IEEE 802.16 (WiMax)

Sachin Gajjar

sachin.gajjar@nirmauni.ac.in

Reading Material

- Computer Networks, Fourth Edition by Andrew S Tanenbaum
  - Chapter 4, Topic 4.5

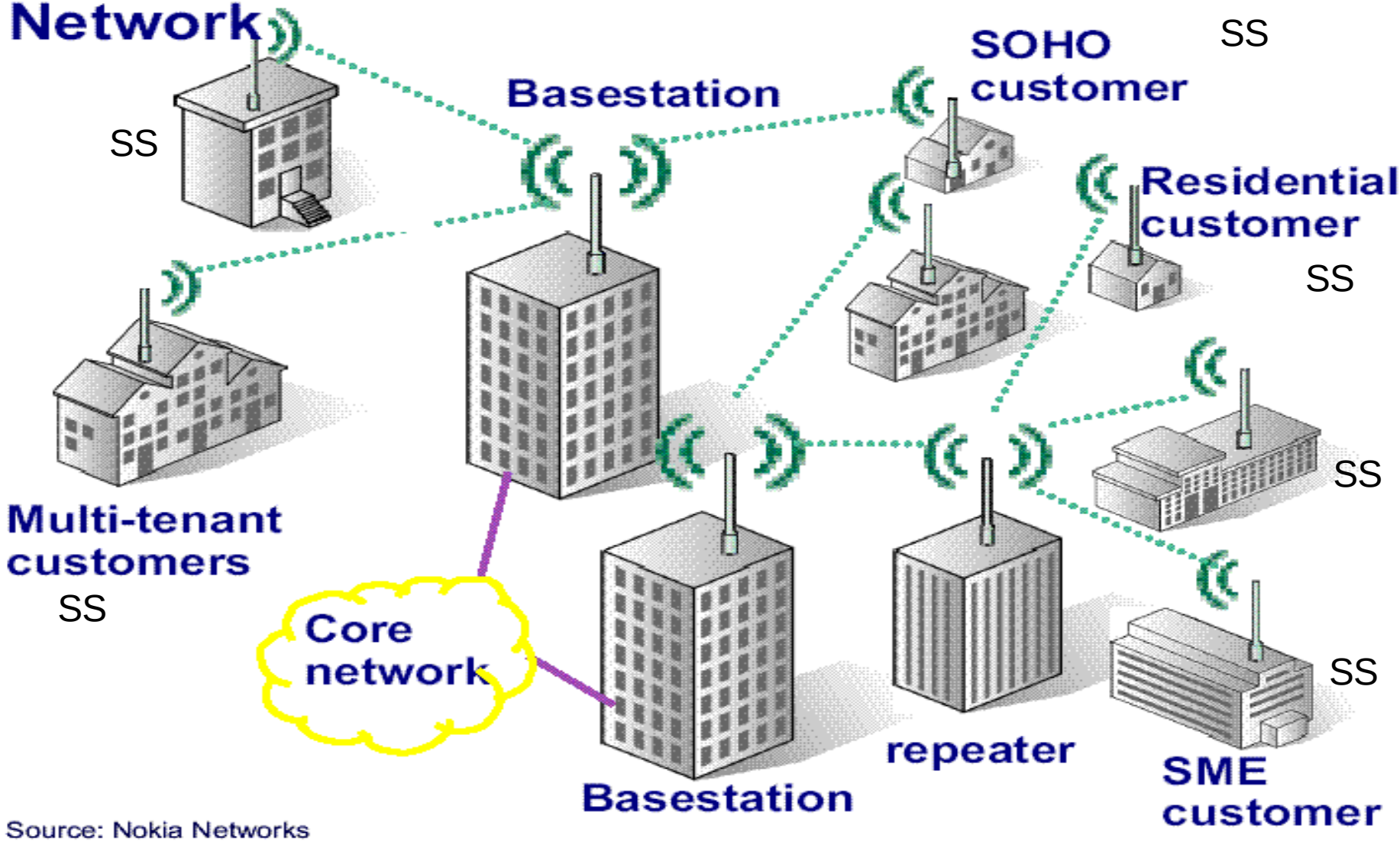
IEEE 802.16

- Goal: Provide high-speed Internet access to home and business subscribers, without wires with speed in Mbps
- To setup a Wireless Metropolitan Area Network (WMAN)
- WiMax (Worldwide Interoperability for Microwave Access)
- Standard for delivery of “last mile” wireless broadband access as alternative to cable and DSL
- Cable/DSL required lot of coax, fiber, UTP to millions of homes/business
- Point to multipoint wireless networking
- Base station and infrastructure required
- Defines MAC and PHY layer options, for Broadband Wireless Access (BWA) systems

Difference between 802.16 & 802.11

802.16	802.11
• For MAN	• For LAN
• Originally not designed for mobility. Was added later in 802.16e	• It is designed for mobile terminals.
• Full duplex can be done.	• Avoids full duplex to decrease cost of radio interface.
• Distance between station is more, power varies from station to station.	• Power variation is not the case.
• Open communication in city. more privacy & security concern	• Privacy & security are less concerned.
• No. of users & BW usage/user is high. More spectrum is required.	• Bandwidth is not so high.

