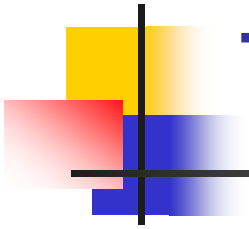


AWG-AATG F2F
University Experiences:
Scheduling in a DOCSIS Cable Network

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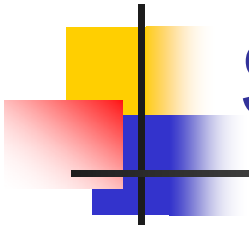
Presented to the WiMAX Forum's AWG 9/21/2006



Talk Agenda

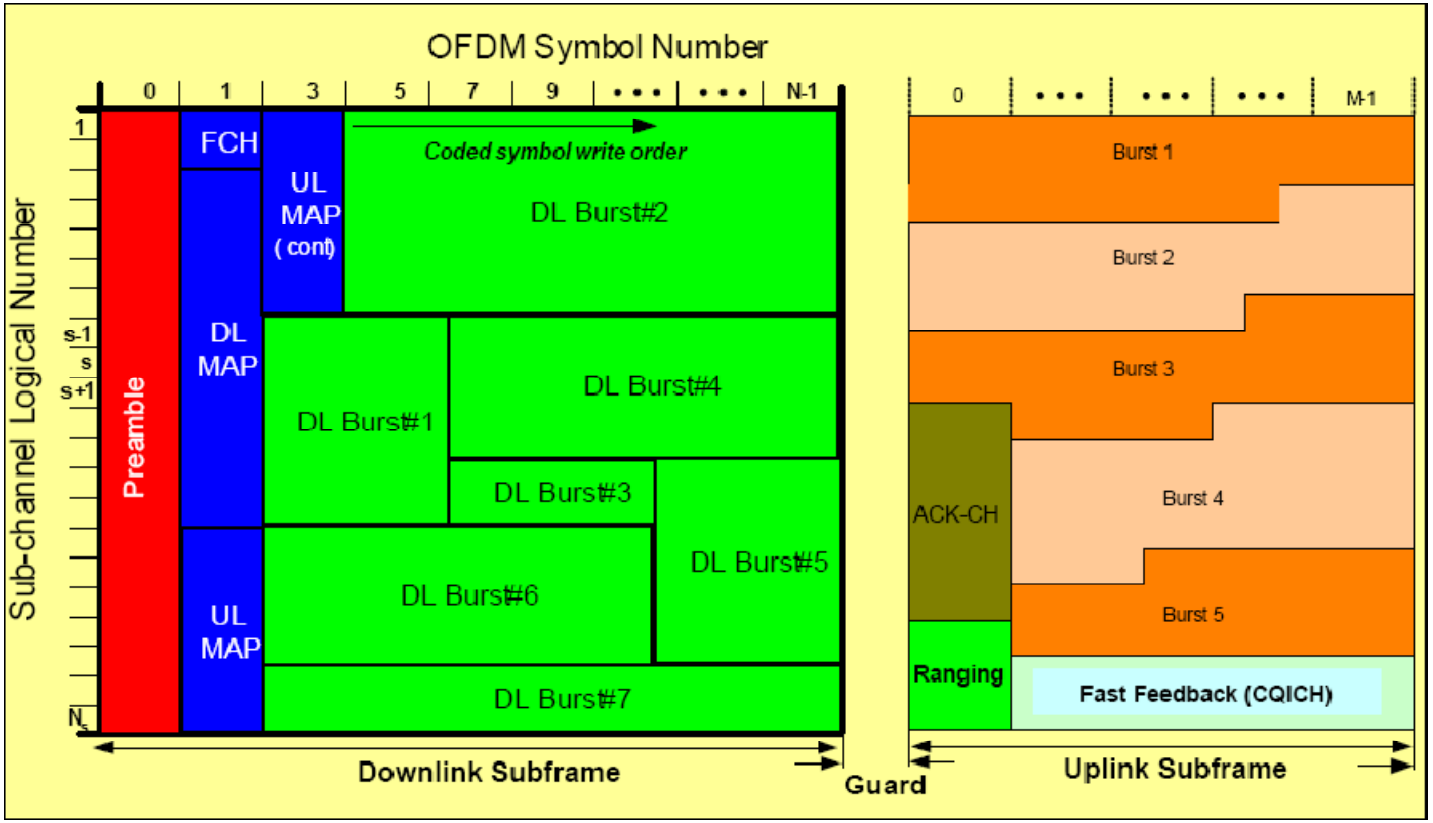
- Setting the stage: the scheduling problem in a DOCSIS cable network
- DOCSIS simulation model scheduler
- Reality check: Cisco's scheduler

