NC STATE UNIVERSITY


# Next Generation Wireless Networking

# **W**orldwide **I**nteroperability for **M**icrowave **Acc**ess

# (WiMAX)

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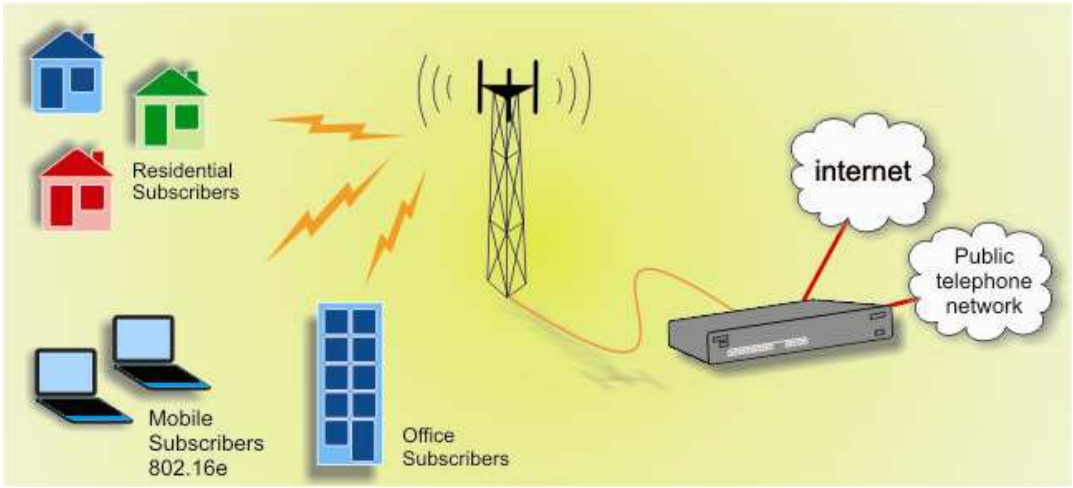
# IEEE 802.16 Key Features and Capabilities

- High Bandwidth Service (134Mbps per BS in each 28MHz channel)
- A range of 50km (in LOS environment 10-66GHz) and 6.5km (in NLOS environment 2-11GHz).
- Excellent Backhaul for enterprise campuses, Wi-Fi Hotspots and Cellular Networks.
- MAC protocol is connection-oriented
- Use of License and Non-License spectrum.
- (802.16e) mobility of users.



# Outline

1. 802.16-2004 QoS

2. 802.16e

2.A. Handover - Mobility

2.B. Energy Conservation

3. 802.16 Mesh Mode

4. 802.16j Mobile Multi-hop Relay (MMR)

# Section 1: IEEE 802.16-2004

MAC layer is divided in three layers

- Service Specific Convergence Sublayer

  Accept Higher layer PDUs and classify
- Common Part Sublayer

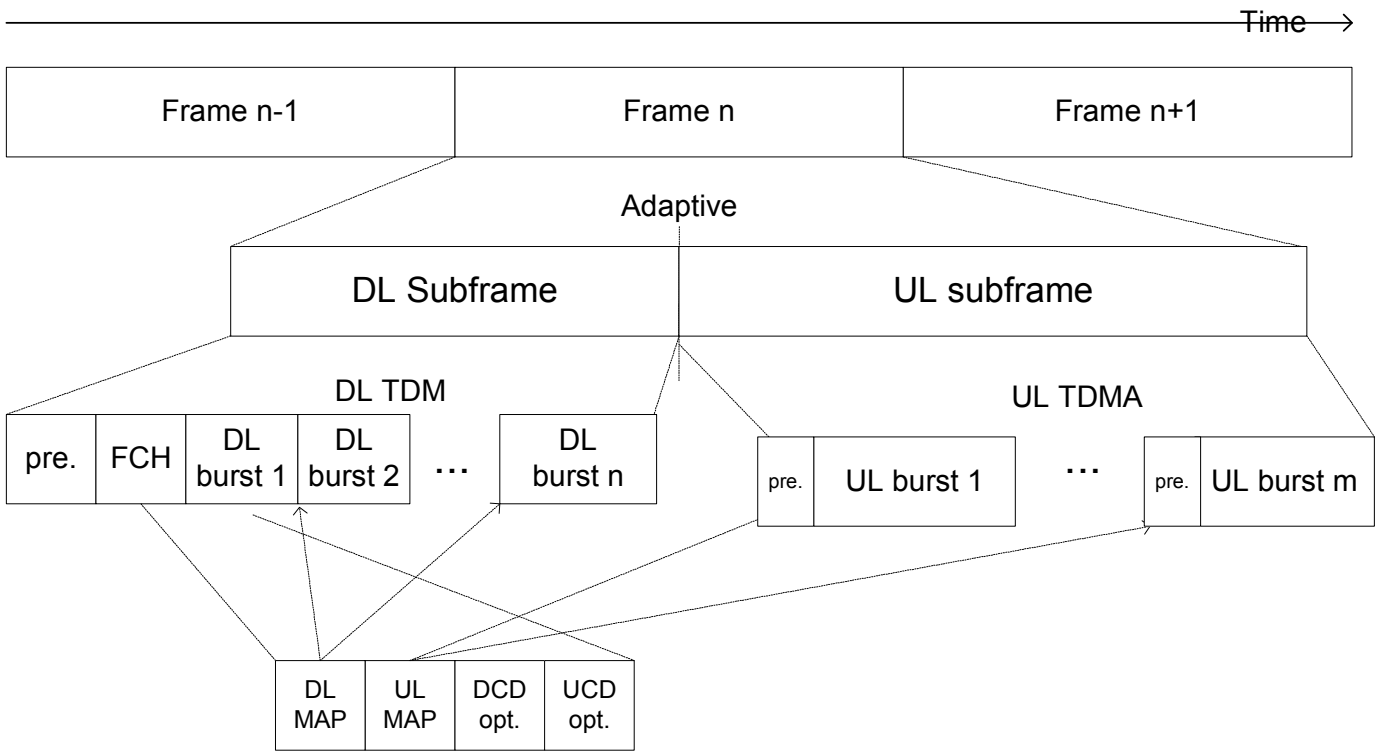
  Facilitate the sharing of the transmission medium
- Security Sublayer

