802.16 MAC layer: structure and QoS support

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Content

1. Introduction
2. 802.16 MAC layer
   2.1. MAC Service-Specific Convergence Sublayer
   2.2. Common Part Sublayer
3. QoS support
   3.1. Bandwidth request-grant mechanisms
   3.2. Services classes
   3.3. QoS architecture for 802.16
4. Conclusion
Introduction

- **WiMAX** is defined as **Worldwide Interoperability for Microwave Access** by the WiMAX Forum, formed in June 2001 to promote conformance and interoperability of the IEEE 802.16 standard (WirelessMAN).

- Two available standards:
  - IEEE 802.16-2004: fixed WiMAX
  - IEEE 802.16e-2005: amendment to IEEE 802.16-2004, mobile WiMAX support added
Introduction

- **WiMAX salient features:**
  - Speed: 70Mbps (more practically 10Mbps at 10km)
  - Range: many kilometers (WiFi – meters)
  - OFDM-based physical layer
  - Link layer retransmissions: support ARQ
  - Flexible and dynamic per user resource allocation
  - Quality-of-Service support
  - Support for mobility.
Introduction

- WiMAX terms:
  - BS (Base Station), SS (Subscriber Station), MS (Mobile Station).
  - Fixed WiMAX: BS and SSs communicate with each other, no direct links between SSs.
  - Mobile WiMAX: MSs can operate in the way of adhoc mechanism.
  - Two directions between BS and SSs: uplink (from SS to BS) and downlink (from BS to SS).
### Introduction

- **Fixed WiMAX operation overview:**
  - **TDD frame**

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#### TDD Frame

<table>
<thead>
<tr>
<th>Frame Length = 5ms</th>
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<tbody>
<tr>
<td><strong>Downlink Subframe</strong></td>
</tr>
<tr>
<td>Preamble</td>
</tr>
</tbody>
</table>

**MAP:**

- \{ CID1, Interval Usage Code(IUC), StartTime, Duration \}
- ...
- \{ CIDn, Interval Usage Code(IUC), StartTime, Duration \}
- ...

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**SS transition gap**
Fixed WiMAX operation overview:

- **Downlink:**
  - Only BS transmits in broadcast manner. Each SS picks up the **data** destined to it.
  - BS determines the number of time slots that each SS will be allowed to transmit in an uplink subframe.

- **Uplink:**
  - Upon power up, SSs synchronize with channel.
  - Get UL-MAP from downlink subframe, determine transmission opportunities. UL-MAP is scheduled by BS.
Fixed WiMAX operation overview (cont):

Uplink (cont):
- Perform Initialization and Registration setup.
- SSs request for transmission opportunities on the UL channel by sending BW-Request.

Scheduling:
- BS gathers and then schedules these requests.
- The information is broadcasted in the DL channel by BS using the UL-MAP message at the beginning of each DL subframe.
802.16 MAC layer

Sender
Packet
M-SDU
M-PDU
MAC

Receiver
Packet
M-SDU
M-PDU

CS SAP
Service-Specific Convergence Sublayer
MAC SAP
MAC Common Part Sublayer
CPS peer connection
Privacy Sublayer
PHY SAP
Transmission Convergence Sublayer
P-PDU
PHY LAYER
P-PDU

Airlink
The MAC layer consists of 3 sublayers:

1. The Service-specific Convergence Sublayer (CS)
   - Classifying external network service data units (SDUs)
   - Associating SDUs to the proper MAC service flow identifier (SFID) and connection identifier (CID).
   - Payload header suppression (PHS).

2. The MAC Common Part Sublayer (CPS)
   - Provides the core MAC functionality of system access
   - Fragments or combines SDUs to appropriate MAC PDUs

3. The Security Sublayer (SS)
   - Authentication, secure key exchange, and encryption
802.16 MAC layer
The Service-specific Convergence Sublayer

- Classification of the higher-layer protocol PDU into the appropriate connection
- Suppression of payload header information (optional)
- Delivery of the resulting CS PDU to the MAC SAP associated with the service flow for transport to the peer MAC SAP
- Receipt of the CS PDU from the peer MAC SAP
- Rebuilding of any suppressed payload header information (optional)
802.16 MAC layer
The Service-specific Convergence Sublayer

Classification:

Classification and CID mapping (BS to SS) [2] 
Classification and CID mapping (SS to BS) [2]
Packet Header Suppression

- Avoid the transmission of redundant information in the headers of the MAC SDUs (optional)
- A packet is mapped to a PHS rule by classifier
- In sender: each MAC SDU is prefixed with a PHSI which references the Payload Header Suppression Field (PHSF)
- In receiver: uses CID and PHSI to restore the PHSF
Addressing and Connections

