WiMAX and Its Applications (3)

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Editor's Desk:
Worldwide Interoperability for Microwave Access (WiMAX), an emerging broadband radio access technology, has attracted much attention from the whole telecom industry in recent years. Its main features are the high-speed transmission rate, large coverage, support for mobility, QoS guarantee and all-IP architecture. The technology fulfills the integration of packetized data, broadband access and mobilized terminal; therefore, it has a bright future for wide application. This lecture discusses WiMAX in four parts, and this part introduces QoS mechanism of the MAC layer and the WiMAX network architecture.

5.4 Ranging

Ranging is a collection of processes between the Base Station (BS) and the Subscriber Station (SS) for maintaining the quality of the Radio Frequency (RF) communication link. Distinct ranging processes are used for managing downlink and uplink.

5.4.1 Downlink Burst Profile Management

Burst profile is a set of parameters for describing the transmission attributes of downlink or uplink, including modulation scheme, error correction encoding type, preamble length, and protection time.

The BS determines the burst profile based on the quality of the signal received by each SS. To reduce the transmission overhead of uplink, the SS monitors the Carrier-to-Interference-and-Noise Ratio (CINR) and compares it with the predefined threshold. If the received CINR goes outside of the range allowed by the current burst profile, the SS will use basic Connection Identifier (CID) to send a ranging request (i.e. RNG-REQ) to the BS, asking for another burst profile. Upon receipt of acknowledgement from the BS, the SS continues to monitor the quality of received signals against the new burst profile.

5.4.2 Uplink Periodic Ranging

The uplink ranging takes two steps: first, the initial ranging, when the SS first accesses the network, which will be discussed in the next chapter; and second, periodic ranging after initialization. With the periodic ranging, the SS can timely adjust its transmission parameters to adapt to any change in the environment, thus maintaining its communication with the BS's uplink.

The basic principles of the periodic ranging are as follows:

- The BS maintains a T27 timer for each SS. Whenever the timer expires, the BS will grant uplink bandwidth to the related SS so that the SS can transmit data or perform ranging. Each time when the BS executes a unicast grant, the timer will be restarted. As a result, the BS does not need to allocate special bandwidth to the SS for ranging so long as the SS keeps active.
- After each uplink bandwidth authorization, the BS measures the quality of signals received from the SS. If the quality is poorer than its acceptable threshold, the BS sends a RNG-RSP (Continue) message to the SS, where the correction information may be included. If the quality is higher than its acceptable threshold, the BS sends a RNG-RSP (Success) message, where the correction information may also be included. If the quality of signals received from the SS is unacceptable after the correction information is sent for several times, the BS sends a RNG-RSP (Abort) message to terminate link management of the related SS.
- The SS processes each RNG-RSP message it receives: If the message status is Continue, it adjusts the physical layer based on the received correction information; and if the message status is Abort, it re-initializes the Media Access Control (MAC) layer. If correction cannot be made, the SS will send a RNG-REQ message in the next data grant or ranging opportunity, reporting the anomaly.

The uplink ranging based on the Orthogonal Frequency Division Multiple Access (OFDMA) physical layer differs, where the SS randomly selects a ranging code from the subset of periodic ranging codes to send the ranging request on a timeslot of ranging sub-channel. In this case, it is the SS rather than the BS that controls the ranging period. The SS sends the ranging request periodically and makes necessary adjustment according to the BS's response.

5.5 Network Entry and Initialization

According to related protocols, the SS takes the steps listed below to access the network and perform initialization process.

(1) Scan frequency list to search valid

downlink signals and achieve synchronization with the BS's physical layer.

(2) Obtain downlink parameters necessary for synchronization with the BS's MAC layer, such as Downlink Map (DL-MAP) and Downlink Channel Descriptor (DCD). Then the SS waits for the Uplink Channel Descriptor (UCD) message, which is periodically broadcast by the BS to obtain the transmission parameter set of available uplinks and select a suitable uplink channel.

