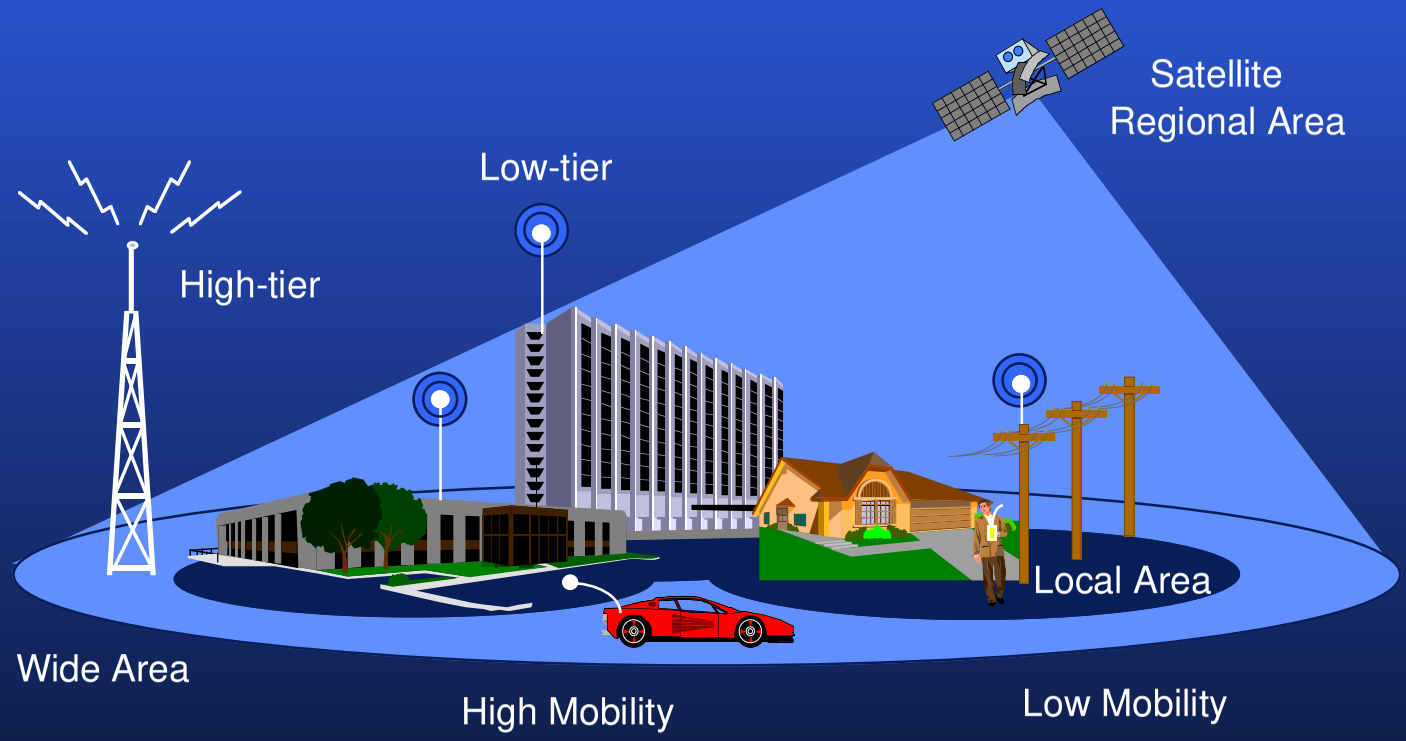
# The Case for Wireless Overlay Networks




Randy H. Katz

Computer Science Division, EECS Department
University of California, Berkeley, CA 94720-1776
© 1996

# Presentation Outline

- The Promise: Anywhere/Anytime Access
- The Challenge: Wireless Data
- Promising Strategies
  - Overlay Networks
  - Proxy Architecture
- Research at Berkeley
- Summary and Conclusions

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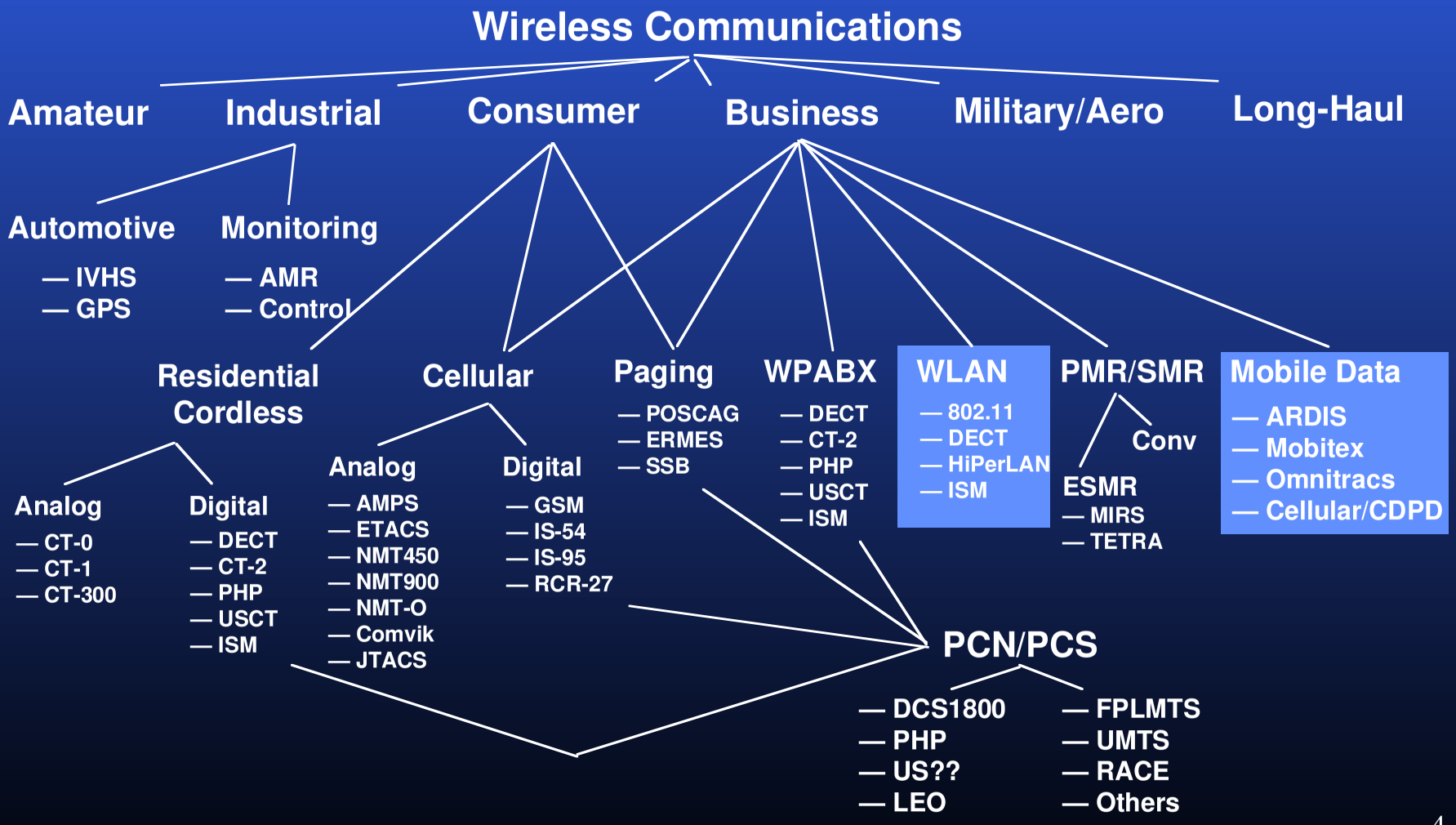
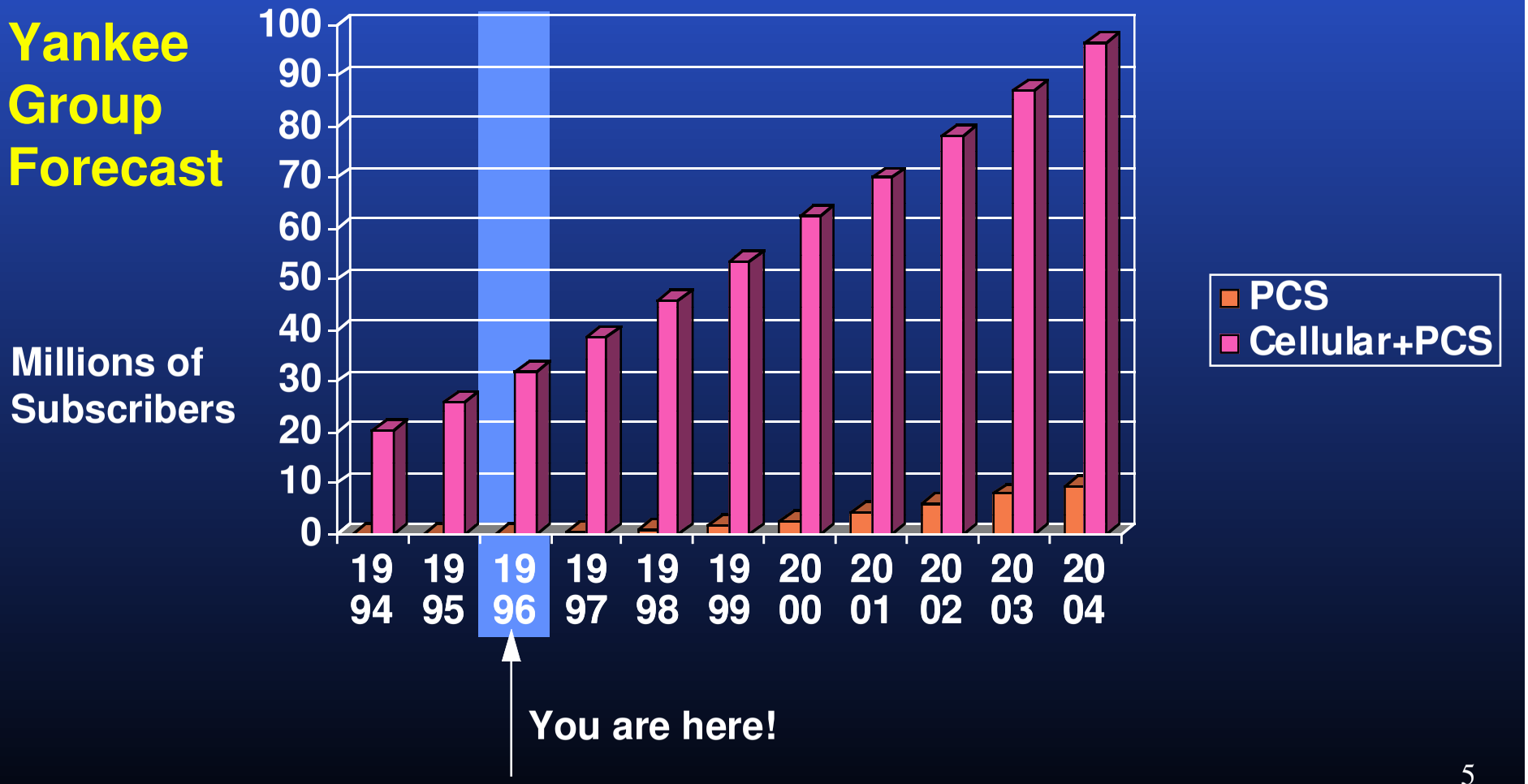
# The Wireless Universe



# Proliferation of Wireless Services

**Yankee Group Forecast**



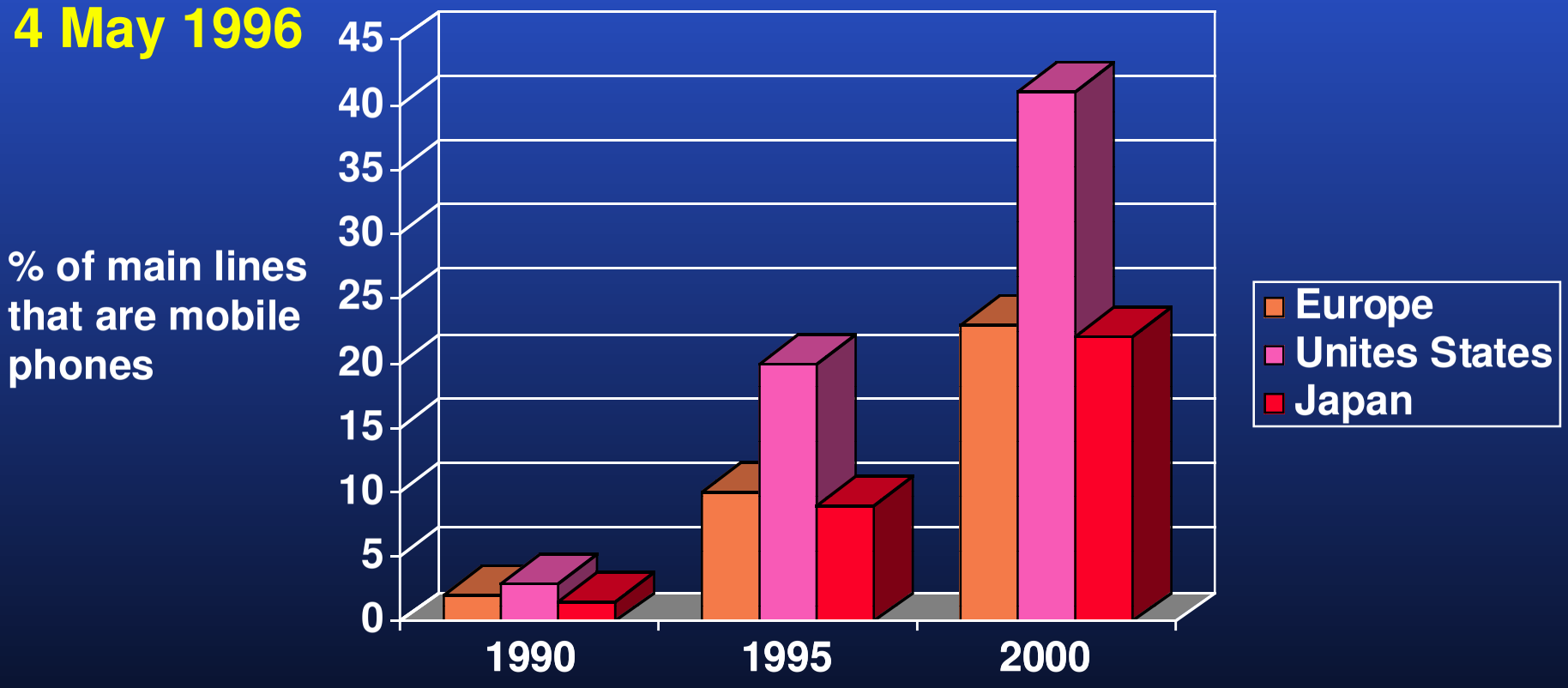
# PCS Standards(?)

