802.16 MAC layer: structure and QoS support

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Introduction

- **WiMAX** is defined as **W**orldwide **I**nteroperability for **M**icrowave **Acc**ess 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

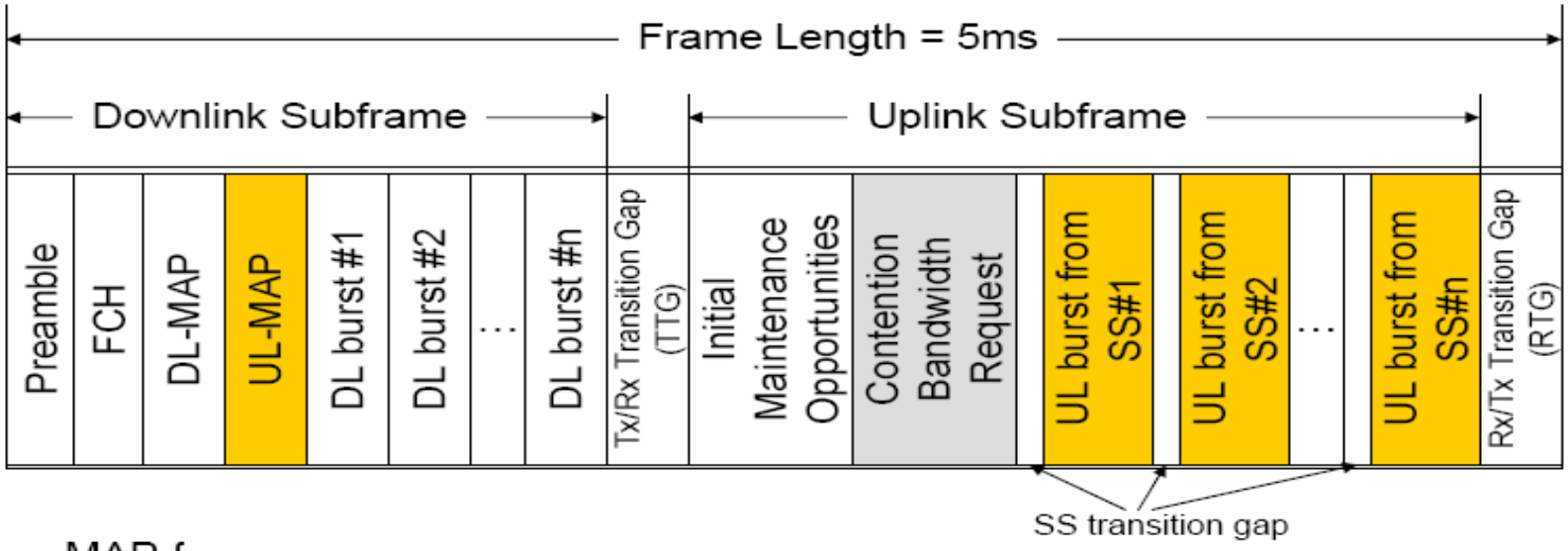
- WiMAX salient features:
  - Speed: 70Mbps (more practicaly 10Mbps at 10km)
  - Range: many kilometers (WiFi – meters)
  - OFDM-based physical layer
  - Link layer retransmissions: support ARQ
  - Flexible and dynamic per user resource allocation
  - Quality-of-Service support
  - Support for mobility.

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




```
MAP {
  { CID1, Interval Usage Code(IUC), StartTime, Duration }
  ....
  { CIDn, Interval Usage Code(IUC), StartTime, Duration }
 ...
}
```

