condition where a signal from a wireless transmitter passes several obstructions before arriving at a wireless receiver. The signal may be reflected, refracted, diffracted, absorbed or scattered. These create multiple signals that will arrive at a receiver at different times, from different paths, and with different strength. Consequently, wireless systems developed for NLOS environment have to incorporate a number of techniques to overcome this problem and that make the systems more complex than those for LOS. But NLOS capable systems simplify network planning and site acquisition.

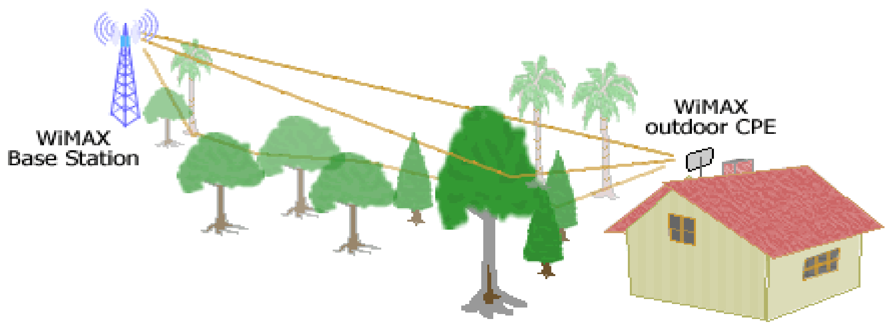

Figure. 4.10.1 Multipath in NLOS environment Signal travels thru multiple paths. Multiple reflected signals hit a receiver.

WiMAX offers operators the solution to address many applications with its outstanding performance in NLOS environment. WiMAX is built on the robust OFDM/OFDMA physical layer (PHY) which can work with larger delay spread typical in NLOS environment. It can easily overcome frequency selective fading by equalizing at sub-carrier level. And its long symbol period (due to its use of parallel sub-carriers) will eliminate the ISI (inter symbol interference).

A number of advanced techniques such as sub channelization, adaptive modulation and coding (AMC), AAS and MIMO are also incorporated into WiMAX to make it even perform better in NLOS environment. Sub channelization allows WiMAX to concentrate transmit power on sub-channel(s), increasing the reach of a signal. AMC in both downlink and uplink enables WiMAX to adjust modulation and code rate dynamically based on each sub-channel condition and data rate requirement. AAS can focus the WiMAX Base Station sector beam to the direction of a user device. And MIMO can improve signal strength and throughput significantly with every additional antenna at the BS and the SS. Those techniques can collectively improve WiMAX performance and coverage in areas with difficult terrain (hilly), many obstructions (buildings and trees), or inside a building.

4.11 The mobile wireless channel:

Two types of object:

-Base station

–Mobile station

Channel is time variant:

-Motion

-Weather

-Interference

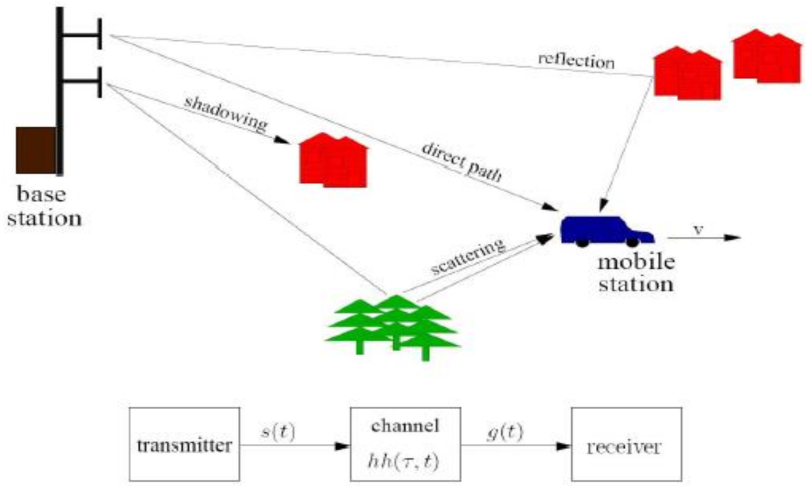

Fig: 4.11 The mobile wireless channel:

4.12 The channel transfer function looks like:

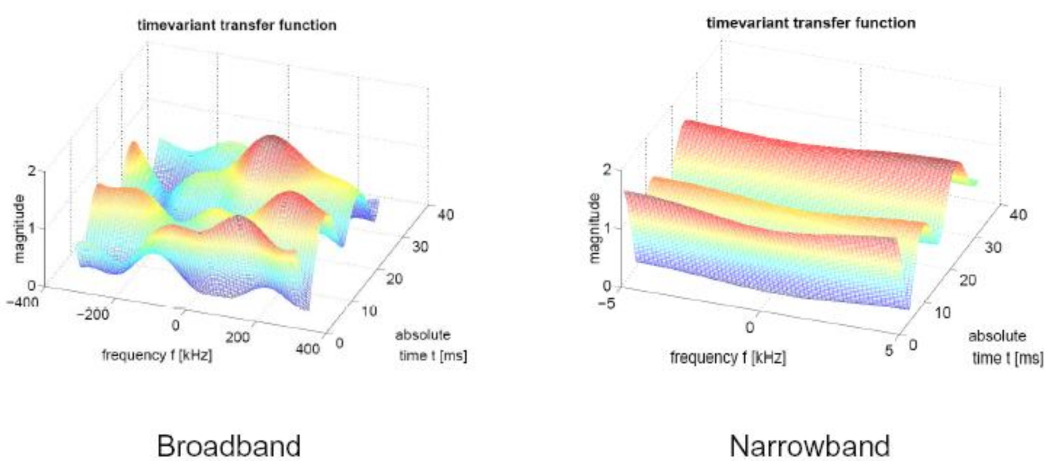

Fig: 4.12 The channel transfer function looks like