| Proposal | Mobility | Supporters |
|---|---|---|
| CDMA (IS-95) | High | Qualcomm, AT&T, Motorola, ALPS, GSIC, Samsung, Sony, US West, Sprint Bell Atlantic, Time Warner |
| PCS1900 | High | Pac Bell, Nokia, MCI, Siemens, Kycom |
| IS-54 | High | AT&T, McCaw |
| Omnipoint | High/Low | Omnipoint, Rockwell |
| WACS | Low | Bellcore, Motorola, Panasonic, US West, Sprint, Bell Atlantic, Time Warner |
| DECT | Low | Ericsson |
| PHP | Low | NEC, Panasonic, Hitachi, Toshiba, PCSI |
| 5 MHz CDMA | Low | Interdigital, Oki |

- PCS Primeco, STV have selected CDMA
- AT&T Wireless has selected TDMA
- RBOCs have selected PCS1900 (Upbanded GSM)

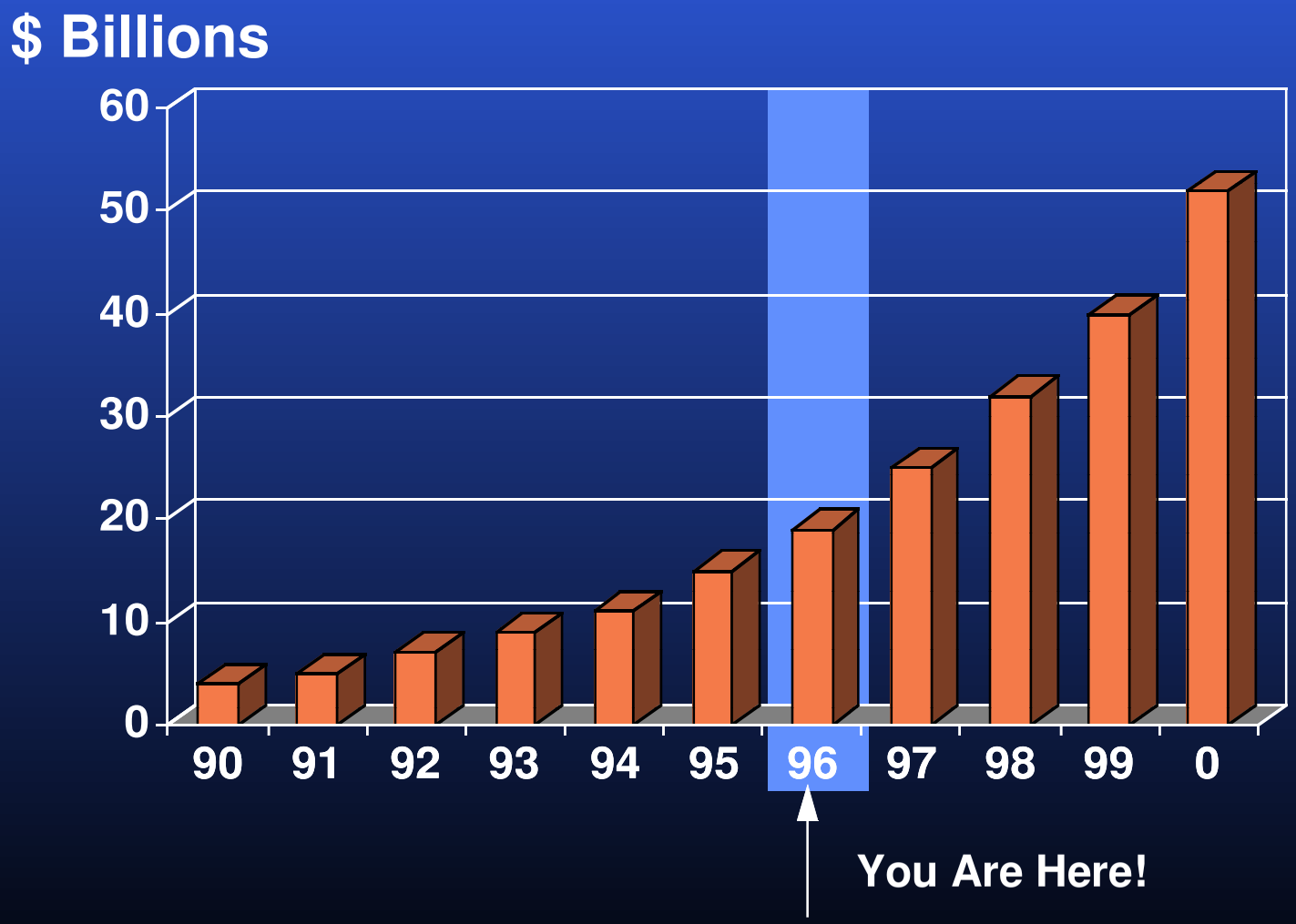
# Cellular Phone Growth

**Economist**
**4 May 1996**

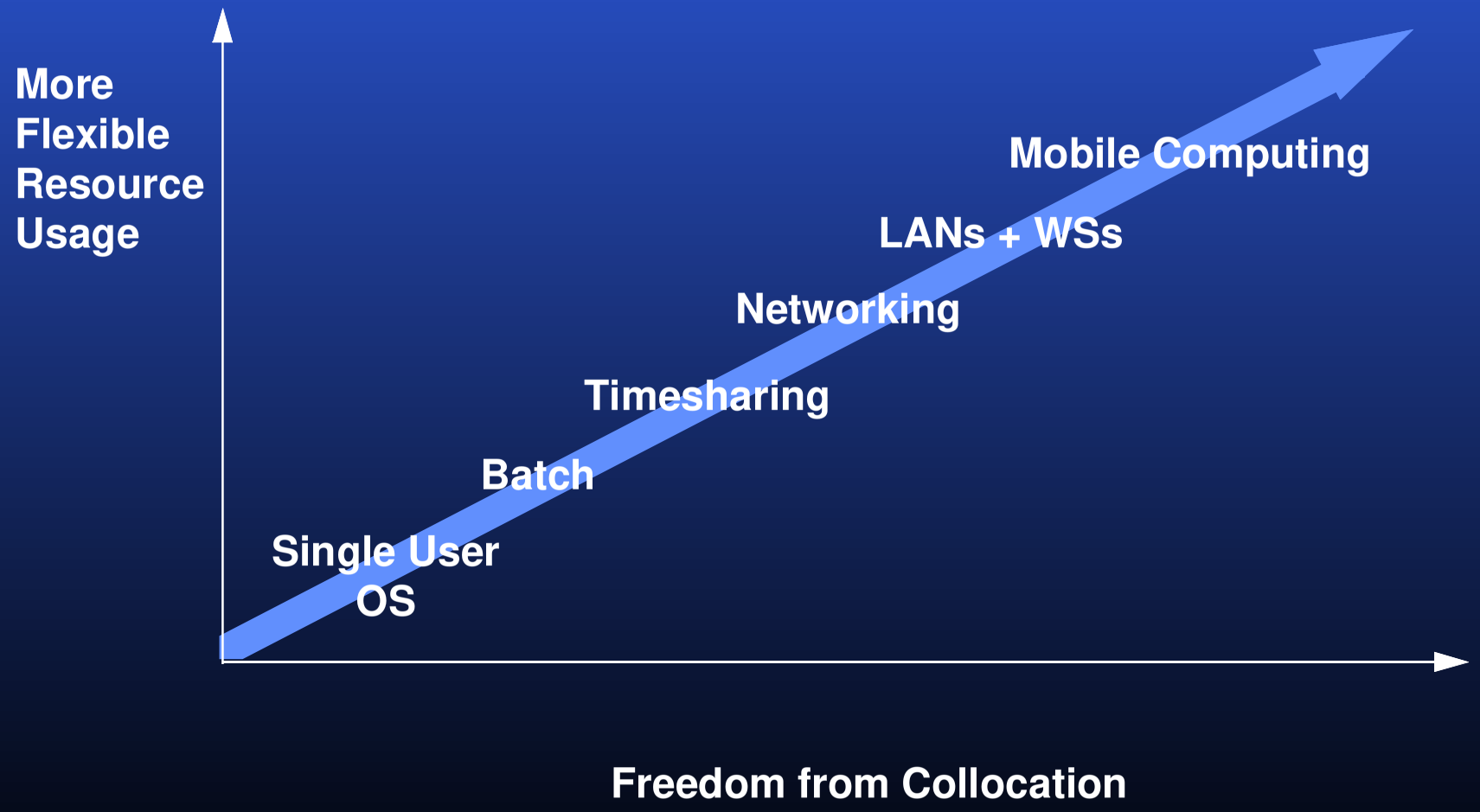



**Year 2000: Mobile phones will reach 42% of fixed-line subscribers**

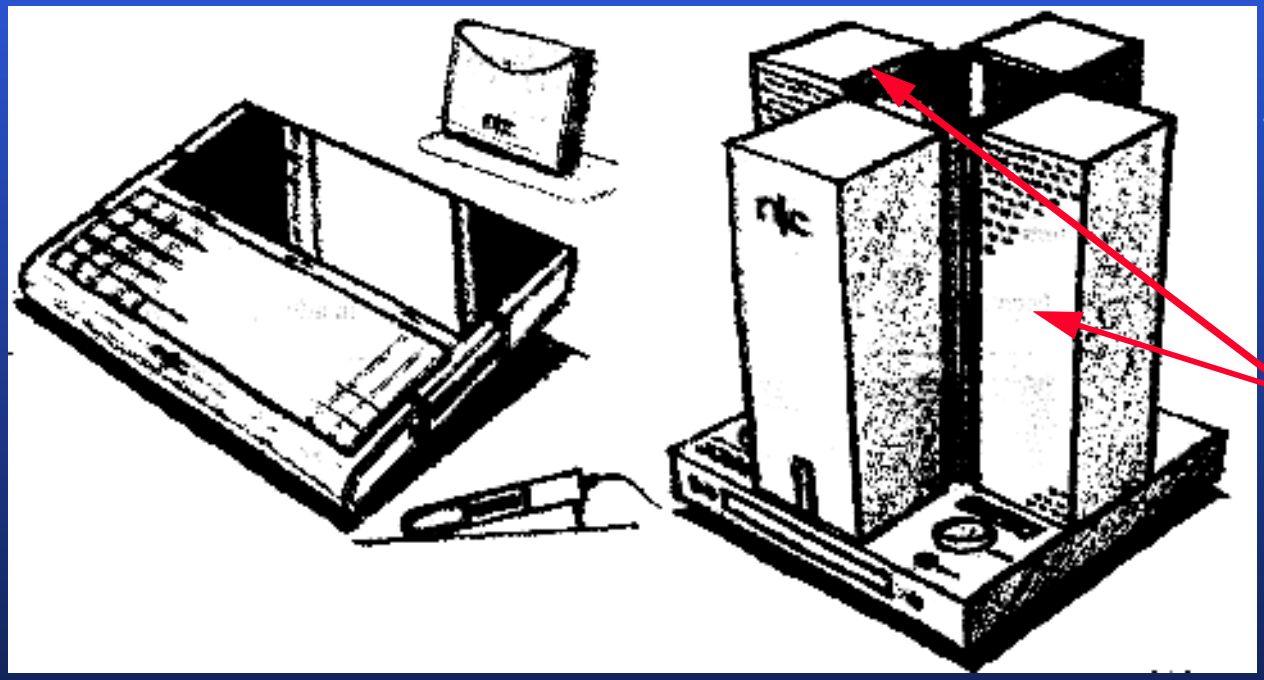
# Global Markets for Portable Computers



# Mobile Computing is the *Natural Evolution* of Computing



# Oracle's Magic Box: The Network Computer (N/C)



From
SF Chronicle,
18 Jan 96

Speakers

μProcessor: $30; 8 MBytes DRAM: $200
Ethernet connection/modem: $20-35
PC card: $15 (optional)
Keyboard and mouse: $35
Miscellaneous (e.g., case): $50
Total Cost: $365; Selling Price: $495
Note: no monitor!

Modular, stereo component design

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# Is Wireless Data Dead?

