NTT DoCoMo
DoCoMo USA Labs

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4G Services, Architecture and Networks: Speculation and Challenges

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Outline

- Introduction and Motivation
- What is 4G anyway?
- Pet peeves
- Summary

Summary

- 4G should be defined in terms of applications and services
  - Not purely by air interface protocol, backbone network or bandwidth
- Coming: Gazillions of gizmos
  - Need for massive mobile data management
- Rapid service introduction and heterogeneous technologies (air interface, terminal device, backbone)

  => programmability and open APIs at all levels of the system

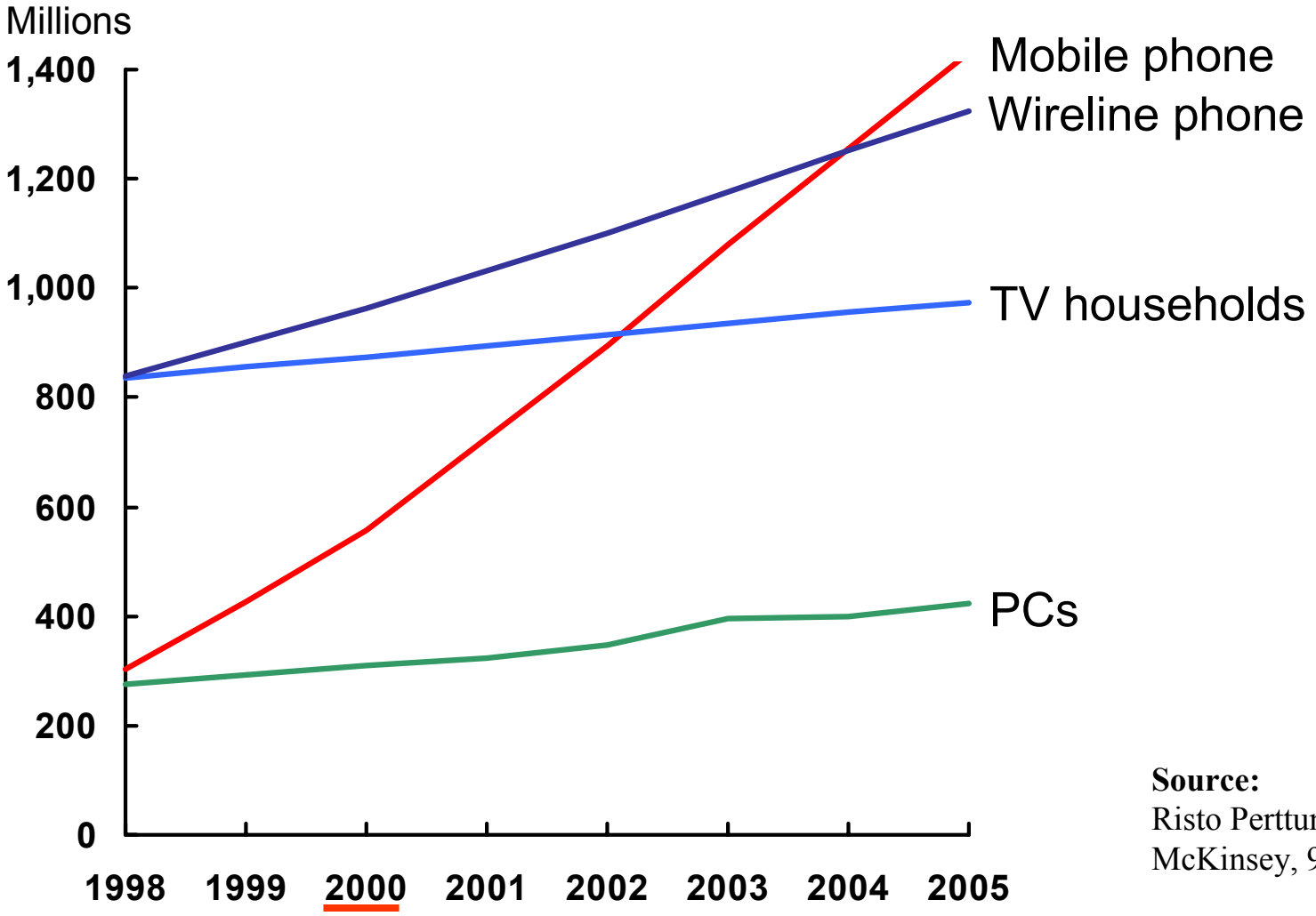
  => applications with market size of 1
- Maturing industry

  => attend to environmental impacts (*Jain & Wullert,* Mobicom 02)
  - Plateau of revenue in current markets