WirelessMAN: Wireless Metropolitan Area Network



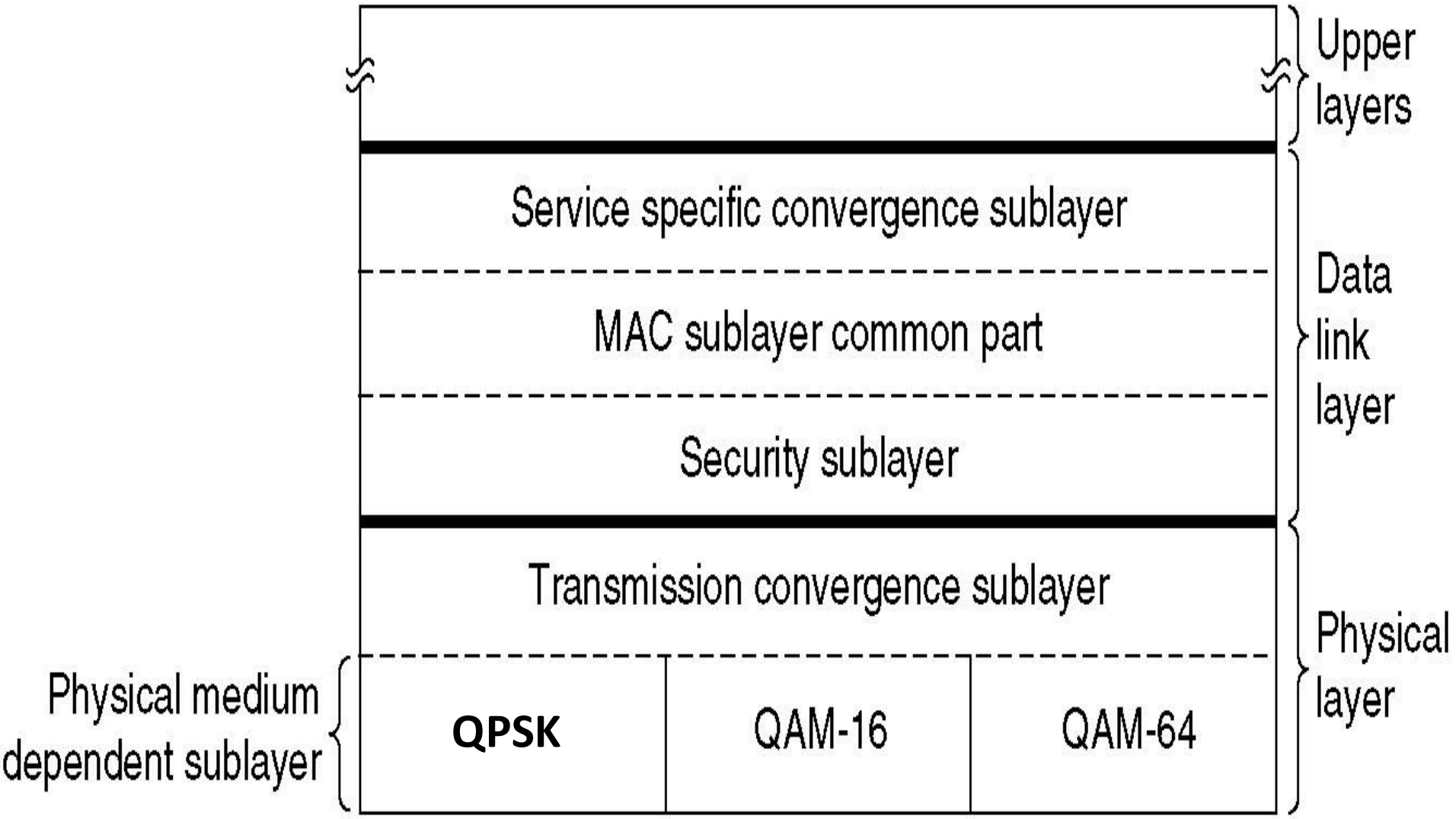
Source: Nokia Networks

Green coloured lines – would be cables if DSL/Cable modem is planned to be used
SOHO – Small Office Home Office
SME – Small and Medium Enterprise , SS – Subscriber Station

Base Station and Subscriber Stations

- Centralized access control to prevents collisions
- Base Station (BS): Controls entire network, frame size, scheduling, admission control, QoS, 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, follow transmission/ reception schedule from BS, perform initial ranging
- Ranging - process by which new stations adjust their timing and request initial bandwidth to connect to BS

The 802.16 Protocol Stack



data link layer

- consists of three sublayers
  - Security Sub Layer
  - MAC sublayer common part
  - service-specific convergence sublayer

Data Link Layer

- Security Sub Layer
  - deals with privacy and security,
  - more crucial as it is public outdoor network
  - manages encryption, decryption, and key management
  - Payloads encrypted, not headers
  - Snooper can identify participants in transmission, not data being transmitted
  - When subscriber connects to BS, they perform mutual authentication with RSA public-key cryptography using X.509 certificates

Data Link Layer

- MAC sublayer common part
  - Base station controls the system
  - Channel management and slot allocation to subscriber stations
  - Completely connection oriented, to provide QoS guarantees for telephony/multimedia communication
  - Schedule downstream (BS→SS) channels
  - Manages upstream (SS→BS) channels
  - Fragmentation and reassembly of large MAC SDUs
    - Service Data Unit (SDU) a unit of data that is passed down from layer to lower layer.