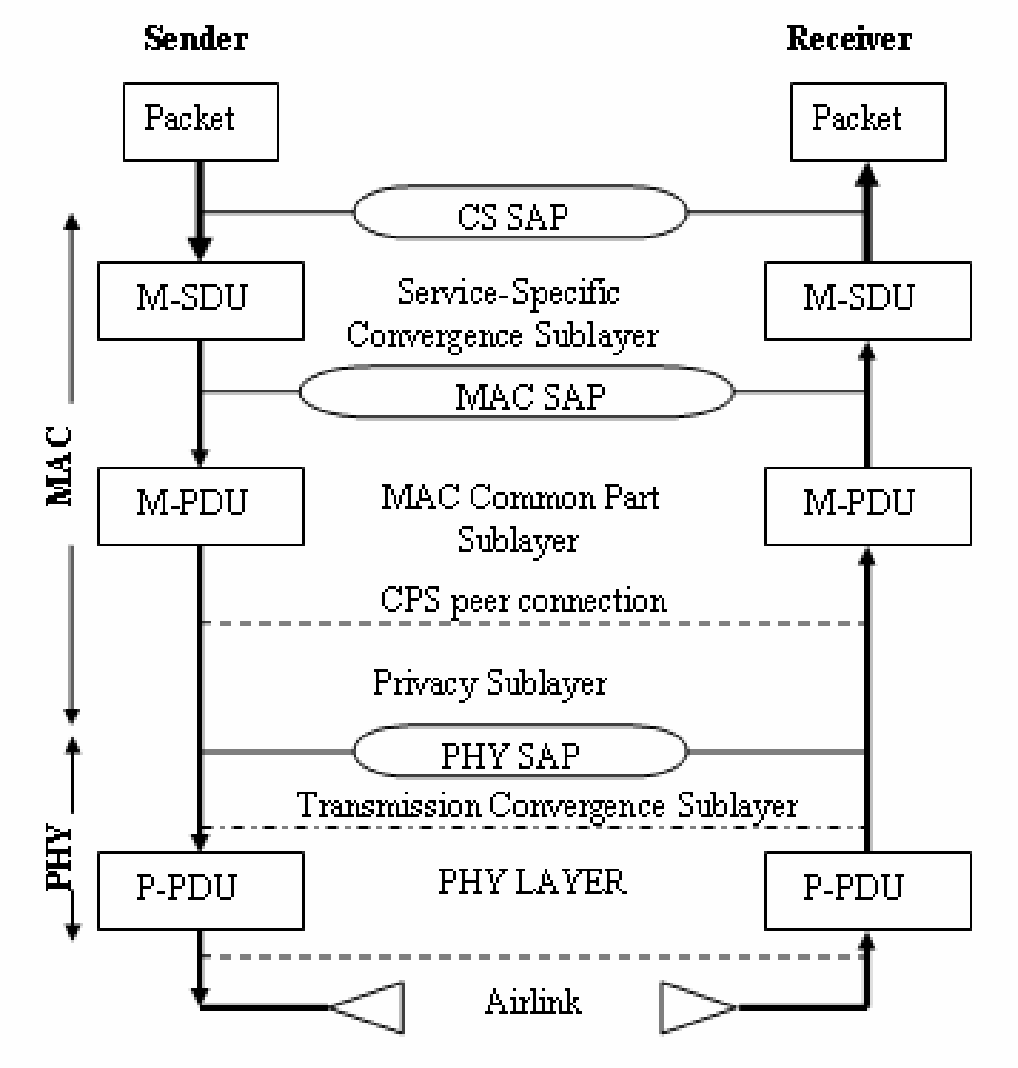
Introduction

- 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 chanel.
    - Get UL-MAP from downlink subframe, determine transmision opportunities.
      UL-MAP is scheduled by BS.

