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Integrated Wi-Fi / WiMax Networks : A Comparitive Study

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Abstract - Wireless network operators provides wireless broadband services by using various wireless technologies such as Wi-Fi, WiMax, HSPA etc. Each of which provides different facilities and uses separate and different architecture and hence operation and services provided may become complex, costly, and sometimes limited.

In this paper, we consider two different network architecture, using Wi-Fi and WiMax as candidate technologies, integrated WiFi-WiMax network and WiFi-WiMax mesh network.With reference to both networks we study how the complementary features of WiFi and WiMax provides supplement services to each other to fulfil the limitations in individual and other existing networks.

Keywords – Wi-Fi, WiMax, Wireless mesh network, Integrated WiFi/WiMax.

1. INTRODUCTION

Recently most of the data services are provided by wireless access network based on ieee 802.11 known as wireless LAN. Traditionally WLAN's (Wi-Fi hotspots) are connected to to internet or other networks through wired infrastructure in remote rural and suburban areas.The implementation is not easy and also costly. Therefore the wired network infrastructure has been suggested to be replaced by employing ieee 802.16(WiMax)[1] technology of wireless metropolitian area network (WMAN).Different WiMax technologies provide promising solution to provide backhaul support for WLAN wifi hotspot. WiMax based network serves as backbone to connect multiple dispersed wifi hotspots to the internet. WiMAX technology has been designed for high-speed broadband wireless access network with capability of providing point-to-multipoint transmission and mesh networking. In such a network both static and mobile nodes, generally referred to as mesh routers and mesh clients, respectively, communicate wirelessly in a multihop fashion. In an infrastructure Wireless Mesh Network (WMN), the mesh routers form a backbone network for the mesh clients to connect to the Internet. Therefore, an integrated 802.11/802.16 network can be used to extend the coverage area of a WLAN and augment the service availability for mobile Internet applications [2]. In such an integrated 802.11/802.16 mesh network, mobile nodes provide mesh capabilities to the WLAN, while the WiMAX-WiFi Routers (WWRs) give this ability to WMAN segment.

In this paper, we first provide overview of the candidate technologies in section II. Architectures and properties of two internetworking model of Wi-Fi / WiMax are explained in section III. Finally we conclude paper in section IV.

2. OVERVIEW OF CANDIDATE TECHNOLOGIES

2.1. IEEE 802.11 (Wi-Fi)

Wi-Fi is flexible data communication systems that can be used for Internet connectivity within a small range of 300 ft in the indoor business environment or outdoor environment. It is used in different applications for wireless network connectivity where mobility is required.

Wi-Fi is a brand name of the Wi-Fi Alliance. There are various Wi-Fi enabled devices such as smart phone, personal computer, video game console and digital audio player to access wireless network by connecting the device within the range of a Wi-Fi network connected to the Internet. When one or more access points are used to provide wireless connectivity by overlapping way in different public places around the world then this type of network scenario is called hotspots.

Wi-Fi is not actually a technical term but the Wi-Fi Alliance [3] has usually imposed its use to depict only a narrow range of connectivity technologies including wireless local area network (WLAN) based on the IEEE 802.11 standards, device to device connectivity, and a range of technologies that support LAN, PAN and even WAN connections. Wi-Fi is usually operated in industrial, scientific, and medical (ISM) radio bands and unlicensed-national information infrastructure (U-NII) bands. Currently, Wi-Fi can be able to offer data rates up to 11 Mbps, but the industry is making a move toward high-speed Wi-Fi. Manufacturers are trying to develop some Wi-Fi to provide data rates up to 54 Mbps or higher. High speed connectivity to the Internet would make Wi-Fi a promising technology for the future data communications market.

According to its speed and the presented time, Wi-Fi technology can be divided into IEEE 802.11b, IEEE 802.11a, IEEE 802.11g and IEEE802.11n. IEEE802.11b and IEEE802.11g are commonly used [4]. IEEE802.11b is the oldest wireless network criterion and the most widely used Wi-Fi standard. Its maximum bandwidth is 11Mbps. When the signal is weak or there are interferences, the bandwidth can be adjusted to 5.5Mbps, 2Mbps and 1Mbps.The auto conditioning of bandwidth effectively ensure the stability and reliability of network.