(3) Perform initial ranging and automatic adjustment. The BS provides a contention period in the header of each uplink sub-frame, where the initial ranging time is included. After determining its initial ranging period by scanning the Uplink Map (UL-MAP) message, the SS sends a RNG-REQ message to the BS through contentions. In response, the BS returns a RNG-RSP message to assign CIDs of basic connection and primary management connection, and to provide such correction information as timing offset, frequency offset and power adjustment. Then the SS continues to interact with the BS via the basic connection regarding the ranging, and adjusts the physical layer parameters accordingly until the RNG-RSP (Success) message is received. In addition, as discussed in Section 5.3.3 in the initial ranging based on OFDMA physical layer, the ranging request is not sent in the contention period, but sent via a special ranging sub-channel.

(4) Finally, the BS and the SS does the following operations successively: both negotiate their basic capabilities, the BS authenticates the SS and exchanges keys with the SS, the SS registers with the BS, the SS establishes IP connectivity, the SS determines the time of day, the BS transfers operational parameters to the SS, and the BS sets up service connections with the SS.

5.6 Handover

When the Mobile Station (MS) moves out of the coverage of the original BS or another BS can provide better services, it is required to perform the Handover (HO) process. In this process, the MS can get DCD/UCD of neighboring cells from the topology message broadcast by the BS. A scanning period is also assigned by the BS to the MS, allowing the MS to scan and range neighboring BSs, evaluate the quality of their physical layer channels, and look for target BSs for possible handovers. The actual handover process can be initiated by the MS or the BS, and this type of handover is called hard handover.

Other two optional types of handover defined in IEEE 802.16e are: Macro Diversity Handover (MDHO) and Fast Base Station Switching (FBSS). In the MDHO, the MS can communicate simultaneously with several BSs to acquire diversity gains, thus improving link quality. In the FBSS, the MS can perform fast handover between any two BSs of a BS set without regular handover process.

5.7 Sleep Mode and Idle Mode

In mobile environment, to reduce the MS's power consumption as well as its usage of BS air interface resources, two terminal management modes are added in IEEE802.16e: sleep and idle.

The sleep mode is a state where an MS is temporarily absent from current BS services within pre-negotiated periods. The state of the MS that supports sleep mode is divided into two intervals: availability and unavailability. During the availability interval, the MS can normally receive all downlink signals. The unavailability interval is an intersection of sleep times of all MS service connections. During the interval, the BS does not transmit data to the MS, so the MS can power down some physical components or execute other activities that do not require communication with the BS, for instance, scanning neighbor BSs. For the SS in sleep state, the BS can buffer or discard the packets directed to the SS.

The idle mode allows the MS which has not any service to receive downlink broadcast messages in discrete intervals. And the MS does not perform handovers or other regular operations during its passing through multiple BSs. Consequently, this mode can conserve more power than sleep mode. In this mode, several BSs make up of a paging group following this principle: the group should be large enough so that the MS

can remain within the group most of the time. If one MS is in idle mode and new service arrives, all BSs in the paging group will send the paging message, prompting the MS to exit the idle mode, re-enter the network and receive data. Moreover, the BS can request one idle MS to update its location information with broadcast polling.

6 WiMAX Network Architecture

IEEE 802.16 only includes the specifications for the physical layer and the MAC layer of WiMAX system, and does not involve the network layer specifications. As a result, this standard is not enough for constructing an all-sided mobile network. As a mobility-supporting broadband wireless Metropolitan Area Network (MAN) technology, WiMAX needs to provide complete networking functionalities before it is successfully deployed and commercially applied. It should provide support to the core network functions, including mobility management, radio resource management, security and Quality of Service (QoS). Therefore, the Network Working Group (NWG) for WiMAX was established in 2004, aiming to develop IEEE 802.16-based end-to-end network architecture and protocols. The development is divided into three release phases. Currently, Release 2 is in progress. This chapter mainly introduces Release 1, which has

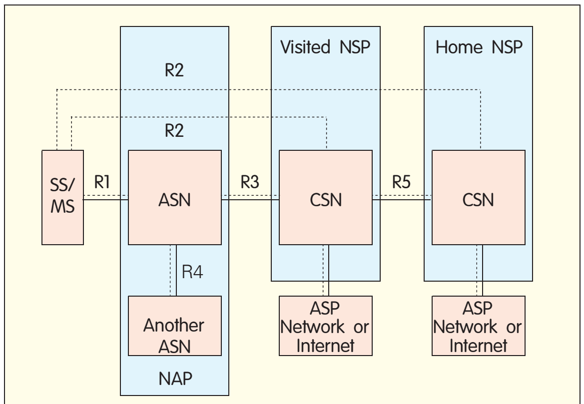


Figure 7.
WiMAX network reference model.

already been published.