- Cellular Voice Services
  - Approx. 34 million subscribers in US
  - $7 billion in primary PCS license auctions
  - $10.2 billion in secondary PCS auctions
- Wireless Data Services
  - Have been around for about 10 years
  - Wide-Area Data Networks
    - » Less than 100,000 subscribers in US
  - Wireless Local Area Networks
    - » Large number of manufacturers yet small sales volumes
    - » Major companies dropping out of the business

# Technical and Economic Challenges

- Pricing
  - $/airtime, $/data transfer, flat rate?
  - Transmitted packets or received packets?
  - Artifact provider vs. pipe provider vs. service provider
- Performance
  - 20 kbps but not quite fast enough for “multimedia”
  - Coverage, non-interoperability
- Killer App
  - Vertical application vs. email, paging, web access
- Formfactor
  - Laptops vs. PDAs vs. Smart Phones

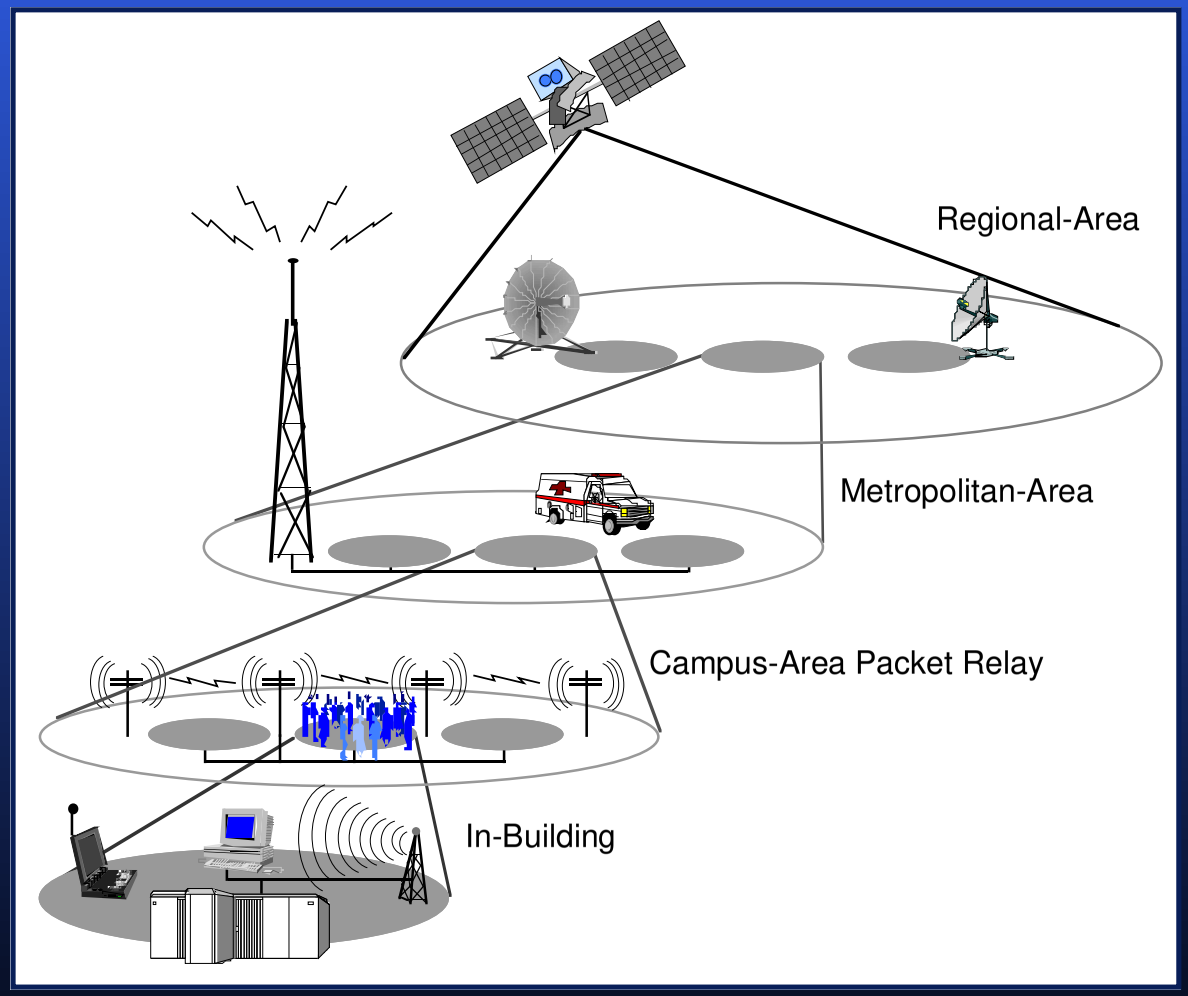
# Promising Developments

- Converging Platforms
  - Smart phones: cellular phone + built-in pager/PDA
    - » e.g., Nokia/Geoworks “Internet” Phone
    - » e.g., IP-addressable pagers
- PCS Licenses
  - Room for *all* of those cellular service providers?
- Emerging Industry Standards
  - CDPD, IEEE 802.11, WINFORUM
  - Better interoperation or co-existance in the future

# *Access* is the Killer App

- Killer Capabilities
  - Access to your desktop environment while on the move
  - Be connected whenever possible via the “best” available network
  - Support the application’s graceful adaptation to the available bandwidth and latency
- Technical Strategies
  - Continuous Connectivity: Wireless Overlays
  - Proxies: Network- and Type-Aware Applications Building Blocks

# Wireless Overlay Architecture




**Remote Clinics**

↓

**Emergency Dispatch**

↓

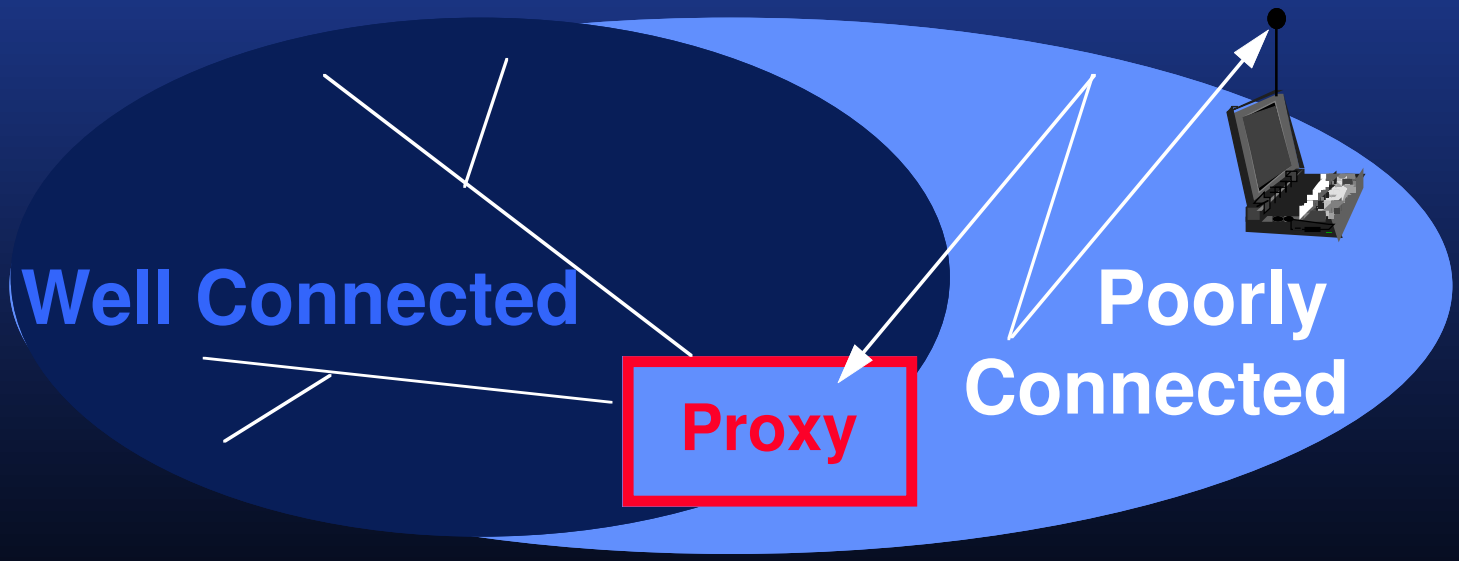
**Hospital Campus**

↓

**Hospital**
**Operating Room**
**Emergency Room**

# Proxy Architecture

- Proxy
  - Mediates between wireless and wireline environment
  - Ideally executes at “well-connected” boundary
  - Manages caches & chooses representations on-the-fly
  - Trade transcoding time against communications time

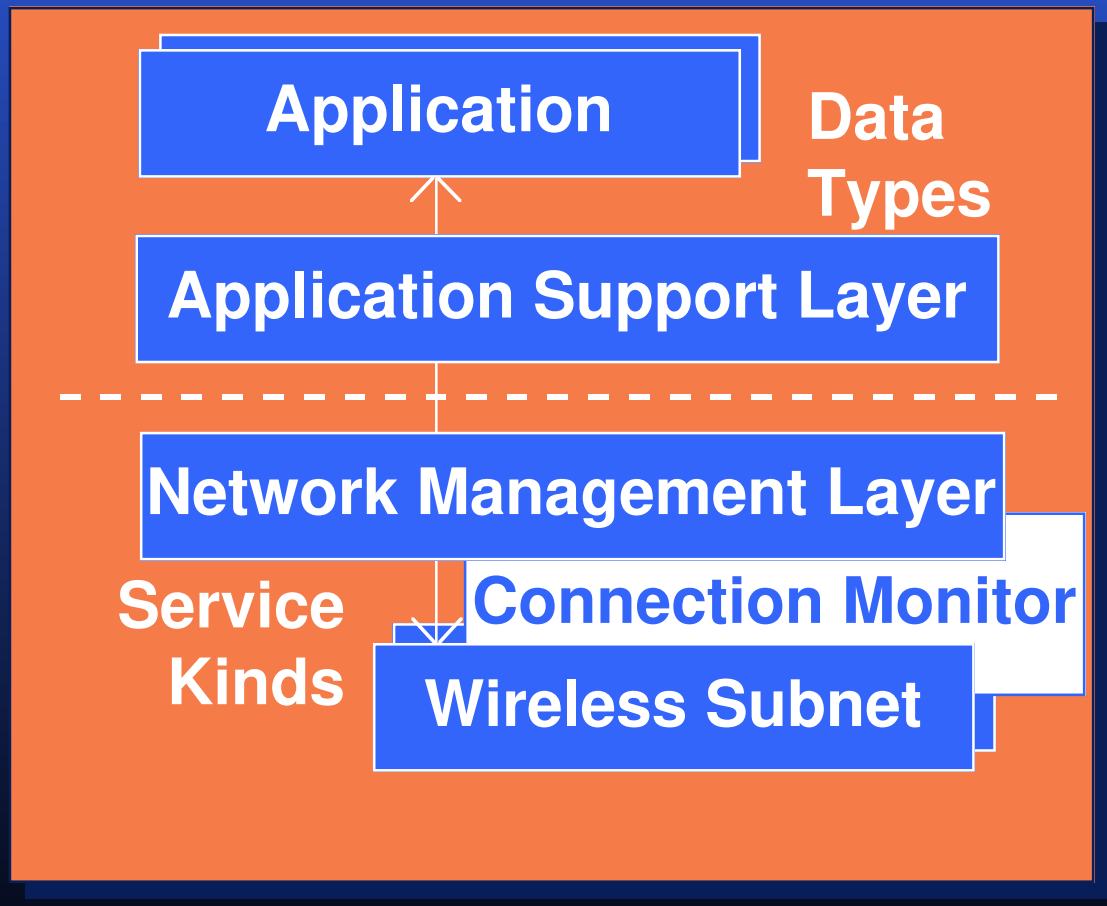


# Bandwidth Adaptive Application Interfaces

**Application Support:**
- Subtype specific modules
- Transmission constraints

**Network Management:**
- Routing & handoff
- Choose subnet based on application constraints, network capabilities

**Connection Monitor:**
- Determines network perf.
- Collects statistics for representation/subnet choices




Applications can be proxy and/or mobile aware, but need not be

# Wide Range of Network Performance

| Type of Network | Bandwidth | Latency | Mobility | Typ Video Performance | Typ Audio Performance |
|---|---|---|---|---|---|
| In-Building | >> 1 Mbps<br>Comm'l RF: 2 Mbps<br>Research IR: 50 Mbps | < 10 ms | Pedestrian | 2-Way 'ractive<br>Full Frame Rate<br>(Comp) | High Quality<br>16-bit Samples<br>22 Khz Rate |
| Campus-Area Packet Relay Network | ≈ 64 Kbps | ≈ 100 ms | Pedestrian | Med. Quality<br>Slow Scan | Med. Quality<br>Reduced Rate |
| Wide-Area | 19.2 Kbps | > 100 ms | Vehicular | Freeze Frame | Asynchronous<br>"Voice Mail" |
| Regional-Area<br>(LEO/DBS/VSAT) | 4.8 kbps–10+ Mbps<br>(asymmetric) | > 100 ms | Vehicular<br>Stationary | Seconds/Frame<br>Freeze Frame | Asynchronous<br>"Voice Mail" |