IEEE 802.11a has a larger throughput than IEEE 802.11b. It works in the 5.8GHz frequency band and has good anti-interference ability. But it can not be compatible with IEEE 802.11b and IEEE 802.11g. Moreover, its coverage is relatively small (only about 30m indoor). So IEEE 802.11a is still rarely used among all the Wi-Fi standards currently. In order to solve the incompatible problems between IEEE 802.11a and IEEE 802.11b, IEEE 802.11 working group formally approved the IEEE 802.11g standard in July 2003[4]. It can be compliant with IEEE 802.11b. So the applications of IEEE 802.11g are more than IEEE 802.11a. IEEE 802.11n standard approved in 2009 by IEEE is the latest Wi-Fi standard. It has a standard of 300Mbps and up to 600Mbps transmission speed [5]. The IEEE 802.11n standard combined MIMO and OFDM technology [6], not only to improve the quality of wireless transmission, but also greatly enhance the transmission speed.

WI-FI NETWORKING SCHEME

2.1.1.Wi-Fi Networking Equipments

Wi-Fi is a wireless network consisting of wireless network adapter and AP [7][8]. AP is commonly called as access point or a network bridge, which is a bridge between traditional wired local networks and wireless local network. Wireless network adapter is the client device responsible for receiving transmit signals from AP.

2.1.2. The common Networking Scheme

Compared with wired networks, the construction of wireless network is more flexible and convenient. For the networking with two computers, point-to-point structure can be used and the

wireless AP is not required. For the networking with more than two computers, the infrastructure mode is used. A wireless AP (or wireless router) is adopted as the center of network [8].

I. Ad-Hoc network

Ad-Hoc network is the simplest wireless LAN topology. It is also known as point-to-point network or peer-to-peer network. It consists of a group of computers with wireless interfaces (wireless client). These wireless clients share the same workgroup name, extended service set

Identifier (ESSID) and password. Any two sites on the network can communicate directly [4]. All nodes in self organized network have the equal status[9]. Nodes can be joined and left the network at any time. The damage of node can not affect the entire network. So it has strong survivability.

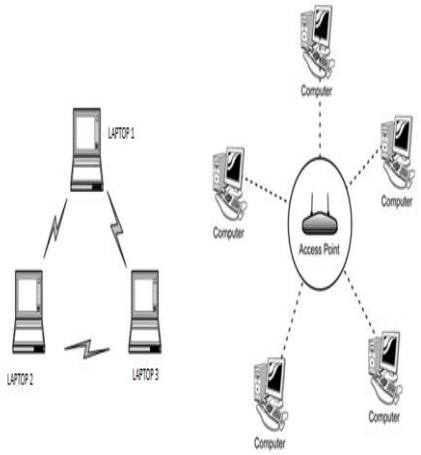

Figure 1. WLAN Ad-hoc network and Infracture network.

II. Infrastructure Network

Infrastructure network is also known as the network with a center. It consists of one or more wireless AP and a series of wireless client[4]. A wireless AP is used as a central station. All the wireless clients access to network by wireless AP. Since each site within the coverage of the central station can communicate with other sites, network layout confined by environment is relatively small. The largest shortage of infrastructure network is its poor survivability. The damage of central station is easy to result in paralysis of the entire network. Moreover, the central station increases the network cost.

2.2. IEEE 802.16 (WiMax)

WiMAX, the Worldwide Interoperability for Microwave Access, is a telecommunications technology that provides fixed and mobile Internet access in a very high speed, low-cost and flexible way. The name "WiMAX" was suggested by the WiMAX Forum, which was established in June 2001 to promote conformity and interoperability of the standard. The WiMAX forum [10] describes WiMAX as an IEEE- 802.16 standards-based technology to find an alternative solution to cable and Digital Subscriber Line (DSL) for the delivery of last mile wireless broadband Internet access.

The WiMAX network is mainly designed to fulfill the needs of business and consumer broadband service on the scale of the metropolitan area network (MAN). It has a facility to offer initially up to about 40 Mbps data rate per wireless channel for both fixed and portable applications to afford high speed connectivity in trains or buses for a better mobile wireless broadband Internet experience.

