Beyond Third Generation Telecommunications Architectures: The Convergence of Internet Technology and Cellular Telephony

Prof. Randy H. Katz

EECS Department
University of California, Berkeley
Berkeley, CA 94720-1776
randy@cs.Berkeley.edu
http://www.cs.Berkeley.edu/~randy

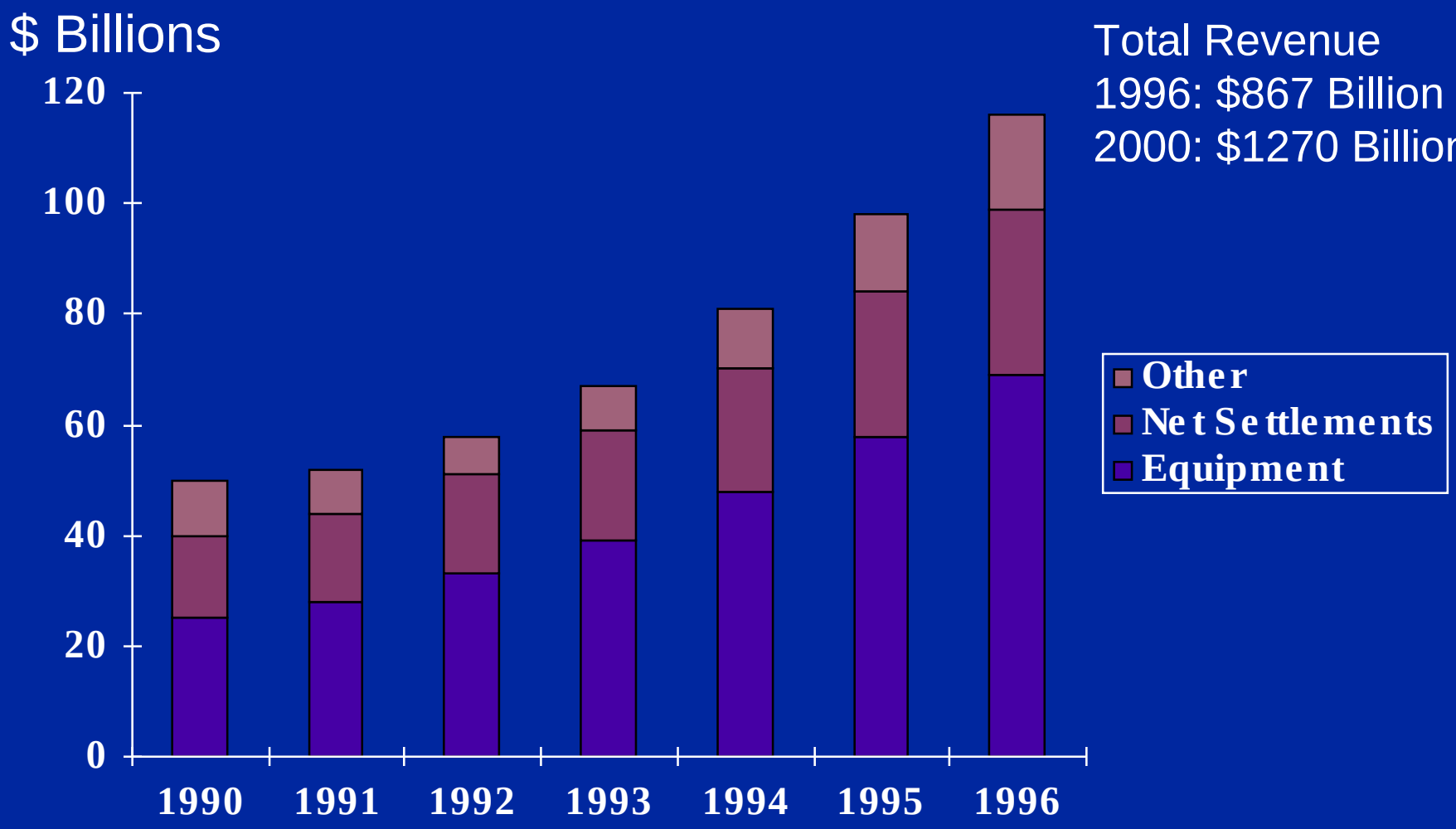
Presentation Outline

- Comparison of Telecomm & Data Comm Industries
- Voice-centric versus Data-centric Viewpoint
- Internet versus Telephone Technology
- Implications Beyond the Third Generation

Presentation Outline

- Comparison of Telecomm & Data Comm Industries
- Voice-centric versus Data-centric Viewpoint
- Internet versus Telephone Technology
- Implications Beyond the Third Generation

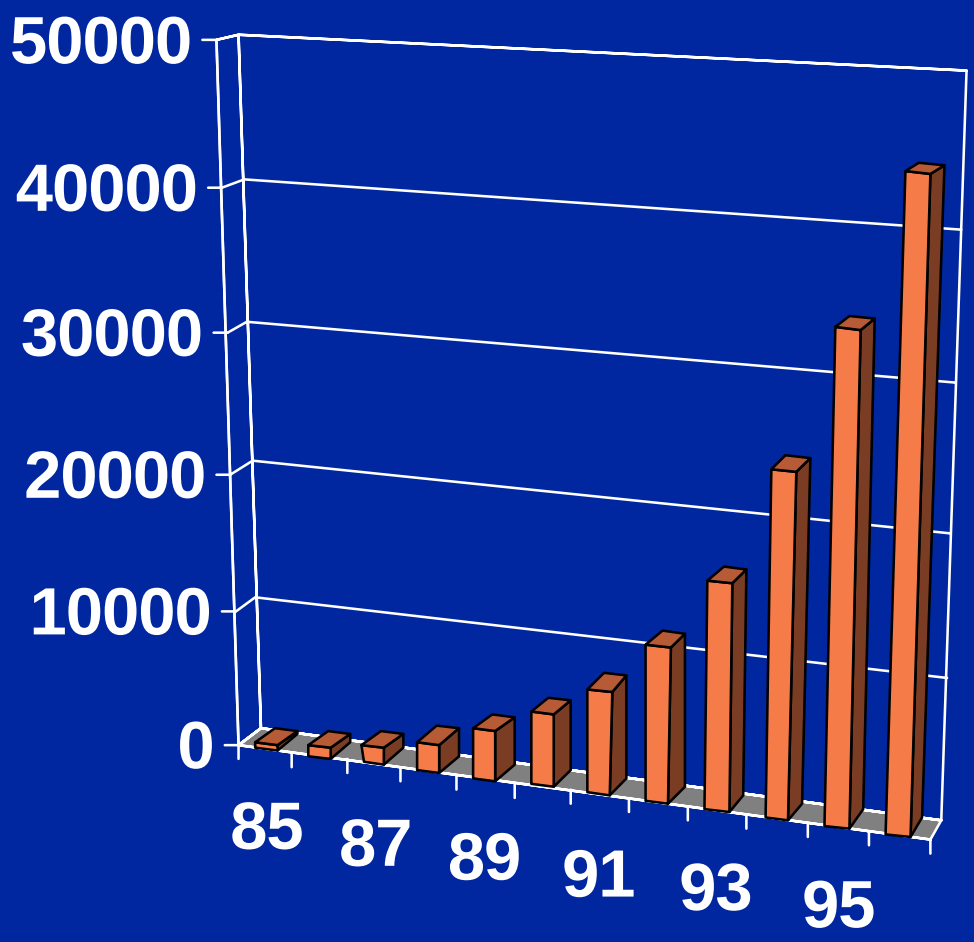
Global Telecommunications Trade



Total Revenue
1996: $867 Billion
2000: $1270 Billion

Source: ITU (The Economist, 8 March 1997)

Cellular Subscriber Growth in US



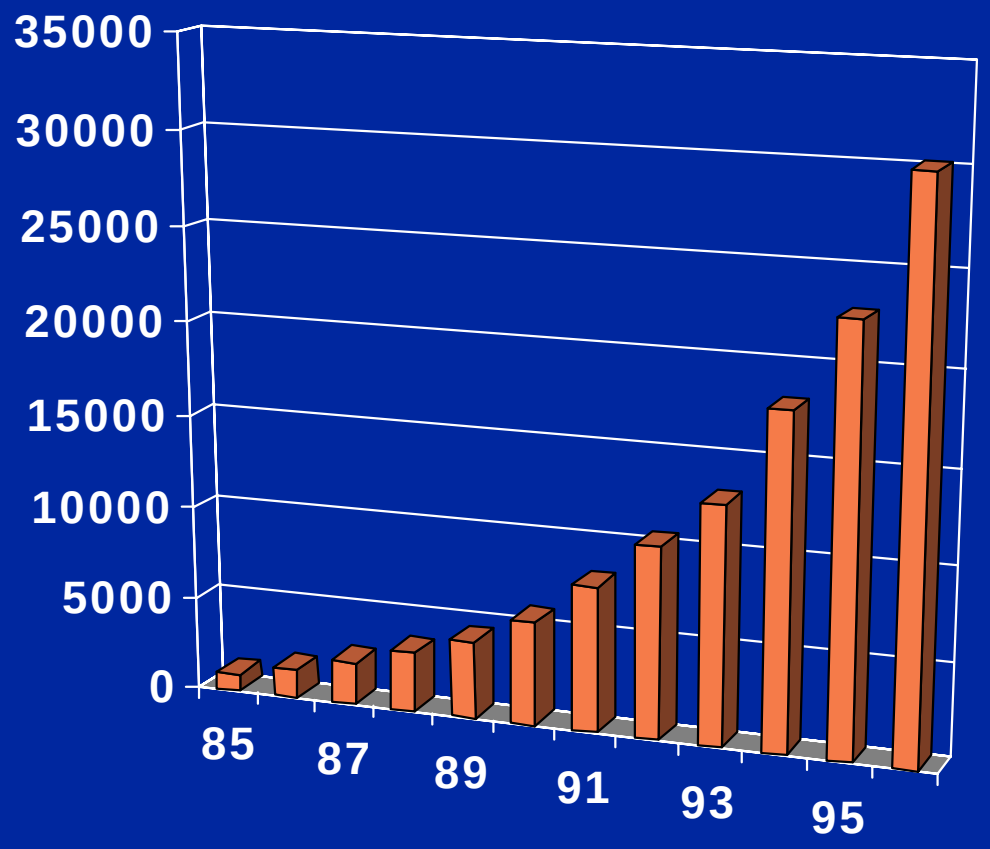
← 44 million

Cellular telephony remains the hottest and fastest growing sector of the telecomm market

Nordic Countries: 10 mobile phones being added for each wireline phone!

