Presentation Outline

- Historical Overview
- Radio Fundamentals
- US Developments in PCS
- Mobile Data
- Satellite Systems
- **Problems with existing schemes**
- Wireless Overlay Networks
- US Government Research Initiatives

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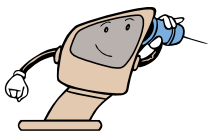
Interoperability?

- **Dueling "standards":**
  - **Cellular: analog AMPS, narrow AMPS, digital TDMA, CDMA**
  - **PCS technology: all digital, but 8 different proposals dominated by European and Japanese standards already deployed**
  - **LEO services: similar problems due to diverse, non-interoperable systems**
- **Impact on competitiveness of U.S. industry?**
  - **Compare to the HDTV Grand Alliance**
  - **International consumers want interoperable systems**



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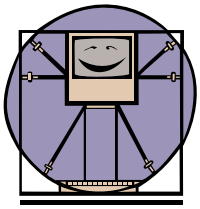
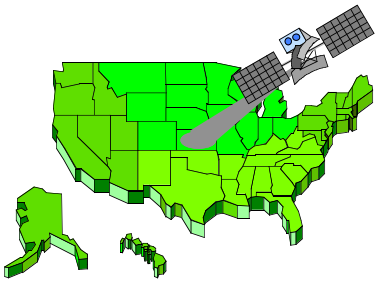
Ubiquity?

- NII focus on telcos and cable
- Little discussion of roles of wireless and satellite (at least until Gore's speech to the ITU)
- Interoperability of wireless/wireline networks
- Satellite services potentially attractive for rural, "fill in the hole" coverage





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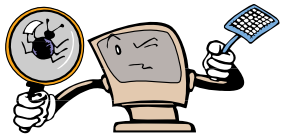
Flexible Regulatory Environment?

- Rapid technological progress enables new services; regulatory environment limits dissemination
  - hold back some spectrum for experimentation
- Difficult to reallocate once allocated
  - "Negreponte Switch": only mobile services should be wireless; stationary services should be wired
    e.g., relegate TV broadcasting to cable
- Not efficiently allocated
  - LOS microwave tenants in allocated PCS bands



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Beyond Voice?

- **Wireless "killer app" is telephony**
  - Industry focus on low bandwidth voice
  - Higher bandwidth data communications not considered
  - B&W to Color TV analogy
- **Variable rate vocoder designs impact data transmission characteristics**
  - Finely tuned to the human voice
- **Narrow-band vs. broad-band focus**
  - Broad-band modulation more flexible, but more expensive

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Wireless Data Networks

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

Wide diversity of network performance parameters
Mutually distrusting infrastructure providers
Pedestrian vs. vehicular mobility
APIs that are network-aware

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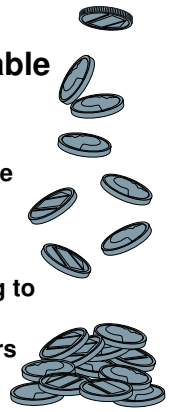
If Competition is Good . . .

. . . is more competition better?

- Many cellular companies are barely profitable
  - National network created through acquisition binge
  - Took many years to build interoperable network
  - Successive waves of new users generate less income
- PCS: the next $0 billion business?
  - Many franchises per market
  - Auction process driving large scale consortia hoping to create national-scale networks
  - Cut-throat competition with existing cellular providers



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Some Observations (and Fears)

- US strategy: pro-competitive market regulations
  - Multiple cellular standards, no cordless standards
  - Absence of mandatory, strict technical standards leads to significant incompatibilities
    - » fosters proprietary standards
    - » highly fragmented market
    - » provision of nation-wide services increasingly difficult
    - » prohibitively expensive to build next generation system
    - » who can afford to build advanced mobile communications systems?
- European strategy: few, widely adopted, consensus-developed standards

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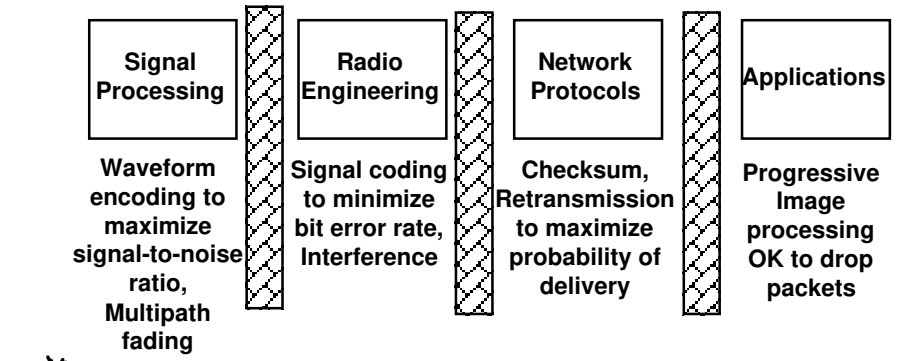
Crossdisciplinary Expertise Needed



Optimized Result?