The 802.16 Protocol Stack

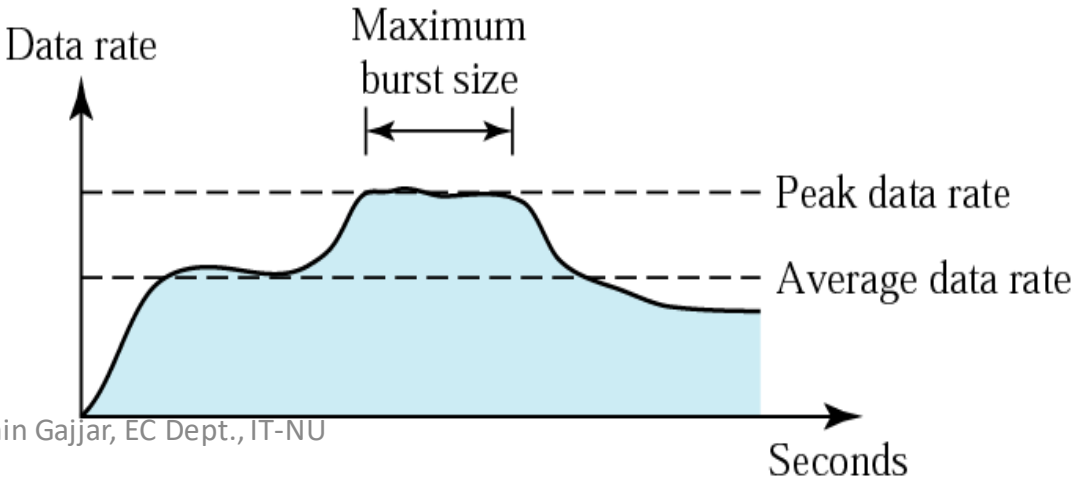
- Service-specific convergence sublayer
  - interface to the network layer
  - 802.16 was designed to integrate seamlessly with
    - PPP, IP, Ethernet (connectionless)
    - Asynchronous Transfer Mode (ATM) (connection oriented)
  - Map ATM connection to 802.16 lower layer
  - Classify SDUs based on MAC address, VLAN, priorities
  - Assigns Service Flow ID (SFID) and a connection identifier

MAC Frames

- SSs share media using TDMA based on class of service
- Each MAC frame made of subframes
- 1st 2 subframes have downstream (BS to SS) & upstream (SS to BS) maps
  - Maps indicate traffic are in which time slots, and which time slots are free
  - Downstream map also contains various system parameters to inform new stations as they join the network

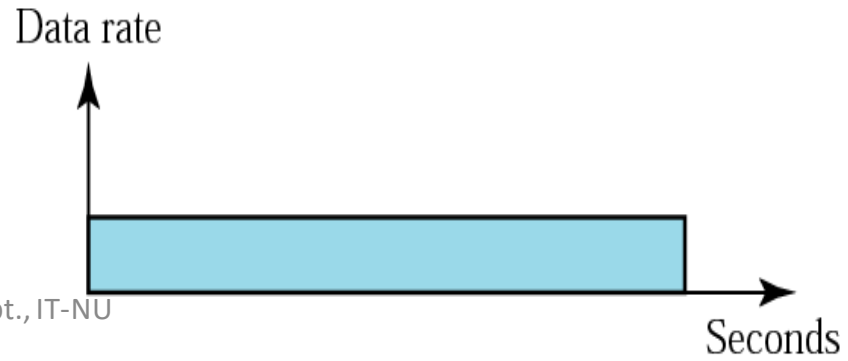
Channel Access based on Service Class

- Uncoordinated subscribers request to access upstream channel (SS→BS)
- Its allocation is tied to quality-of service issue
- Each SS connection gets one of the classes of service, determined when the connection is set up
  1. Constant bit rate service (CBR), Fixed Rate traffic
  2. Real time variable bit rate service (VBR)
  3. Non real time variable bit rate service
  4. Best effort service