  Facilitate Authentication and Encryption

Architectures

- Point-to-Multipoint
- Point-to-Point
- Mesh

# Frame Structure




## Duplexing

1. Time Division Duplexing (TDD)
2. Frequency Division Duplexing (FDD)

# IEEE 802.16 MAC addressing and Identifiers

- SS has 48-bit IEEE MAC address
- BS has 48-bit base station ID
  - Not a MAC address
  - 24-bit operator indicator
- 16-bit connection ID (CID)
- 32-bit service flow ID (SFID)
- 16-bit security association ID (SAID)

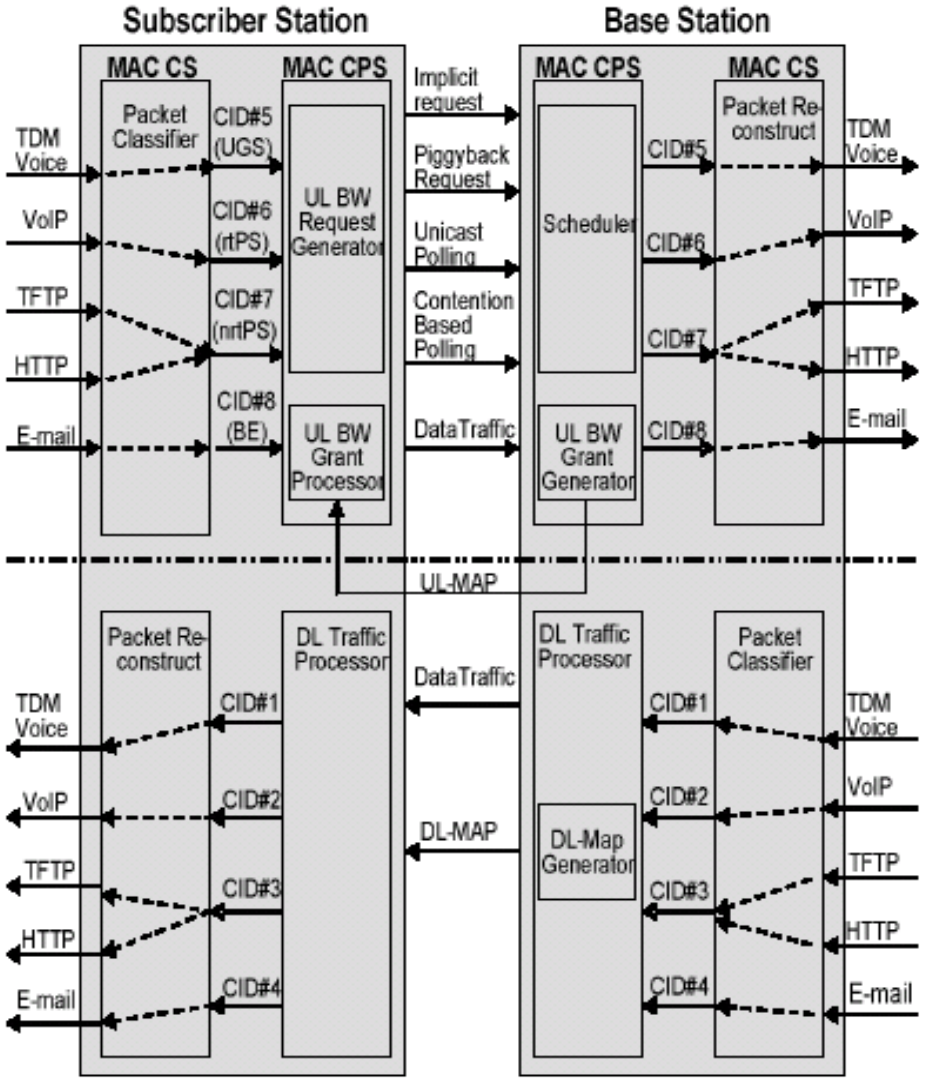
***Service Flow***
A unidirectional MAC-layer transport service characterized by a set of QoS parameters, e.g., latency, jitter, and throughput assurances

# Quality of Service (QoS) #1

1. Fragmentation
2. Concatenation
3. Contention
4. Piggyback

Scheduling Service Flows in IEEE 802.16

1. Unsolicited Grant (UGS)
2. Real-Time Polling (rtPS)
3. Non Real-Time Polling (nrtPS)
4. Best Effort (BE)



# Quality of Service (QoS) #2

| Service Flow | Definition | Applications |
|---|---|---|
| UGS | Real time data streams with fixed size data packets issued at periodic intervals | T1/E1, VoIP without silence suppression. |
| rtPS | Real time data streams with variable size data packets issued at periodic intervals | MPEG video, VoIP with Silence suppression |
| nrtPS | Delay Tolerant data streams with variable size data packets issued at periodic intervals | FTP, Telnet |
| BE | Delay Tolerant data streams, background traffic or any either application without significant QoS constrains | HTTP, E-mail |