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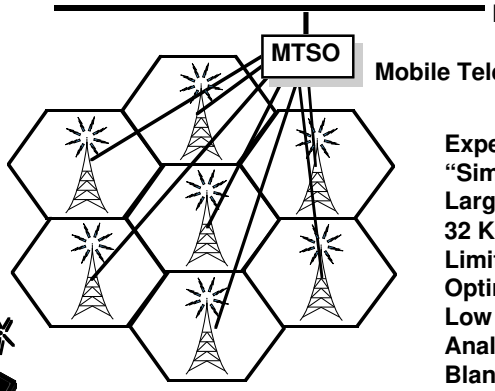
Cellular Phone Model

Centralized Intelligence



Expensive Switches
"Simple" Basestations
Large (40 m) Antennas
32 Km radius
Limited Handoff Capability
Optimized for Voice Channels
Low Bandwidth (< 32Kbps)
Analog Design
Blank & Burst Signaling

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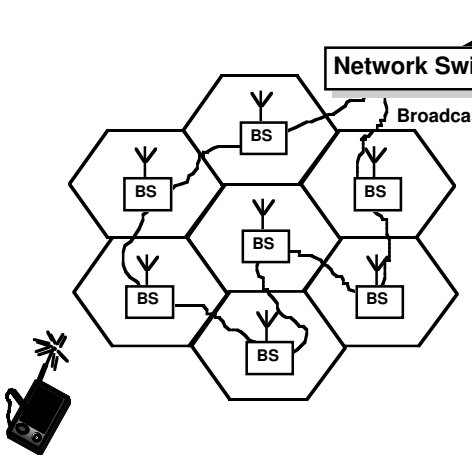
Micro/Nano Cellular

Smart Infrastructure



Inexpensive Switches
Smart Basestations
Small Antennas
100 m radius
Extensive Handoff Capability
Optimized for Data Channels
High Bandwidth (>1Mbps)
Digital Design
Dedicated Control Signaling

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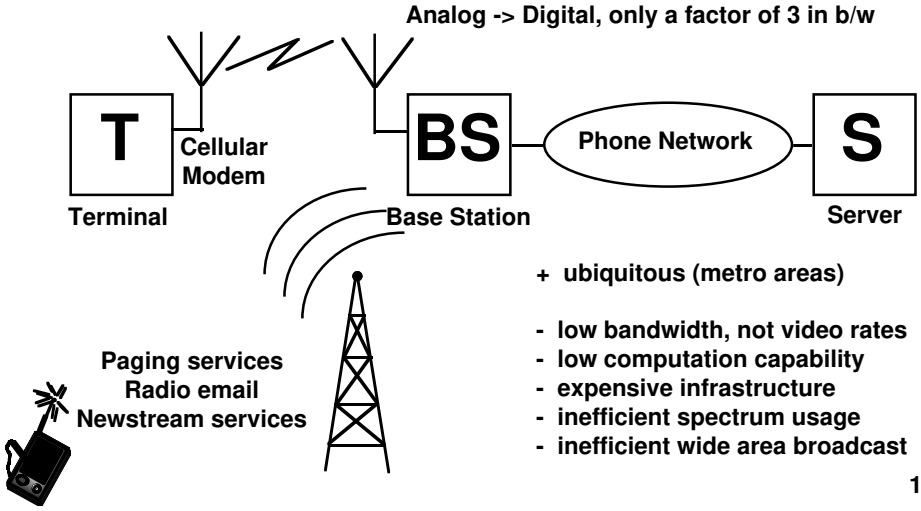
Architectural Alternative #1

TelCo View



+ ubiquitous (metro areas)

- low bandwidth, not video rates
- low computation capability
- expensive infrastructure
- inefficient spectrum usage
- inefficient wide area broadcast