    => B24B

Introduction
Mobile devices will dominate

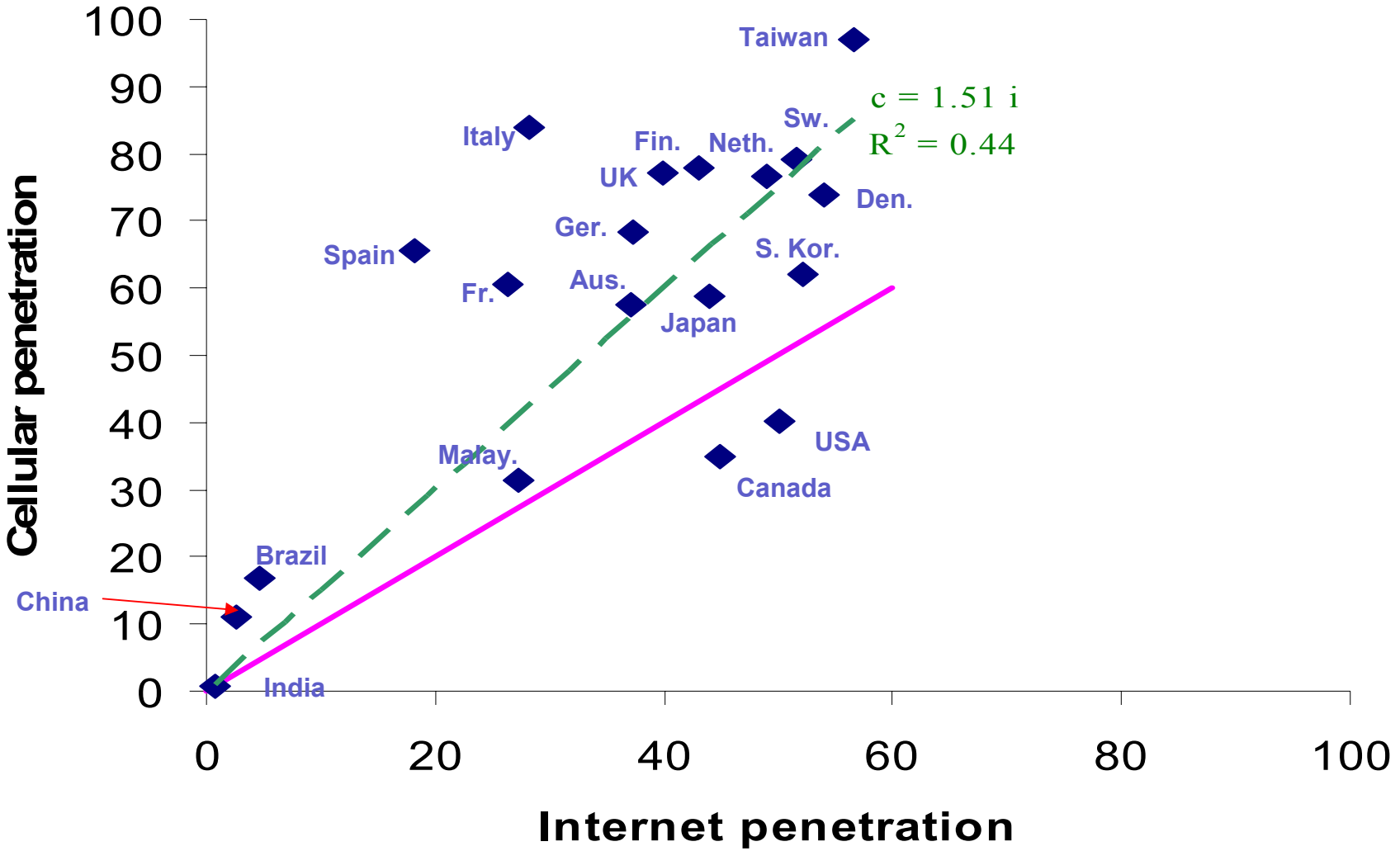
Subscribers worldwide



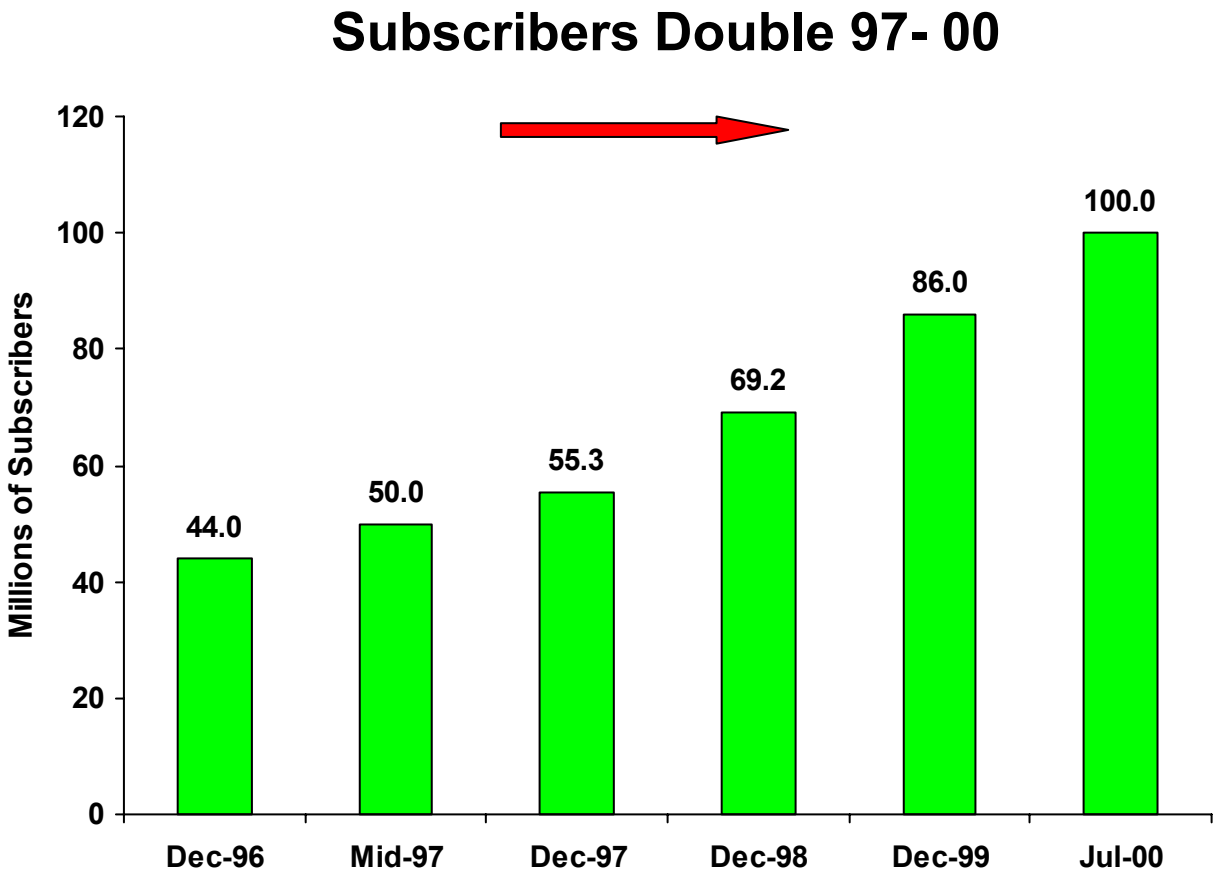
Source:
Risto Perttunen,
McKinsey, 9/00

Cellular vs Internet penetration

(Data from: ITU, 2001)