Data over Cable System Interface Specification (DOCSIS)



- DOCSIS borrowed heavily from the IEEE 802.14 ATM over cable effort
- 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: specs released, equipment on the way
  - Hundreds of Mbps
  - IP data is 'striped' over multiple channels (channel bonding)
  - Supports IPv6
  - Multicast QoS support

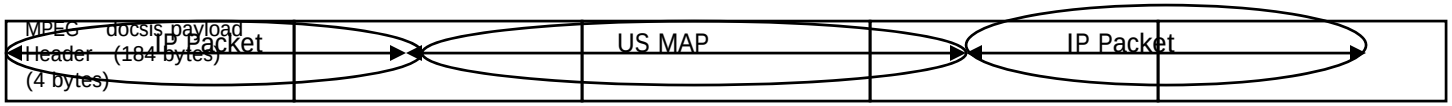
In WiMAX, a 2-D frame packing algorithm is needed....



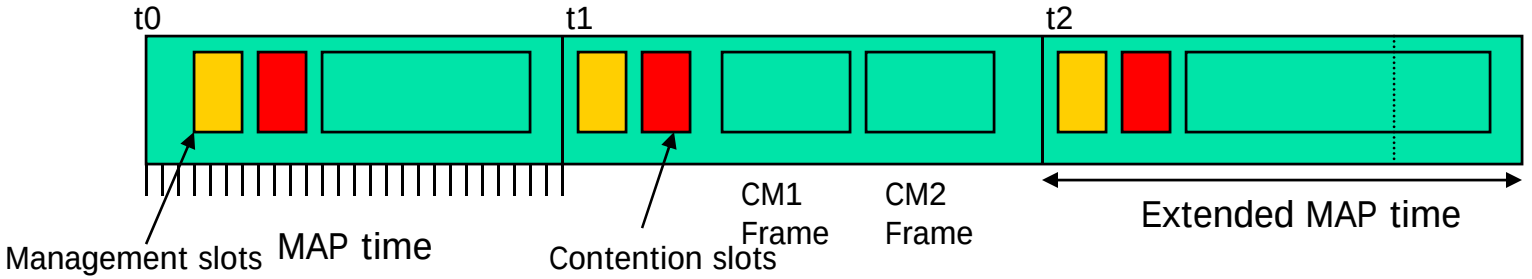
WiMAX OFDMA Frame Format

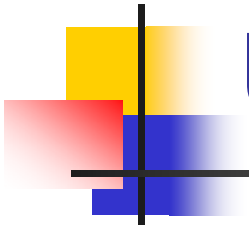
DOCSIS Assumes FDM and Frame Packing is 1-D

- Downstream:
  - TDM: A continuous series of 188 byte MPEG packets



- Upstream:
  - TDMA: The CMTS assigns slots to CMs based on periodic data grants or dynamically through contention-based requests or piggybacked requests