The 802.16 standard is usually used to provide end-to-end connectivity through point-to-multipoint topologies, where a base station offers traffic to many subscriber stations that are mounted on rooftops. The point-to-multipoint configuration in WiMAX network uses a particular scheduling strategy to attain high efficiency of data transmission as

stations transmit in their scheduled slots and do not compete with one another. The 802.16 also supports for mesh mode configuration such that subscriber stations can be able to relay traffic to one another by means of relaxing the line-ofsight requirement and reducing the deployment costs for high frequency bands.

WiMAX can be used as WiMAX backhaul services to provide the Internet connectivity to home, office building etc through Wi-Fi hotspots. Alternatively, users can also connect mobile devices such as laptops and handsets directly to WiMAX base stations without using Wi-Fi access points. Mobile devices linked directly to WiMAX tower can attain a range of 4 to 6 miles, because mobility makes links vulnerable. The WiMAX technology can also be used in rural areas that lack infrastructure for fast and cheap broadband access. It can be also applied in disaster management where the wired networks have broken down. WiMAX is capable to provide different real time applications such as VoIP, real-time video streaming, file transfer, and web traffic.

There are three topologies for WiMAX network: fixed point-to-point (P2P), fixed point-to-multipoint (P2MP) and mobile WiMAX. The WiMAX network consists of two key components: a base station and a subscriber device. The WiMAX base station is mounted on a tower or tall building to broadcast the wireless signal. The subscriber can receives the signals on a WiMAX-enabled notebook or mobile Internet device (MID). For fixed WiMAX deployments, a Customer Premises Equipment (CPE) is needed to act as a wireless modem providing interface to the WiMAX network for a specific location, such as a home, cafe, or office. A point-to-point (P2P) topology consists of a dedicated longrange, high-capacity wireless link between two sites. The central site hosts the base station (BS), and the remote site hosts the subscriber station (SS), as shown in Figure 1. The BS controls communications and security parameters in establishing the link with the SS. The P2P topology is used for high-bandwidth wireless backhaul services at a maximum operating range of approximately 48 km using line of sight (LOS) or non-line of sight (NLOS) signal propagation [11].

An example of point-to-multipoint (P2MP) topology, composed of a central BS supporting multiple SSs, providing network access from one location to many other locations. It is commonly used for last-mile broadband access such as private enterprise connectivity to remote offices, and longrange wireless backhaul services for multiple sites. P2MP networks can operate using LOS or NLOS signal propagation. Each P2MP BS has a typical operating range of 8 km [11]. Figure 2 illustrates the P2MP topology.

A mobile WiMAX topology is similar to a cellular network due to the fact that multiple BSs collaborate to provide seamless communications over a distributed network to both SSs and mobile subscribers (MSs). Coverage for a geographical area is divided into a series of overlapping areas called cells. Each cell provides coverage for users within its vicinity. The wireless connection is handed off from one cell to another when a user is crossing the border between two cells. Each BS radial coverage area is apprximately 8 km.

2.3. WI-FI V/S WIMAX

WiMAX is different from Wi-Fi in many respects. In fact, Wi-Fi can operate at distances as great as WiMAX but there are

two reasons why it doesn't. One of the reasons is that radios operating in the unlicensed frequencies are not allowed to be as powerful as those operated with licenses; and from convention, less power means less distance. These regulations are based on the dated assumption that devices can't regulate themselves — but the assumption may be correct over great enough distances. The second reason as to why Wi-Fi access points don't serve as wide an area as WiMAX access points do is the common engineering belief that the problem of everybody shouting at once, even if it's surmountable in a classroom, would be catastrophic in a larger arena. The Wi-Fi MAC layer uses contention access. This causes users to compete for data throughput to the access point. Wi-Fi even has problems with interference, and throughput and that is why triple play (voice, data, and video) technologies cannot be hosted on traditional Wi-Fi. In contrast, 802.16 use a scheduling algorithm [12]. This algorithm allows the user to only compete once for the access point. This gives WiMAX inherent advantages in throughput, latency, spectral efficiency, and advanced antenna support. From the technical point of view, it can be seen that both of these two wireless technologies are not basically addressed at the same market but are very complementary. Wi-Fi is basically an implementation of wireless local area network within a short range like a small building, a college or an institutional campus. WiMAX on the other hand is a metropolitan technology whose objective is to interconnect houses, buildings or even hot spots to allow communication between them and with other networks.

