# Scheduling in WiMAX Networks

Ritun Patney and Raj Jain
Washington University in Saint Louis
Saint Louis, MO 63130
Jain@cse.wustl.edu
Ritun@cse.wustl.edu

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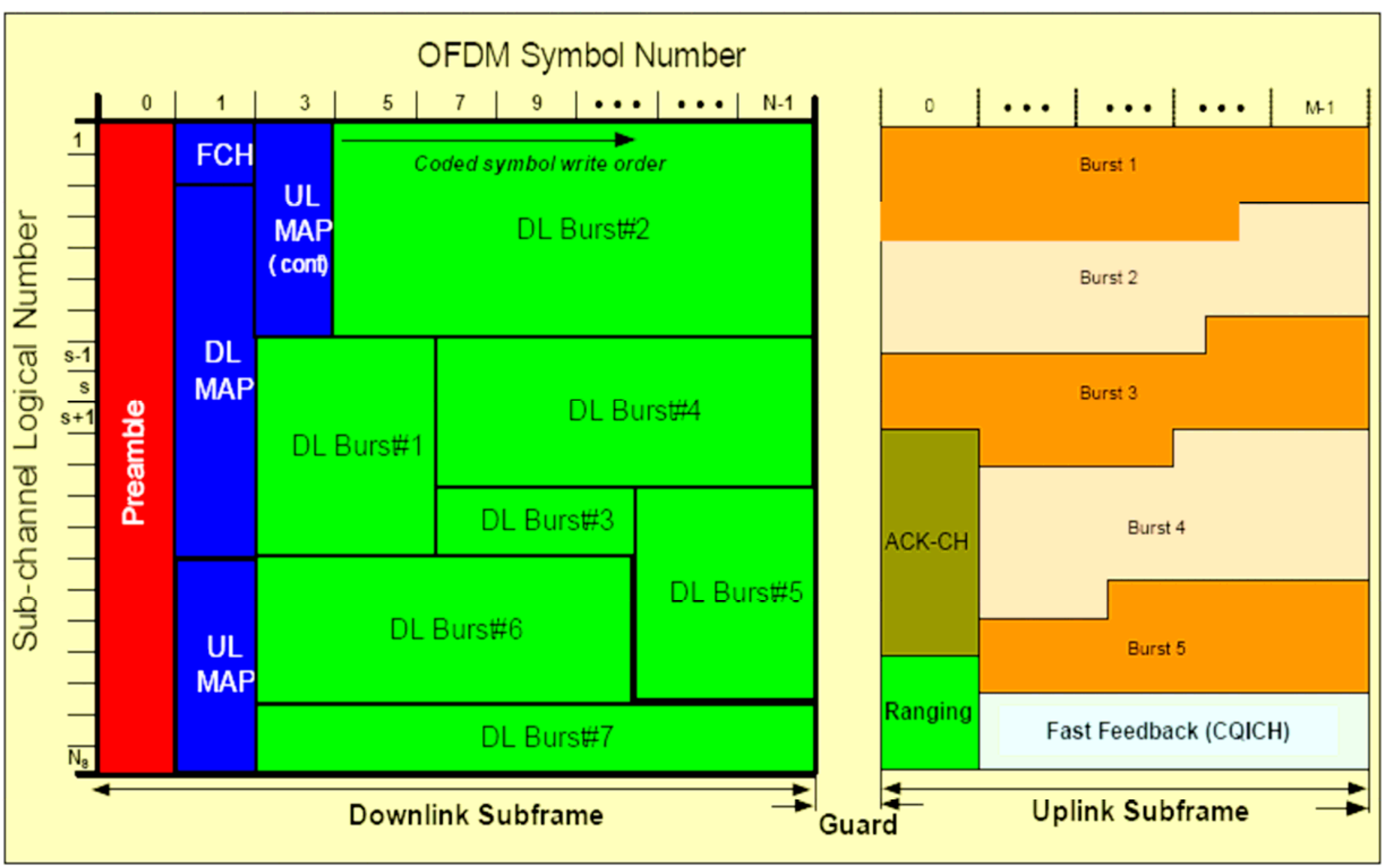
These slides are available on-line at:

http://www.cse.wustl.edu/~jain/wimax/sch704c.htm


- WiMAX Schedulers
- Issues and Challenges
- Status of our work
- Survey of Current Literature

