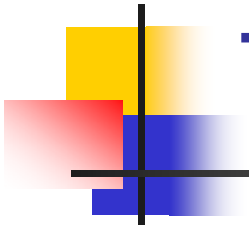
Modeling a MAC Scheduler: Experiences with a DOCSIS Cable Network Simulation Model

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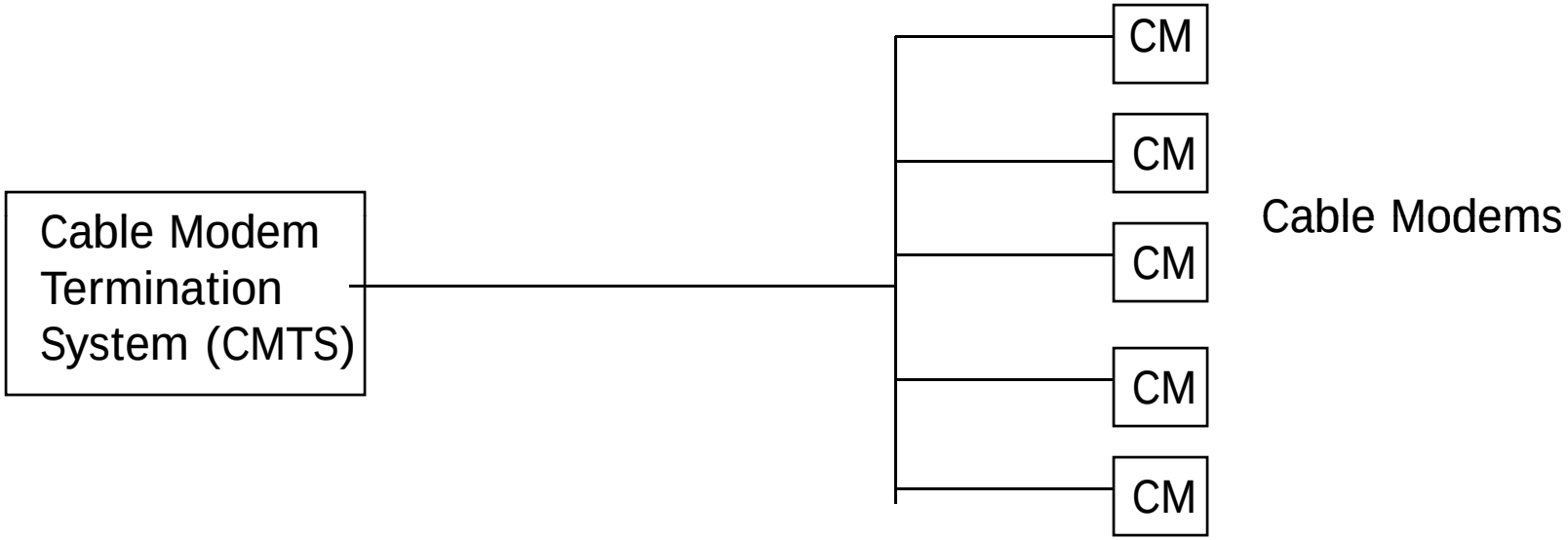
Presented to the WiMAX Forum Application Architecture Working Group 7/12/20006



Talk Agenda

- Introductions
- DOCSIS overview
- DOCSIS model
- Modeling a bandwidth scheduler
  - Background
  - Design and implementation in ‘ns2’
  - Validation
- Moving towards a WiMAX scheduler

