Case for Wi-Max Technology

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Abstract -- **Wireless communication requires a technology that gives higher speed. Wi-Max is giving more speed than existing technologies, like DSL, Wi-Fi, and Dial up access. Wi-MAX has answers to the problems faced by Broadband Access (DSL, Cable Modem), Wi-Fi Access (Wi-Fi Hotspots), Dial-up Access. This technology provides high speed broadband wireless access (BWA) and covers a large geographical area. In fact, WiMAX is not a technology, it is a certification mark. IEEE 802.16 has designed 'Interoperability Tests'. The devices which pass these tests get the 'Wi-MAX' certification. This interoperability certification is done by the WI-MAX Forum which is a non-profit organization intended to promote Wi-MAX worldwide.**

Keywords: Worldwide interoperability for microwave access, WiFi, DSL, Cable modem, Dial-up access, Broadband wireless access

I. INTRODUCTION

THERE are three different options to access Internet:

1. Broadband Access (DSL, Cable Modem)
2. Wi-Fi Access (Wi-Fi Hotspots)
3. Dial-up Access.

Broadband access doesn't cover all areas and it is quite expensive. Wi-Fi access has very small area coverage and dial-up access has very low speeds. So, it was necessary to have a technology to solve all of the above problems. Wi-MAX stands for "Worldwide Interoperability for Microwave Access". Wi-MAX is based upon the IEEE 802.16 standard. In fact, Wi-MAX is not a technology, it is a certification mark. IEEE 802.16 has designed 'Interoperability Tests'. The devices which pass these tests get the 'Wi-MAX' certification. This interoperability certification is done by the Wi-MAX Forum which is a non-profit organization intended to promote Wi-MAX worldwide. The IEEE 802.16 standard was designed for Wireless Metropolitan Area Networks (WMAN). Wi-MAX has two applications, namely Fixed Wi-MAX and Mobile Wi-MAX. Fixed Wi-MAX is based upon the IEEE 802.16-2004 standard. It deals with wireless communication between fixed devices. It provides BWA up to 30 miles. Mobile Wi-MAX is based upon the IEEE 802.16-2005 standard (formerly known as IEEE 802.16e). It deals with the wireless communication between a Wi-MAX base station and portable devices such as laptops and cell phones. It provides BWA up to 3-10 miles.

II. WI-MAX ARCHITECTURE

Fixed Wi-MAX has two types of architectures: Point-to-Point (P2P) architecture and Point-to-Multipoint (P2MP) architecture.

Point-to-Point Architecture: In P2P architecture, there is one transmitter and one receiver. In Wi-MAX's application as a backhaul, this architecture is used, in which a Wi-MAX base station acts as a transmitter and another base station acts as a receiver as shown in Fig. 1. Due to P2P architecture connectivity as far away as 30 miles becomes possible. So P2P finds application in providing wireless backhaul between two locations, thus connects cellular towers and Wi-Fi networks to cover a large geographical area [5].

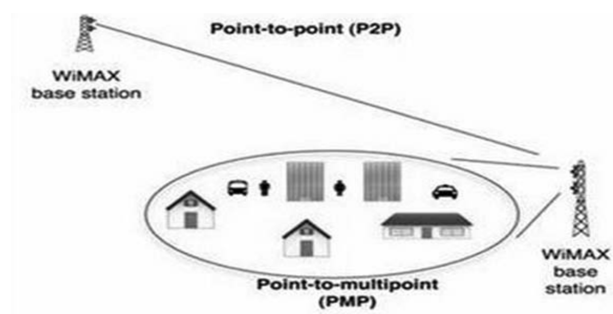

Figure 1. Point-to-point architecture.

Point to Multipoint Architecture: P2MP architecture is based upon IEEE 802.16.2004 standard. As the name suggests, in this architecture, there is one transmitter and several receivers. P2MP is synonymous with distribution. One base station supports thousands of subscribers which might be similar or dissimilar.

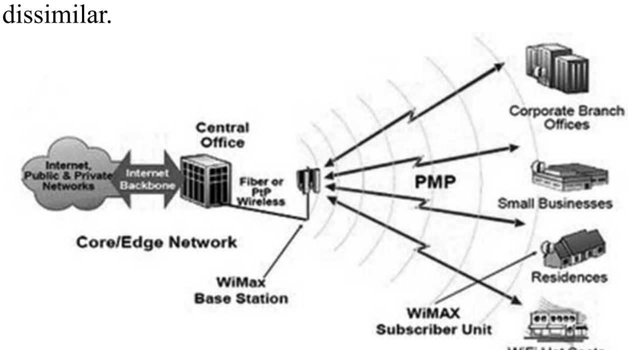

Figure 2. Point-to-multipoint architecture.