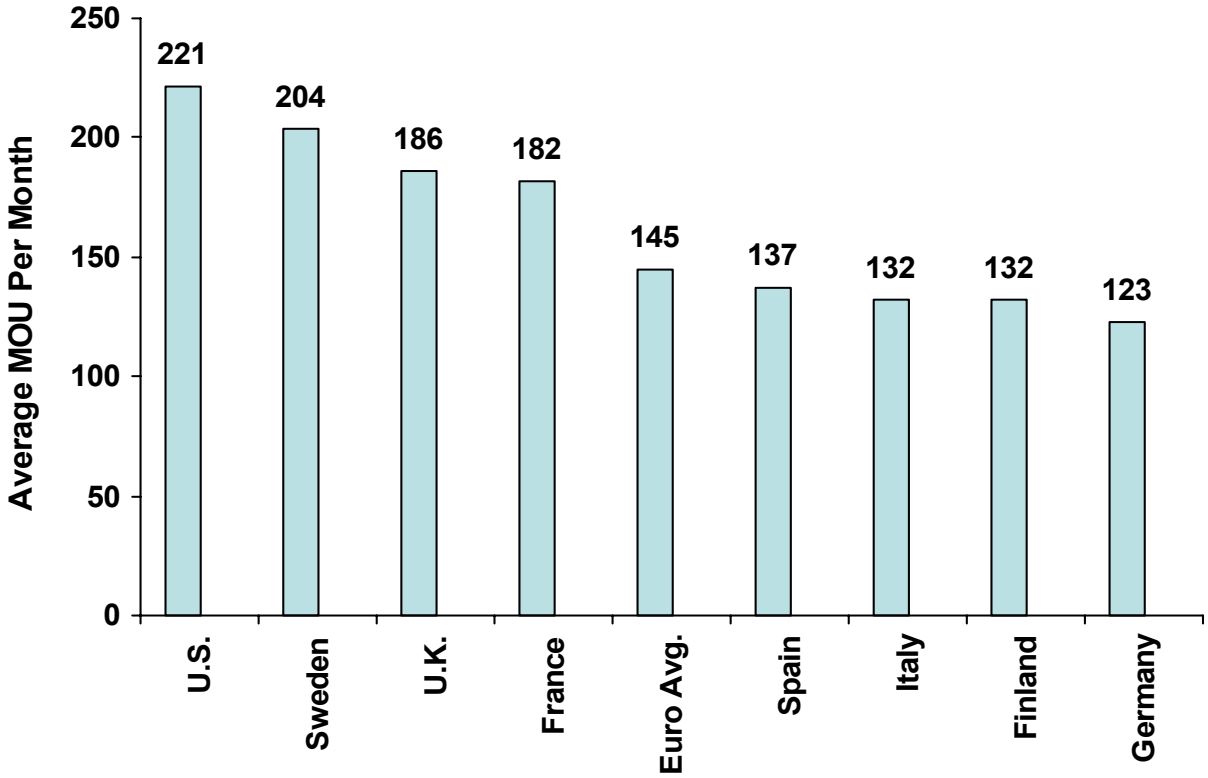


Strong growth in subscribers



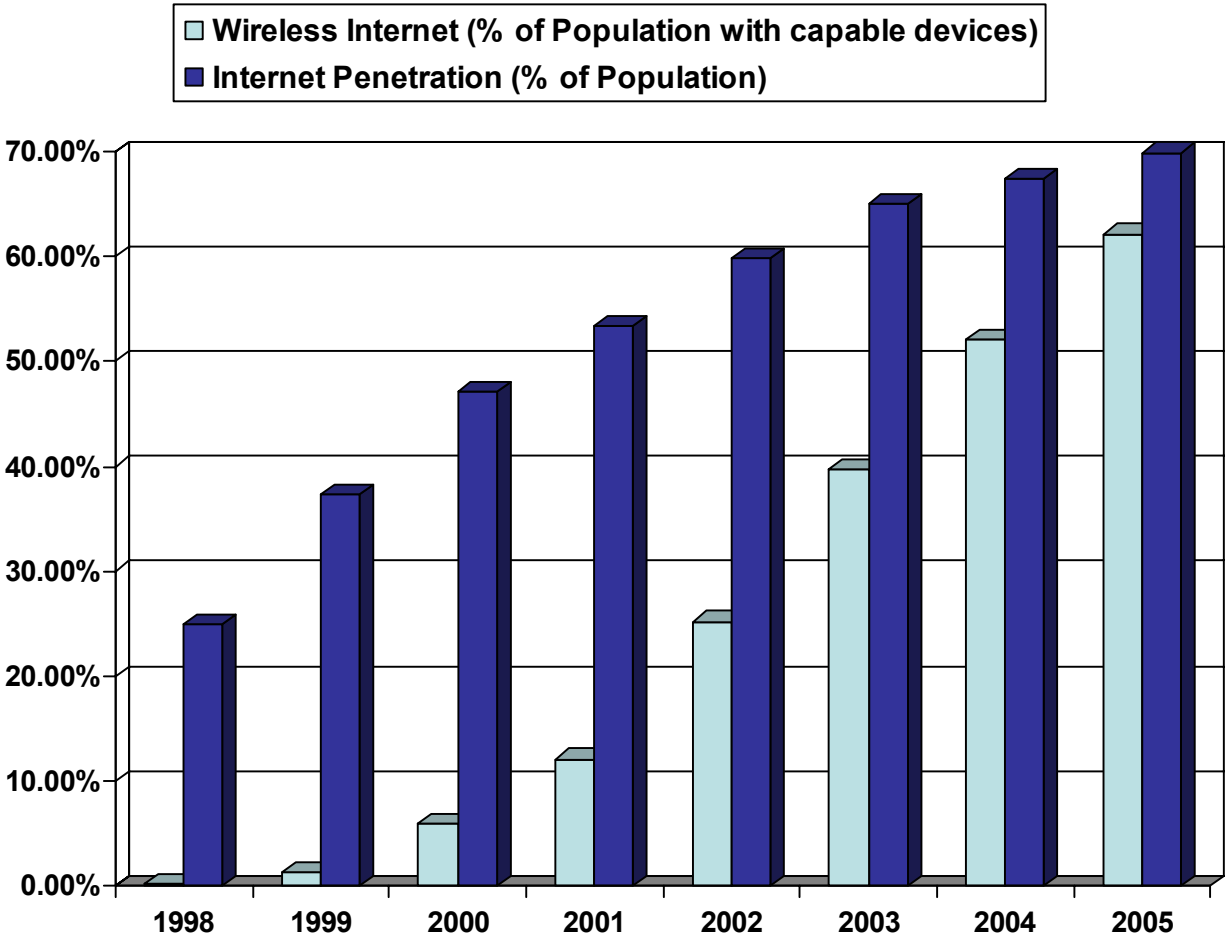
Source: CTIA, 2000

Usage high … and rising in all countries



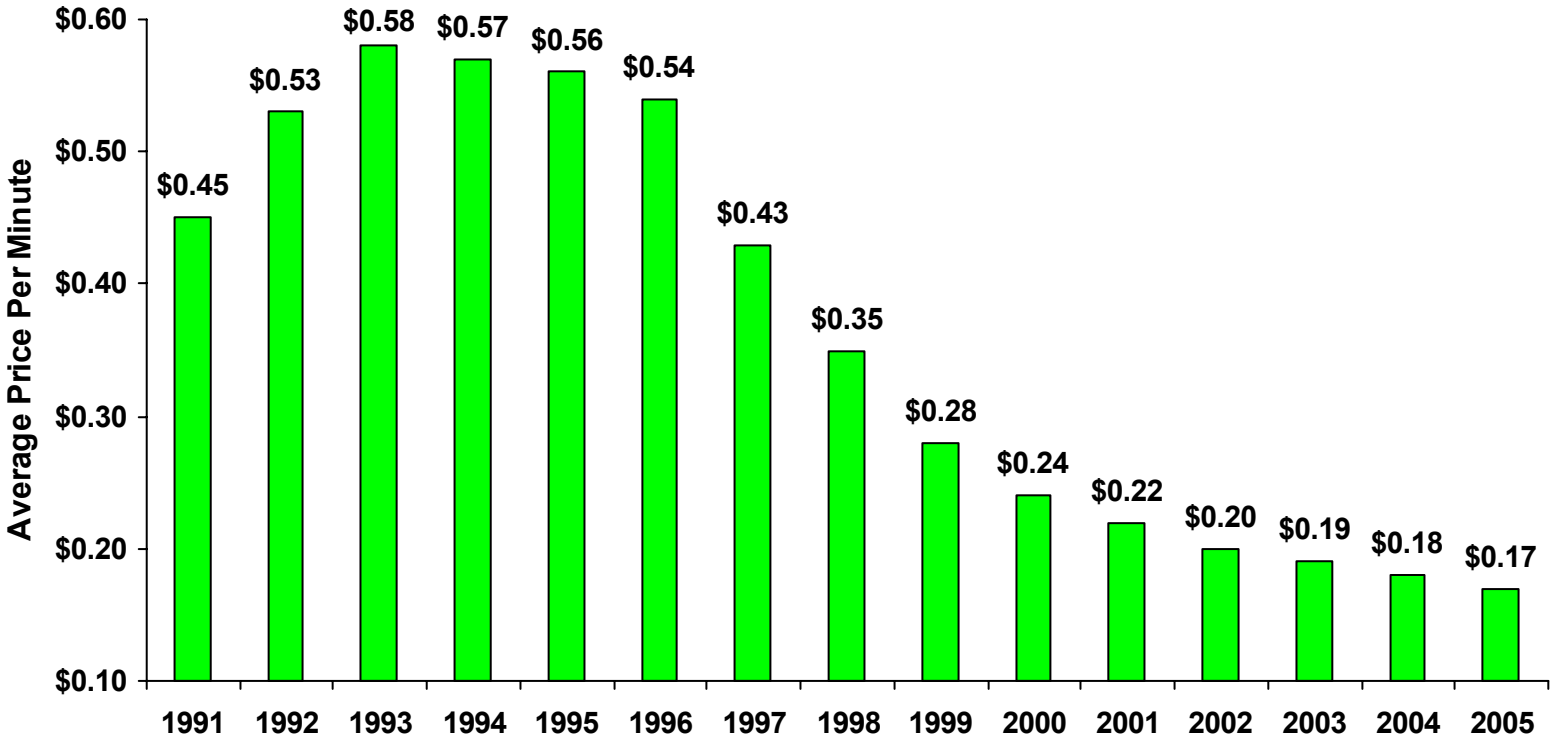
Source: CTIA, 2000

Availability of wireless data devices increasing



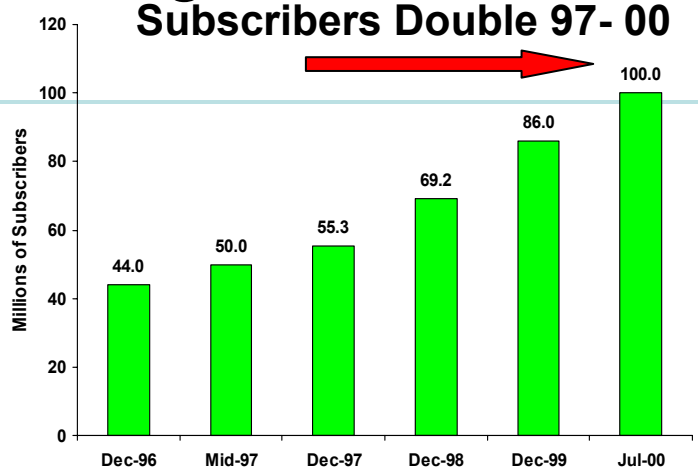
Source: CTIA, 2000