Network Model

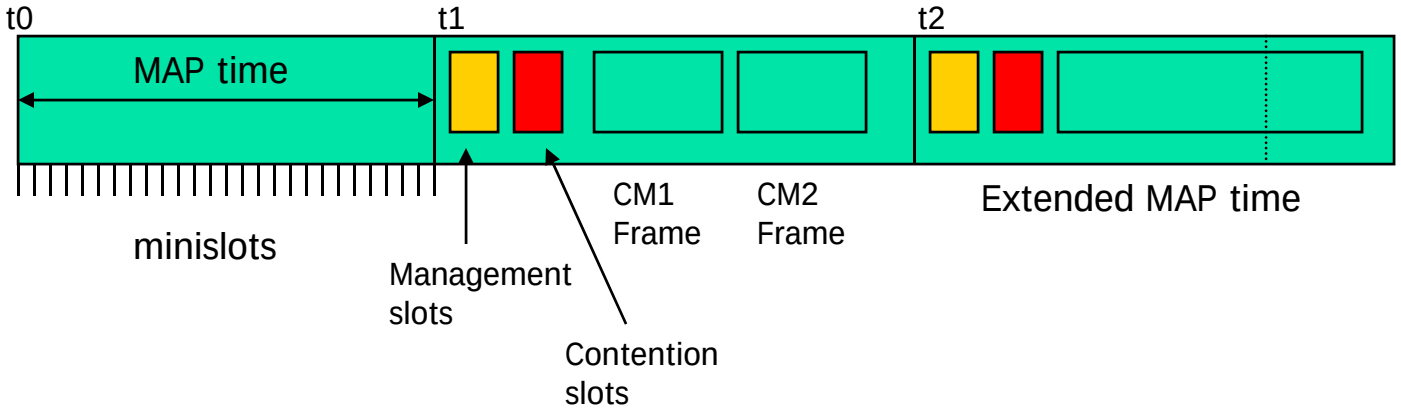


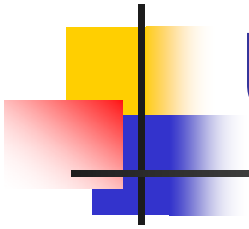
Downstream channel:
Spectrum: 45Mzh-850Mhz
BW/channel: 6Mhz
Modulation: 64QAM with 6bits/channel
256QAM with 8 bits/channel
Data rate: 27-56Mbps
Transmission mode: continuous stream of data received by all cable modems.

Upstream channel(DOCSIS 2.0):
Spectrum: 5Mhz-42Mhz
BW/channel: 200Khz to 3.2Mhz(6.4Mhz)
Modulation: QPSK or 16 QAM (64-QAM)
Data rate: .32 to 10.24Mbps (30.72Mbps)
Transmission mode: TDMA (CDMA), CMTS handles bandwidth allocation, providing transmission opportunities for particular CM's and also providing contention- based opportunities

Upstream Service

- Upstream channel managed in units of time called minislots.
  - Base time tick: 6.25microseconds
  - System parameter: number of ticks per minislot.
    - E.g.,4 ticks/minislot at a data rate of 5.12Mbps leads to 16 bytes per minislot and 80 slots in a .002 second MAP time (about 1280 bytes)
- The CMTS assigns slots to CMs based on periodic data grants or dynamically through a contention-based request mechanism.

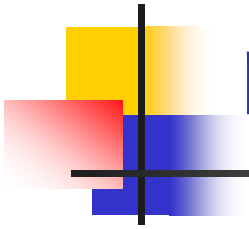




Upstream Services

Upstream Services:

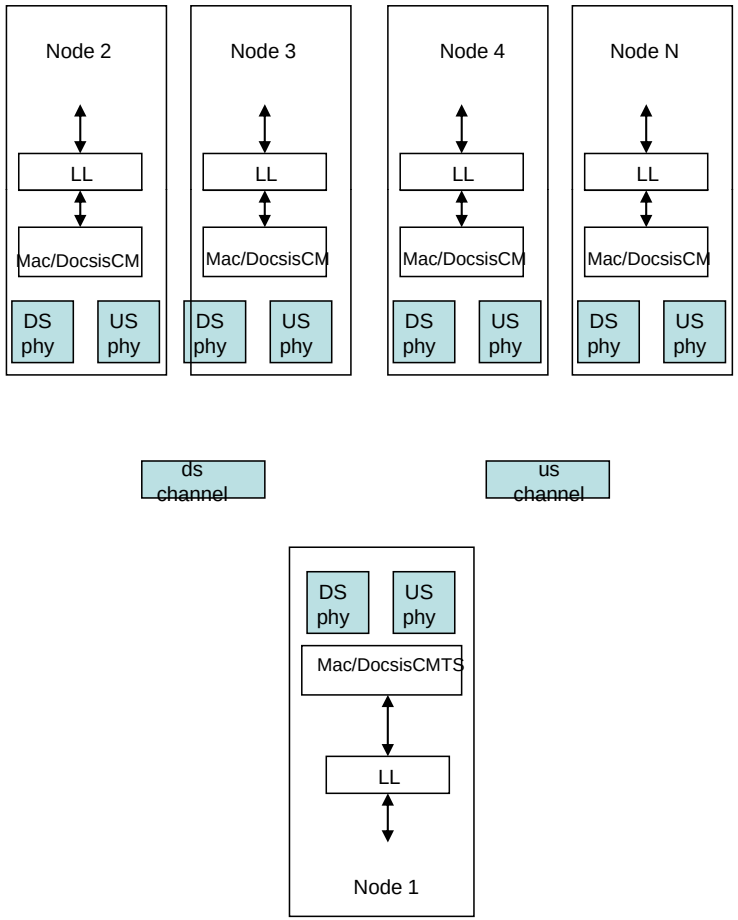
- UGS: Unsolicited grant service
  - QoS Params: nominal grant interval, tolerated grant jitter.
- rtPS: realTime polling service
  - QoS Params: nominal polling interval, tolerated polling jitter.
- BE: Best effort service
  - QoS Params: minimum reserved traffic rate, maximum sustained traffic rate.

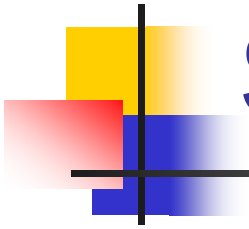


ns2 DOCSIS Model

- Extends the existing ns2 LAN model
- Create a Cable Modem (CM) node type and a Cable Modem Termination System (CMTS) node type
- CMs limited to a single default best effort service flow and a single UGS or rtPS flow
- One upstream channel for each downstream channel
- Assumes that the CMTS and the CM clocks are synchronized
- Physical layer greatly simplified
  - Does not incorporate modulation schemes, interleaving, FEC (aside from estimating framing overhead)
  - Channel impairments are not modeled

ns2 DOCSIS Model

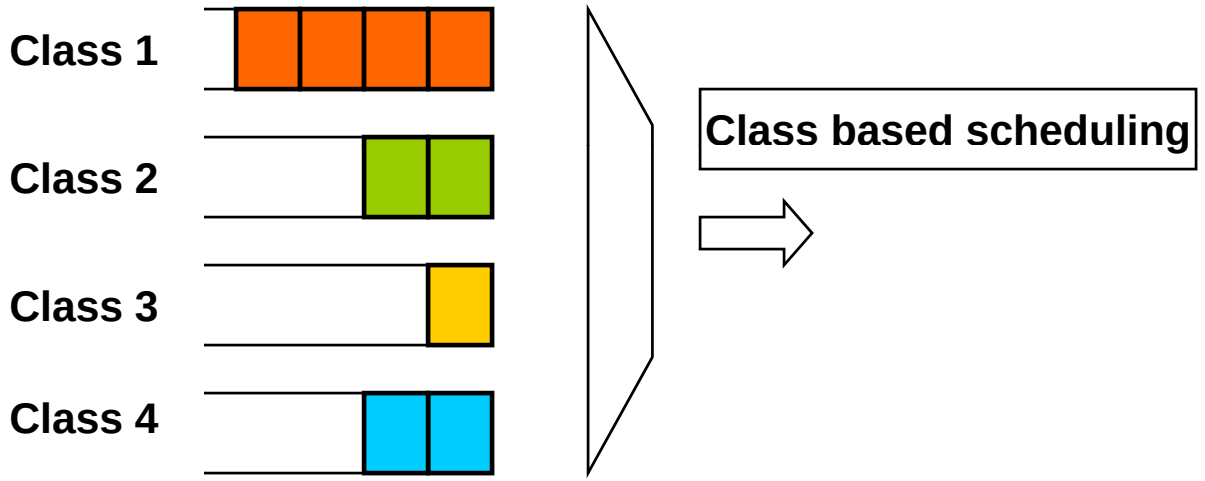




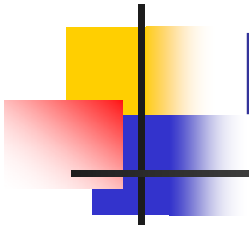
Scheduling in a Wired Network

- The scheduling problem deals with allocating bandwidth among flows that have been admitted.
- Non-Class based scheduling: first come first serve
  - Fairness must be implemented through end-to-end congestion control algorithms

