IEEE 802.16: WiMAX Overview, WiMAX Architecture

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Abstract—**WiMax, the Worldwide Interoperability for Microwave Access is a new technology dealing with provision of data over long distance using wireless communication method in many different ways. Based on IEEE 802.16 WiMax is claimed as an alternative broadband rather than cable and DSL. This paper is a quick technical overview and covers:WiMAX overview(Fundamental Concept; Technology; Standard update) andWiMAX architecture(Network and Node Architectures; Physical Layer; MAC Layer)**

Index Terms— **Broadband, IEEE 802.16, WiMAX.**

I. WiMAX Overview

A. Fundamental Concept

WiMAX (Worldwide Interoperability for Microwave Access) is a *connection-oriented* wide area network [1]. It supports high bandwidth and *hundreds of users per channel* at speeds similar to currently seen for DSL, Cable or a T1 connection; Promises to provide a *range of 30 miles* as an alternative to wired broadband like cable and DSL. It could potentially provide *broadband access to remote places.* Use point-to-multipoint *(P2MP)* architecture. It is designed for delivering broadband seamless *quality multimedia services* to the end users. "WiMAX combines the familiarity of Wi-Fi with the mobility of cellular that will deliver personal mobile broadband that moves with you" [2].

B. WiMAX Devices

- A WiMAX base-station which is similar to a cellular tower, except that it can cover of almost of 3,000 square miles (~8,000 square km).
- A WiMAX receiver could be standalone tower or a PCMCIA card inserted into your laptop. By having such large coverage areas, potential problems of handoffs associated with 802.11 seems to be solved.

C. Challenge

QoS is a challenge. Efficient scheduling design is left for designers and developers. Consequently providing QoS Scheduling Architecture for WiMAX Base Stations is a challenge for system developers.

D. WiMAX and Wireless Mesh Network

"If WiMAX and Wi-Fi technologies can work together in a mesh environment, it would bring at least a temporary resolution to the issue of whether or not the technologies are actually competitive with one another. It seems that as the

wireless newcomer, WiMAX always has been viewed as being potentially competitive with every other wireless broadband access technology, including 3G and Wi-Fi, but using WiMAX as the backhaul method in a Wi-Fi mesh topology will prove the two technologies to be complementary."[3].
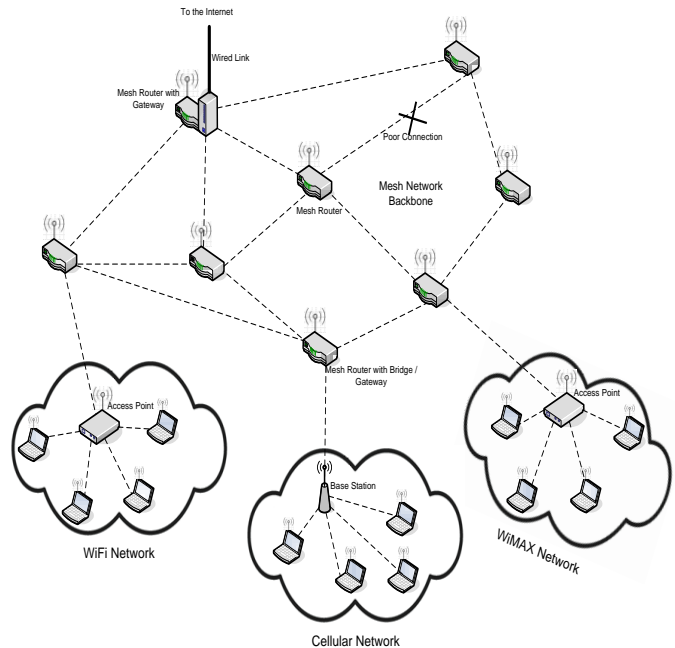

Fig. 1. Overview of a backbone mesh network and connections to WiFi, WiMAX, and wireless cellular networks [4].