Although not being targeted on the same use, more recently WiMAX technology has several advantages compared to Wi-Fi. Such as: a better reflection tolerance; a better penetration of obstacles; and an increased in the number of interconnections (a few hundreds of equipment rather than some tens of equipment for Wi-Fi). It's obvious that the WiMAX standard goal is not to replace Wi-Fi in its applications but rather to supplement it in order to form a wireless network web. Despite the similarity in equipment cost, WiMAX technology requires a costly infrastructure in contrast to Wi-Fi which can easily be installed using low cost access points. These two wireless technologies have common components in their operations with a major difference in the communication range.

3. WIMAX / WIFI INTERNETWORKING

WiMAX which is WMAN (Wireless Metropolitan Area Network) standard complements Wi-Fi which is a WLAN (Wireless Local Area Network) standard, by providing support for high speed applications requiring data rates of up to 100 Mbps (802.11 a and d) over a wider coverage area with a radius of up to 1 mile as compared to lower coverage radius of 802.11 standards. The complementary nature of both the networks makes the integration of Wi-Fi and WiMAX favorable to offer several advantages such as ubiquitous high data rate provision, high quality of service (QoS) from the inbuilt QoS provision of WiMAX, etc. The service operators get larger network coverage with a small investment and the users get ubiquitous network access with guaranteed service .

Motorola and Intel in [13] recommended four different deployment models for the integrated

802.11 and 802.16 architecture. The different deployment models were:

I. Broadband 'on the go'

Deployment of 802.11 and 802.16 in the user devices, allows service providers to offer transparent service between 802.11 in hotspots and 802.16 beyond the hotspots. Deployment of 802.16 in areas with high density of Internet users extends broadband services beyond hotspots providing both users and service providers the utility and value of service.

II. Last mile broadband

In rural areas where the population density is scarce the expansion of DSL will be very expensive and in urban areas where it could be difficult to add wired connections to existing multiple dwelling units (MDU) the integrated network can be used to extend broadband connectivity in the last mile. 802.16 will be used as backhaul which will make the extension less costly.

III. Broadband Campus coverage

802.16 can cover larger area. It can provide connectivity beyond the individual buildings to an entire campus as blanket coverage. This allows service providers to offer choice of connectivity to users enabling them to connect to the 802.11 (Wi-Fi) network in the building or the 802.16 network which covers the campus. This usage of 802.16 can reduce the number of 802.11 access points needed to cover the entire campus, thereby reducing maintenance cost.

IV. Citywide Broadband

Municipalities are deploying IEEE 802.11 mesh networks to offer low-cost broadband connectivity across the city, but these networks can be costly. A cost-effective alternative is to use WiMAX to "backhaul" the WiFi mesh portals to the Internet wirelessly. In addition to using WiMAX to interconnect WiFi mesh portals, the same WiMAX network can provide an overlay solution enabling the service provider to offer a two- tier service to subscribers, where subscribers connect based on their mobility, bandwidth, and QoS requirements. For example, when in close proximity to a WiFi mesh access point, users connect via WiFi for high-bandwidth streaming; when users are in an area not covered by the mesh network or need higher QoS for a video session, they connect via WiMAX.

3.1. INTEGRATED WIMAX /WIFI NETWORK

When constructing integrated WiMAX/WiFi networks, one of the most challenging issues facing network designers is that of designing efficient links and Medium Access Control (MAC) layer protocols to optimize the QoS between the WiMAX and the WiFi components of the architecture [14]. Several researchers have recently proposed QoS provisioning mechanisms for integrated WiMAX/WiFi systems. QoS framework for 802.16/802.11 internetworking applications designed to map the QoS requirements of an application originating in an IEEE 802.11e network to an IEEE 802.16 network. Similarly, a QoS control protocol was also presented to support an integrated QoS for converged networks comprising WiMAX and WiFi systems[15][16]. To meet QoS, Researcher evaluates proposed efficient and unified connection-oriented architecture for integrating WiMAX and WiFi technologies in broadband wireless networks [17]. In the proposed approach, a new wireless Access Point (AP) device, designated as WiMAX/WiFi AP (W2-AP), is developed to manage the WiMAX/WiFi interface.

