WiMAX
Part II: MAC

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Audio/Video recordings of this lecture are available at:
http://www.cse.wustl.edu/~jain/cse574-10/

- Key Features
- QoS Classes
- ARQ, Hybrid ARQ (HARQ)
- Protocol Structure
- Payload Header Suppression
- MAC Headers
- Scheduling and Link Adaptation

WiMAX MAC: Key Features

- Flexible and Extensible - Same MAC for all current and future PHYs
- Modular: Several optional features. Negotiable SS/BS features
- Multiple Topologies: PTP, PMP, mesh
- Multiple Antenna Technologies: Adaptive Antennas, MIMO
- Multiple Protocol Payloads: ATM, Packets (IP or Ethernet), W or w/o header suppression
- Flexible Retransmission Policies: ARQ, HARQ
- TDD and FDD Support
- Variety of Subscribers: Several per subscriber or per connection parameters
- Integrated QoS
- Security

Base Station and Subscriber Stations

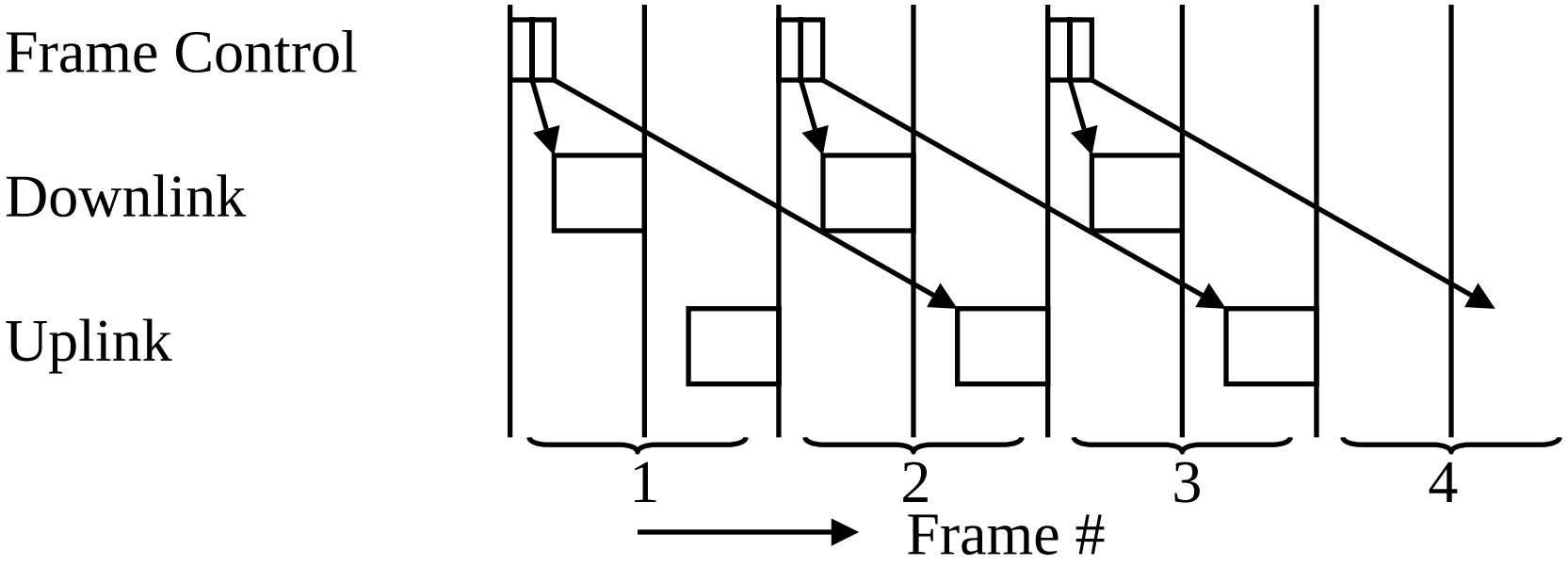
- Base Station (BS): Controls the entire system, frame size, scheduling, admission control, QoS, Ranging, clock synchronization, power control and handoff.
  - All traffic goes through BS
- Subscriber Station (SS): Find BS, Acquire PHY synchronization, Obtain MAC parameters, Generate bandwidth requests, make local scheduling decisions, follow transmission/reception schedule from BS, perform initial ranging, maintenance ranging, power control
- Mobile Station (MS): Mobility management, Handoff, Power Conservation

