Supporting Quality of Service in the Wireless Internet

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Summary

- Wireless Internet & Mobile Multimedia: Problems and Solutions
- Introduction: TCP/IP over Wireless Networks
  - HTTP Performance between Two Wireless Hosts
- Enhancing Wireless Internet Links: A Flexible, Multi-Service Link Layer
  - MSLL for the Wireless Internet
  - MSLL: QoS Specification
  - MSLL Contributions
- Adaptive Applications for Mobile Wireless Internet Appliances
- MobiWeb
  - Sample MobiWeb Performance Results
- Differentiated Services for the GPRS Access Network
  - GPRS Overview
  - GPRS Quality-of-Service
  - DiffServ Architecture Review
  - DiffServ over GPRS
  - GPRS DiffServ Architecture
  - Implementation @ the BS
  - Rationale for Charging Wireless Transport Services
- Objectives of Mobile Charging
- Conclusions

Wireless Internet and Mobile Multimedia: Problems and Solutions

- unpredictable wireless channel (performance)
  - even for a single channel, with no hand-offs
  - error characteristics, high error rate…
- low bandwidth
- unfriendly physical layer designs
  - dominated by single application (voice)
  - usually, just retrofited packet/Internet architecture requirements

- difficult to ensure QoS because of
  - unpredictable wireless channel performance
  - mobility (hand-offs)
  - low bandwidth – high contention for resources
  - unfriendly physical layer designs

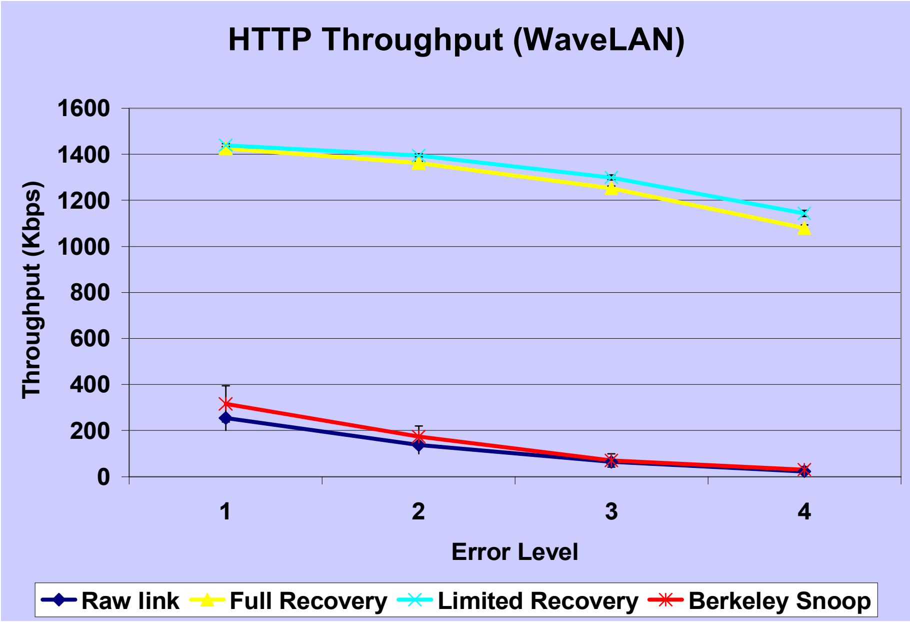
Introduction: TCP/IP over Wireless Networks

- Internet protocols developed for networks that were
  - wired (low transmission error rate)
  - fixed (no mobility, no handoffs)
- TCP
  - makes **(strong) assumptions**…
    - packet errors/drops = congestion
      - refrain from transmission, WRONG
    - performance degrades
  - *not* most efficient error control
    - now the TCP-SACK option is available, but not widely
  - TCP aware link layer enhancements (snoop TCP)
- UDP
  - real-time, interactive applications use it, assuming **few** errors
  - rarely studied over wireless networks

➪ G. Xylomenos and G.C. Polyzos, "Internet Protocol Performance over Networks with Wireless Links," *IEEE Network*, vol. 13, no. 4, pp. 55-63, July-August 1999.

➪ G. Xylomenos, G.C. Polyzos, P. Mahonen, and M. Saaranen, "TCP Performance Issues over Wireless Links," *IEEE Communications Magazine*, April 2001.