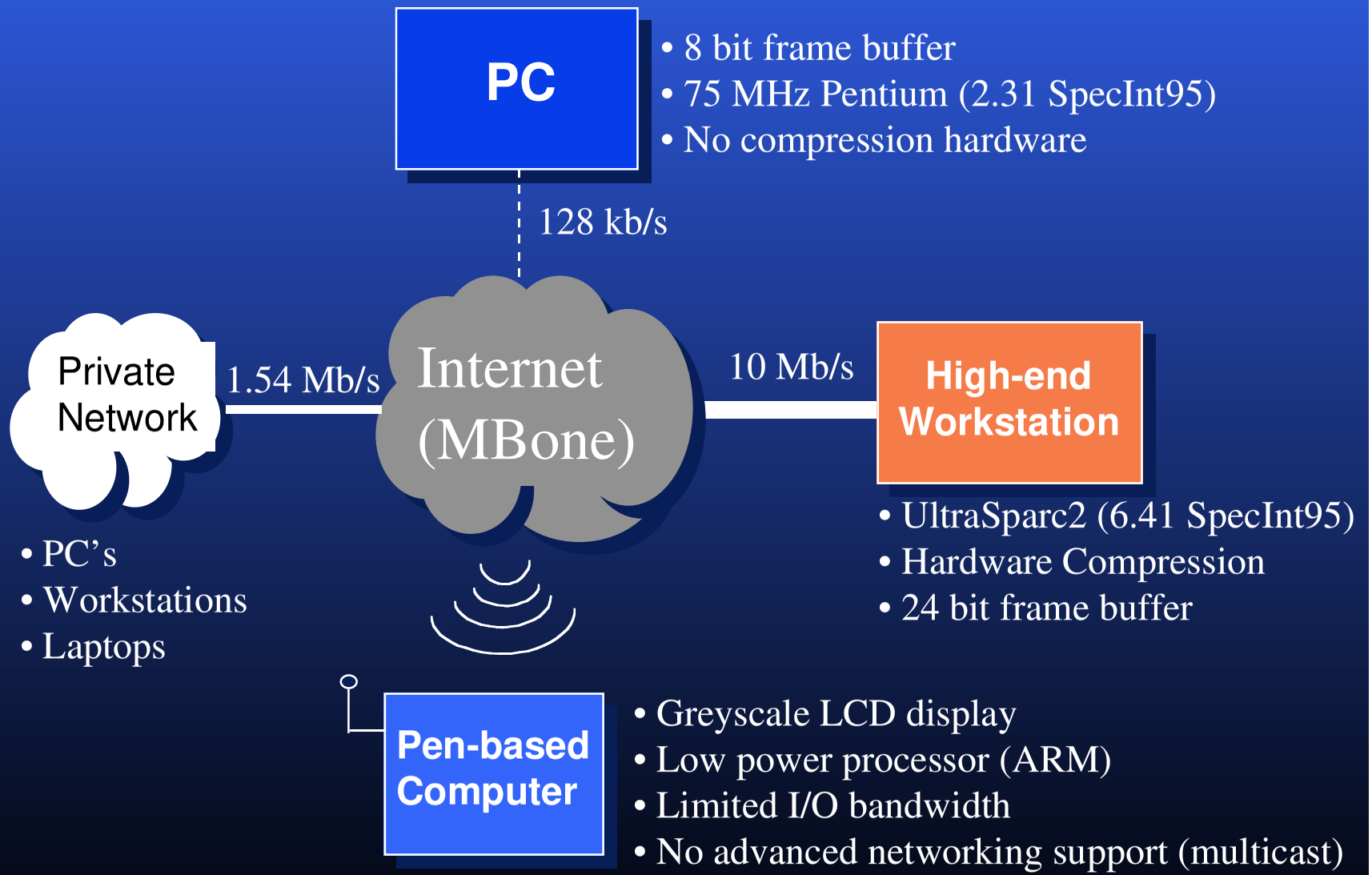
**Latency as critical as bandwidth in wireless networks**

# The Office/PDA Mismatch

| Device | Bandwidth, bits/sec | CPU | Mem/ Disk | Screen size | Bits/ pixel |
|---|---|---|---|---|---|
| High-end PC | Ethernet (10Mbits), ISDN (128K) | 120 Mhz Pentium | 16/2G | 1280x1024 | 16-24, color |
| Low-end PC | | 75-100 Mhz Pentium | 8/500 | 1024x768 | 8-16, color |
| High-end notebook | Cellular (9600) or wireline (28.8K) modem | | | 800x600 | 8, color |
| Low-end notebook | | 50-66 Mhz 486 | | 640x480 | 4, gray |
| PDA | 2400-14.4K modem | 20 Mhz RISC or x86 | 2/0 | 320x200 | 1–2, gray |

**Client variation spans an order of magnitude**

# Video Conferencing Heterogeneity



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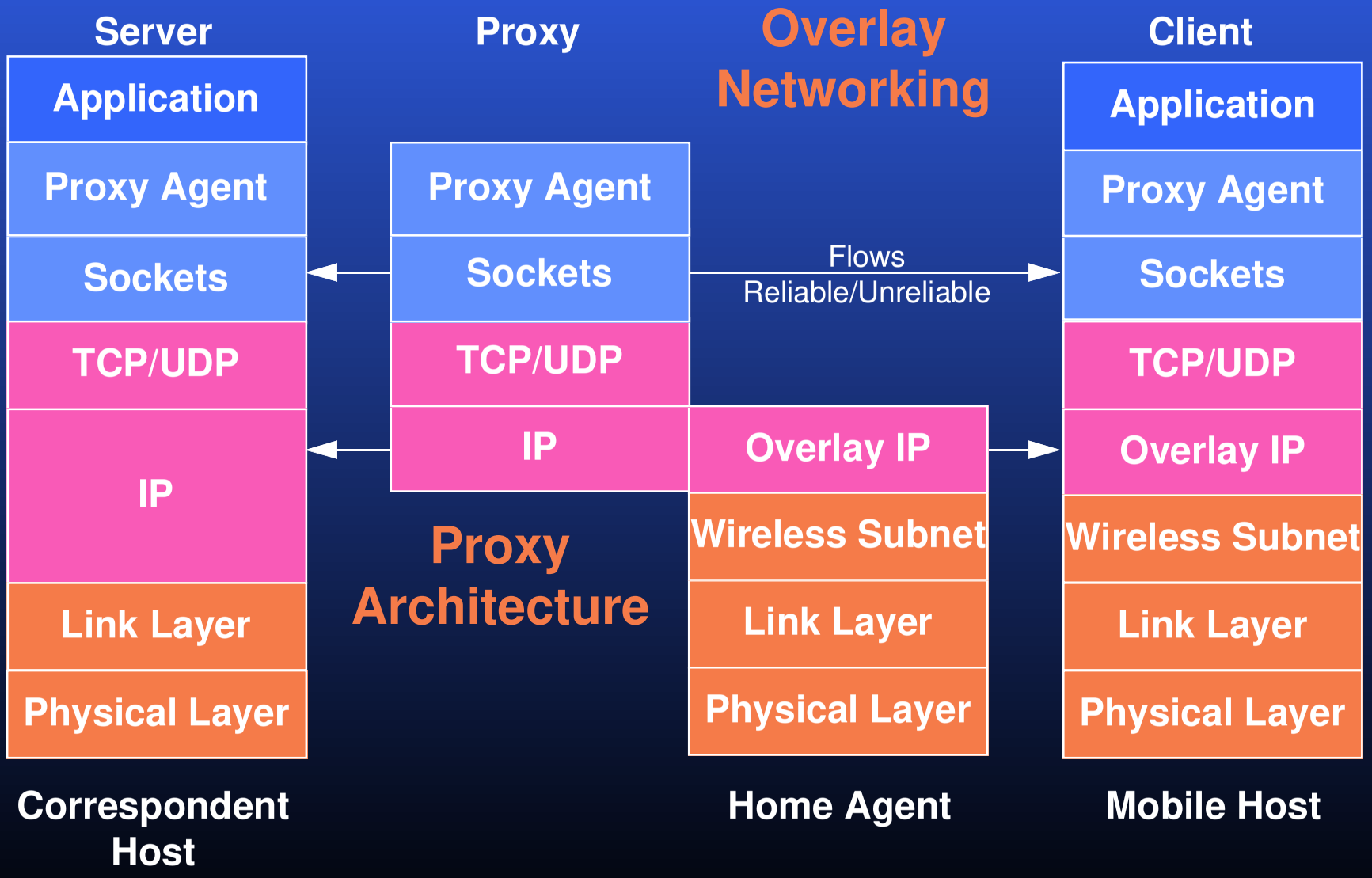
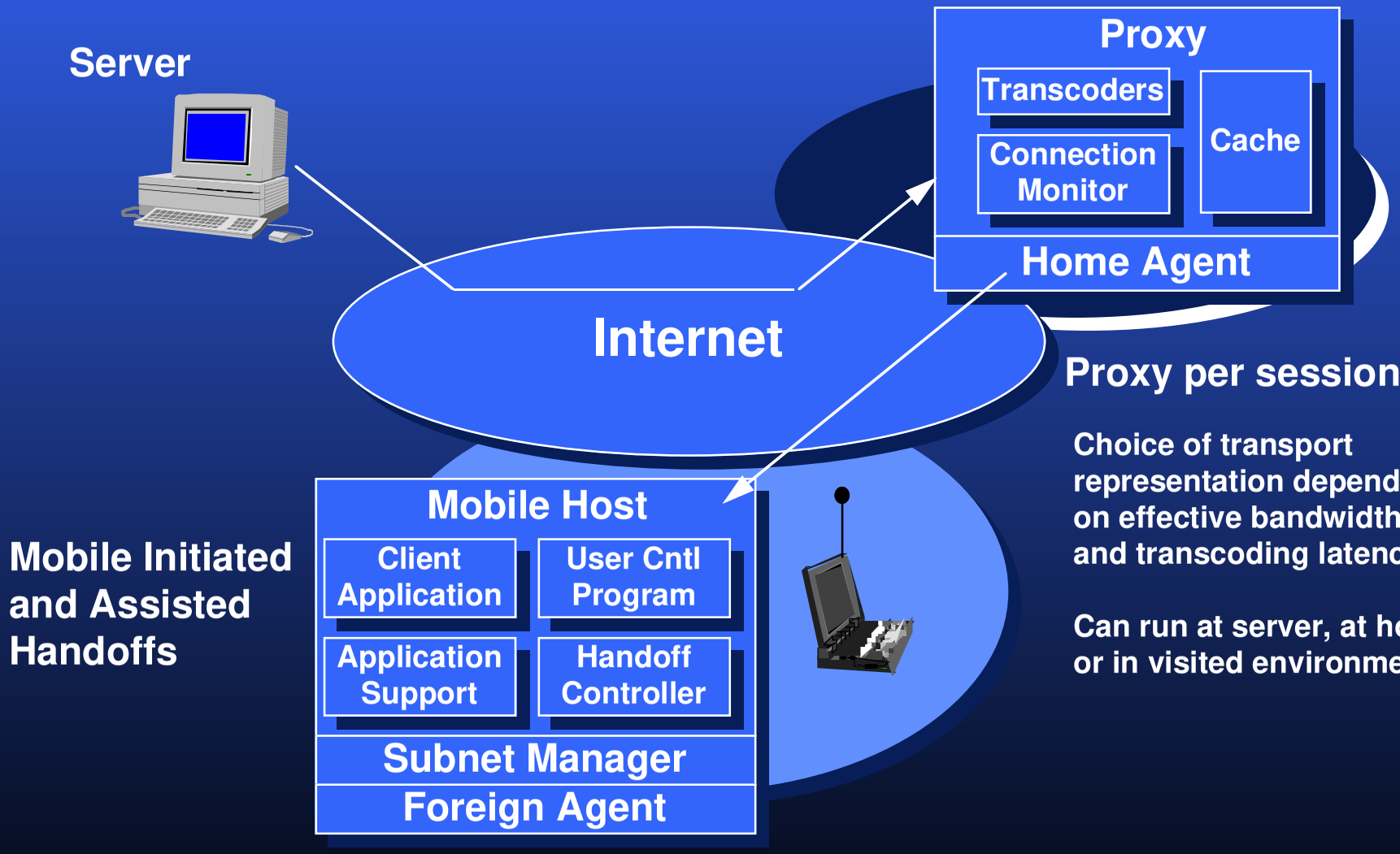
# Application/Network Architecture