Framing and Duplexing

- Burst = n MPDUs with per burst CRC
- Burst Profile: Modulation type, FEC, preamble type, guard time
- Downlink Interval Usage Code (DIUC): Identifies burst profile
- DL Channel Descriptor (DCD): Describes DL PHY. Broadcast periodically by BS. Frame duration, Defines DIUCs.
- Uplink Interval Usage Code (UIUC): Identifies UL burst profiles
- UL Channel Descriptor (UCD): Describes UL PHY.

MAP Time Relevance

- DL MAP always refers to current frame
- UL MAP may be broadcast one frame ahead
- FDD UL MAP allows for a round-trip delay and MAP processing time



Connections and Service Flows

- Service Flows = Higher layer flows
- Each Service flow has a connection
- Extra connections for management and control
- 16-bit CID $\Rightarrow$ 65,535 connections
- Each station has many connections with BS:
  - Initial Ranging CID
  - Basic CID
  - Primary Management CID
  - Secondary Management CID: Higher layer
  - Multicast Polling CID: Bandwidth requests

IEEE 802.16 – QoS Classes

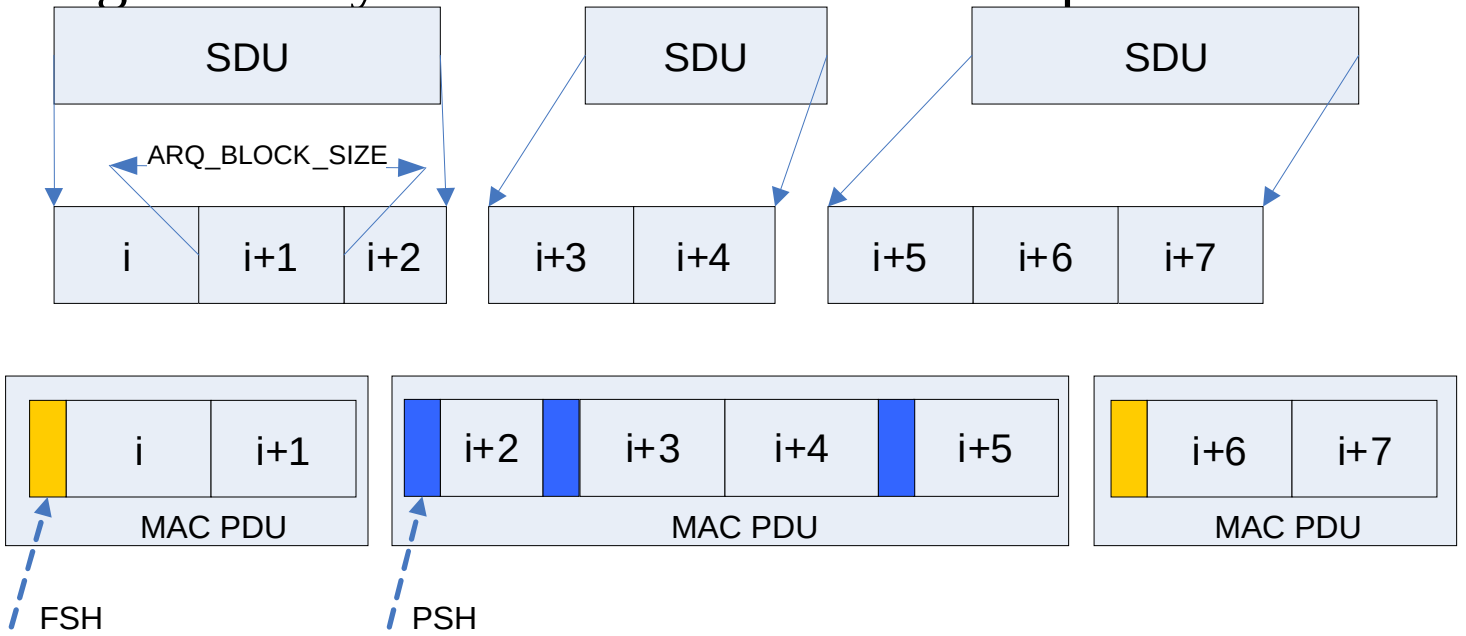
Connection oriented: All traffic is assigned a connection

