Improving Quality of Service in Shared Access Networks

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Motivation

- Best-effort service is inadequate for real-time, multimedia applications
- Challenges for Access networks
  - Heterogeneity
    - Wireless Local Area Network: CSMA/CA, 802.11
    - Wide Area Cellular Network: CDPD, GPRS
    - Wireless Cable Modems: MCNS, 802.14
  - Higher and less predictable bit error
  - Bandwidth is limited or asymmetric
  - Medium access is inefficient and/or unfair

QoS over Wireless

- Guaranteed QoS is not possible over wireless
  - Losses are high, bursty, and unpredictable
- New non-guaranteed model: diff-serv
- Link-layer adaptation is crucial
  - QoS provision must factor in link quality
  - Better collision avoidance depending on load
  - Smarter use of FEC and ARQ depending on loss
  - Feedback to higher layers

Differentiated Service

- No per-flow state or per-hop signaling
- Many proposal with different terminologies
  - Assured, Nominal Bit Rate, Premium
  - different classes of delay, drop, and bandwidth
  - only promise higher classes receive better QoS
- Basic Mechanisms
  - IP v4/v6 TOS bits defining per-hop behavior
  - Traffic conditioner at network boundary
    - classifying, shaping, policing (drop if out of profile)

Our Approach

- Channel-dependent Class Based Queuing
  - Channel dependent component takes into account fluctuations in link quality
  - Class Based Queuing component provides flexible framework to meet application needs
- Predictive scheduling
  - Improve the uplink performance
  - Reduce collisions and channel access delay

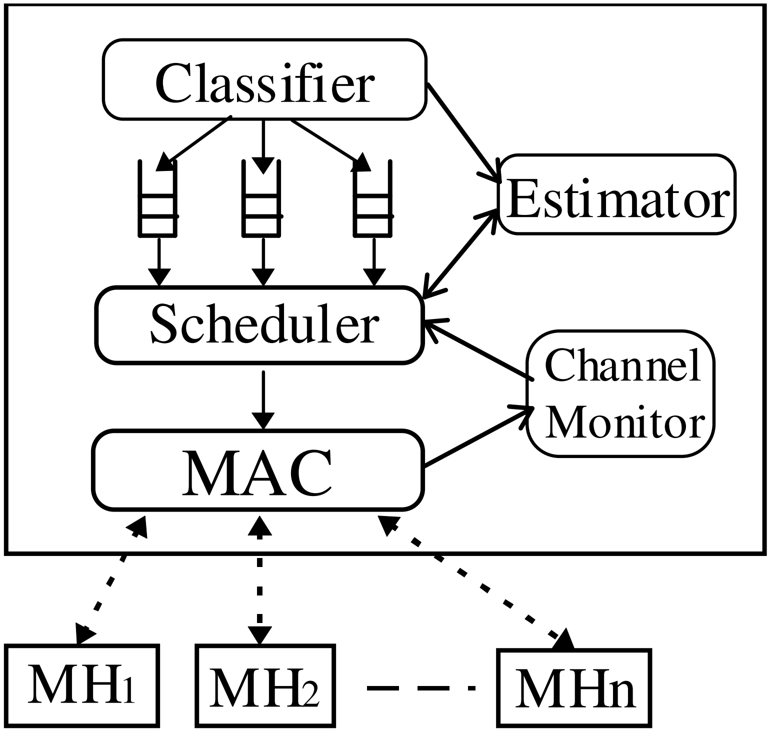
Goal: general link scheduler for heterogeneous access network