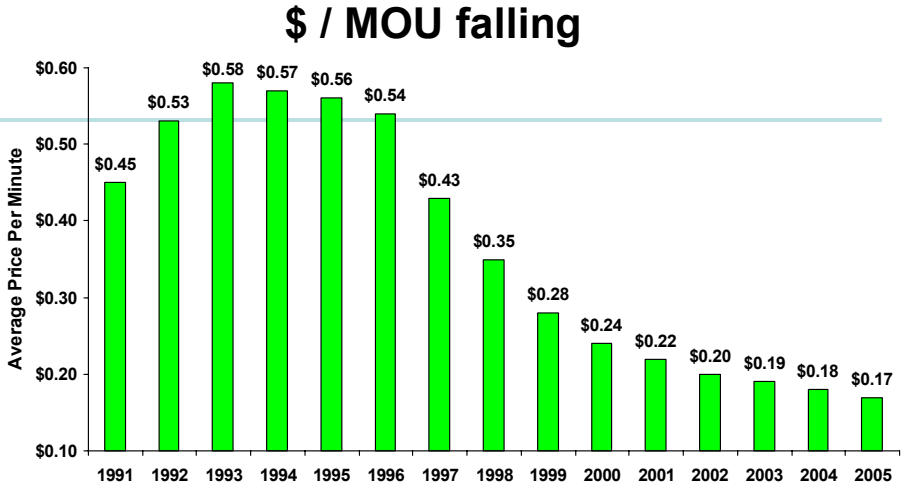
BUT ….
$ / MoU Falling

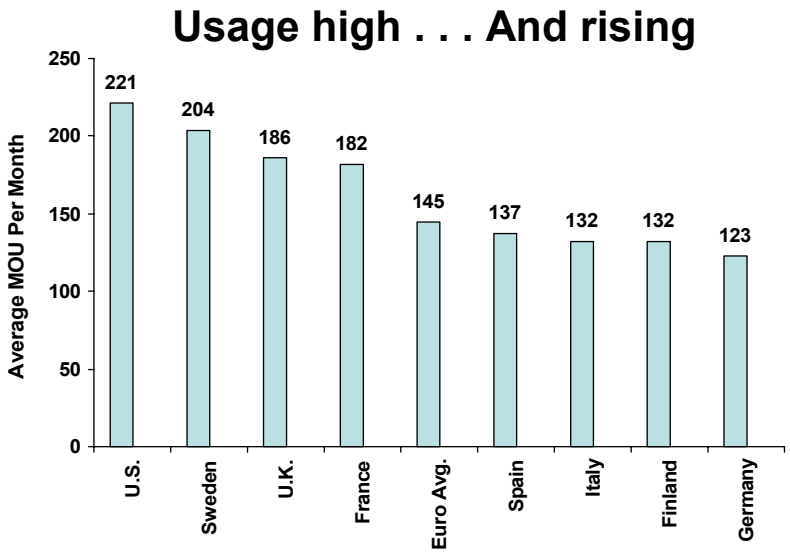


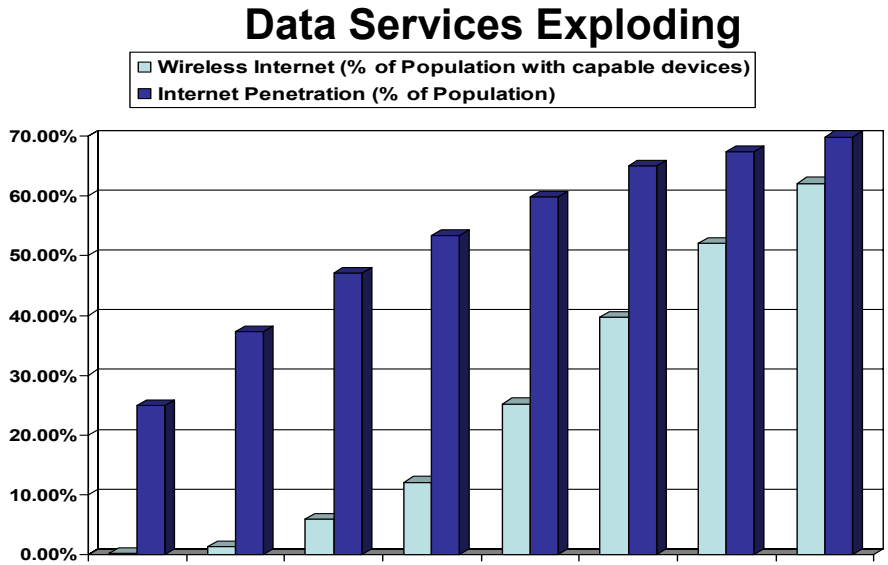
Source: CTIA, 2000

Strong Growth in Subscribers, Minutes, Data BUT Falling $/MOU



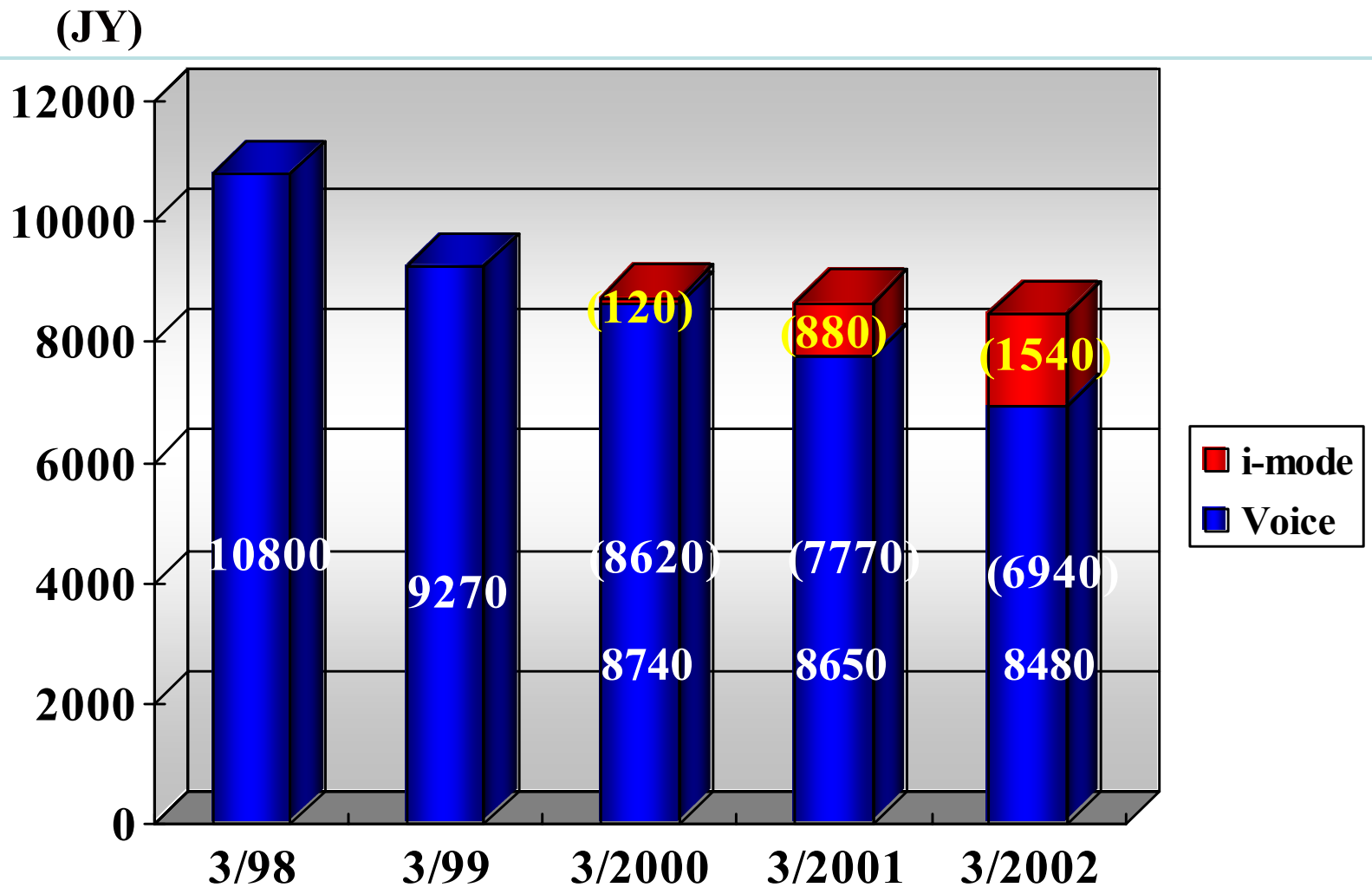






Source: CTIA, 2000

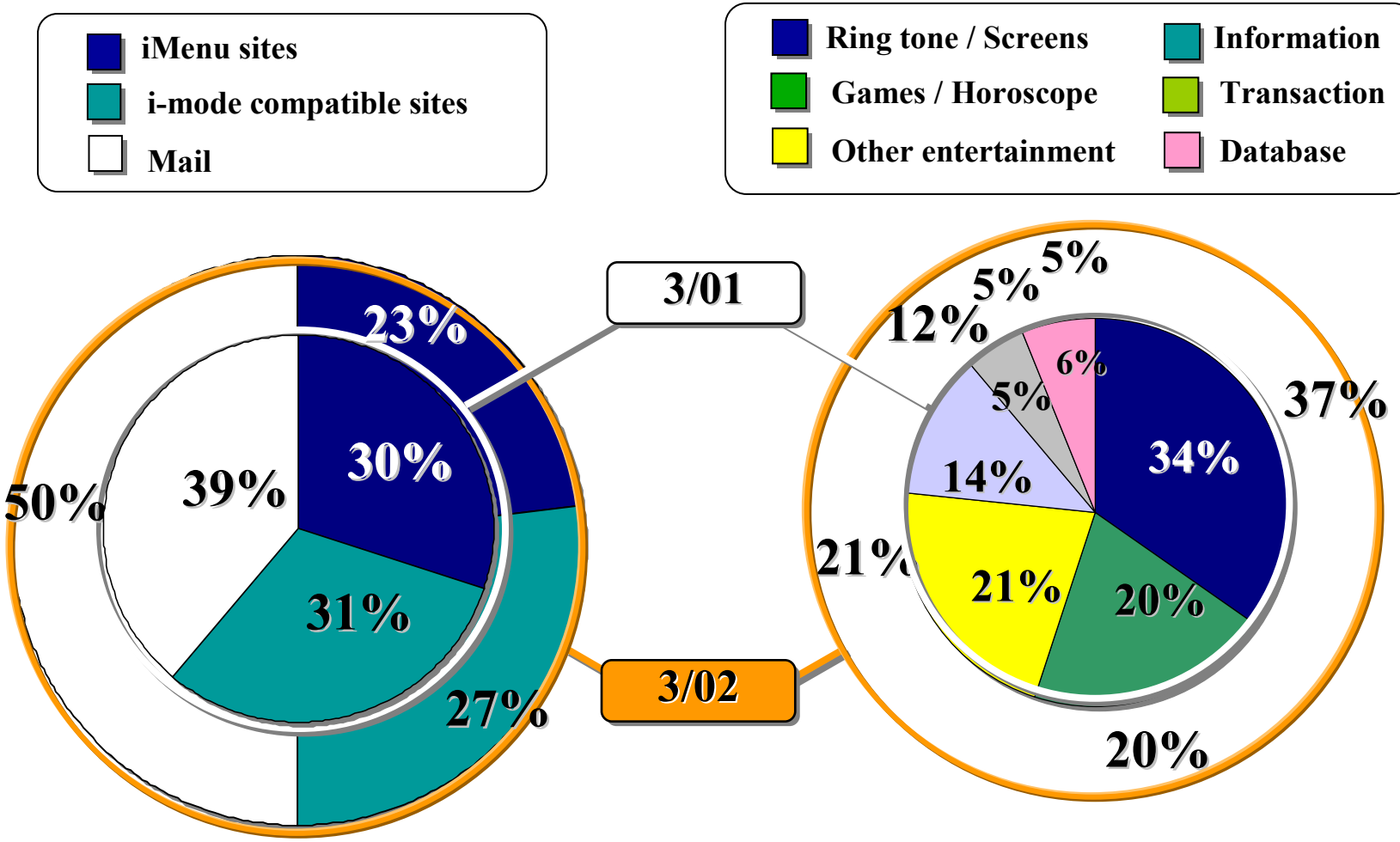
DoCoMo ARPU (voice and i-mode)



