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Survey on Mobile WiMAX- Technical Overview

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Abstract—

Worldwide Interoperability for Microwave Access (WiMAX), is a wireless communications technology aiming to provide wireless data over long distances in a variety of ways as an alternative to cable and DSL, from point-to-point links to full mobile cellular type access. It is based on the IEEE 802.16 standard.

The goal of this deliverable is to provide an overview of the functionality and a description of the WiMAX network architecture. We also evaluate the special features of the WiMAX technology, such as the improved coverage in Non Line Of Sight (NLOS) environments, in order to examine the applicability of well-known localization techniques. Some of the advanced features such as adaptive antenna systems (AAS) which can significantly improve the performance are discussed. The performance will enable transparency of quality of service (QoS) between Mobile WiMAX and broadband wired services such as Cable and DSL. The scalable architecture, high data throughput and low cost deployment make Mobile WiMAX a leading solution for wireless broadband services. Due to "friendly ecosystem" hundreds of companies have contributed to the development of the technology. Finally, we investigate the characteristics of WiMAX technology.

Keywords—WiMAX, DSL, NLOS, AAS, QoS.

I. INTRODUCTION

WiMAX, meaning Worldwide Interoperability for Microwave Access is a technology that provides wireless transmission of data using a variety of transmission modes, from point-to-point links to portable internet access. The WiMAX technology, based on the IEEE 802.16-2004 Air Interface Standard is rapidly proving itself as a technology that plays a key role in fixed broadband wireless metropolitan area networks. In December, 2005 the IEEE ratified the 802.16e amendment [2] to the 802.16 standard. Mobile WiMAX is a broadband wireless solution that enables convergence of mobile and fixed broadband networks through a common wide area broadband radio access technology and flexible network architecture. The Mobile WiMAX Air Interface adopts Orthogonal Frequency Division Multiple Access (OFDMA) for improved multi-path performance in non-line-of-sight environments. The Mobile WiMAX System Profile enables mobile systems to be configured based on a common base feature set thus ensuring baseline functionality for terminals and base stations that are fully interoperable. Release-1 Mobile WiMAX profiles will cover 5, 7, 8.75, and 10 MHz channel bandwidths for licensed worldwide spectrum allocations in the 2.3 GHz, 2.5 GHz, 3.3 GHz and 3.5 GHz frequency bands. Following figure 1.1 shows working of WiMAX.

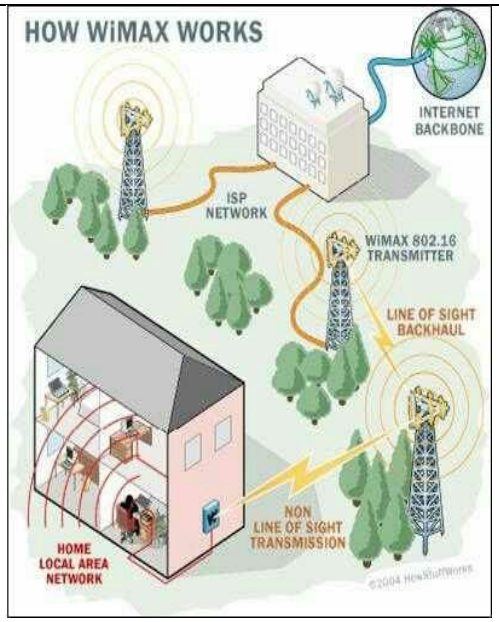

Fig.1: Model of WiMAX

II. FEATURES OF WIMAX

A. *High Data Rates:*

The inclusion of MIMO antenna techniques along with flexible sub-channelization schemes, Advanced Coding and Modulation all enable the Mobile WiMAX technology to support peak DL data rates up to 63 Mbps per sector and peak UL data rates up to 28 Mbps per sector in a 10 MHz channel.

B. *Quality of Service (QoS):*

The fundamental premise of the IEEE 802.16 MAC architecture is QoS. It defines Service Flows which can map to DiffServ code points or MPLS flow labels that enable end-to-end IP based QoS. Additionally, subchannelization and MAP-based signaling schemes provide a flexible mechanism for optimal scheduling of space, frequency and time resources over the air interface on a frame-by-frame basis.

C. *Scalability:*

Despite an increasingly globalized economy, spectrum resources for wireless broadband worldwide are still quite disparate in its allocations. Mobile WiMAX technology therefore, is designed to be able to scale to work in different channelizations from 1.25 to 20 MHz to comply with varied worldwide requirements as efforts proceed to achieve spectrum harmonization in the longer term. This also allows diverse economies to realize the multi-faceted benefits of the Mobile WiMAX access in rural settings versus enhancing the capacity of mobile broadband access in metro and suburban areas.

