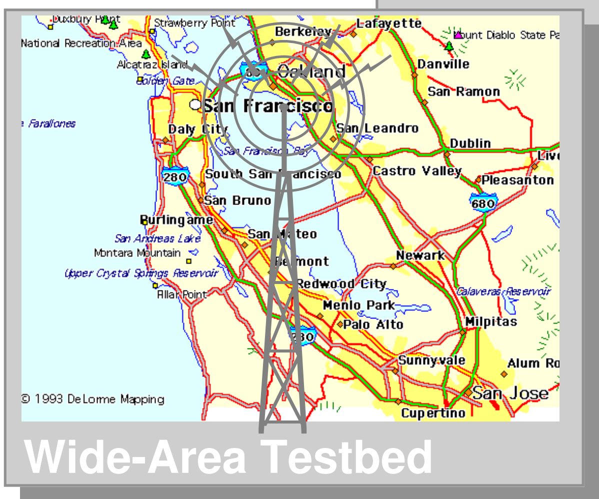
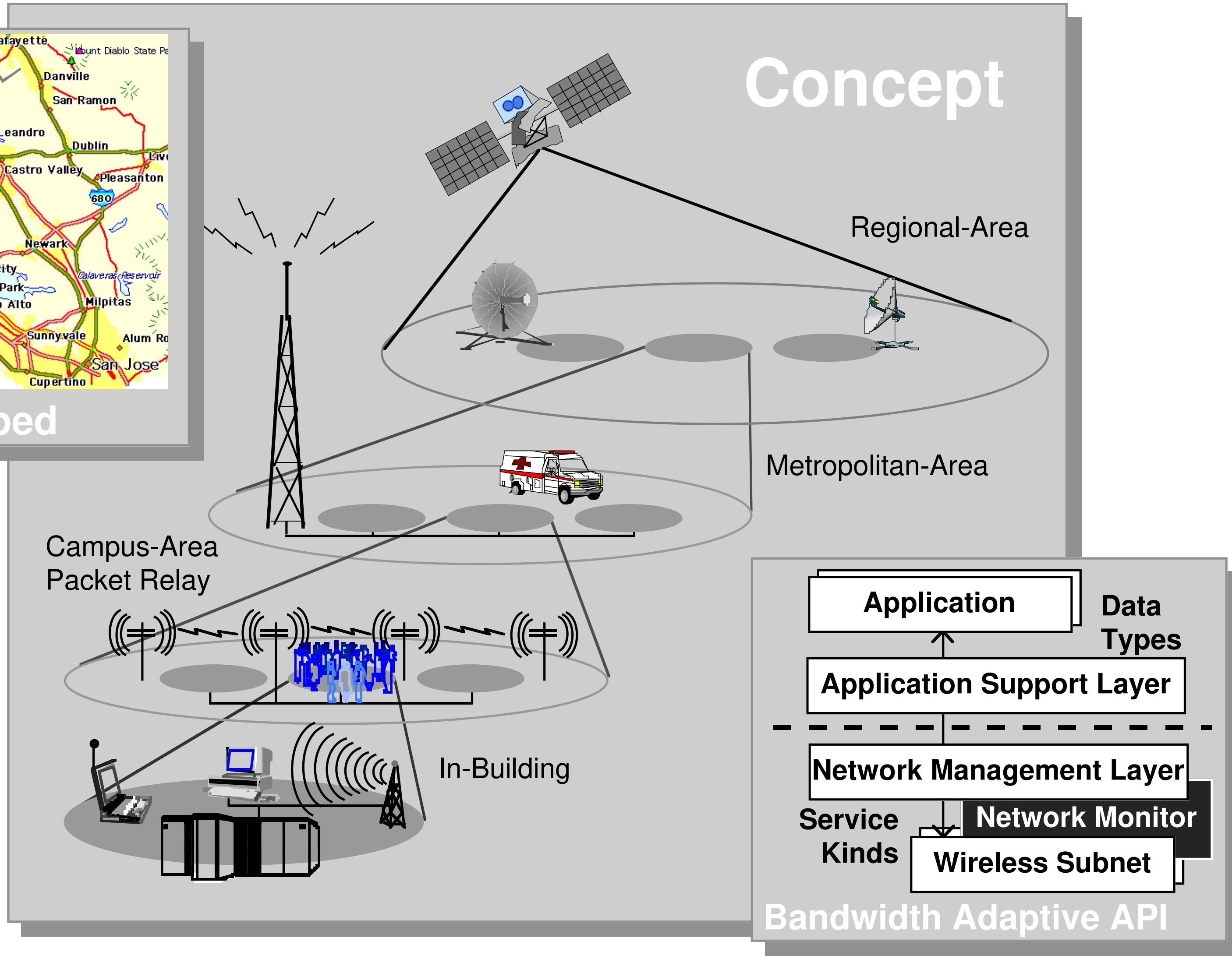
Bay Area Research Wireless Access Network: Towards a Wireless Overlay Internetworking Architecture

Randy H. Katz, Eric A. Brewer, UC Berkeley





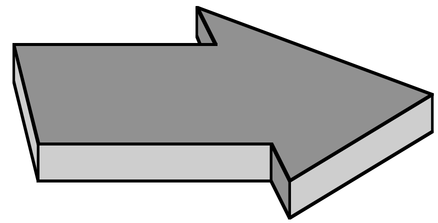
Subcontractor:
Hughes Malibu
Research Labs

The UC Berkeley Team

- **Networking**
  - Hari Balakrishnan (Reliable Transport)
  - Todd Hodes (Wide Area Roaming)
  - Daniel Jiang (Wide Area Roaming)
  - John Loffeld (System Support)
  - Ken Lutz (Network Infrastructure)
  - Giao Nguyen (Mobility Traces)
  - Venkat Padmanabhan (Mobile Routing)
  - Keith Sklower (DBS Unix Driver)
  - Mark Stemm (Vertical Handoff)
- **Applications**
  - Elan Amir (Video over Wireless)
  - Armando Fox (Proxy Architecture)
  - Steve Gribble (Mobile Applications)
  - David Gurley (Applications)

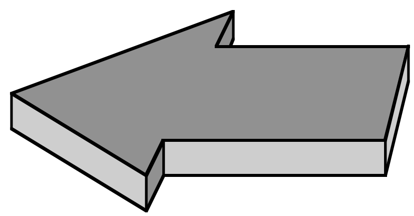
Retreat Goals & Technology Transfer

UC Berkeley Project Team



People
Project Status
Work in Progress
Prototype Technology

Early Access to Technology
Promising Directions
Reality Check
Feedback



Industrial Collaborators
Government Sponsors
Friends

Retreat Schedule

- **Sunday, January 7:**
  - 5:00 PM Check-in and Dinner
  - 6:30 PM Project Overview, Randy Katz
  - 7:30 PM Work In Progress Session, Randy Katz
    - » Mobility Trace Collection, Giao Nguyen
    - » Wide Area Architecture Issues
      - Hierarchical Routing, Venkat Padmanabhan
      - Roaming Services, Todd Hodes
  - 9:00 PM Posters and Demos
    - » UCB, UC Santa Cruz, and Stanford Research Groups
    - » Refreshments will be served