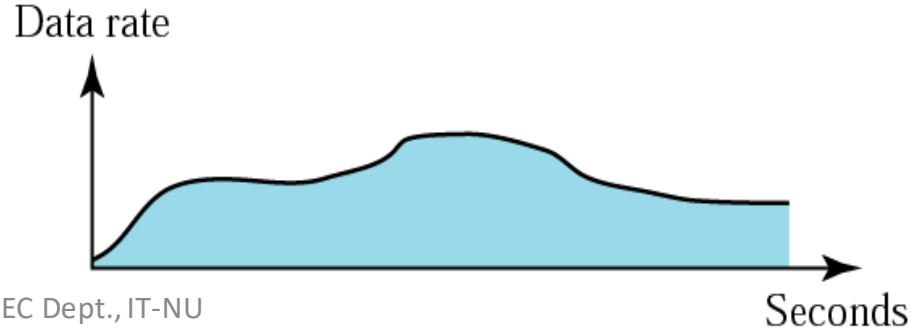
Service Class

1. Constant bit rate service (CBR), Fixed Rate traffic
   - data rate that does not change
   - average data rate = peak data rate
   - Easy to handle as BW requirement is known in advance
   - Predetermined amount of data is generated at fixed time interval by SS
   - BS has to dedicate certain time slot to connect without explicit request
   - e.g. uncompressed voice
   - e.g. MP3 audio



Service Class

2. Real time variable bit rate service (VBR)
   - rate of the data flow changes in time
   - changes smooth instead of sudden and sharp
   - average data rate ≠ peak data rate
   - BW required may vary w.r.t to time
   - BS polls SS periodically to query BW required for following period
   - E.g. compressed multimedia & soft real time communication



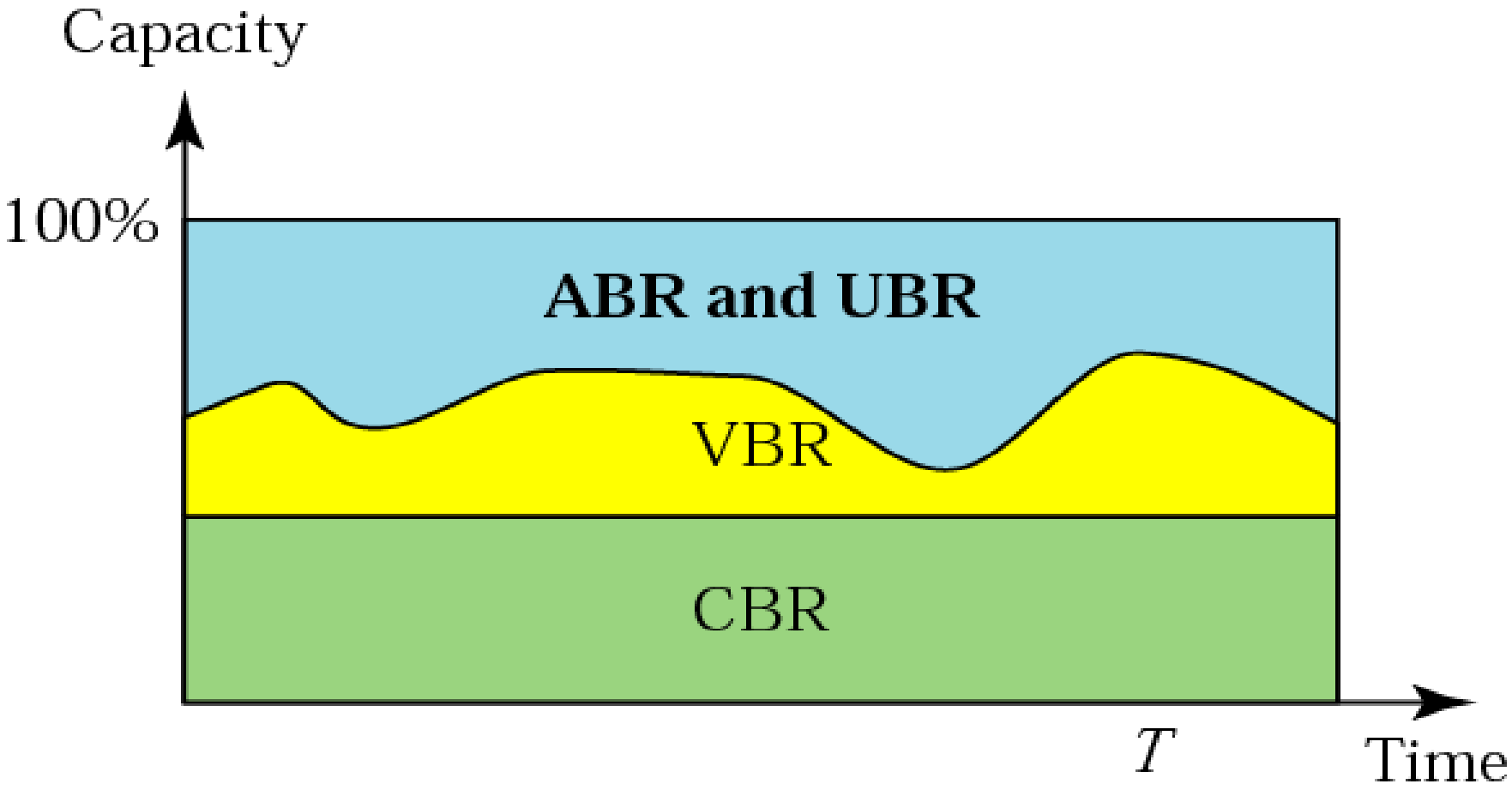
Service Class

3. Non real time variable bit rate service
   - Eg. Large file transfer
   - BS polls SS but not periodically
   - Non real time so no deadlines in transmission time requirements
   - No worry of Jitter