Five Service Classes:

1. Unsolicited Grant Service (UGS): CBR traffic, e.g., voice
   Specified throughput, delay, and delay jitter
2. Enhanced Real-Time Polling Service (ertPS):
   Silence suppressed voice. On/off UGS.
3. Real-Time Polling Services (rtPS):
   rtVBR, e.g., streaming video.
   Specified peak and average throughput, delay and delay jitter.
4. Non-Real-Time Polling Service (nrtPS): nrtVBR, e.g., FTP.
   Specified peak and average throughput
5. Best Effort (BE); No throughput or delay guarantees

ARQ

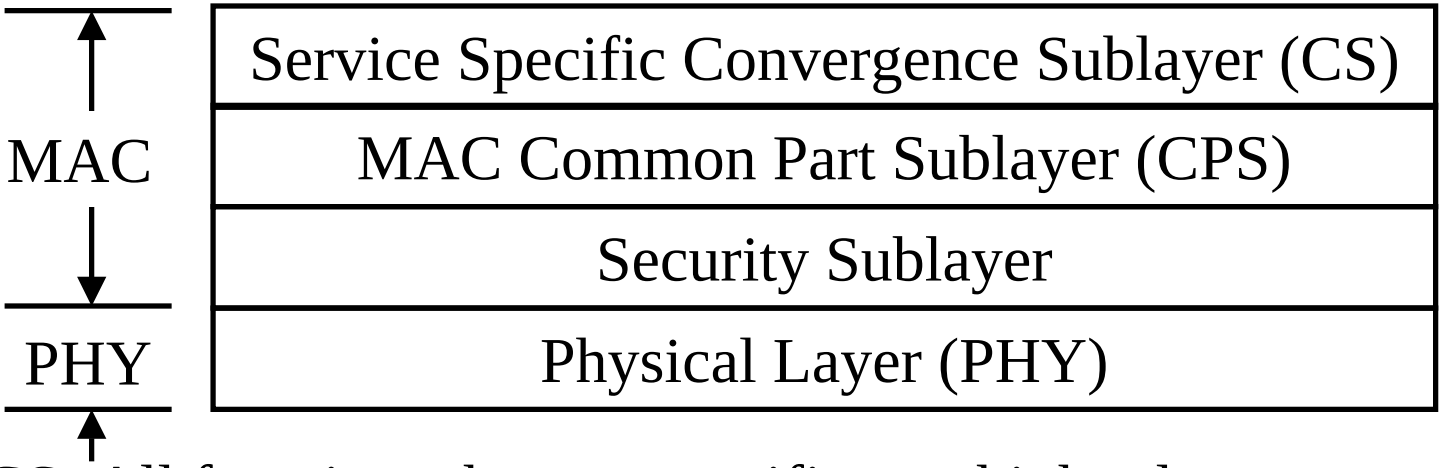
- Allows selective repeat (Stop and Wait, go back n)
- ARQ block size negotiated at connection setup
  Depends upon the Type of Service (ToS), expected delay, etc
- ARQ block cannot be fragmented
- A fragment may contain blocks from multiple SDUs



Hybrid (HARQ)

- Only in OFDMA PHY
- Four variants (subpackets) of the burst
- 2nd subpacket is sent iff 1st is not received correctly
  $\Rightarrow$ Stop and Wait with immediate or synchronous acks
  $\Rightarrow$ Dedicated PHY channel for acks
- The receiver tries to decode using both 1st and 2nd subpackets
- Process continues until success or 4th subpacket