Retreat Schedule

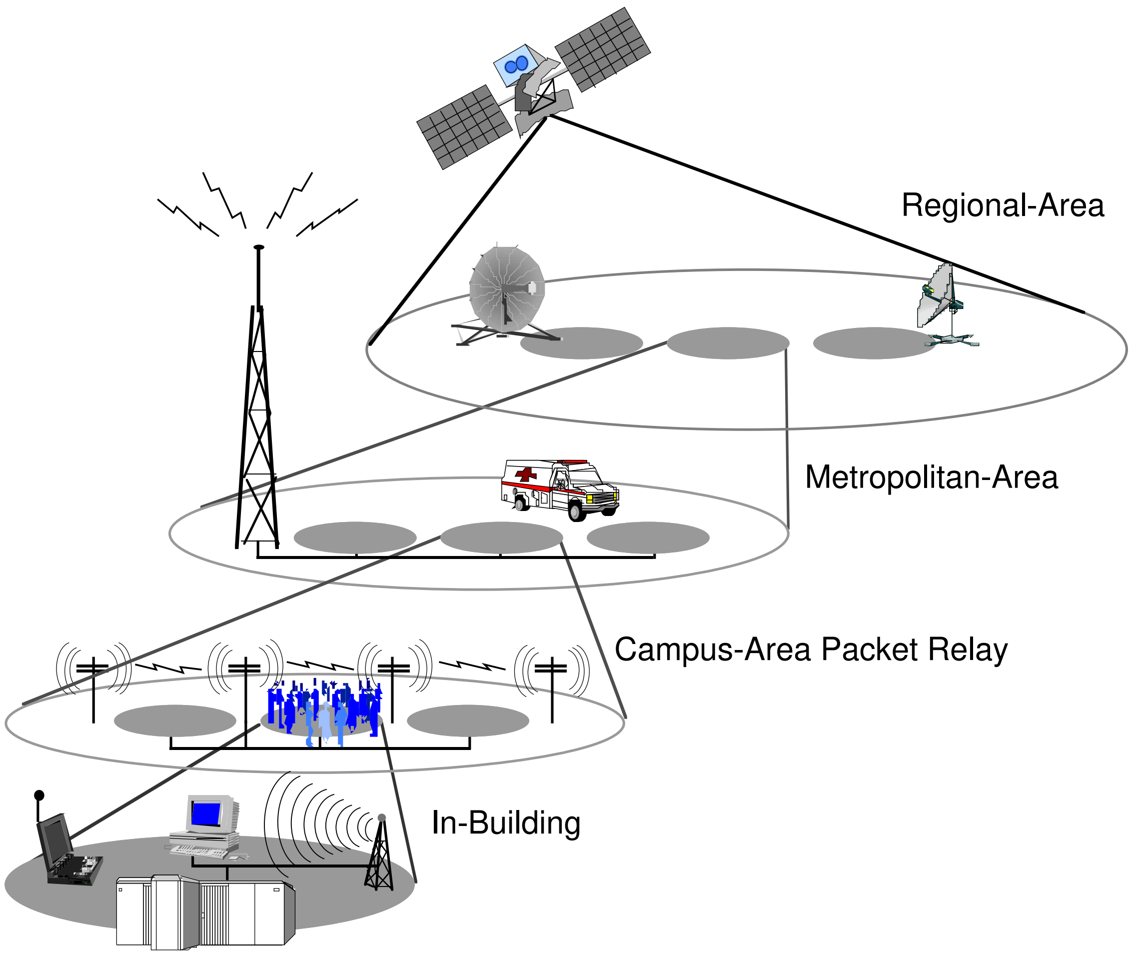
- **Monday, January 8:**
  - 7:30 AM Breakfast
  - 8:30 AM Application Support Architecture Design Review, Armando Fox and Steve Gribble
  - 10:00 AM Break
  - 10:30 AM Work In Progress II, Eric Brewer
    - Vertical Handoff, Mark Stemm
    - Heterogeneous Environments
      - Video Dissemination, Elan Amir
      - Reliable Transport, Hari Balakrishnan
  - Noon Lunch with the InfoPad Retreat
  - 1:30 PM InfoPad Retreat
  - Evening Banquet at the Monterey Bay Aquarium

Project Vision

“Access is the Killer App”

- Goals
  - Be connected anywhere, anytime via the “best” available (wireless/wireline) network
  - Adapt the application to the available bandwidth and latency
- Strategies
  - Wireless Overlay Internetworking Architecture
  - Network- and Type-Aware Applications Building Blocks

Wireless Overlay Concept



Theatre of Operations

↓

Rear Echelons

↓

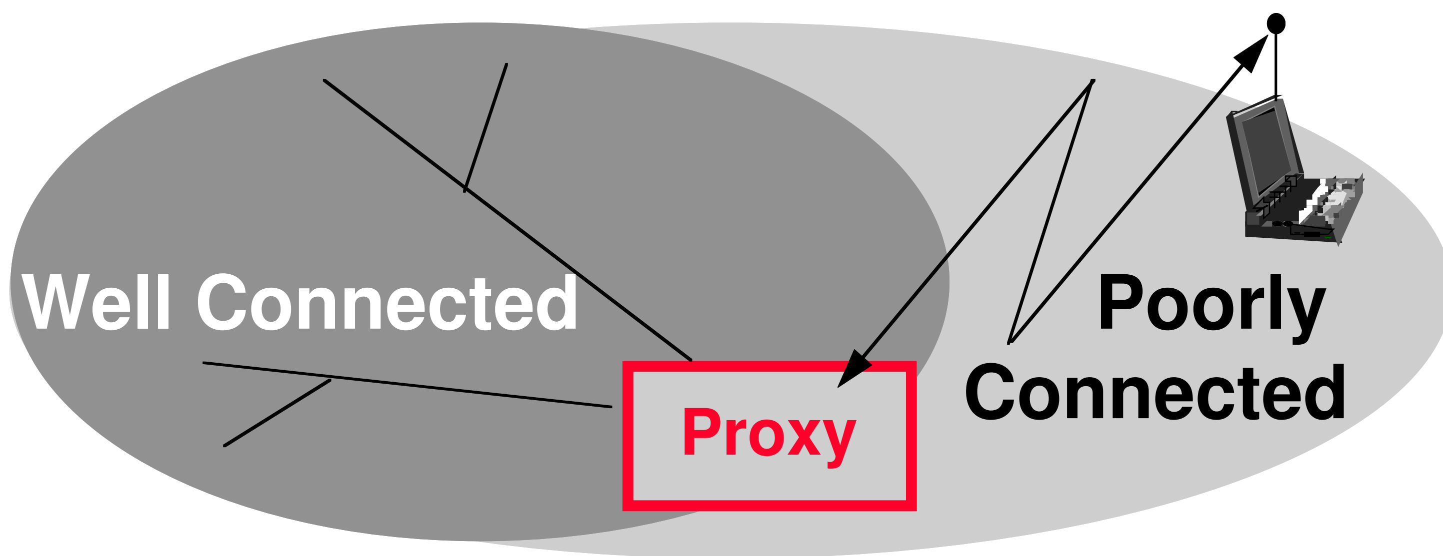
Bases, Depots, Ranges

↓

Command Centers
Training Centers

Proxy Architecture

- **Proxy**
  - Mediates between wireless and wireline environment
  - Ideally executes at "well-connected" boundary of internetwork
  - Changes data representations on-the-fly
  - Trade-off in transcoding time and communications time



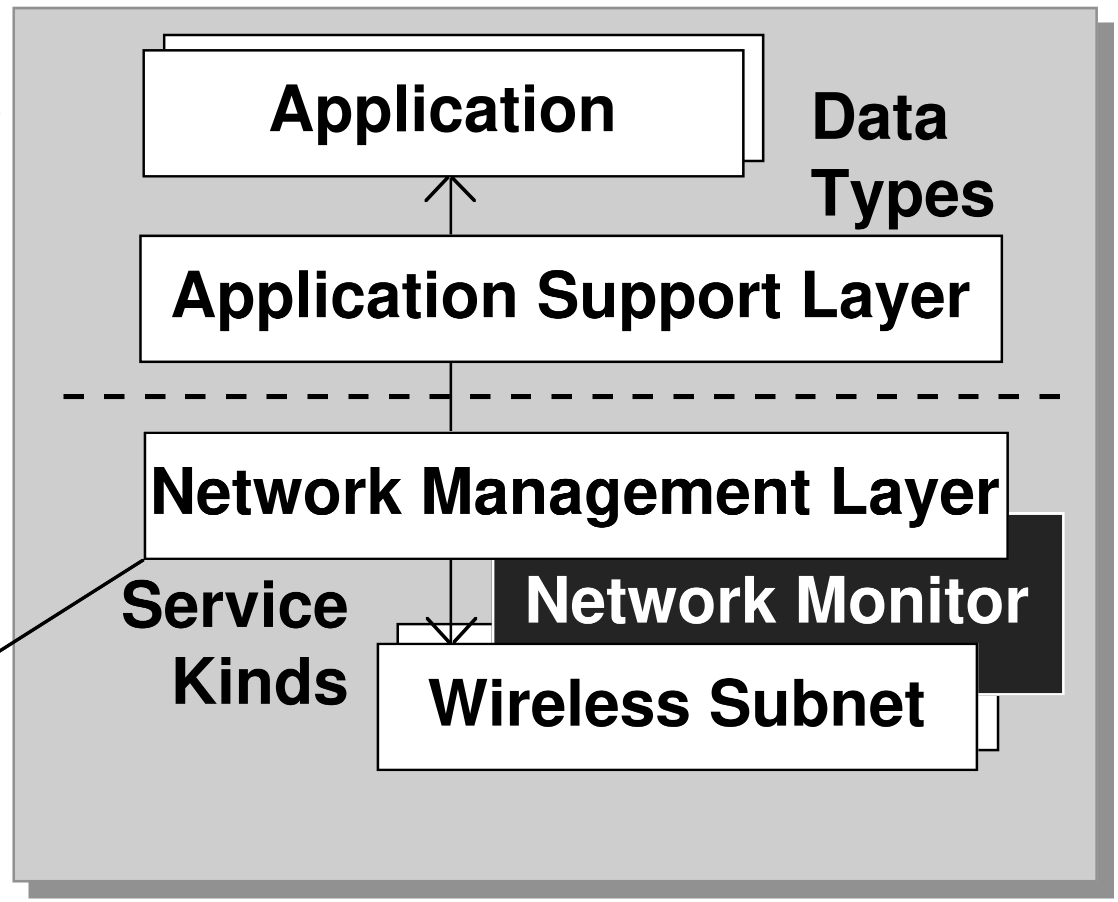
Bandwidth Adaptive Application Interfaces

When to switch from one overlay network to another?