D. *Security:*

The features provided for Mobile WiMAX security aspects are best in class with EAP-based authentication, AES-CCM-based authenticated encryption, and CMAC and HMAC based control message protection schemes. Support for a diverse set of user credentials exists including; SIM/USIM cards, Smart Cards, Digital Certificates, and Username/Password schemes based on the relevant EAP methods for the credential type.

E. *Mobility:*

Mobile WiMAX supports optimized handover schemes with latencies less than 50 milliseconds to ensure real-time applications such as VoIP perform without service degradation. Flexible key management schemes assure that security is maintained during handover.

III. TECHNICAL OVERVIEW

A. *OFDMA Basics*

Orthogonal Frequency Division Multiplexing (OFDM) [6,7] is a multiplexing technique that subdivides the bandwidth into multiple frequency sub-carriers.

In an OFDM system, the input data stream is divided into several parallel sub-streams of reduced data rate (thus increased symbol duration) and each sub-stream is modulated and transmitted on a separate orthogonal sub-carrier. The increased symbol duration improves the robustness of OFDM to delay spread. Furthermore, the introduction of the cyclic prefix (CP) can completely eliminate Inter-Symbol Interference (ISI) as long as the CP duration is longer than the channel delay spread. The CP is typically a repetition of the last samples of data portion of the block that is appended to the beginning of the data payload. The CP prevents inter-block interference and makes the channel appear circular and permits low-complexity frequency domain equalization. A perceived drawback of CP is that it introduces overhead,

which effectively reduces bandwidth efficiency. While the CP does reduce bandwidth efficiency somewhat, the impact of the CP is similar to the "roll-off factor" in raised-cosine filtered single-carrier systems. Since OFDM has a very sharp, almost "brick-wall" spectrum, a large fraction of the allocated channel bandwidth can be utilized for data transmission, which helps to moderate the loss in efficiency due to the cyclic prefix.

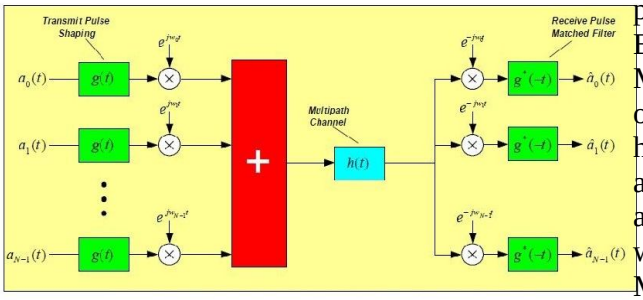

Fig. 2: Basic architecture of OFDM system

OFDM exploits the frequency diversity of the multipath channel by coding and interleaving the information across the sub-carriers prior to transmissions. OFDM modulation can be realized with efficient Inverse Fast Fourier Transform (IFFT), which enables a large number of sub-carriers (up to 2048) with low complexity. In an OFDM system, resources are available in the time domain by means of OFDM symbols and in the frequency domain by means of sub-carriers. The time and frequency resources can be organized into sub-channels for allocation to individual users. Orthogonal Frequency Division Multiple Access (OFDMA) is a multiple access/multiplexing scheme that provides multiplexing operation of data streams from multiple users onto the downlink sub-channels and uplink multiple access by means of uplink sub-channels.

B. Mobility Management

Battery life and handoff are two critical issues for mobile applications. Mobile WiMAX supports Sleep Mode and Idle Mode to enable power-efficient MS operation. Mobile WiMAX also supports seamless handoff to enable the MS to switch from one base station to another at vehicular speeds without interrupting the connection.

C. Power Management

Mobile WiMAX supports two modes for power efficient operation – Sleep Mode and Idle Mode. Sleep Mode is a state in which the MS conducts pre-negotiated periods of absence from the Serving Base Station air interface. These periods are characterized by the unavailability of the MS, as observed from the Serving Base Station, to DL or UL traffic. Sleep Mode is intended to minimize MS power usage and minimize the usage of the Serving Base Station air interface resources. The Sleep Mode also provides flexibility for the MS to scan other base stations to collect information to assist handoff during the Sleep Mode. Idle Mode provides a mechanism for the MS to become periodically available for DL broadcast traffic messaging without registration at a specific base station as the MS traverses an air link environment populated by multiple base stations. Idle Mode benefits the MS by removing the requirement for handoff and other normal operations and benefits the network and base station by eliminating air interface and network handoff traffic from essentially inactive MSs while still providing a simple and timely method (paging) for alerting the MS about pending DL traffic.