Source: CTIA Web Page

Growth in Cell Sites in US

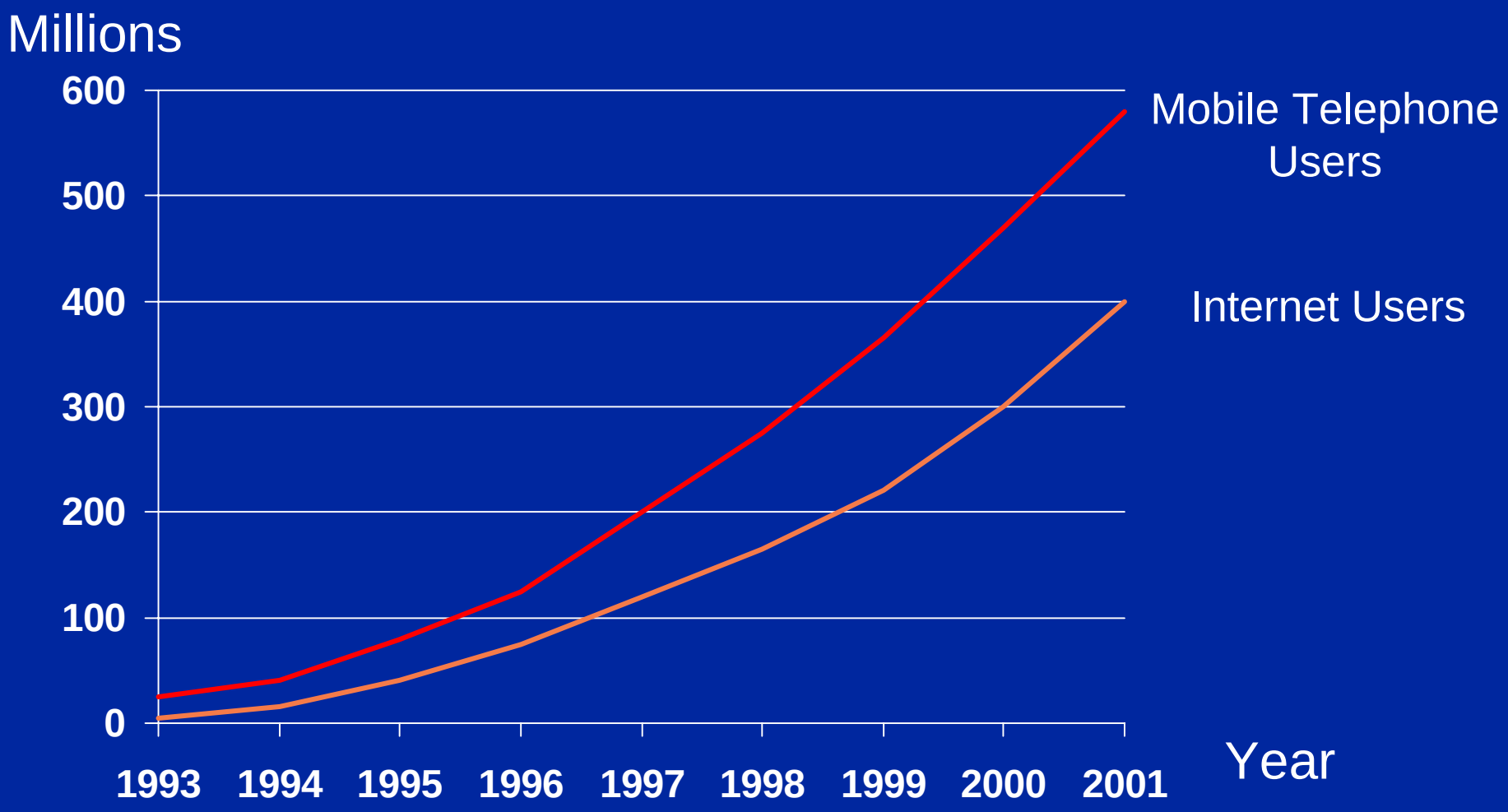


30000

25% growth in one year represents major market for infrastructure vendors

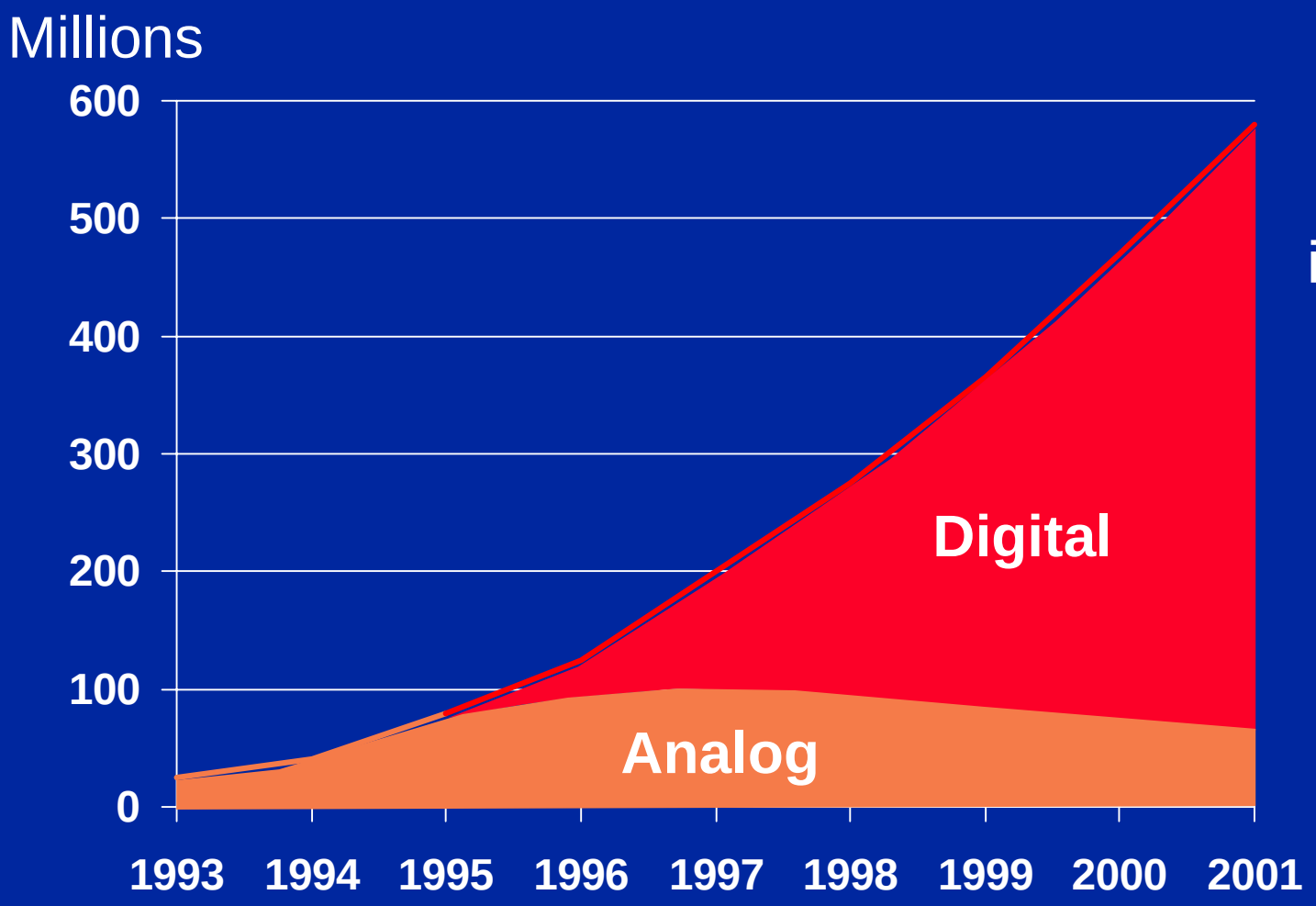
Source: CTIA Web Page

Mobile Telephone and Internet Users



Source: Ericsson Radio Systems, Inc.

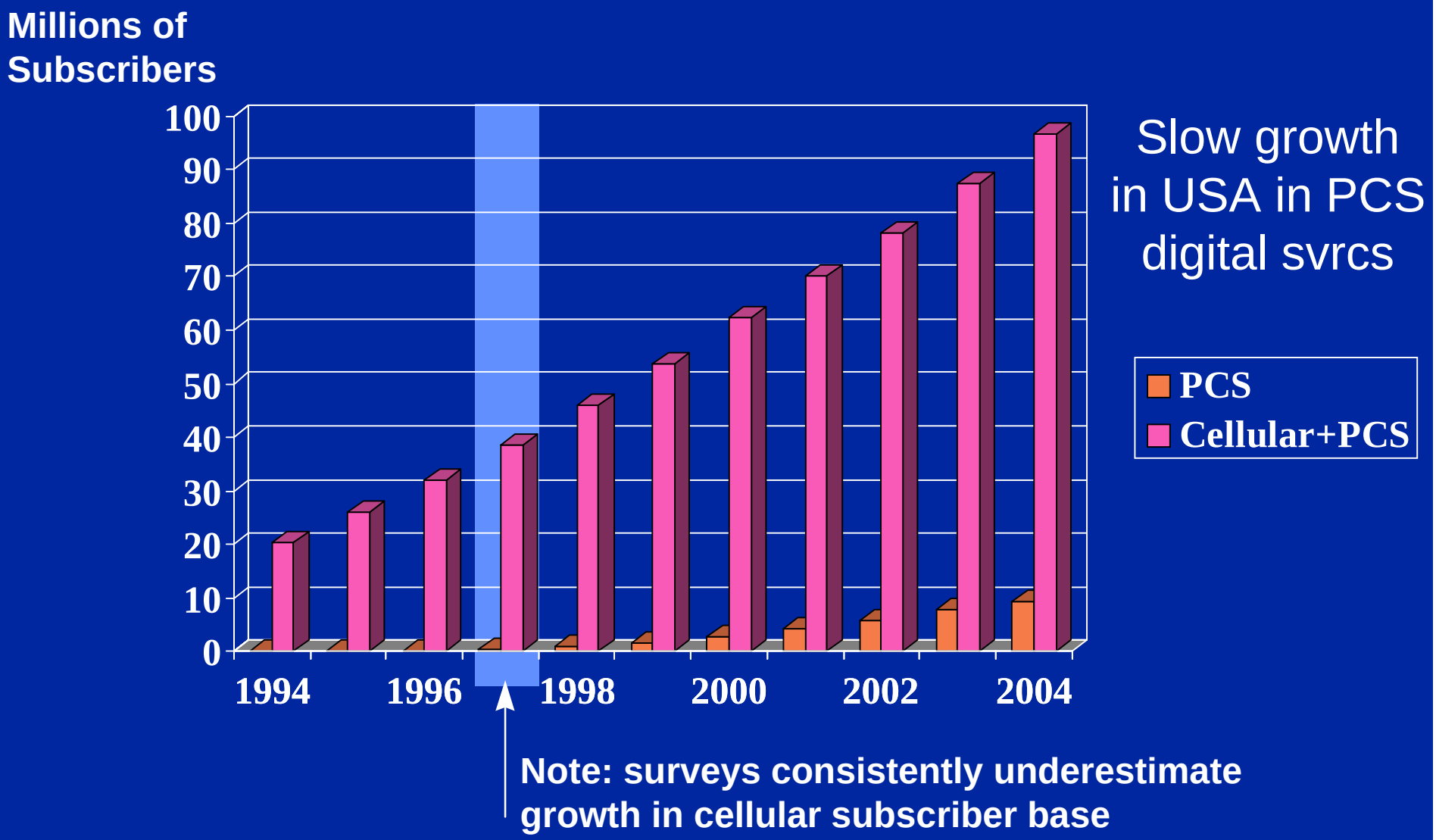
World's Cellular Subscribers



Will provide a ubiquitous infrastructure for wireless data as well as voice

Source: Ericsson Radio Systems, Inc.