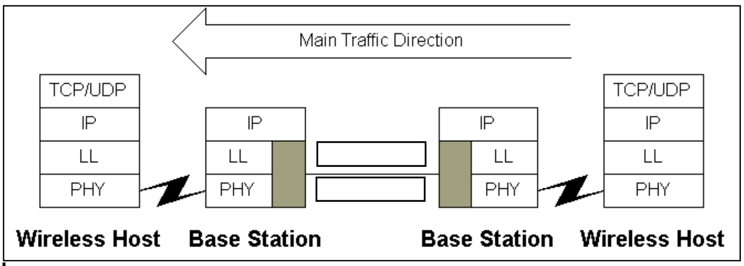
Sample TCP Application Performance Result: HTTP between Two Wireless Hosts



- High speed links: TCP recovery is very slow
- Snoop doesn't work over two wireless links

Enhancing Wireless Internet Links:
A Flexible, Multi-Service Link Layer

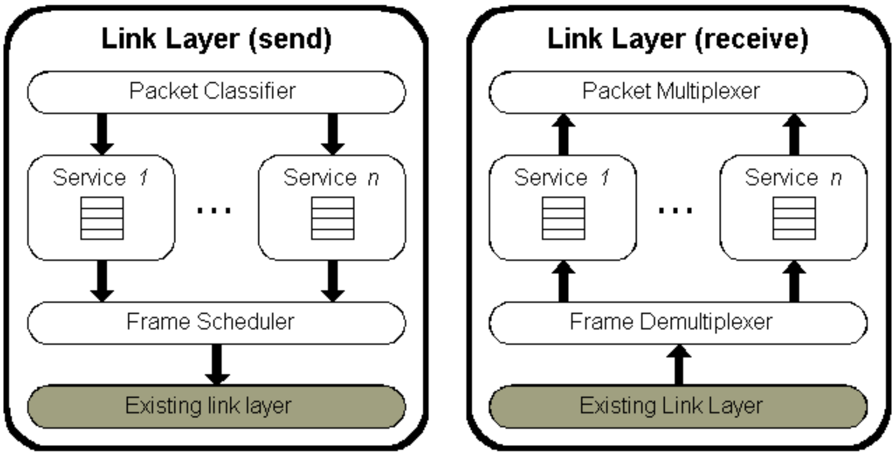
- **Multiple, simultaneous**, adaptive, **QoS-aware** streams over the wireless link
- Tradeoffs (stream specific):
  - delay
  - throughput
  - reliability
- Advantages
  - **local solution** to a local problem
  - (higher layer) **protocol independent**
  - close to the physical medium (can be medium specific)
  - a step towards **QoS provision** in the Internet



- Implementation: medium and application/QoS dependent
  - ARQ: efficiency, simplicity, but delay jitter
  - FEC: low delay, no jitter, limited recovery (in software)
  - adaptation to medium variations
  - interface issues: link/network state, application QoS

Multi-Service Link Layers for the Multimedia Wireless Internet

(joint work with G. Xylomenos)

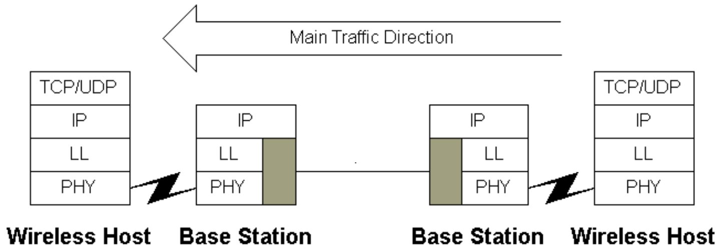


- MSLL: multiple simultaneous Link-Layer
  - classifier: assign IP packets to services
  - services: independent LL schemes
    - each service is totally unaware of the others
  - scheduler: protect services from each other, apply QoS policy
    - error recovery overhead would otherwise skew results

MSLL: QoS Specification

- Implicit QoS requests
  - based on ToS field (IPv4, IPv6)
  - end-to-end or local packet classifier
  - settings for existing protocols
    - TCP: mostly reliable, delay sensitive
    - UDP: application/port dependent (from no error control to fully reliable)
- Explicit QoS requests
  - based on flow ID (IPv6)
  - RSVP … or other signaling protocols
  - ad hoc

MSLL Contributions



- TCP ***and*** UDP considered
  - usually, focus on TCP only
- QoS Support
- MSLL results
  - all applications (FTP/HTTP/CBR) simultaneously
  - two simultaneous services: TCP & UDP oriented
  - proportional performance improvements
- more than one wireless link per flow considered
  - mobile peer-to-peer communication
- various environments
  - data rates, propagation delay, error rates and patterns
- more than one type of traffic
  - ftp, www, and real-time conferencing