Class Based Queuing

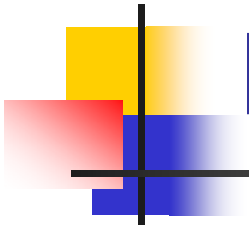


- At each output port, packets of the same class are queued at a specific priority queue
- Traffic is classified to a known class through system policy:
  - Type of application
  - Specific flow
  - ....



Priority Queuing

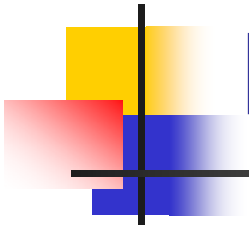
- Lower priority packets are served only if all higher priority queues are empty
  - Provides low latency for the highest class
- Problems:
  - No bandwidth partition. A higher class can take over the entire link, at the expense of lower priority packets
  - No QoS guarantee for lower priority traffic, unless higher priority classes are strictly controlled by some other method



Fair Queuing

- Separate queue for each flow. Service disciplines:
  - Round Robin (RR): each queue is served in a round robin fashion, one packet at a time
  - Weighted Round Robin (WRR): the bandwidth partition is adjustable
  - Weighted Fair Queuing (WFQ)
    - A refinement of WRR, accounting for variable packet size

Scheduling to Meet Absolute Deadlines

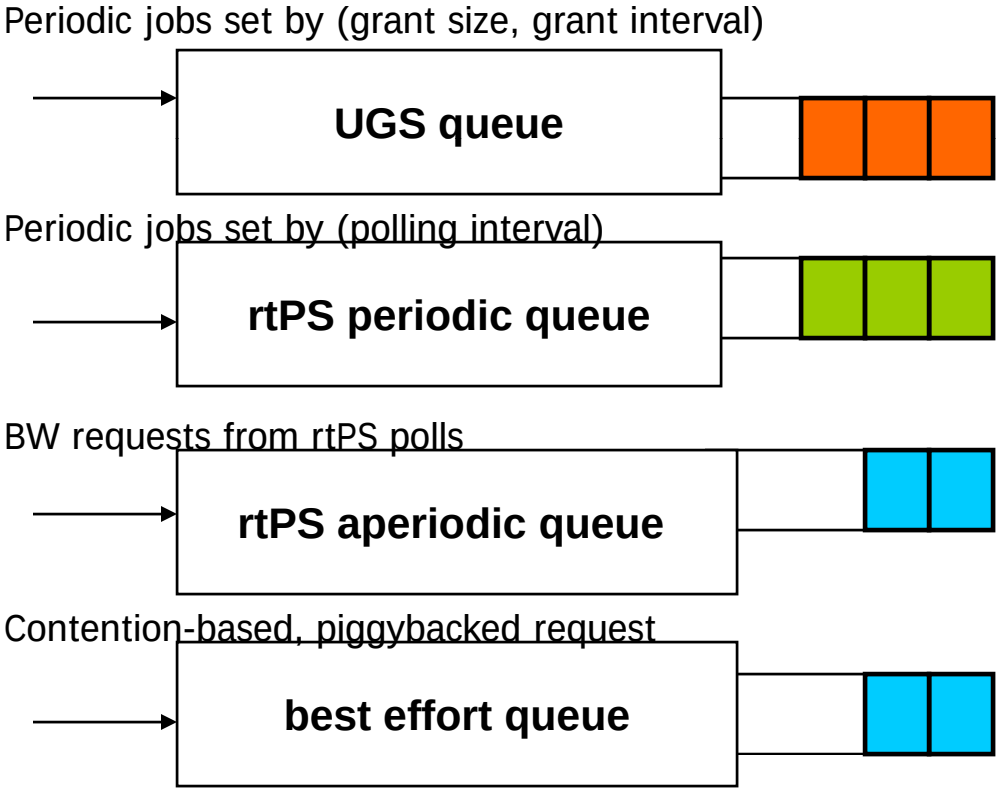


- Hard deadline: missing the deadline is not tolerated
- Soft deadline: missing the deadline ‘occasionally’ is tolerated
  - E.g., tolerated jitter of .001 seconds 99% of the time