Introduction

- 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



802.16 MAC layer

- 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

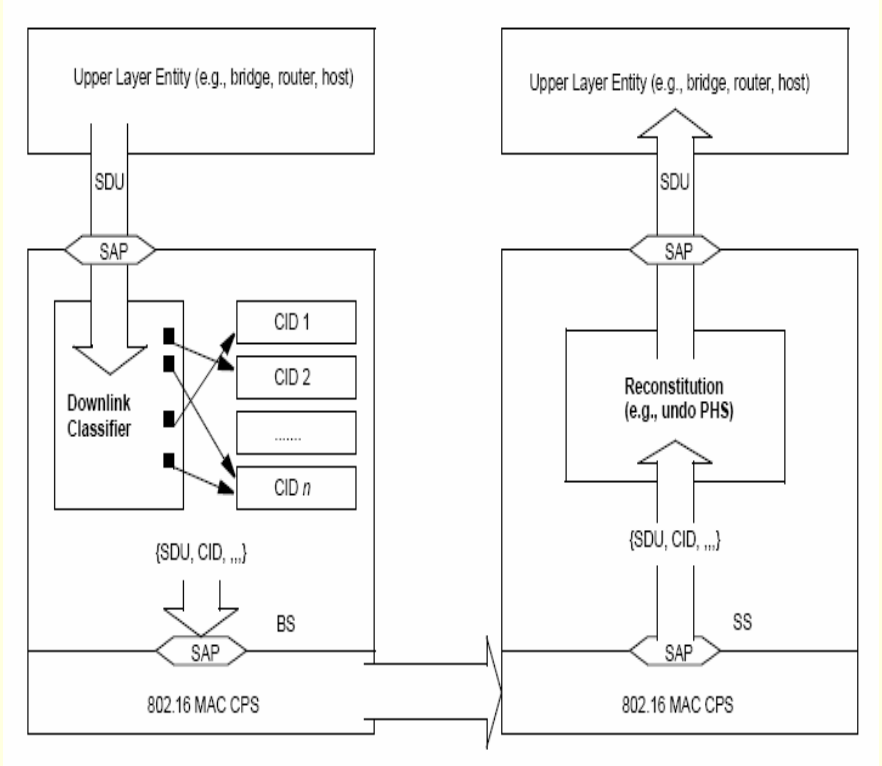
The Service-specific Convergence Sublayer

- 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)

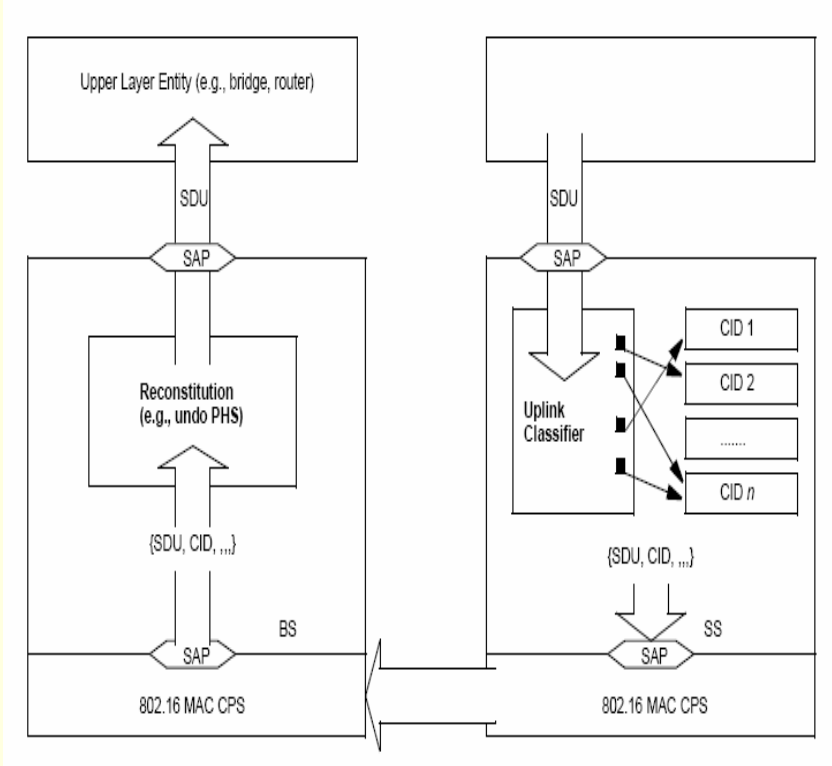
802.16 MAC layer

The Service-specific Convergence Sublayer

- Classification:



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



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

802.16 MAC layer

The Service-specific Convergence Sublayer

- 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

802.16 MAC layer

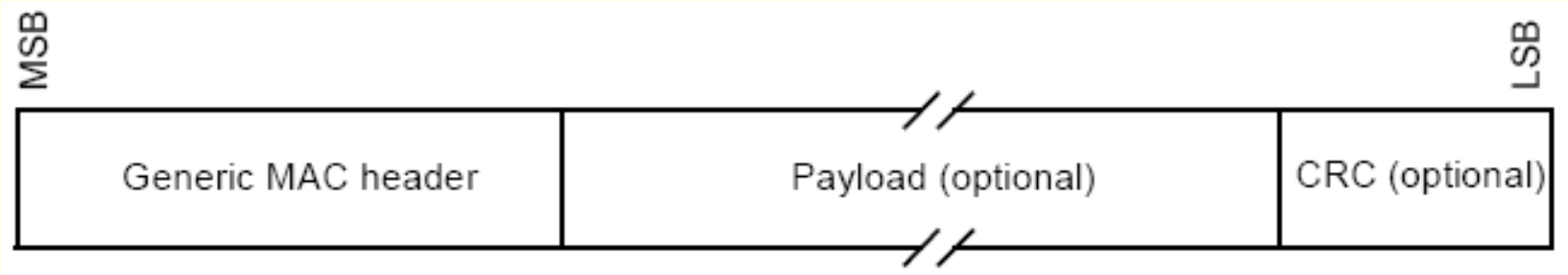
The MAC Common Part Sublayer

- 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



802.16 MAC layer

The MAC Common Part Sublayer