Related Works

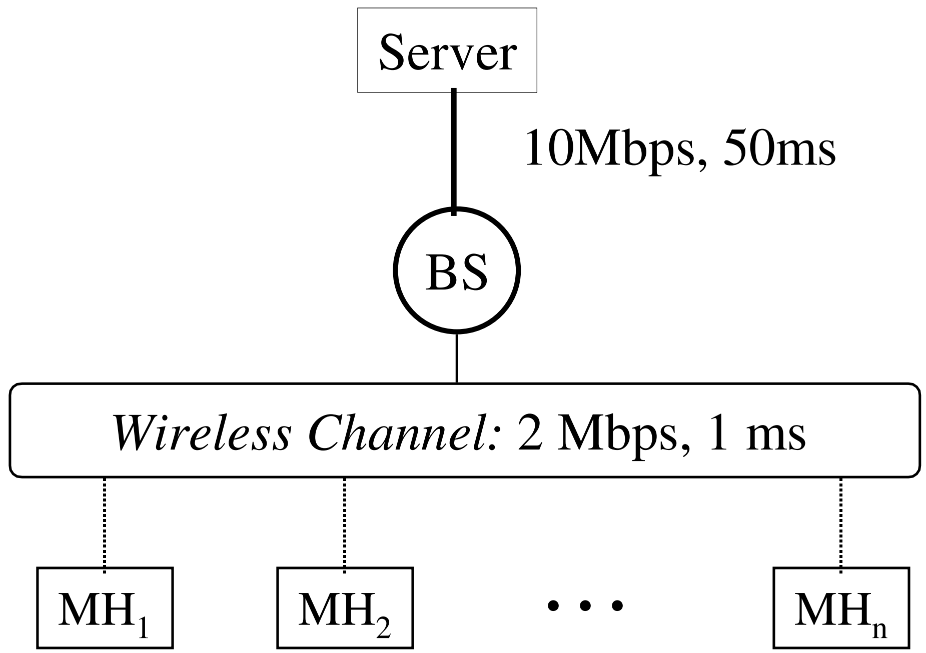
- Channel State Dependent Packet scheduling [IBM]
  - first to suggest use of channel quality
- Fair Queuing over wireless [UIUC]
  - aim for fairness under varying link quality
- Class Based Queuing
- Kathleen Nichols's suggestions on predictive scheduling

Channel Dependent Scheduler

- Mechanism
  - monitor channel quality for individual mobile host (MH)
  - estimate future error rates
- Policy
  - scheduling priority inversely proportion to error rates
  - varying FEC (GPRS)
  - varying uplink bandwidth