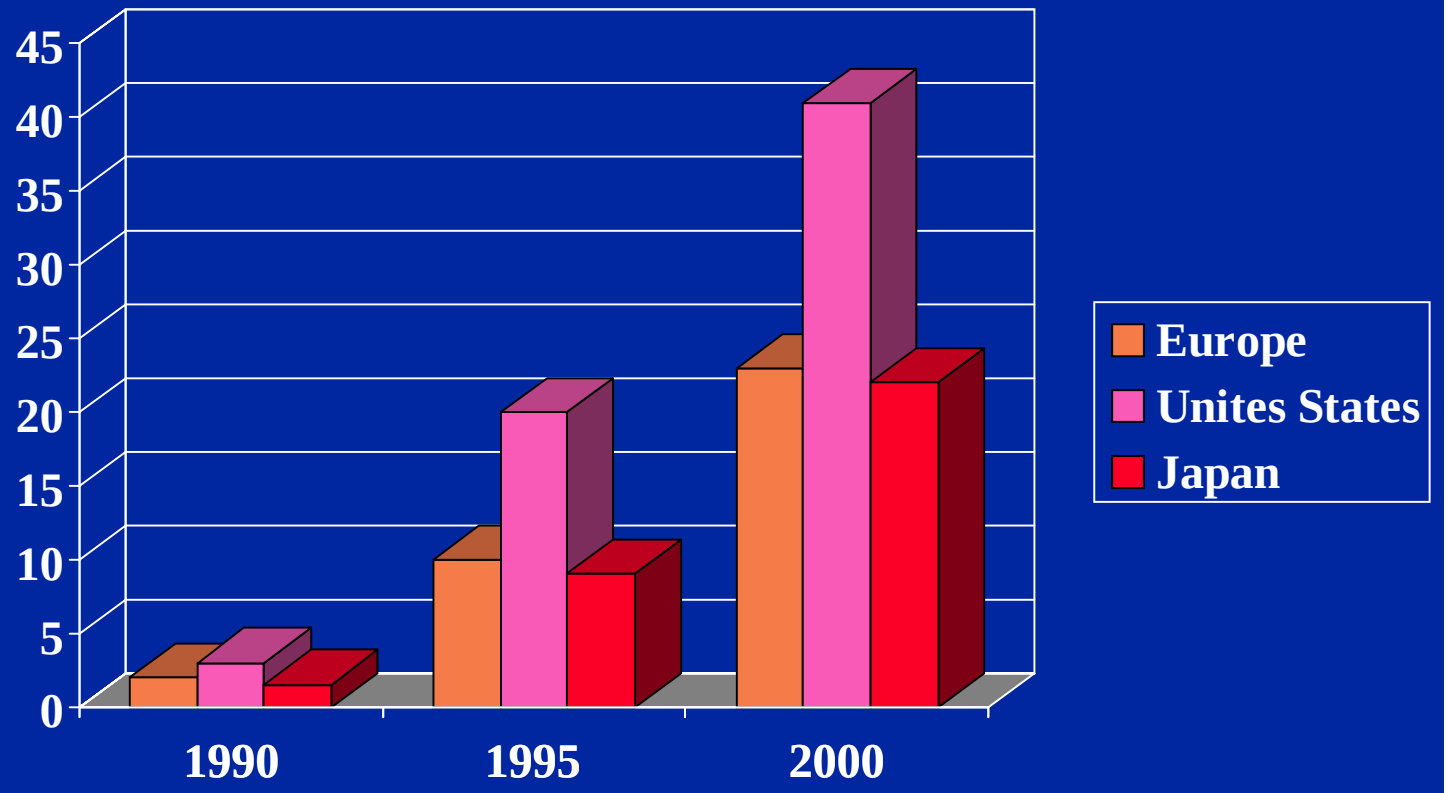
Predicted Continued Growth of Wireless Telephony



Source: Yankee Group Forecast, 1996

Cellular Phone Growth: An International Phenomenom

% of main lines that are mobile phones



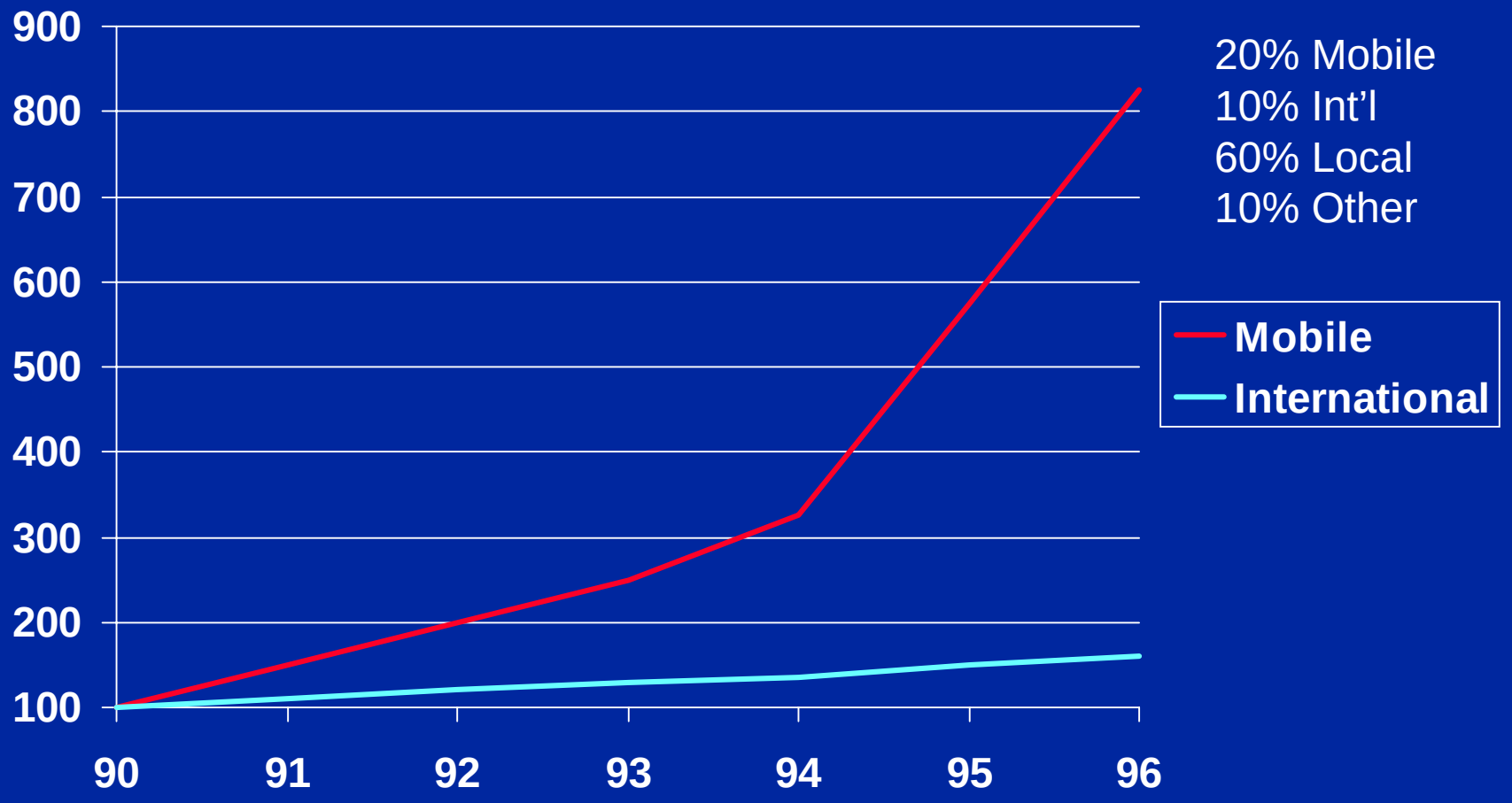
By Year 2000:

- One in three telephones will be mobile
- Mobility becomes a lifestyle

Source: Economist, 4 May 1996

Telecomms Service Revenue Growth

Total Revenue 1996: $670 Billion



Source: ITU (the Economist, 13 Sept 97)