- Each SS has a 48-bit universal MAC address
- The primary addresses used during operation are the 16-bit CIDs
- Three management connections reflecting the three different QoS requirements used by different management levels:
  - Basic connection – for short and critical MAC and RLC messages,
  - Primary management connection – for longer and more delay-tolerant messages such as authentication and connection setup.
  - The secondary management connection transfers standards-based messages such as DHCP, TFTP, and SNMP.
- Transport connections – are unidirectional to facilitate different UL and DL QoS and traffic parameters.
802.16 MAC layer
The MAC Common Part Sublayer

MAC PDU format:
- The MAC PDU is the data unit exchanged between the MAC layers of the BS and its SSs
- 3 parts:
  - Fixed-length generic header with two formats (generic and bandwidth request).
  - Payload: optional and varies in length
  - CRC: optional
MAC PDU format (cont):
- Payload may contain zero or more subheaders and zero or more MAC SDUs and/or fragments thereof.
- Three types of MAC subheader:
  - Grant management subheader
  - Fragmentation subheader (FSH)
  - Packing subheader (PSH)
802.16 MAC layer
The MAC Common Part Sublayer

- Construction and transmission of MAC PDUs:
  - Incoming MAC SDUs from corresponding convergence sublayers are formatted according to the MAC PDU format.
  - IEEE 802.16 takes advantage of incorporating the packing and fragmentation processes.
  - Multiple MAC PDUs may be concatenated into a single transmission in either the uplink or downlink directions:
    - Fragmentation is the process in which a MAC SDU is divided into one or more MAC SDU fragments.
    - Packing is the process in which multiple MAC SDUs are packed into a single MAC PDU payload.
QoS support

- The 802.16 MAC protocol is connection-oriented and uses strict admission control.
  - At the start of each frame, the BS schedules the DL and UL bandwidth grants and time schedule in order to meet the negotiated QoS requirements.
  - All information are communicated to the SSs by the BS in the UL-MAP at the start of the DL subframe of each frame.
  - SSs are allowed to transmit data only in their own predetermined transmission opportunity.
QoS support
QoS support

Bandwidth request-grant mechanisms

There are four request-granting mechanisms used for bandwidth allocation for UL:

1. unsolicited granting of a fixed bandwidth requested by the SS only during the set-up phase of an UL connection;
2. unicast polling allocating just enough bandwidth for the polled UL connection to transmit a bandwidth request;
3. broadcast polling by the BS to all UL connections for sending requests; and
4. piggy-backed request onto a PDU when there is backlog in the UL.
QoS support

Bandwidth request-grant mechanisms
The WiMAX Standard specifies the 5 different service classes:

- Unsolicited Grant Service (UGS):
  - No need to request bandwidth for each packet
  - The BS periodically assigns slots
  - *Scheduling for DL UGS traffic is not required*

- Real-time Polling Service (rtPS):
  - Packets are not fixed in size
  - BS polls the connection of this class periodically (unicast polling) to ask how much bandwidth is needed.
QoS support

Service classes

- Non real-time Polling Service (nrtPS):
  - Used to support traffic with no QoS.
  - May have additional bandwidth allocated through non periodic polling.

- Best Effort (BE):
  - Used to support traffic with no QoS.
  - There is possibility that BE traffic is starved by the lack of bandwidth.

- Extended real-time Polling Service (ErtPS):
  - In mobile WiMAX
  - Used for VoIP with silence suppressed
QoS support
QoS architecture for 802.16
QoS support
QoS architecture for 802.16

“Undefined details such as UL and DL bandwidth scheduling and admission control and traffic policing, are subjects of research and propriety implementation”.

Various detailed QoS architectures have been proposed by researchers:

- Downlink scheduler in BS
- Uplink scheduler in BS
- Uplink scheduler in SS
QoS support

QoS architecture for 802.16

- Cross-layer scheduling
  - Scheduling based on information from physical layer only is called channel-aware scheduling.
  - Scheduling based on information of higher layer is called queue-aware scheduling.
  - cross-layer packet scheduling: manage the users’ access to resources according to both instantaneous traffic requirements (higher layer) and dynamic channel conditions (physical layer).
Conclusion

- WiMAX is a new trend for network and communication.
- 802.16 standard has many undefined subjects for researchers.
- Bandwidth scheduling has two research directions:
  - MAC scheduling
  - Cross-layer scheduling
THANKS FOR YOUR ATTENTION!