IEEE 802.16 Protocol Structure



- CS: All functions that are specific to a higher layer protocol
  - Classify SDUs based on MAC address, VLANs, priorities
  - Assigns Service Flow ID (SFID) and a connection identifier
  - Optional payload header suppression (PHS)
- CPS:
  - Fragmentation and reassembly of large MAC SDUs
  - Packing and unpacking of several small MAC SDUs

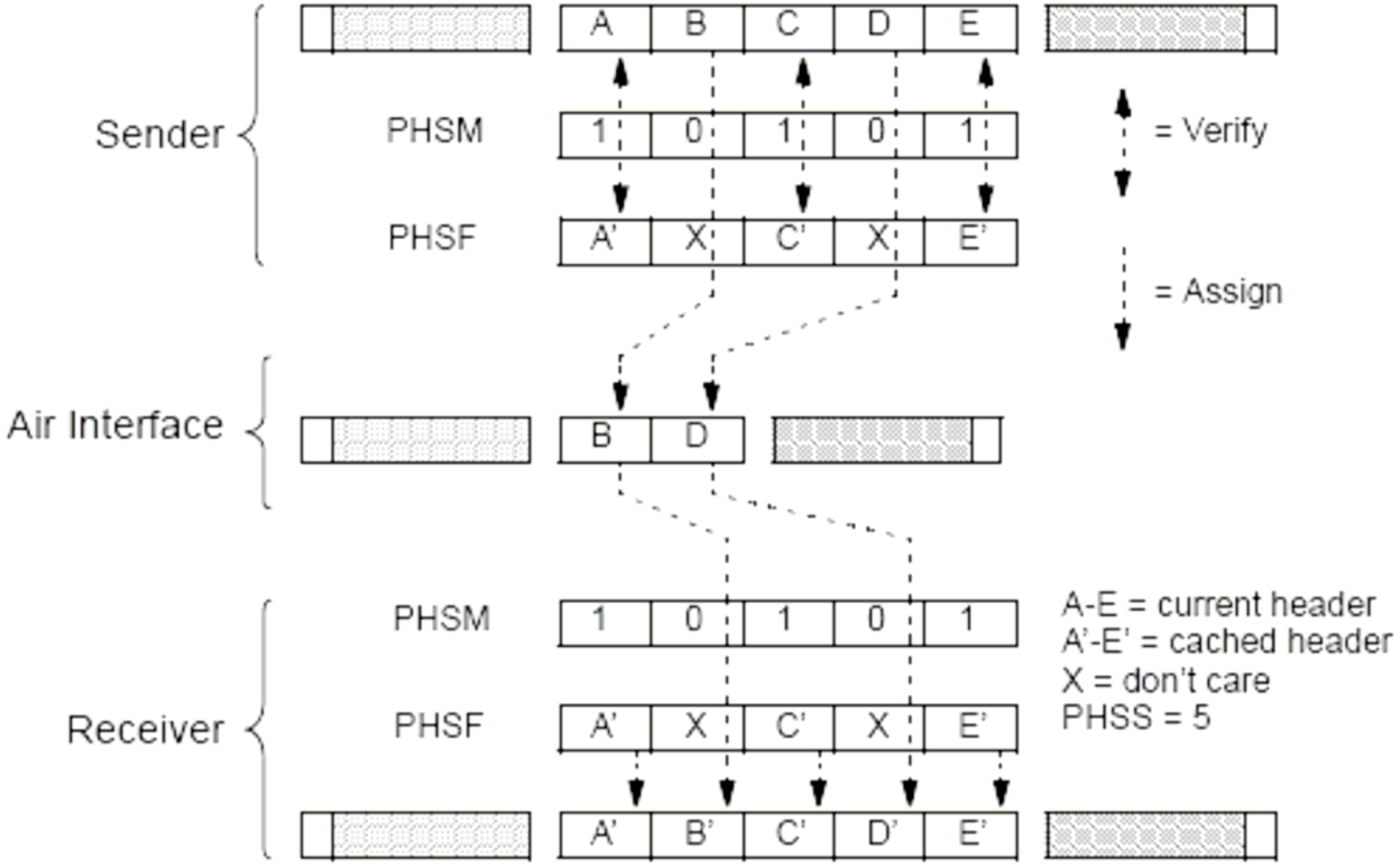
IEEE 802.16 Protocol Structure (Cont)