# System Architecture



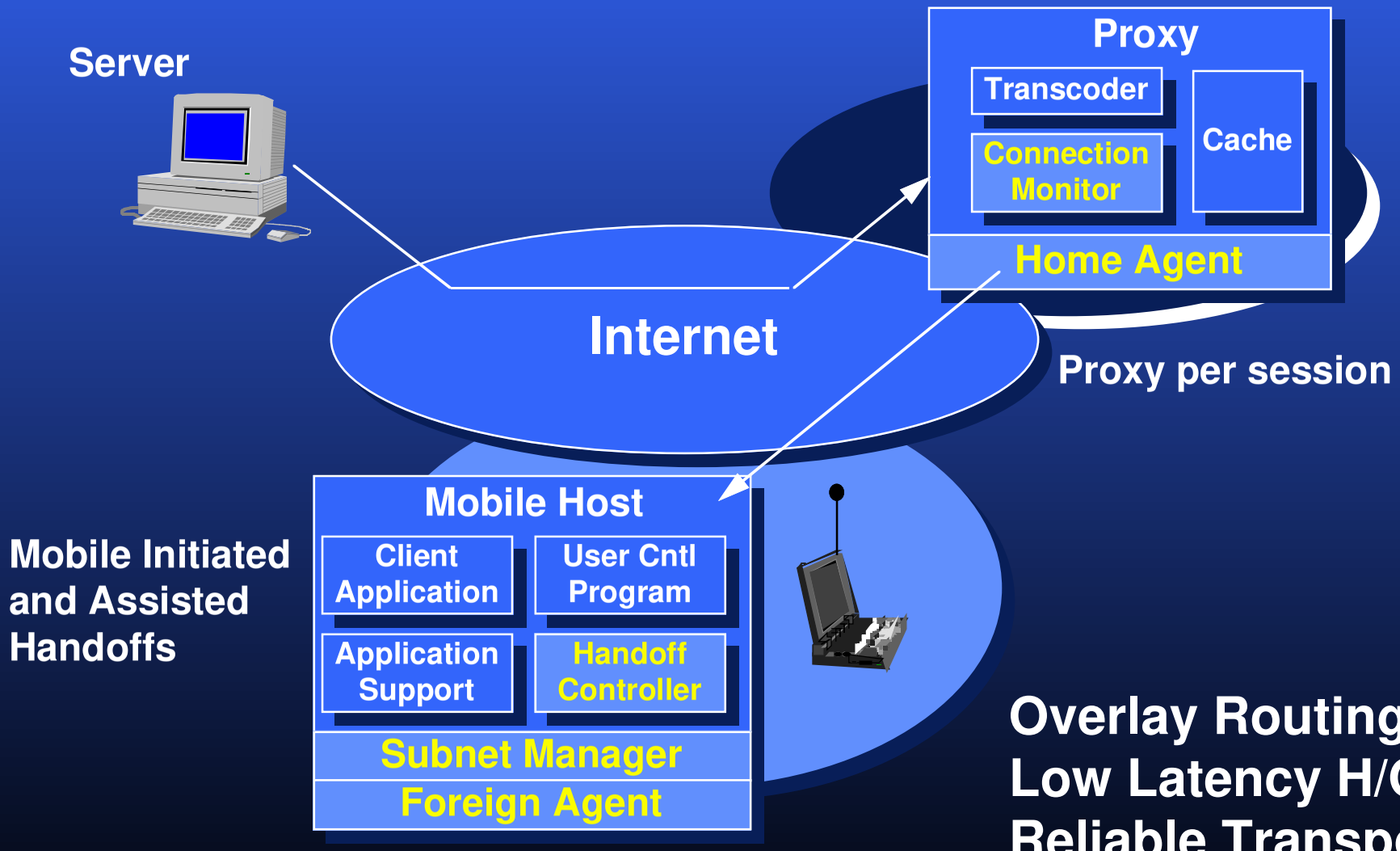

Mobile Initiated and Assisted Handoffs

Proxy per session

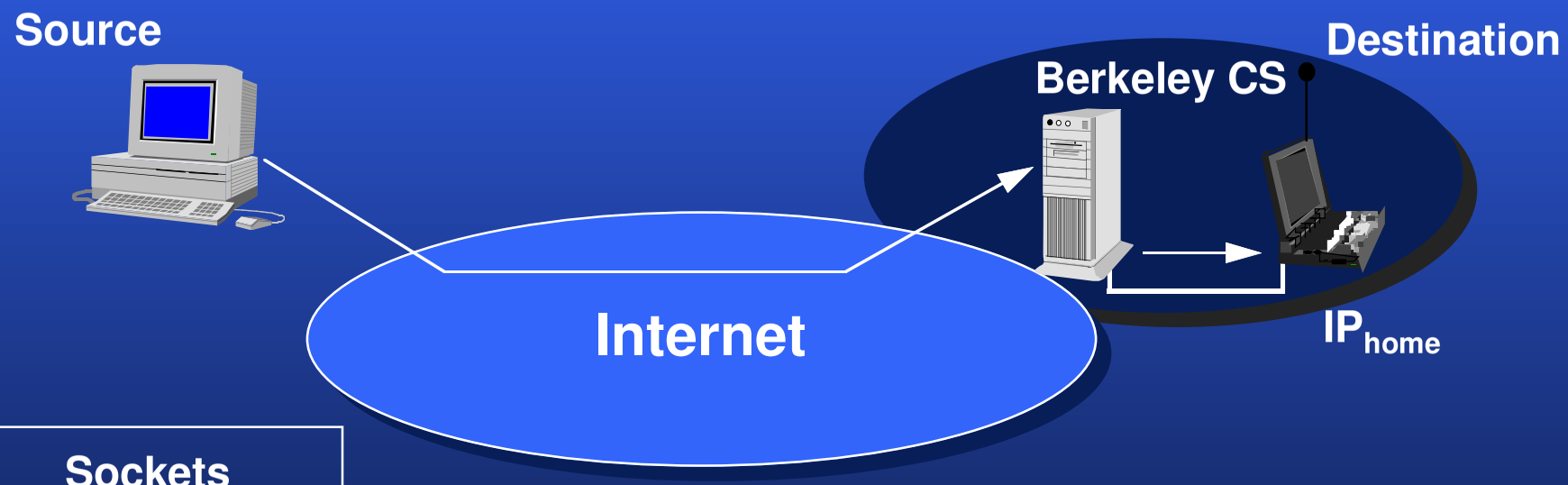
Choice of transport representation depends on effective bandwidth and transcoding latency

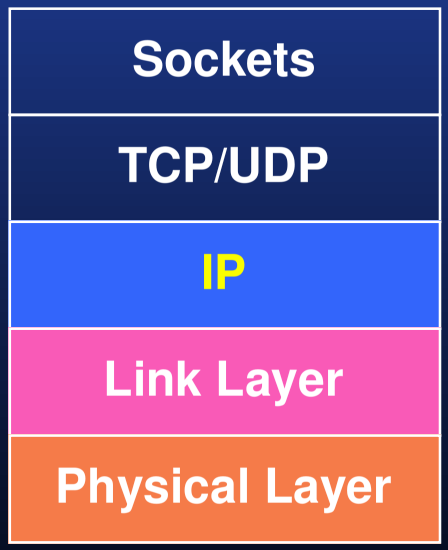
Can run at server, at home, or in visited environment