3.1.1.ARCHITECTURE

Figure 1 presents architecture includes a WiMAX BS, SSs, and WWRs. Additionally, there are some WiFi mobile STAs that are able to connect to their allotted WWR. In this architecture, we can have three types of connections: (i) between WiFi mobile STAs in the same domain, (ii) between WiFi mobile STAs of two different domains, and (iii) between the WiMAX SSs and WiFi STAs. In the first type of connection, STAs are able to simply connect to each other through the AP component of WWR. In the second type of connection,

the source STA should send its request packet to the WWR and it will forward the packet to the WiMAX BS, which forwards the packet to the destination STA through the assigned WWR in another domain. In the last type of connection, the WiMAX SS sends its request packet to the BS, which forwards it to the destination STA through the allotted WWR. In the case that a STA wants to make a connection with a SS, it should send its request packet to the BS by means of WWR.

A single WiMAX Base station BS, operating in a licensed band, serves both multiple WiMAX Subscriber Stations (SSs) and multiple W2-APs within its coverage area. In other words, the WiMAX system provides broadband wireless access to multiple W2-AP devices in a point-to-multipoint (PMP) topology. Each WiFi network is connected to the WiMAX BS through a WiMAX/WiFi (W2)-AP. The connection between the BS and a SS is connected to

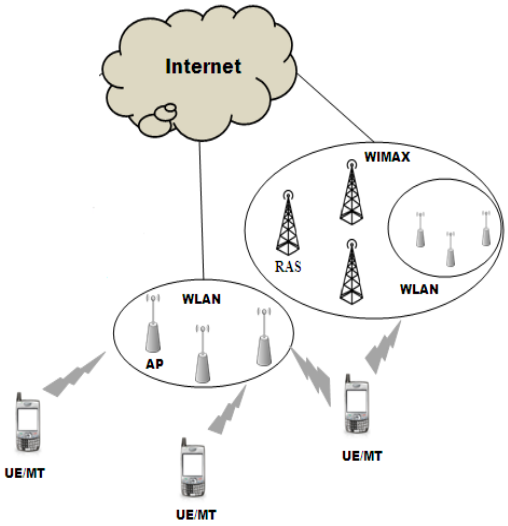

Figure.1 Integrated WiMAX/WiFi Network structure.

the WiMAX BS through a WiMAX/WiFi (W2)-AP. The connection between the BS and a SS is dedicated to a single user. However, the connection between the BS and each W2-AP is shared amongst all the nodes within the Wireless LAN served by the W2-AP. As a result, the WiMAX network guarantee secured communications service for connecting multiple scattered WiFi nodes to the Internet.

3.2.WIRELESS MESH NETWORK

As a flavor of ad hoc networking, Wireless Mesh Networks (WMNs) are dynamically self-organized and self-configured and mesh nodes automatically establish connections among themselves. This desirable feature helps significantly reduce up-front and maintenance costs. In addition, the wireless infrastructure provides the required robustness and reliability. However, further growth and widespread deployment of WMNs is not viable unless a number of serious issues are addressed. As multihop wireless networks, WMNs suffer from poor scalability of both the network architecture and protocols, which stem from the

noticeable degradation in capacity as the number of nodes increases. While capacity is not a very challenging issue in many ad hoc networks due to the low scale of communication patterns, it is considered a key factor in determining whether or not a WMN has an acceptable performance. Furthermore, the need for interoperability and compatibility with the existing wireless networks implies that designing new protocols from scratch is not a feasible option which means that a lot of protocols designed and tailored for mobile ad hoc networks are not applicable to WMNs. Overall, the need for high scalability along with interoperability and compatibility issues imposes serious challenges on protocol design in WMNs. It is often argued that, under such circumstances, a cross-layer deign in the protocol stack is indispensable.

Nodes in WMNs can be classified as either "mesh router", or "mesh client". While mesh routers are dedicated to routing the end-user packets, mesh clients can function as both endusers and routers by forwarding packets of the other mesh clients. Mesh routers and clients are different in terms of their mobility patterns and hardware/software architecture. While mesh routers are typically stationary or have restricted mobility so as not to cause mobility-induced failures, mesh clients can have arbitrary mobility patterns. Furthermore, routers are usually installed on streetlights, lampposts, or on the roof of buildings and are directly connected to power supplies and therefore have no energy constraints whereas mesh clients are typically battery-powered and therefore energy-constrained.