- 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

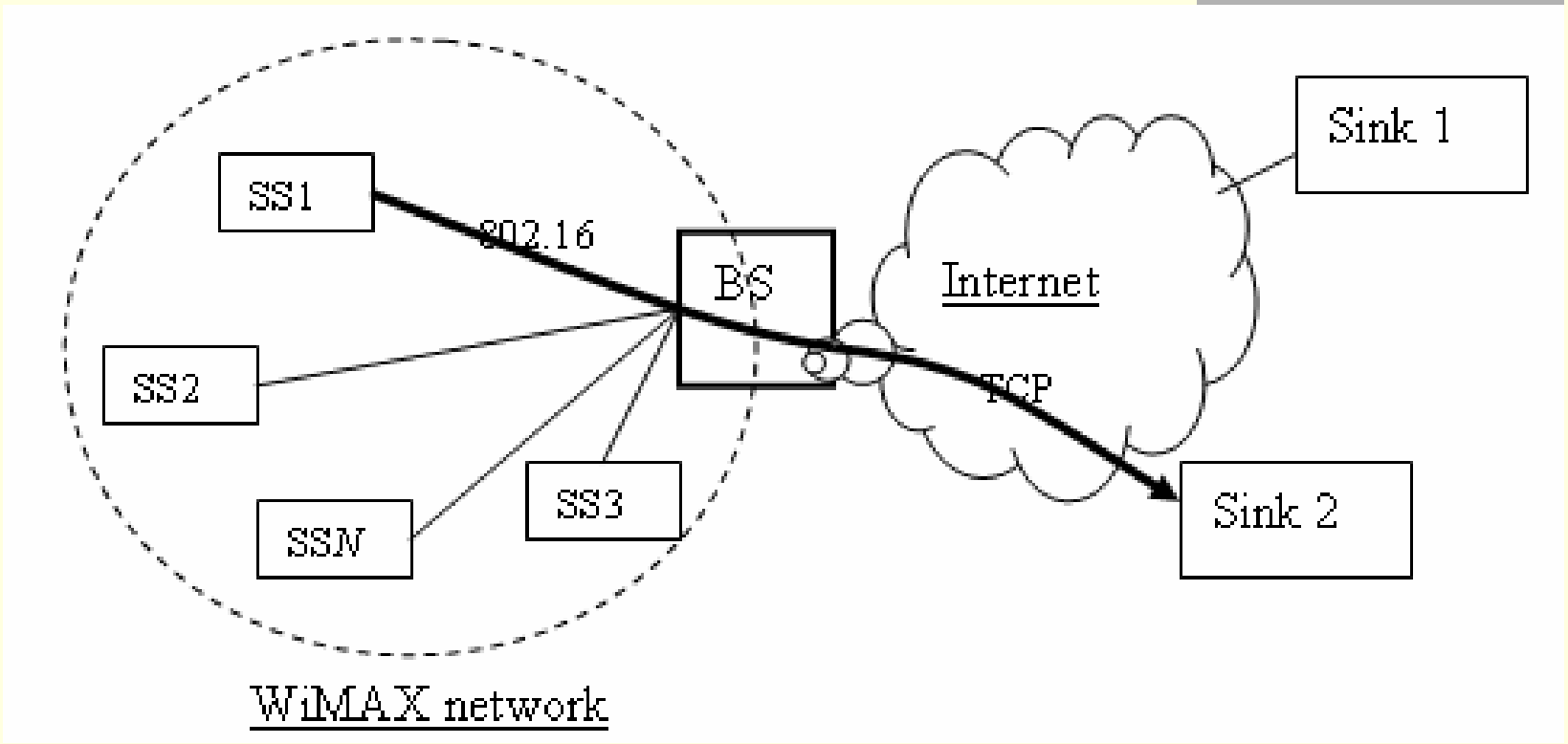
The MAC Common Part Sublayer

- Contruction 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


SS1
802.16
BS
Internet
Sink 1
SS2
TCP
SS3
SSN
Sink 2
WiMAX network

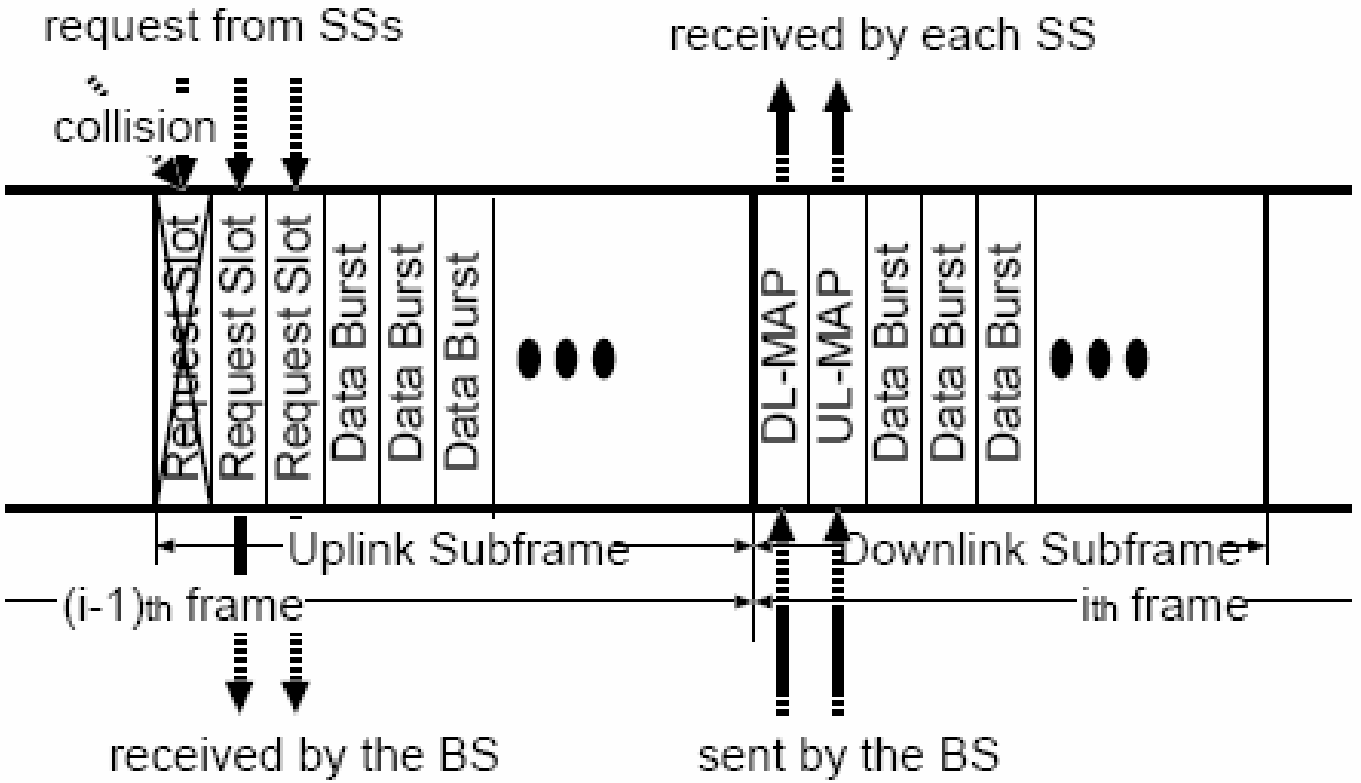
QoS support

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



QoS support

Service classes

- 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.