# System Architecture: Overlay Networking

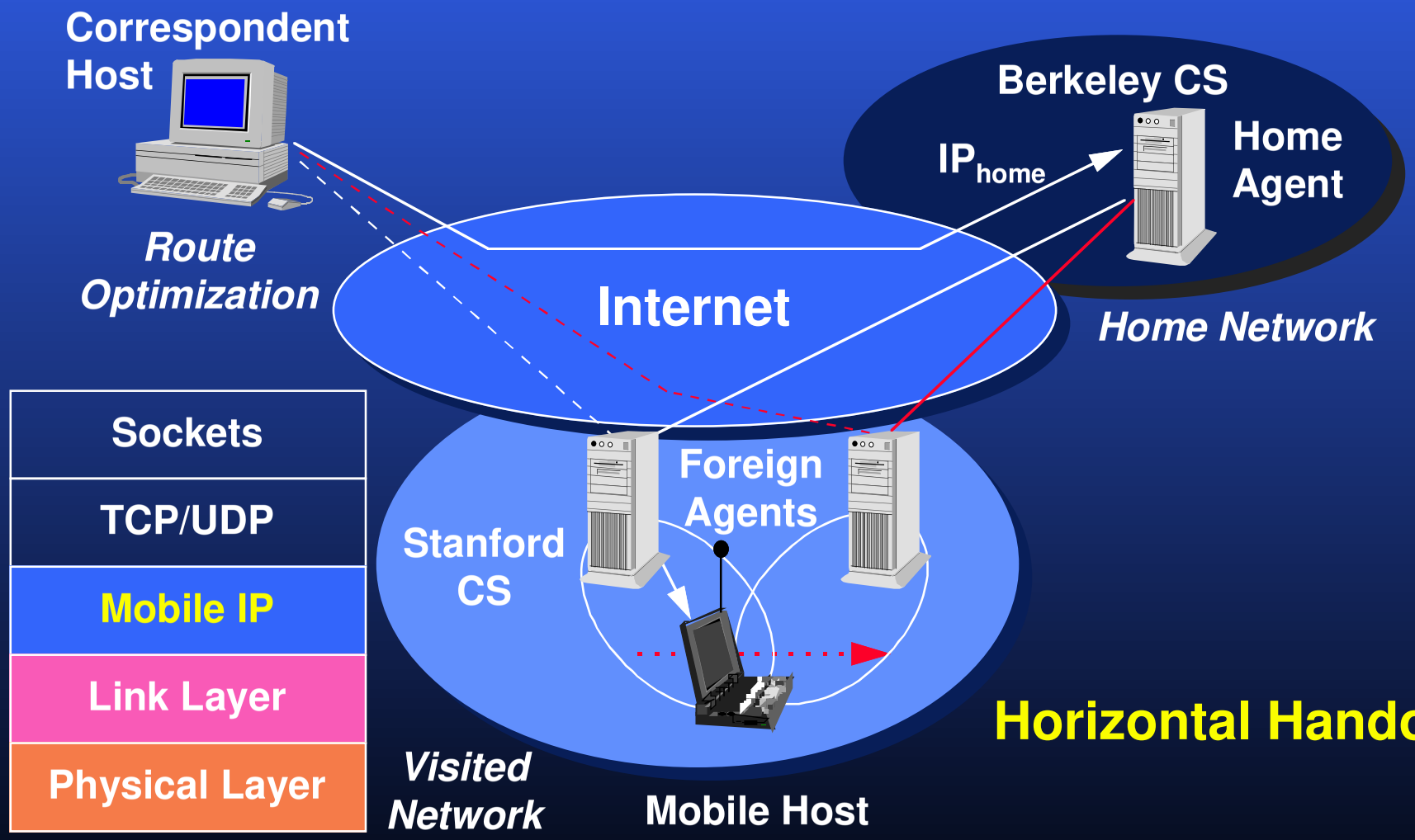


# Overlay Routing: IP Routing

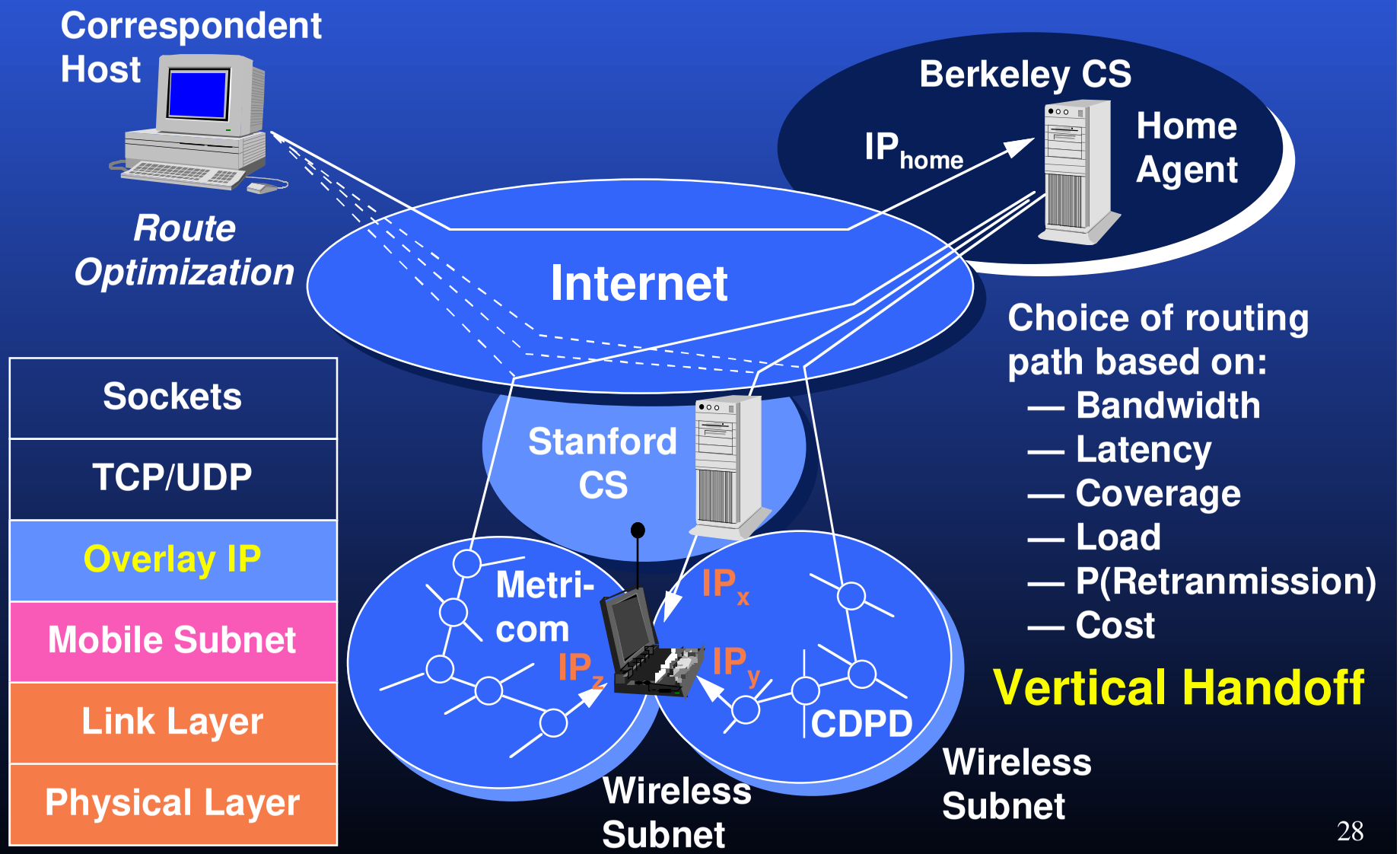


# Overlay Routing: Mobile IP



# Overlay Routing: Mobile IP + Multi-homed Hosts

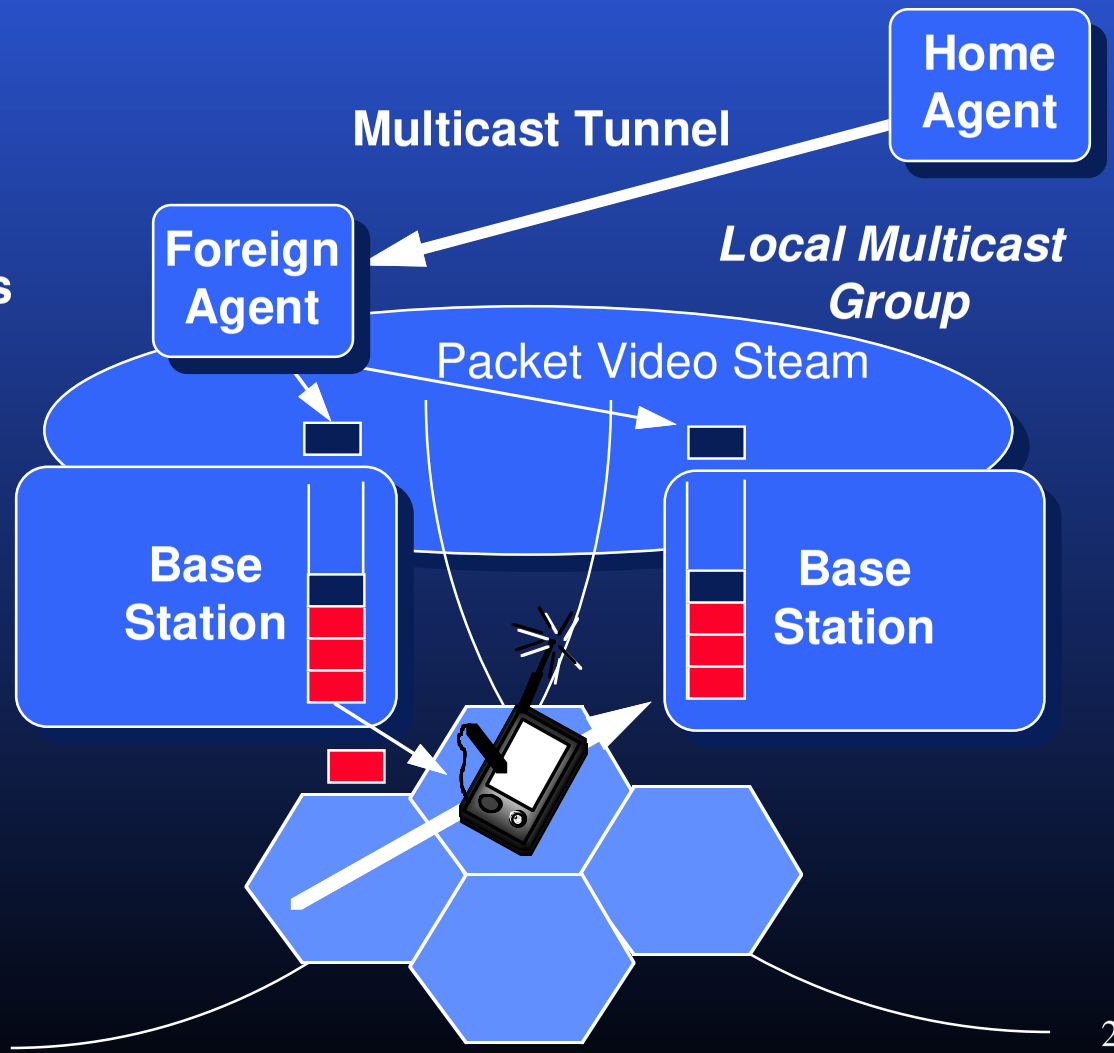


# Low Latency Handoff

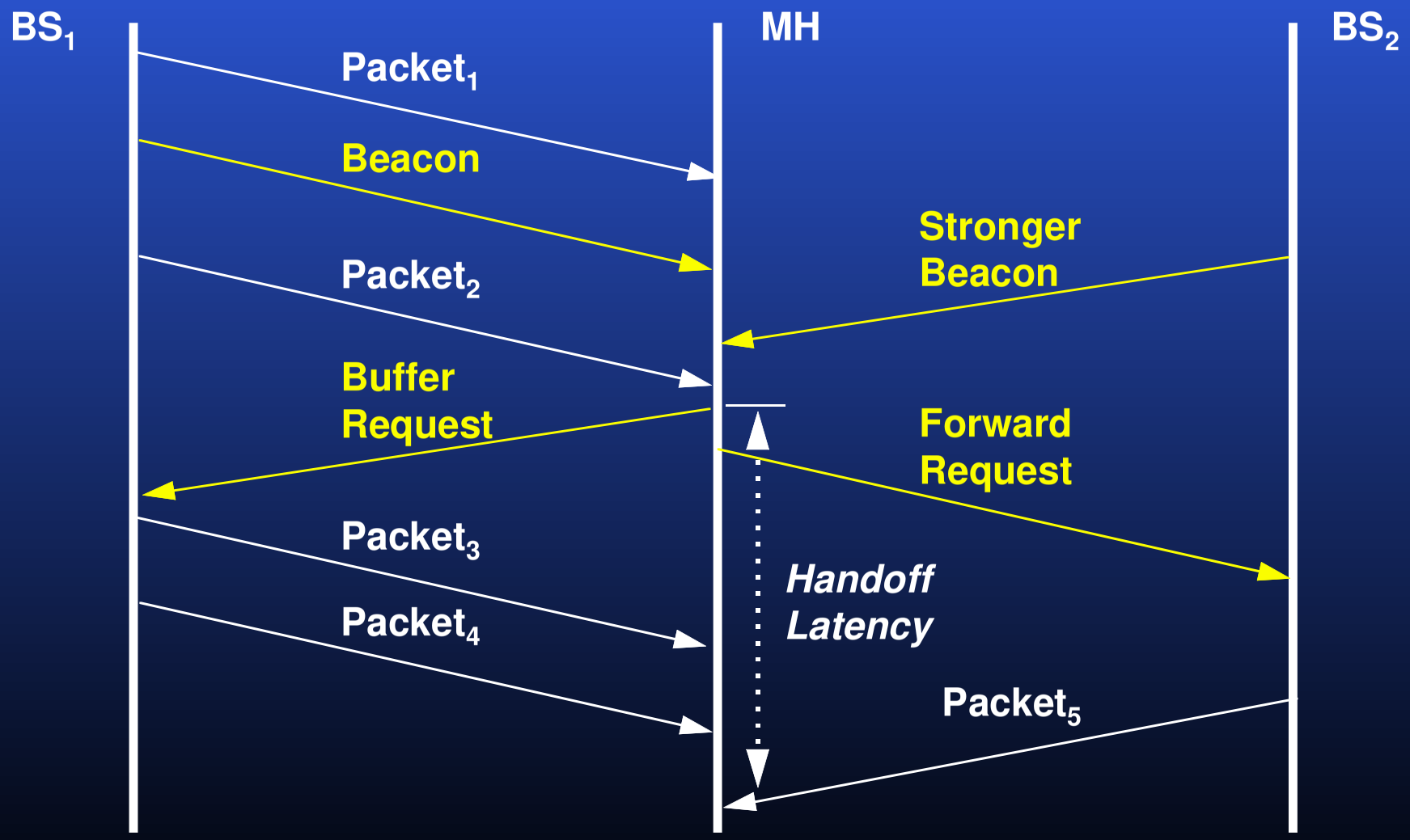
Use hints about terminal trajectory to form MC groups

Multicast packets to "regional" base stations to smooth hand-offs for R/T streams

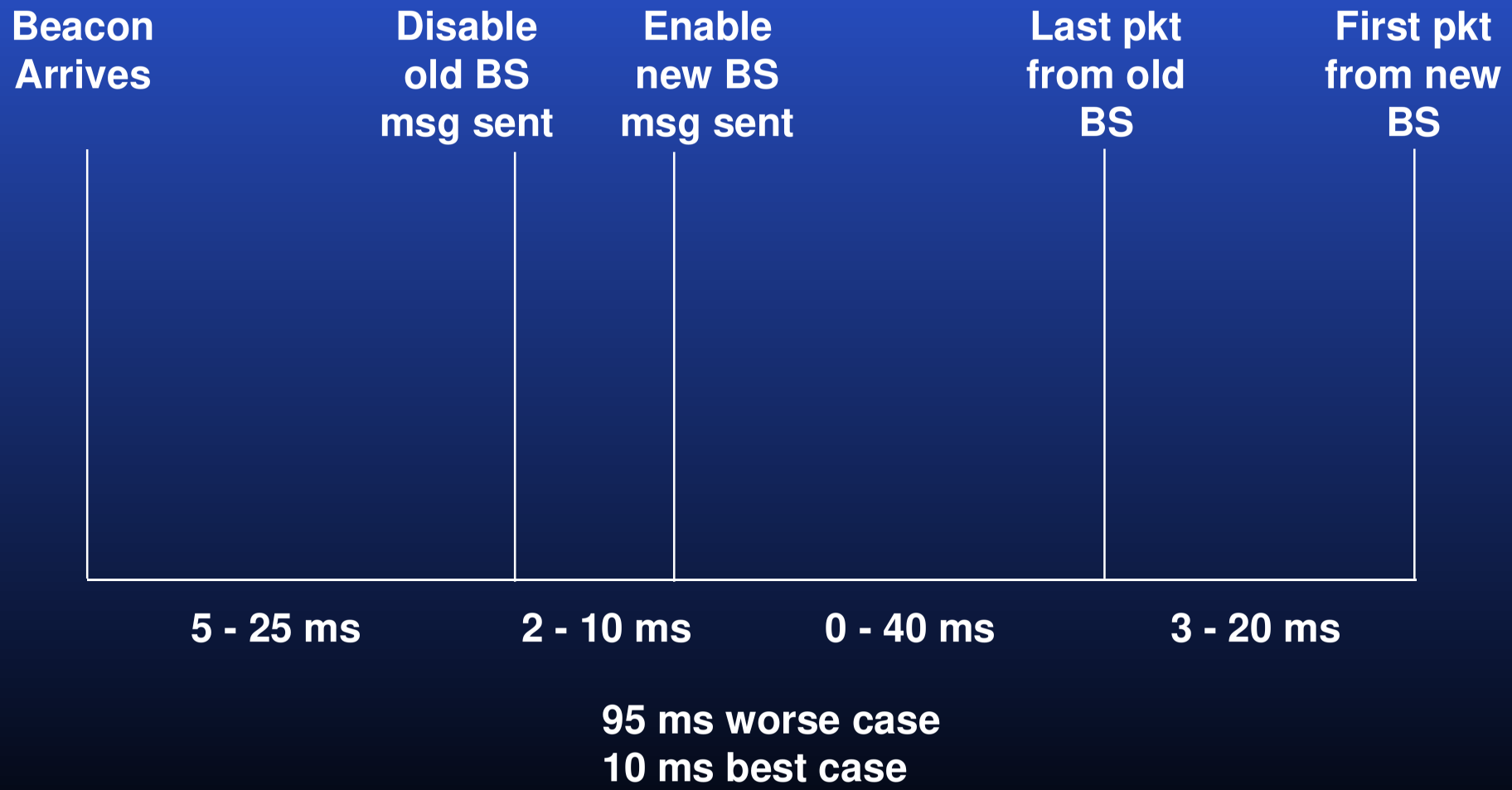
Minimize location update traffic to home agent and mobility aware CHs