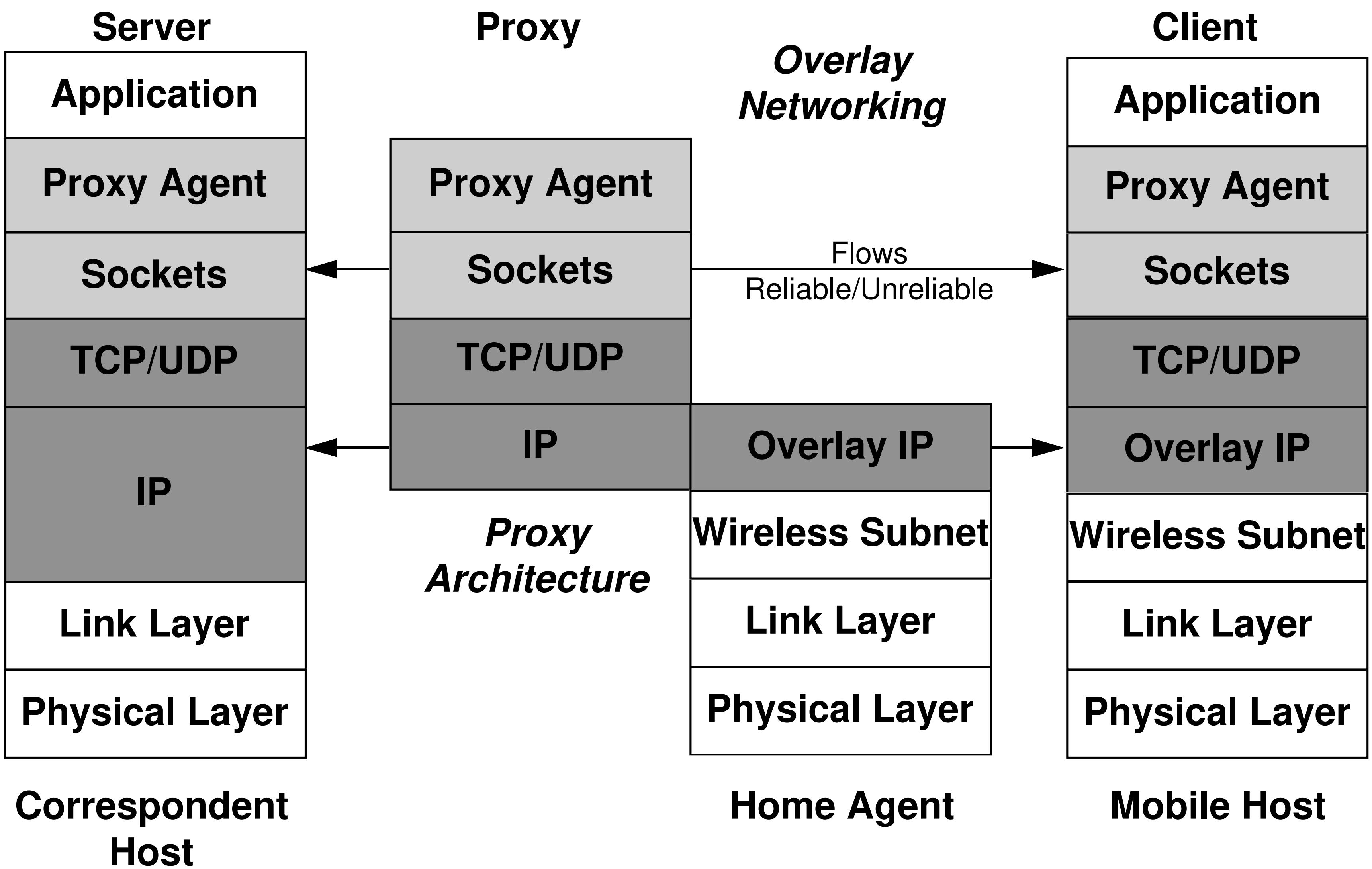
Strategy:
- Monitor network state
- Detect edge of coverage
- Initiate vertical h/o