# Section 2: IEEE 802.16e

- SSs → MSSs, Mobile Stations
- Defines Handover, HO "an MS migrates from the air interface provided by one BS to the air interface provided by another BS"
- Defines Sleep Mode, "in sleep mode the MS is no longer receiving any traffic from the BS and so it can set its power usage to minimum"
- Defines Idle Mode,
- Changes to the PHY layer

  OFDMA → SOFDMA

# IEEE 802.16e QoS classes

| Type | Symbolic name of service type | Meaning |
|---|---|---|
| 0 | UGS | Unsolicited Grant Service<br>For UL connections should be supported by UGS Scheduling Service |
| 1 | RT-VR | Real-Time Variable Rate Service<br>For UL connections should be supported by rtPS Scheduling Service |
| 2 | NRT-VR | Non-Real-Time Variable Rate service<br>For UL connections should be supported by nrtPS Scheduling Service |
| 3 | BE | Best Efforts Service<br>For UL connections should be supported by BE Scheduling Service |
| 4 | ERT-VR | Extended Real-Time Variable Rate Service.<br>For UL connections should be supported by ertPS Scheduling Service. |

# Section 2.A Types of Handover

- MSS Initiated HO
- BS Initiated HO
- Soft HO

- When
  - Moving out of coverage of its serving BS
  - If it can get a higher QoS at another BS

# MS Initiated Handover Slide 1

- **STEP #1**: BS transmits Mobile Neighbor Advertisement, MOB_NBR-ADV

(inform listening stations of the characteristics of any neighboring BSs

  - Frequency of this BS
  - BS identifier
  - Types of Service
  - Available Radio Resources

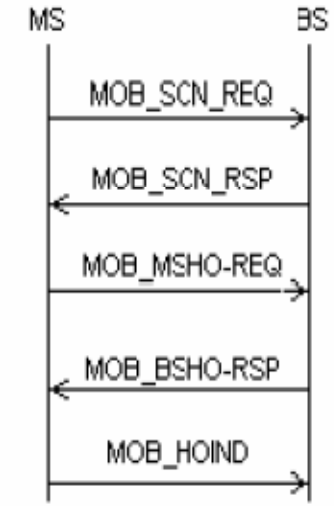
  (if the SSs runs quicker than MOB_NBR-ADV no HO can be made

- **STEP #2**: MSS transmits Neighbor Scanning, MOB_SCN-REQ

(tells BS that it wishes to scan its neighbors) – Response: MOB_SCN-RSP

  - Length of time in frames for this interval
  - Types of association it will scan its neighbors with
    - Without Coordination
    - With Coordination
    - Network Assisted Association Reporting
- **STEP #3**: Negotiating Handover with Serving BS,
  - MSS Transmits MOB_MSHO-REQ (transmitted on the basic connection and contains a list of stations the MS recommends as targets – result of scanning)
  - BS sends HO-pre-notification-response to other BSs (it can include the Information Element IE) – ask the other BSs about their capability of serving the MSS
  - BS transmits MOB_BSHO-RSP (via basic connection)
  - MS transmits MOB_HO-IND (via basic connection – this messages tells either cancellation of HO or correct HO)

# BS Initiated Handover




- Advantages
  - Centralized HO Procedure
  - Computation can be performed from the BS, so as to minimize energy consumption
- BS transmits Mobile Neighbor Advertisement, MOB_NBR-ADV

(inform listening stations of the characteristics of any neighboring BSs

  - Frequency of this BS
  - BS identifier
  - Types of Service
  - Available Radio Resources

  (if the SSs runs quicker than MOB_NBR-ADV no HO can be made
- BS transmits MOB_BSHO-REQ
  - tells the MS it needs to perform HO and so to start scanning its neighboors
  - contains BS's list of recommended target stations with such relevant info (service level predictions and channel details)
  - Transmitted in basic connection
- MS transmits MOB_BSHO-RSP

(list of all recommended stations)

# Section 2.B Sleep Mode Operation

Scope:

- Minimize MS power usage
- Decrease usage of serving BS

- Awake Mode: Transmit and receive data

- Sleep Mode (absent from the serving BS during a pre-negotiated period)
  - Sleep Window
  - Listening Window

- Three types of Power Saving Classes
  - Type 1: Best Effort (BE) and Non-Real-Time Variable Rate (NRT-VR)
  - Type 2: Unsolicited Grant Service (UGS) and Real-Time Variable rate (RT-VR)
  - Type 3: Contentions of multicast connection with one time sleeping

# Power Saving Classes, Type 1

Classes:

1. BE
2. NRT-VR

Steps:

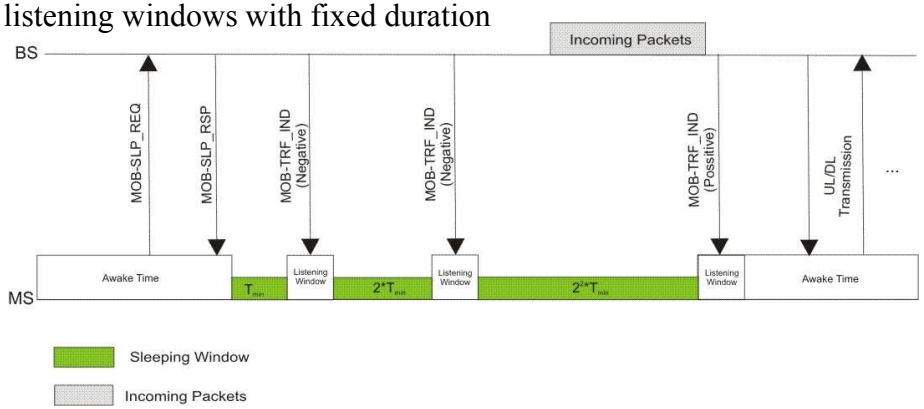
1. MS sends a sleep request Message (MOB-SLP-REQ)
2. BS responds with a (MOB-SLP-RSP), to determine whether it agrees
3. MS gets initial-sleep window first.
4. After that, MS wakes up at the beginning of the listening window and receives the traffic indication message (MOB-TRF-IND)
   - If data are buffered to the BS, for the MS, it gets the Positive-TIM broadcast and goes back to the awake
   - If data are not buffered for the MS, it gets the Negative-TIM and remains to sleep mode (double size of the previous one until the final-sleep window).

Parameters:

1. Initial sleep window
2. Final sleep window
3. Final sleep window exponent
4. The listening window is negotiated between BS during MOB-SLP-REQ/MOB-SLP-RSP
5. Start frame number for first sleep window
6. Traffic triggered wakening flag

Sleep Mode Operation:

1. Sleep Windows increases binary exponentially
2. And are interleaved with listening windows with fixed duration



# Power Saving Classes, Type 2

Classses:

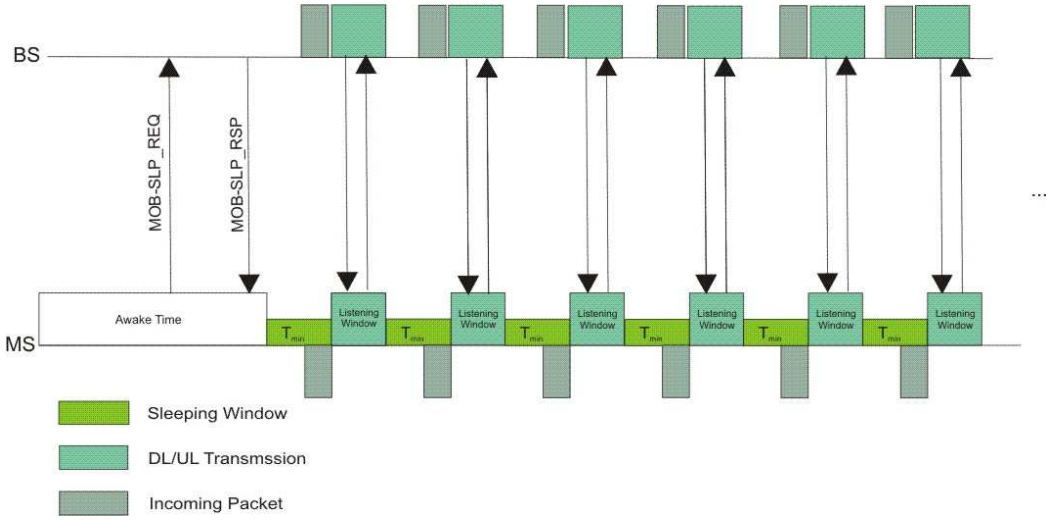
1. UGS
2. RT-VR

Steps:

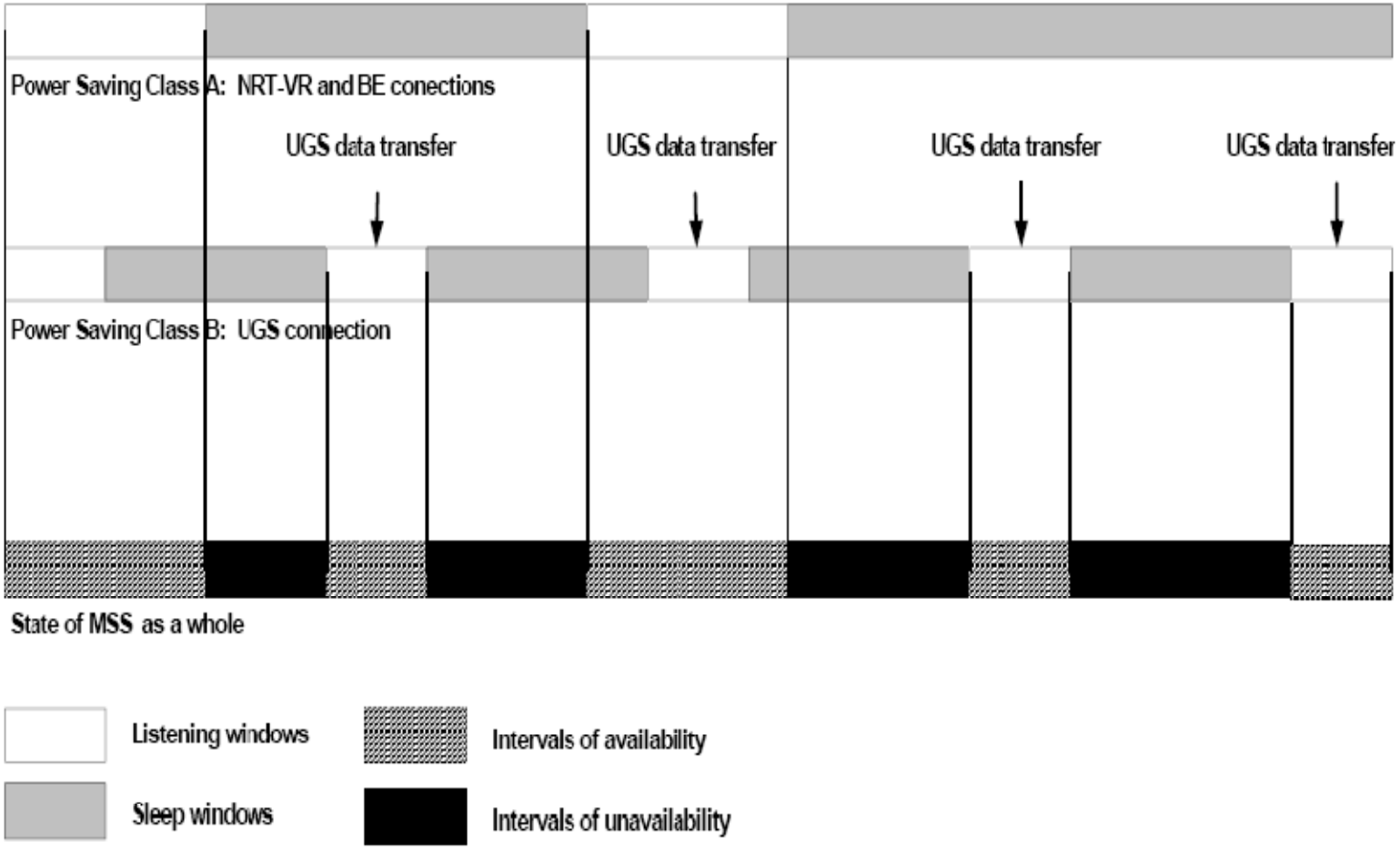
1. MS sends a sleep request Message (MOB-SLP-REQ)
2. BS responds with a (MOB-SLP-RSP), to determine whether it agrees
3. MS gets initial-sleep window first
4. Opposite to Type 1, MS can sent and receive data during listening window interval