# Typical Handoff Messaging

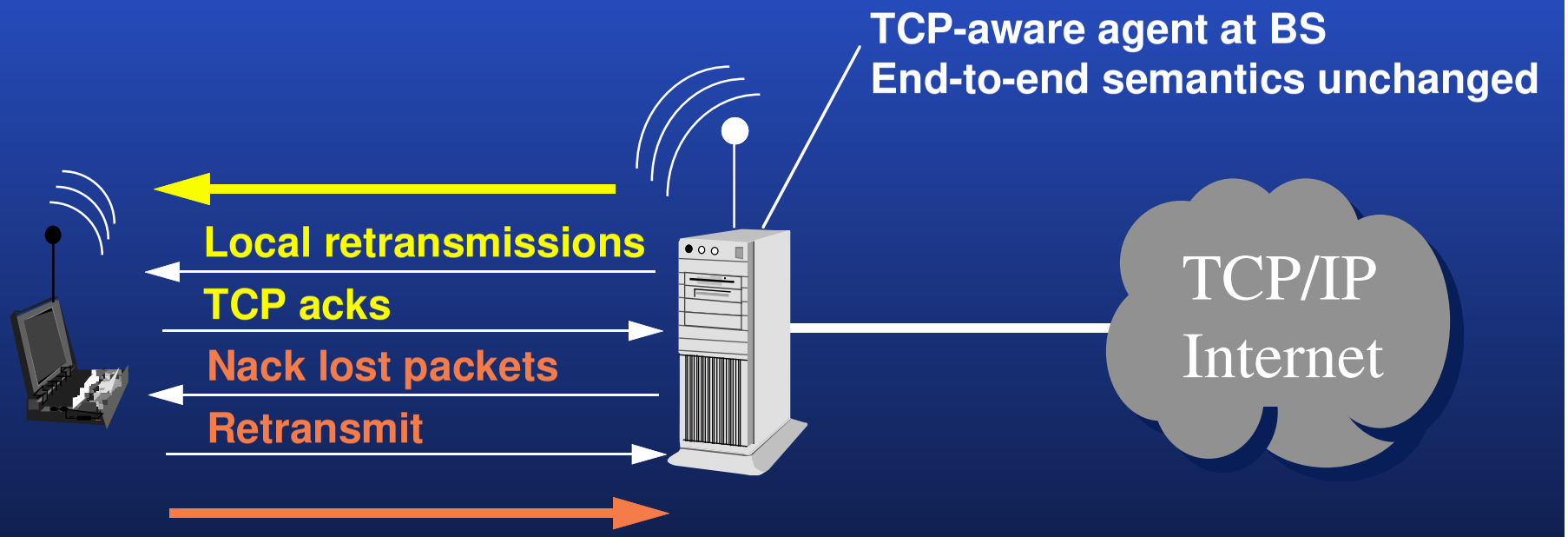


# Measured Handoff Latency




95 ms worse case
10 ms best case

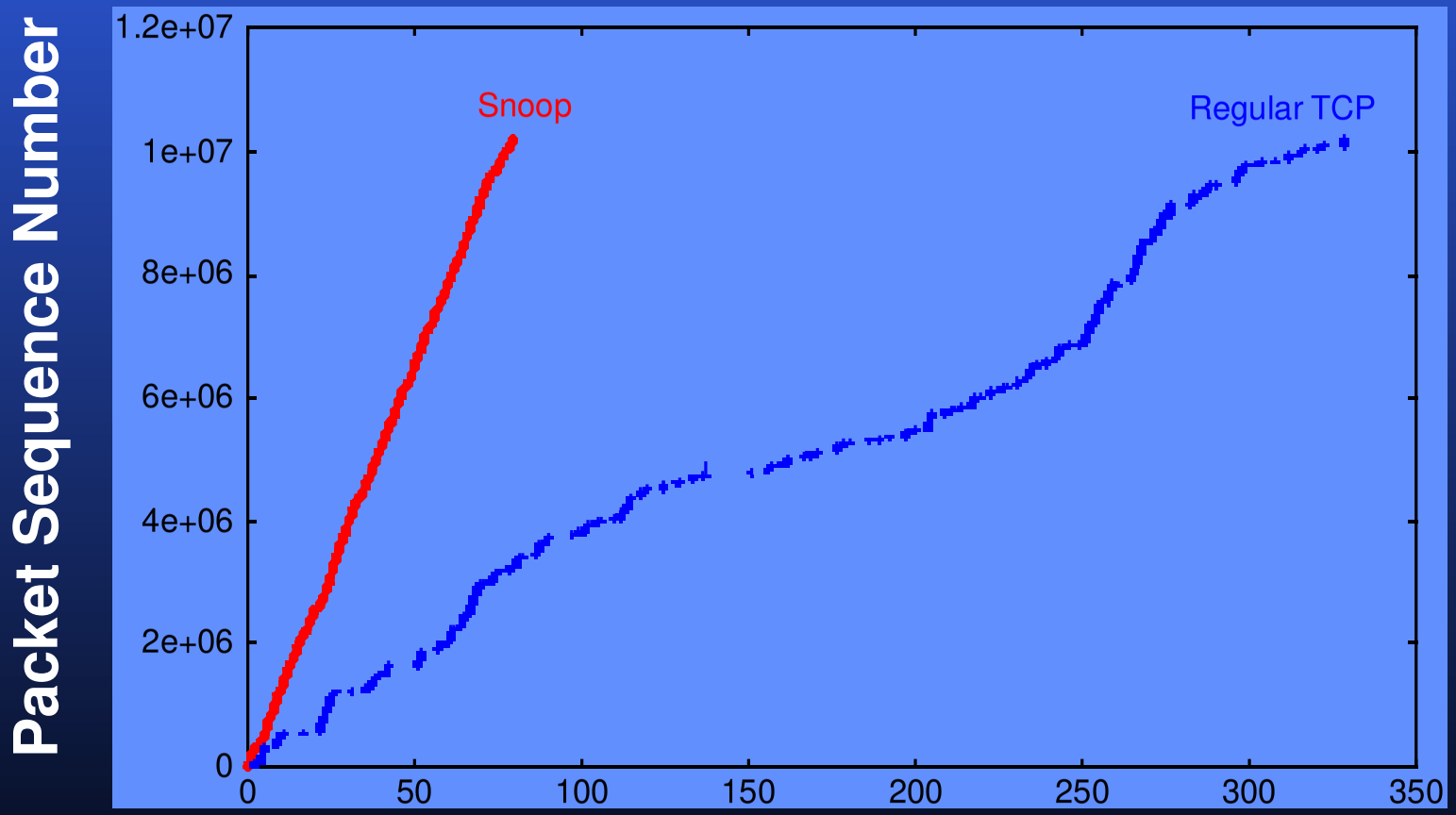
# Reliable Mobile Transport: Snoop Packet Filter



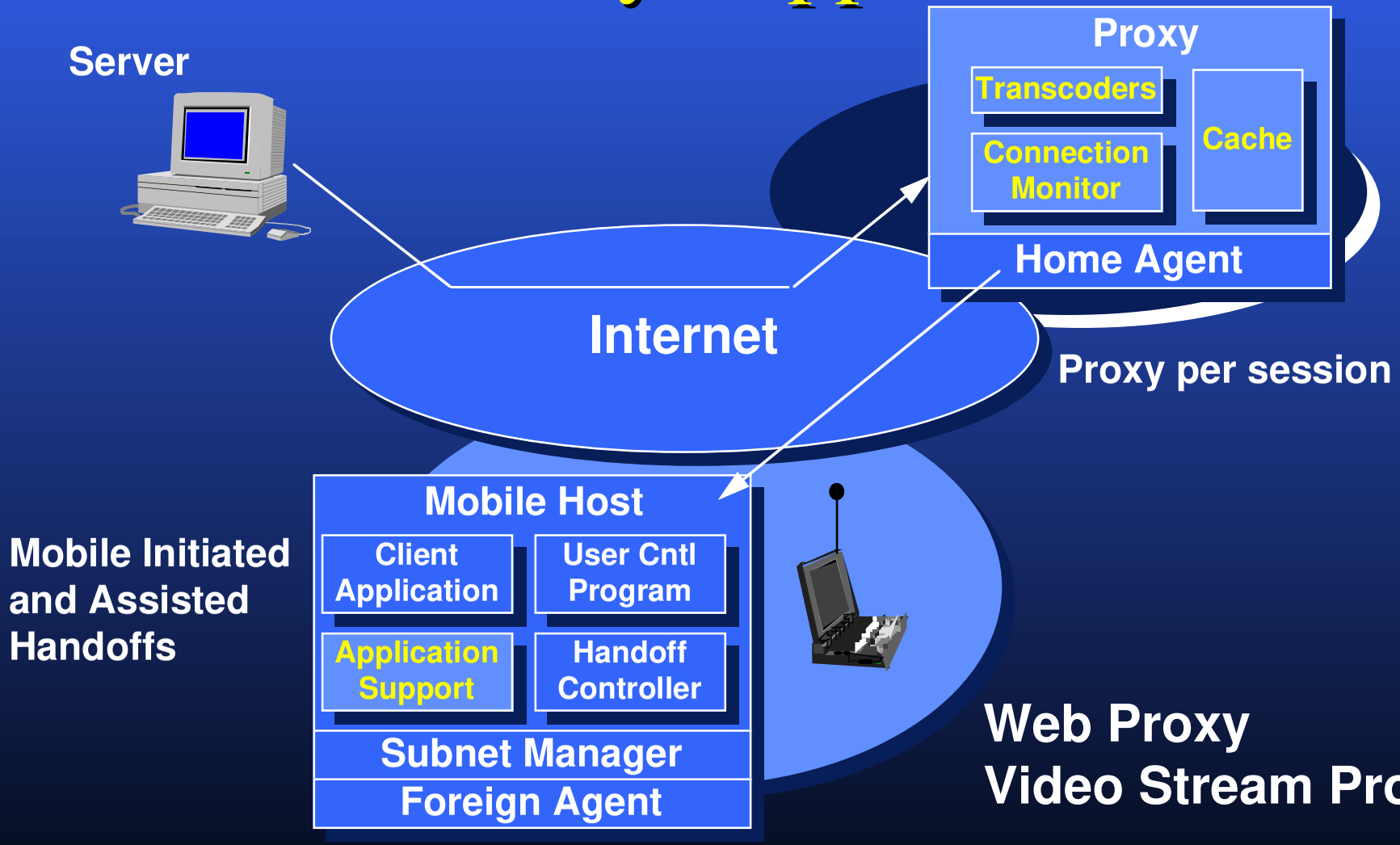

Cache unacknowledged packets at BS (costs extra “soft” state)
Perform local retransmissions based on duplicate acks & time outs

Base station explicitly NACKs lost packets from MH using Selective Ack (SACK) mechanism

# Snoop vs. TCP Performance



# System Architecture
# Proxy Support



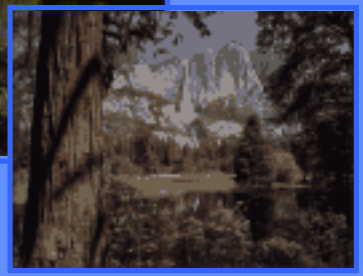
# Web Proxy: On-Demand Distillation

78 colors,
49K bytes

4 grays,
530 bytes,
<2 sec.

>256 colors,
759K bytes (1024x768)

16 colors,
12K bytes,
<6 sec.



- Lossy compression that preserves semantic content
- Each *transcoder* is datatype-specific

***Distillation works in real time on desktop PCs***

# Web Proxy: Image Refinement

- View some part of distilled object at higher quality
- Example: Zoom in on region of an image

*249 colors, 12K bytes, <1 sec.*

*Refinement allows you to expend bandwidth on only the things you're interested in*

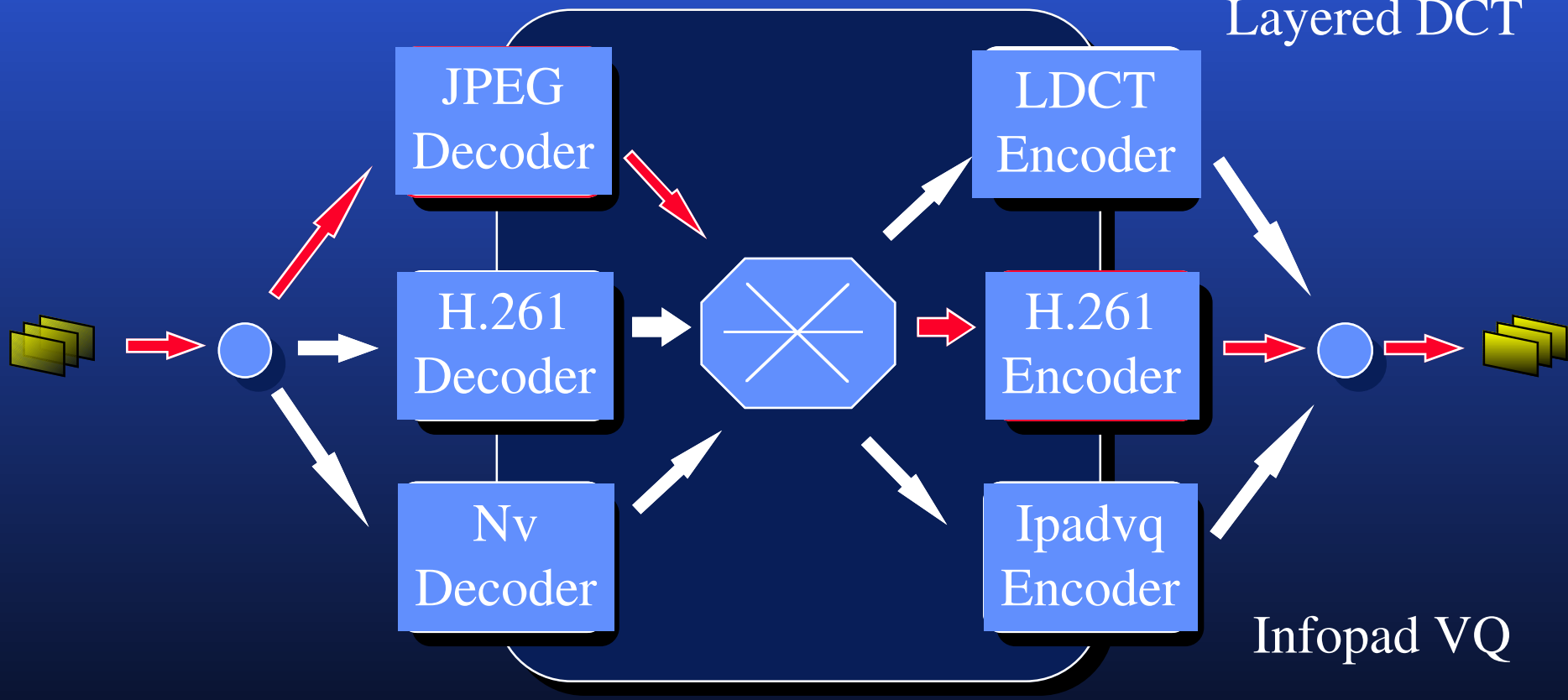
# Web Proxy: Execution Times

| 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 |

*Image refinement times on a SparcStation 20*

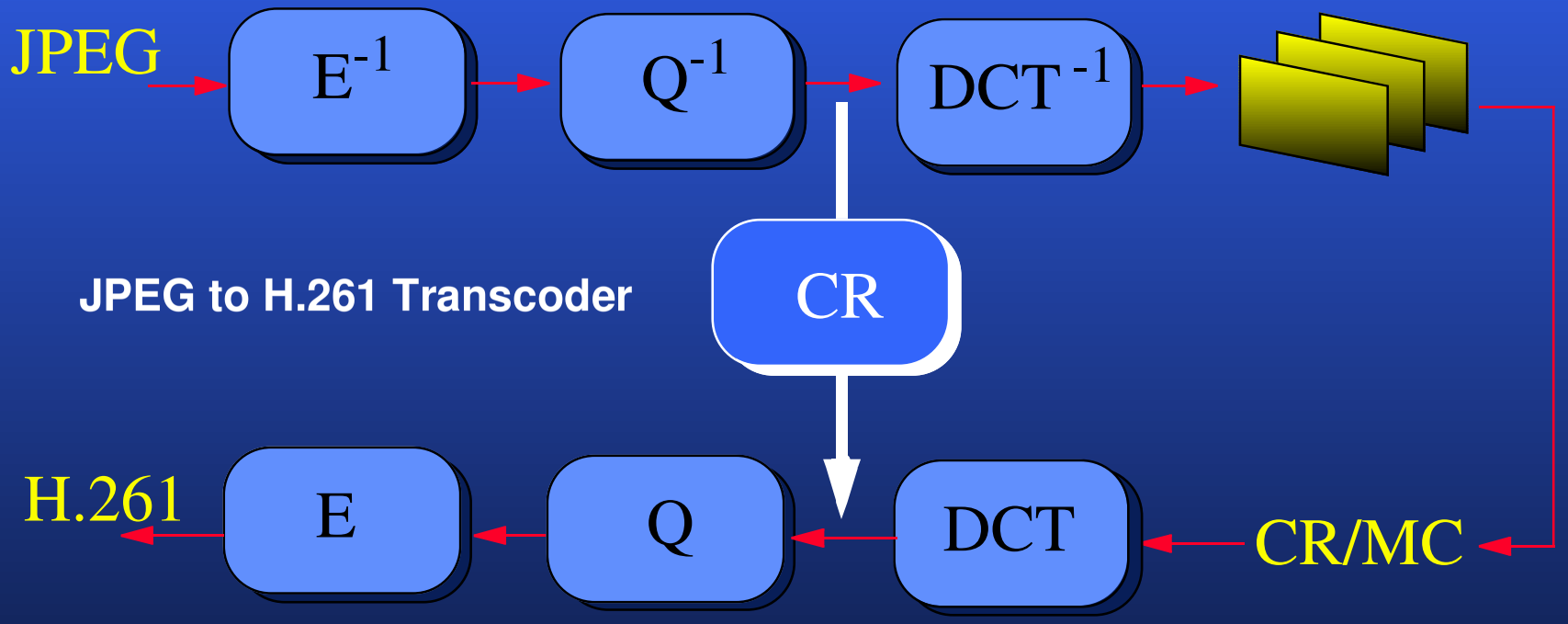
*Contrast with time tp transmit @ 10-20 kbps*