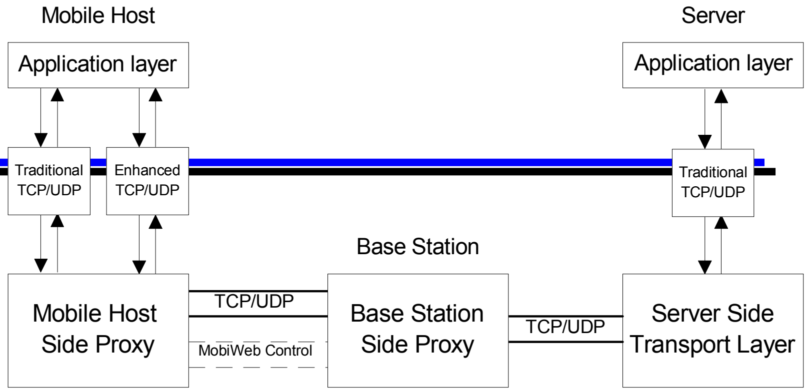
➪ G. Xylomenos and G.C. Polyzos, “Link Layer Support for Quality of Service on Wireless Internet Links,” *IEEE Personal Communications*, October 1999.

➪ G. Xylomenos and G.C. Polyzos, “Quality of Service Support over Multi-Service Wireless Internet Links,” *Computer Networks*, 2001.

Adaptive Applications for Mobile Wireless Internet Appliances

- cooperating “agents” across wireless link/network
  - communicate with
    - link, network
      - performance estimates
      - hand-off notifications
    - application
      - acceptable quality ranges
      - relative importance of media, streams
  - operate on traffic
    - intercept
    - transform
    - pre-fetch, cache
    - prioritize, specify QoS

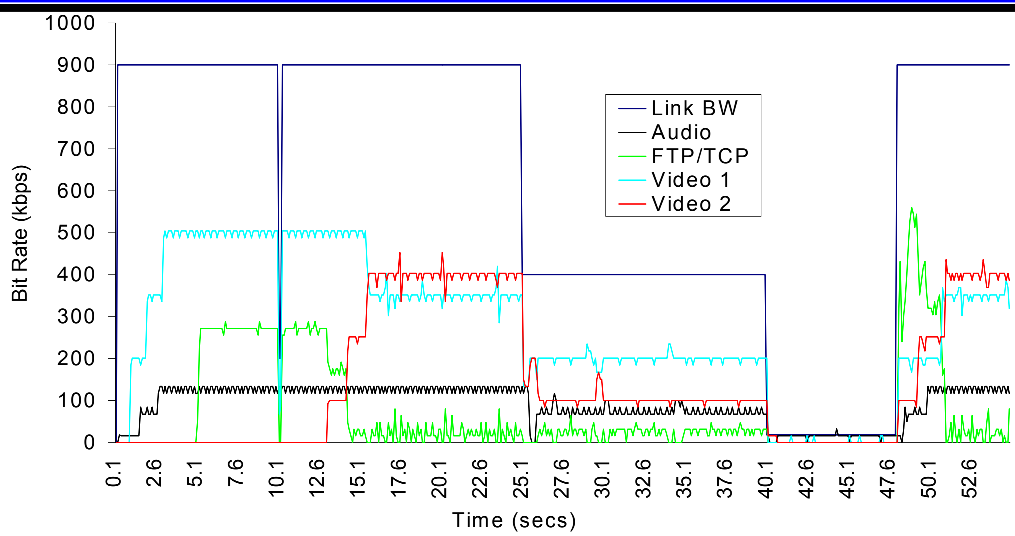
MobiWeb



(joint work with
M. Margaritidis)

- Proxy Architecture
- Support for adaptive applications
  - filtering
  - multiple levels of quality for each stream
- Shielding real-time applications from short-term link variations
  - specialized timers
- Eliminate inter-stream interference
  - dynamic priorities
  - admission control on minimum requirements
- Transparent to traditional Internet traffic
- Simple and powerful interface

Sample MobiWeb Performance Results



- M. Margaritidis and G.C. Polyzos, “MobiWeb: Enabling Adaptive Continuous Media Applications over Wireless 3G Links,” IEEE Personal Communications, December 2000.
- M. Margaritidis and G.C. Polyzos, “Adaptation Techniques for Ubiquitous Internet Multimedia,” Wireless Communications and Mobile Computing, 2001.