# WiMAX OFDMA Frame



# WiMAX Schedulers

- BS Downlink
  - Similar to BS Uplink scheduler
  - Creates DL subframe which includes the DL MAP and UL MAP
- BS Uplink
  - Scheduling the BW requests received by the SSs
  - Needs to consider both old and new requests
  - Creates the UL MAP
- SS
  - BS provides bandwidth to SSs not connections

# QoS Service Classes

- UGS – Unsolicited Grant Service
  - Constant bit-rate services = CBR
- rtPS – Real Time Polling Service
  - Variable bit-rate, but sensitive to delay
- ertPS – Extended Real Time Polling Service
  - VoIP with silence suppression = CBR with Gaps
- nrtPS – Non-real Time Polling Service
  - Time insensitive, but require a minimum bandwidth allocation
- BE – Best Effort

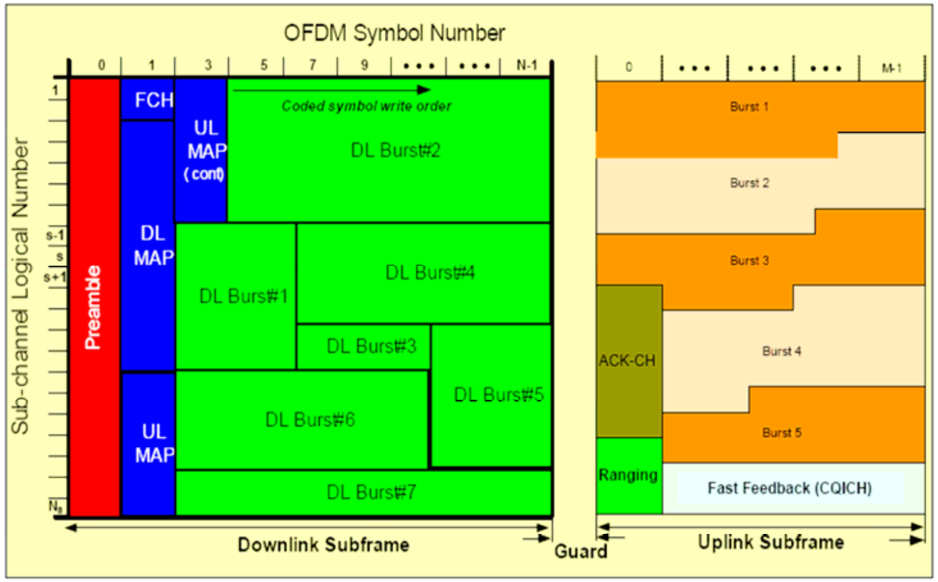
# Scheduling System Considerations

- Total available bandwidth
- Service flow specific scheduling policy
- Service flow QoS parameters
- Data queue backlog
- Request/Grant Mechanisms: Contention, Polling, Piggyback
- Connection air link quality
- Impact of burst allocation on PHY
  - Burst concurrency
  - Interference property
  - Memory/processing limitation
- ARQ, H-ARQ

# WiMAX Scheduling: Challenges

- Quality of the wireless channel is typically different for different users, and randomly changes with time (on both slow and fast time scales).
- Wireless bandwidth is usually a scarce resource that needs to be used efficiently (can not overprovision the wireless link).
- Excessive amount of interference and higher error rates are typical.
- Scheduling decides MCS and affects error rate. Error rate affects MCS.
- Mobility complicates resource allocation

# OFDMA Schedulers Complexity




- OFDMA schedulers are too complex
  - Constantly evaluating the channel fading
    - Needs to satisfy QoS
  - Computational complexity too much
    - NP-hard
    - Must provide sub-optimal solution

# Status

- Completed the data structures and basic code for OFDMA schedulers related to WiMAX NS2 RPI code.
- Waiting for the RPI-NIST merged model
- Literature survey of current proposals