Earliest Deadline First (aka Earliest Due Date)

- EDF scheduling overview
  - Due Date(DD) = arrival_time + delay target
  - All packets are timestamped with the arrival time
  - examine head-of-line packets of class based queues
  - serve the packet with earliest (smallest) due date
- Applied to DOCSIS
  - ***UGS deadline:*** ***arrival time +nominal grant interval***
  - ***rtPS deadline:*** ***arrival time + nominal polling interval***
  - ***Best effort deadline:*** ***arrival time + max tolerated access delay***

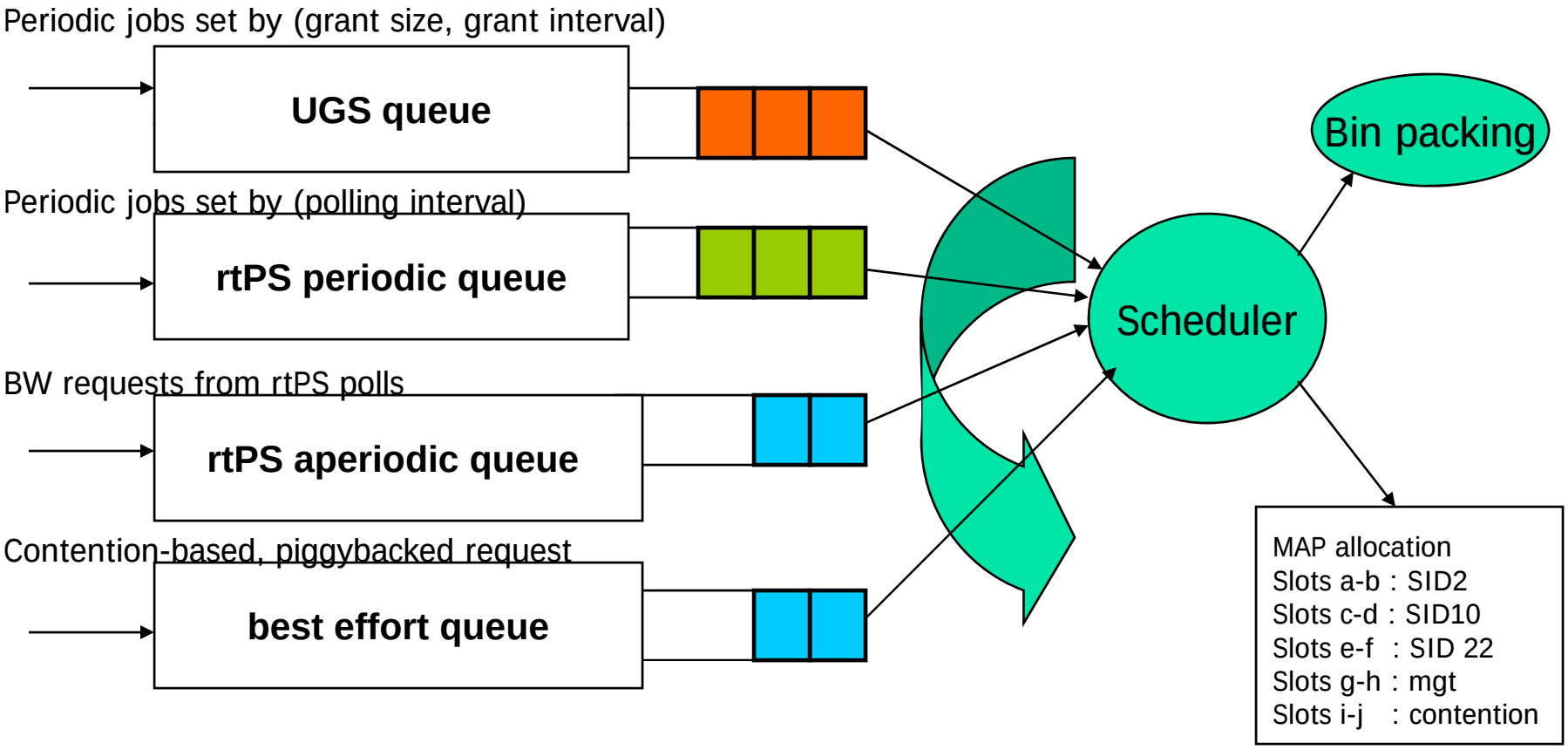
Ns2 DOCSIS Model Scheduler



•Requests for BW are periodic or aperiodic
•When a request arrives, the releaseTime is set to the current time.
•The deadline is set to : releaseTime+period
•The request is scheduled if the releaseTime falls in the current MAP time or if the deadline will expire by the end of the MAP time.

The implementation currently does not support
• a tolerated grant jitter, the tolerated polling delay or the max tolerated access delay
•Minimum BW reservations

Ns2 DOCSIS Model Scheduler

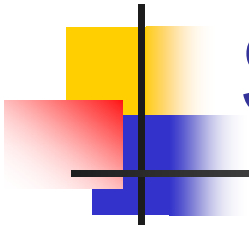


Ns2 DOCSIS Model Scheduler

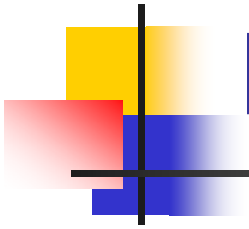
Tthe following algorithm allocates bandwidth to CMs for the next MAP time:

- Add all UGS periodic requests with deadlines in the next MAP
- Add all rtPS poll periodic requests with deadlines in the next MAP
- The number of slots granted must be less than the smaller of
  - Statically configured MAP size + MAP_LOOKAHEAD
  - 4096
- Find the number of slots left (numberSlotsLeft)
- Grant *proportionParam*numberSlotsLeft* to rtPS Periodic requests
- Grant the remainder to best effort requests.

