A Tour of My Networking Research: Problems, Results, Techniques and Tools

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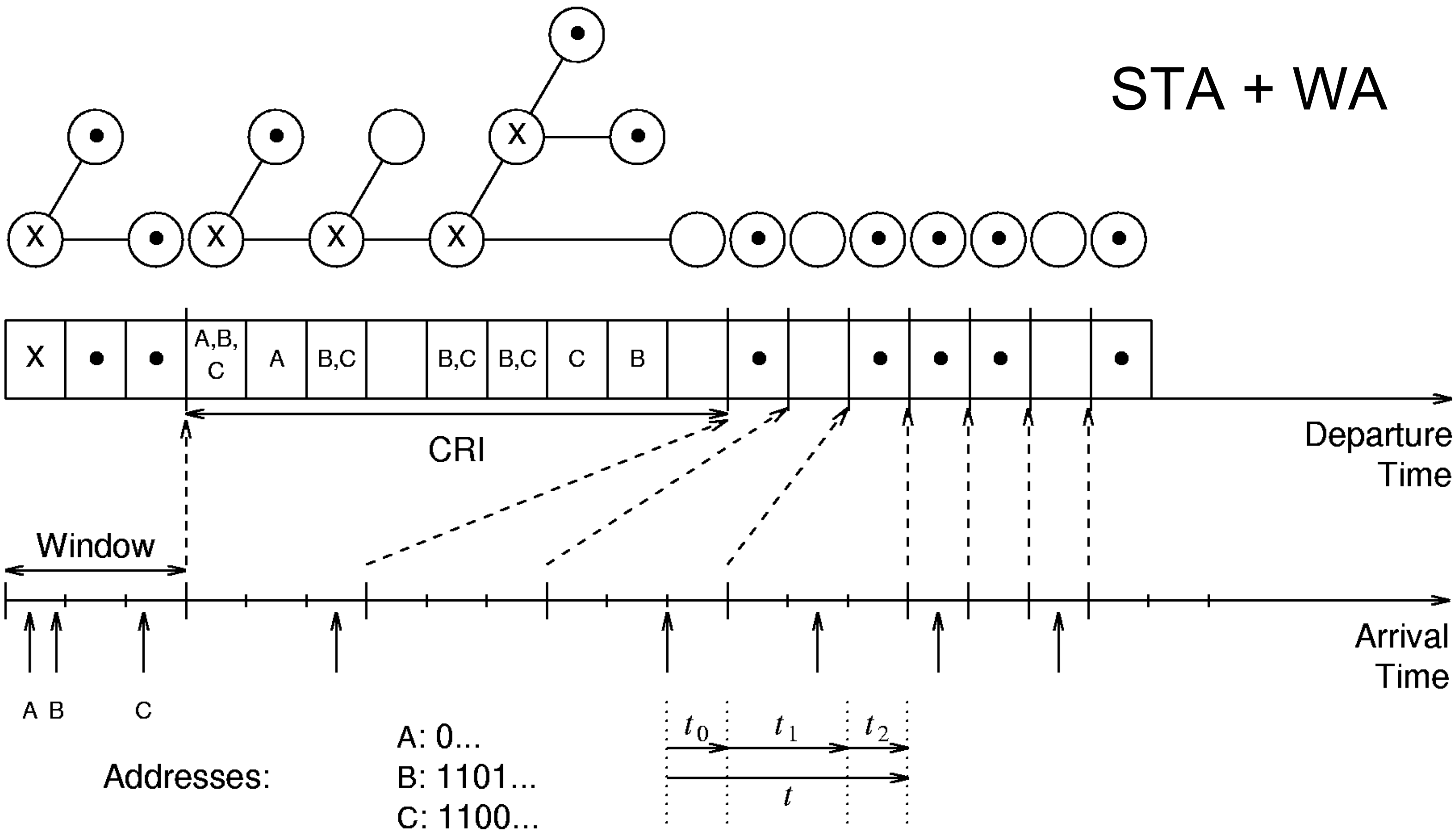
Outline

- Conflict Resolution Algorithms: Modeling and Performance Evaluation
- IP Flows: Definition, Measurement and Applications
- Multimedia Multicast
  - Optimal Routing under Delay Constraints
  - Robust Multimedia Dissemination
  - Mobile IP Multicast
  - The *B-Bone* Project
- Wireless Networks & Mobile Multimedia
  - TCP
  - FLLIP
  - ***MobiWeb***: Real-Time Continuous Media Support over Wireless Packet Networks
  - Mobile Marketing using a Location Based Service
  - ***Mobishare***: An Architecture for Sharing, Discovering and Accessing Mobile Data and Services
    - The *DBGlobe* Project
- P2P Wireless Network Confederation (*P2PWNC*): P2P Approach to WLAN Roaming
  - The *MMAPPS* Project: Market MAnagement of Peer-to-Peer Services
- Mobile Multimedia Laboratory

Conflict Resolution Algorithms:
Modeling and Performance Evaluation



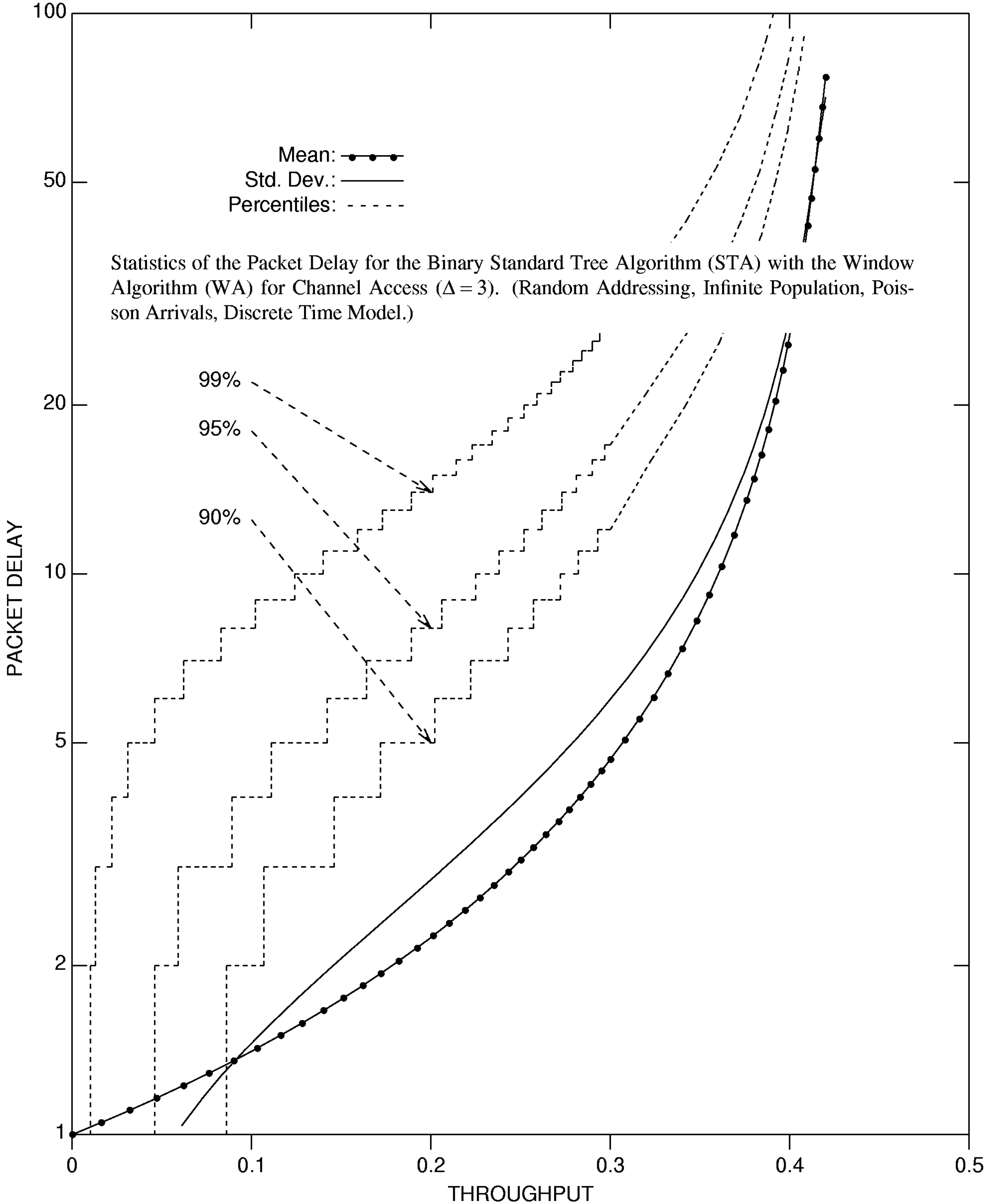
The Standard Tree Algorithm (STA) with the (non-simplified) Window Algorithm (WA) for Channel Access.

Packet Delay

- Analytical Results
  - obtained through
    - System modeling
    - Probability theory
    - Queueing theory
      - PGFs

Publications

- "Performance Analysis of Finite Nonhomogeneous Population Tree Conflict Resolution Algorithms Using Constant Size Window Access," ***IEEE Trans. on Communications***, Nov. 1987 (with M.L. Molle, and A.N. Venetsanopoulos).
- "A Queueing Theoretic Approach to the Delay Analysis for the FCFS 0.487 Conflict Resolution Algorithm," ***IEEE Trans. on Information Theory***, Nov. 1993 (with M.L. Molle).
- "A Queueing Theoretic Methodology for Performance Analysis of Separable Window Access Conflict Resolution Algorithms with Variable Length Elementary Events," ***Queueing Systems: Theory and Applications***, 1994 (with M.L. Molle).