Service Class

4. Best effort service
   - unspecified-bit-rate (UBR)
   - Other services than above
   - SSs contend by sending request for BW in time slots marked in upstream map as available for contention
   - If a request is successful, its time slot will be noted in the next downstream map
   - If it is not successful SS has to try again later.
   - Binary exposure back off used to decrease collisions

Relationship between service classes to the total capacity of the network

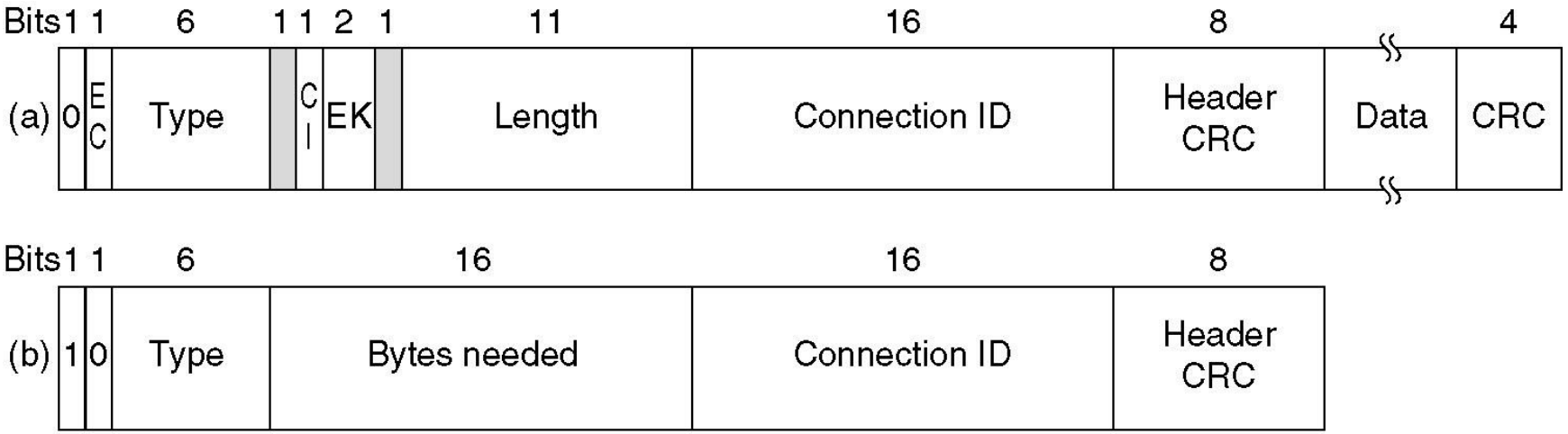


Forms of slot allocation

- Per station
  - One SS aggregates needs of all users and makes collective requests for them to BS
  - When it is granted slots, it shares out slots to its users as it sees fit
- Per connection
  - BS manages each user connection directly

The 802.16 MAC Frame Structure

(a) A generic frame. (b) A bandwidth request frame.

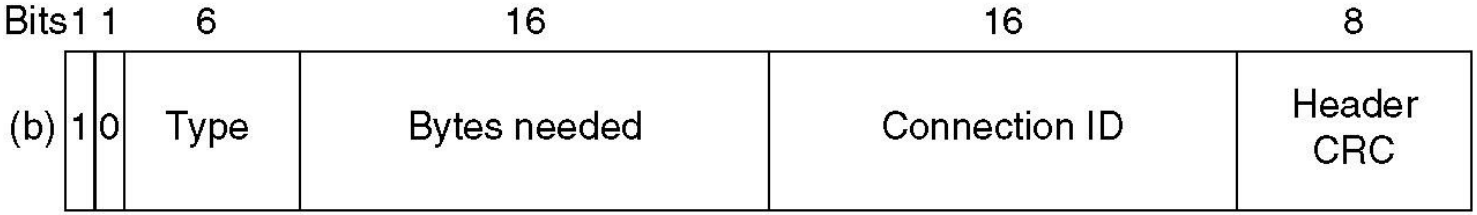


Header of Generic Frames

- 0 - 1st bit
- EC - 1 bit tells if payload is encrypted
- Type - 6 bits – frame type, tells if packing & fragmentation is done
- CI-1 bit tells checksum present/not
- EK- 2 bit tells which encryption key is used
- Length – 11 bits tells length of frame + header
- Connection identifier – 16 bits tells which connection the frame belongs to (SS serving several users, each user identified with one CI)
- HeaderCRC – 8 bits checksum for the header only
- Data
- CRC – 4 bits for full frame CRC