Network Monitor:
- Determines network state
- Basis for trace collection

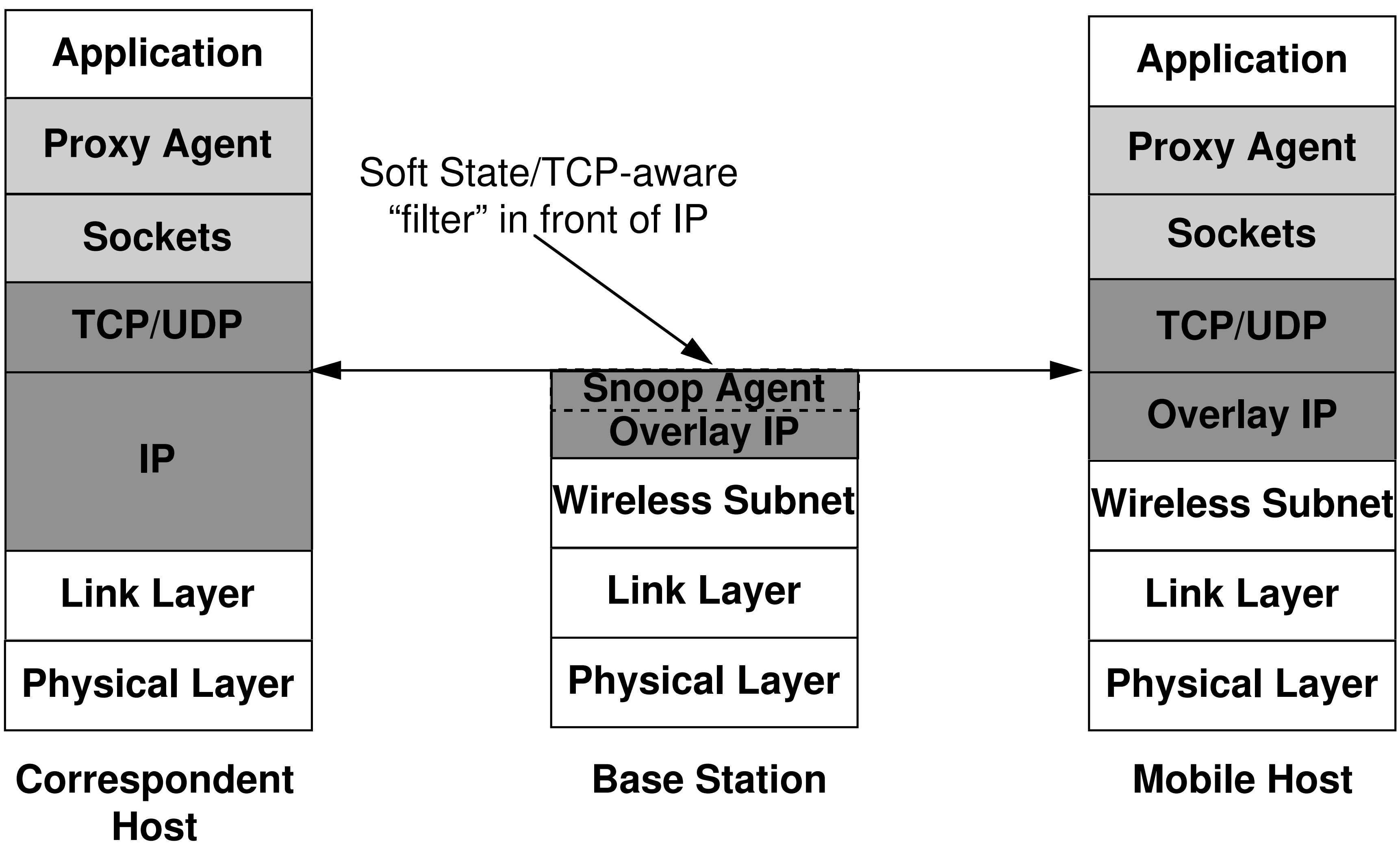
Routing + Handoff



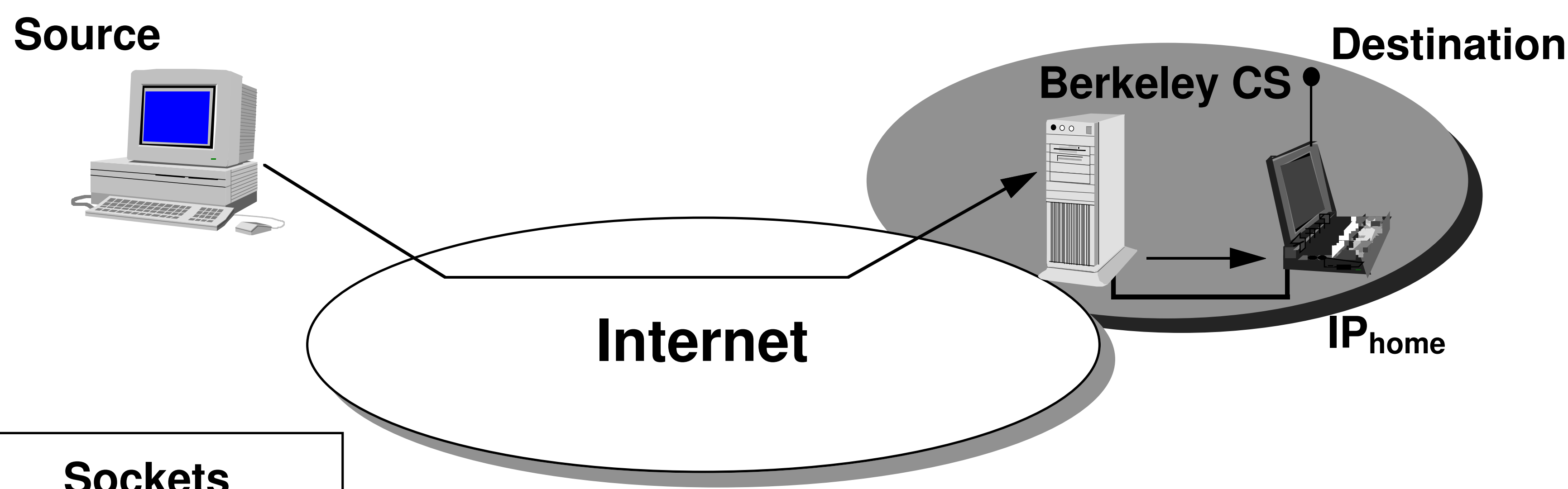
Application/Network Architecture



Application/Network Architecture

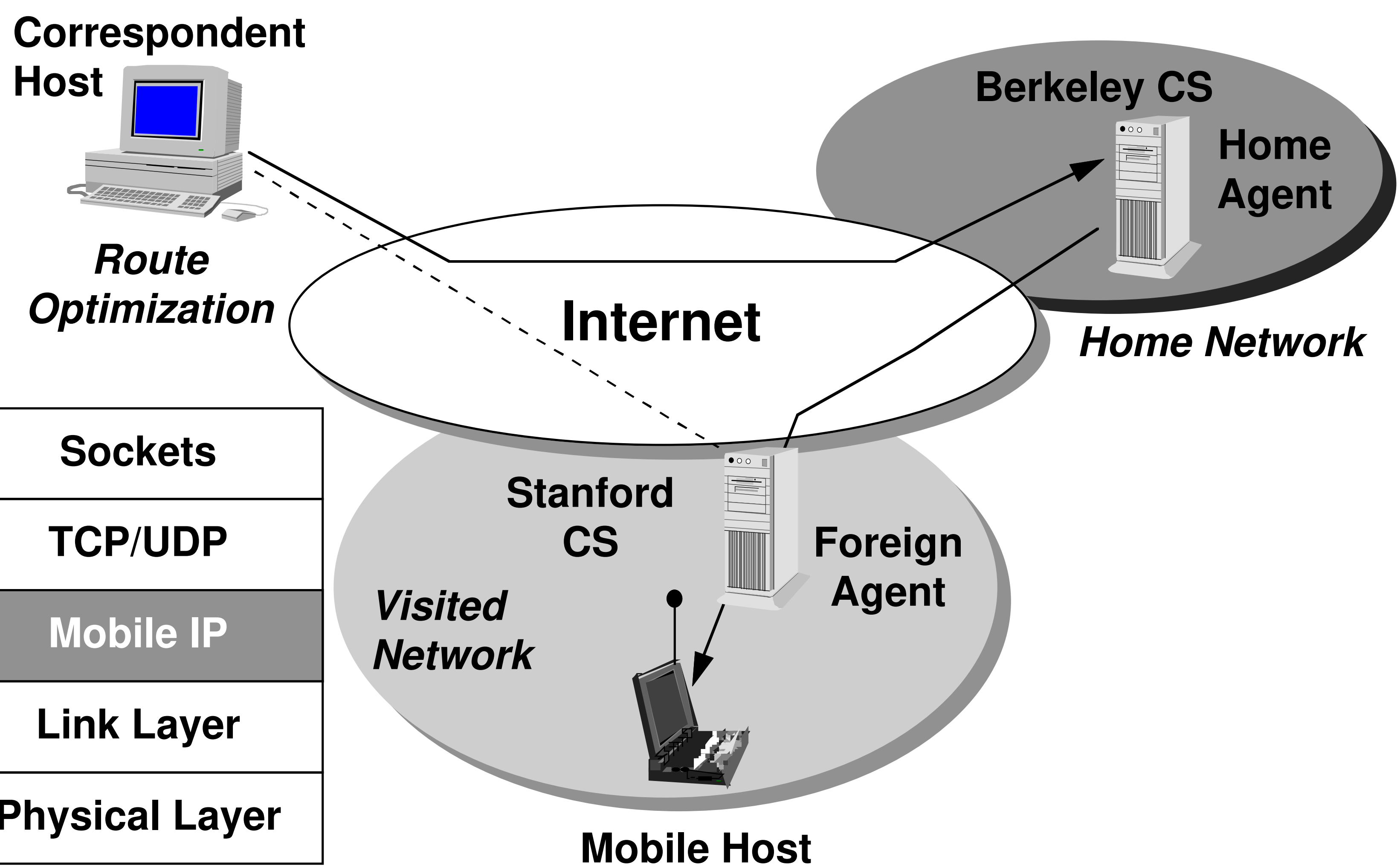


IP Routing



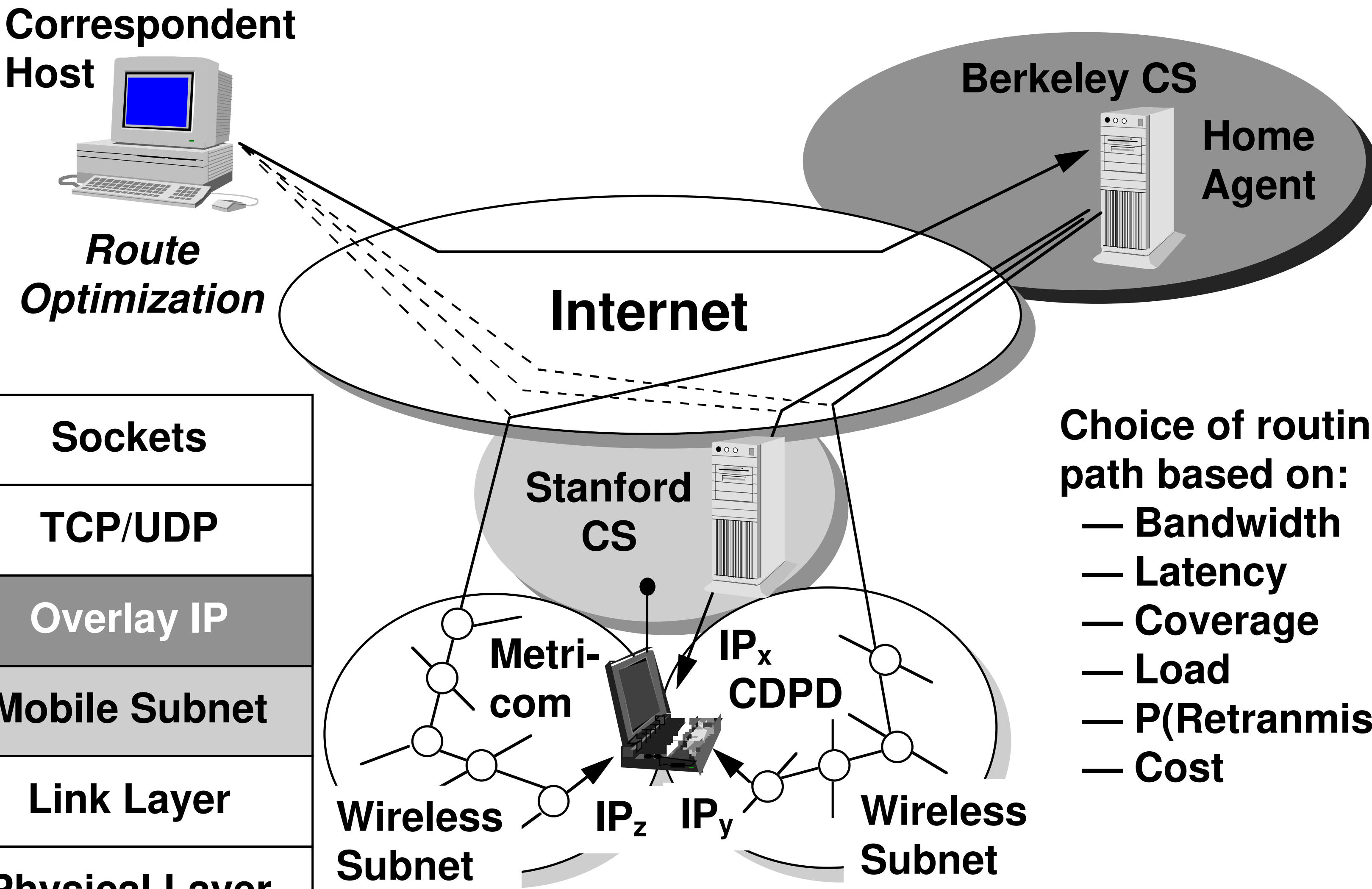
Sockets
TCP/UDP
IP
Link Layer
Physical Layer