Source: NTT DoCoMo Website, www.nttdocomo.com Investor Relations

Mobile Multimedia (i-mode Access Breakdown*1)

i-mode Accesses



iMenu Site Breakdown by Category *2

*1 The numbers represent the percentage to the total accesses made as March 2001 and March 2002. Source: NTT DoCoMo website

*2 % of each category out of total number of hits to iMenu sites as provided by content providers in March and March 2002

1 billion gizmos by 200x (Choose x = 4, 5, ...)

- Gizmos and technology originally developed for one purpose will be used in new and innovative ways for other purposes
  - e.g. Bluetooth was primarily designed as a cable replacement but can be used as a location technology

- Two parallel, contradictory (or complementary) gizmo trends leading to different location needs and capabilities
  - Integration:
    - cell phone as pager, organizer, e-wallet, radio, media player ...
  - Specialization:
    - different functionality, form factors, power requirements, connectivity, processing and storage, fashion niches

Example: integration

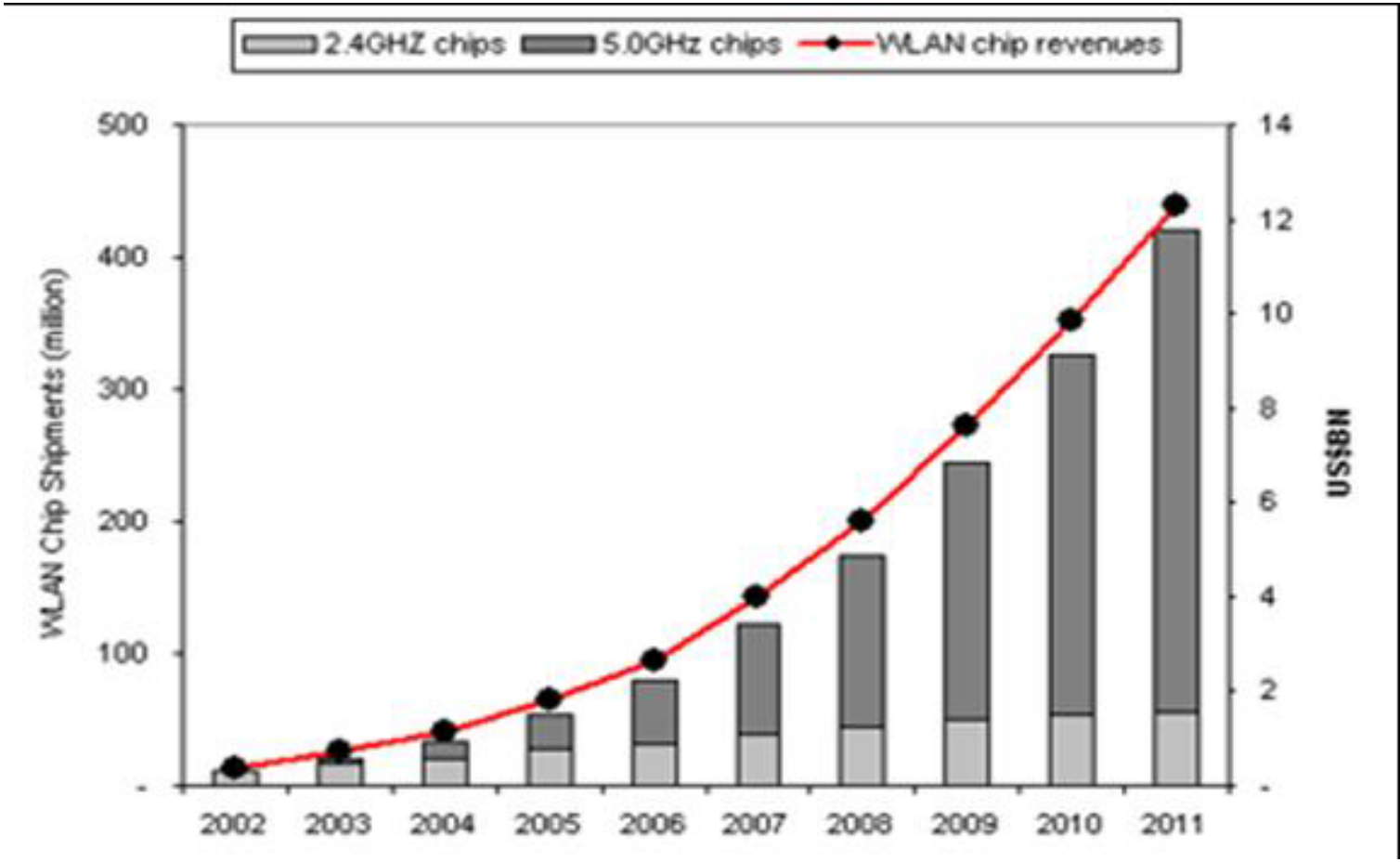
- **DoCoMo 3G FOMA phone**
- **Download 684 kbps, Upload 64 kbps (nominal)**
- **Still and video digital camera**
  - **Add text and frames to pictures or split into a jigsaw puzzle**
  - **Send as email**
  - **Share video while talking**
- **Remote video monitoring using a second phone**
- ***i-motion* service for multimedia content download (music, movie clips etc)**

Source: NTT DoCoMo website

3G Woes

- 3G in Europe
  - Too little, too late, too pricey?
  - Sonera/Telefonica cancellation
- 3G in USA
  - Sprint PCS
  - AT&T rollout
- 3G in Japan
  - FOMA: first out the gate