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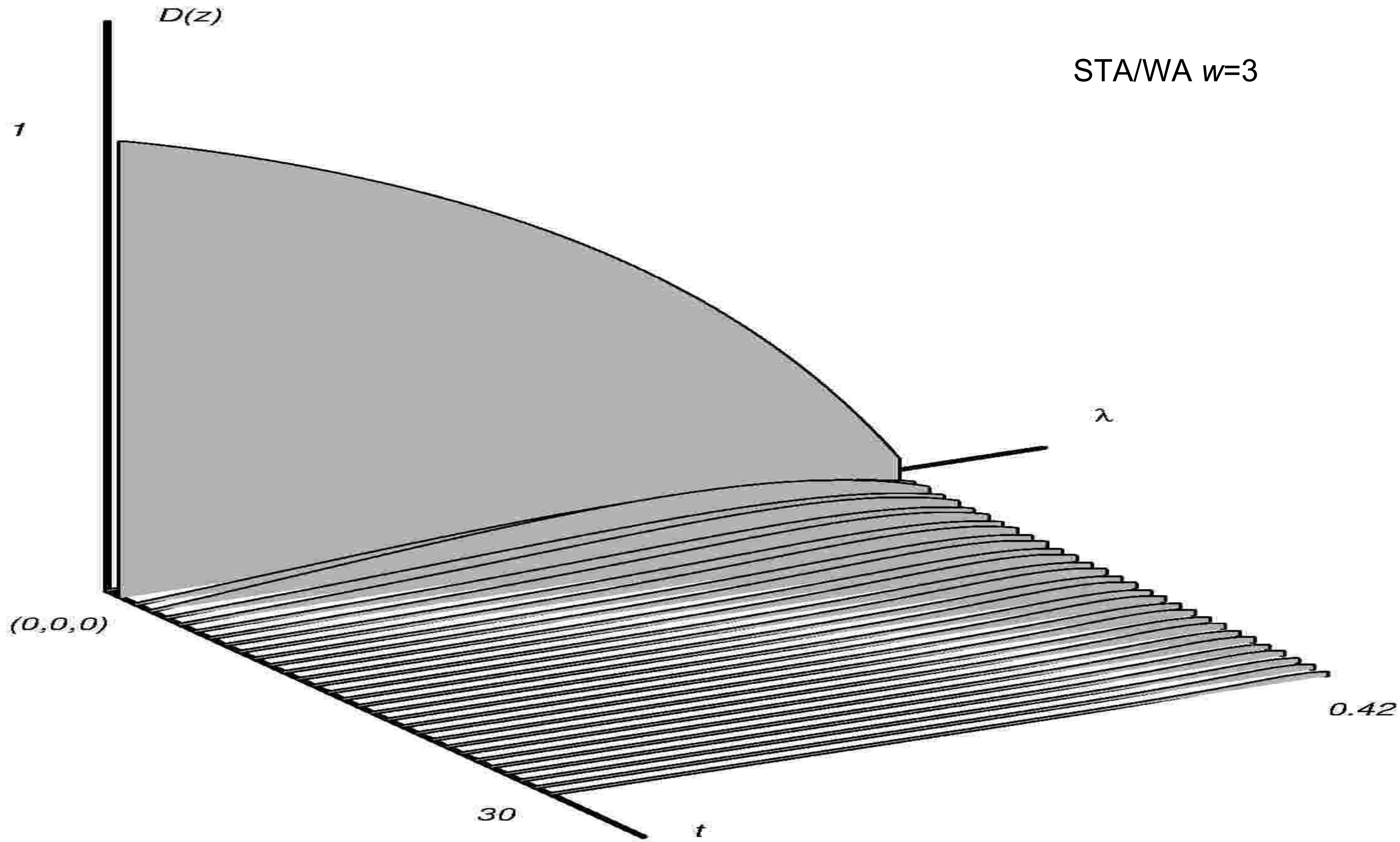
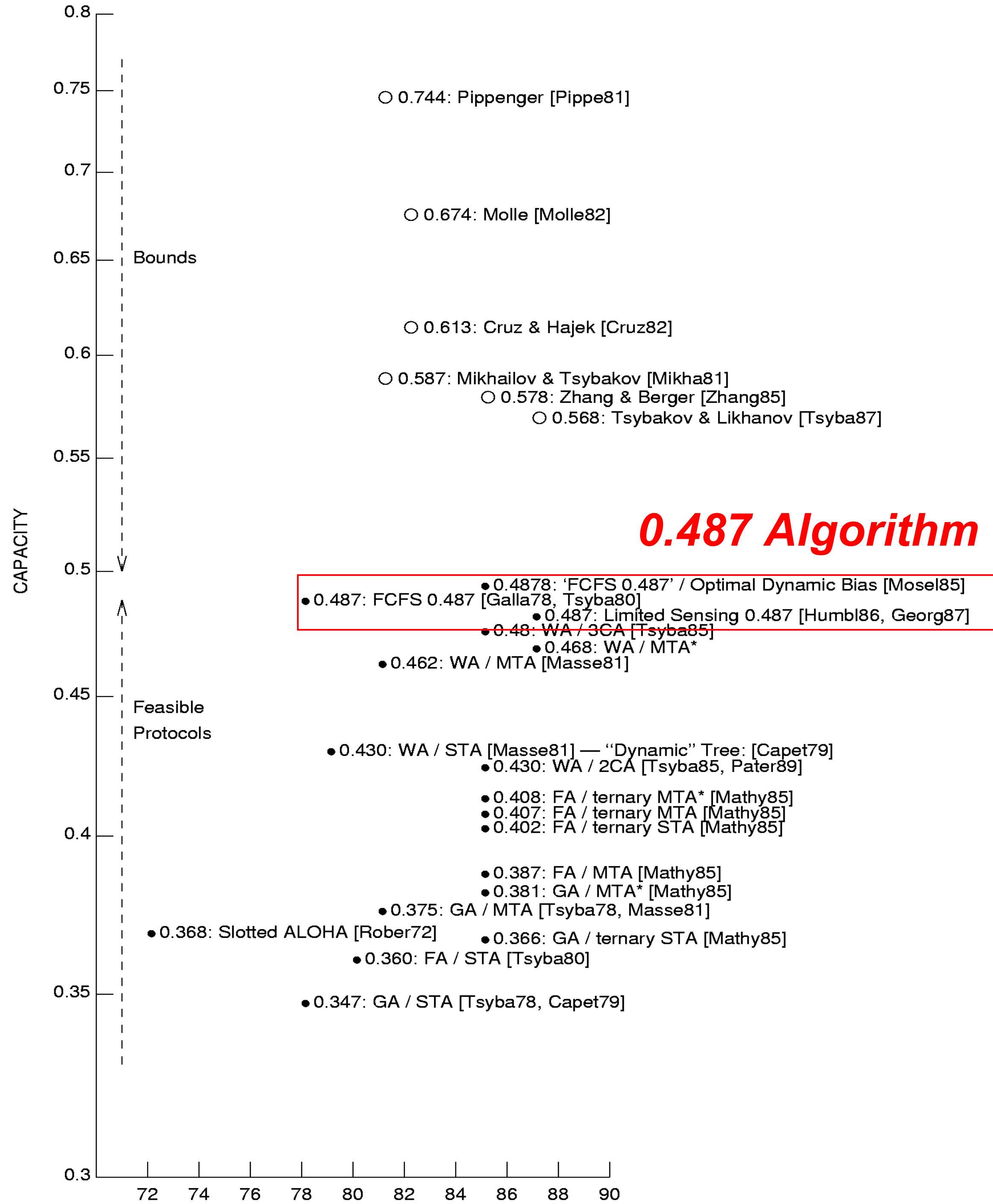
Packet Delay Distribution



STA/WA *w*=3

CRA
Capacity Results

- Upper Bounds on Capacity
- Constructive Lower Bounds
  - through specific algorithms / protocols

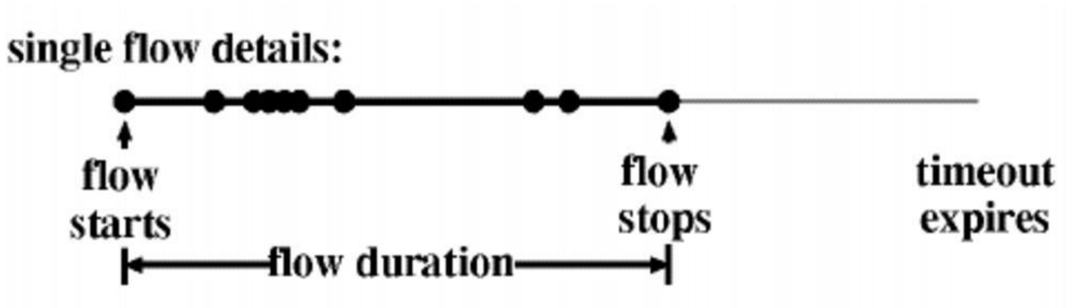


λ	Mean							Standard Deviation		
	Analysis					Simulation		Analysis	Simulation	
	QT	[Georg87b]		[Huang85]		95% c.i.		QT	95% c.i.	
	(approx.)	lower	upper	lower	upper	mean	(+/−)	(approx.)	mean	(+/−)
0.01	1.53	1.53	1.53							
0.05	1.64	1.64	1.64							
0.10	1.81	1.80	1.81	1.80	1.80	1.807	0.004	1.057	1.060	0.011
0.20	2.31	2.27	2.35	2.29	2.30	2.312	0.005	1.78	1.782	0.016
0.25	2.73	2.66	2.80							
0.30	3.40	3.27	3.53	3.33	3.43	3.384	0.026	3.13	3.134	0.030
0.35	4.58	4.36	4.82							
0.40	7.22	6.80	7.67	6.53	7.31	7.191	0.160	7.34	7.297	0.097
0.42	9.43	8.80	10.11	7.91	9.30	9.440	0.223	9.66	9.657	0.233
0.44	13.57	12.58	14.63	9.94	12.6	13.46	0.35	13.91	13.674	0.451
0.45	17.34	16.03	18.75					17.75	18.149	0.907
0.46	23.92	22.04	25.95	14.00	19.2	23.78	1.03	24.40	24.771	1.426
0.48	92.91	85.09	101.45	22.4	38.5	94.09	13.11	93.55	100.071	22.702
0.487	5691.	5200.	6228.							

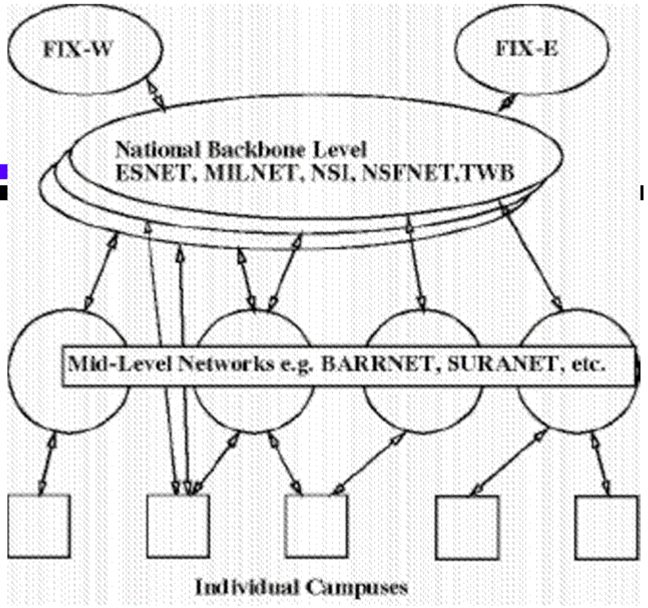
Table 7: Packet Delay for the FCFS 0.487 Algorithm

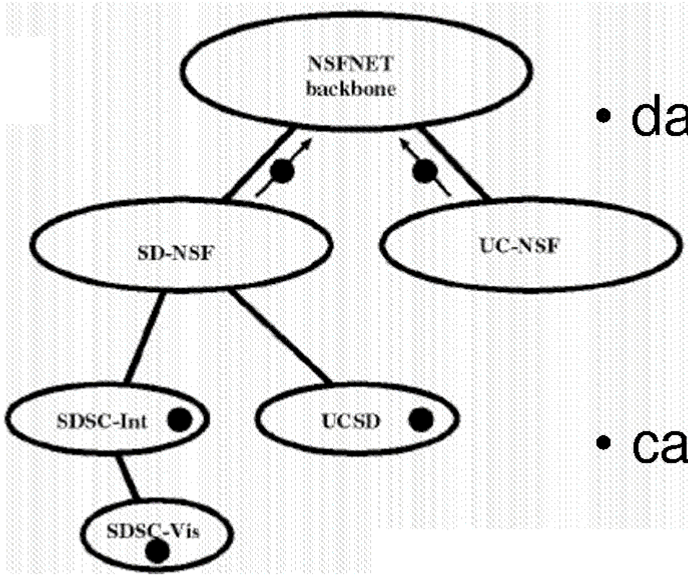
IP Flows

- IP-layer
  - network-centric perspective
  - pure layering: no access to transport and higher layer information within the (inter)network
    - but it might be worthwhile to cheat if you can...
  - significant/increasing non-TCP uses of the network
  - routing, accounting, network management
  - SYN/FINs are problematic for routers (datagram network)
  - implicit (IPv4), timeout based



IP Flow Data Collection

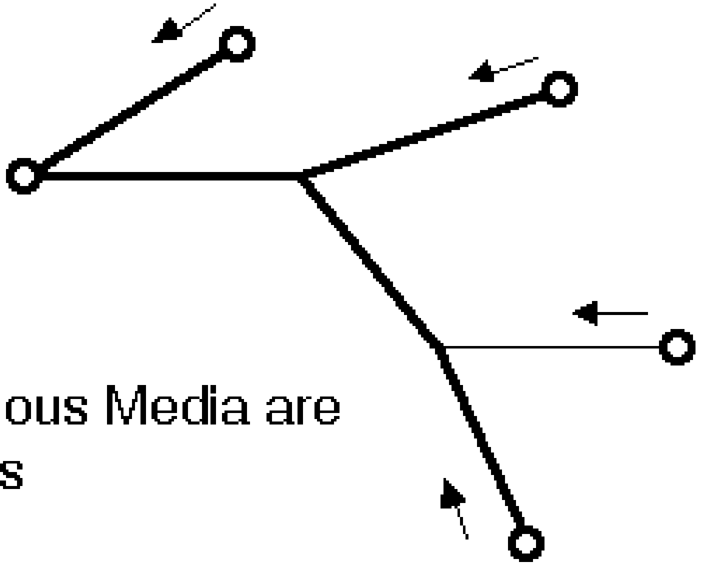




- data collection
  - non operational
    - at multiple points (router interfaces)
    - at different levels of the network "hierarchy"
    - ... "sampling" (non-scientific) over the topology
- captured data
  - timestamp (µs)
  - src/dst IP adddress
  - protocol id
  - TCP flags
  - src/dst TCP/UDP port