Mobile IP



Sockets
TCP/UDP
Mobile IP
Link Layer
Physical Layer

Overlay Networks: Mobile IP + Multi-homed Hosts



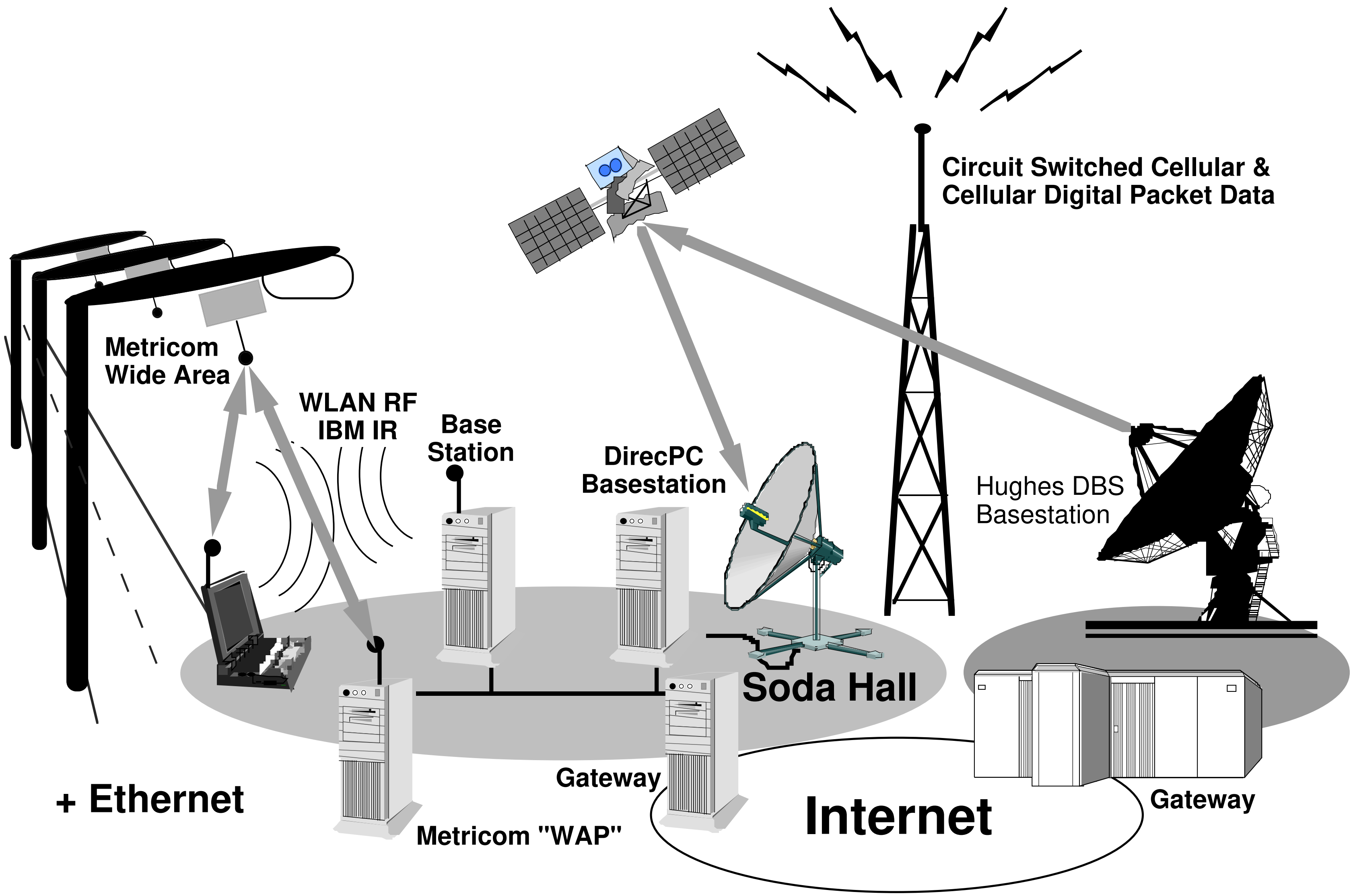
Sockets
TCP/UDP
Overlay IP
Mobile Subnet
Link Layer
Physical Layer

Choice of routing path based on:
- Bandwidth
- Latency
- Coverage
- Load
- P(Retranmission)
- Cost

Achievements to Date

- **Establishment of heterogeneous wide-area and local area wireless access technology testbed ("BARWAN")**
- **"Proof of concept" prototypes of proxies for web/image, video, postscript, maps**
  - Leveraged in UCB InfoPad and UCLA WAMIS Projects
- **Prototype bandwidth adaptive applications**
  - PDA MIME mail, Internet conferencing/collaboration tools
- **Prototype implementations of reliable transport and mobile handoff mechanisms**
  - Algorithms leveraged in UCB InfoPad Project
- **Development of industrial collaborations for eventual technology transfer**

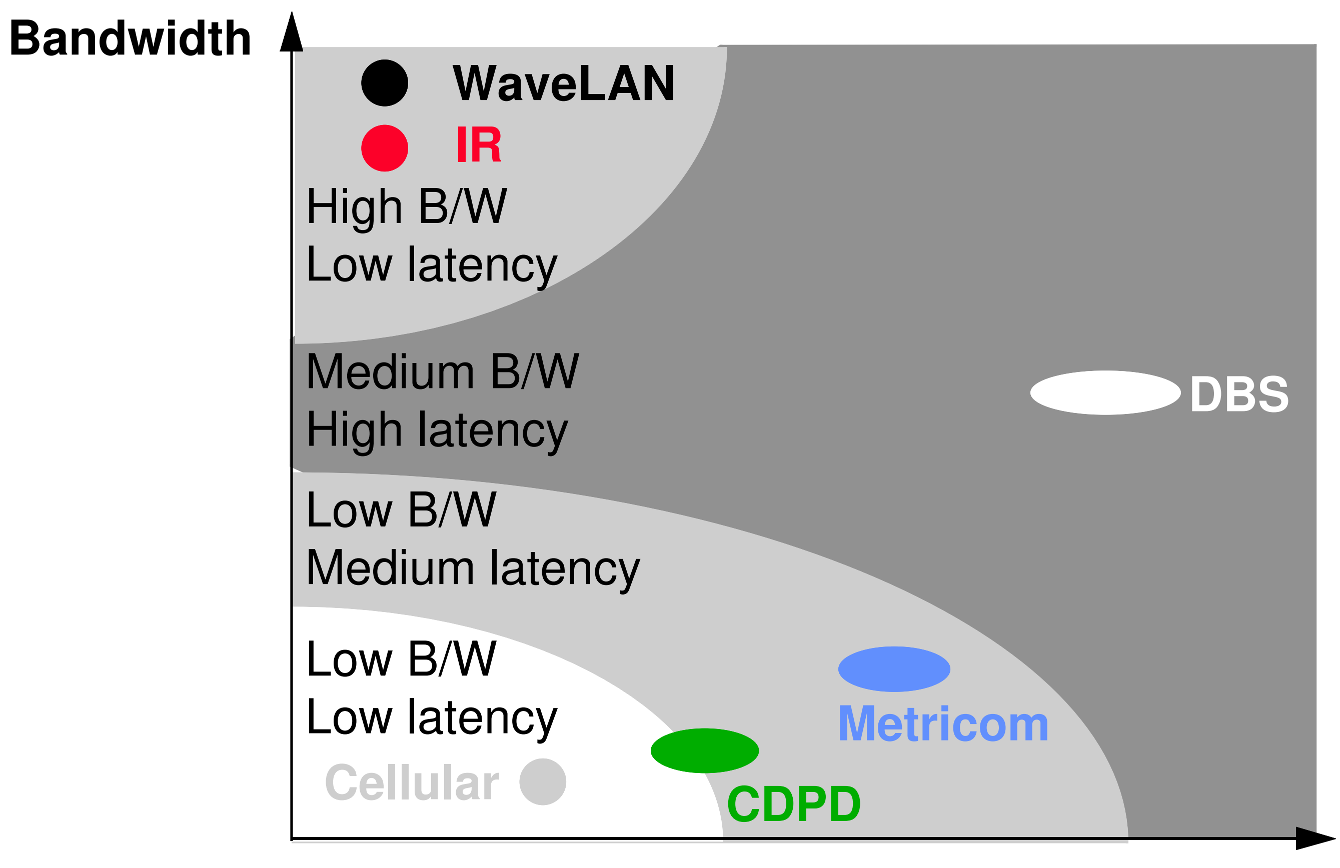
BARWAN Testbed



Characteristics of Alternative Overlay Technologies

Type of Network	Bandwidth	Latency	Mobility	Typ Video Performance	Typ Audio Performance
In-Building IBM IR ATT WaveLAN	 1 Mbps 1.5 Mbps	 <3 ms <3 ms	Pedestrian	2-Way ’ractive Full Frame Rate (Compressed)	High Quality 16-bit Samples 22 Khz Rate
Packet Radio Metricom	 40-60 Kbps pt-to-pt 20-30 Kbps multi-hop	 60 ms 100 ms+	Pedestria[illegible]	Me[illegible] Quality S[illegible] Scan	Med. Quality Reduced Rate
Wide-Area CDPD Cellular Modem	 9.6 Kbps 4.8 Kbps	 100 ms+ 30 ms	Vehicular	Freeze Frame	Asynchronous “Voice Mail”
Regional-Area DirecPC DBS	 400-800 Kbps	 > 250 ms	Stationary	1-Way Full Frame Rate (Compressed)	High Quality 1 Way or Asynchronous