Services Most Often Requested

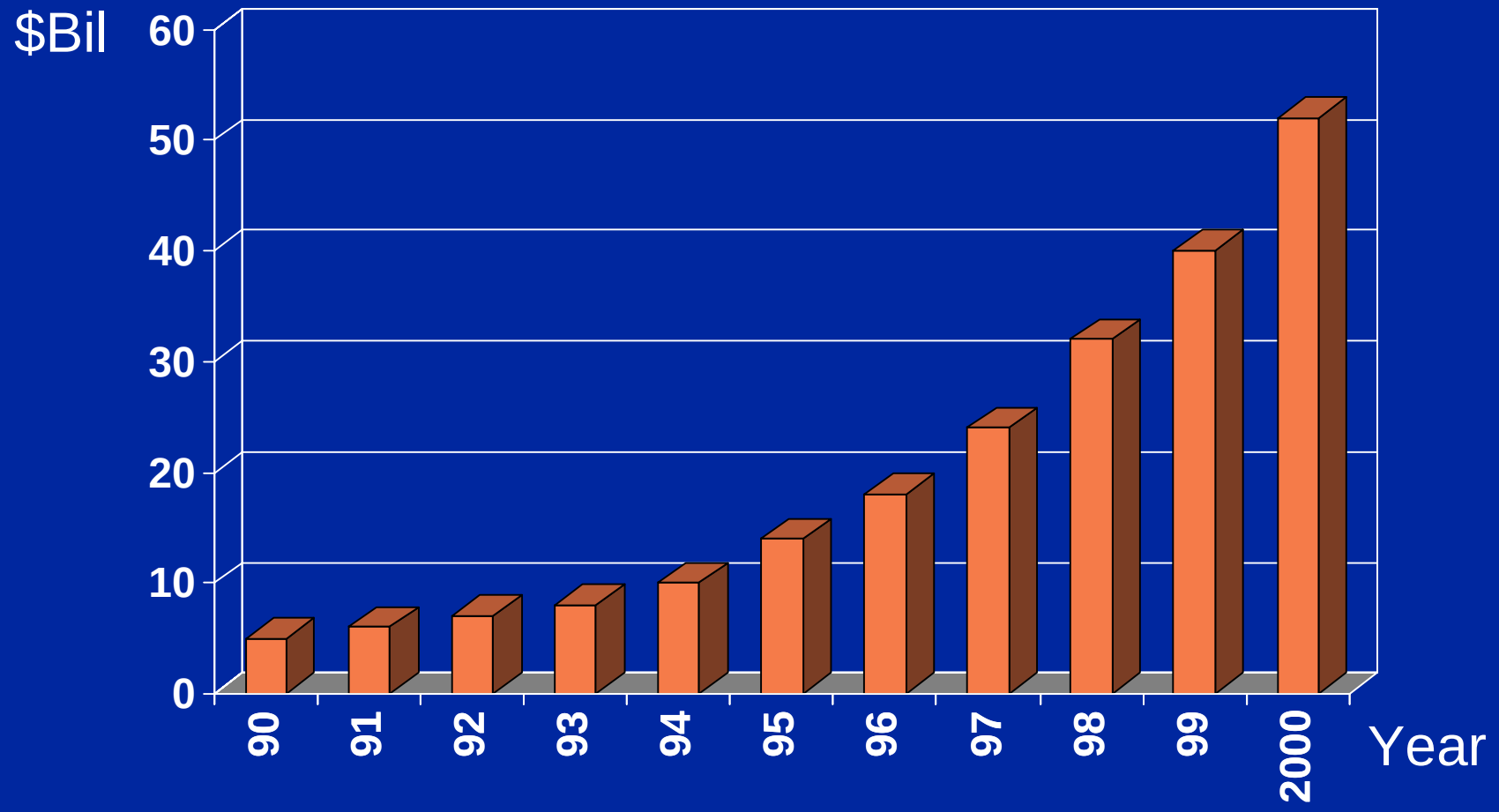
After basic wireless telephony service

• Call Forwarding	37%
• Paging	33%
• Internet/E-Mail	24%
• Traffic/Weather	15%
• Conference Calling	13%
• News	3%

Data Applications

Source: CTIA Web Page
Peter D. Hart Research Associates, March 1997

Global Markets for Portable Computers



Most rapid growing sector of the PC market
Nokia: 20-30% of revenue from data services

Source: Arthur D. Little, Industry Estimates in the Economist Magazine, 14 May 94

Data Giants vs. Telecomm Giants

- CISCO
  - Market Cap: $46 Billion
  - Annual Sales: $6 Billion
- 3COM/US Robotics
  - Market Cap: $16.1 Billion
  - Annual Sales: $5.5 Billion
- Ascend/Cascade
  - Market Cap: $7.7 Billion
  - Annual Sales: $1.3 Billion
- Newbridge
  - Market Cap: $7.4 Billion
  - Annual Sales: $0.9 Billion
- About $29 Billion in revenue; growing to $72 Billion by 2000

- AT&T
  - Market Cap: $57 Billion
  - Annual Sales: $52 Billion
- LUCENT
  - Market Cap: $48 Billion
  - Annual Sales: $24 Billion
- GTE
  - Market Cap: $42.3 Billion
  - Annual Sales: $21.7 Billion
- Bell Atlantic
  - Market Cap: $33.3 Billion
  - Annual Sales: $13.3 Billion
- About $860 Billion in TOTAL revenue; growing to $1272 Billion by 2000

Presentation Outline

- Comparison of Telecomm & Data Comm Industries
- Voice-centric versus Data-centric Viewpoint
- Internet versus Telephone Technology
- Implications Beyond the Third Generation

Voice-Centered vs. Data-Centered?

- The dramatic rise of the Internet and the World Wide Web
  - Reuters
    - » 82 million PCs on Internet today
    - » Growing to 286 million by Year 2001
  - Internet Demographic Survey (CommerceNet)
    - » 55 million Internet Users in US & Canada
    - » 100 million worldwide
  - Telephone Subscribers
    - » 1 billion worldwide
    - » 180 million mobile phone users worldwide

Voice-Centered vs. Data-Centered?

- More than 50% of telecomm traffic in Bay Area is already data, not voice
  - Internet FIND/SVP Survey (Nov/Dec 95)
    - » 25% of Internet users make fewer long distance calls
    - » 32% watch less television
- Telephone switching infrastructure has been brought to its knees
  - Design metrics based on voice quality, not data throughput
  - Design for short duration voice conversations, not long duration computer sessions

Voice-Centered vs. Data-Centered?

	Average Peak-Hour Local Circuit Use		Average Residential Call Length	
	All Circuits	Circuits to ISPs	All Circuits	Circuits to ISPs
Bell Atlantic	5.0	43-47	4-5	17.7
US West	5.0	45.0	2-4	14
Pacific Bell	6.7	31.7	3.8	20.8
SBC	6.7	52.3	na	na

Network Usage, Minutes

Source: FCC (The Economist, 13 Sept 97)

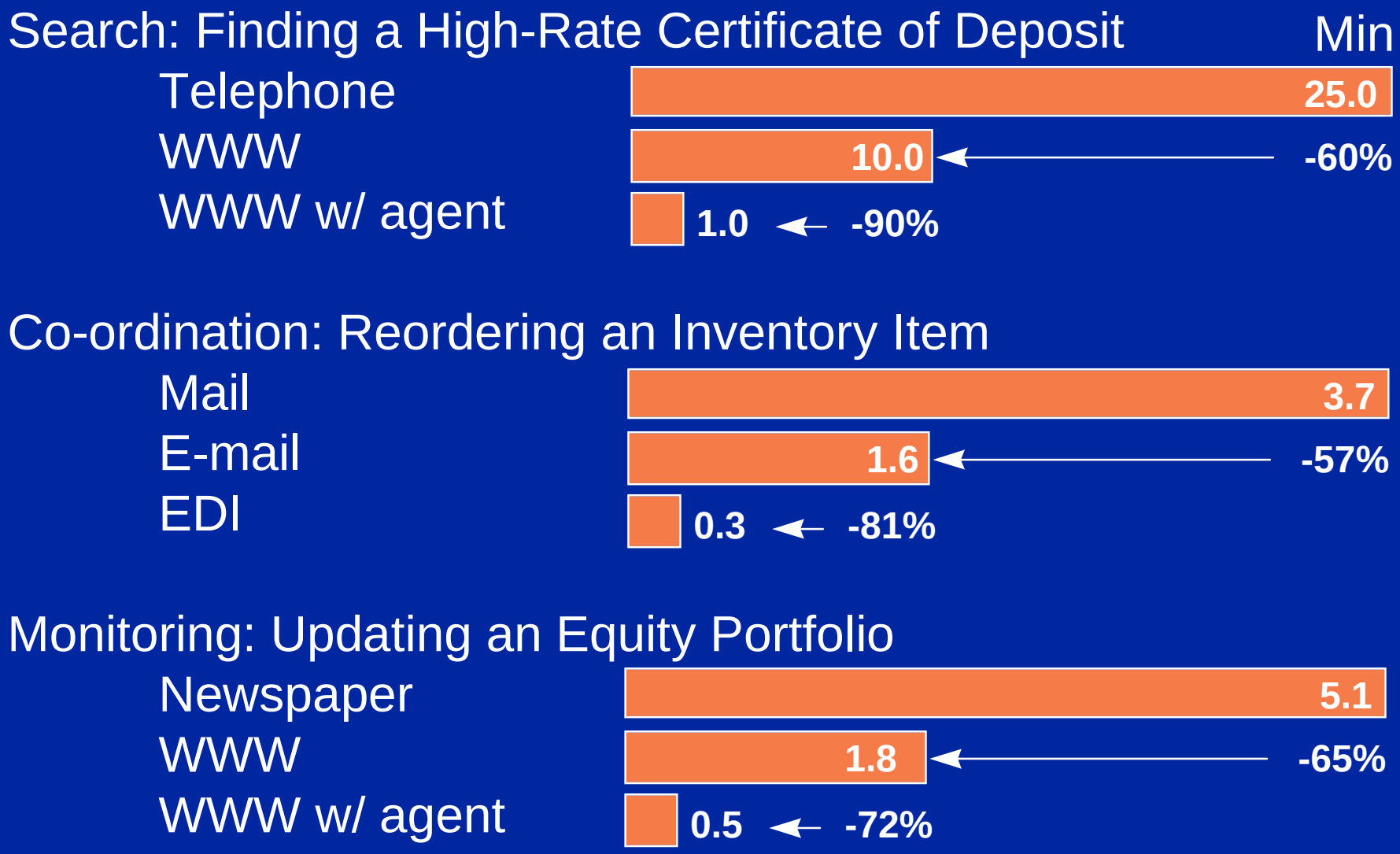
Will Trend Towards Data-Centric Accelerate?

- Sir William Preece, Chief of the British Postal System, 1876:
  "The Americans may have need of the telephone, but we do not. We have plenty of messenger boys."
- Analogy with the Post Office
  - Telephones have largely replaced the personal letter
  - Posts used mainly for business-oriented correspondence: documents (Fed-Express), bills (direct debit/e-commerce), advertising (WWW), delivery of merchandise (UPS)
  - Email reduces number of telephone conversations
  - What will be the effect of the Internet/WWW?

Will Trend Towards Data-Centered Accelerate?

- Many calls to obtain information are already being replaced by the WWW
  - E.g., Ordering Books
  - E.g., Ordering CDs
  - E.g., Fyte Trax Service
  - E.g., Package Tracking
  - E.g., Booking Flights
  - and so on

Efficiencies of Interaction



Source: McKinsey (The Economist, 13 Sept 97)

Presentation Outline

- Comparison of Telecomm & Data Comm Industries
- Voice-centric versus Data-centric Viewpoint
- Internet versus Telephone Technology
- Implications Beyond the Third Generation

What is the Internet?