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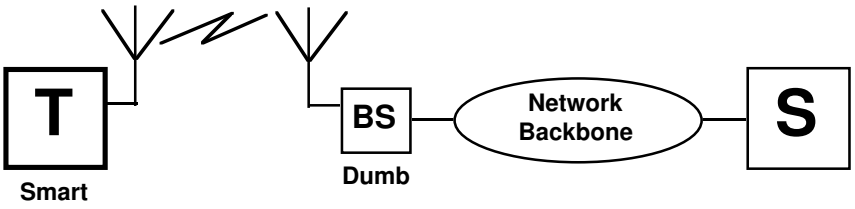
Architectural Alternative #2

Computer Vendor View



+ standalone terminal works when detacted or the network is down

- power in the portable unit
- file system reconcilation when re-attached
- existing wireless LANs don't allow terminals to move

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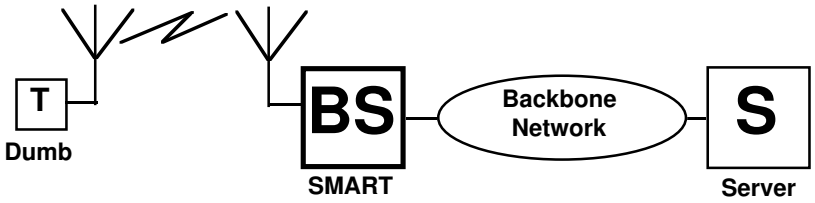
Architectural Alternative #3

Alternative View: **"Smart" Infrastructure**



+ low power possible = long battery life
+ centralized file system image

- useless when decoupled from network

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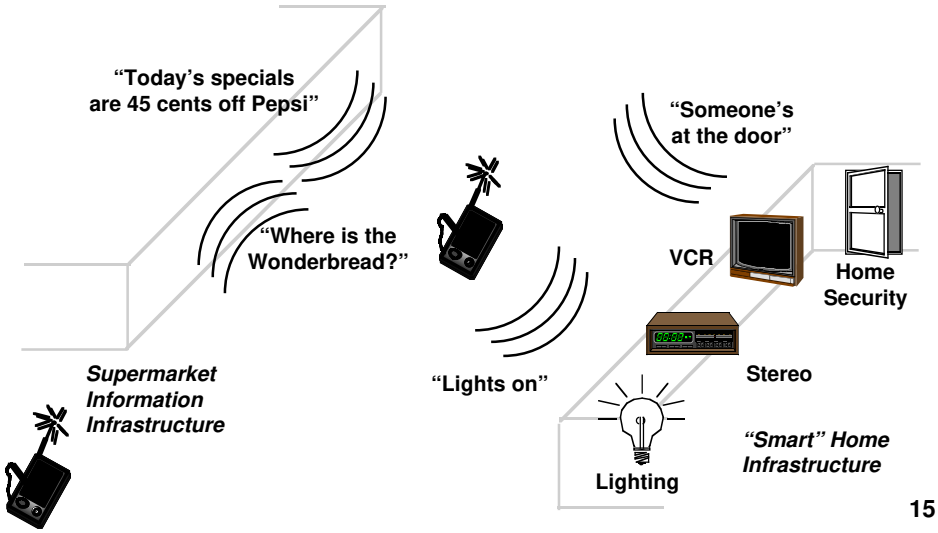
Universal Interactor: Adaptation to Services



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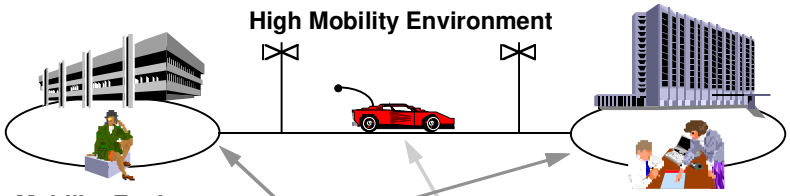
Adaptation to Mobility

To enable users to take their "InfoEnvironment" with them …



Low Mobility Environment

High bandwidth in-building infrastructures

Complex security/privacy issues
Guest users of infrastructure
Protecting privacy of users

Low Mobility Environment

Lower bandwidth outside infrastructures + asymmetric (low b/w uplink, high b/w downlink)

Leverage existing cellular infrastructure where possible;
Establish "instant infrastructure" when necessary

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