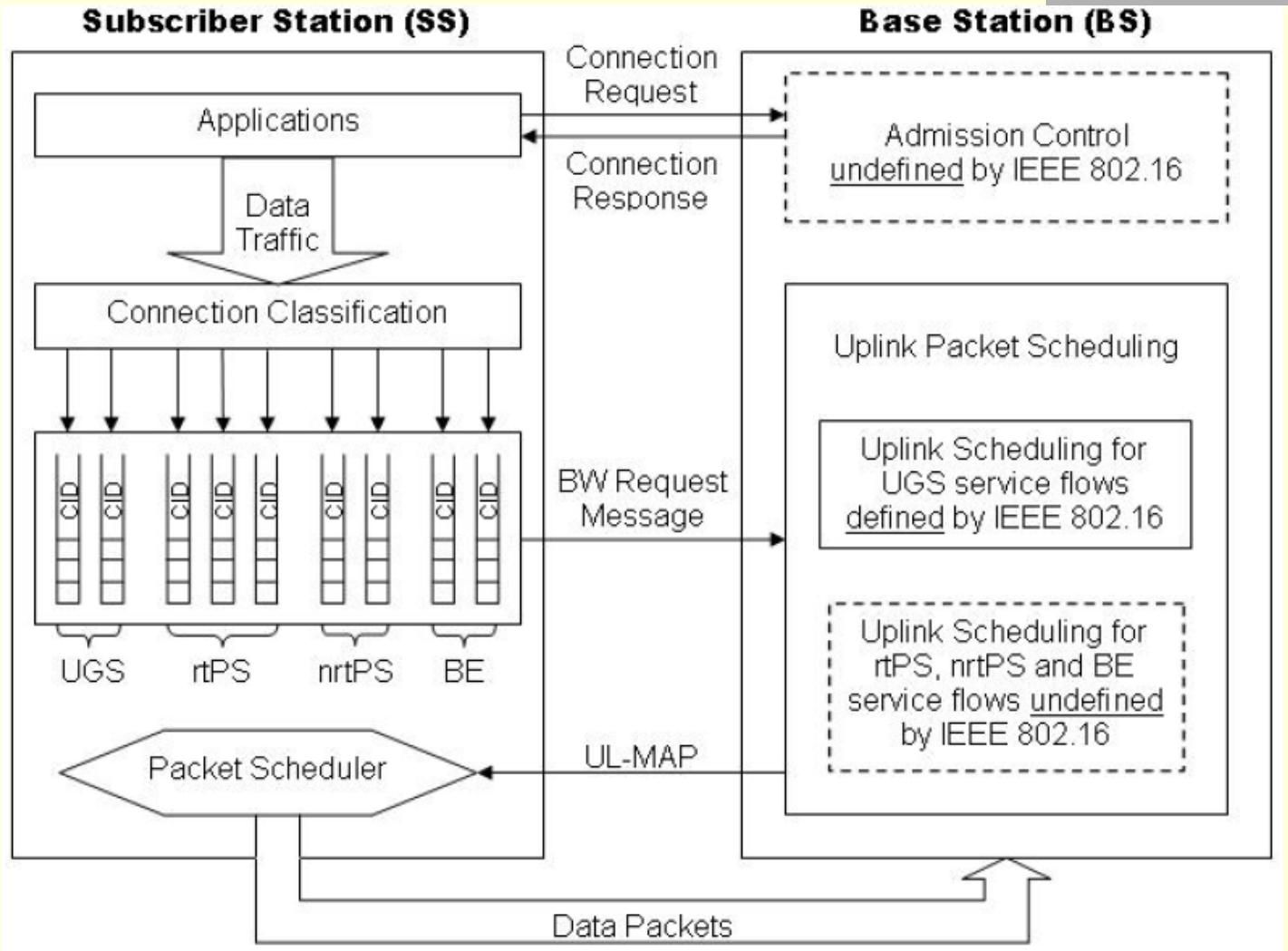
QoS support

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!