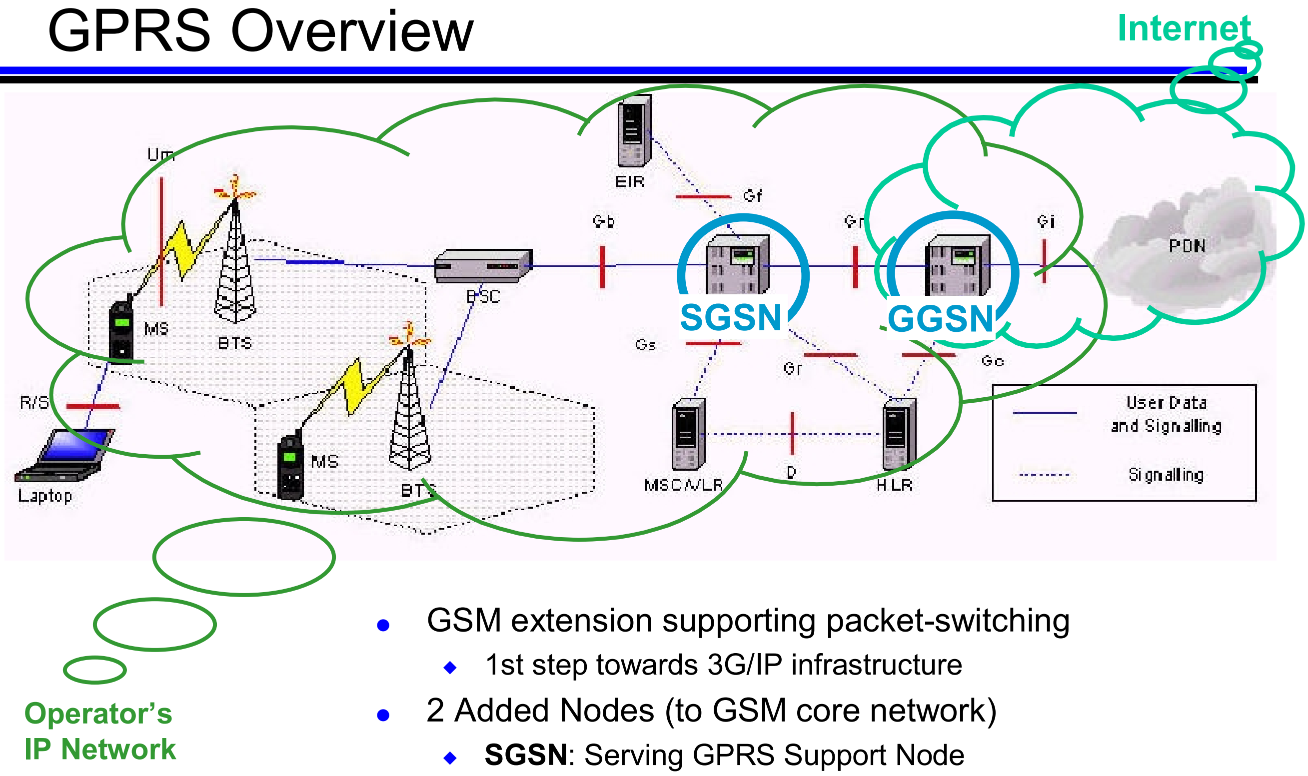
Differentiated Services for the GPRS Access Network

(joint work with Sergios Soursos and Costas Courcoubetis)

- Apply Internet QoS techniques in the GPRS environment
  - End-to-end QoS (Internet)
  - Emphasis on the access network (radio link) ⇒ congestion point
  - Use existing resource allocation techniques of GRPS specs
- Two-bit Differentiated Services
  - fields in the headers request the type of service
- Charge the use of priority/service classes
  - According to the congestion level of each class

    ⇒ Congestion Pricing
- Optimal prices for each class maximize both
  - social welfare, and
  - users' net benefit