Multicast

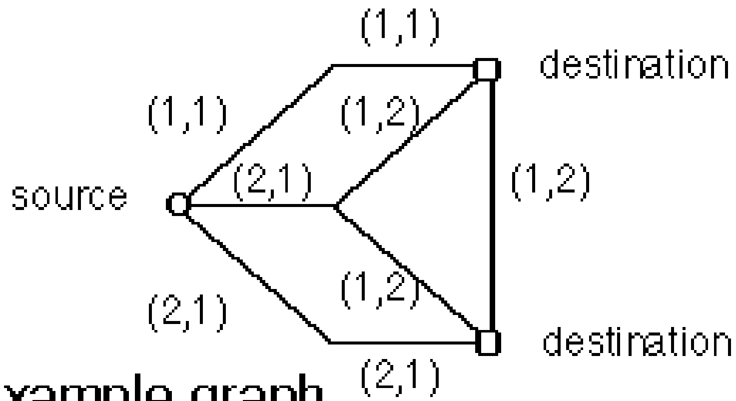
- multicast vs. unicast vs. broadcast
  - one-to-many vs. many-to-many
- multicasting to avoid multiple copies
  - conserve network bandwidth
  - conserve resources at the source
  - router/switch support for multicast
- problems of real-time, interactive Continuous Media are intensified with multipoint communications
  - feedback implosion
  - weakest link/receiver may dictate performance
    - wireless network constraints (typically the weak link):
      - limited bandwidth
      - limited terminal processing capabilities
  - "The Multimedia Multicast Problem," *Multimedia Systems*, (with J.C. Pasquale and G. Xylomenos).



Multicast Routing for Interactive Continuous Media

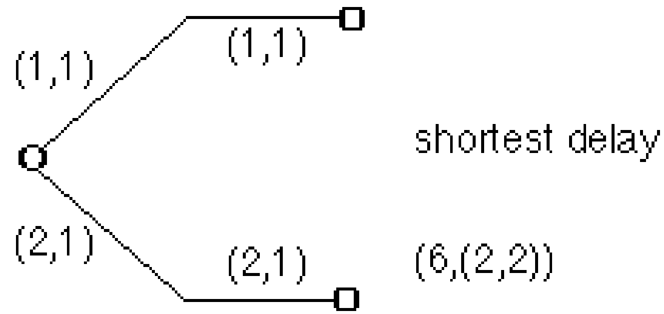
- efficient multicast routing with QoS constraints
- interactive continuous media:
  - minimize bandwidth consumption
  - meet delay, jitter, or loss constraints
  - connection oriented traffic
    - routing decisions at connection set-up
- centralized solution (source routing)
  - "Multicast Routing for Multimedia Communication," IEEE/ACM Transactions on Networking, vol. 1, no. 3, pp. 286-292, June 1993 (with V.P. Kompella and J.C. Pasquale).
- distributed routing
  - "Optimal Multicast Routing with Quality of Service Constraints," Journal of Network and Systems Management, vol. 4, no. 2, pp. 107-131, 1996 (with V.P. Kompella and J.C. Pasquale).

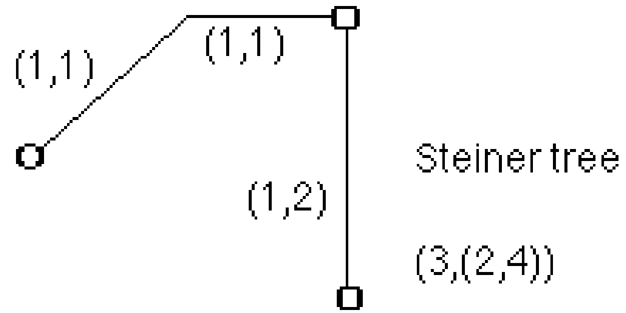
Constrained Steiner Tree

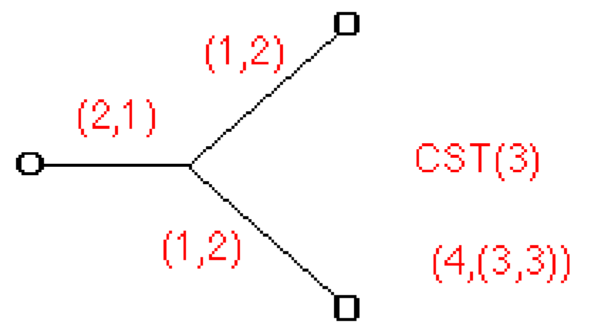


example graph

link metrics: (cost, delay)







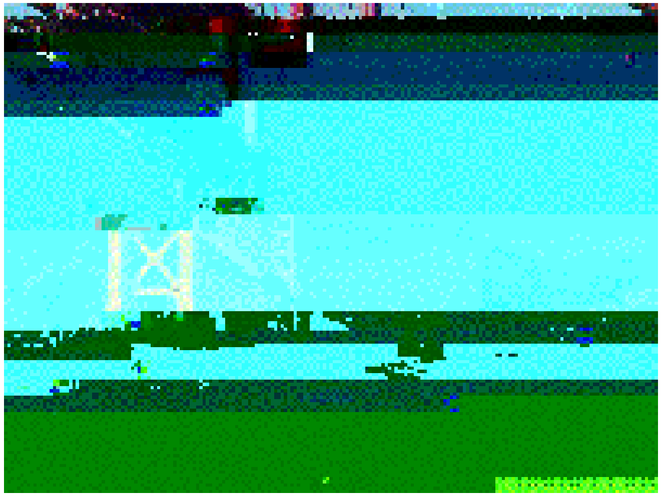
- least cost tree with ...
- ... all source-destination paths having bounded delay
- NP-hard
- need fast heuristic

Multimedia in a Wireless Environment

- limited bandwidth, power
  - trade-off processing and transmission bandwidth
  - remote/asymmetric processing
  - data/information selection
- error-control
  - circuit-switching (CBR, open-loop): residual errors
  - packet-switching (VBR): ARQ protocols
    - delay (TCP: end-to-end retransmission)
    - variable bandwidth overhead
- addressing network and terminal heterogeneity
  - wireless - wireline network interface
  - user participation to the fullest degree allowed by resources
- fast changing channel conditions
- support for mobility/handoffs

Impact of Errors on JPEG (HJPEG)

<u>HJPEG</u>
2% loss
(all in
layer 4)



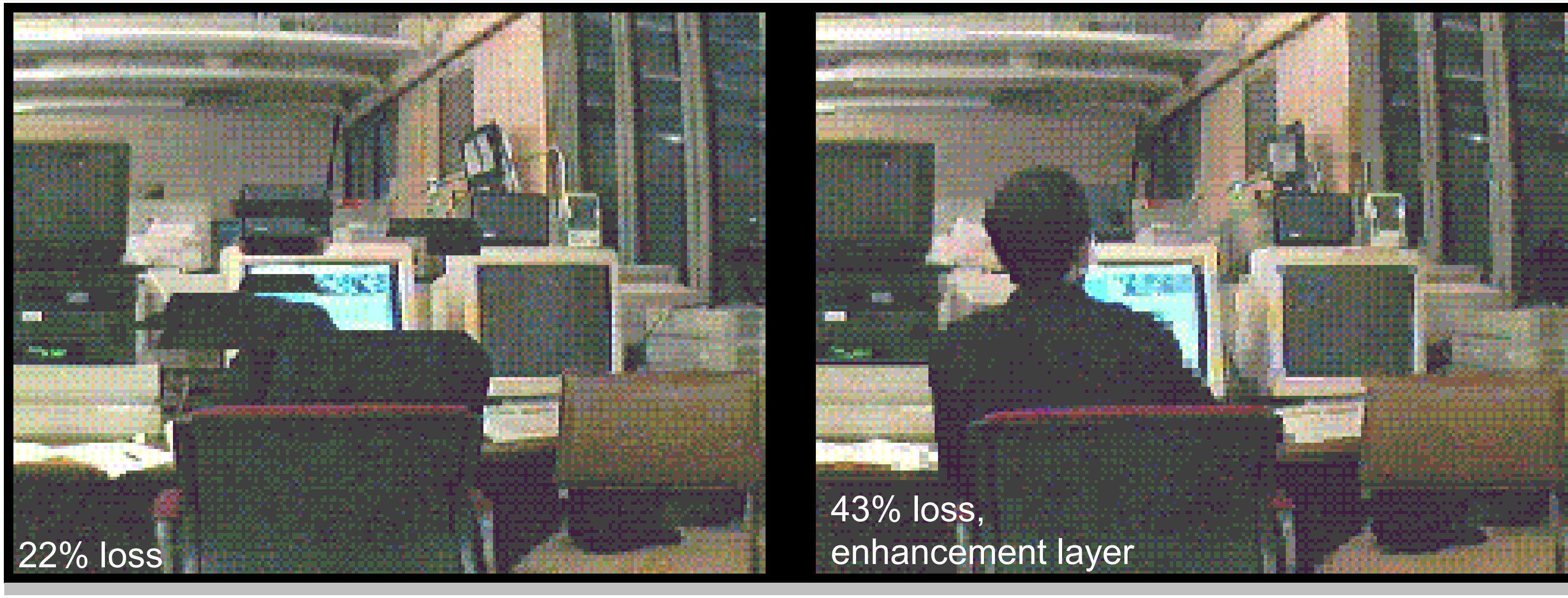
<u>JPEG</u>
2% loss
(tables
intact)

<u>HJPEG</u>
3 layers
(~55%
loss)

Filters and Media Stream Quality

- **Filters and transcoders**
  - Absolutely necessary for mobile multicast
  - Help maintain a level of **Perceived Quality of Service (P-QoS)**
  - “Smart” filters, “Simple” filters
- Layered coding and **multi-resolution layered coding**
  - A media stream is separated into more than one stream
    - Sub-streams can be transmitted in different multicast groups
    - Receivers “tune into” as many as possible
- Filter mobility characteristics
  - Fixed
    - Usually located at the boundary between wired and wireless section
  - Mobile
    - In multicast trees, they can propagate upstream, closer to the source, combine into one and serve many receivers in the same sub-tree

Robust Multimedia Dissemination



- Video decomposition into components:
  - basic component (low resolution)
  - enhancement layer (high resolution)
- transmission through UDP streams
- FEC based protection of basic component

demo:

- based on **nv** (Internet video)
- block-based inter- and intra-frame compression
- … UDP/IP

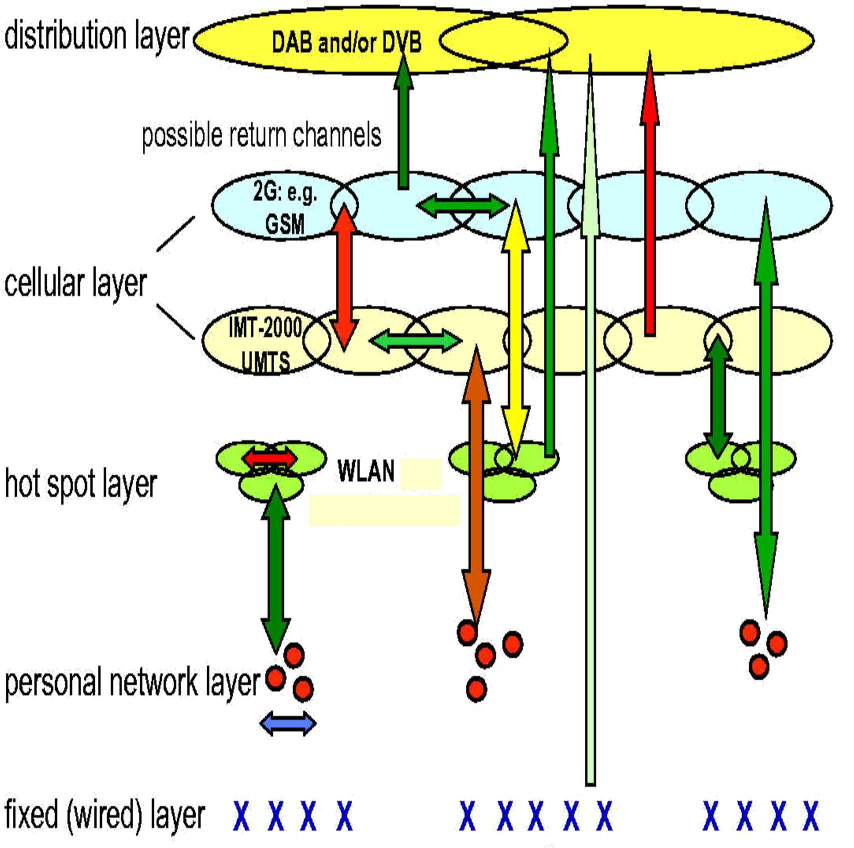
➔ **"Multi-Resolution Layered Coding for Real-Time Image Transmission: Architectural and Error Control Considerations,"** *Real-Time Imaging*, vol. 4, no. 4, pp. 275-298, August 1998 (with J.K. Han).