WLAN: Threat or Opportunity

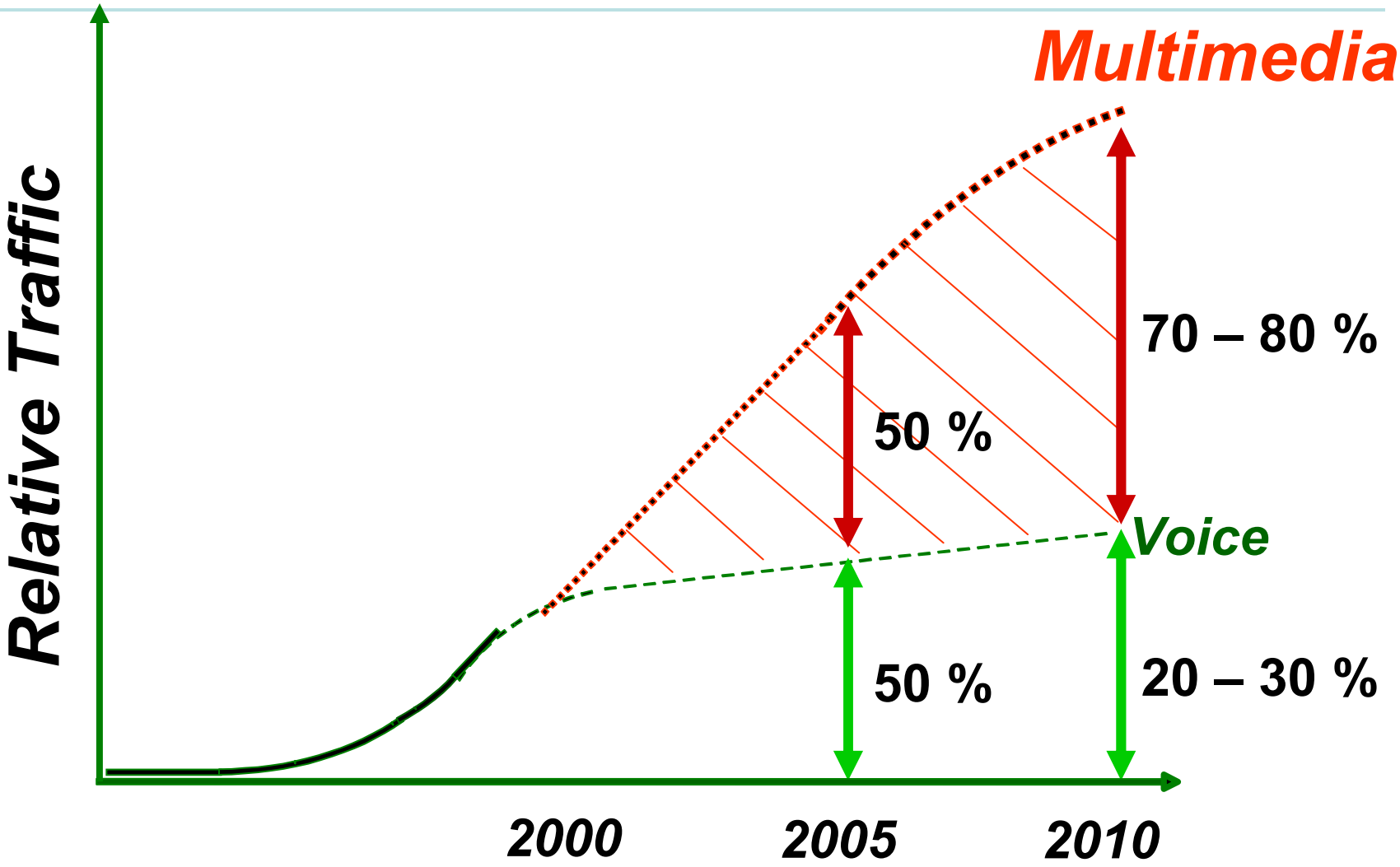


Source: Pyramid research

Interaction characteristics

- Human-Human:
  - voice, text, multimedia conversation and messaging
  - 3D video
- Human-Machine:
  - web access, remote operation
  - virtual reality
- Machine-Machine:
  - telemetering, sensor/actuator networks
  - ubiquitous computing

Traffic characteristics



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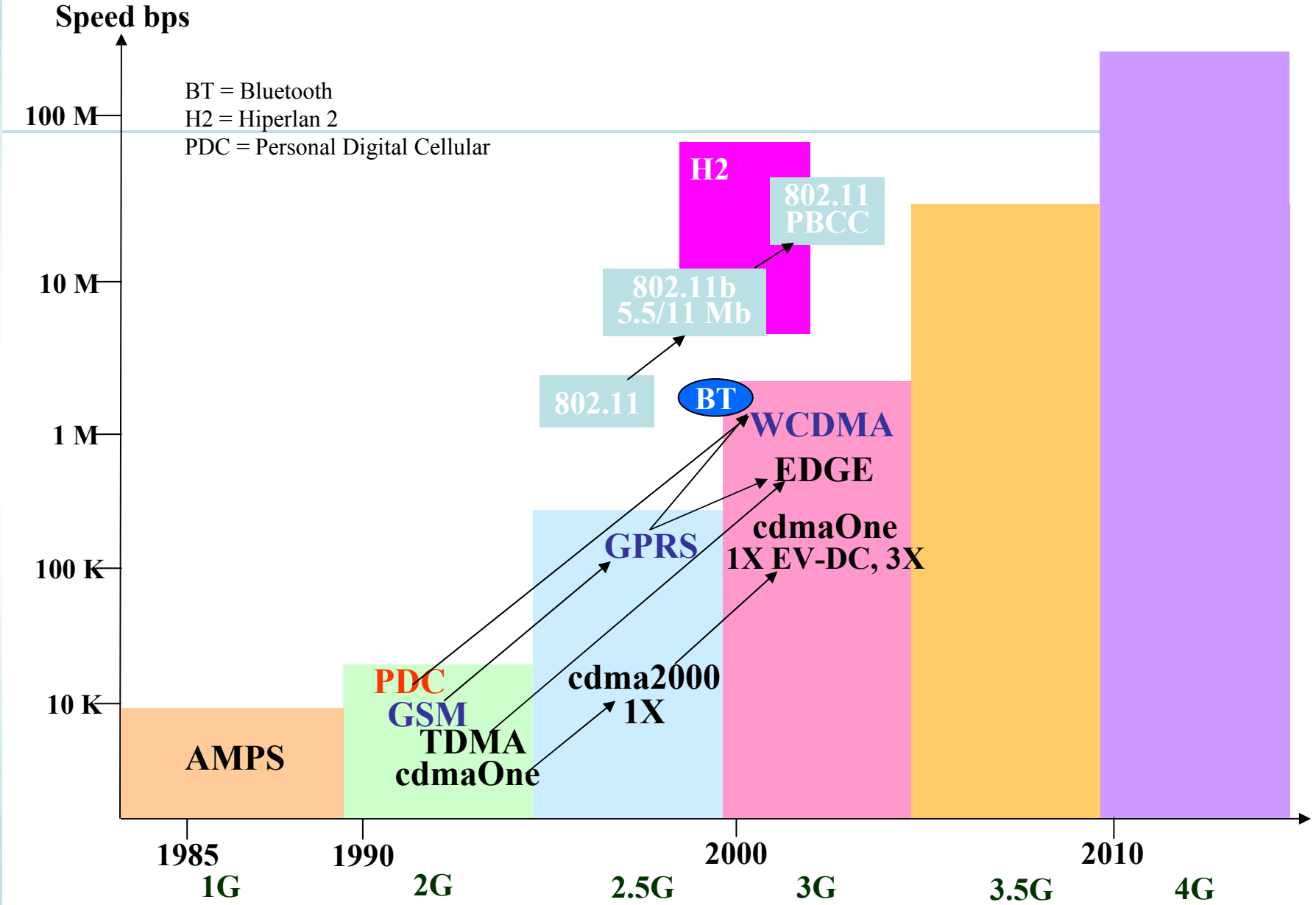
- Introduction and Motivation
- What is 4G anyway?
  - Ways of defining 4G
  - My view: 4G Imperatives
  - Database issues in 4G
- Pet peeves
- Summary

Ways of defining 4G

- Historically wireless generations have been defined in terms of air interface technology, focusing on raw bandwidth
- As 3G demonstrates, good wireless access technology and high raw bandwidth is no longer sufficient for business success
- Thus for 4G it seems more appropriate to use other criteria
  - Technology view
  - Network operator view
  - User view

Technology view: Bandwidth



Alternative ways of classifying generations: Other technology views

- Layer 1 and Layer 2 wireless interface protocols
  - Analog -> Digital -> WCDMA
- Cell sizes or types
  - Cells -> Microcells -> Picocells … Hotspots
- Network (Layer 3) wireless layer protocol
  - Layer 1&2 specific -> (proposed) Wireless ATM -> (proposed) Wireless IP
- System architecture
  - Loosely connected wireless islands -> Tightly integrated with PSTN -> Tightly integrated with Internet

- But this is really a bottom-up view …
- Where's the money?

Alternative ways of classifying generations: Network operator view

- Cost: Spectral efficiency
  - bps/Hz
  - bps/Hz per cell
- Cost: System efficiency
  - $ per bps/Hz
  - $ / (bps/Hz) m^2
- Revenue
  - ARPU
  - $ / MoU
  - $ / packet
  - $ / bit
- Market share:
  - Penetration
  - ARPU*penetration

- But where's the user in all this …?