As shown in Fig. 2, a Wi-MAX base station provides services to corporate branch offices, small businesses, residences and Wi-Fi hot spots. So, WiMAX MAN uses P2MP architecture to locate base stations strategically so as to cover a large metro-area via microwave links.

III. FOUNDATION TECHNOLOGIES

Physical layers specified by the 802.16 standard, what spectrums they operate in, and the channel bandwidths that are possible for each. Data modulation schemes supported by each PHY are listed. A briefing of two technologies relied upon in the design of BWA networks is done: Orthogonal Frequency Division Multiplexing (OFDM) and Time Division Multiple Access (TDMA) and duplexing techniques such as Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD).

PHYs, Bands and Modulations: The 802.16 standard specifies five possible physical layers (PHY). These are also referred to as Air Interfaces. The reason for multiple PHYs is to fill differing needs around the world. Regulatory bodies across the globe do not present a uniform allocation of bands for specific uses. With this in mind, the IEEE tried to create a standard that is flexible enough to meet the needs of a broad constituency.

The frequency spectrum is divided into the following categories: -
Frequencies in the 10-66 GHz licensed bands; Frequencies between 2 and 11 GHz; License-exempt frequencies below 11 GHz. Frequency bands below 11 GHz are useful for applications where non-line-of-sight (NLOS) communication is necessary. In particular these bands are best used for wireless access from fixed locations where obstacles such as trees may obstruct the line-of-sight (LOS) between base stations and subscriber stations. These bands are also the focus of mobile systems [3].

Single Carrier PHY Characteristics: The IEEE standard for fixed BWA calls for default channel sizes of 20, 25 and 28 MHz for the SCa PHY and has the following to say about the SCa PHY:

"Channel bandwidths allowed shall be limited to the regulatory provisioned bandwidth divided by a power of 2 no less than 1.25 MHz."

Clause 12 of the standard which defines system profiles "to be used in typical implementation cases" specifies profiles for only 25 and 28 MHz wide channels for the S Ca PHY.

The standard calls for derivatives of Phase Key Shifting in all single carrier data modulations. QPSK and 16-QAM data modulations are mandatory for SC implementations, whereas 64-QAM modulation is optional. SCa implementations require support of Spread BPSK, BPSK, QPSK, 16-QAM and 64-QAM while 256-QAM is optional [6].

Multiple Carrier PHY Characteristics: The multiple-carrier PHYs use orthogonal frequency division multiplexing (OFDM or OFDMA) signal modulation and operate in the lower frequency bands. These PHYs are intended for NLOS applications. Two of the OFDM PHYs (Wireless MAN-OFDM and Wireless MAN-OFDMa) use the licensed bands between 2 and 11 GHz. Wireless MAN-HUMAN uses unlicensed bands below 11GHz. OFDM profiles specifying channel bandwidths from 1.75 MHz wide up to 28 MHz wide are identified in clause 12.

All of the OFDM PHYs operating in the licensed frequency bands require support of BPSK, QPSK, and 16-QAM modulations.

IV. MULTIPLEXING TECHNIQUES

OFDM: Orthogonal Frequency Division Multiplexing is used in wireless systems such as WiMAX to achieve high speed bi-directional wireless data communication. OFDM is based upon FDM and like FDM it transmits multiple signals simultaneously on a single transmission medium. Each signal is modulated on its own carrier frequency (sub-carrier). In FDM, sub-carriers are separated from each other by guard bands so that they do not overlap with each other (Fig. 3).

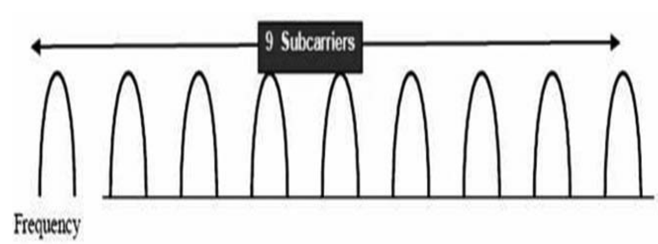

Figure 3. FDM with 9 Sub carriers.

The difference between OFDM and FDM is that in OFDM sub-carriers are more tightly packed than that of in FDM. And here the principle of orthogonality comes into picture. Frequencies are said to be orthogonal, if power spectral density of a frequency reaches at its peak when power spectral densities of other frequencies are at zero (Fig.4).

Figure 4. OFDM with 9 sub carriers.