6.1 WiMAX Network Reference Model

The end-to-end WiMAX network reference model developed by the NWG is illustrated in Figure 7. As a logic representation of WiMAX network architecture, this model identifies function entities as well as reference points over which interoperability is achieved between functional entities, in order to meet the requirements of various application scenarios. The function entities in this model include MS, Access Service Network (ASN), Connectivity Service Network (CSN), and Application Service Provider (ASP). Each of them represents an aggregation of several functions. In specific implementation, these functions can be integrated into one physical device or realized with several devices. The normative reference points include air interfaces R1—R5. But in the specifications, the interface between the CSN and the ASP is not defined.

6.2 ASN and CSN

The ASN is defined as a complete set of network functions needed to provide radio access to a WiMAX subscriber. The ASN mainly provides the following functions:

- WiMAX Layer-2 (L2) connectivity with WiMAX MS;
- Transfer of Authentication, Authorization and Accounting (AAA) messages to WiMAX subscriber's Home Network Service Provider (H-NSP) for authentication, authorization and session accounting for subscriber sessions;
- Network discovery and selection of the WiMAX subscriber's preferred NSP;
- Relay functionality for establishing Layer-3 (L3) connectivity with a WiMAX MS (i.e. IP address allocation);
- Radio resource management;
- Mobility management within ASN, for instance, handover, paging and location management;
- ASN-CSN tunneling.

The ASN can be decomposed into one or more BSs and one or more ASN gateways. The main function of the BS is to provide air interfaces for the MS, while the ASN gateway acts as a L2 service convergence point within the ASN. One ASN can be shared by several CSNs. That is to say, it can provide wireless access services for CSNs of different NSPs at the same time.

The CSN is defined as a set of network functions that provide IP connectivity services to the WiMAX subscriber(s). A CSN mainly provides the following functions:

- MS IP address and endpoint parameter allocation;
- Internet access;
- AAA proxy or server;
- Admission Control based on user subscription profiles;
- ASN-CSN tunneling support;
- WiMAX subscriber billing and inter-operator settlement;
- Inter-CSN tunneling for roaming;
- Inter-ASN mobility management;
- WiMAX services, such as location based services, peer-to-peer services, broadcast and multicast services, IP multimedia services and emergency call services.

To realize the above functions, a CSN may comprise network elements such as routers, AAA proxy/servers, user databases, and Interworking gateway devices.

6.3 Network Reference Point

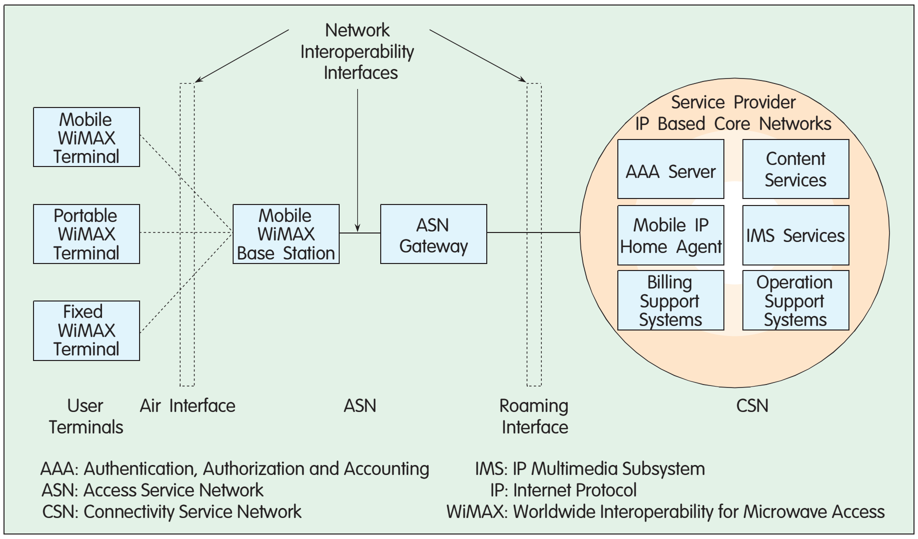
The WiMAX network architecture defines 5 open interfaces, i.e. reference points R1—R5. The functions of these reference points are described as follows:

- R1: It is the air interface between the MS and the ASN, having all physical layer and MAC layer characteristics specified in IEEE 802.16. It carries both user traffic and control plane messages.
- R2: Being the logic interface between the MS and the CSN, it consists of all protocols and procedures associated with Authentication, Services Authorization and IP Host Configuration management.
- R3: It is the logic interface between the ASN and the CSN, and it transfers control plane messages (e.g. AAA, end-to-end QoS control, and mobility management) and user data through tunneling between the ASN and the CSN.
- R4: Interconnecting two ASNs or gateways, this interface is mainly used to transfer the control and data plane messages associated with mobility management.
- R5: Used to interconnect two CSNs, this interface consists of the set of control and data plane methods between the CSNs in the home NSP and in the visited NSP.

6.4 WiMAX Network Architecture

Figure 7 is a logically defined network reference model, while Figure 8 gives a direct and clear description of WiMAX network architecture. This architecture is roughly divided into three parts: user terminals, ASN, and CSN. The user terminals are further classified into three types: fixed, portable, and mobile. The ASN and the CSN includes some main network devices mentioned in Section 6.2.

The end-to-end WiMAX network architecture in Figure 8 is based on an IP platform and adopts packet-switched technology. The benefit of the all-IP based approach is to reduce the costs.



▲Figure 8. WiMAX network architecture.

The core network is not required to support both packet-switched and circuit-switched technologies, so the overhead is reduced. The services supported by this architecture include voice/multimedia services, access to a variety of independent ASPs, mobile telephony communications using Voice over IP (VoIP), providing interfaces with various internetworking gateways to support 2G and 3G network services (e.g. Short Message Service (SMS), Multimedia Message Service (MMS), and Wireless Application Protocol (WAP)), and supporting delivery of IP broadcast and multicast services over WiMAX access networks.

In addition, in terms of interworking and roaming, this architecture provides the support for the following:

- Loosely-coupled interworking with existing wireless networks (e.g. 3G Partnership Project (3GPP) and 3GPP2) or existing wireline networks (e.g. Digital Subscriber Line (DSL));
- Global roaming across WiMAX operator networks;
- A variety of user authentication credential formats such as username/password, digital certificates, and Subscriber Identity Module (SIM).

(to be continued)

Biographies

Liu Danpu

Liu Danpu received her doctoral degree from Beijing University of Posts and Telecommunications (BUPT). She is a professor at BUPT. Her research interests include broadband wireless communications technologies, MIMO/OFDM, physical-layer and MAC technologies for ultra-wideband wireless communications systems. She has published more than 30 technical papers.

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Roundup

ZTE Plans to Deploy Colombia's First Mobile WiMAX Network by the End of 2008

ZTE Corporation announced on August 19, 2008 that it had clinched an exclusive bid from Colombia's leading operator Emcali to build the country's first WiMAX 16e network. For the 3.5G WiMAX 16e project, ZTE will provide Emcali core network equipment, wireless access equipment and various outdoor/indoor terminals. Emcali, which was awarded by the Colombian government WiMAX licenses two years ago, has been required to make the network commercially available by the end of this year.

After a thorough bidding process, Emcali chose ZTE to exclusively provide them the network equipment in developing comprehensive commercial network services and advanced WiMAX technologies in Colombia. Under the project, ZTE will also provide WiMAX base stations to help Emcali offer extensive mobile wireless coverage in the Colombian regions of Cali and Popayan.

ZTE is one of the biggest champions in the WiMAX industry. It is also the only Chinese company among the 15 Board of Directors in the WiMAX Forum. In early 2006, ZTE achieved significant in-roads in Singapore by developing the mobile WiMAX network in the island state, one of the first commercial trial networks worldwide. Last year, the company clinched a major WiMAX terminal procurement contract with Sprint Nextel, the third largest mobile operator in the United States.

ZTE is a pioneer in promoting the concept of "carrier-grade WiMAX MAN" globally, and has successfully established 21 commercial trials and trial networks for 802.16e WiMAX worldwide. To date, ZTE has established WiMAX commercial trial centers and experiment labs in more than 20 countries and regions, including the U.S., Africa, Asia and Europe.