"Internet" refers to the global information system that -- (i) is logically linked together by a globally unique address space based on the Internet Protocol (IP) or its subsequent extensions/follow-ons; (ii) is able to support communications using the Transmission Control Protocol/Internet Protocol (TCP/IP) Suite or its subsequent extensions/follow-ons, and/or other IP-compatible protocols; and (iii) provides, uses or makes accessible, either publicly or privately, high level services layered on the communications and related infrastructure described herein.

Federal Networking Council Resolution, 24 October 1995

Today's Internet Technology

- Strengths
  - Intelligence at the end points; No state in the network;
  - Highly decentralized control
  - Enables operation over very heterogeneous collection of access technologies; few assumptions about the network necessary
  - Achieves robust communications through packet switching & store-and-forward routing
  - Depends on cooperative forwarding of packets
- Weaknesses
  - No differential service
  - No control mechanisms for managing bottleneck links
  - Store-and-forward routing introduces variable delay in end-to-end performance
  - Decentralized control makes introduction of new protocols/functions difficult since all end nodes must be upgraded
  - Lack of truly trusted infrastructure leads to security problems

Today's Telephone Network

- Strengths
  - Requires no end-point intelligence; supports heterogeneous end devices
  - Provides excellent performance for voice
  - End-to-end performance guarantees achieved through well-defined signaling layer to switching function
  - True utility functionality through sophisticated and hierarchically arranged switches controlled by service providers
- Weaknesses
  - Achieves performance by overallocating resources
  - 3.4 KHz audio voice band signal converted to 64 kbps digital representation
  - Switching design determined by statistics of call traffic
  - Difficult to add new services to the so-called "Intelligent Network" due to complex feature interaction
  - Expensive approach to robustness

ATM: The Grand Convergence?

- Strengths
  - Virtual circuits with call set-up to manage scarce resources and achieve QoS guarantees
  - Fixed/small size “cells” to enable fast switching
  - Sophisticated statistical multiplexing mechanisms to make possible variety of traffic models
  - Integrated services
- Weaknesses
  - Connection-orientation has some problems with latency and robust operation; every cell must follow same path in order
  - ATM unlikely to be a universal end-to-end technology, especially for data traffic in local area
  - Quaranteed performance end-to-end in heterogeneous environments is lost

Next Generation Internet

- “Integrated Services Packet Network (ISPN)”
- Ubiquitous support for multipoint-to-multipoint multicast communications
- Built-in support for mobility and mobile route optimization
- Resource allocation mechanisms based on RSVP signaling
  - Performance promises rather than guarantees
  - Receivers initiate signaling; nice scaling properties
  - Soft state in the network allows robust recovery to failure; protocol works around link and switch failures

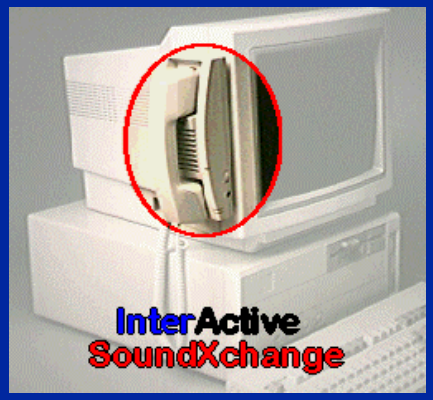
Next Generation Internet

- Microprocessor performance/software algorithms now sufficient for real-time encode/decode of video and audio
  - Traditional telephony hardware operates at 64 kbps for PCM coding
  - Mbone software audio coding at many rates
    - » 36 kbps ADPCM
    - » 17 kbps GSM
    - » 9 kbps LPC

    Adequate video at 28.8 to 128 kbps
    - » Scalable codecs
    - » Layered video

Next Generation Internet

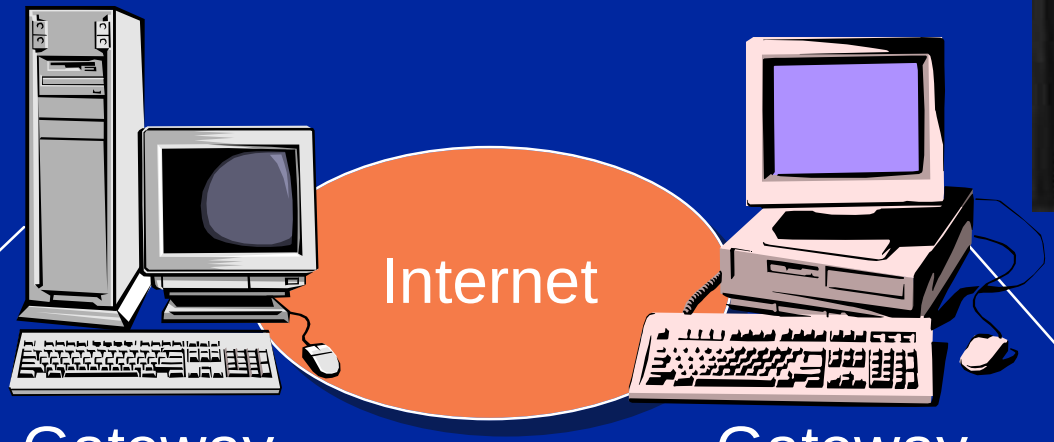
- Real Time Protocol (RTP)
  - Application Level Framing
  - End nodes adapt audio/video streaming rates to what the network can support
- Easy integration of new services like proxies
  - Hardware/software is not specialized
  - Easy to integrate distributed applications
- Solve performance problems by adding more bandwidth



Internet Telephony

Analog Voice to Packet Data

Packet Data to Analog Voice



Local Call

Internet

Local Call

Gateway

Gateway

SF to Frankfurt via Internet Service: **$0.28 per min**
via AT&T Long Distance: **$1.25 per min**

Why so Cheap?

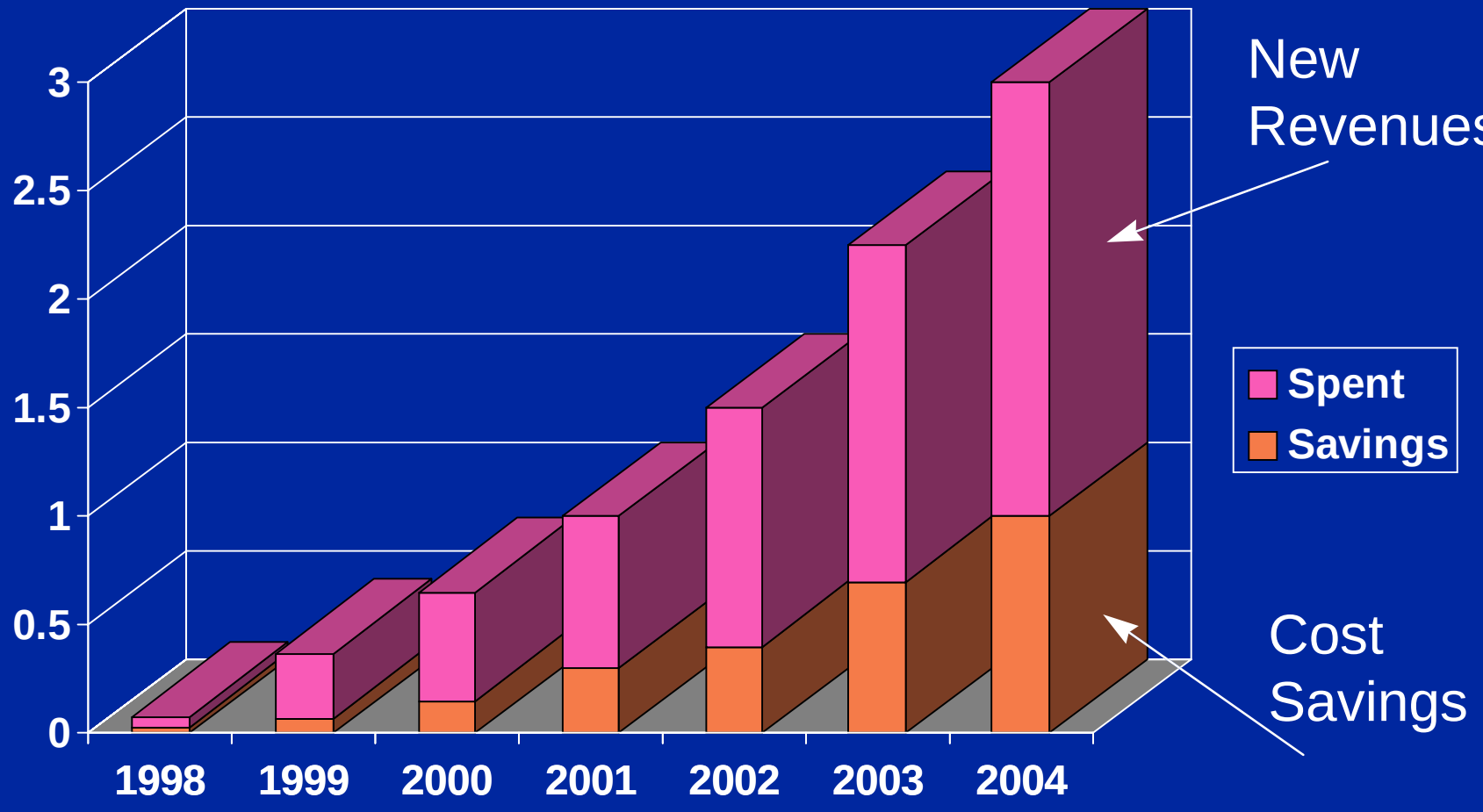
- Less expensive infrastructure
- Circumvents government-backed monopolies
- Existing long distance tariffs far exceed costs
- WTO worldwide deregulation

Source: G-Cubed

Internet Telephony

- Quality Issues: High Latencies, Dropped Packets
  - Solutions
    - » Deployment of private networks
    - » Faster and scalable hardware reduces gateway latency
    - » RSVP + H.323 + Reconstruction of lost packets + Better voice coding at 8 kbps
    - » VoIP: Voice over Internet Protocol Forum
- Integration of circuit-switched local infrastructure with packet-switched wide-area infrastructure
  - Wide-area b/w is a commodity, not true for local access
    - » 1996-2000: 5X increase in Atlantic/Pacific cable capacity
  - Many leading telecomms already doing this
    - » Internet FAX services
    - » Cheap way for RBOCs to get into long distance service