Parameters of MOB-SLP-REQ:

1. Initial sleep window
2. Listening window
3. Start frame number for first sleep window

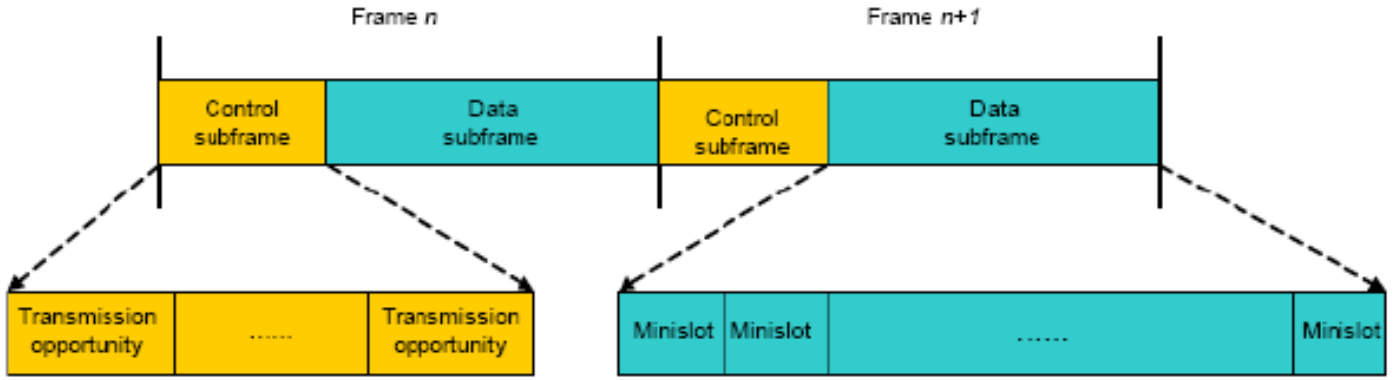


# Total Functioning of Sleep Mode (1)



# Section 3: IEEE 802.16 Mesh Mode

- In mesh mode the nodes are organized in an adhoc fashion; All stations are peers and each node can act as routers to relay packets for its neighbors.
- Although Backhaul links between BSs can exist there is no need to have direct link from SS to the BS of the mesh network.
- TDMA is used among the mesh BSs and MSs, where a radio channel is divided in frames
- The control and data channels are separated and every node competes for the control channel access (thus do not affect the current data transmission)



# IEEE 802.16 vs 802.11 mesh

## 802.16

1. Connection-Oriented
2. All transmission are synchronized
3. Three-way handshake to set up connection before data transmission
4. Control and data channels are separated. One does not affect the other
5. Nodes can reserve multiple slots for the following packets without exchanging control message again