So in OFDM, spectrums of signals overlap but they do not interfere with each other. So an efficient use of bandwidth is achieved as guard bands are removed. To modulate the data streams to be transmitted, modulation techniques such as Phase Shift Keying (PSK) or Quadrature Amplitude modulation (QAM) are used. To demodulate signals, Discrete Fourier Transform (DFT) technique is used at receiver. Multiple sub-carriers can be assigned to different users using Orthogonal Frequency Division Multiple Access (OFDMA). Suppose there are 5 sub-carriers. Then sub-carriers 1, 3 and 5 can be assigned to user 1 and sub-carriers 2 and 4 can be assigned to user 2 [3].

Time Division Multiple Access: In wireless networks multi-access methods, also known as channel access methods, allow multiple users access to the same physical medium and to share its capacity. Time Division Multiple Access (TDMA) is an example of a multi-access method. Using TDMA, multiple users access a single RF channel. A single RF channel is divided into a number of time slots and each unique slot is allocated to each user.

The difference between Time Division Multiplexing (TDM) and TDMA is that with TDM, the multiplexed signals come from the same node, whereas for TDMA the multiplexed signals come from different source\transmitters. The same concepts apply to Frequency Division Multiplexing (FDM) and Frequency Division Multiple Access (FDMA). In 802.16 BWAs, TDM is used for the downlink since the base station is a single source and TDMA is used for the uplink since there are multiple sources communicating with the base station. On the uplink, a single RF channel is shared by multiple users.

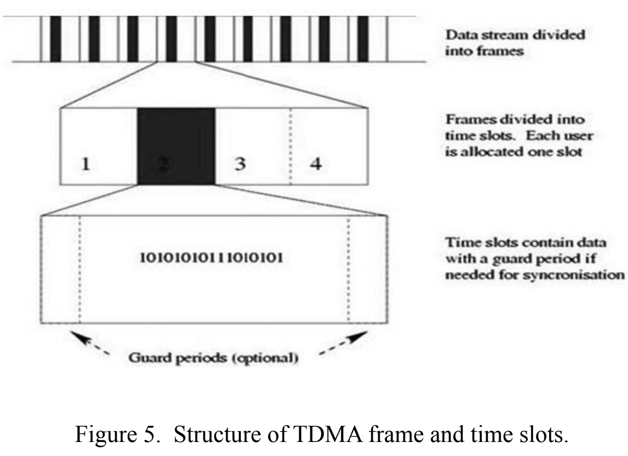

Figure 5. Structure of TDMA frame and time slots.

Figure 5 depicts structure of a TDMA frame and time slots. The RF channel is divided into number of frames. Each frame is divided into number of time slots. Each time slot is allocated to individual user. Each user transmits and receives through its own timeslot. Each timeslot is separated from other timeslots using guard time which might be optional. In dynamic TDMA, allocation of time slots to users depends upon demand. So sources with different data rates can be handled if time on the medium is allocated dynamically.

Duplexing: Duplexing means bidirectional communication between two devices. There are two forms of duplexing: Half-duplex and Full-duplex. In half-duplex, when one device transmits another device receives and vice versa. But transmission and reception do not take place simultaneously. In full-duplex, transmission and reception take place simultaneously.

In TDMA, there are two types of duplexing: Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD). In TDD, bidirectional communication takes place on the same frequency channel. So both Uplink (UL) and Downlink (DL) frequencies are same. So by definition, TDD is an example of half-duplex, as one device transmits, other device receives and vice versa.

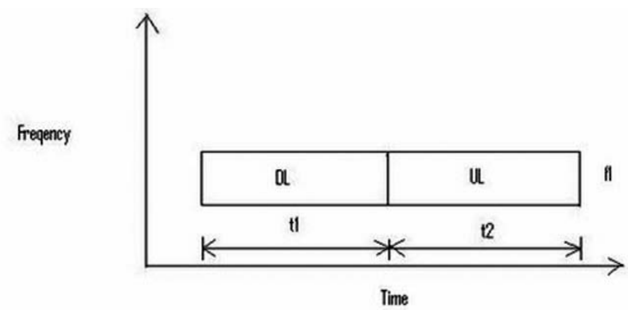

Figure 6. Data Frame.

As shown in the figure, a data frame is divided into two time slots. Time t1 is allocated to DL and time t2 is allocated to UL. So transmission takes place on DL during time t1 and reception takes place on UL during time t2 or vice versa [1].

It can be seen from the figure that, time allocated for UL and DL streams may be fixed or adaptive. If this allocated time varies, then it is called as A-TDD (Adaptive Time Division Duplexing). This dynamic time adjustment depends upon traffic conditions. A-TDD is widely used in broadband wireless systems because of its flexibility factor. It supports UL and DL asymmetric traffics and uses spectrum efficiently. As time allocation takes place depending upon traffic conditions, A-TDD supports both symmetric and asymmetric communication. So if data traffic is more in downstream compared to upstream, then more time is allocated for downstream than upstream. Take example of Google search engine, in which, we enter a small text, and in return we get a large information.