Wireless generations: User's view *(1 of 2)*

Attribute	1G	2G	3G	*4G*
Cost				
Initial	High	Low	Low	*Flexible*
Per-min	Very high	High	Affordable	*Flexible*
Installation	Inconvenient	Quick or instant	Instant	*Instant; DIY*
Handset	Clunky, heavy	Reasonable for voice, poor for data	Good for voice, poor for data	*Many, app-specific*
Battery life	Very Low	Low	Low	*1 week use*

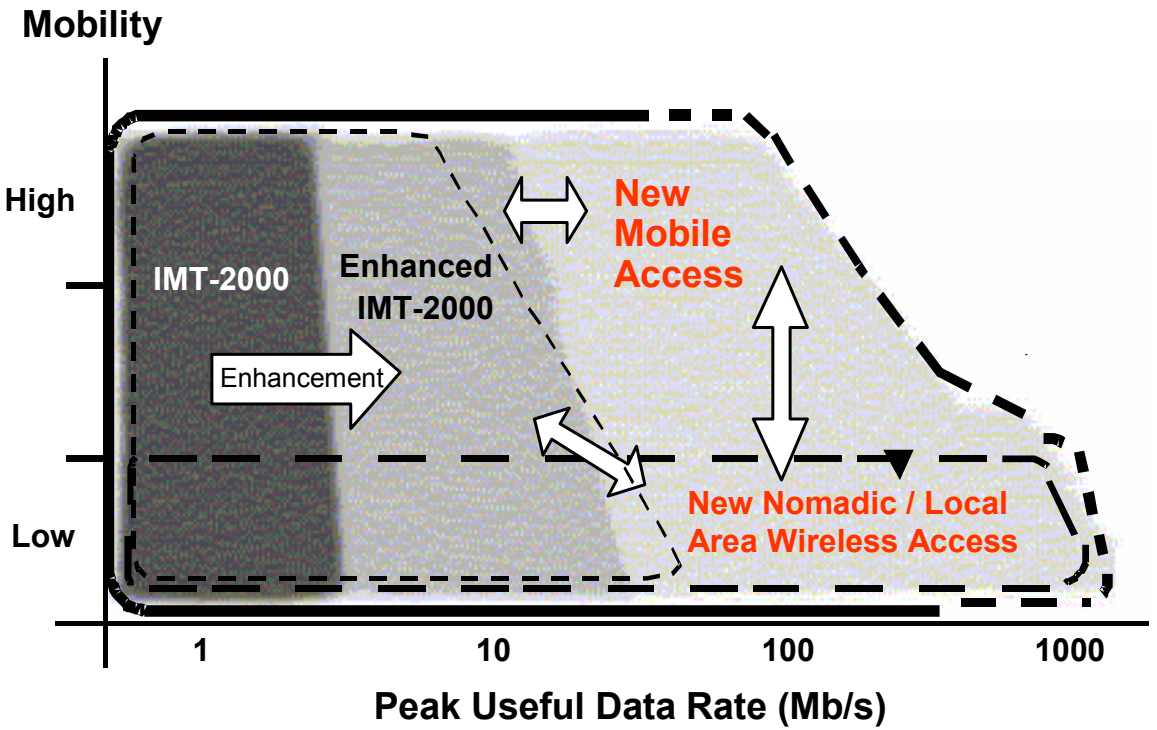
Wireless generations: User's view *(2 of 2)*

Attribute	1G	2G	3G	*4G*
Voice quality	Poor	Reasonable	Good	*Excellent*
Coverage	Poor	Reasonable	Good	*Excellent*
Roaming	None or Inconvenient	Reasonable	Good for voice	*Seamless for all apps*
Voice services	Few	Basic telephony	Reasonable	*Many; DIY*
Data	None	Limited	Limited	*Many*
WWW	N/A	Poor	Limited	*Convenient*
Other user issues		Decreasing $/MoU but Increasing total $/month	Security: w-spam, privacy, etc	*Tradeoff security/QoS for price.* *Low Environment Impact*

User's view: This is just the beginning

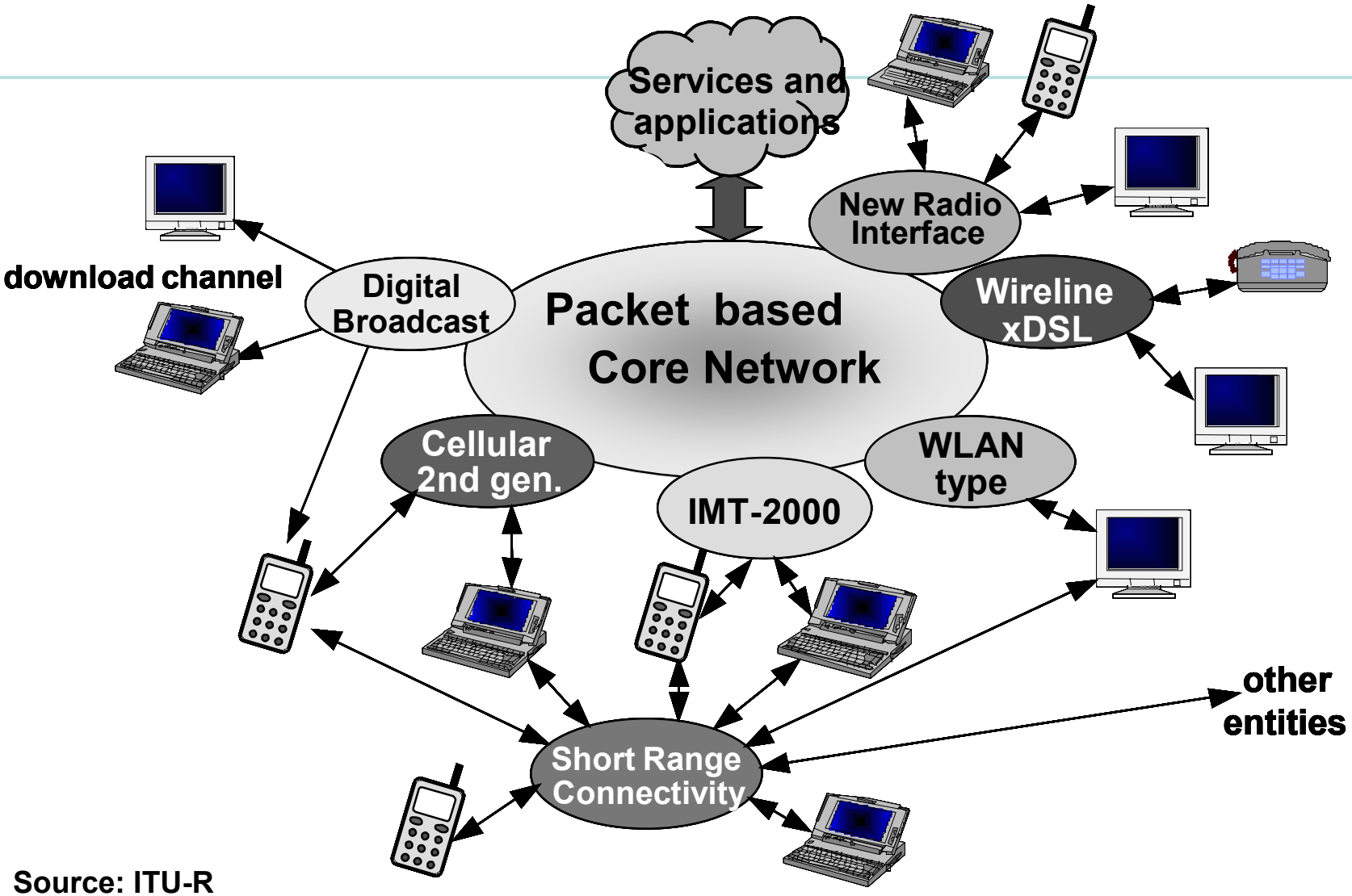
Source:
Rainer Malaka, EML
ICDE 2001

ITU-R view



Source: ITU-R WP8F Vision

ITU-R view



Source: ITU-R WP8F Vision

Another view: 4G Imperatives *(1 of 4)*

- Innovative applications, not voice, will be the key revenue generator
  - ⇒Programmability and Open APIs
    - while maintaining security, QoS, and bill-ability
  - ⇒Foster a 3rd-party app developer community
    - Build on work centered on fixed networks (Parlay, JAIN, OSA)
  - ⇒*The search for the killer app should never end*
    - Any static portfolio of applications and services will eventually become a commodity
  - ⇒Radical personalization and niche applications
    - *Applications with a market size of 1*

Another view: 4G Imperatives *(2 of 4)*

- True convergence with the Internet is critical
  - ⇒IP must be supported efficiently
  - ⇒Remove discontinuities at the wired/wireless interface and the data/voice interface
  - ⇒*The Internet must also evolve to support wireless mobility and ubiquity efficiently*
    - Example: Fundamental addressing issues dictate IPv6
    - Example: Fundamental inefficiencies in supporting mobility must be removed
    - Example: Use of proxies vs the end-to-end argument must be investigated critically

Another view: 4G Imperatives *(3 of 4)*

- Spectrum will remain the vital resource
  - Integrate with unlicensed spectrum
    - Allow creative technology and business models for seamless inclusion of hotspots and multihop WLAN and other technologies
      - Operator-owned and 3rd-party owned WLAN elements
      - Aggregator and community access models
  - Manage licensed spectrum efficiently
    - Consider dynamic and market-based mechanisms for on-demand spectrum allocation