# Our Implementation

- Data structures for two dimensional frame structure with uplink and downlink subframes
- Multiple parallel receptions at the base station for OFDMA (single carrier allows only SS transmission at a time)
- OFDMA PHY MIB (Subchannels, symbols)
- Tiles and slots
- Different modulation and coding
- Allocation of slots
- Mapping of slots to the frequency and time
- Null PHY $\Rightarrow$ No interference, No contention slots

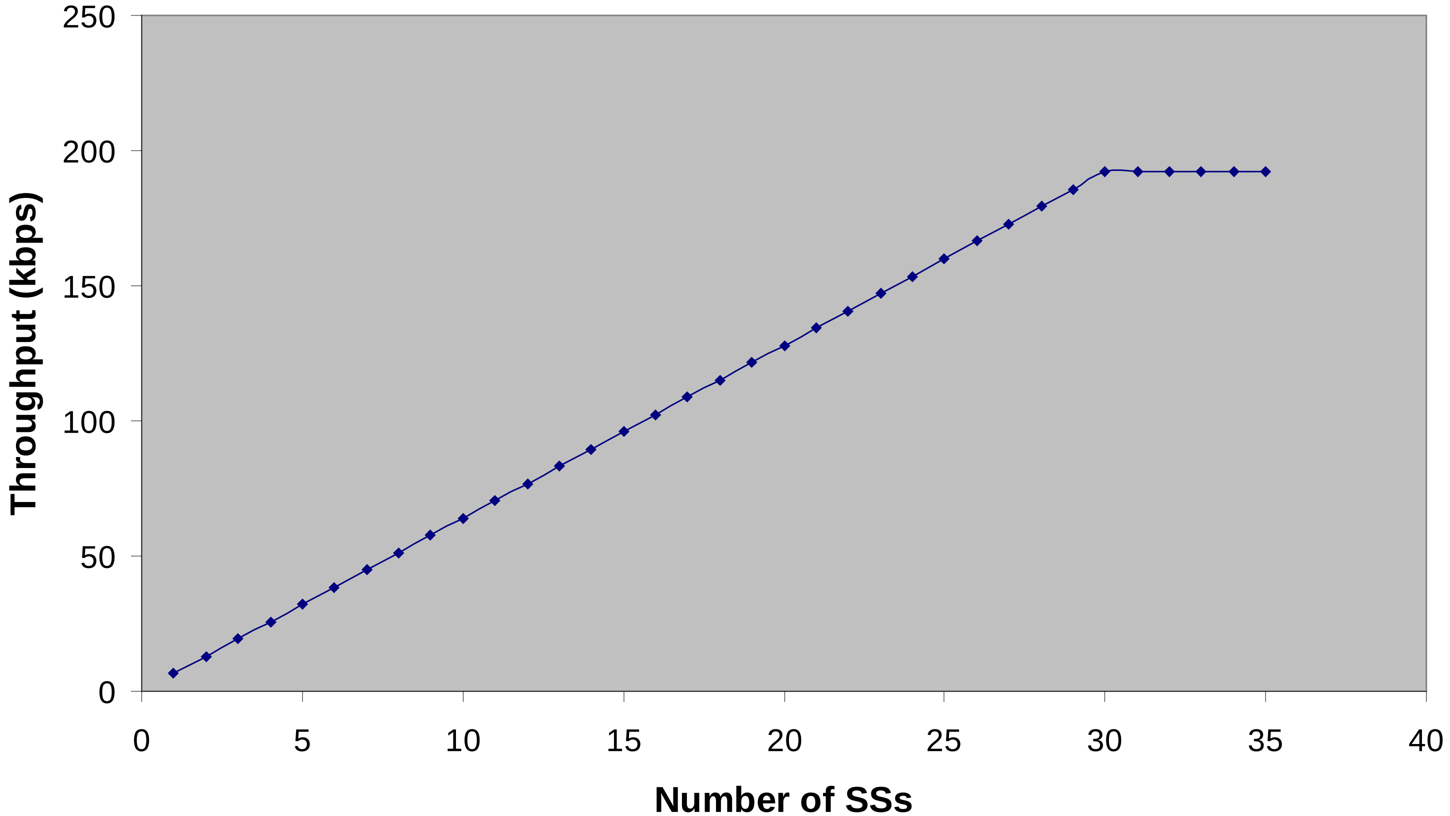
# Simulation Parameters

- Frame Duration: 5ms
- Downlink:Uplink symbols = 26:21
- Modulation Scheme: QPSK ½
- Bandwidth: 10 MHz
- Number of DL Subchannels: 30
- Number of UL Subchannels: 35
- ARQ Enabled
- Single BS with multiple SSs