Multipoint Communications in a Beyond-3G Internetwork

- The Internet Beyond 3G
  - Diverse network technologies
    - 2.5G and 3G networks
    - Digital Video Broadcasting (DVB) networks
      - Terrestrial (DVB-T), Satellite (DVB-S) flavors
      - 30 Mbps of shared downlink bandwidth
    - IEEE 802.11 networks
    - Traditional wired access networks
  - Goal: All-IP internetwork
    - IP-over-everything, IP-under-everything
    - Integrated services spanning network technologies
      - Audio, video, data
      - Unidirectional and bidirectional
    - Support for Multipoint Communications?
    - Support for Mobility?
- Our focus: The Mobile Multicast Problem
  - IP-based quasi-reliable mobile multipoint communications
    - assuming IPv4, but taking IPv6 into account

Networks Beyond 3G: Wireless Access & Interconnection

- 3+G: network of networks
- "new" issues
  - Technological
    - disparity in
      - Bands, data rates
      - channel characteristics
  - economic & social
    - wide disparity in
      - cost
      - network ownership models
      - economic models
- Publications
  - I.D. Constantiou, N.A. Mylonopoulos, and G.C. Polyzos, "**Fourth Generation Network Interconnection Issues**," Proc. 1st WWRF Meeting, March 2001.
  - G.C. Polyzos and C. Courcoubetis, "**Pricing for Efficient Quality of Service Support in Wireless Packet Networks**," Proc. 2nd WWRF Meeting, May 2001.
  - I.D. Constantiou, E.I. Rodina, and G.C. Polyzos, "**Adverse Selection in Fourth Generation Networks: Quality of Services for Entertainment**," Proc. M-Business, July 2002.



The Book of Visions 2000

Mobile Multicast: High-level Issues

- ***IP Multicast***
  - Easy for some technologies only
    - “Native” support in Ethernet and broadcast networks…
    - …but, **point-to-point links** in Cellular, PSTN/ISDN and DSL
- ***Mobility***
  - Not supported in the original Internet design
    - An IP address is a subnet and interface identifier but it’s also used in packet routing
    - TCP connection identifiers include lower layer IP identifiers and do not allow them to change
  - **Answer: Mobile IP**
    - One address for identification, another for routing
- ***Hostile Wireless Environment***
    - Higher BER challenges original TCP and IP assumptions

IP Multicast

- Host group service model
  - a receiving host may join and leave a multicast group at any time
  - all IP hosts can communicate unidirectionally with all group members using only the group’s identifier (its class D multicast address)
- Routing packets and tracking membership
  - Global and Local mechanisms respectively
- Global Routing Mechanisms
  - Multicast routing protocols deliver a group’s packets to multicast routers that have expressed interest in receiving packets for a particular group
    - DVMRP, CBT, MOSPF, PIM
  - Graft delay when a multicast router joins the multicast tree
- Local Membership Tracking Mechanisms
  - Multicast router: the “interface” between the local and the global mechanism
    - Exposes aggregate list of groups all its hosts have joined
  - Protocols for membership tracking
    - IGMP (for IPv4) and MLD (for IPv6)
  - Soft-state principle – no explicit LEAVE_GROUP primitive
  - IGMP assumes link-level native broadcast

Combining IP Multicast and Mobility

- **Mobile devices are fundamentally different**
  - Limited battery life → have to avoid unnecessary operations
    - constant network traffic monitoring is impractical
  - Radio interface → cannot assume high bandwidth nor low BER
  - Handoffs → forced disconnections
    - Vertical and horizontal
  - TDMA and CDMA with power control → no link-level multicast yet
- **IPv4 address shortage**
  - GPRS operators rely on NAT
    - NAT makes IP multicast more difficult
- **Cellular operators interpret "multicast" differently**
  - Cell-limited usually
  - Not the IP-based multicast envisaged for the Beyond-3G Internet

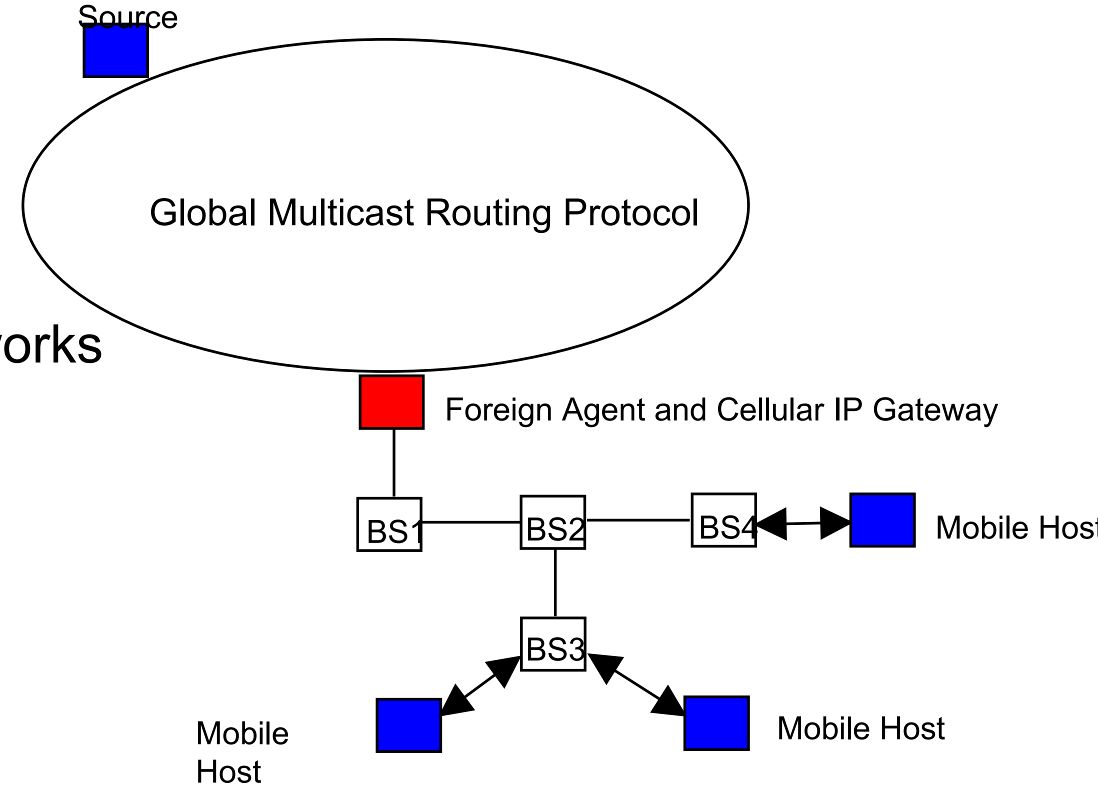
IGMP Mobility Support & IGMP Assumptions

- IGMP was designed with Ethernet in mind
- IGMP is not suitable for routers with point-to-point links
  - IGMP queries have to be issued to each one of these links
  - Not everyone will hear responses…
  - … unless the router multi-unicasts them
  - More state information needed at the router
- IGMP is not suitable for mobile hosts
  - Mobile hosts cannot constantly monitor network traffic
  - Mobile hosts should not be forced to resend unnecessary data
  - Solution → use explicit **JOIN_GROUP** and **LEAVE_GROUP** primitives

Mobile Multicast Requirements

- Significant vs. non-significant moves
  - If a MH move causes the new subnet's multicast router to subscribe to new groups, the move is significant
  - Non-significant moves should have no effect on the global mechanisms
  - Both types must appear similar from the user's perspective
- Multicast packet buffering
  - Buffer packets until when?
  - Disconnections due to
    - Handoffs
    - Physical layer problems
    - User intent
- Mobile subnets
  - Deal with them as one logical entity
- Roaming
  - Sophisticated authentication and pricing schemes are also required

Mobile IP Multicast



- Multicast over IP-based Wireless Networks
  - Mobile Mobile IP and/or
  - Cellular IP
- Relevance: 3G and 4G
- Publications
  - G. Xylomenos and G.C. Polyzos, "**IP Multicast for Mobile Hosts**," *IEEE Communications Magazine*, vol. 35, no. 1, January 1997.
  - E.C. Efstathiou and G.C. Polyzos, "**Multipoint Communications in a Beyond-3G Internetwork**," Proc. Intern. Workshop on Wired/Wireless Internet Communications, Las Vegas, NV, June 2002.

The *B-BONE* Project: Broadcasting and Multicasting Over Enhanced UMTS Mobile Broadband Networks

- Project Goal: Evaluation of multicast and broadcast in 4G
  - Characterise requirements of broadcast services
  - Develop algorithms for QoS provision
  - Investigate integration of broadcast/multicast/unicast
  - Evaluate handovers with broadcasting/multicasting
  - Evaluate TCP enhancement schemes
  - Develop schemes to aggregate resource requests
  - Develop auction based resource allocation schemes
  - Develop mechanisms for cost splitting
  - Build a link and system level simulator for the network

Project Partners

- Portugal Telecom Inovação – PTIN (Portugal)
- ADETTI (Portugal)
- Technical University of Lisbon - IST (Portugal)
- University of Cyprus – UCY (Cyprus)
- Athens University of Economics – AUEB (Greece)
- Aristotle University of Thessalonica – AUTh (Greece)
- Motorola Ltd. – MOT (UK)
- Alcatel SEL AG – SEL (Germany)

AUEB's Role in B-Bone

- Definition of scenarios
  - What are the needs of the users?
- Evaluation of alternative schemes
  - Investigate resource management techniques
  - Evaluate multicast and broadcast over UMTS
  - Design an all-IP access and core network
  - Development of auction-based resource allocation
  - Development of cost-splitting techniques
  - Provision of QoS to heterogeneous recipients
- Simulation of overall system
  - Integration with physical layer work from others

Wireless Networks and Mobile Communications

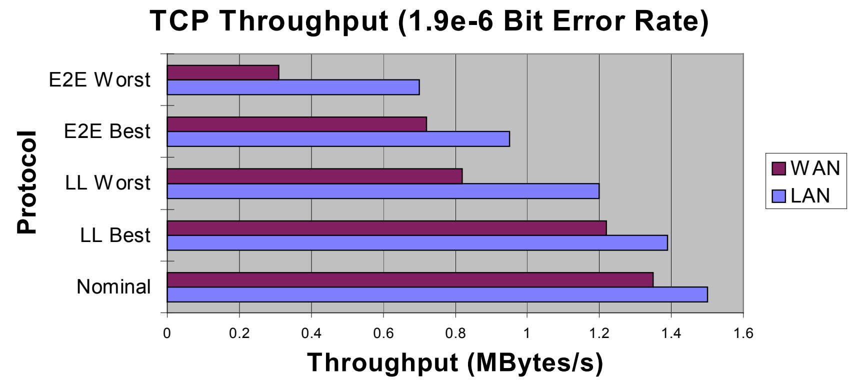
- TCP/IP Performance over Wireless Networks
- Flexible, Adaptive Link-Layer Protocol
- Adaptation for Wireless/Mobile Internet Multimedia
- GPRS DiffServ Architecture and Pricing
- Mobile Marketing using a Location Based Service
- Peer WLAN Consortia

Performance of Internet Protocols over Wireless Links

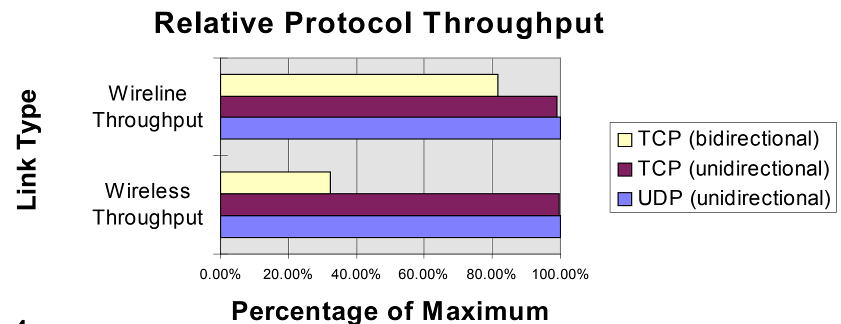
- Wireless Technologies
  - wireless LANs
  - PCS/cellular telephony
  - future broadband wireless
- Poor TCP performance
  - TCP assumes: loss = congestion
  - in wireless: loss mostly due to channel errors
  - with mobility: delay => loss ...
- Unpredictable UDP performance
  - unacceptable for some applications (NFS,...)
  - possibly OK for others

➔ "**Internet Protocol Performance over Networks with Wireless Links**," *IEEE Network*, vol. 13, no. 4, pp. 55-63, Jul-Aug 1999 (with G. Xylomenos).