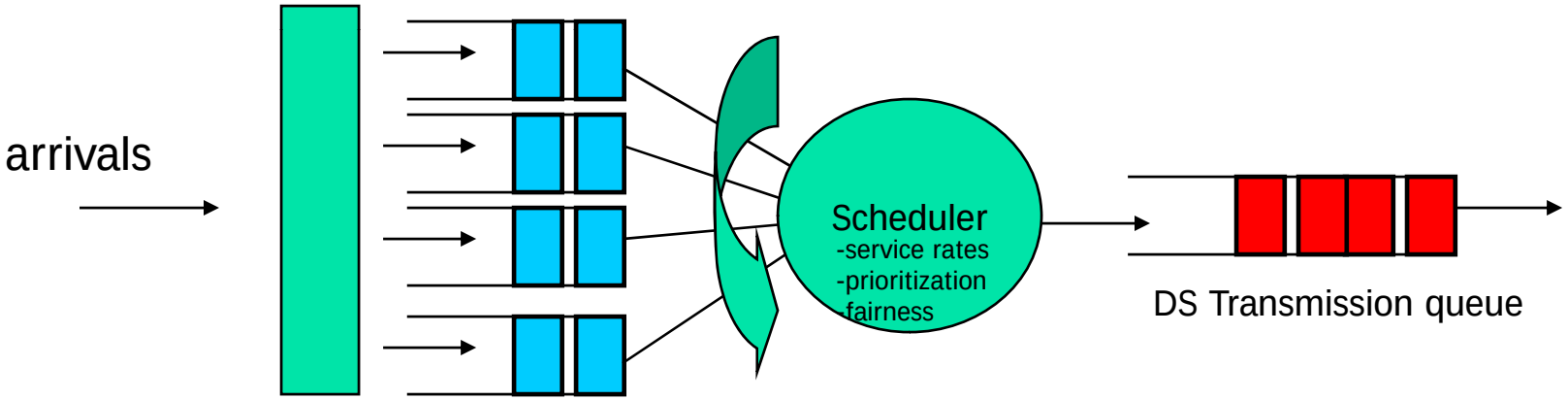


Upstream Services

- UGS: Unsolicited grant service (optionally with Activity Detection)
  - QoS Params: nominal grant interval, tolerated grant jitter.
- rtPS: realTime polling service (non-rtPS not used??)
  - QoS Params: nominal polling interval, tolerated polling jitter.
- BE: Best effort service
  - QoS Params: minimum reserved traffic rate, maximum sustained traffic rate.

The DS Scheduling Problem

- Traffic is classified by Service Flow ID
- Traditional scheduling can be used

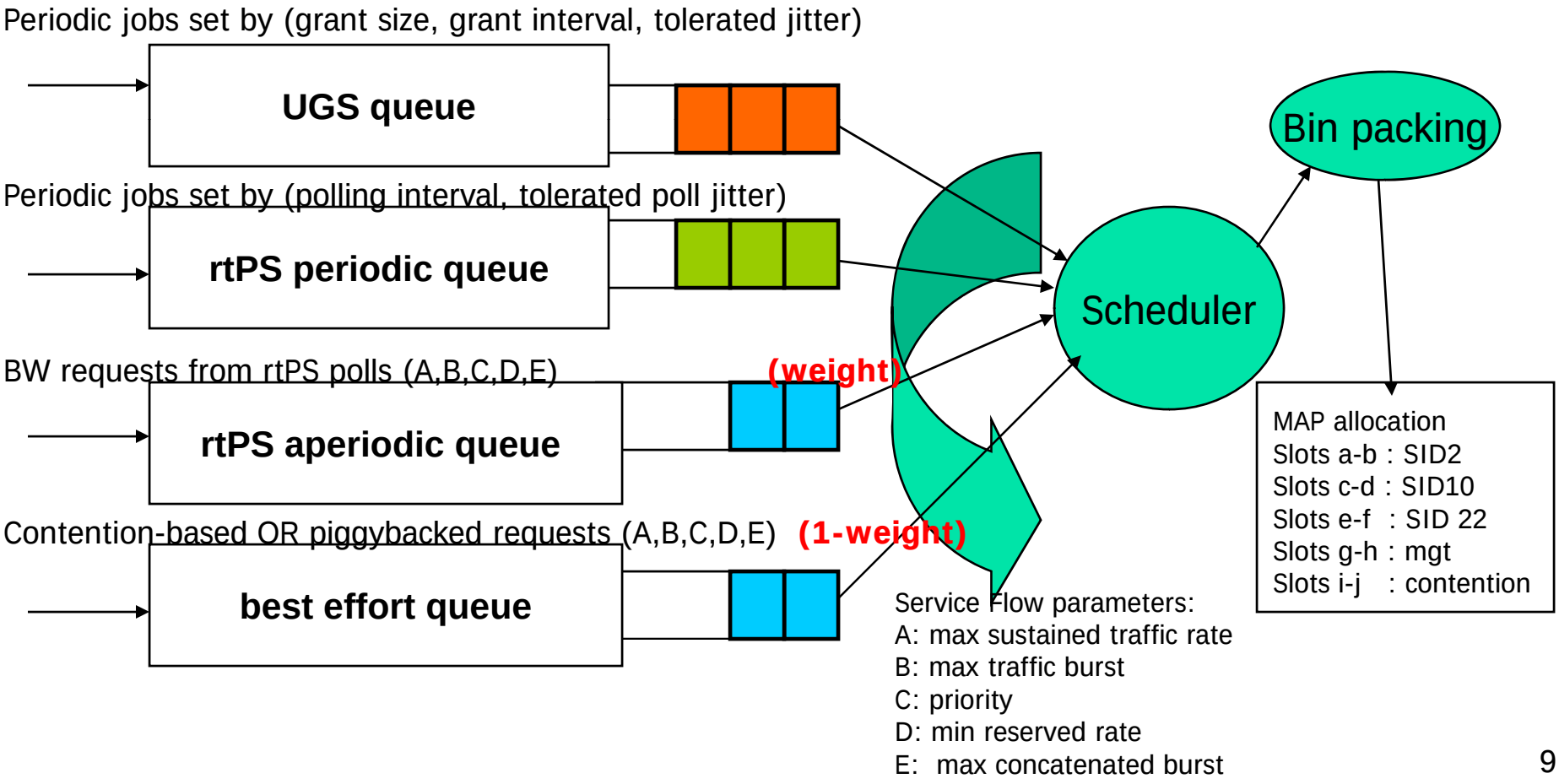


- Our model currently uses FCFS
  - Exception: MAP messages inserted at front of the queue
  - Have found that RED can be very helpful