Header of Bandwidth Request frame

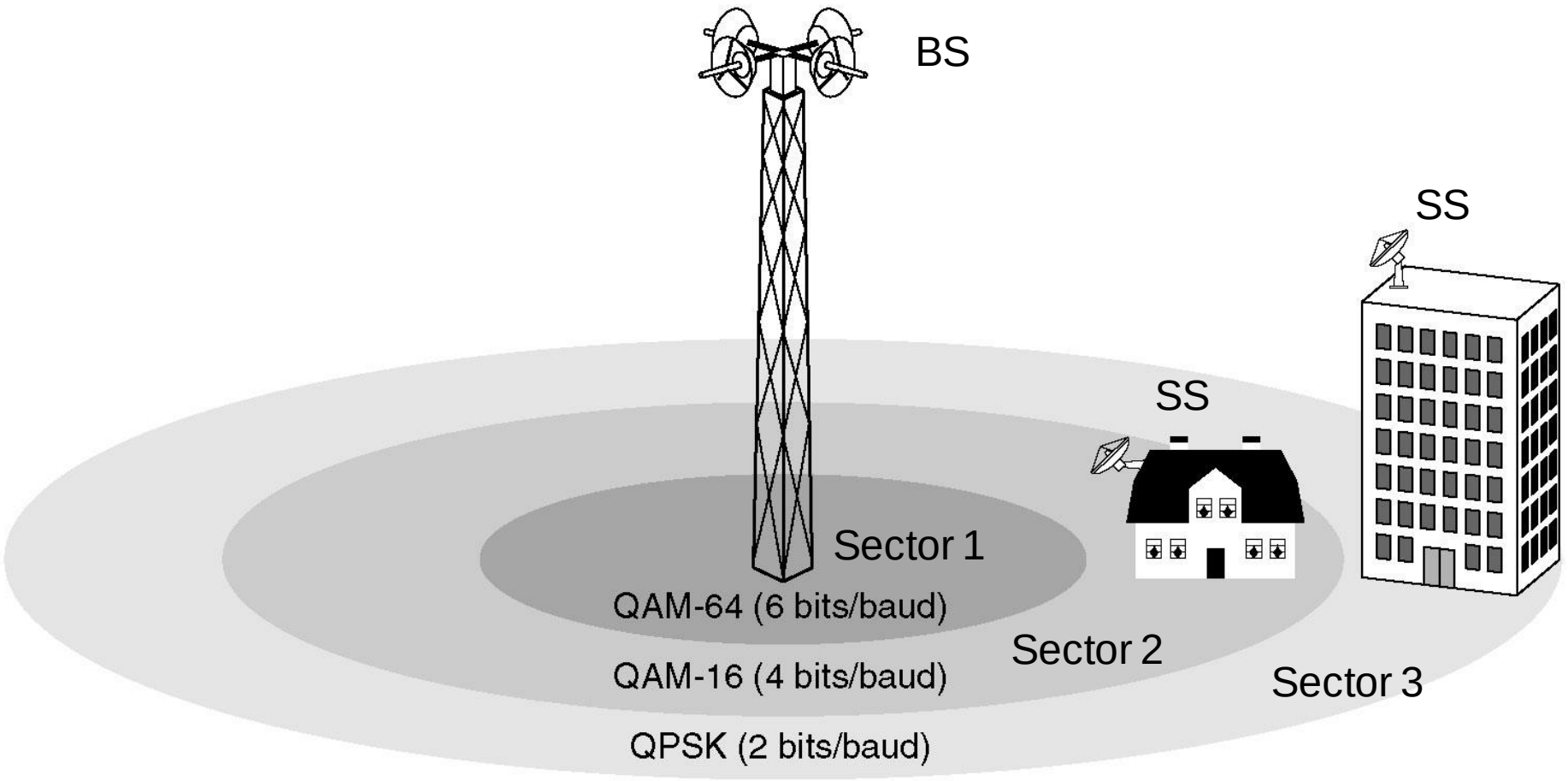
- Frame send from SS to BS
- 1- 1st bit
- Same as generic frame except
  - 2nd and 3rd byte – tells BW required by SS
  - Bandwidth request frames do not carry data or full-frame CRC



Physical layer

- 10 to 66 GHz range spectrum with millimeter waves is used
- Millimeter waves travel in straight line
- Thus BS can have multiple antennas each pointing at different sector of surrounding land
- Each sector has its own users and is fairly independent of the adjoining sector users

Physical Layer



The 802.16 transmission environment.