- Balakrishnan *et al.* (1996)



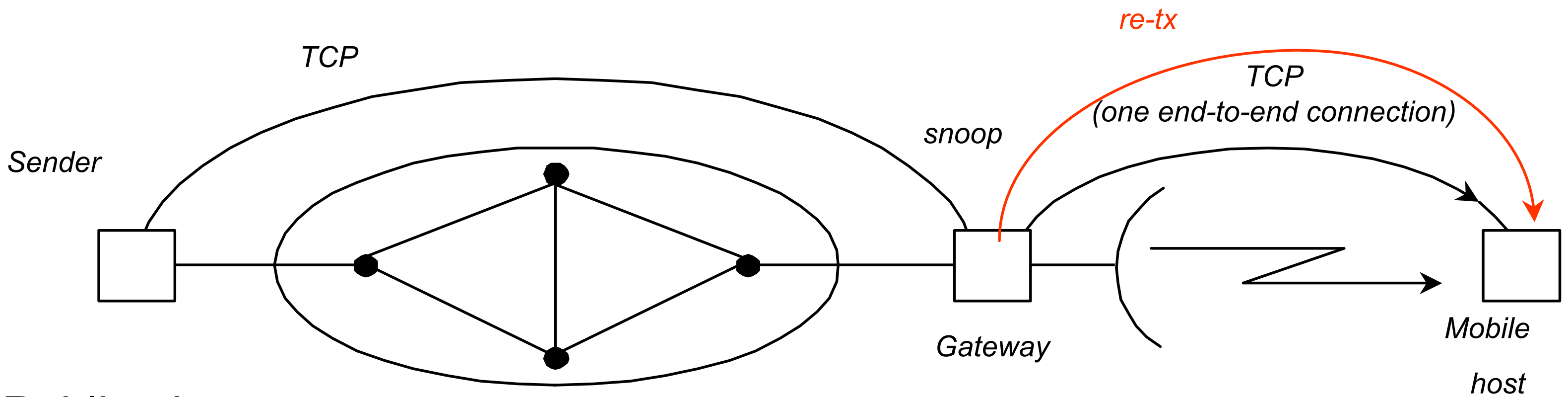
- our Wireless LAN measurements



TCP/IP Performance over Wireless Networks

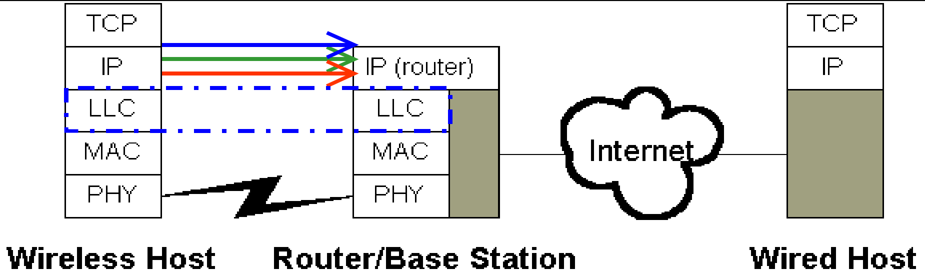
	Nominal Bandwidth	Actual TCP Throughput	% Achieved
LAN	1.5 Mbps	0.70 Mbps	46.66%
WAN	1.35 Mbps	0.31 Mbps	22.96%

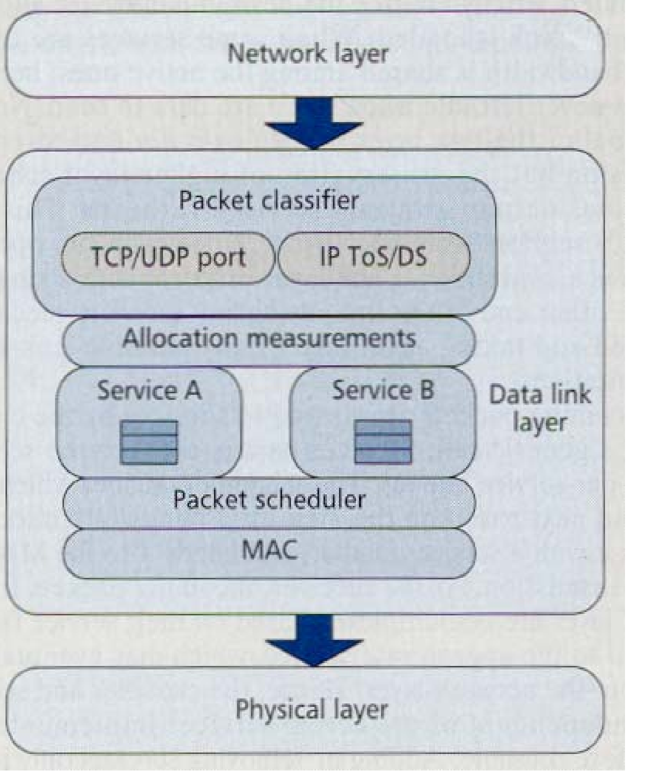
	Nominal Bandwidth	Actual TCP Throughput	% Achieved
IEEE 802.11	2 Mbps	0.98 Mbps	49%
IEEE 802.11b	11 Mbps	4.3 Mbps	39.1%



- Publications
  - G. Xylomenos and G.C. Polyzos, "**Internet Protocol Performance over Networks with Wireless Links**," *IEEE Network*, vol. 13, no. 4, July-August 1999.
  - G. Xylomenos, G.C. Polyzos, P. Mahonen, and M. Saaranen, "**TCP Performance Issues over Wireless Links**," *IEEE Communications Magazine*, vol. 39, no. 4, April 2001.

Flexible, Adaptive Link-Layer Protocol





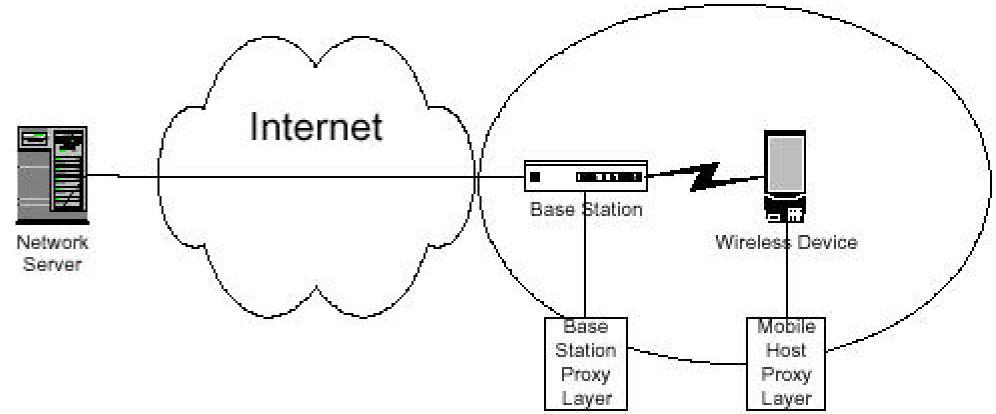
- TCP not the only Internet Transport Protocol
  - Real-Time Interactive Multimedia
- Multiple streams over a single wireless link
  - even to a single host
  - dynamic application/stream mix
- QoS support must start at the bottom
- Enhance QoS per stream
  - explicit: signaling
  - implicit: flow id or ToS
- Publications
  - G. Xylomenos and G.C. Polyzos, "**Link Layer Support for Quality of Service on Wireless Internet Links**," *IEEE Personal Communications*, vol. 6, no. 5, October 1999.
  - G. Xylomenos and G.C. Polyzos, "**Quality of Service Support over Multi-Service Wireless Internet Links**," *Computer Networks*, vol. 37, no. 5, November 2001.

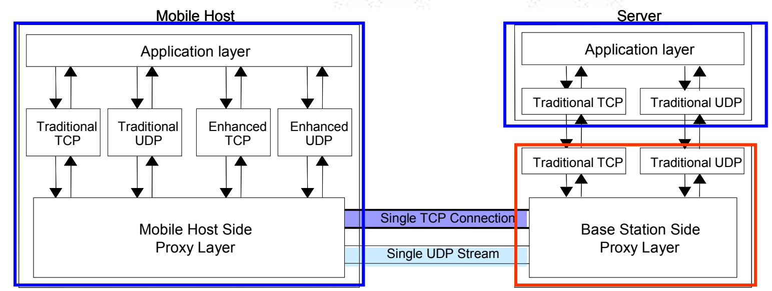
Mobile Multimedia: Problems

- low(er) bandwidth
- unpredictable wireless channel performance
  - even for a single channel, with no hand-offs
  - error rate, error characteristics
- unpredictable/difficult to ensure QoS because of mobility
  - traditional (horizontal) hand-offs: different cells, same network/technology
  - vertical hand-offs: across networks and technologies
    - e.g., cellular to satellite
- unfriendly physical layer designs
  - single application (voice) designs dominate physical layer
  - retrofit packet/Internet architecture