Moving Towards a WiMAX Scheduler

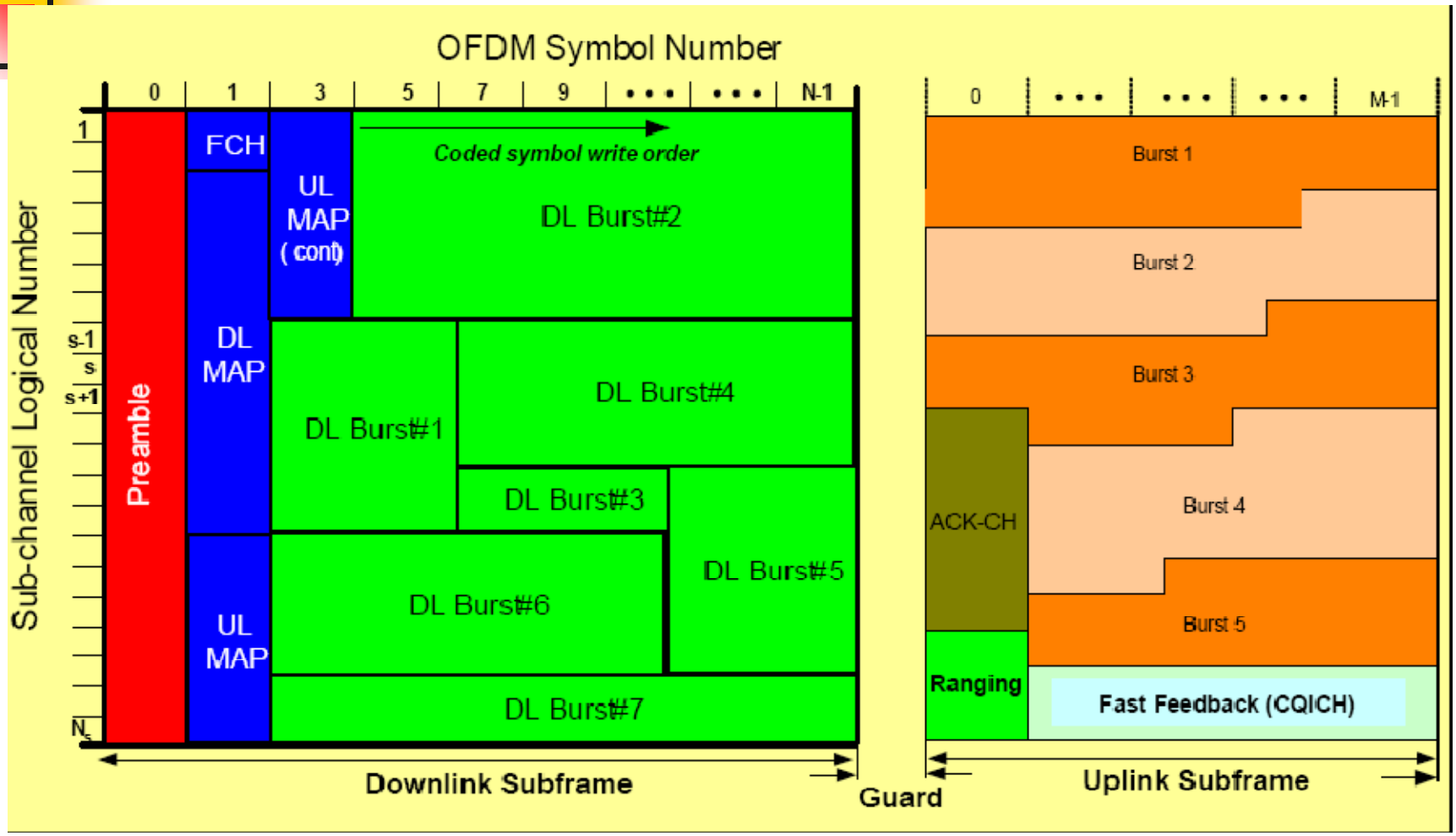


- Wireless causes problems to traditional wired network schedulers since channel conditions vary over short time scales (multipath) and over long time scales (mobility and interference)
- Link/Rate Adaptation: adapt modulation, power, antenna diversity to counter observed channel degradation
- Opportunistic Scheduling: takes advantage of multiuser diversity. Simple example that incorporates fairness:
  - approximate wired WFQ over all channels
  - Except defer transmissions over poor quality channels
  - Supplement these sessions with additional BW later to achieve long-term fairness



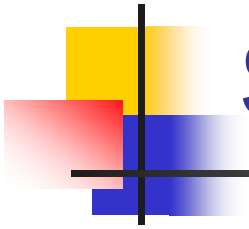
Future Work

- Model development
  - HARQ
  - Physical layer support
    - OFDM subchannels
    - Propagation models
    - Cross layer design
- Research
  - Scheduling and adaptation



WiMAX OFDMA Frame Format

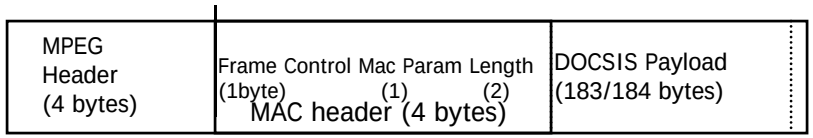
Data over Cable System Interface Specification (DOCSIS)



- DOCSIS 1.0: base version.
  - About 30Mbps DS, 5 Mbps US
- DOCSIS 1.1: currently deployed.
  - Added QoS capabilities.
  - About 30Mbps DS, 10Mbps US
- DOCSIS 2.0: now available in products.
  - Increases upstream capacity
  - About 30Mbps DS, 30 Mbps US
- DOCSIS 3.0: in requirements phase
  - 200Mbps DS, 100Mbps US