E. WiMAX vs. 3G

The common Misconceptions about WiMAX & 3G CDMA are [5]:

1) Cost considerations

- WiMAX networks cost less (by a factor of 2 – 10x)
- WiMAX devices will cost less
- WiMAX IPR cost will be lower
- WiMAX has larger ecosystem (many participants, more competition)

2) Services and revenue

- WiMAX is optimized for data, 3G CDMA is for voice
- 16d WiMAX systems are easily upgraded to mobility
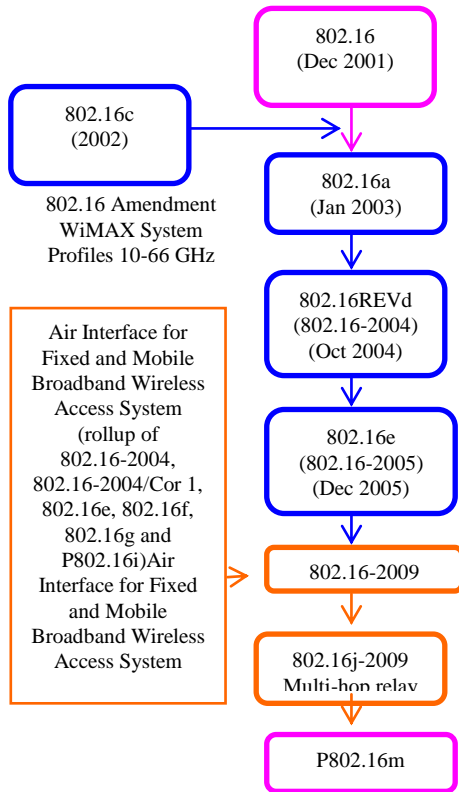- WiMAX is Wi-Fi with greater range

F. IEEE 802.16 Features

802.16 is used for WiMAX with the features:
- Uses wireless link with *microwave or millimeter waves.*
- Uses licensed spectrum
- Provides public network service to fee-paying customers
- Uses point-to-multipoint *(P2MP)* architecture
- Simple stationary *rooftop* or tower-mounted antennas
- Provide broadband and *QoS guarantee data transmissions.*

G. IEEE 802.16 Standard History

802.16
(Dec 2001)

802.16c
(2002)

802.16 Amendment
WiMAX System
Profiles 10-66 GHz

802.16a
(Jan 2003)

Air Interface for
Fixed and Mobile
Broadband Wireless
Access System
(rollup of
802.16-2004,
802.16-2004/Cor 1,
802.16e, 802.16f,
802.16g and
P802.16i)Air
Interface for Fixed
and Mobile
Broadband Wireless
Access System

802.16REVd
(802.16-2004)
(Oct 2004)

802.16e
(802.16-2005)
(Dec 2005)

802.16-2009

802.16j-2009
Multi-hop relay

P802.16m

H. 802.16 Standards

	IEEE 802.16	IEEE 802.16a/ Rev'd	IEEE 802.16e	IEEE 802.16j- 2009
Completed	December 2001	May 2004	Mid-2005	May 2009
Frequency	10 - 66 GHz	2 – 11 GHz	2 – 6 GHz	10 – 66 GHz Below 11 GHz
Application	Backhaul	Wireless DSL and Backhaul	Mobile Internet	Wireless MAN
Channel Conditions	Line of Sight Only	Non-Line of Sight	Non-Line of Sight	LOS NLOS
Bit Rate	32 – 134 Mbps at 28 MHz Channelization	Up to 75 Mbps at 20 MHz Channelization	Up to 15 Mbps at 5 MHz Channelization	Up to 120 Mbps at 25 MHz or 28 MHz Channelization
Modulation	QPSK,16QAM and 64QAM	OFDM 256, OFDMA 2048 QPSK,16QAM,64QAM	Same as 802.16d,Scalable OFDMA	BPSK, QPSK, 16-QAM, 64-QAM, OFDM, OFDMA
Channel Bandwidths	20,25 and 28 MHz	Selectable Channel Bandwidths Between 1.5 and 20 MHZ	Same as 802.16d	25 MHz or 28 MHz are typical

II. WiMAX Architecture

A. WiMAX Network Architecture

BS: Base Station
SS: Subscriber Station
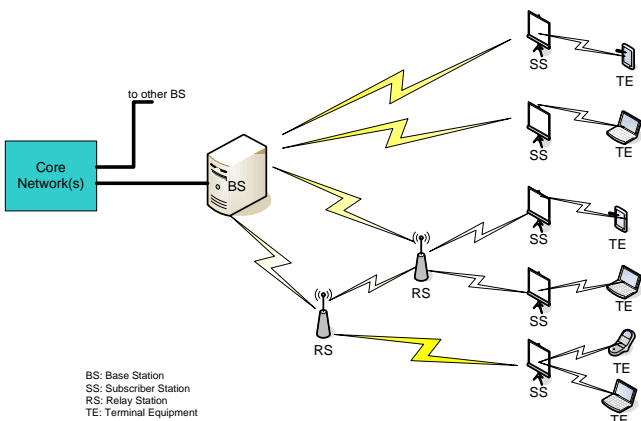RS: Relay Station
TE: Terminal Equipment