# Video Stream Proxy: Video Gateway




**Motivation: Heterogeneous Video Conferencing Environments**

# Video Transcoder Optimizations




- Prototype proxy
- R/T transcode from high b/w video to low bandwidth video formats
- Integrated with existing Internet MM infrastructure via RTP

| Motion | Full Dec/Enc | DCT Dec/Enc |
|---|---|---|
| Low | 26 fps | 30 fps |
| High | 15 fps | 27 fps |

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

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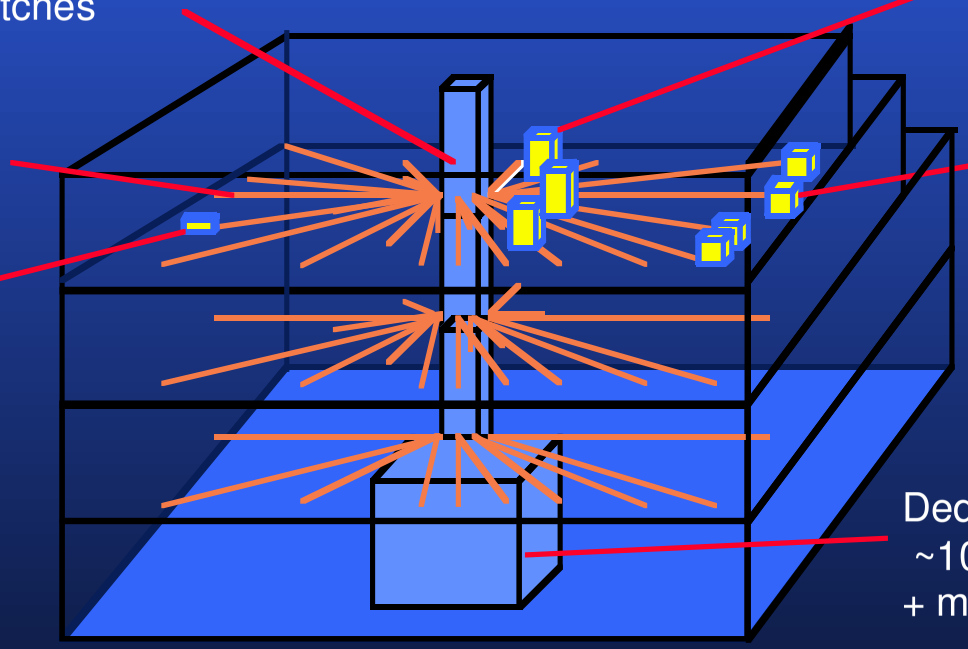
# Local Area Wireless Testbed
# Soda Hall, UC Berkeley

Scalable, High Bandwidth
Low Latency Switches

Organized
Fiber Physical
Links

Wireless
Transceivers



Computing / Interactive
“Light” workstations

Interactive
Media Access
workstations

Dedicated Computing Resources
~100 “dark” workstations
+ mass store, special servers

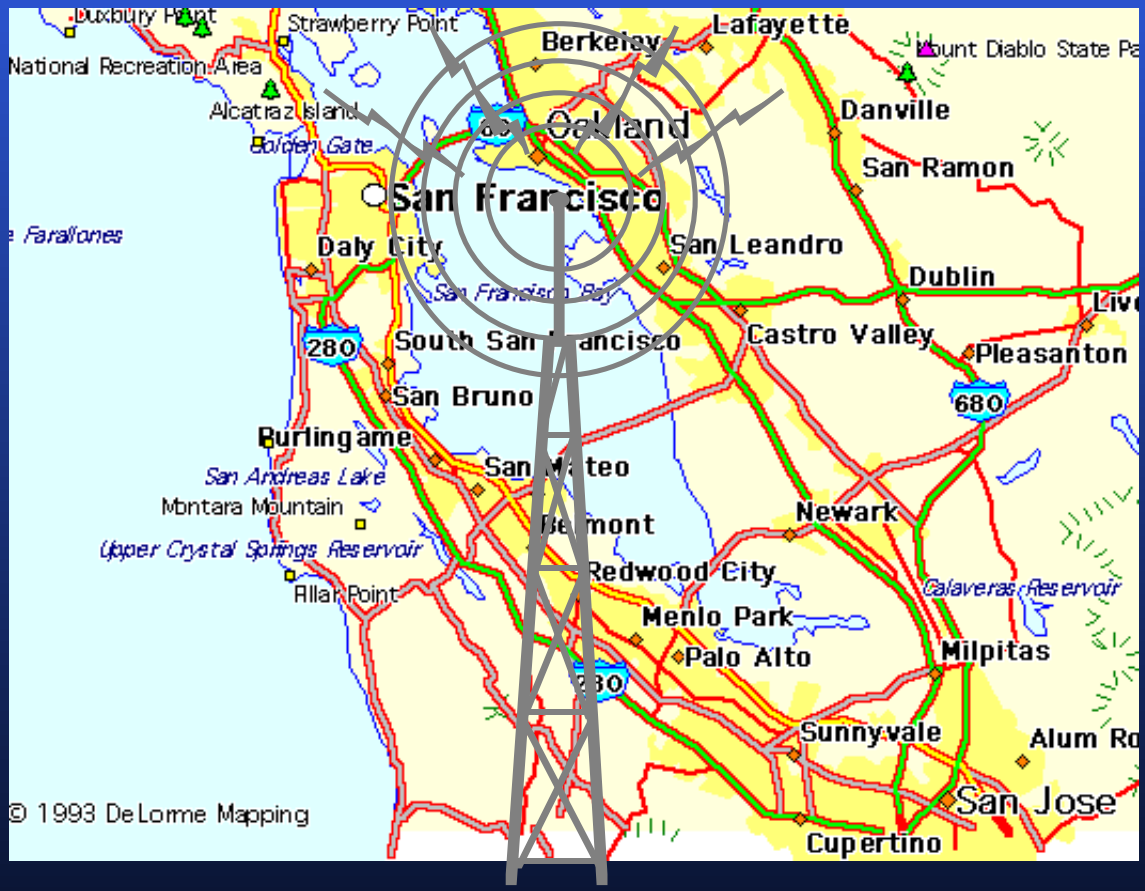
**Cooperative In-building Wireless Overlays:**

- **IR for offices, meeting spaces, classrooms**
- **RF overlay for “between” spaces, connectivity load sharing**

**Integration with building-scale computing resources**

# Wide-Area Wireless Testbed

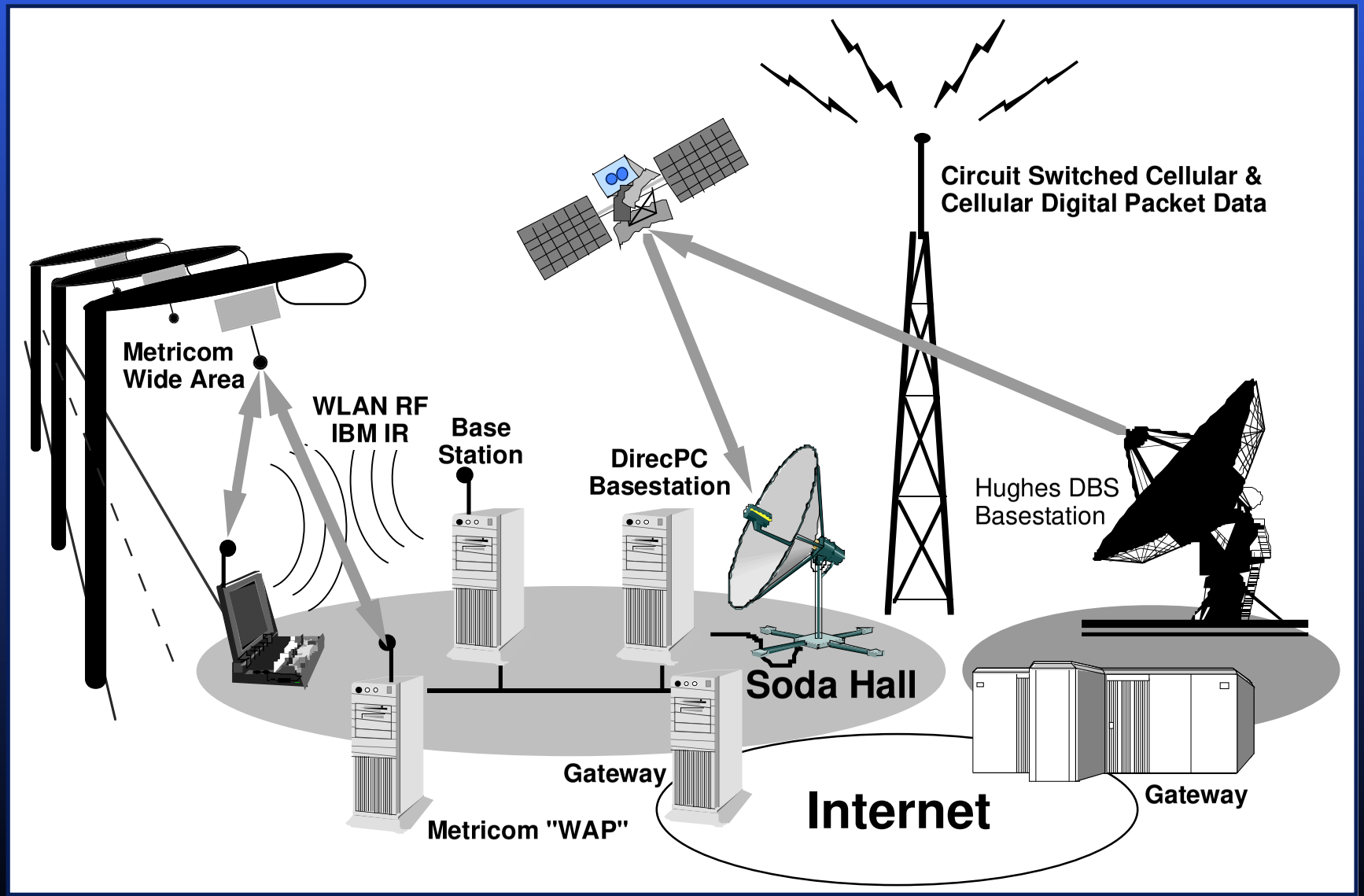
**Multiple Overlayed Wireless Networks**




**Seamless Mobility Across Overlays**

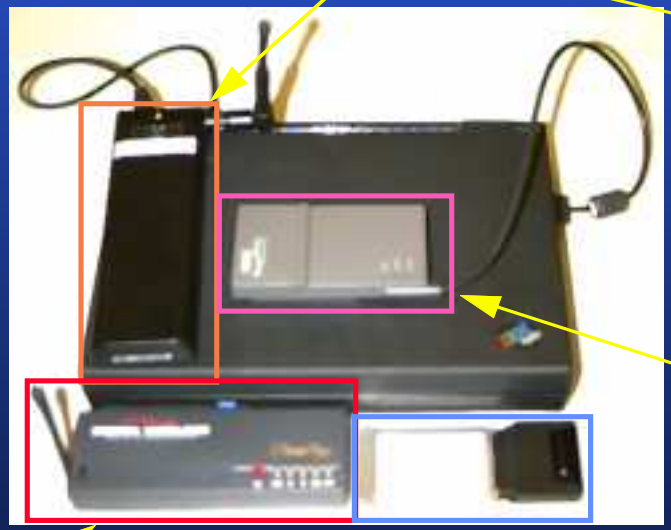
**Early deployments of new wireless technologies**
**E.g., Metricom packet radio network**

# BARWAN Testbed



# BARWAN Testbed

Metricom Packet Radio



WaveLAN PCMCIA Card

CDPD Modem

IR PCMCIA Card

IBM ThinkPad 755x
BDSI OS 2.1

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# Marconi's Vision Re-visited

"It is dangerous to put limits on wireless."

Guglielmo Marconi (1932)

# Summary

- Wireless data is *not* dead
  - Moving from hardware and infrastructure to services
- Access is the killer app
  - Connectivity through wireless overlays
  - Adaptivity through proxy services
- Need for IP-dial tone
  - IP to the pager, phone, PDA, laptop, etc.
  - Internet service integration
    - » But a phone is not a workstation:
      limited bandwidth, local storage, displays
  - Better strategies for interoperation and co-existance

# Conclusions

- Promising Approaches:
  - Wireless Overlay Internetworks
  - Proxy Architecture
- Many of these ideas apply equally well in today's heterogeneous network environments
  - Asymmetries in satellites and cable modem links
  - High loss links: bandwidth achieved?
  - Adapt representations to the quality of the end device and its network connectivity