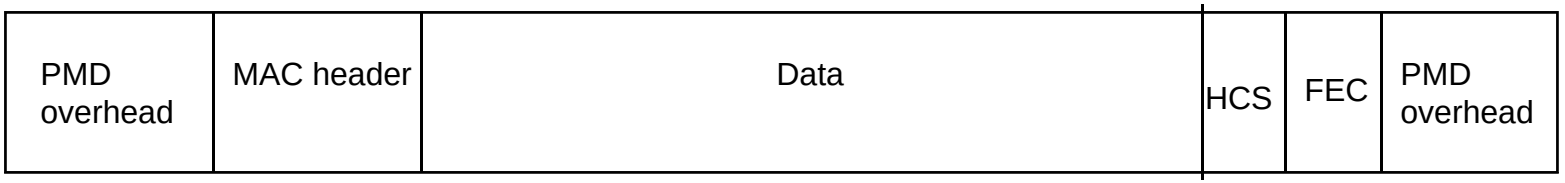
Downstream Service

- A continuous series of 188 byte MPEG packets
  - Allows data and MPEG video to be interleaved over the channel
  - Frame format and overhead analysis



Example: Starting with a 1500 byte IP packet		1500 bytes
+ETHERNET_HEADER:		+18 bytes
+DOCSIS MAC OVERHEAD :		+ 6 bytes
+downstream channel overhead bytes:		+ 4 bytes
		1524
+MPEG frame alignment:	+	ceiling[1524/188]
		1560 (about 6.4%)
+ FEC overhead (6 symbols added per 122)	+	13*6
		1638 (**about 7.3% overhead)**

Upstream Frame Format



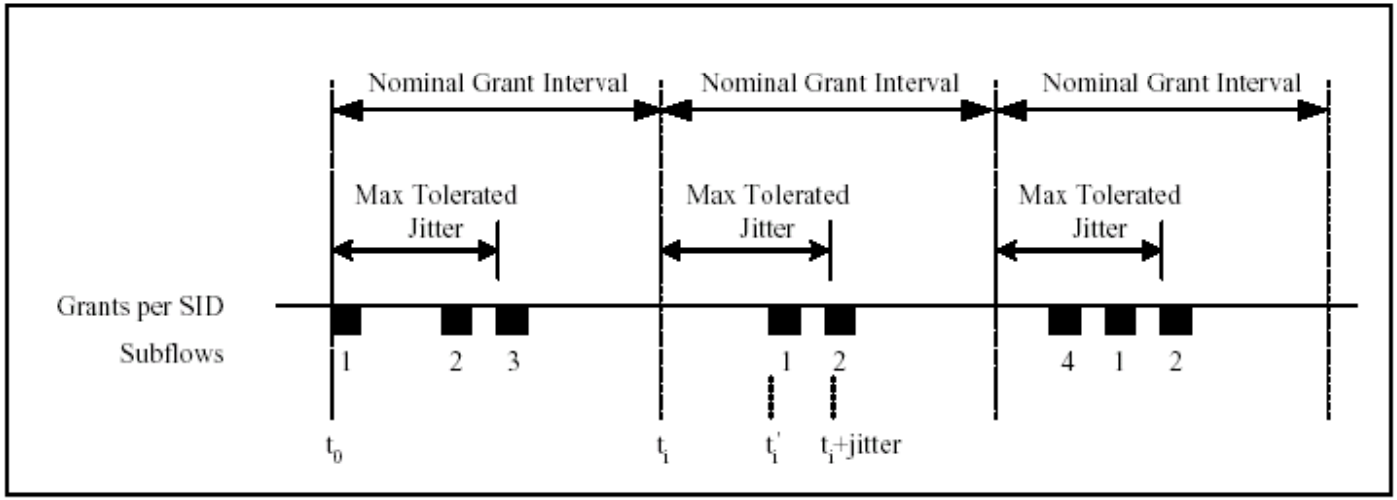
Upstream Frame Format

- Frame format and overhead analysis

Example, start with a 1500 byte IP datagram 1500
ETHERNET OVERHEAD + 18
MAC Header/checksum + 6
3Bytes Extended Header(assuming piggybacking)
+ 3
Physical overhead + 10

1533 bytes (consumes 96 slots for a 16byte/slot configuration)

Validating the Scheduler



•The Tolerated Grant Jitter is the maximum difference between the actual grant time (t'i) and the nominal grant time (ti)

•To verify that the scheduler meets the requirements of UGS and RT-Polling service type we monitored the jitter in the grant allocation (difference between the actual grant time and the nominal grant time) is monitored