# Workload

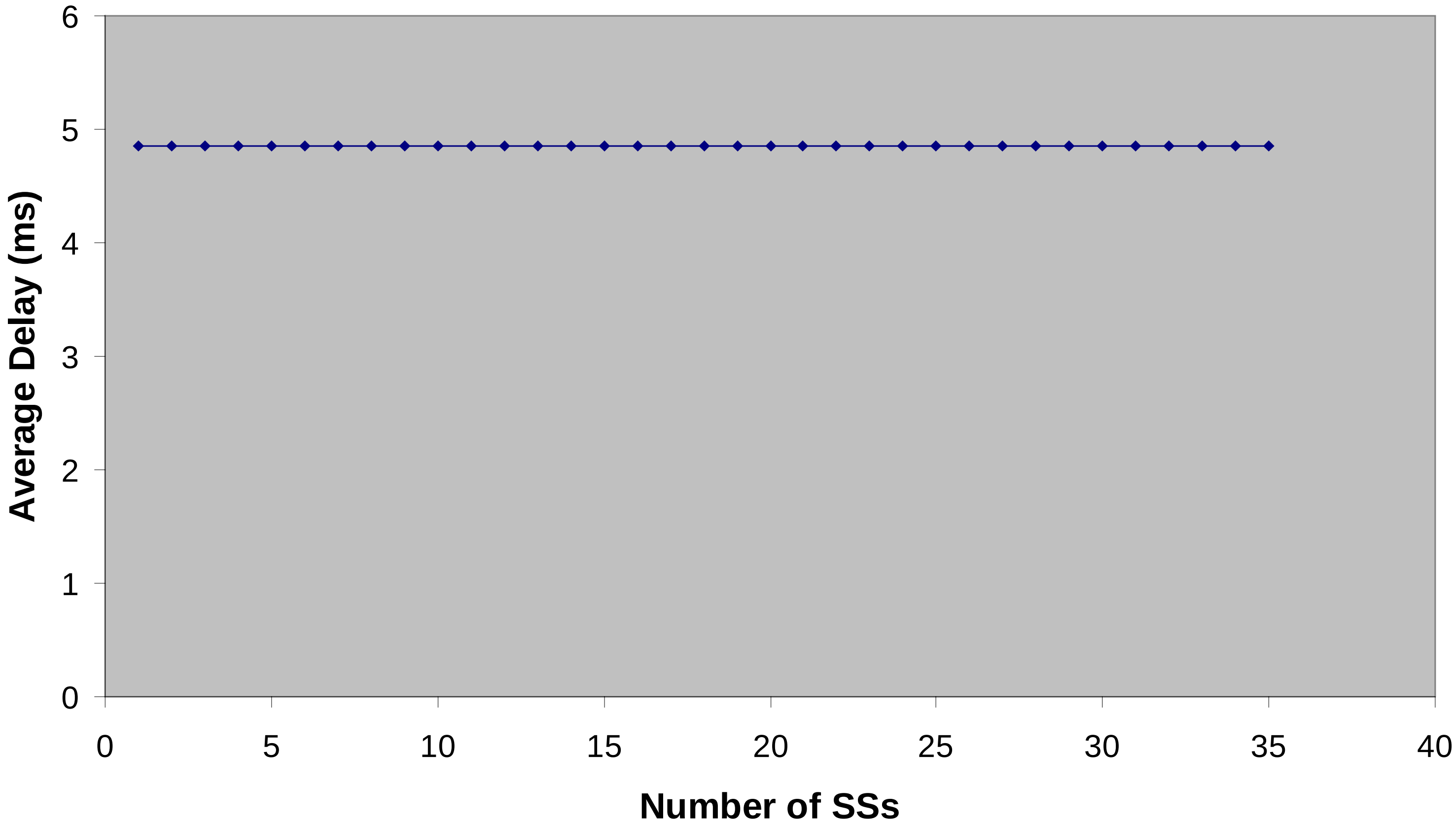
- UL; CBR Traffic over UDP
- 40 bytes MAC SDU per 50 ms per SS
  6 more bytes for MAC header.
- UGS Allocation
  = 46 bytes with an allocation counter of 1
  ⇒ Every user every frame
  ⇒ 9 of 10 frames have no UL traffic
  with this UGS workload
- Vary the number of SSs
- Performance Metrics: Throughput (kbps) and Delay (ms)