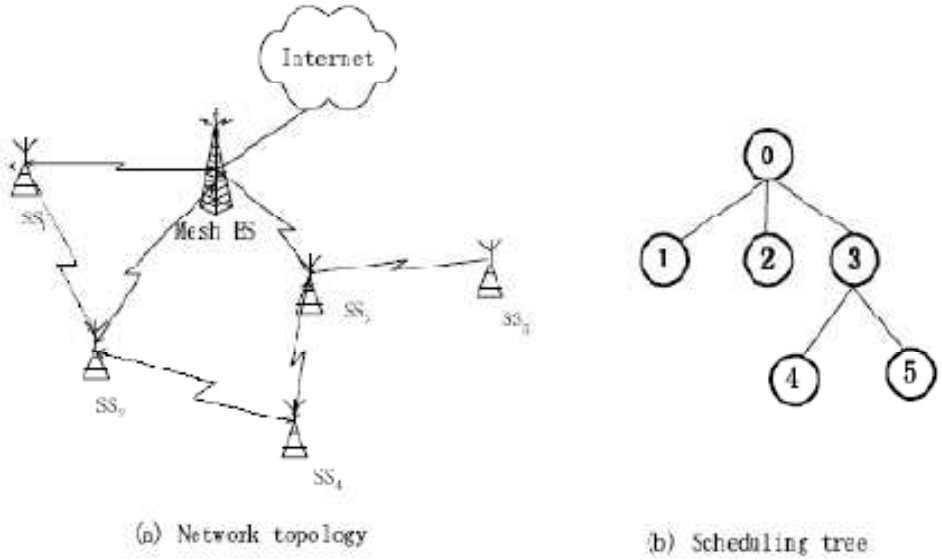
## 802.11

1. Connectionless
2. Nodes sense the channel before transmission
3. Four-Way RTS/CTS/Data/ ACK exchange
4. Control packets are sent between data packets in the same channel
5. Nodes must compete for the channel for every packet

# WiMAX Mesh Networks

Mesh Network Configuration (MSH-NCFG) and Mesh Network Entry (MSH-NENT) for creation and maintenance of the network configuration. A scheduling tree rooted at the mesh BS is established for the routing path between each SS and the mesh BS

- MSH-NCFG are periodically advertised which contain network descriptor that includes the network configuration information.
- A new node that wishes to join scans for active networks by listening the MSH-NCFG message. Upon receiving it the node established synchronization with the mesh network
- From all the neighbor nodes which advertise MSH-NCFG the new node select one as its sponsor node
- The new node sends, through the sponsor node to the mesh BS the MSH-NENT message with registration information.