Similar to FDD, where two frequency channels are separated by guard bands, in TDD time frames are separated by guard time which is called as TX/RX Transition Gap (TTG). In this time, base station switches from transmit mode to receive mode and subscriber switches from receive mode to transmit mode or vice versa. This guard time is in terms of micro-seconds.

As shown in Fig.7, downlink stream has frequency f1 and the uplink stream has the frequency f2. So the transmission and reception overlap in time, that is, transmission and reception take place simultaneously. Half-duplex communication is also possible using FDD. As transmission by a device takes place on the frequency f1, the reception by another device takes place on another frequency f2, but not simultaneously. This system is called as H-FDD (Half-duplex Frequency Division Duplexing) or Frequency Shift Division Duplexing.

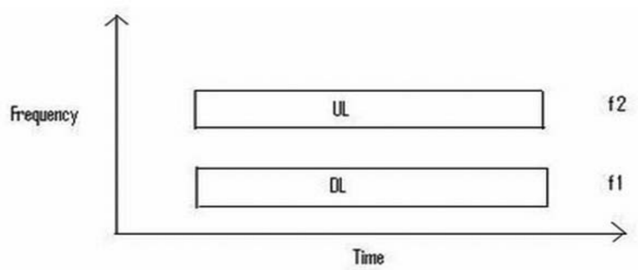

Figure 7. Downlink stream.

Multiplexing: Multiplexing means combining multiple signals and transmitting them on a single transmission medium so as to use transmission medium efficiently. Commonly used multiplexing techniques in telecommunication network are Frequency Division Multiplexing (FDM) and Time Division Multiplexing (TDM). FDM is based on the fact that useful bandwidth of the transmission medium exceeds the required bandwidth of a signal to be transmitted. Multiple signals are transmitted simultaneously by modulating them onto different carrier frequencies separated by guard bands. TDM is based on the fact that maximum channel capacity of the transmission medium exceeds the channel capacity required to transmit a signal. So transmission medium is divided into number of timeslots and multiple signals are transmitted simultaneously with each time slot dedicated to each signal to be transmitted [4].

V. ACCESS METHOD

Communication between wireless devices can be accomplished using protocols and techniques that require an antenna to transmit and receive radio waves. The physical layer (PHY) modulates and demodulates the signal. The Medium Access Control layer (MAC) coordinates access to the medium through control of the PHY. Furthermore, the MAC performs following functions [5]:

- Manages connections between the subscriber stations and base stations
- Manages link Quality of Service (QOS)
- Enforces security.

The PHY deals with:
- Encoding and modulation schemes
- Ranging
- Power control
- Dynamic Frequency Selection (DFS).

VI. INITIALIZATION AND SECURITY

In the access method of P2MP architecture, before WiMAX interacts with other wireless devices/ equipment, there will be a set of complex processes to set up a communication link between the BS and SS.
The complex steps that undergo before there is a call setup are:

- Channel acquisition
- Initial Ranging and Negotiation of SS capabilities
- SS Authentication and Registration
- IP connectivity
- Connection setup
- Radio Link Control (RLC).

Security framework: An information security framework requires that 3 basic conditions be met:

- Maintain availability of resources
- Ensure integrity of resources and data;
- Ensure confidentiality of data.

A fourth condition which may be met is non-repudiation. Non-repudiation means that a sender of a message may not disclaim it later. Non-repudiation is not provided for by the 802.16 standard and will not be discussed here.

Maintaining resource availability deals more with the choices of radio spectrum and bandwidth; modulation and encoding schemes, and antenna selection. 802.16 Security Objectives address confidentiality, integrity and protection from theft of services [7].

802.16 Security Objectives: The 802.16 standard specifies a Security Sub layer as part of the Medium Access (MAC). The Security Sub layer is sandwiched between the MAC Common Part Sublayer (MAC CPS) and the Physical Layer (PHY). The 802.16 security architecture is designed to provide subscribers with privacy across the wireless medium and to provide operators protection from theft of service.

VII. CONCLUSION

As compared to other technologies Wi-Max gives higher speed. Broadband access doesn't cover all areas and it is quite expensive. Wi-Fi access has small area coverage and dial-up access has very low speeds. So it was necessary to have a technology to solve these problems. An emerging technology, Wi-MAX, has answers to these problems. Wi-MAX is a technology in its infancy. It supplies solutions for backhaul connectivity for existing wireless hotspots and also offers end-user access in the unlicensed portion of the wireless spectrum. Local regulations may prevent Wi-MAX from reaching its full potential in the unlicensed spectrum.

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