# UL Throughput vs. # of SSs for UGS



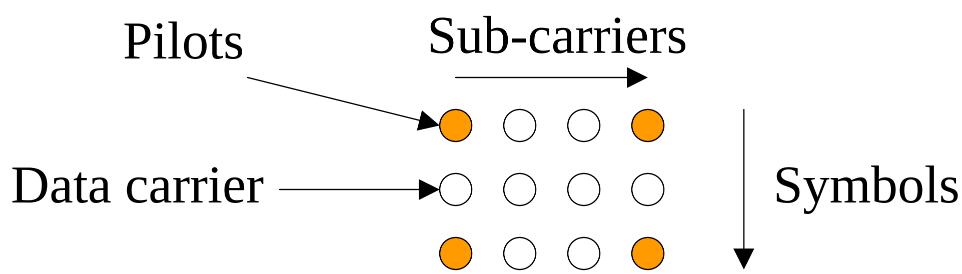

- **Observations**:
  - The throughput increases linearly
  - Maximum 30 users

# Average Delay vs. # of SSs




- Observation:
  - 4.86 ms average delay

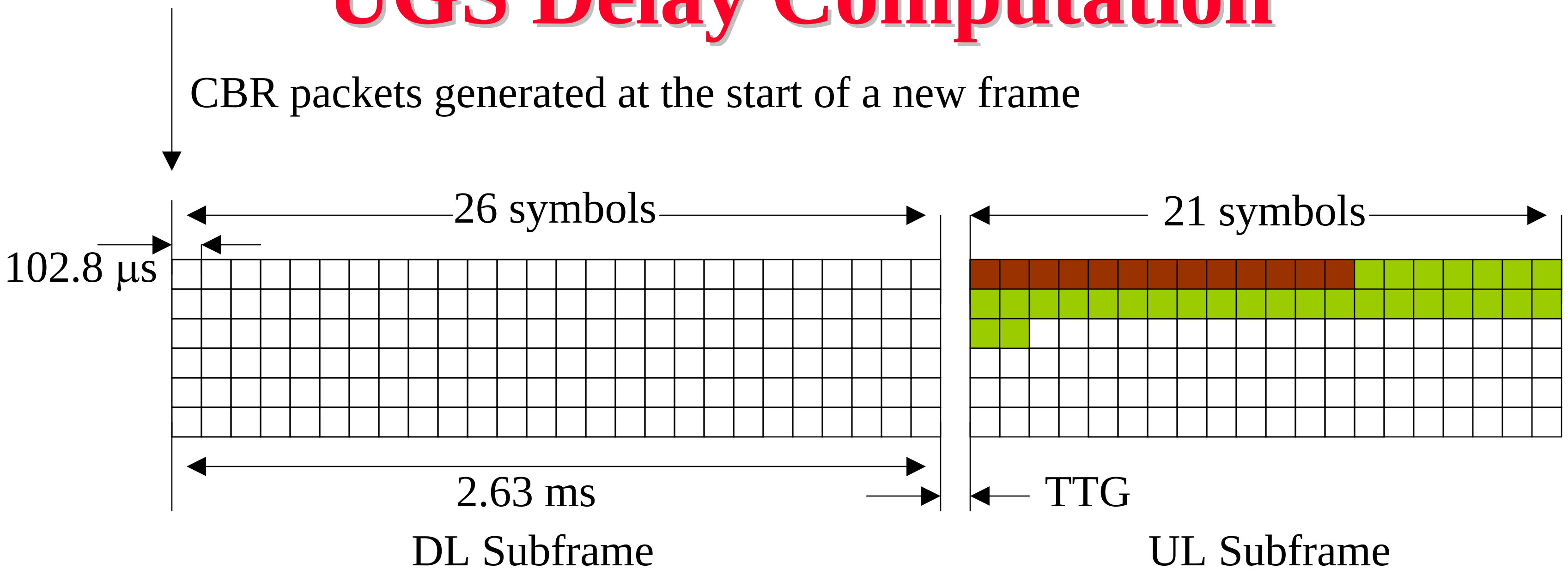
# UGS Throughput Computation



Tile Structure

- 1 tile = 8 data carriers across time and frequency
  8 data symbols/tile, QPSK ⇒ 2 bits/symbol
  QPSK ½ ⇒ 8 × 2 × 1/2 = 8 bits/tile
- 6 tiles/slot ⇒ Slot Capacity = 48 bits = 6 bytes
- Total Slots/UL subframe = (21/3) × 35 subchannels = 245
- Workload of 46 bytes, requires 8 slots.
- Allocated connection IDs/UL subframe = 245/8 = 30
  ⇒ Max Number of SS = 30

# UGS Delay Computation




- Scheduling algorithm: round robin.
- Always allocates the first n connections until frame is full.
- Connections beyond n are not serviced and hence the delay is constant even when throughput becomes constant.
- Delay for individual users can vary from 2.63 ms to 5 ms $\Rightarrow$ Average of 4.8 ms

# Scheme 1

- Allocate the minimum slots per connection
  - Fixed for UGS, ertPS
  - Minimum reqd. bandwidth for rtPS, nrtPS
  - Min. bandwidth for BE is 0
- Allocate remaining free slots
  - Only done for rtPS, nrtPS and BE
  - Processed in the following order: rtPS, nrtPS, BE
  - Free slots distributed proportionally in a class
  - No connection allocated more than its maximum
- Cons: Not a OFDMA scheduler, no call admission control

[1] A. Sayenko, O. Alanen, J. Karhula, T. Hamalainen, "**Ensuring the QoS requirements in 802.16 scheduling**," Proceedings of the 9th ACM International Symposium on Modeling Analysis and Simulation of Wireless and Mobile Systems, Pages: 108 – 117, c2006

# Scheme 2

- Grant capacity to all UGS connections