- QoS control, Scheduling
- Bandwidth request
- Automatic repeat request (ARQ)

Payload Header Suppression

- PHS Fixed = Fixed header bytes
- PHS Mask = Which bytes?
- PHS Index = Which rule?
  Indicates mask and fixed values
- PHS Verify ⇒ Compare before removing

Payload Header Suppression (Cont)



MAC Headers

- Generic MAC Header: Total 6 bytes per MPDU

Header Type	Encryp Control	Payload Type	CRC Indicator	Encryp Key #	Len	Connection Identifier	Header Check
1b	1b	6b	1b	2b	11b	16b	8b

Header type: Generic or Stand-alone

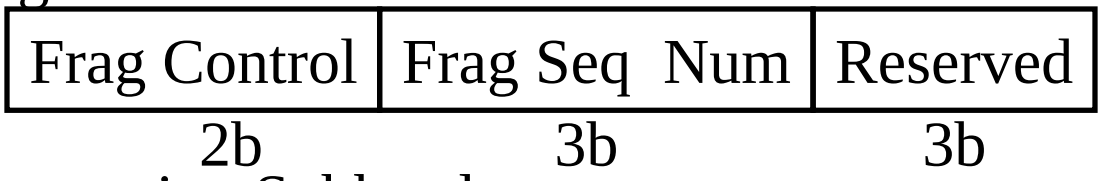
Payload type bits: Fast Feedback allocation/Grant management, Packing, Fragmentation, Frag/packing with ARQ, ARQ feedback, Mesh

- Bandwidth Request Header: Total 6 bytes

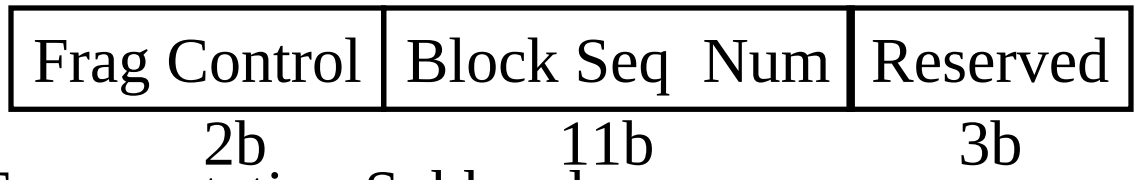
Header Type	Encryption Control	Type: Incremental/ Aggregate	Bandwidth Request (Bytes)	CID	HCS
1b	1b	3b	11b	16b	8b

Fragmentation Subheader

- Fragmentation Control: 00=No Frag, 01 Last Frag, 10=First Frag, 11=Middle
- Fragment Seq #: Mod 8 or mod 2048
- Block Seq #: Sequence # of the first block in this SDU
- Regular Fragmentation Subheader:



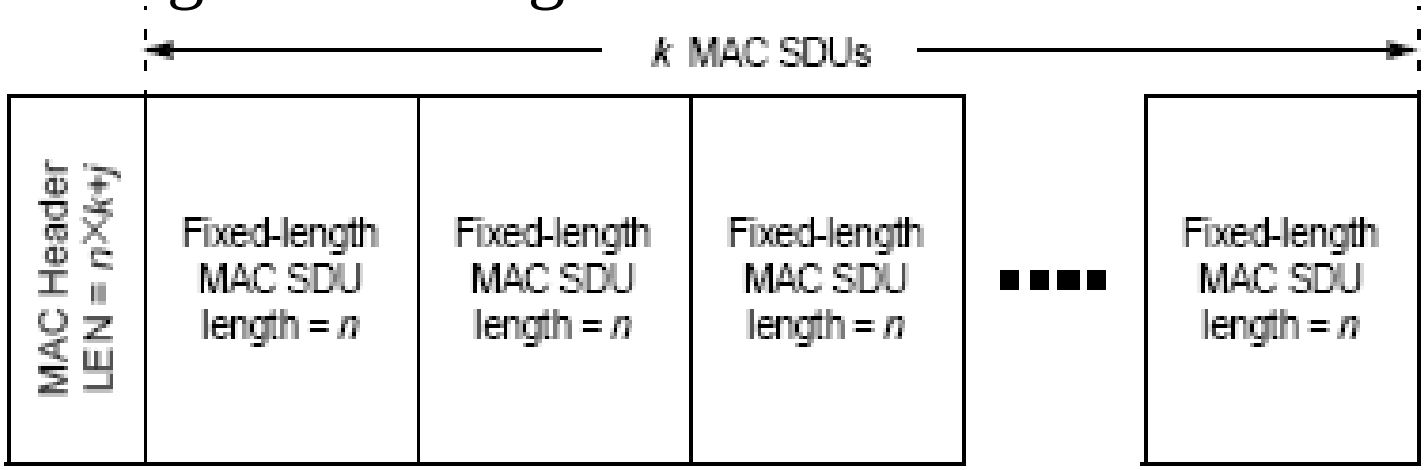
- ARQ Fragmentation Subheader



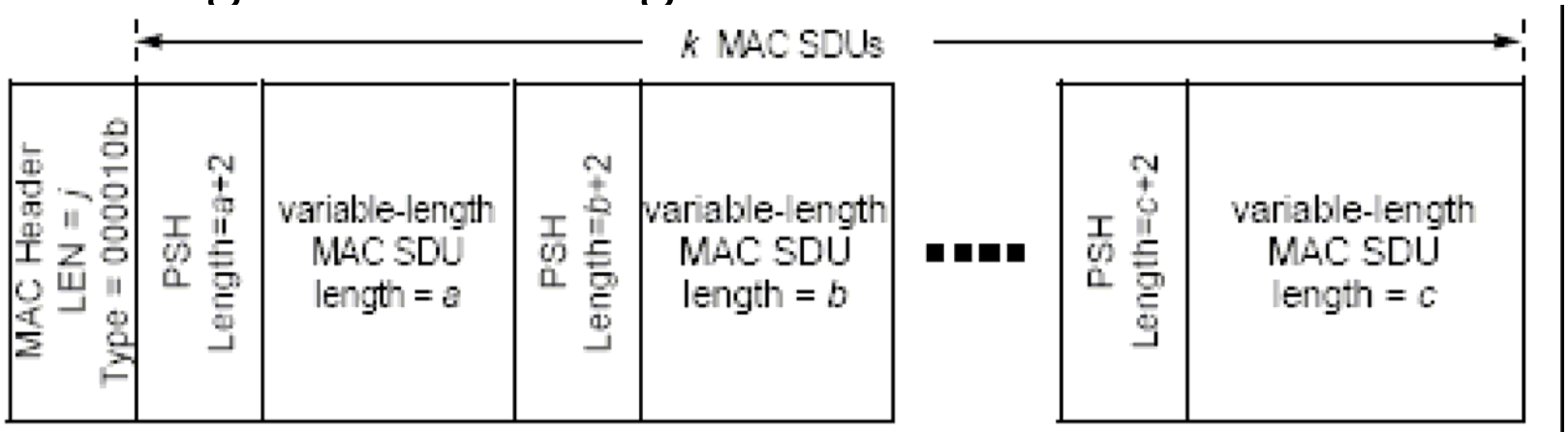
- Extended Fragmentation Subheader

Packing Subheader

- Packing Fixed Length SDUs

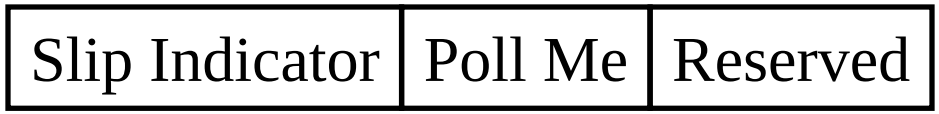


- Packing Variable Length SDUs

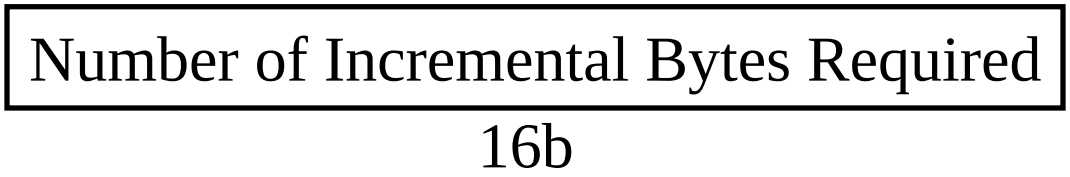


Grant Management Subheader

- Piggybacked bandwidth request
- UGS connections may use UGS-GMSH
  - Slip indicator: Backlog building up