U.S. Internet Telephony Market



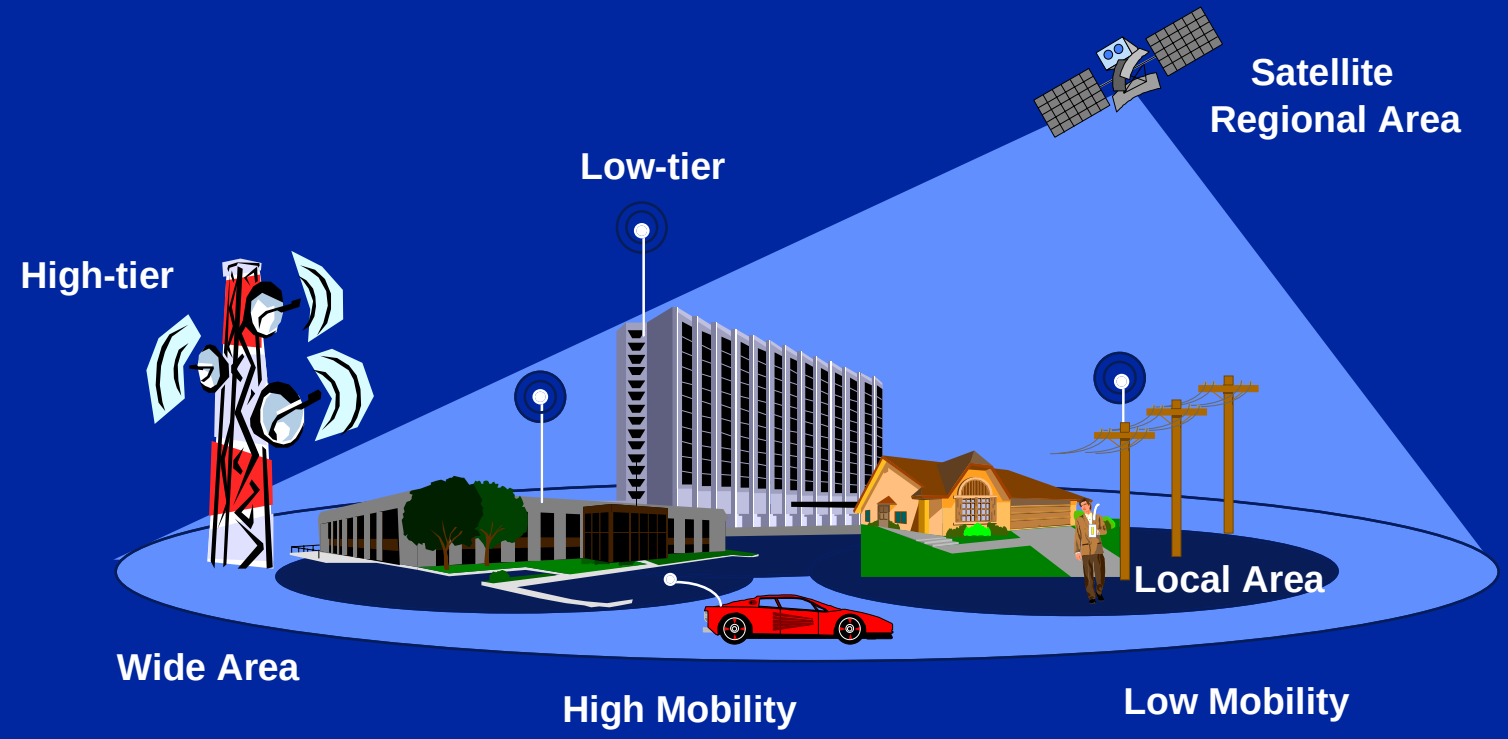
4% of U.S. Telephony Revenue

Source: Forrester Research (The Economist, 13 Sept 97)

Presentation Outline

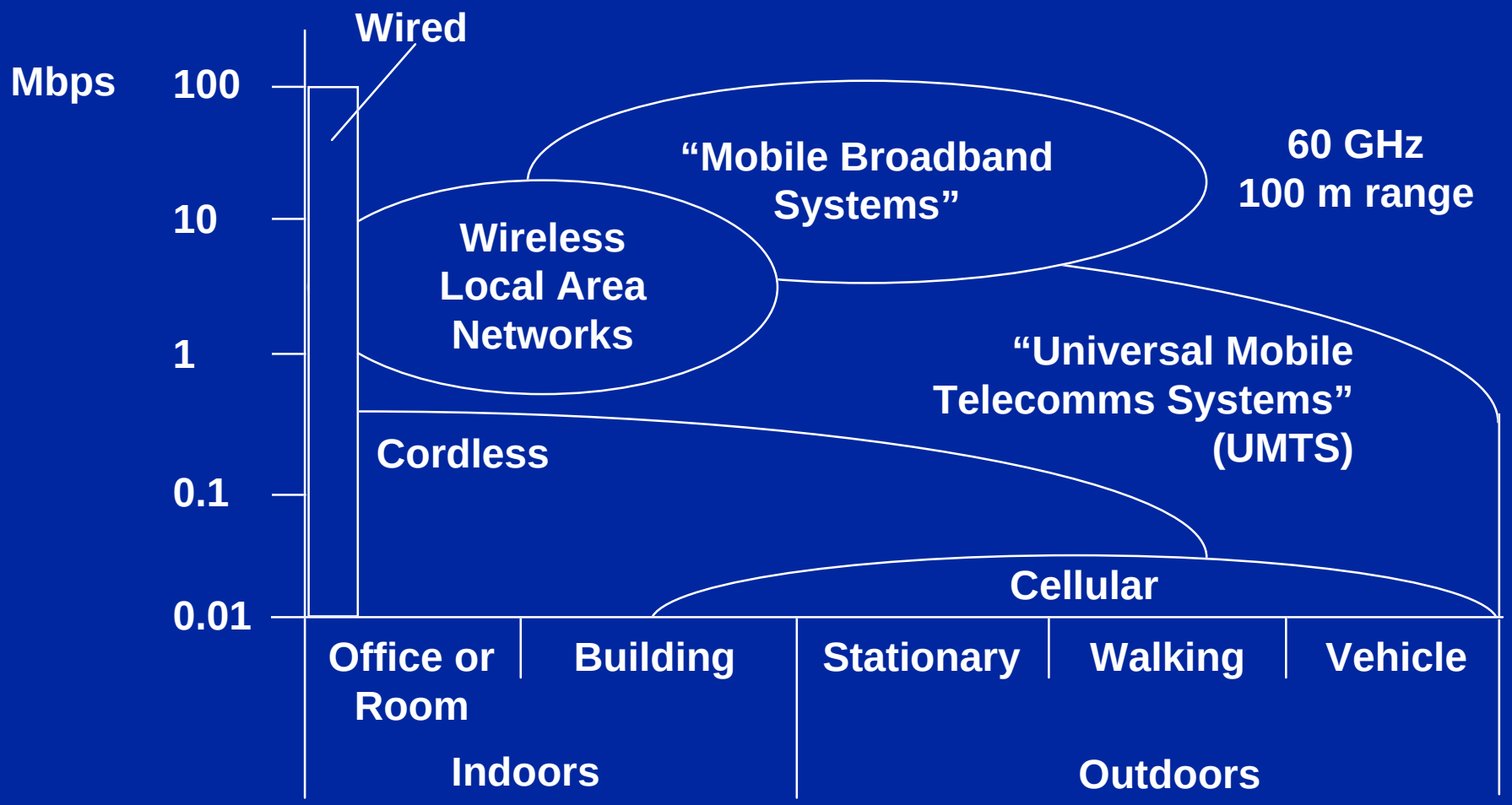
- Comparison of Telecomm & Data Comm Industries
- Voice-centric versus Data-centric Viewpoint
- Internet versus Telephone Technology
- Implications Beyond the Third Generation

Third Generation Telecommunications Architectures



- FPLMTS/UMTS/IMT-2000
  - Universal multimedia information access with mobility spanning residences, businesses, public/pedestrian, mobile/vehicular, national, and global regions
  - Low end: 512 kbps; High end: 155 mbps??