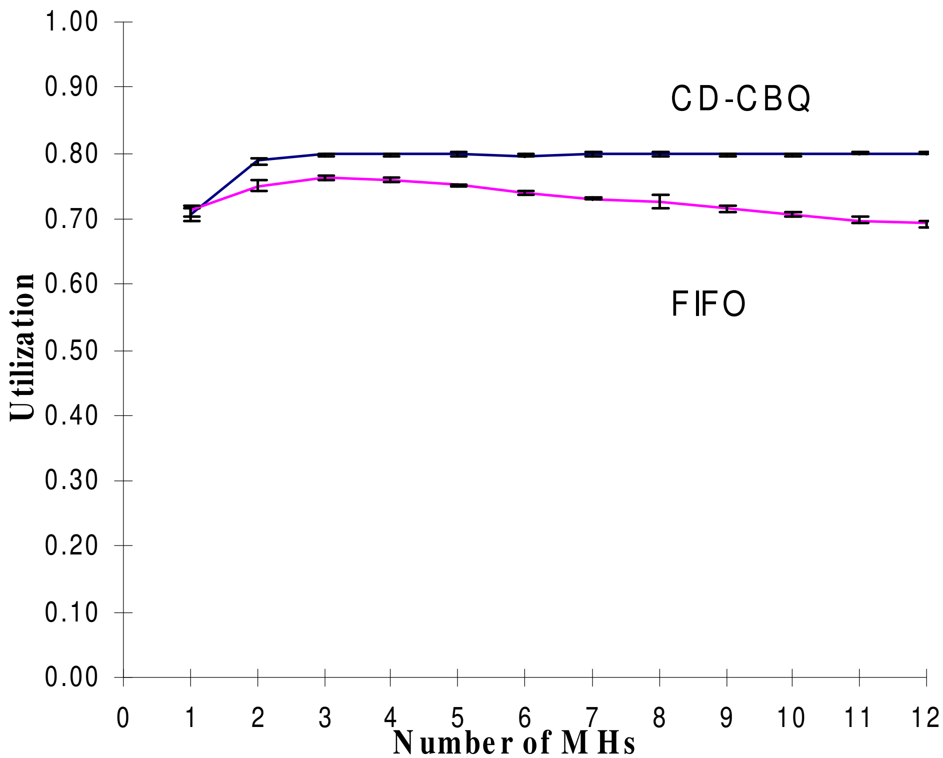


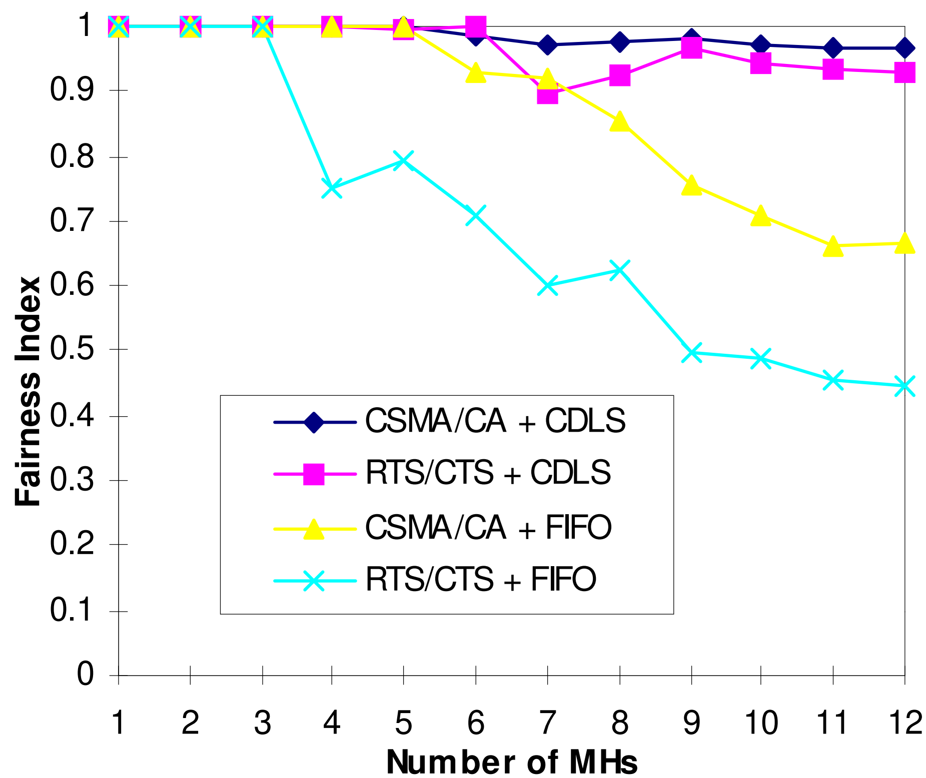
WLAN Simulation Setup



- Parameters match WaveLAN + empirical error model
- Each MH has a single FTP download from server
- Metrics: Throughput and Fairness Index

CD-CBQ Results





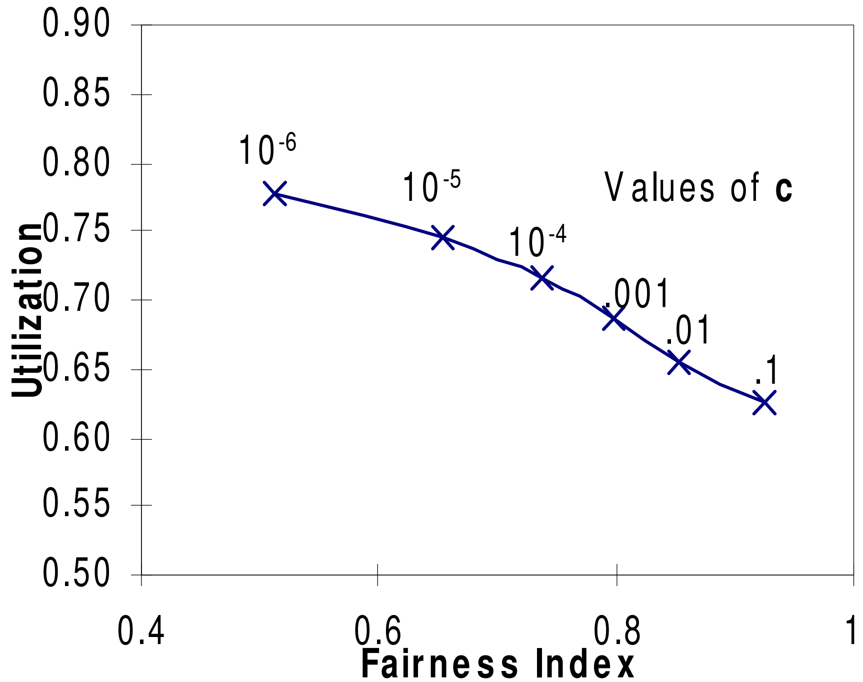
- FIFO problem: one host tend to capture the channel
- Utilization: 10-15% improvement
- Fairness: up to 50% improvement