Fig. 2. IEEE 802.16 network architecture

WiMAX architecture consists of two types of fixed (non mobile) stations:
- Subscriber Stations (SS): serves a building (business or residence)
- Base station (BS): connects to public network and provide SS with first-mile access to public networks

The communication path between SS and BS has two directions:
- Uplink (from SS to BS)
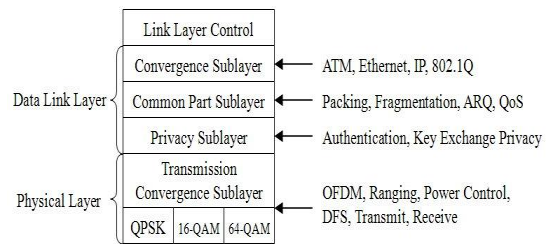- Downlink (from BS to SS)

B. WiMAX Layer Architecture

Physical layer functions are encoding/decoding of signals, preamble generation/removal, and bit transmission/reception.

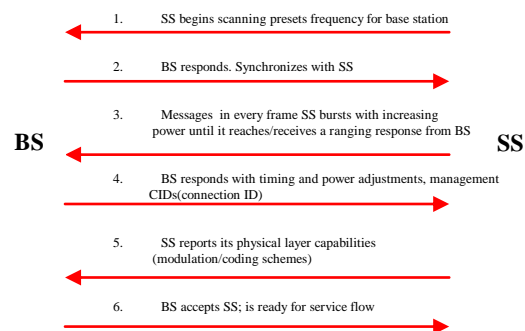In the *Data link layer,* medium access control functions are:
- On transmission, assemble data into a frame with address and error detection fields
- On reception, disassemble frame, and perform address recognition and error detection
- Govern access to the wireless transmission medium
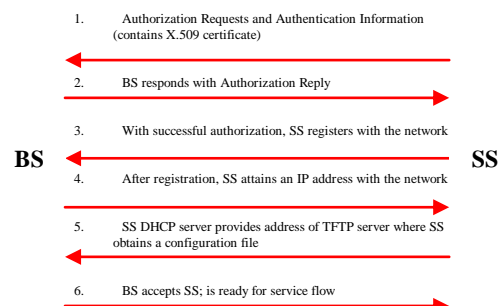For the convergence layer, functions are:

Encapsulate PDU framing of upper layers into native 802.16 MAC/PHY frames, map upper layer's addresses into 802.16 addresses, translate upper layer QoS parameters into native 802.16 MAC format, and adapt time dependencies of upper layer traffic into equivalent MAC service.

C. Channel Acquisition Process between an SS and BS [6]

1. SS begins scanning presets frequency for base station
2. BS responds. Synchronizes with SS
3. Messages in every frame SS bursts with increasing power until it reaches/receives a ranging response from BS
4. BS responds with timing and power adjustments, management CIDs(connection ID)
5. SS reports its physical layer capabilities (modulation/coding schemes)
6. BS accepts SS; is ready for service flow

D. SS Authentication and Registration [5]

1. Authorization Requests and Authentication Information (contains X.509 certificate)
2. BS responds with Authorization Reply
3. With successful authorization, SS registers with the network
4. After registration, SS attains an IP address with the network
5. SS DHCP server provides address of TFTP server where SS obtains a configuration file
6. BS accepts SS; is ready for service flow

E. Multimedia over WiMAX

The basic idea of multimedia streaming is transporting different types of desired media content to the user over a network, and displaying it to the user. Both, 'Live and interactive audio/video' on the other hand, involve a client and two servers.

WiMAX has the capability to deliver broadband speeds over 70Mb/s in an efficient manner. A sophisticated QoS scheme is needed to have a real time experience of voice and Video applications.