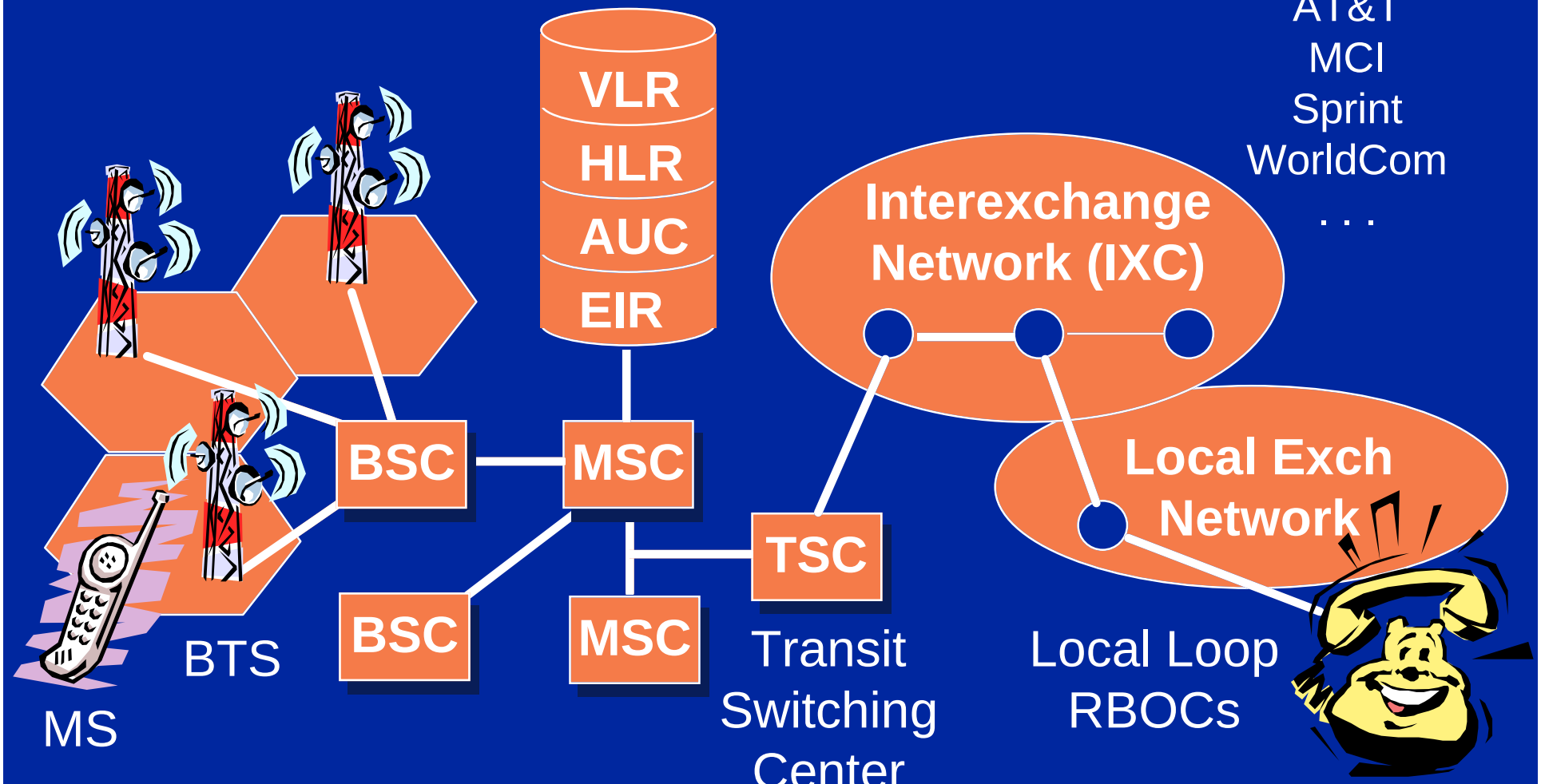
Wireless Access Technologies



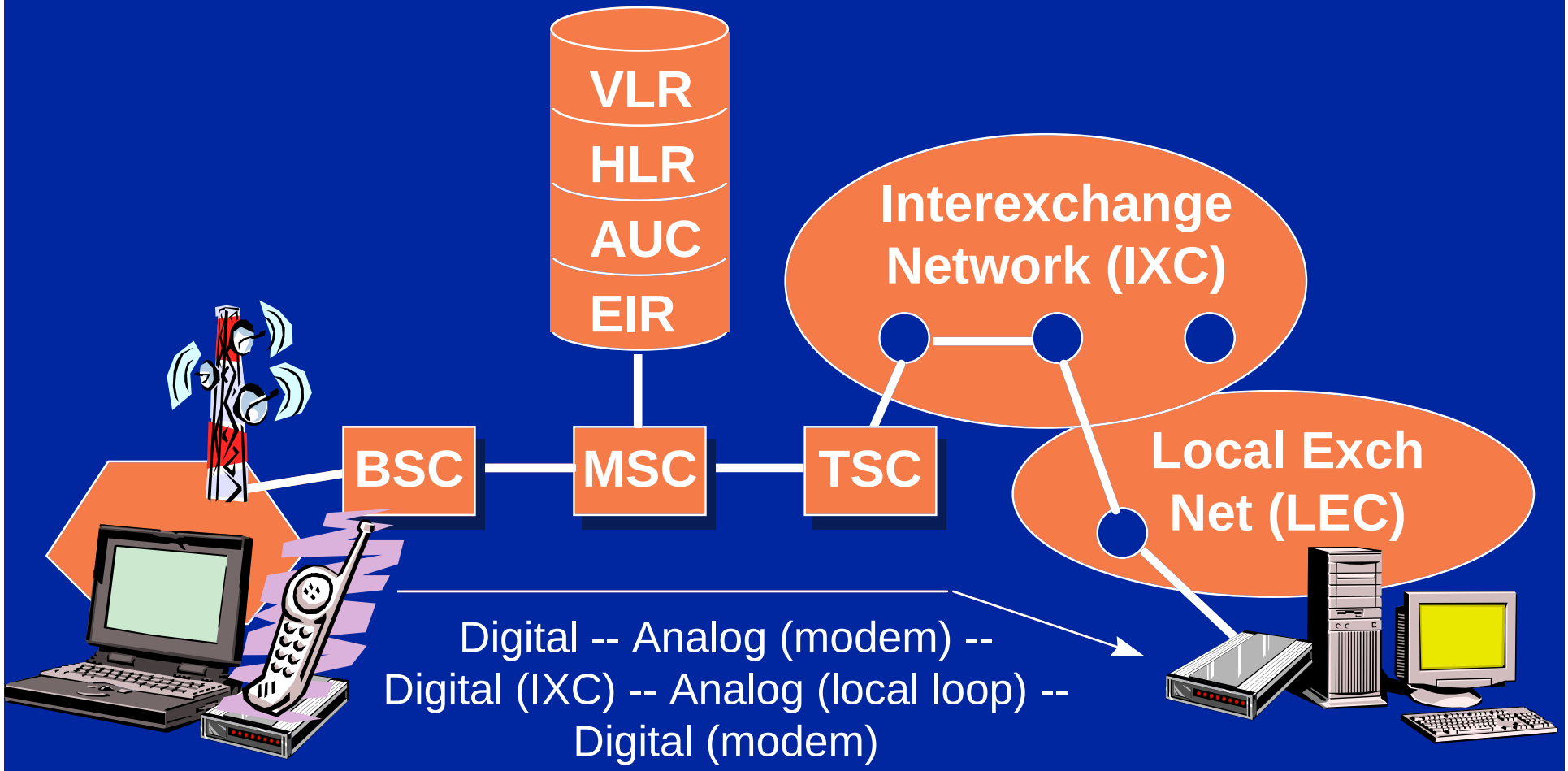
Beyond Third Generation

- 1st Generation was analog cellular
  - e.g., AMPS
- 2nd Generation is digital cellular
  - e.g., IS-54 (TDMA), IS-95 (CDMA), GSM (TDMA)
- 3rd Generation
  - Still being defined . . .
  - Will embrace multiple radio access technologies suitable for local, wide-area, satellite, etc. and able to achieve higher bandwidth than existing airlinks
  - Likely to be based on GSM wireline infrastructure
- 4th Generation
  - ???