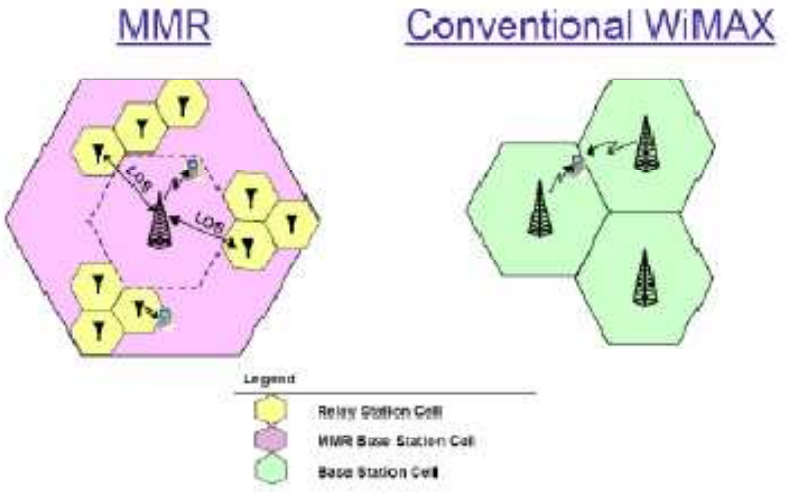



(a) Network topology

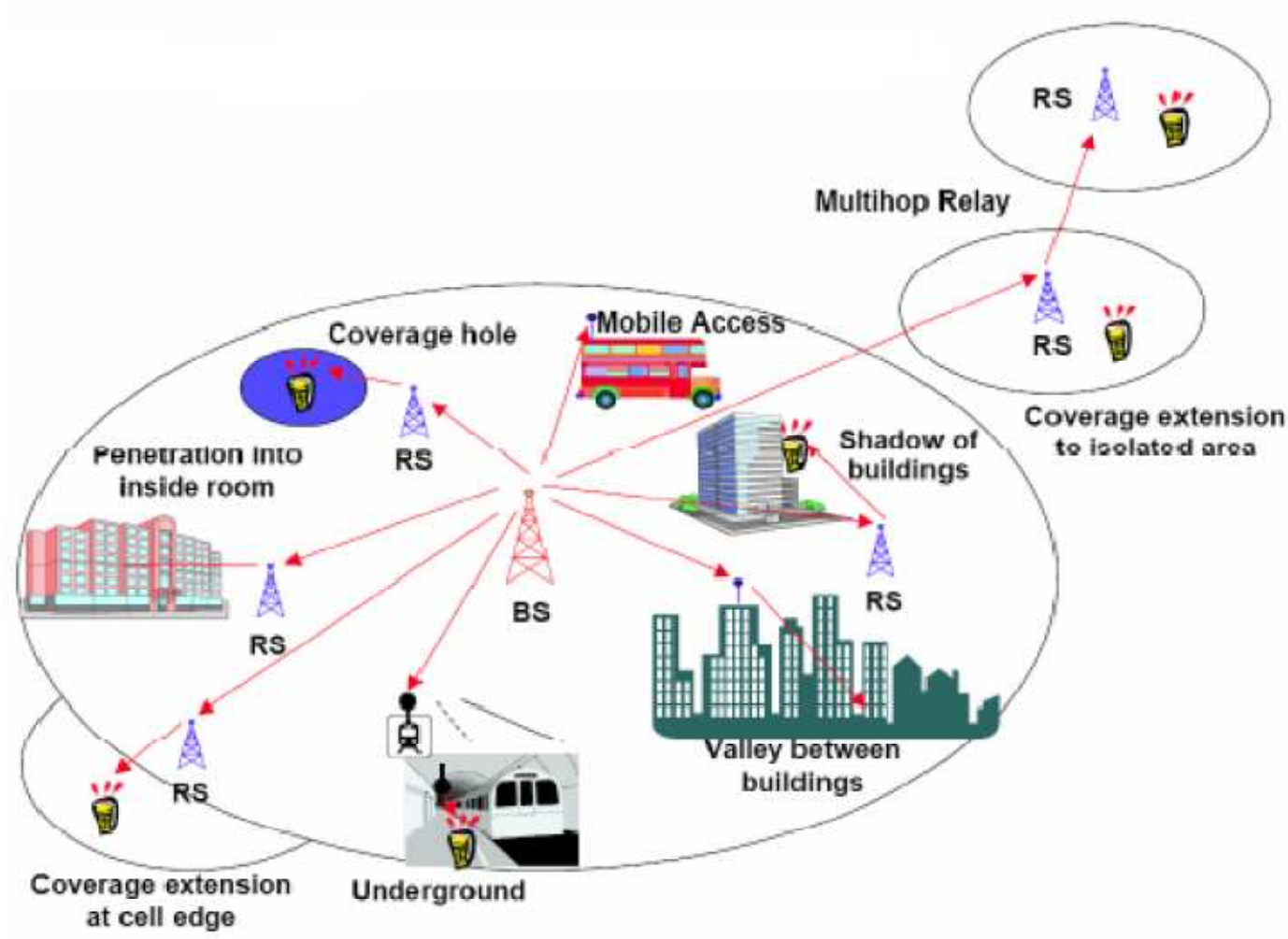
(b) Scheduling tree

# Section 4: IEEE 802.16j Mobile Multi-hop Relay (MMR)

- Aiming to enhance IEEE 802.16 to gain:
  - Coverage Extension
  - Throughput Enhancement
- by specifying a Relay Station




# Concept of IEEE 802.16j



# Mesh mode vs Multi-hop Relay

- Relay: Dedicated *carrier owned infrastructure,* topology. One end of the path is the base
- Mesh: Routing by *subscriber equipment,* Multiple connections, mesh topology

# Relay Nodes

- Mobile multihop relay (MMR):
  - The system function that enables mobile stations to communicate with a base station through intermediate relay stations
- MMR-base station (MMR-BS):
  - A base station that is compliant with amendment IEEE 802.16j to IEEE Standard 802.16e
- Relay station (RS) Type:
  - Fixed relay station (FRS):

A relay station that is permanently installed at a fixed location

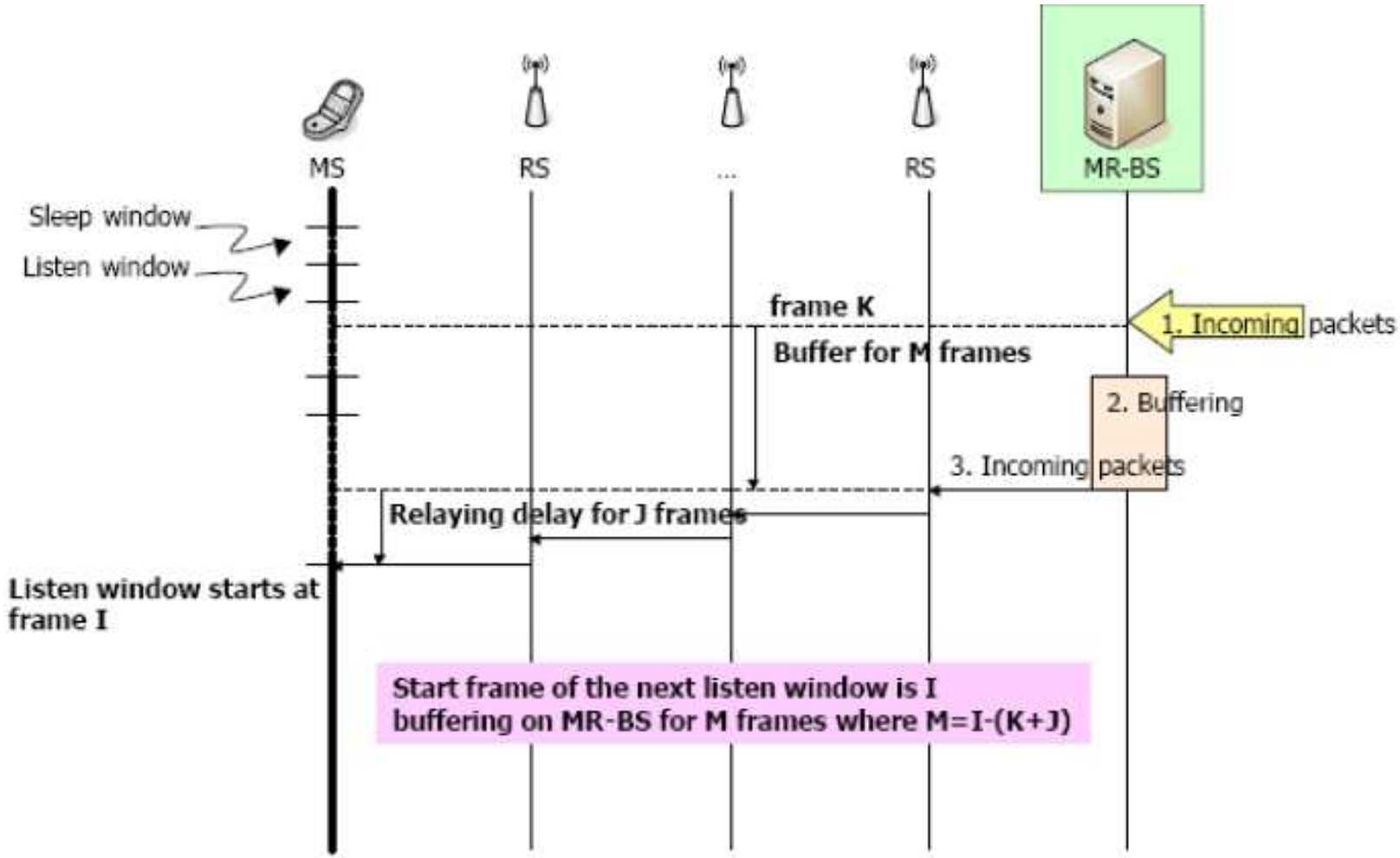
  - Nomadic relay station (NRS):