- Grant BW to rtPS according to BW requests, and Earliest Deadline First.
- Grant minimum bandwidth to nrtPS and BE. Allocate remaining slots to both in order.
- If more remain, allocate them to contention period of nrtPS and BE.
- Proposes a CAC based on max. allowable BW occupancy per class.
- Cons: Single Carrier, no ertPS, QoS parameters ignored, only for uplink

[2] *Chi-Hong Jiang Tzu-Chieh Tsai*, "**Token bucket based CAC and packet scheduling for IEEE 802.16 broadband wireless access networks**," *3rd IEEE Consumer Communications and Networking Conference, 2006, CCNC 2006, Jan. 2006*

# Scheme 3

- Studies real time video traffic
  - Video contains I, P, and B frames
  - I-frames are very bulky and periodic
- Avoids over-lapping of I-frames during connection setup via CAC.
  - Delays the connection start time such that a single frame doesn't get overloaded by I-frames
  - If the connection cant be established within a certain delay, it is rejected.
- Cons: Only for video traffic, only uplink traffic, no OFDMA scheduler, no other traffic classes considered

[3] Ou Yang, Jianhua Lu, "**New scheduling and CAC scheme for real-time video application in fixed wireless networks**," 3rd IEEE Consumer Communications and Networking Conference, 2006. CCNC 2006. Jan 10 2006

# Scheme 4

- Proposes a heuristic algorithm
- In a slot, a particular sub-channel is assigned to the SS that can transmit maximum amount of data over it.
- Above algorithm run for every class of traffic in the following order: UGS, rtPS, nrtPS, BE
- Cons: Slot definition not very clear, no rectangular slot allocation, best sub-channels get allocated to UGS connections, no ertPS, QoS parameters incomplete, no CAC. Goal: Maximize system throughput.