According to [18], the WMN architectures might be classified into three main groups. These groups are in fact distinguished by the level at which mesh capability is implemented

I. Infrastructure/Backbone WMNs.

This type of WMNs consists of mesh routers for forming an infrastructure for clients that connect to them. The clients can be Mesh clients or Conventional clients. The WMN infrastructure/ backbone may be built using various types of radio technologies, in addition to the mostly used IEEE 802.11 technologies. The mesh routers form a mesh of self-configuring, self-healing links among themselves, which acts as a backbone. The gateway functionality enables mesh routers to connect to the Internet.

II. Client WMNs.

Client WMNs have almost the same characteristics as a Mobile Ad-Hoc Network. Client meshing is used to enable peer-to-peer networking among client devices. In this type of architecture, client nodes constitute the actual network to perform routing and configuration functionalities as well as providing end-user applications to customers. This type of WMNs does not constitute mesh routers. In Client WMNs, a packet destined to a node in the network hops through multiple nodes to reach the destination. Client WMNs are formed using one type of radios on devices. Moreover, the requirements on end-user devices are increased due to the added routing and configuration functions.

III. Hybrid WMN

Hybrid WMN is the combination of infrastructure and client meshing. Mesh clients are able to access the network through mesh routers as well as directly meshing with other mesh clients. While the infrastructure provides connectivity to other networks ,such as the Internet, Wi-

Fi, WiMAX, cellular, and sensor networks. The routing capabilities of clients provide improved connectivity and coverage inside the WMN. The hybrid architecture provides full advantage of the WMN. Of all the Architectures it is best and has maximum applicability.

3.2.1. ARCHITECTURE

The difference between the WiFi-WiMAX mesh architecture and the previous architecture is the ability of two WWRs to connect to each other without the intervention of the BS. WWR is a device consisting of two omni-antennas. It integrates the properties of a WiMAX SS and a WiFi AP, in addition to routing ability. So it is able to be used as an integration interface to map different traffic classes and translate the protocols in MAC layer. More specifically, the

WiMAX and WiFi MAC PDU are converted into one another.Fig. 2 shows an example of mesh connectivity between WWRs which provides mesh capabilities in WiMAX segment of
our proposed solution. In the second type of connection, the source STA should send its request packet to the WWR, which forwards the packet to the other WWR instead of forwarding it to the BS. The intended WWR simply forwards the packet to the destination STA.

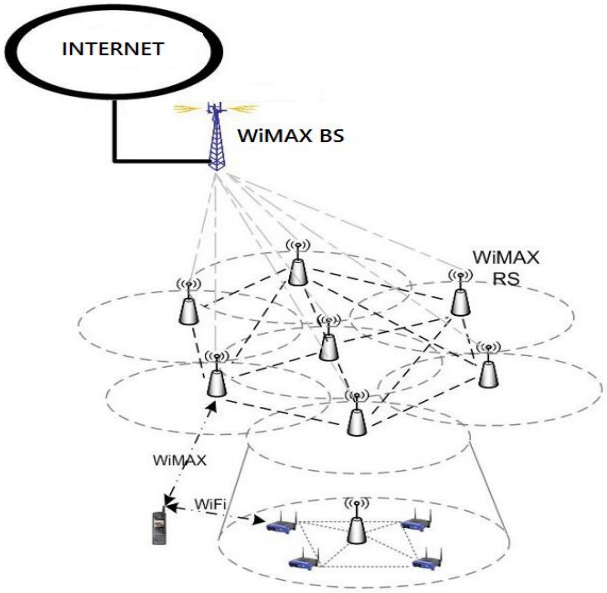

Figure.2 WiMAX/WiFi Mesh Network.

4. CONCLUSION

In this paper, we have discussed the nature and working scenario of Wi-Fi, WiMax, and there internetworking as integrated WiFi / WiMax and WiFi-WiMax mesh network.We can conclude from above discussion that WiFi and WiMax are the two of the most prominent developing wireless access networks and how these technologies may collaborate together to form an alternatives for implementing last-mile wireless broadband services. Detailed technical comparative analysis between the 802.11 (Wi-Fi) and 802.16 (WiMAX) wireless networks that provide alternative solution to the problem of information access in remote inaccessible areas where wired networks are not cost effective has been looked into. This work has proved that the WiMAX standard goal is not to replace Wi-Fi in its applications but rather to supplement it in order to form a wireless network web.

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