Spanning Space of Wireless Network Technologies



Figures of Merit:
- **Cost?**
- **Variability?**
- **Reliability?**
- **Range?**
- **bps/ft^3?**

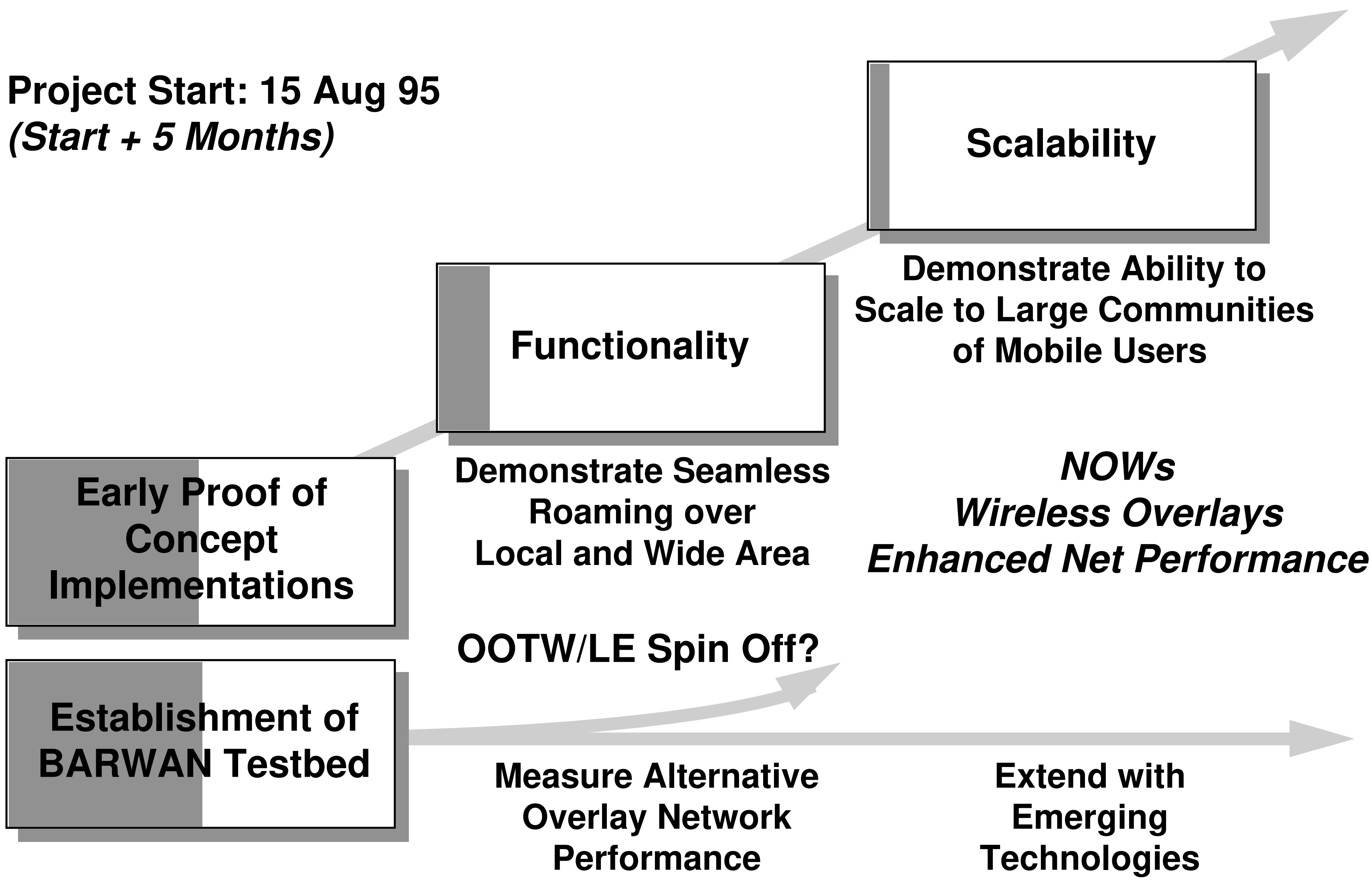
Project Strategy

Architectural Design
Scaled Implementations

Early Prototypes
Proof of Concepts
Measurements & Evaluation

Project Plan and Status

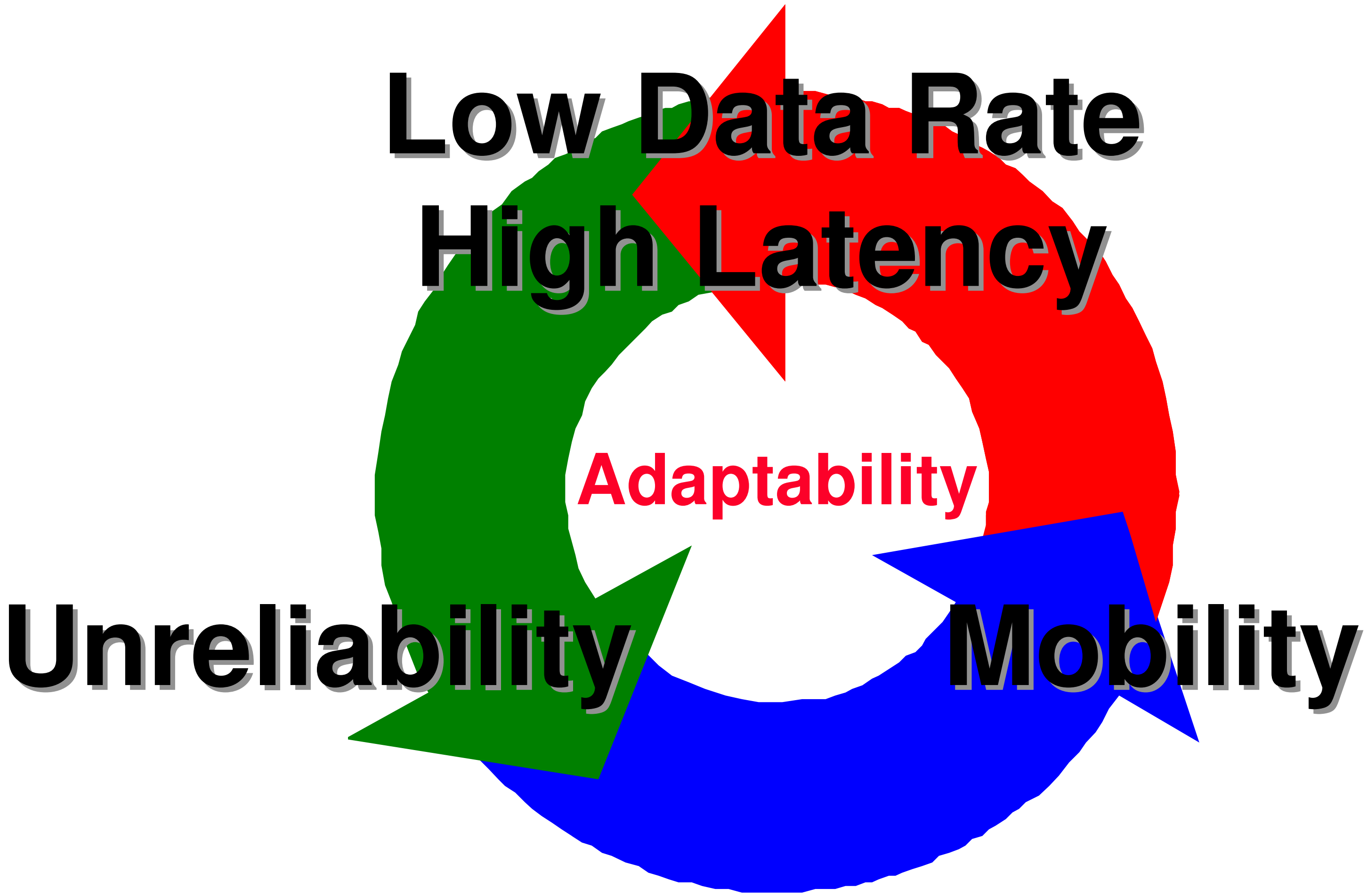
Project Start: 15 Aug 95
(Start + 5 Months)



Scalability

- Network Scaling
  - Mapping of traffic classes onto alternative routing paths
  - Load balancing across overlays
  - Hierarchical Foreign Agents in Mobile/Overlay IP
- Application Support Scaling
  - Scalable processing techniques for proxies
  - Exploit networks of workstations (NOWs)
- Geographic Scaling
  - Integration of wide-area wireless subnetworks
  - Wide-area roaming architecture