Utilization & Fairness Tradeoff

- Channel-dependent Policy
  - weight function more sensitive to error rate

$$w_i = \frac{1}{c + p_i}$$

- Results:
  - depends on differences in channel quality
  - fairness can be significantly improve with small degradation in utilization

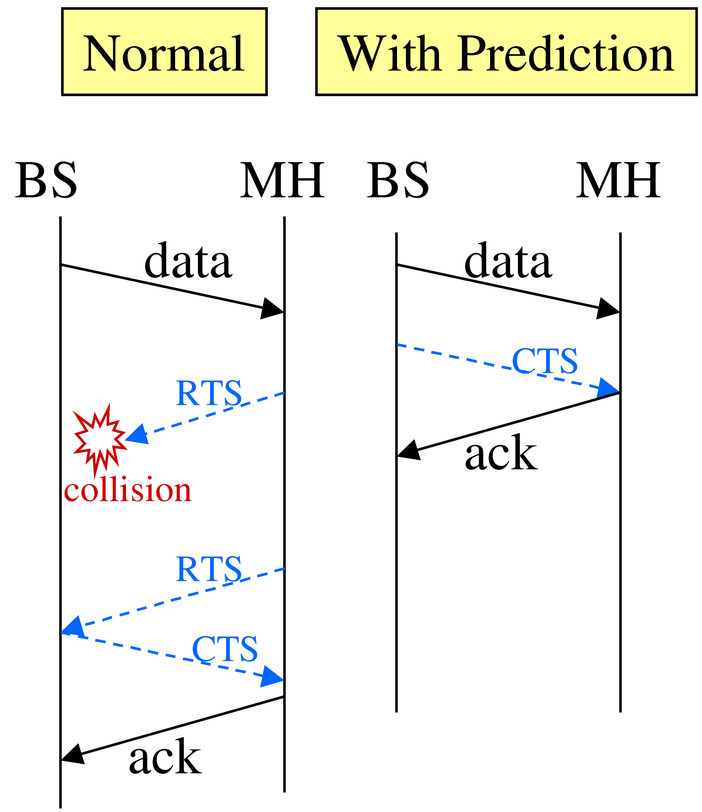


Predictive Scheduling

- BS scheduler
  - monitor downlink traffic to predict uplink traffic
  - allocate time slots for uplink transmissions
- MH scheduler
  - cooperate by waiting for slots
  - reduce random access
  - piggyback information to BS
    - queue status, size of the next transmission, ...
    - BS can these to improve scheduling of uplink

Tradeoffs in Predictive Scheduling

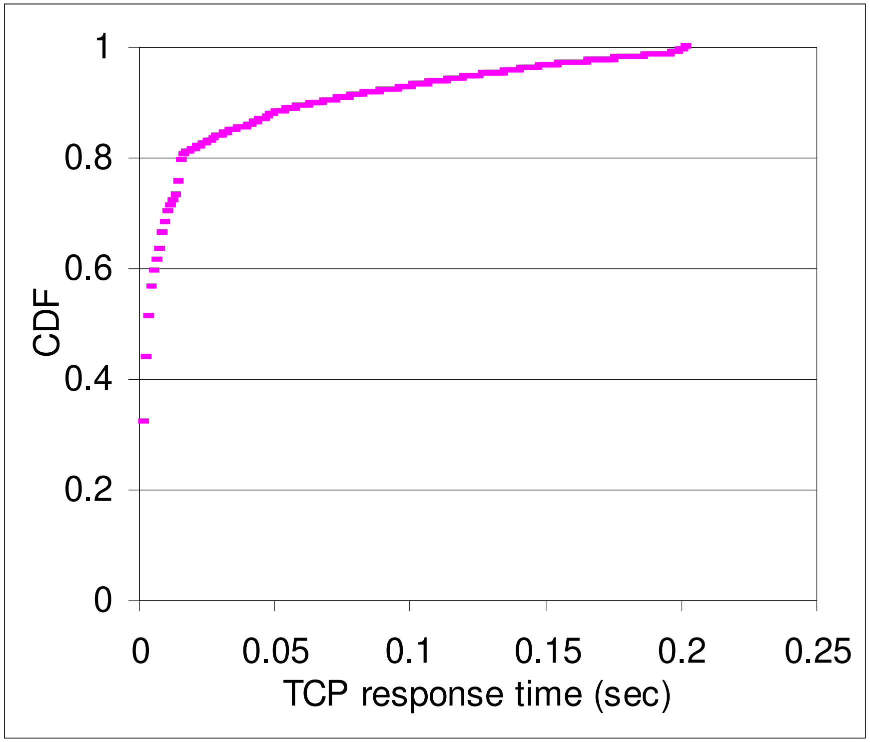
- Advantages
  - Avoid RTS/CTS exchange
  - Reduce collisions
- Disadvantages
  - Missed predictions
  - Need clock synchronization
- Worse Case = Polling
  - Better under high load