The US Scheduling Problem

- Bandwidth requests (i.e., jobs) arrive at the centralized scheduler
- Our ‘ns’ simulation model scheduler
  - A form of Earliest Deadline First scheduling
    - ***UGS deadline:*** ***arrival time +nominal grant interval***
    - ***rtPS deadline:*** ***arrival time + nominal polling interval***
    - ***Best effort deadline:*** ***arrival time + max tolerated access delay***
  - The objective of the scheduler is to transmit each packet before its deadline
  - It has been shown that EDF is optimal under certain conditions (i.e., ideal channels, exponential arrival processes) but NOT in realistic wireless channels

NS2 DOCSIS US Scheduler



Issues and current work

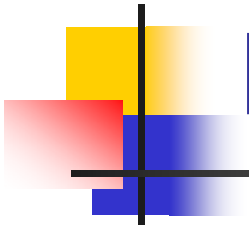
- What is the optimal number of contention slots each MAP time?
  - Adaptive algorithm that monitors collision rates and US utilization
- Fairness versus throughput: adjusting the bias
  - BitTorrent traffic can be the highest BW consuming application (20-90% of all traffic depending on location and ToD)
  - Define a normalized access delay (access delay adjusted by the size of the request) to show sustained flows benefit from a bias towards flows that use piggybacking or concatenation and flows like best effort VoIP suffer
  - Adaptive algorithm that adjusts MAC params on a per CM basis to remove the bias

Reality Check: Cisco's CMTS

- MAP time 2ms
- Default frag threshold: 2000 bytes. If a request exceeds this threshold, three equal length fragments are generated
- Default max concatenated size 1522 bytes
- Two schedulers
  - Docsis compliant
  - LLQ: Low Latency Queueing

Reality Check: Cisco's CMTS

- DOCSIS compliant scheduler
  - Strictly enforces UGS and rtPS jitter
  - UGS and rtPS grants are given strict priority over BE and rtPS data requests
  - Requires admission control to guarantee jitter tolerance
  - Uses strict priority queueing for BE SIDs of different priorities
  - The amount of BW allocated to each service can be defined.
    - E.g., 40% UGS, 10% rtPS polls, 25% rtPS data, 25% BE data



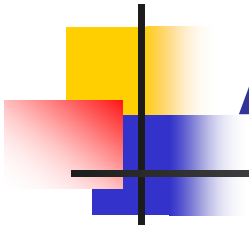
Reality Check: Cisco's CMTS

- Low Latency Queueing (LLQ) scheduler
  - Objective is to maximize the number of UGS/rtPS/BE flows but at the expense of the UGS and rtPS jitter