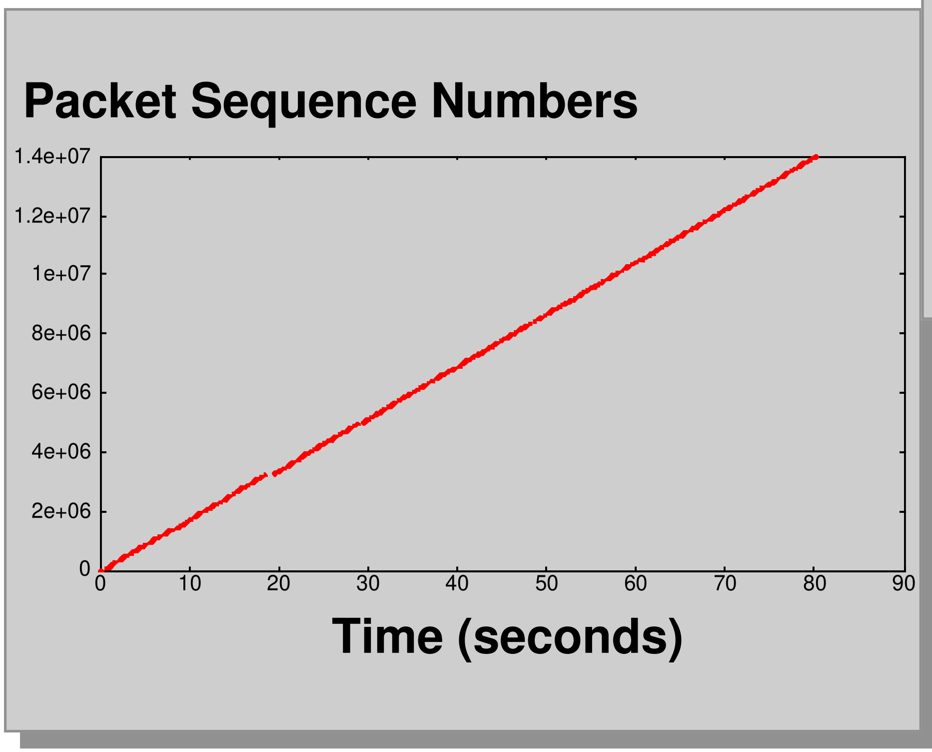
Mobile Computing Challenges

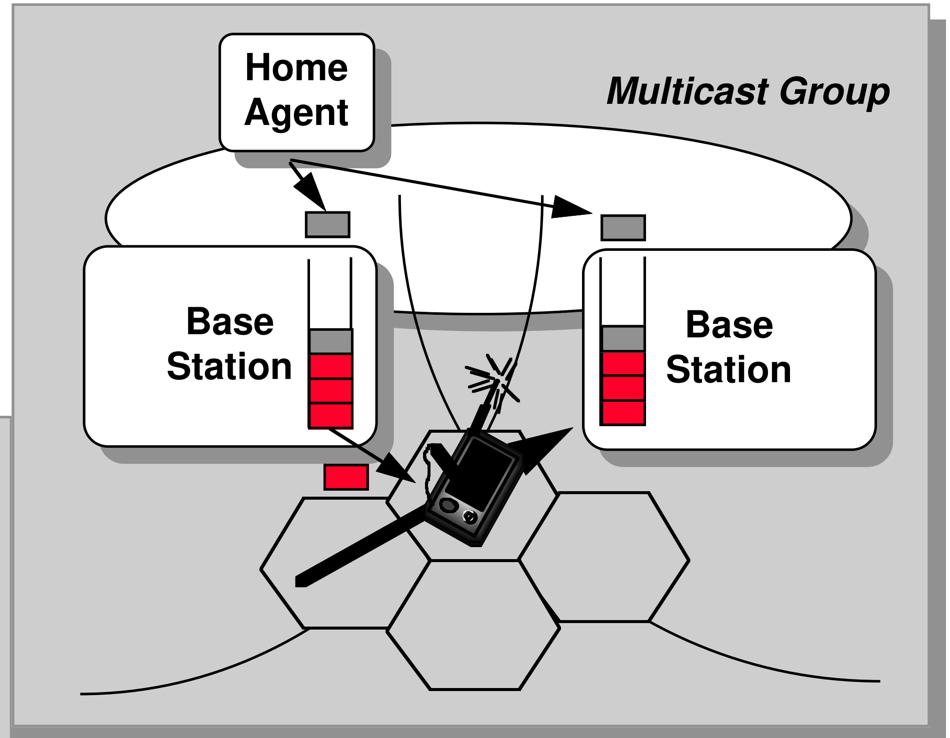


Early Proof of Concepts in all of these areas

Mobility Meets Multimedia: Low Latency Handoff

- Use hints about terminal trajectory to assist in handoffs
- Multicast packets to adjacent base stations to smooth handoffs



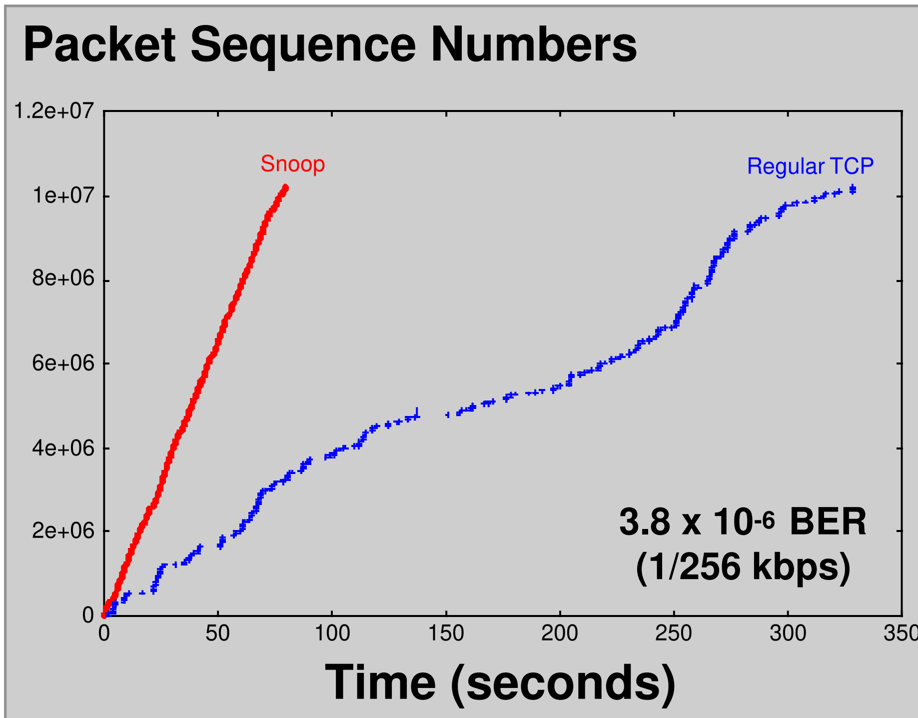


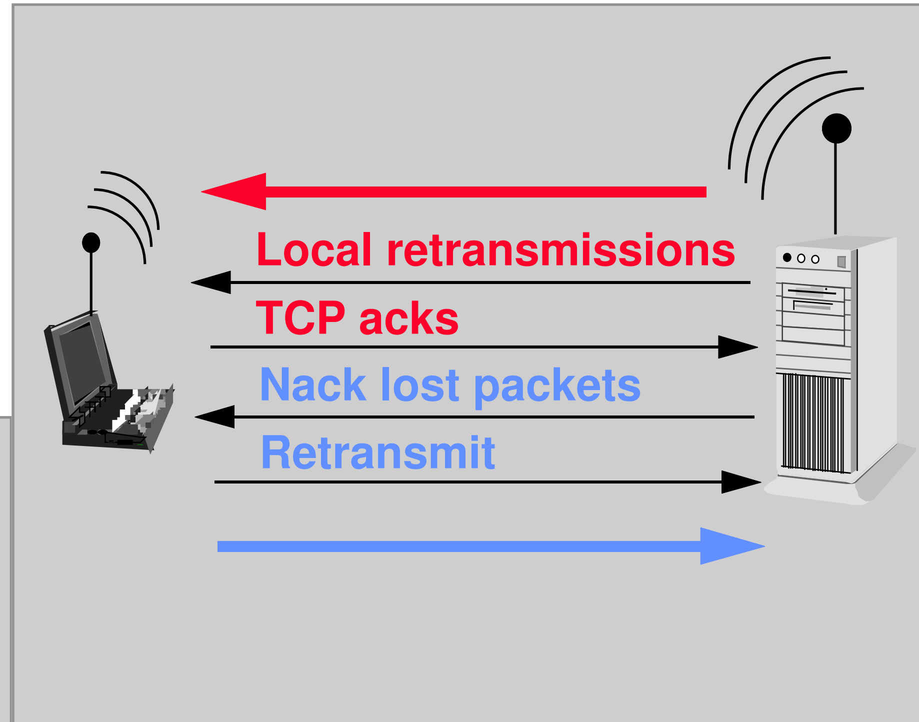
Handoffs every 10 seconds

Code release 1st Quarter 1996

Web Browsing on the Move: Reliable Wireless Transport

- Cache unacknowledged TCP data; Snoop on TCP acks, do local rexmit
- BS explicitly NACKs MH's lost pkts
- Maintain end-to-end TCP semantics