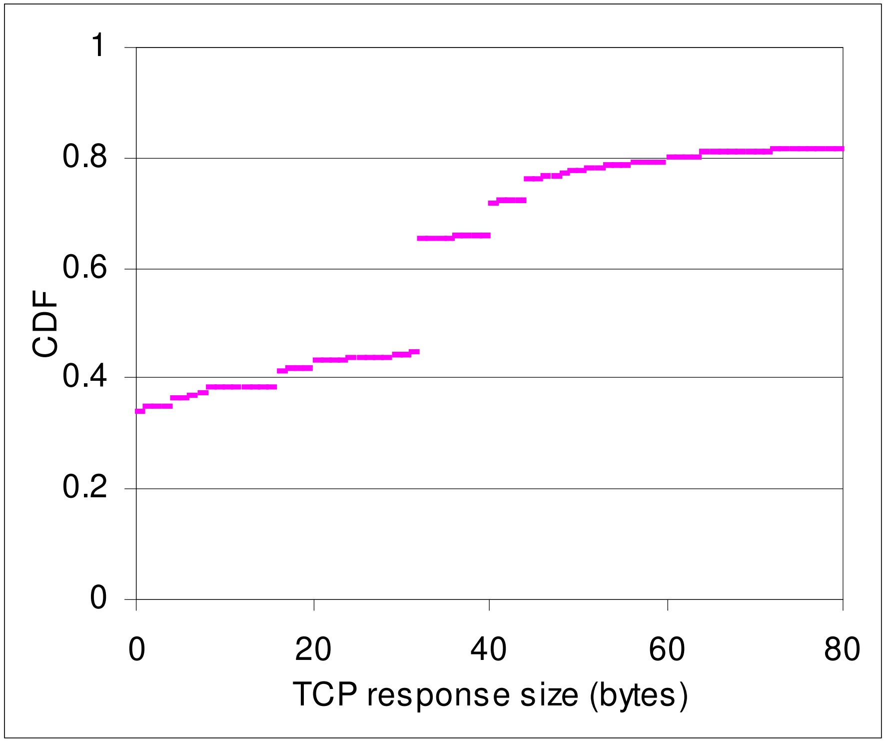


Prediction Strategies

- Guidelines for pre-scheduling
  - high accuracy predictions based on causality
  - short transmissions so smaller miss penalty
- Promising traffic patterns
  - TCP: ACKs for data segments
  - HTTP: image requests following HTML download
  - Rate-based traffic:
    - periodic based on rate (RTCP sender reports in RTP)
    - aggregation might smooth out the rate