Adaptation for Wireless Mobile Internet Multimedia

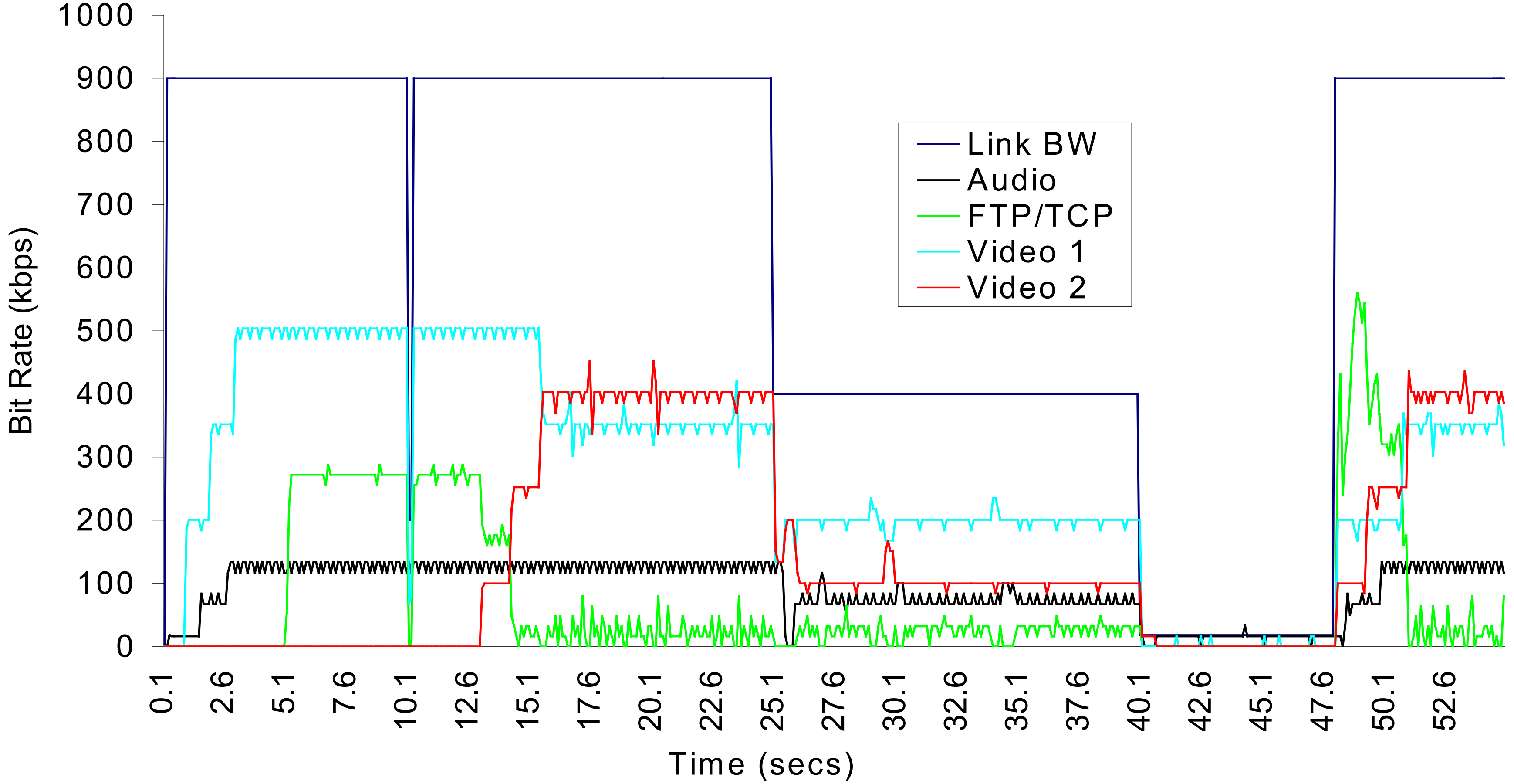
- multi-modal/multi-bit-rate/multi-format content
  - static/dynamic
- Transcoding
- Hierarchical coding (particularly for multicast)
- Proxy architectures
  - ***MobiWeb***
    - soft admission control/reservations
    - priorities, control inter-stream contention
    - dynamic adaptation



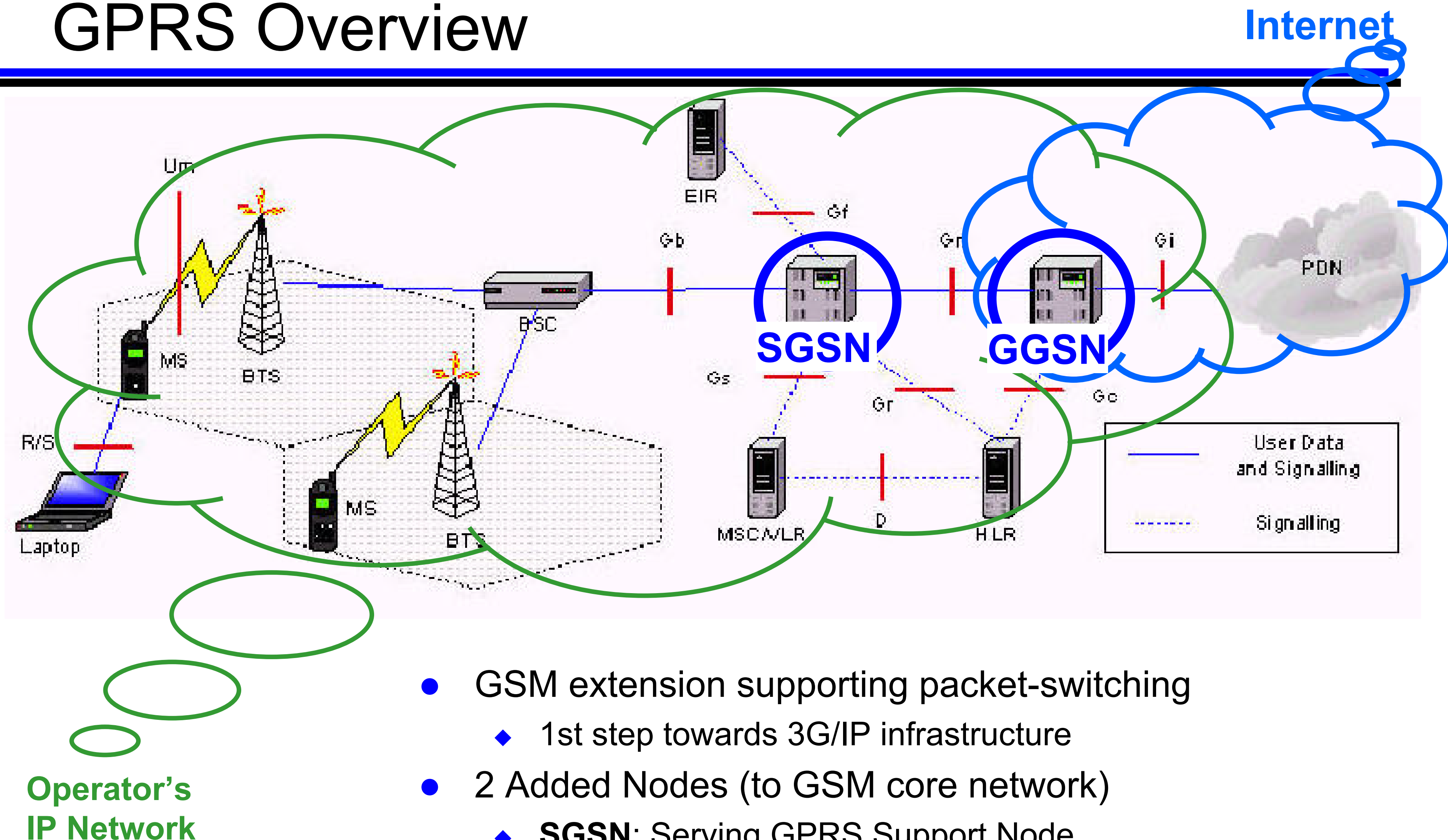


- Publications
  - M. Margaritidis and G.C. Polyzos, "**MobiWeb: Enabling Adaptive Continuous Media Applications over Wireless 3G Links**," *IEEE Personal Communications*, vol. 7, no. 6, Dec. 2000.
  - M. Margaritidis and G.C. Polyzos, "**Adaptation Techniques for Ubiquitous Internet Multimedia**," *Wireless Communications and Mobile Computing*, vol. 1, no. 2, April-June 2001.

Sample MobiWeb Performance Results

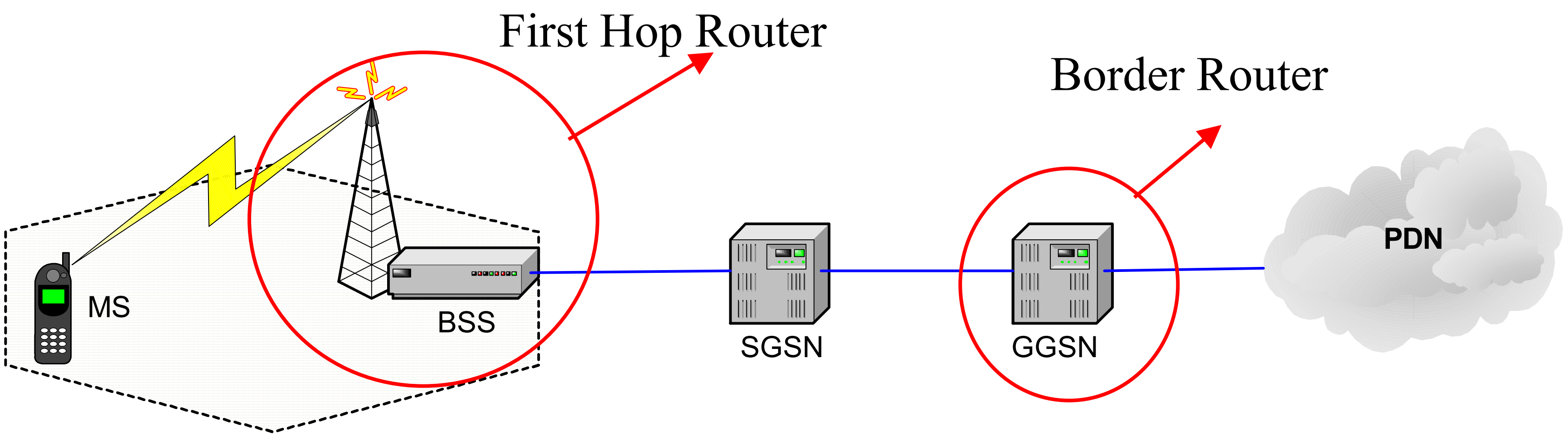


GPRS Overview



- 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

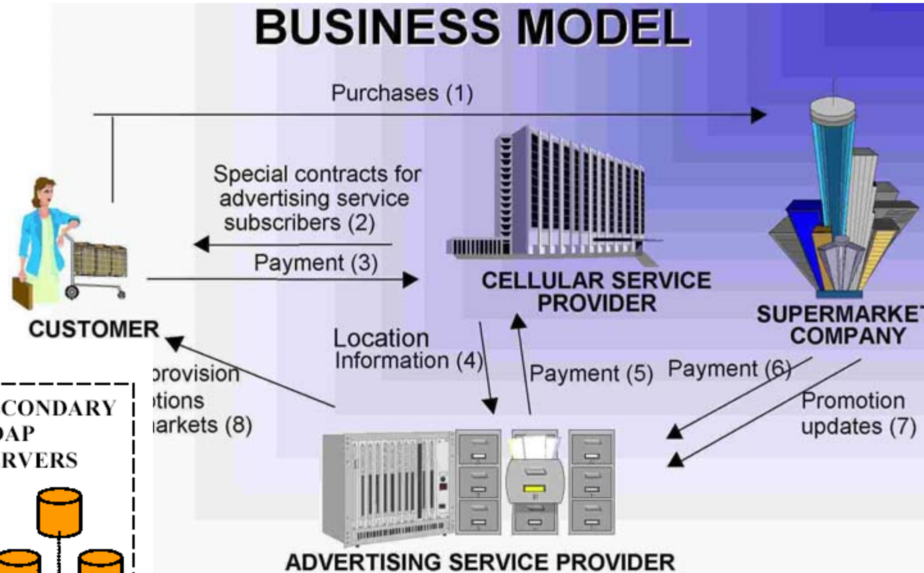
GPRS DiffServ Architecture and Pricing

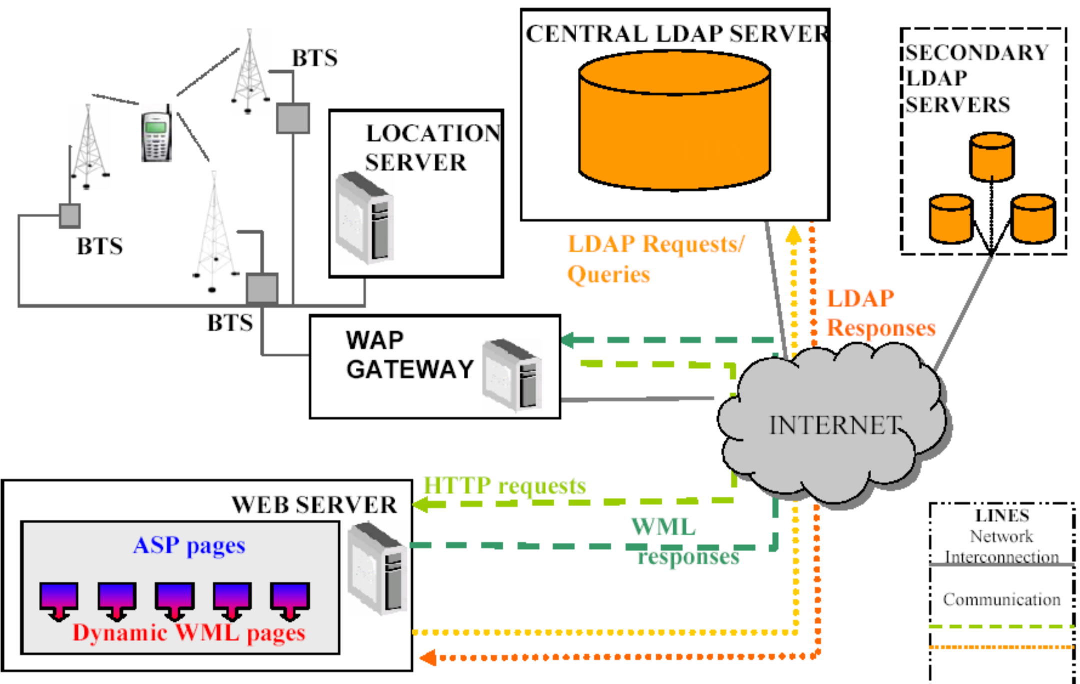


- (Two-Bit) Differentiated Services Architecture
- **Distributed** traffic conditioner (MS and BSS)
- @ BSS: simulation of first hop router's functions (software upgrade)
- Use of Uplink State Flag (USF), Countdown Value (CV) and the existing procedures of PDP Context activation and TBF establishment
- Publications
  - S. Soursos, C. Courcoubetis, and G.C. Polyzos, "**Pricing Differentiated Services in the GPRS Environment**," *Wireless Networks*, vol. 9, no. 4, 2003 (Special Issue on Wireless Mobile Internet).