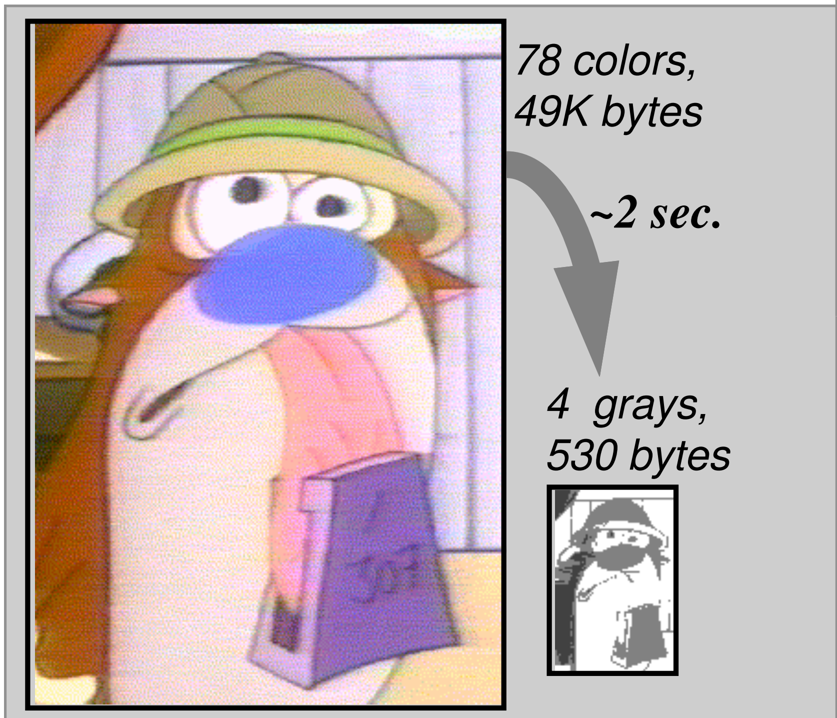
20X speed-up in presence of bit errors

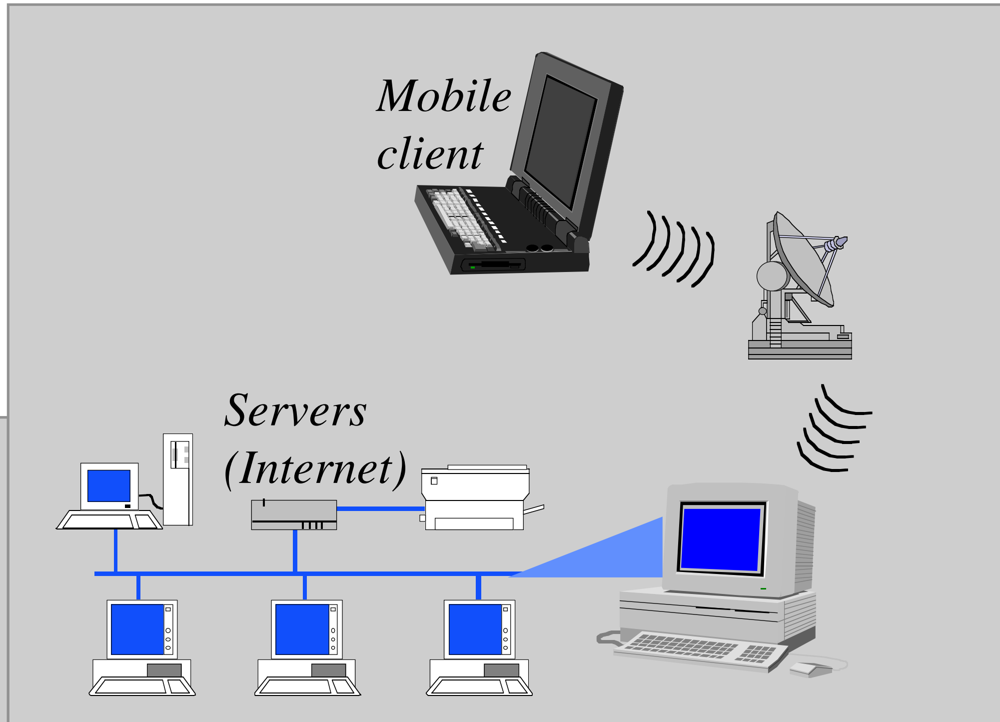
Aggregate b/w 1 Mbps vs. 0.25 Mbps

Code release integrated with handoff

Proxy Architecture: Image Proxy

- **Distillation**: lossy compression that preserves semantic content
- Works in R/T on desktop PC
- Client can request **refinement** of distilled image



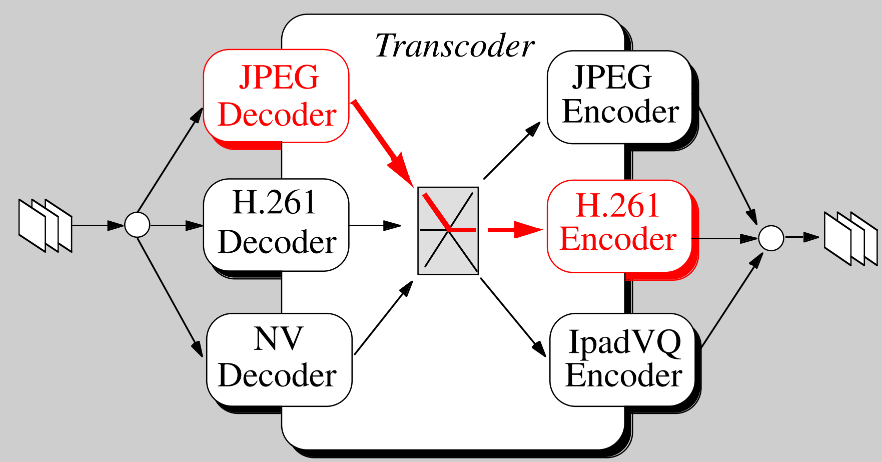


Orig. size (bytes)	New size	New size as % of original	Pixel dimensions	Scaled by	Time (sec.)
34K	2022	0.058	320x200	2	1
848K	5938	0.007	1280x1024	4	13
848K	1676	0.002	1280x1024	8	10
361K	24311	0.066	1022x703	2	8
361K	6240	0.017	1022x703	4	7
173K	4974	0.028	640x480	2	4
173K	1644	0.009	640x480	4	3

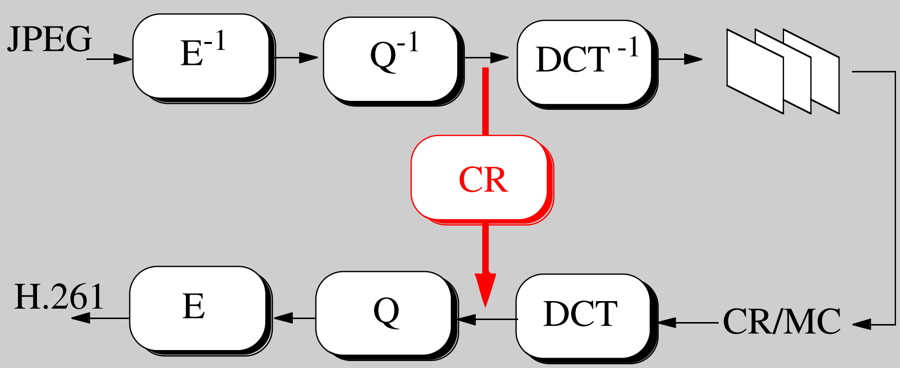
Proxy Architecture: Video Gateway

- Another early instance of a proxy
- R/T transcode from high b/w video to low bandwidth video formats
- Integrated with existing Internet MM infrastructure via RTP

Gateway Architecture



JPEG to H.261 Transcoder



Motion	Full Path	Opt. Path
Low	26 fps	30 fps
High	15 fps	27 fps

1/4 NTSC JPEG to CIF H.261 on SparcStation 20

Six Month Plan

- Mobility traces/benchmarks to drive design efforts
  - Collection and analysis in collaboration with CMU
- Performance evaluation of alternative *wide-area* wireless overlay technologies
  - Metricom, DBS, CDPD
- Complete architectural design
  - Overlay network and application support architectures
    - » Application Layer to Application Support Layer
    - » Application Support Layer to Network Layer
    - » Mobile Host/Home Agent Path Negotiation
    - » Wide Area Mobile Services

Industrial/University Partnerships

- **Research Access to Wireless Network**
  - Metricom (Ricochet)
  - GTE MobileNet (CDPD)
  - Hughes DBS (DirecPC)
  - *PacTel (PCS)*
- **Research Collaborations**
  - Fuji Xerox PA Labs (Mobile applications and networks)
  - Hughes (DBS data architecture, satellite protocols)
  - Metricom (High performance reliable transport)
  - IBM (Mobile routing)
  - CMU (Mobile trace collection and analysis)
  - UCSC Wings (Extend BARWAN to Monterey Bay)
  - *Stanford (Wide area mobile services architecture)*
  - *UCSF (Medical imaging applications)*