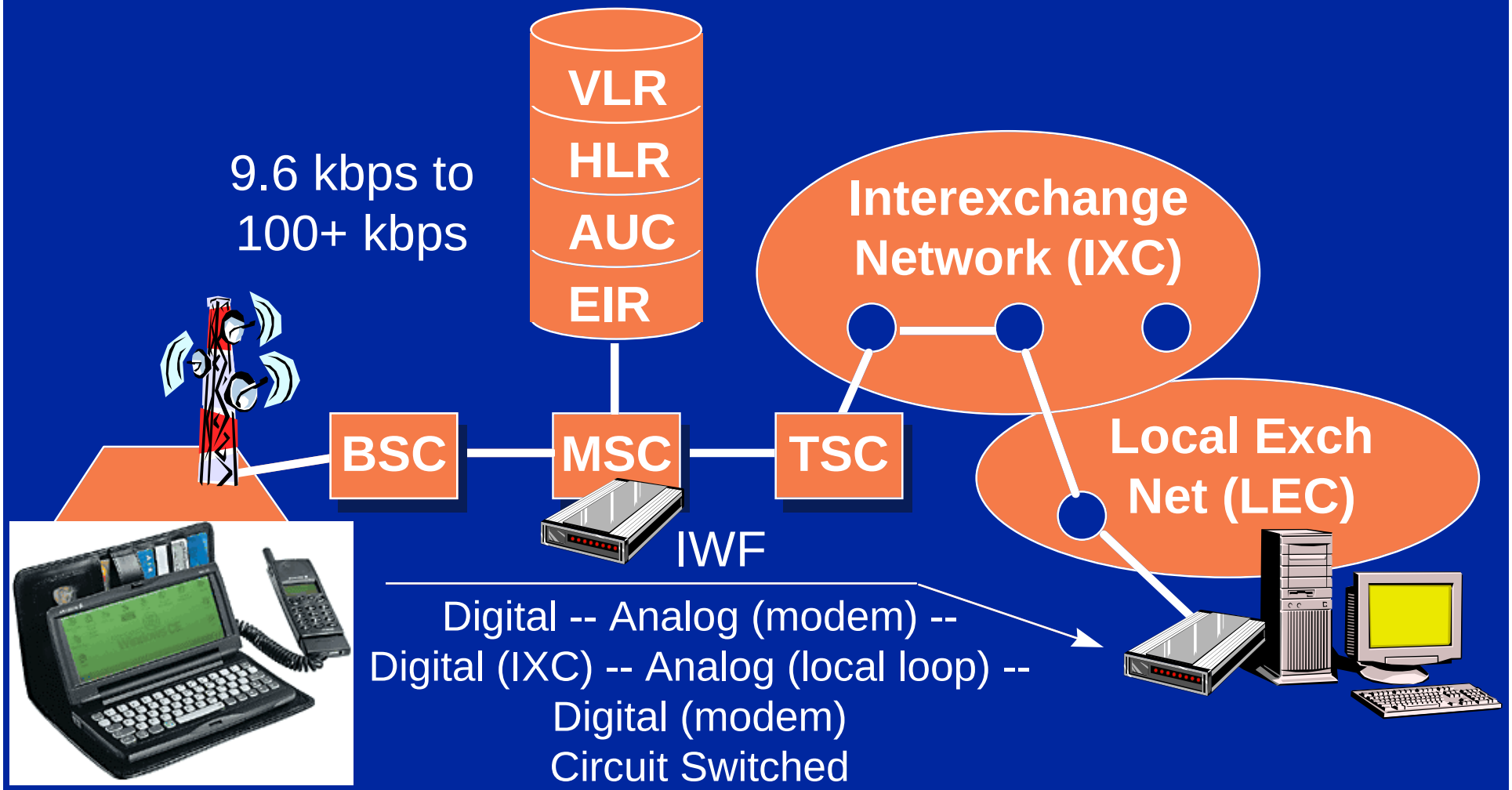
Mobile Telecomm Network



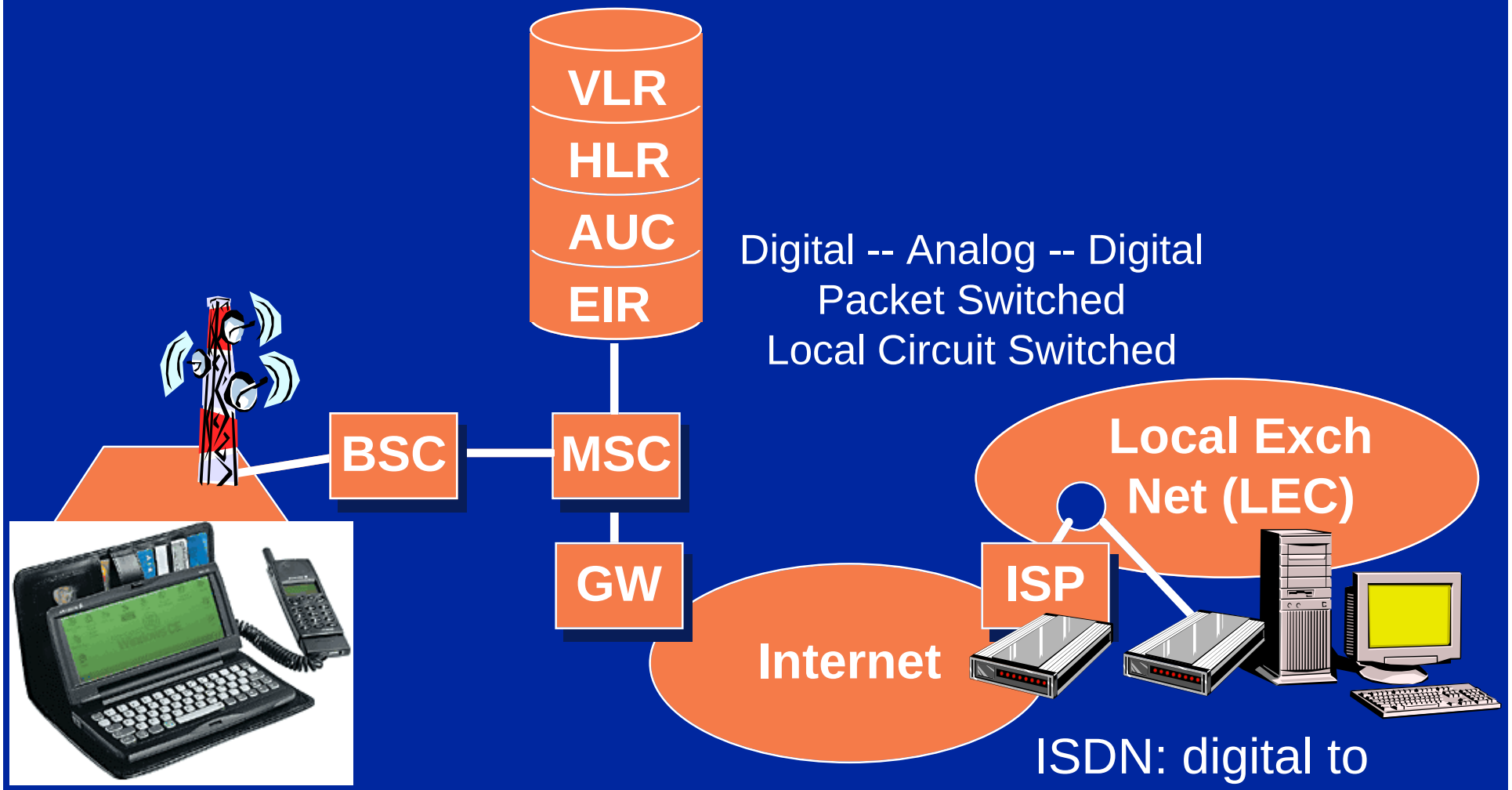
Data Over Analog Cellular



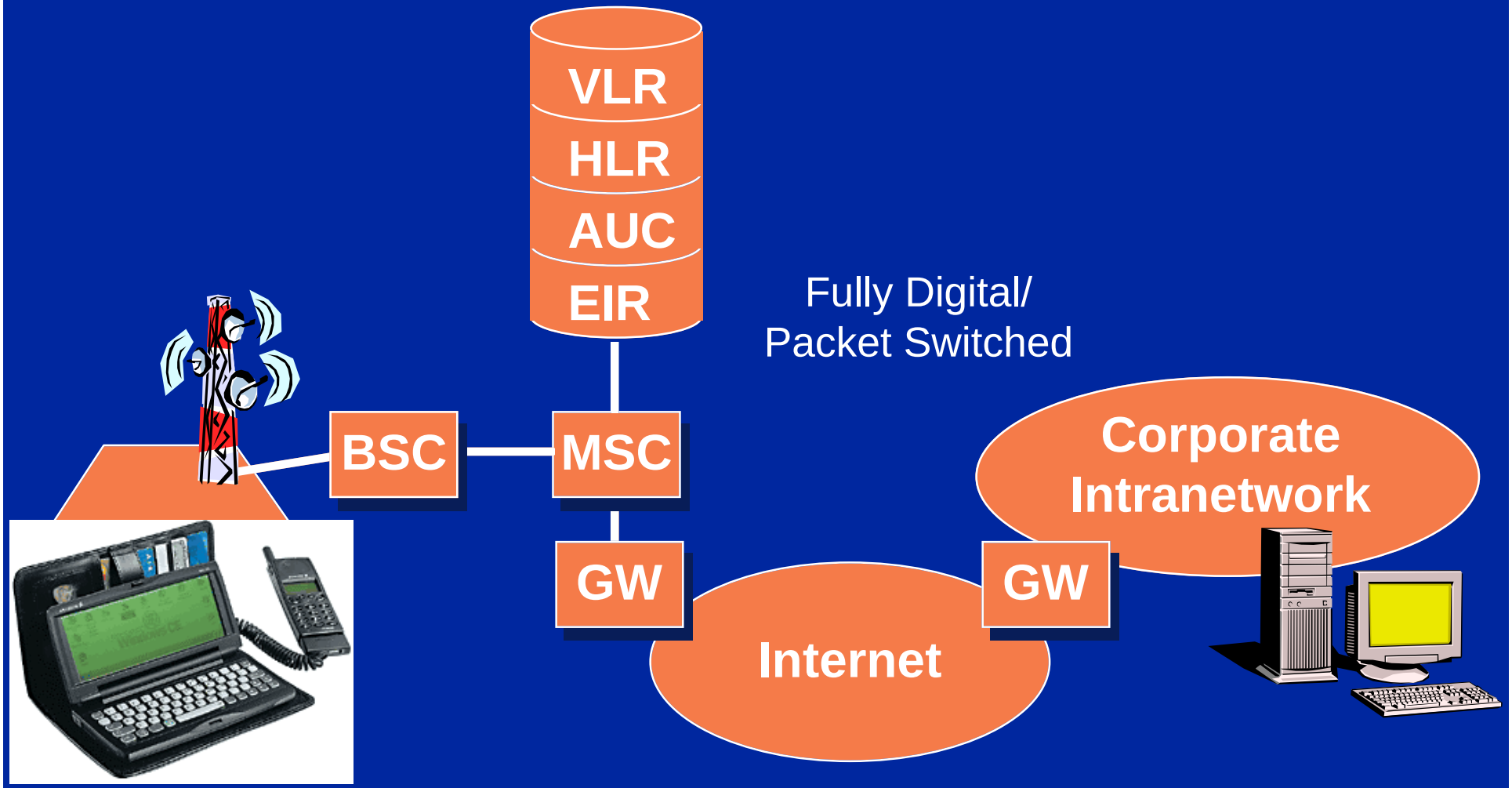
Data Over Digital Cellular



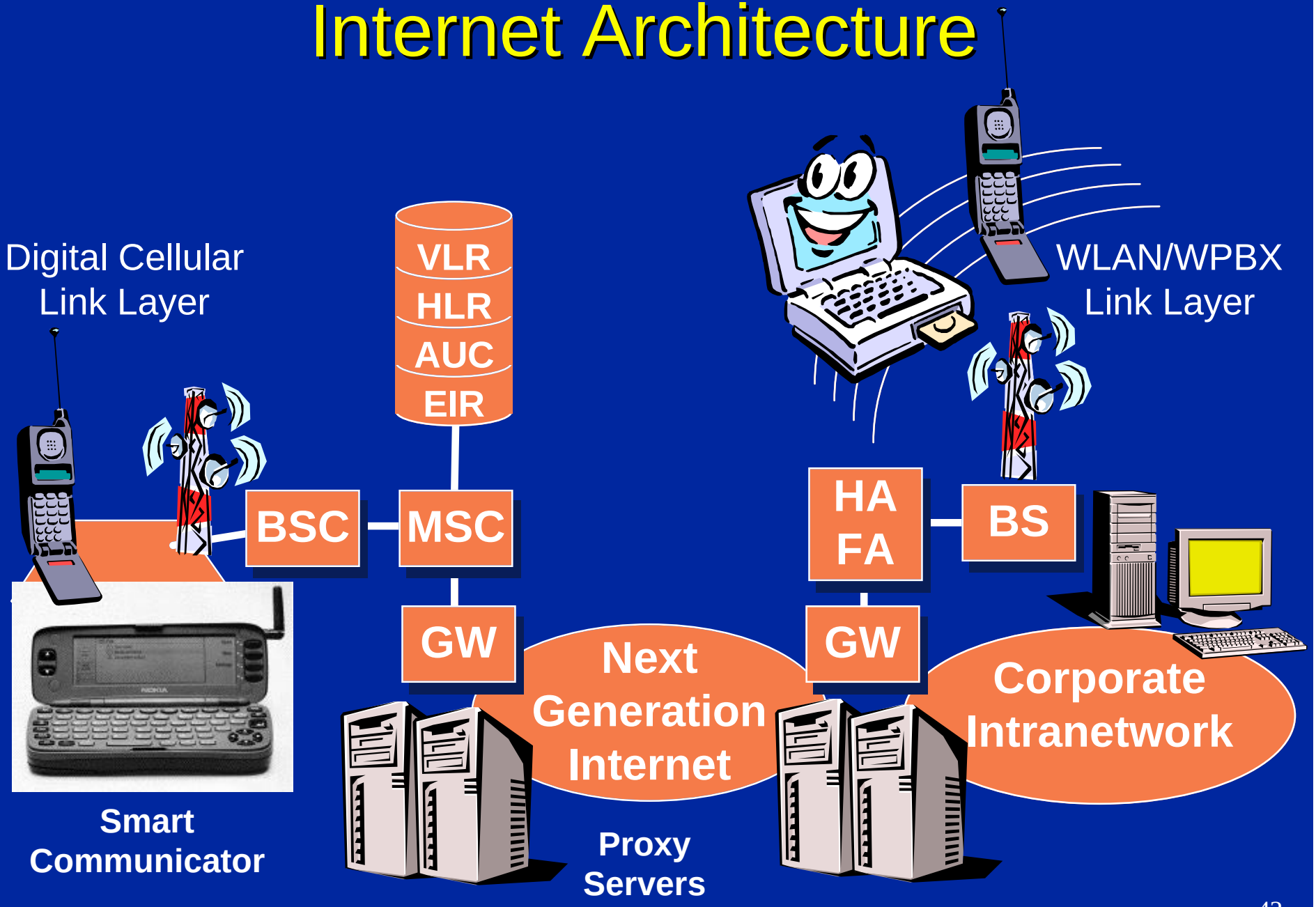
Internet Architecture



Internet Architecture



Internet Architecture



Summary and Conclusions

- Accelerating importance of data access in cellular telecommunications infrastructures: data will dominate voice applications
- Internet's emerging capabilities for real-time traffic, multipoint communications, broadcast-based information dissemination
- Secret of Internet's success
  - Intelligence at the end points
  - Simple and inexpensive infrastructure components
  - Gain performance through bandwidth
- Economies of scale favor the Internet
  - Cause for a dramatic re-thinking of telecomms infrastructure beyond the 3rd Generation