A relay station that is intended to function from a location that is fixed for periods of time comparable to a user session

  - Mobile relay station (MRS):

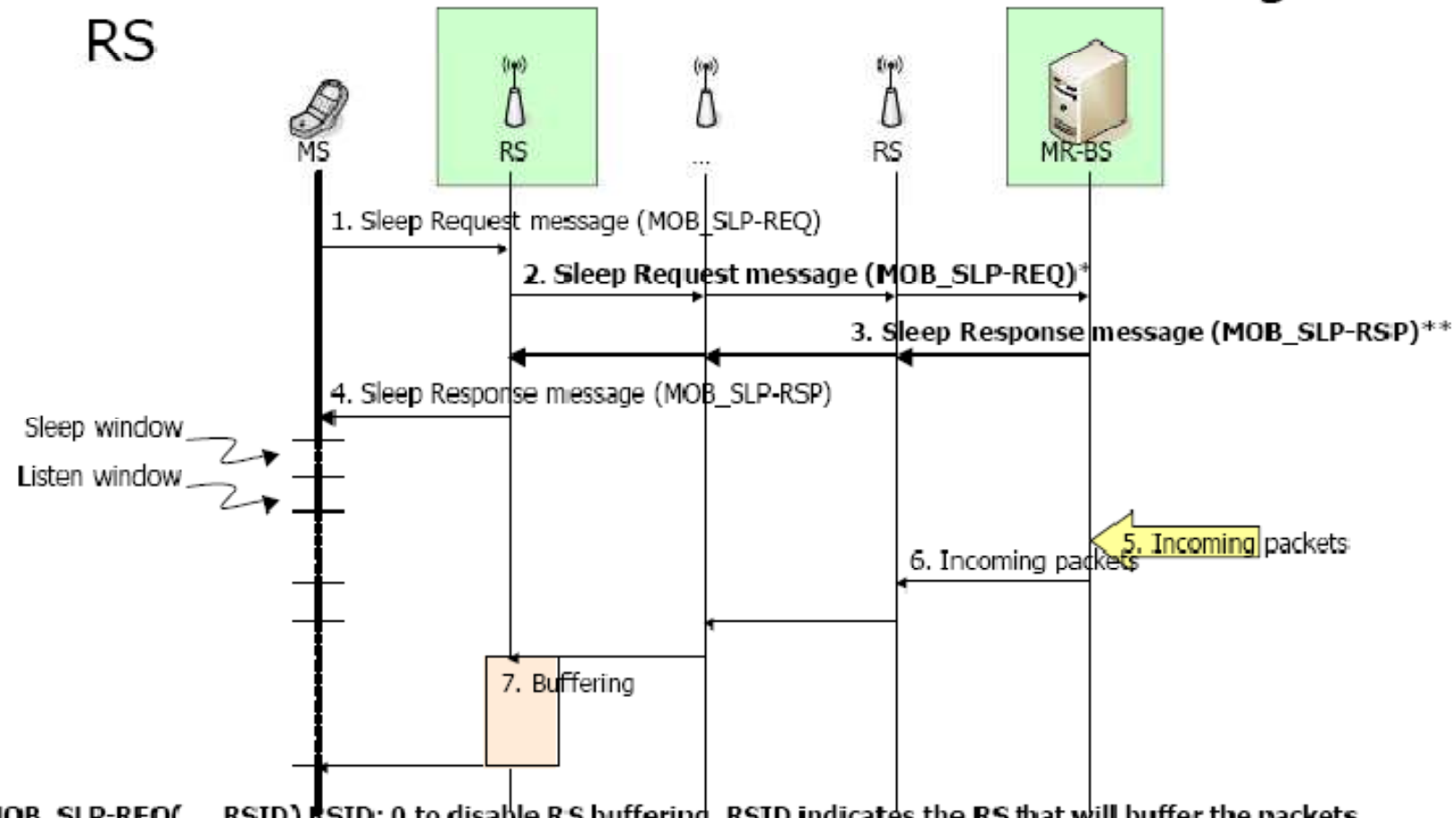
A station that to function relay is intended while in motion

# Sleep Mode with Multi-hop Relay (1)



# Sleep Mode with Multi-hop Relay (2)

- Admission control on MR-BS/RS and buffering on RS




* MOB_SLP-REQ(..., RSID) RSID: 0 to disable RS buffering, RSID indicates the RS that will buffer the packets
** MOB_SLP-RSP(..., RSID) RSID: 0 to disable RS buffering, the MR-BS acknowledges the RS for packet buffering
* parameters such as start frame, initial sleep window, listen window, and etc may be modified by the RS