Physical Layer- Modulation schemes

- Signal strength in millimeter band falls off sharply with distance from BS
- SNR drops with distance from BS
- 3 modulation scheme used depending on distance of SS from BS.
- close-in subscribers (sector 1), QAM-64 is used, with 6 bits/baud
- medium-distance subscribers (sector 2), QAM-16 is used, with 4 bits/baud.
- For distant subscribers (sector 3), QPSK is used, with 2 bits/baud

Physical Layer- Modulation Scheme

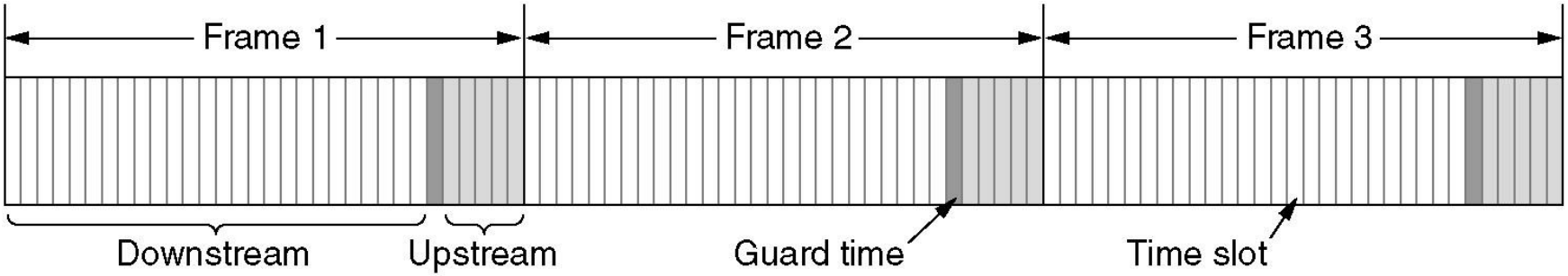
- For a typical value of 25 MHz worth of spectrum
  - QAM-64 gives 150 Mbps,
  - QAM-16 gives 100 Mbps,
  - QPSK gives 50 Mbps.
- farther the subscriber is from the base station, the lower the data rate

Physical Layer – BW allocation

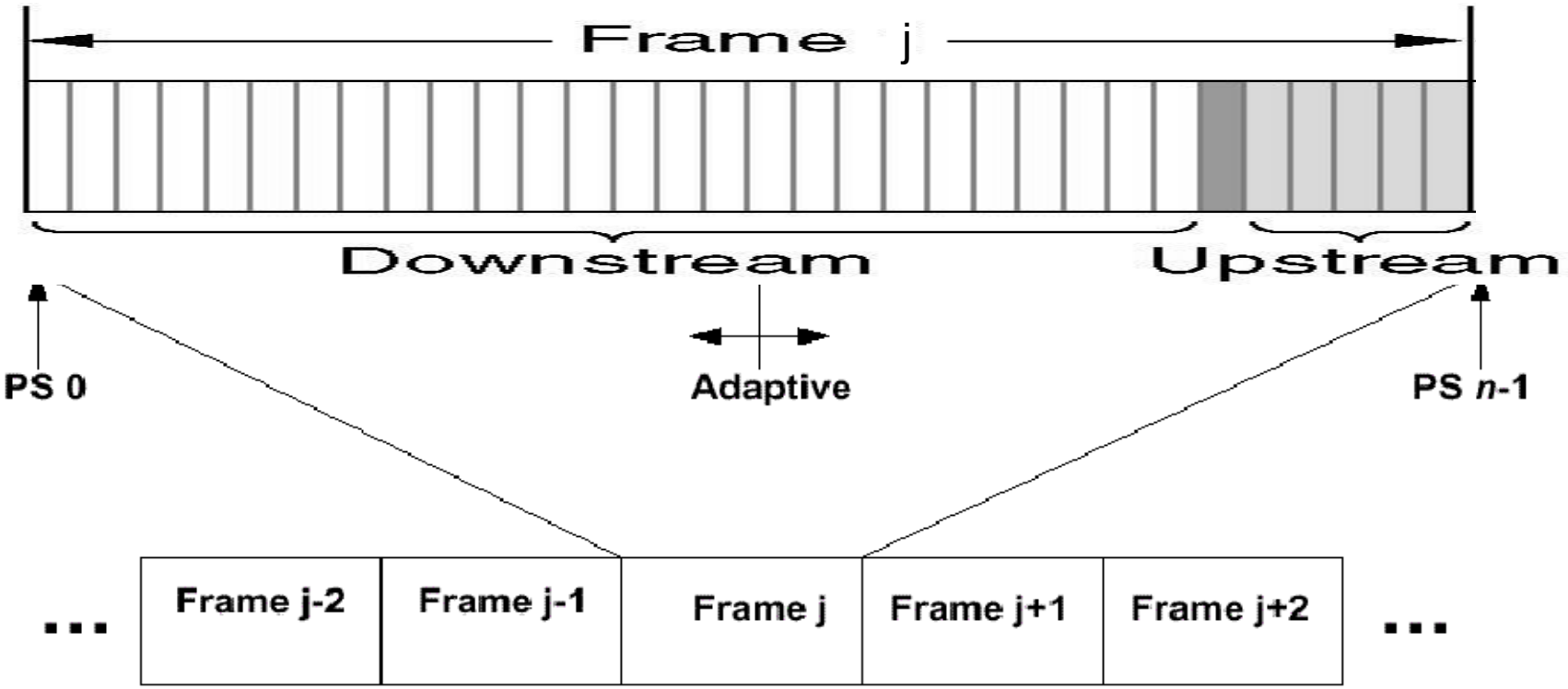
- 802.16 provides 2 schemes
  - FDD (Frequency Division Duplexing)
  - TDD (Time Division Duplexing).