Mobile Marketing using a Location Based Service

- Technical aspects of data distribution
  - LDAP, WAP, etc.
- Business aspects
  - relationships…

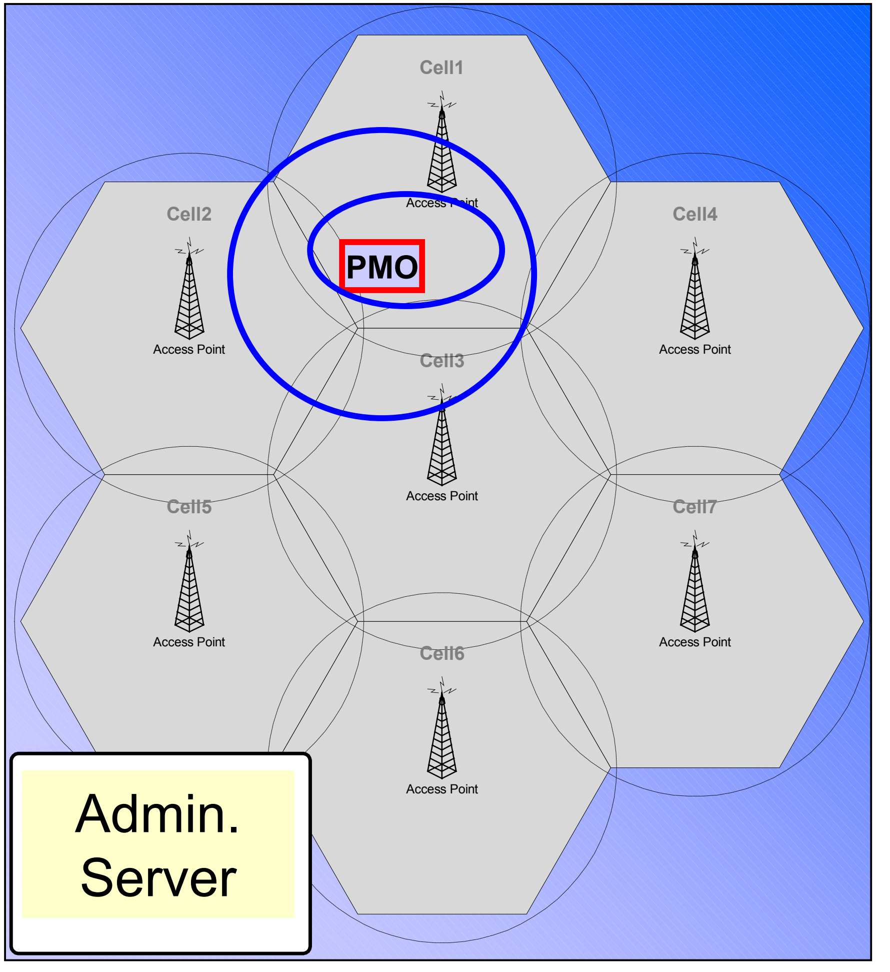




- C. Ververidis and G.C. Polyzos, "**Mobile Marketing Using Location Based Services**," Proc. M-Business, July 2002.

Mobishare Architecture

- An Architecture for Sharing, Discovering and Accessing Mobile Data and Services: Location and Mobility Issues
    - Christopher Ververidis
    - Stratis Valavanis
    - Michalis Vazirgiannis
    - George C. Polyzos
- we propose a hybrid architecture
    - hierarchies of servers
    - peers have significant role
- geographical 2-D space is divided into administrative areas (grid), each managed by an ***Administration Server***
    - similar topology to cellular systems
    - Heterogeneous (cell size, technologies…)



The *DBGlobe* Project

- FET IST project *DBGlobe*
  - *Partners: University of Ioannina, INRIA, Computer Technology Institute, University of Cyprus, UC Riverside, Technical University of Crete and Aalborg University, AUEB*
- *DBGlobe* considers an environment where
  - ubiquitous ***mobile devices act as data and service providers***
  - data and services are heterogeneous and distributed
  - network topology is dynamic and of global scale
  - ***context*** is of great importance in order to locate information and services
- *DBGlobe* Goals
  - to provide new theoretical foundations in all aspects of data management to deal with the problems that arise in such dynamic environments
    - models, storage, querying…

Mobishare Motivation: Observations and Assumptions

- in certain application domains, user queries are of local interest
  - nearest color printer
  - time of next bus departure from the bus stop
- many information and service requests can be served by peers, rather than servers
  - latest slide distributed through the multicast session
- pure peer-to-peer architectures impose high overheads to querying and discovery

  ASIDE: we also participate in IST project *MMAPPS* (Market Management of Peer-to-Peer Services)
- hierarchical architectures demand a large layered infrastructure
  - they might cause a significant delay in answering simple requests

Mobishare: Mobility Issues

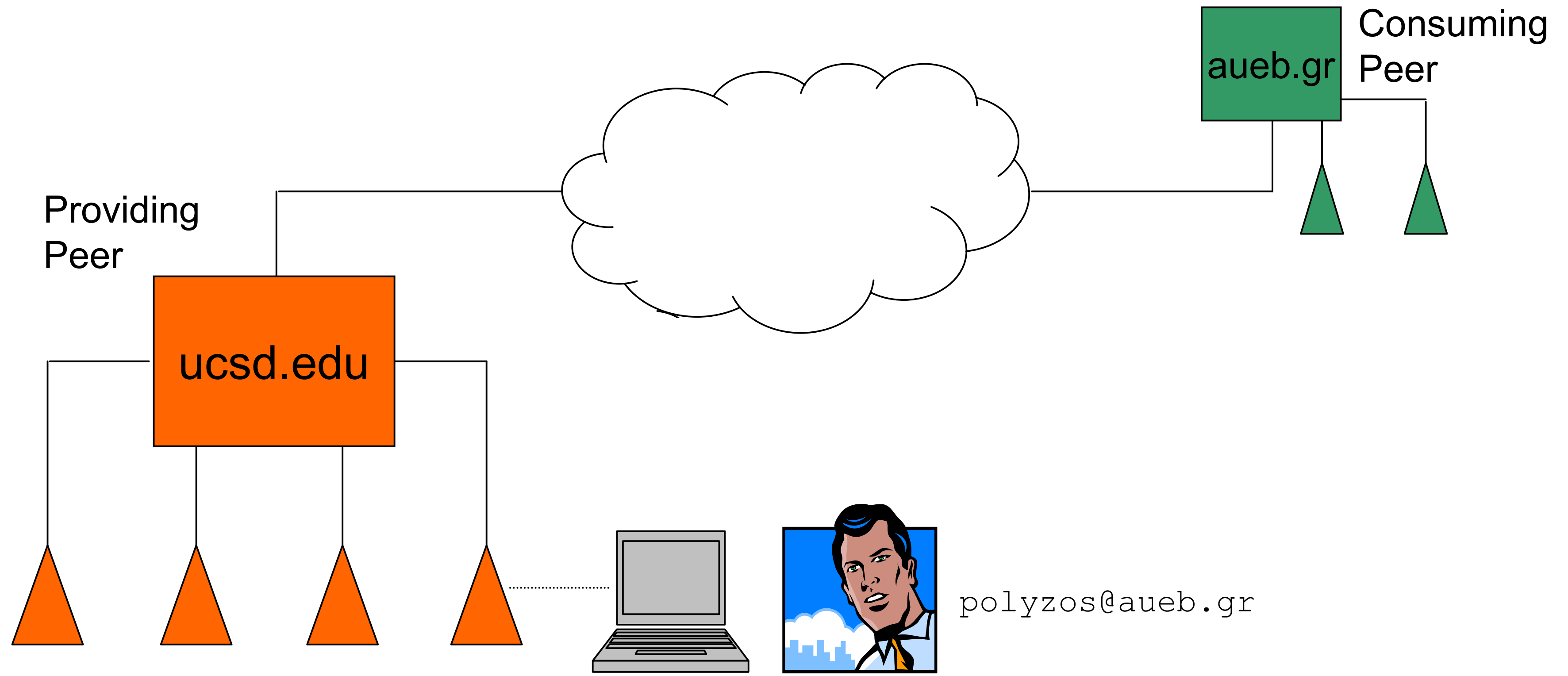
- frequent disconnections and highly variable bandwidth
  - addressed at the ***application*** level
  - adaptive applications
    - media selection, quality, etc.
    - disconnected operation (caching, pre-fetching…)
- frequent context switching
- validity of query results
  - if query is location dependent
  - query results received after the PMO has moved away…
    - print to nearest color printer…
- data(base) consistency issues
  - approximate answers are OK

P2P Wireless Network Confederation: A P2P Approach to Wireless LAN Roaming

- Ubiquitous Internet access is becoming a necessity
  - Useful services
    - email, Web, remote network access
    - VoIP, messaging
- Wireless ISPs
  - Administrative overhead and complexity
  - Insufficient autonomy for the roaming partners
  - Insufficient privacy for the roaming users
  - Hotspot aggregation - e.g. the Boingo model - **is not** WLAN roaming!
- WISP roaming is practically non-existent
- WISPs are facing difficulties
- Metcalfe's law:

  the value of a network increases as the square of the number of people connected to it

The Peer-to-Peer Approach



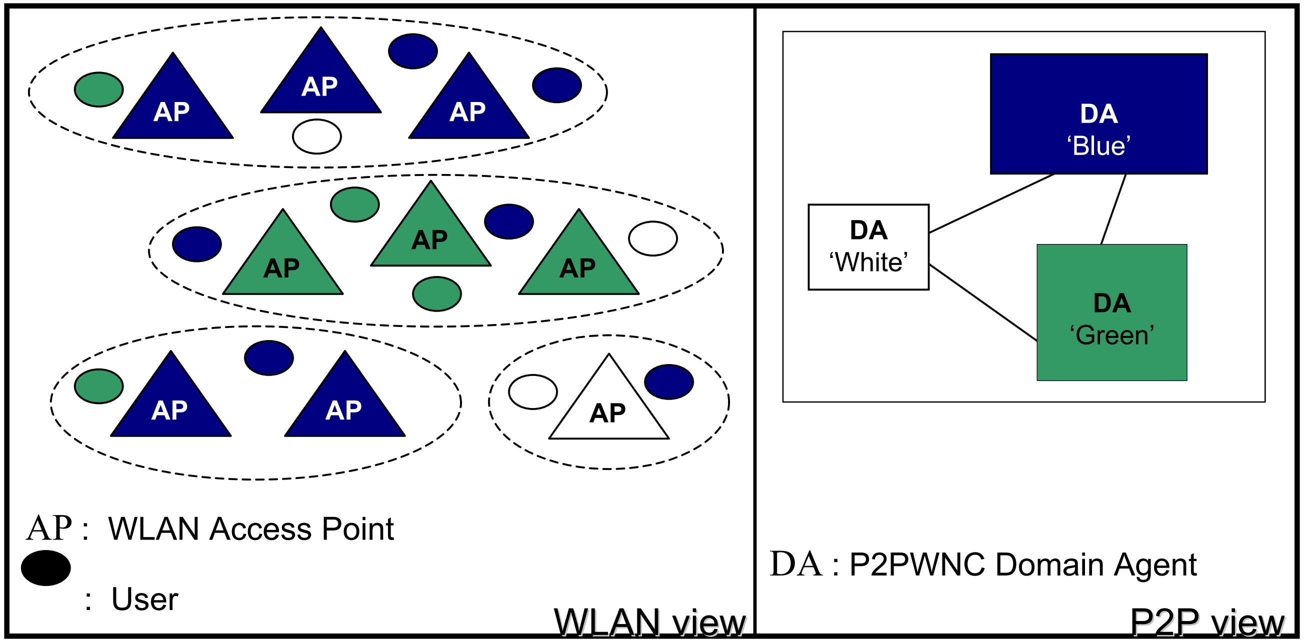
Peers ⇔ Administrative Domains

Home Domain ⇔ Consuming Peer

Visited Domain ⇔ Providing Peer

Registered Users: Unique P2PWNC ID (`username@home_domain_name`)