Analysis of TCP ACKs

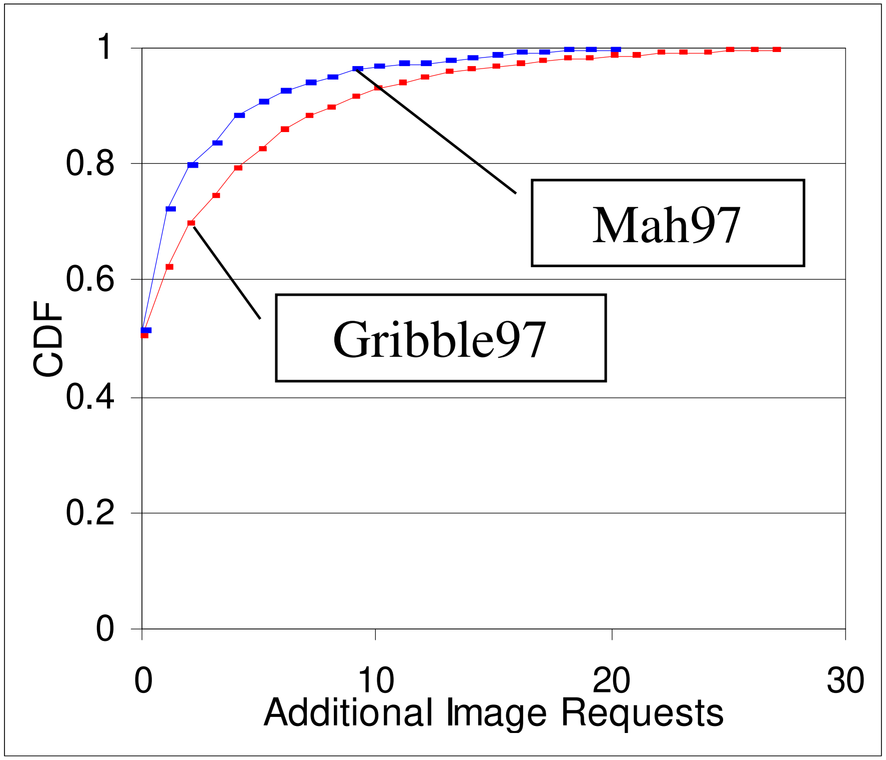


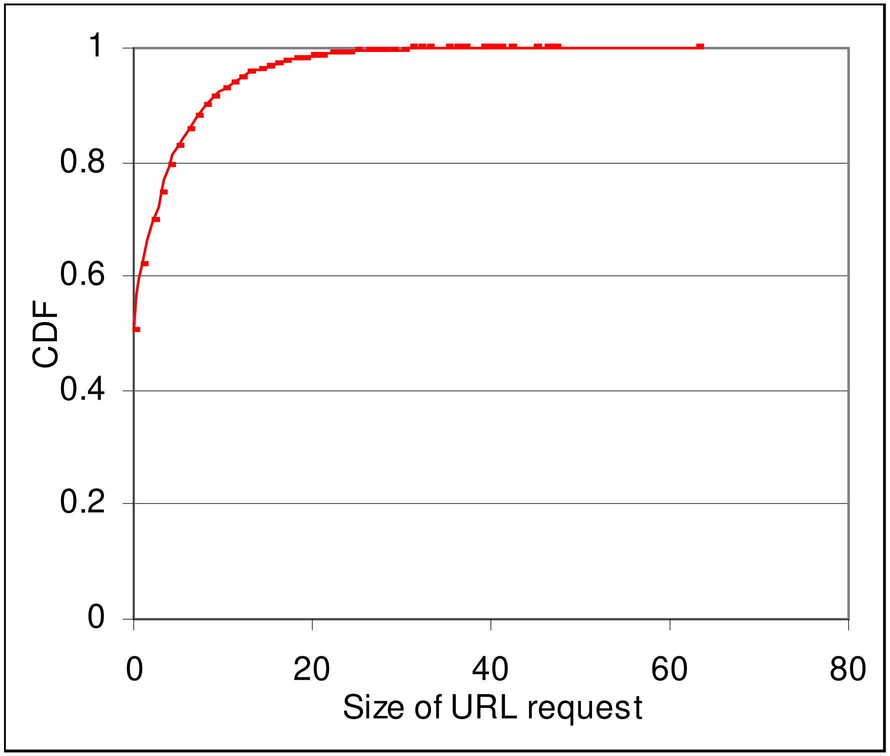


80% of TCP ACKs

- send within 20 ms after receiving a data segment
- less than 60 bytes

Analysis of Web Image Requests





- 50% of Web load does not include image
- Miss penalty is small (98% is less than 20 bytes)

Summary

- Key to improving QoS over wireless networks
  - Sensitive to link-quality
  - Sensitive to application requirements
  - Improve fairness
  - Reduce collision
- Proposed Solution
  - Differentiated service provides the model
  - Channel Dependent and Predictive Scheduling provides the mechanism

On-going Research

- Analyze other traffic for predictive scheduling
  - Rate-based: RTP and RTCP, telnet
- Simulation of GPRS
  - Apply link quality to select coding schemes
  - Evaluate predictive scheduling
  - Analyze the 4 classes of QoS provided by GPRS
    - 3 delay sensitive, and 1 best-effort
    - meeting application requirements
- Policies for Differentiated Service