GPRS Overview

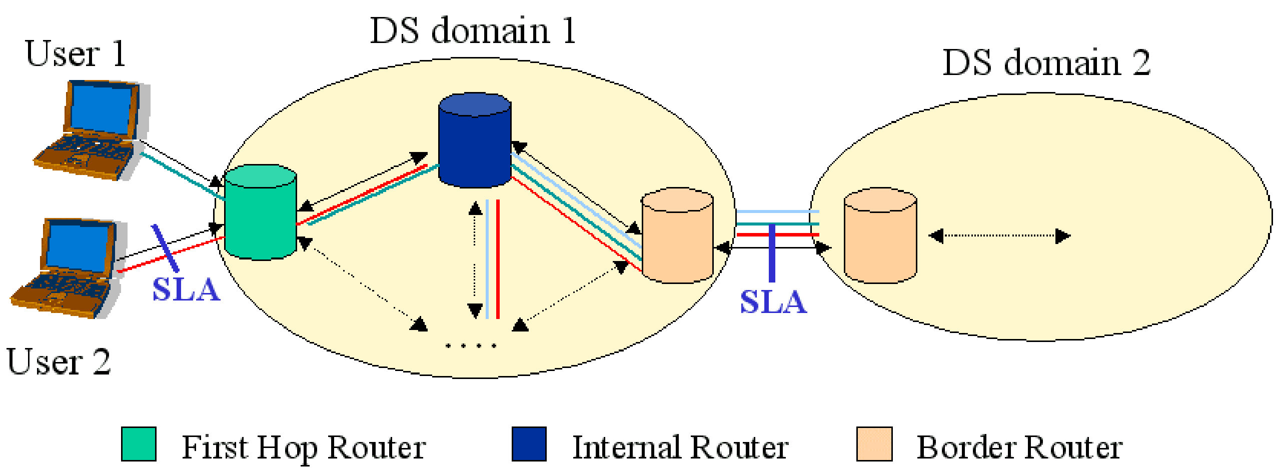


- GSM extension supporting packet-switching
  - 1st step towards 3G/IP infrastructure
- 2 Added Nodes (to GSM core network)
  - **SGSN**: Serving GPRS Support Node
  - **GGSN**: Gateway GPRS Support Node

GPRS Quality-of-Service

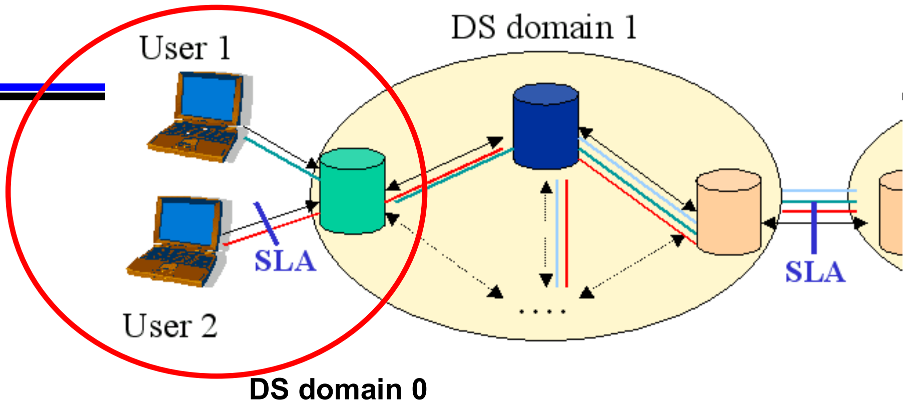
- GPRS specifications define QoS parameters and profiles
  - we are unaware of specific implementation plans and strategies to support specific QoS models
    - particularly over the wireless access network
- Recent proposals in the area of GPRS QoS focus on providing QoS support in the core GPRS network
  - typically non-wireless, IP based
  - using the standard Internet QoS frameworks
    - Integrated Services
    - Differentiated Services
- We focus on the access GPRS network (bottleneck)

DiffServ Architecture Review



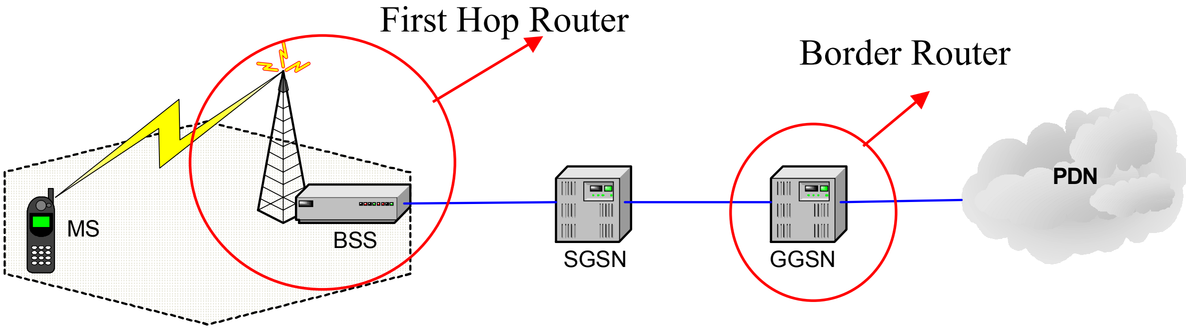
- Per-Hop-Behavior (PHB)
  - Premium Service: true “guarantees” (“CBR”-like)
  - Assured Service: efficient, better than best effort
- 2-bit DiffServ: combination