TDD (Time Division Duplexing)

- BS periodically sends out frames (indications for frames)
- Each frame contains time slots.
- The first ones are for downstream traffic.
- Then comes a guard time used by stations to switch direction.
- Finally, we have slots for upstream traffic.
- Number of time slots devoted to each direction can be changed dynamically to match bandwidth in each direction to traffic.



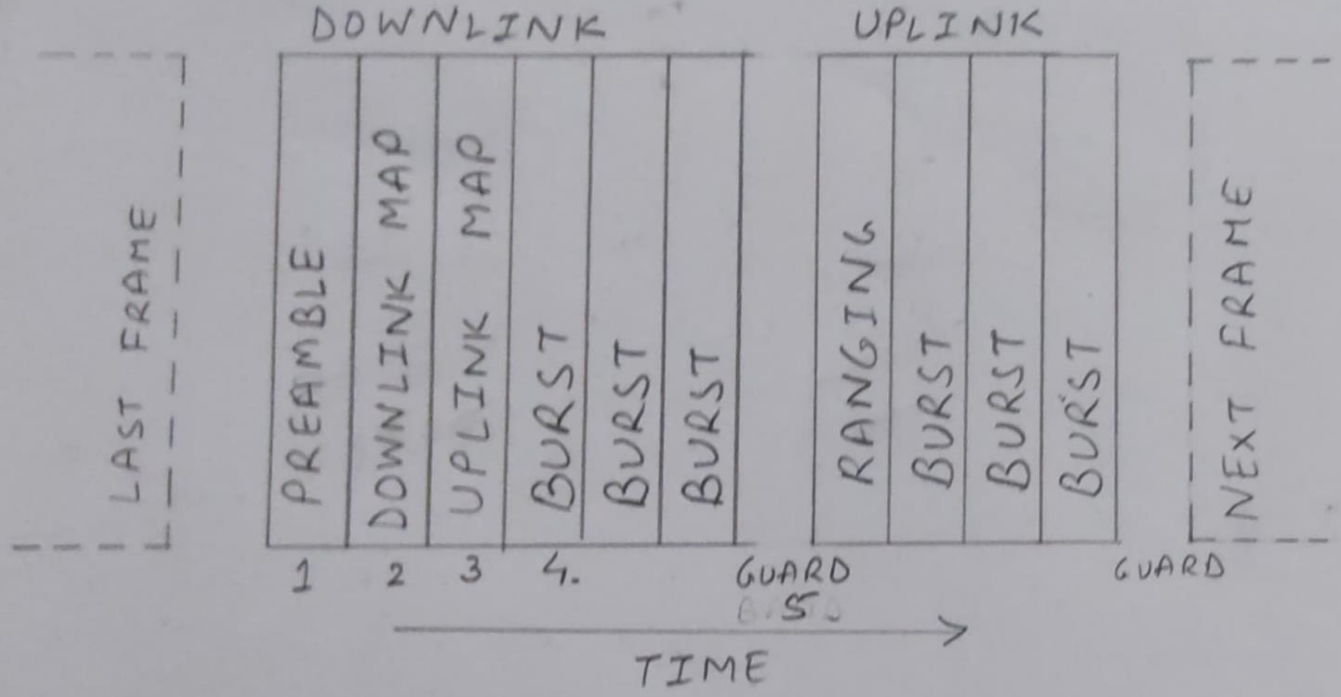
Time Division Duplexing (TDD)



TDD (Time Division Duplexing)

- BS is completely in control for downstream
- Downstream traffic is mapped onto time slots by BS
- Upstream traffic is more complex and depends on QoS required by SS, slots are allocated based on Service Type required by SS

Frame structure with time division duplexing



1. SYNCHRONIZATION
2. DETAILS OF DOWNLOAD SLOTS ALLOCATION
3. " " UPLOAD " "
4. BURST - DATA
5. GUARD- S S. SWITCHES FROM RX. TO TX.
6. RANGING - NEW S.S TO ADJUST THEIR TIME & REQUEST SLOT TO BS
7. BURST- DATA FROM SS AS PER SLOT ASSIGNMENT

Frame structure with time division duplexing

- Frame structure that is repeated over time.
- Preamble to synchronize all stations
- Downlink (DL) transmissions from BS
- DL/UP maps defines how DL/UP slots are assigned over the frame
- BS controls maps to allocate different bandwidth to stations from frame to frame depending on the needs of each station.
- Next, BS sends bursts of traffic to different SS stations at times given in DL map
- Download transmissions end with guard time for stations to switch from receiving to transmitting
- Finally, SS send their bursts of traffic to BS in uplink positions that were reserved for them in UL map

Error

- Networks rely on checksums to detect errors and request retransmission when frames are received in error
- For WiMax
  - Retransmissions not appropriate for real time services
  - There will be high error rate, hence use Hamming codes to do forward error correction in physical layer
  - This error correction is employed in physical layer, in addition to checksums in the higher layers

Thank You!