[4] Singh, V., Sharma, V. (2006). "**Efficient and fair scheduling of uplink and downlink in IEEE 802.16 OFDMA networks**." *IEEE Wireless Communications and Networking Conference.*

# Scheme 5

- Studies voice connections
- Uses a reserved bit in the MAC header to signal the BS of transitions from the silent to non-silent periods and vice-versa.
- BW allocated during non-silent periods by the BS.
- Cons: Specific to voice, might not be practical as uses reserved bit, ertPS not considered, all traffic classes not considered, cross layer communication would be needed to tell the MAC layer of the transitions, analysis not based on real frame values, no slot/2-D mapping presented, only uplink scheduling considered

[5] Howon Lee, Taesoo Kwon, Dong-Ho Cho, "**An enhanced uplink scheduling algorithm based on voice activity for VoIP services in IEEE 802.16d/e system**," IEEE Communications Letters, Aug 2005

# Scheme 6

- Hierarchical Scheduling
- At first level, strict priority in the order of UGS, rtPS, nrtPS and BE.
- Different schedulers proposed per individual classes
  - no separate scheduling policy for UGS
  - Earliest Deadline First for rtPS
  - Weighted Fair Queuing for nrtPS
  - remaining BW split equally into all BE connections.
- Cons: No 2-D Mapping, no CAC, lacks ertPS

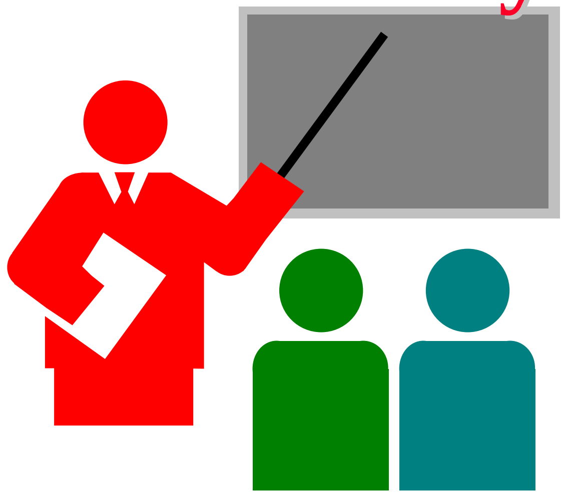
[6] Kitti Wongthavarawat, Aura Ganz, "**IEEE 802.16 Based Last Mile Broadband Wireless Military Networks with Qualithy of Service Support**," IEEE Milcom 2003.

# Scheme 7

- First, sets the number of sub-carriers for every SS
  - Assigns some fixed number of sub-carriers to every user.
  - Remaining sub-carriers are assigned to all users in the ratio of 1/d; d is their delay requirement.
- Second, each user given a priority proportional to the number of packets that got dropped from its queue.
  - The user with highest priority selects the best sub-carriers for itself and so on. Its assumed both the transmitter and receiver know about the channel conditions at all times.
- Cons: Not specific to 802.16, allocated sub-carriers rather than sub-channels, allocation per SS not CID, no traffic classes.

[7] Khattab, A., Elsayed, K., (2006). "**Opportunistic Scheduling of Delay Sensitive Traffic in OFDMA-based Wireless Networks**." *Proceedings of the 2006 International Symposium on World of Wireless, Mobile and Multimedia Networks.*

# Summary



- QoS depends upon a number of implementation details: Scheduling, buffer management, traffic shaping
- OFDMA scheduler implementation started
- Preliminary UGS results using the "round-robin and greedy" scheduler
- Throughput and delay match computed values (preliminary verification)

# References

[1] A. Sayenko, O. Alanen, J. Karhula, T. Hamalainen, "**Ensuring the QoS requirements in 802.16 scheduling**," Proceedings of the 9th ACM International Symposium on Modeling Analysis and Simulation of Wireless and Mobile Systems, Pages: 108 – 117, c2006

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