DiffServ over GPRS



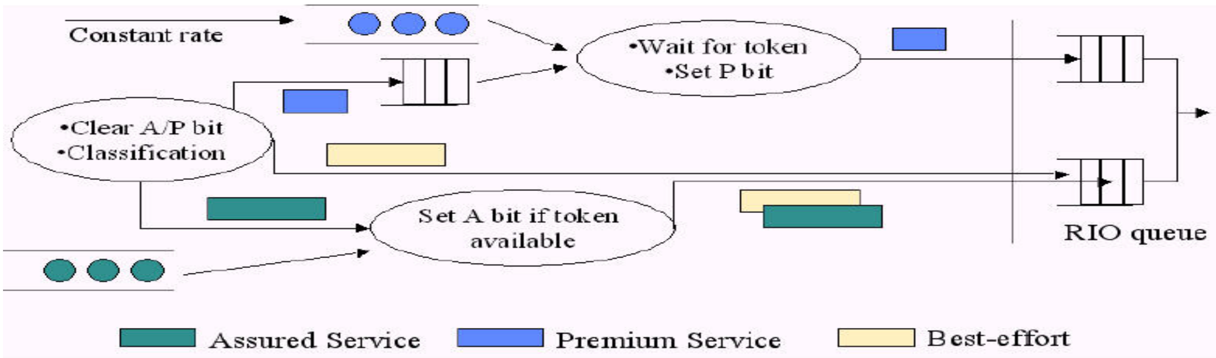
- wireless channel is the bottleneck
  - ingress point
  - difference from typical DiffServ configurations
- BSS assigns slots/regulates traffic
  - multi-access (uplink)
- architecture
- charging DiffServ over GPRS

GPRS DiffServ Architecture



- (Two-Bit) Differentiated Services Architecture
- **Distributed** traffic conditioner (MS and BSS)
- @ BSS: simulation of first hop router's functions (software upgrade)
- Use of Uplink State Flag (USF), Countdown Value (CV) and the existing procedures of PDP Context activation and TBF establishment

Implementation @ the BS (/1st hop router)



- Token circulation at BS/1st hop router emulates DiffServ packet moves to implement a distributed queue
- RIO: RED queue with two thresholds
  - for in-profile packets and
  - for out-of-profile packets

➪ S. Soursos, C. Courcoubetis, and G. C. Polyzos, "Pricing Differentiated Services in the GPRS Environment," to appear in *Wireless Networks*.

Rationale for *Charging* Wireless Transport Services

- (licensed) spectrum is and will continue to be
  - scarce
  - expensive
- an economic approach to resource allocation
  - seems to be the most **realistic** (*fair*) method to provide
    - service differentiation
    - (guaranteed?) Quality of Service

Objectives of Mobile *Charging* Research

- develop a set of pricing models
  - sophisticated, but
  - simple to implement
- develop associated accounting and billing infrastructure

- main thrust
  - dynamic, incentive compatible price setting according to
    - the demand for network resources
    - the congestion level of the network
  - efficient allocation of the scarce wireless access network's bandwidth through actual *market* forces
  - can be consistent with corresponding Internet pricing models

Conclusions

- Flexible, Multi-Service Link Layers
  - TCP ***and*** UDP and more than one wireless link considered
  - QoS Support
  - various environments investigated
    - data rates, propagation delay, error rates and patterns
  - more than one type of traffic
    - ftp, http, real-time conferencing, …
- MobiWeb:
  - Proxy Architecture Supporting adaptive applications
    - filtering
    - multiple levels of quality for each stream
  - Shielding real-time applications from short-term link variations
- DiffServ framework for the GPRS access network
  - using standard GPRS resource allocation procedures
  - using standard Internet DiffServ ⇒ can be **end-to-end** DiffServ
- Pricing Scheme (congestion pricing)

socially optimal prices ⇔ maximize users' net benefit