- Non-UGS connections use simple GMSH: No way to indicate incremental/aggregate => Always incremental

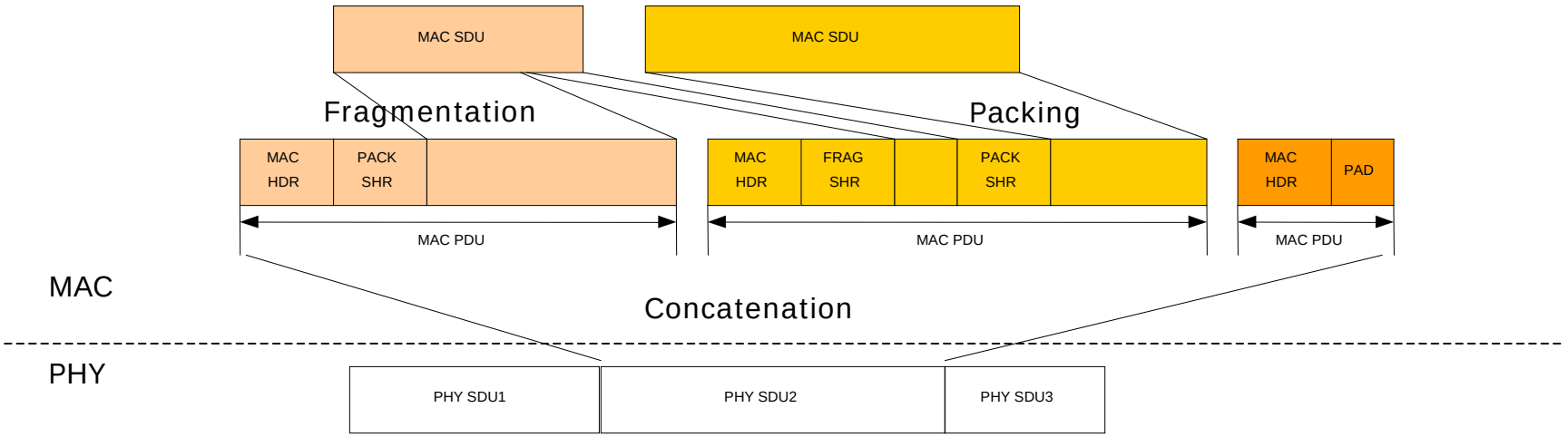


Grant Management Header (Cont)

- Extended piggyback request: For ertPS class.
  - 11 bits of 16-bit header are used for incremental request
  - If msb is set, next 4 bits indicate requested polling size
  - If queue builds up SS sets the msb and BS shifts the grant earlier

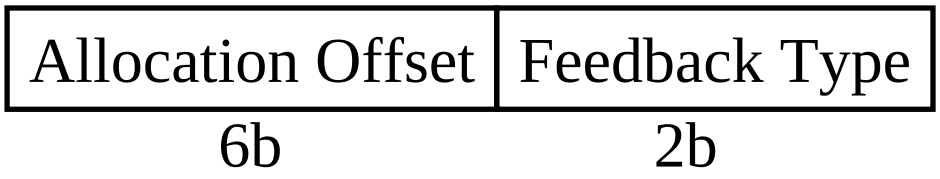
Fragmentation, Packing, Concatenation

- Fragmentation with or without ARQ
- Packing: Fixed size SDU or variable size SDU
- Concatenation: Multiple PDUs in a burst