The Peer-to-Peer Wireless Network Confederation (P2PWNC)



- A framework for uniting WLAN hotspots in a global group
- A community of administrative domains that offer wireless Internet access to each other's registered users
- A P2P network of Domain Agents (DAs)
  - Each DA represents one WLAN administrative domain
  - DA purpose is eliminate the overhead of roaming agreements

P2PWNC Characteristics

- Simplicity
  - No cost of entry for domains
  - No central entity controls the P2PWNC or the interactions of the peers
  - Joining the P2PWNC is similar to joining a file-sharing network
- Domains make **autonomous** decisions
  - Concerning the amount of resources they provide to visitors
- User anonymity and untraceability is a design feature

  - “A Peer-to-Peer Aproach to Wireless LAN Roaming,” Proc. the First ACM International Workshop on Wireless Mobile Applications and Services on WLAN Hotspots (WMASH 2003), San Diego, CA, Sept. 2003 (with E. Efstathiou).
  - “Peer-to-Peer Wireless LAN Consortia: Modelling and Architecture,” Proc. 3rd IEEE International Conference on Peer-to-Peer Computing (P2P 2003), Linkoping, Sweden, Sept. 2003 (with P. Antoniadis, C. Courcoubetis, E. Efstathiou, and B. Strulo).
  - “Designing a Peer-to-Peer Wireless Network Confederation,” Proc. 3rd International Workshop on Wireless Local Networks (WLN 2003), Bonn, Germany, Oct. 2003 (with E. Efstathiou).

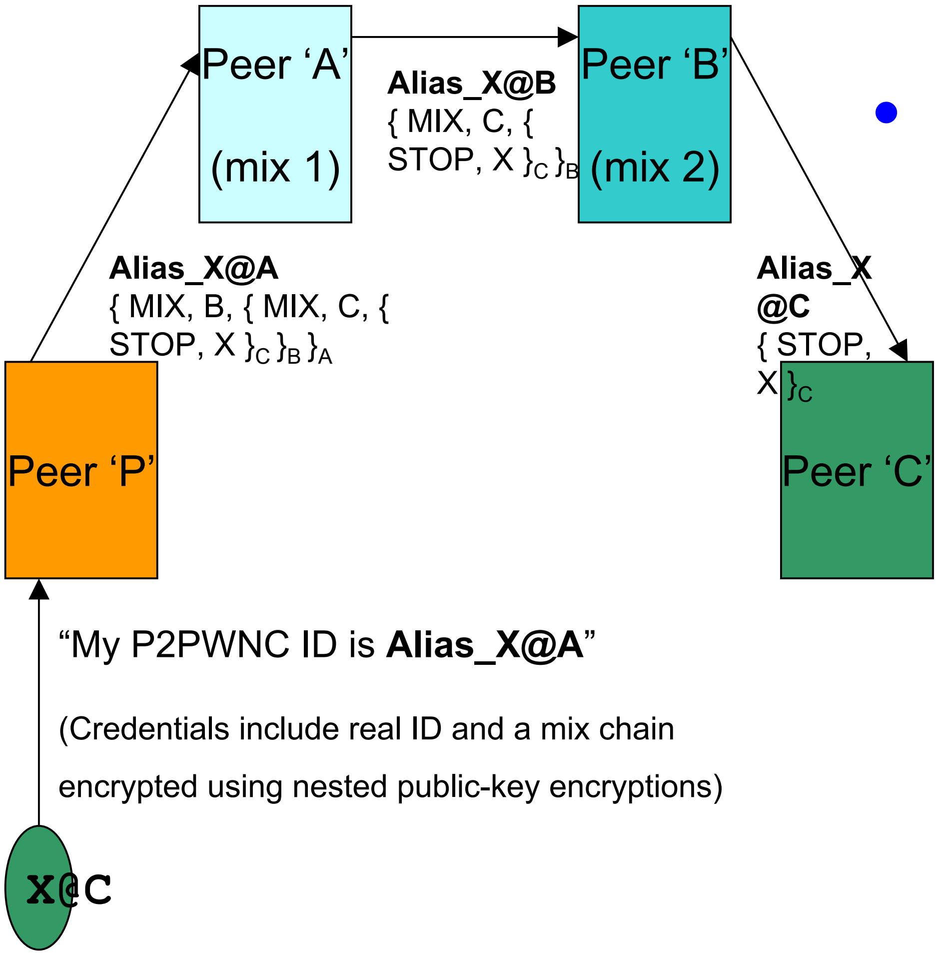
P2P Aspects

- The consortium is governed by rules on reciprocity that are flexible
- Incentives to share a domain's resources are needed
- Each peer attempts to maximize the benefit for its users:
    - Increase geographical coverage and availability
    - Enhance performance
    - Provide value-added services
    - Ensure QoS levels (prevent abuse from visiting users)
- Reputation system
  - Each peer wants to know what the other peers are offering
  - Different types of reputation:
    - Service reputation
    - Network QoS reputation
  - Each peer can devise strategies based on this information
- Free-riding represents a problem.
    - E.g., when peers deny access to visitors
- Repeated game

Domain Agent Modules

- Name service
  - Maps logical domain names to DA IP addresses
  - Uses a **distributed hash table** (DHT)
- Authentication
  - Maintains a database of registered users…
  - …along with their security credentials
- Traffic policing
  - Logs and shapes egress and ingress Internet traffic
  - Allocates specific amounts of bandwidth to visitors
- WLAN infrastructure
  - Firewall, DHCP, DNS, access point control
- Distributed accounting
  - Secure storage of P2PWNC accounting data
  - Also uses a DHT
- Privacy
  - Enhances user anonymity and untraceability
  - Based on traffic mixes

P2PWNC Security Issues: a superset of WLAN security issues



- Usual confidentiality, integrity, and availability problems
- Two additional problems:

1. Traffic logging by untrustworthy providers
   - traffic visible to the visited domain agent
   - Encryption does not hide useful metadata (e.g. remote party address)
   - **SOLUTION**: Always tunnel through the home domain
2. Identity and location privacy
   - Username and home domain visible to the visited domain agent
   - Home domain is usually required for proper accounting of actions
   - Current location (the visited peer) is visible to the home domain
   - **SOLUTION**: P2PWNC privacy architecture

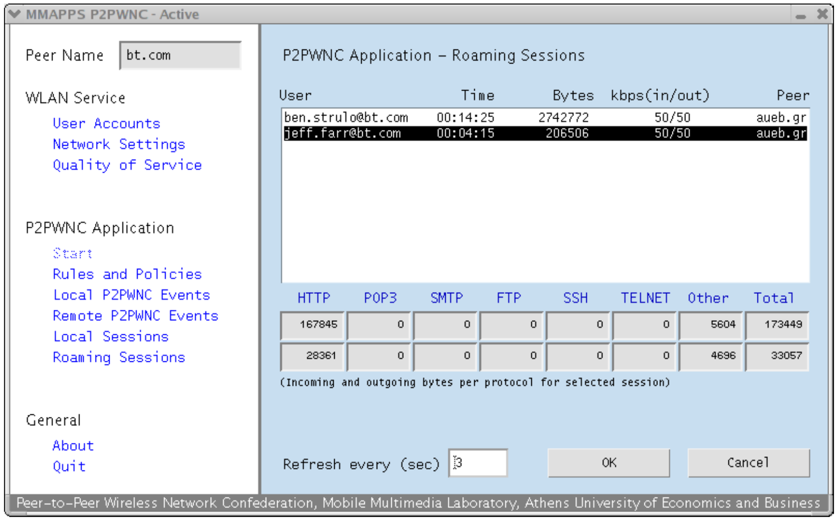
Additional Issues

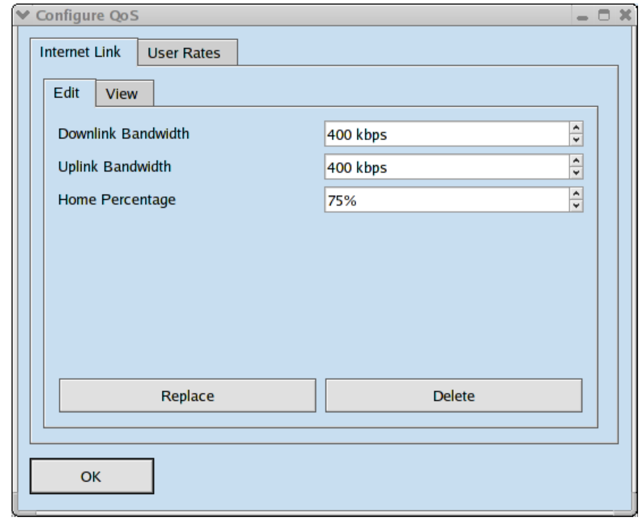
- Need a distributed accounting subsystem that is:
  - Secure
  - Fault-tolerant
  - Scalable
- The “**offline domains**” issue
  - A user’s home domain may be offline
  - No consumer peer available to speak on the user’s behalf
    - Could the user device act as a peer?
    - Could another peer act as the user’s home?
- Lightweight client devices
  - Maybe special software is required on the client device in order to verify received service authoritatively
  - Who else can independently observe the provider?

Deploying the P2PWNC

- DA administrative interface must hide complexity from administrators
  - Requires only a minimum number of input parameters
  - Some of these parameters will be ‘best-guesses’
    - Visitor request rates
    - Request rates of the domain’s registered users when roaming
- P2PWNC profit opportunities
  - Vendors of domain agents
  - Domain aggregators
  - “Pay-as-you-go” domains

Prototype





- Prototype Domain Agent has been built
  - Running on Linux (with the 2.4.21 kernel)
  - Uses MMAPPS Negotiation and Accounting modules
  - Uses standard and custom-made Linux TCP/IP daemons
- Modules are still missing
  - Secure distributed hash table
    - For distributed accounting and the P2PWNC name-service
  - Privacy module

The MMAPPS Project

- EU-funded research project:
  - Market MAnagement of Peer-to-Peer Services (2002-2004)
- how to use techniques from economics and social science to tackle some of the fundamental difficulties in creating well-founded, sustainable, P2P applications
- Project partners:
  - BT Research, UK
  - Athens University of Economics and Business (AUEB), GR
  - ETH, Zurich, CH
  - Darmstadt University of Technology, D
  - Mysterian, UK
  - Telekom Austria, A
  - University of Lancaster, UK

Mobile Multimedia Lab (http://mm.aueb.gr)

- Personnel
  - 5 faculty
    - G. Polyzos, G. Xylomenos
    - C. Courcoubetis, G. Stamoulis, M. Vazirgiannis,
  - ~ 10 PhD students
  - ~ 10 MSc and undergraduate students
- Research Areas
  - Mobile Communications Technologies
    - 2.5G, 3G, and 4G systems issues
    - Internet and Multimedia aspects
  - Enhanced Internet protocols for efficient mobile/wireless operation
  - Pricing and charging wireless and mobile services
  - Advanced network applications and services
  - Interactive Multimedia
  - Multimedia Multicast

Thanks!

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