The architecture of WiMAX Base-Station with QoS provision for Multimedia Application is as follow:

Base Station (BS) QoS architecture:

- A *compensation block* receives *Carrier to Interference Noise Reports (CINR)*, also bandwidth requests, from substations (SSs).
- Based on reports, *compensation block* labels a flow as a bad or a good flow.
- The *Connection Identifiers (CIDs)* belonging to a bad flow are marked as banned by the compensation block.
- The compensation block connects to an *intelligent packet scheduler* to select the appropriate flow for transmission. A system channel aware.
- Before transmitting a packet, the *scheduler checks* whether the packet has a banned CID to stop transmitting it.
- The *classifier* gets feedback from the compensation block.
- Connections with separate connection IDs (CIDs) and classifies traffic based on a class-based approach are differentiated.
- QoS admits frames with only those CIDs that can be serviced without any significant delay to the real time voice and video applications, thus:
- It rejects a CID that experiences bad channel quality and allows unmarked CIDs to utilize the channel at its maximum efficiency.
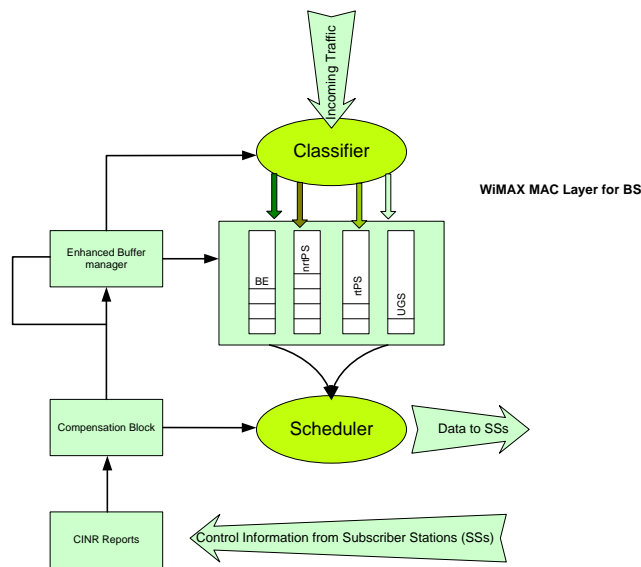

Fig. 3. WiMAX BS Architecture

F. Physical Layer

The physical layer supports:

- OFDM: Orthogonal Frequency Division Multiplexing
- TDD: Time Division Duplex
- FDD: Frequency Division Duplex
- QPSK: Quadrature Phase Shift Keying

G. MAC Layer

WiMAX MAC layer is a point to multipoint protocol (P2MP). It supports high bandwidth and hundreds of users per channel. It utilizes spectrum efficiently by supporting bursty traffic. The MAC convergence sub layer offers support for ATM, Ethernet, 802.1Q, IPv4, IPv6 (a possible future support for PPP, MPLS etc). The core MAC layer provides packet fragmentation, ARQ and QOS. The MAC Privacy Sub layer integrates security features in WiMAX. Authentication, encryption and Key exchange functionality are provided in MAC sub layer.

- Privacy Sublayer
    1) Encapsulation protocol
- Encrypt or decrypt data
    1) Privacy Key Management (PKM) protocol
- Secure distribution of keying data (BS to SS)
    1) Security Association (SA)
- Identified by SAID
- Contains cryptographic suite and security info

H. WiMAX PHY and MAC Summary

- **PHY**
    1) MIMO
    2) Modulation
    3) OFDM, Modulation technique, spread spectrum (used in e.g DSL, WLAN, WiMAX)
- **MAC, control plane, user plane**
    1) Manage resources on the air interface
    2) QoS for multimedia and video streaming
    3) ARQ
    4) Mobility Management
    5) Radio Resource Management
    6) Location

III. CONCLUSION

WiMAX Technology is facing many hurdles in market while it has some great advantages which make it a technology of today. This paper provided the quick and technical overview of concept, technology, standard, and architecture for IEEE 802.16 WiMAX.

REFERENCES

[1] *IEEE Standard for Local and Metropolitan Area Networks*, Part 16: Air Interface for Broadband Wireless Access Systems IEEE Std 802.16™-2009.

[2] Intel leap ahead. Welcome to Your Internet Future. Intel 2007. (August 30, 2010). [Online]. Available: http://download.intel.com/network/connectivity/products/wireless/welcome-to-your-internet-future. pdf

[3] Dan O'Shea. WiMAX Makes a Mesh. (Oct. 17, 2005). [Online]. Available: http://connectedplanetonline.com/mag/telecom_wimax_makes_mesh/index2.html

[4] N. F. Mir, *Computer and Communication Networks*, Printice Hall, 2006.

[5] WiMAX vs 3G CDMA. (January 2008). [Online]. Available: http://www.qualcomm.com.

[6] WiMAX Made Simple. How WiMAX Works. (December 15, 2009). [Online]. Available: http://wimax-made-simple.blogspot.com/2009/12/how-wimax-works.html

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