Fast Feedback Allocation Subheader

- Request feedback from an SS with Advanced Antenna System
- Allocation offset: Number of slots after which the SS should send the feedback (in Ul subframe after 2 frames from now)
- Feedback type: DL measurement, MIMO feedback, antenna #0, MIMO feedback Antenna #1, MIMO mode



ARQ Feedback Information Element

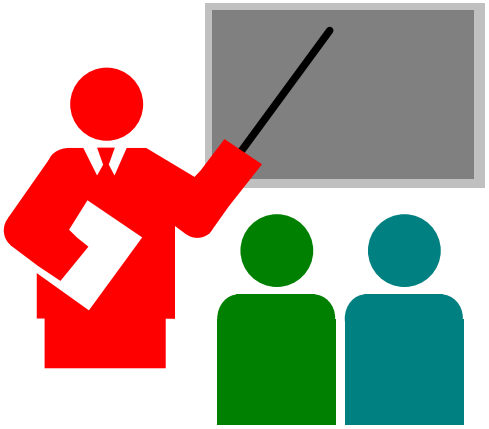
CID	Last	Ack Type	Block Seq Number	#Ack Maps	Ack Map	Ack Map	Ack Map
16b	1b	2b	11b	2b	16b	16b	16b

- Last ⇒ last in a series of ARQ feedback IEs packed together
- # Ack Maps: In this IE
- Ack Type:
  - 00=Selective (Starting BSN and Bit map)
  - 01=Cumulative (Ending successful BSN, no bit map)
  - 10=Cumulative with selective (Successful up to BSN and a bit map)
  - 11=cumulative with BSN (1 bit status for n blocks)

Scheduling and Link Adaptation

- Scheduling:
  - Base schedules usage of the air link among the subscribers
  - Packet schedulers at the base and subscribers give transmission opportunities to multiple connection queues
- Link Adaptation
  - Base determines the contents of the DL and UL portions of each frame
  - Base determines the appropriate burst profile (code rate, modulation level and so on) for each subscriber
  - Base determines the bandwidth requirements of the individual subscribers based on the service classes of the connections and on the status of the traffic queues at the base and subscriber.

Summary



- Centralized resource allocation at base station
  Guaranteed QoS
- Efficient use of available bits
  - Flexing fragmentation and packing
  - ARQ and HARQ
- Complex scheduling to provide guarantees under variable conditions

Related Wikipedia Pages

- http://en.wikipedia.org/wiki/IEEE_802.16#QoS
- http://en.wikipedia.org/wiki/Automatic_repeat-request
- http://en.wikipedia.org/wiki/Hybrid_automatic_repeat_request
- http://en.wikipedia.org/wiki/Duplex_(telecommunications)
- http://en.wikipedia.org/wiki/Time-division_duplex
- http://en.wikipedia.org/wiki/Frequency_division_duplex#Frequency-Division_Duplexing
- See Part I for books and other Wikipedia pages on WiMAX

List of Acronyms

- ARQ Automatic Repeat reQuest
- BE Best Effort
- BPSK Binary Phase Shift Keying
- BS Base Station
- BSN Block Sequence Number
- CID Connection Identification
- CRC Cyclic Redundancy Check
- DCD Downlink Channel Descriptor
- DIUC Downlink Interval Usage Code
- DL Downlink
- DSA Dynamic Service Addition
- DSC Dynamic Service Change
- DSD Dynamic Service Delete
- FDD Frequency Division Duplexing
- FTP File Transfer Protocol
- HARQ Hybrid Automatic Repeat reQuest

List of Acronyms (Cont)

- ID Identification
- IEEE Institution of Electrical and Electronics Engineers
- IP Internet Protocol
- MAC Media Access Control
- MIMO Multiple Input Multiple Output
- MPDU MAC Protocol Data Unit
- OFDMA Orthogonal Frequency Division Multiple Access
- PDU Protocol Data Unit
- PHS Packet Header Suppression
- PHY Physical Layer
- ROHS RObust Header Compression
- SDU Service Data Unit
- SS Subscriber Station
- UGS Unsolicited Grant Service
- UIUC Uplink Interval Usage Code
- UL Uplink