Future Directions

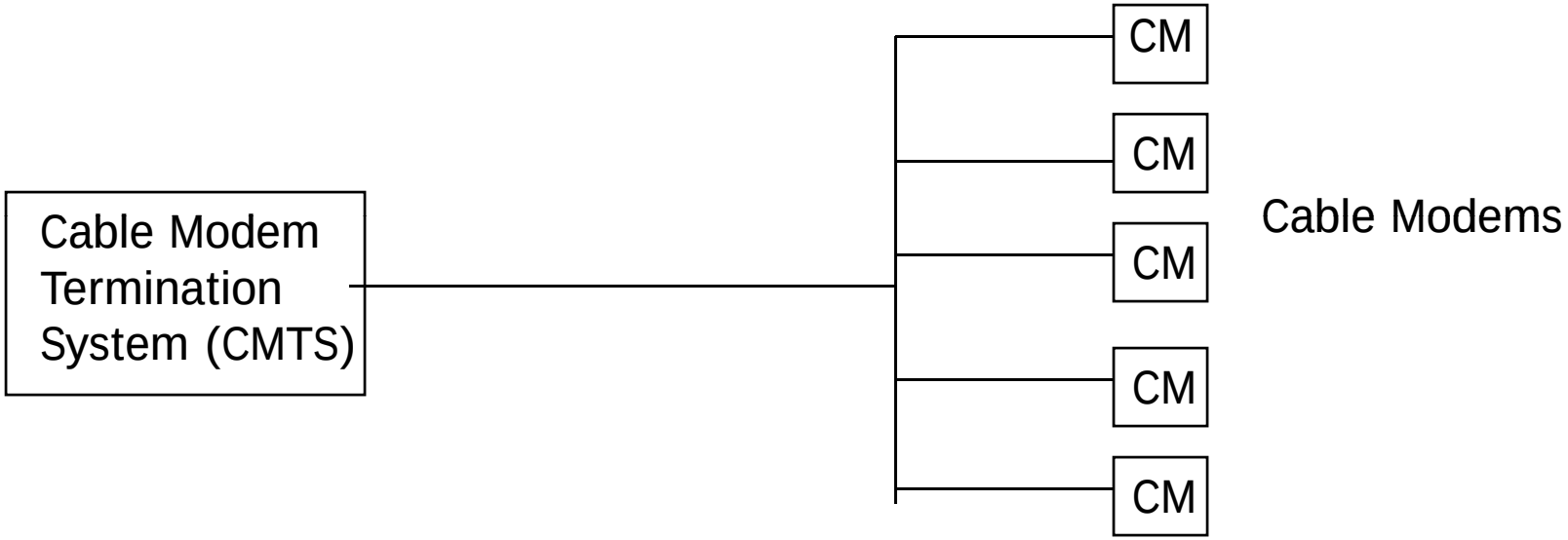
- Plan on continuing with our DOCSIS research
- Moving towards WiMAX
  - Collaborate with AWG on developing a WiMAX ‘ns’ model
  - Research:
    - opportunistic scheduling techniques
    - Self-optimization

Thank You!!!



Additional Slides....

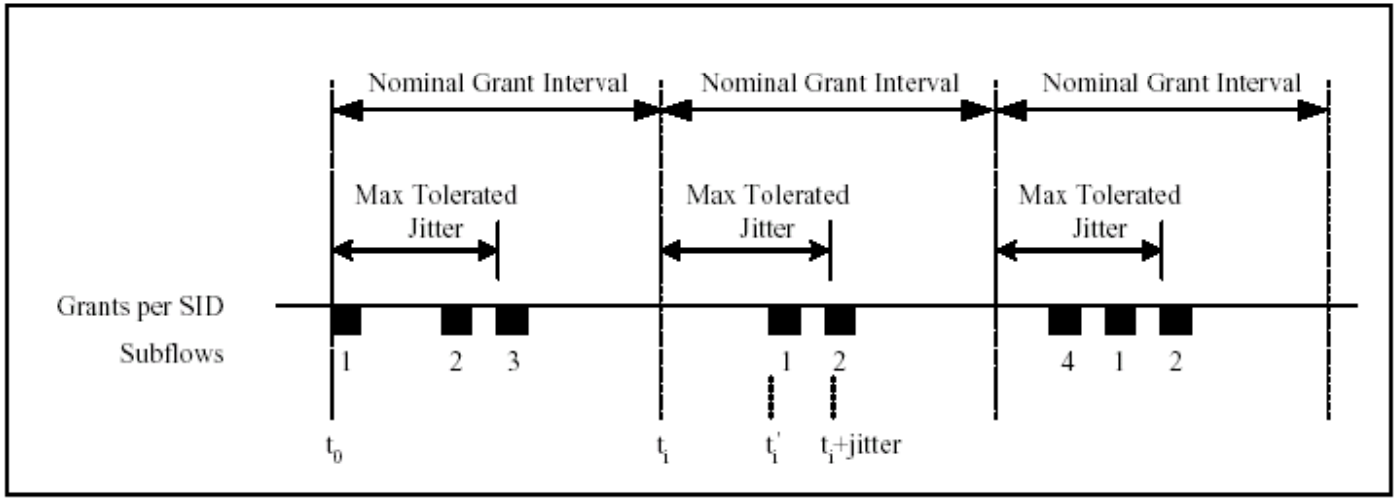
Network Model



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

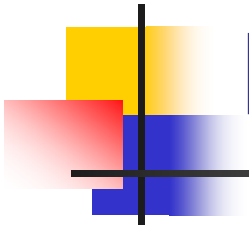
Validating the Scheduler



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

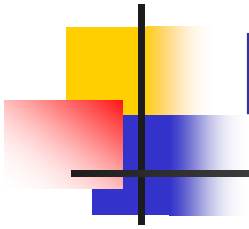
•To verify that the scheduler meets the requirements of UGS and RT-Polling service type we monitored the jitter in the grant allocation (difference between the actual grant time and the nominal grant time) is monitored

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***