D. Handoff

There are three handoff methods supported within the 802.16e standard – Hard Handoff (HHO), Fast Base Station Switching (FBSS) and Macro Diversity Handover (MDHO). Of these, the HHO is mandatory while FBSS and MDHO are two optional modes. The WiMAX Forum has developed several techniques for optimizing hard handoff within the framework of the 802.16e standard. These improvements have been developed with the goal of keeping Layer 2 handoff delays to less than 50 milliseconds. When FBSS is supported, the MS and BS maintain a list of BSs that are involved in FBSS with the MS. This set is called an Active Set. In FBSS, the MS continuously monitors the base stations in the Active Set. Among the BSs in the Active Set, an Anchor BS is defined. When operating in FBSS, the MS only communicates with the Anchor BS for uplink and downlink messages including management and traffic connections. Transition from one Anchor BS to another (i.e. BS

switching) is performed without invocation of explicit HO signaling messages. Anchor update procedures are enabled by communicating signal strength of the serving BS via the CQI channel. A FBSS handover begins with a decision by an MS to receive or transmit data from the Anchor BS that may change within the active set. The MS scans the neighbor BSs and selects those that are suitable to be included in the active set. The MS reports the selected BSs and the active set update procedure is performed by the BS and MS. The MS continuously monitors the signal strength of the BSs that are in the active set and selects one BS from the set to be the Anchor BS. The MS reports the selected Anchor BS on CQICH or MS initiated HO request message. An important requirement of FBSS is that the data is simultaneously transmitted to all members of an active set of BSs that are able to serve the MS. For MSs and BSs that support MDHO, the MS and BS maintain an active set of BSs that are involved in MDHO with the MS. Among the BSs in the active set, an Anchor BS is defined. The regular mode of operation refers to a particular case of MDHO with the active set consisting of a single BS. When operating in MDHO, the MS communicates with all BSs in the active set of uplink and downlink unicast messages and traffic. A MDHO begins when a MS decides to transmit or receive unicast messages and traffic from multiple BSs in the same time interval. For downlink MDHO, two or more BSs provide synchronized transmission of MS downlink data such that diversity combining is performed at the MS. For uplink MDHO, the transmission from a MS is received by multiple BSs where selection diversity of the information received is performed.

E. Security

Mobile WiMAX supports best in class security features by adopting the best technologies available today. Support exists for mutual device/user authentication, flexible key management protocol, strong traffic encryption, control and management plane message protection and security protocol optimizations for fast handovers. The usage aspects of the security features are:

a. Key Management Protocol:

Privacy and Key Management Protocol Version 2 (PKMv2) is the basis of Mobile WiMAX security as defined in 802.16e. This protocol manages the MAC security using PKM-REQ/RSP messages. PKM EAP authentication, Traffic Encryption Control, Handover Key Exchange and Multicast/Broadcast security messages all are based on this protocol.

b. Device/User Authentication:

Mobile WiMAX supports Device and User Authentication using IETF EAP protocol by providing support for credentials that are SIM-based, USIM-based or Digital Certificate or Username /Password-based. Corresponding EAP-SIM, EAP-AKA, EAP-TLS or EAP-MSCHAPv2 authentication methods are supported through the EAP protocol. Key deriving methods are the only EAP methods supported.

c. Traffic Encryption:

AES-CCM is the cipher used for protecting all the user data over the Mobile WiMAX MAC interface. The keys used for driving the cipher are generated from the EAP authentication. A Traffic Encryption State machine that has a periodic key (TEK) refresh mechanism enables sustained transition of keys to further improve protection.

d. Control Message Protection:

Control data is protected using AES based CMAC, or MD5-based HMAC schemes.

e. Fast Handover Support:

A 3-way Handshake scheme is supported by Mobile WiMAX to optimize the re-authentication mechanisms for supporting fast handovers. This mechanism is also useful to prevent any man-in-the-middle-attacks.

F. Smart Antenna Technologies

Smart antenna technologies typically involve complex vector or matrix operations on signals due to multiple antennas. OFDMA allows smart antenna operations to be performed on vector-flat sub-carriers. Complex equalizers are not required to compensate for frequency selective fading. OFDMA therefore, is very well-suited to support smart antenna technologies. In fact, MIMO-OFDM/OFDMA is envisioned as the corner-stone for next generation broadband communication systems [3, 4]. Mobile WiMAX supports a full range of smart antenna technologies to enhance

system performance. The smart antenna technologies supported include:

a. Beamforming:

With beamforming [5], the system uses multiple-antennas to transmit weighted signals to improve coverage and capacity of the system and reduce outage probability.

b. Space-Time Code (STC):

Transmit diversity such as Alamouti code [6, 7] is supported to provide spatial diversity and reduce fade margin.

c. Spatial Multiplexing (SM):

Spatial multiplexing [8, 9] is supported to take advantage of higher peak rates and increased throughput. With spatial multiplexing, multiple streams are transmitted over multiple antennas. If the receiver also has multiple antennas, it can separate the different streams to achieve higher throughput compared to single antenna systems. With 2x2 MIMO, SM increases the peak data rate two-fold by transmitting two data streams. In UL, each user has only one transmit antenna, two users can transmit collaboratively in the same slot as if two streams are spatially multiplexed from two antennas of the same user. This is called UL collaborative SM.

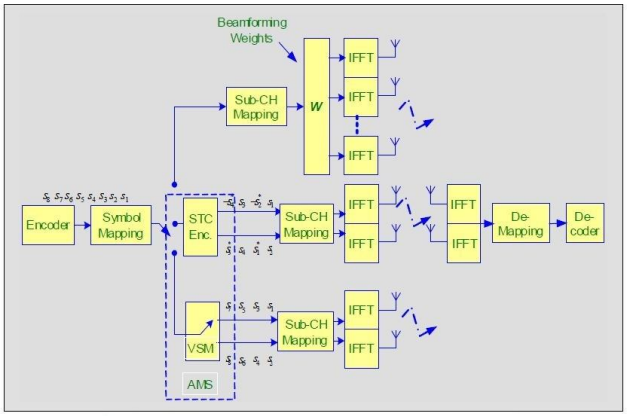

Fig 3.1: Adaptive switching for smart antenna

Mobile WiMAX supports adaptive switching between these options to maximize the benefit of smart antenna technologies under different channel conditions. For instance, SM improves peak throughput. However, when channel conditions are poor, the Packet Error Rate (PER) can be high and thus the coverage area where target PER is met may be limited. STC on the other hand provides large coverage regardless of the channel condition but does not improve the peak data rate. Mobile WiMAX supports Adaptive MIMO Switching (AMS) between multiple MIMO modes to maximize spectral efficiency with no reduction in coverage area. Figure 2 shows the architecture for supporting the smart antenna features. The following table provides a summary of the theoretical peak data rates for various DL/UL ratios assuming a 10 MHz channel bandwidth, 5 ms frame duration with 44 OFDM data symbols (out of 48 total OFDM symbols) and PUSC sub-channelization. With 2x2 MIMO, the DL user and sector peak data rate are theoretically doubled. The maximum DL peak data rate is 63.36 Mbps when all the data symbols are dedicated to DL. With UL collaborative SM, the UL sector peak data rate is doubled while the user peak data rate is unchanged. The UL user peak data rate and sector peak data rate are 14.11 Mbps and 28.22 Mbps respectively when all the data symbols are dedicated to UL. By applying different DL/UL ratio, the bandwidth can by adjusted between DL and UL to accommodate different traffic patterns. It should be noted that the extreme cases such as all DL and all UL partition are rarely used. The WiMAX profile supports DL/UL ratios ranging from 3:1 to 1:1 to accommodate different traffic profiles. The resulting peak data rates that will typically be encountered are in between the two extreme cases.

IV. APPLICATION

A. Eduction Networks :

Taking knowledge to remote place is a difficult task. Providing teachers in remote villages is impossible. Therefore , group of schools could use WiMAX to connect schools within a district and near by rural area. Classroom instruction could be deliver in real time between two or more schools using video link via a private WiMAX network.

B. Public Safety :

In a crisis like terrorist attack, fire, earthquake communication weakest link hampering rescue

operations. WiMAX networks could be used aid response in emergency situation. As well as two-way voice communication, video communication could also be relayed between the accident/disaster site to a dispatch centre allowing emergency teams to asses situation in real time. Also mobile WiMAX could allow emergency teams to access databases of information from moving vehicles.

C. Offshore Communication :

WiMAX could provide a communications link between land based facilities and offshore sites to support remote operations. WiMAX networks are quickly and easily deployed, even when offshore sites are moved to different location.

D. Campus Connectivity :

University, large public sector under takings, reaserch laboratories, government complex are distributed in different buildings over a large area, called as campus. Multiple locations within campuses could be connected via WiMAX.

E. Temporary Constructions Communications :

As constructions sites are temporary wired solutions are impractical. WiMAX equipment is highly portable so therefore can be redeployed and reused at other construction sites.

V. Conclusion

The attributes and performance capability of Mobile WiMAX makes it a compelling solution for high performance, low cost broadband wireless services. Mobile WiMAX is on a path to address a global market through a common wide area broadband radio access technology and flexible network architecture. This technology is based on open standard interfaces developed with close to 400 companies contributing to and harmonizing on the system specifications thus laying a foundation for worldwide adoption and mass market appeal.

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