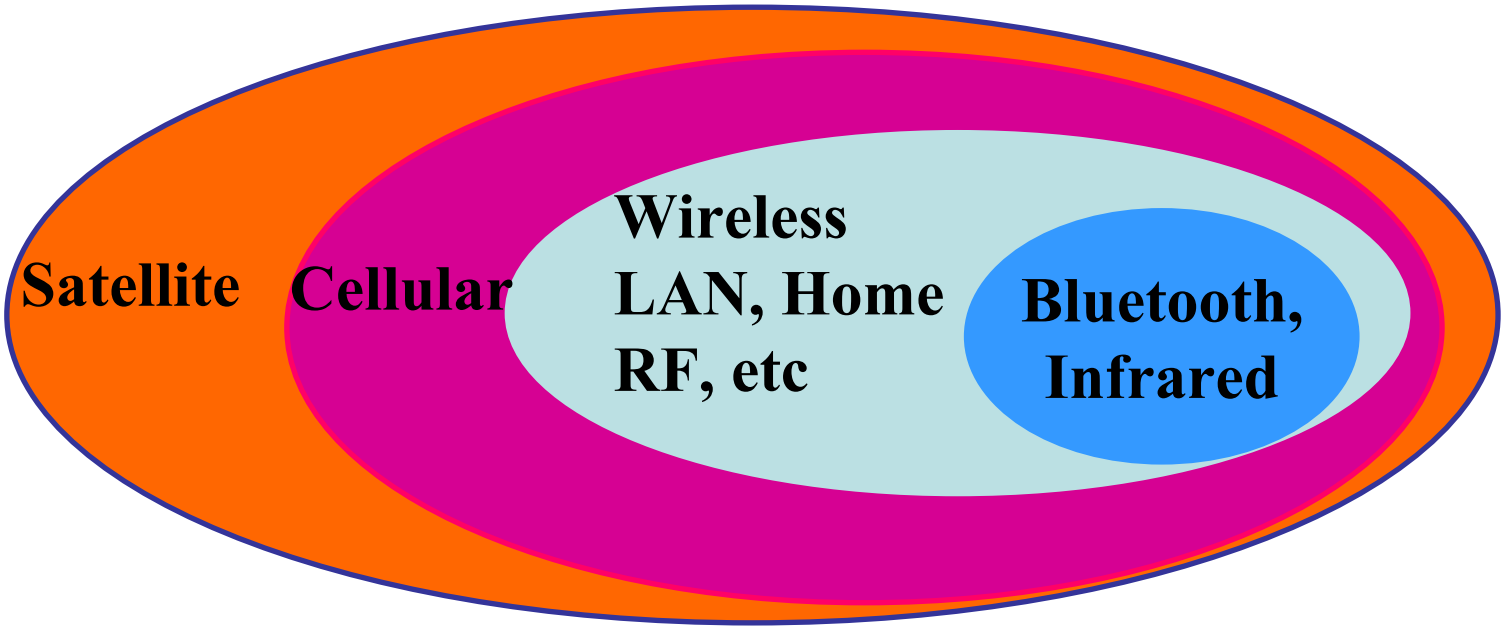
Another view: 4G Imperatives *(4 of 4)*

- Allow rapid organic, bottom-up technology introduction
- Flexibly integrate multiple air interface technologies that coexist and provide synergy
- Flexibly support multiple devices that coexist and provide synergy

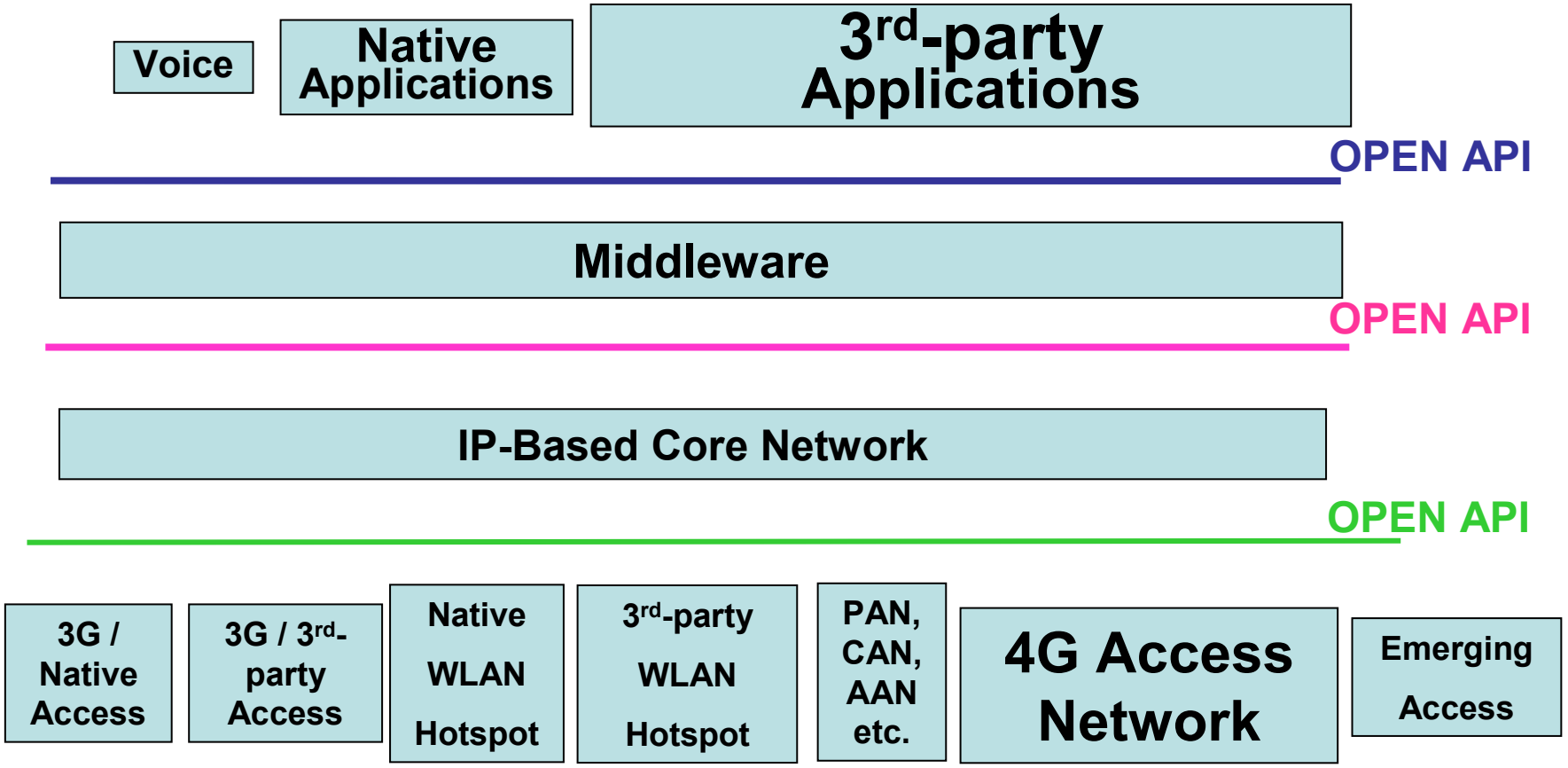
- Usability and User Interfaces will remain key
  - New UI and devices will extend the application space (C.f. Palm PDA)

Needed: The Sony Walkman of 4G (with Tactile, Speech, & other UI)

4G: An evolvable, programmable, multi-tier multi-device network



4G:
The Basic Model

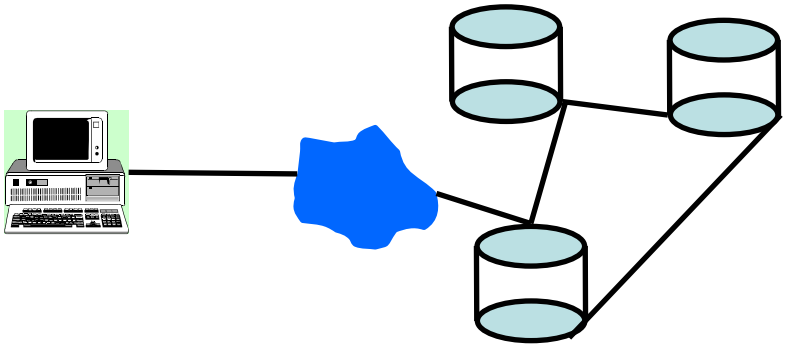


Evolution towards 4G

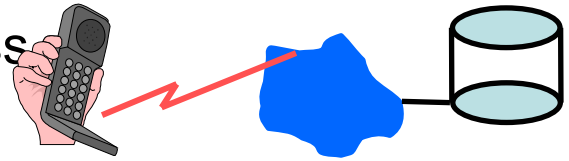
- **3.5G:** An All-IP network (i.e., with Wireless IP) integrating all our current favorite IETF protocols (MIP, FMIP, HMIP, CARD, PANA, etc)
- **4G:** A programmable, flexible, application-oriented Web-based architecture suitable for fundamentally supporting
  - mobility
  - WWW
  - ubiquitous computing
  - semantics-aware applications
  - …

Database issues in 4G: Evolution of database network architectures

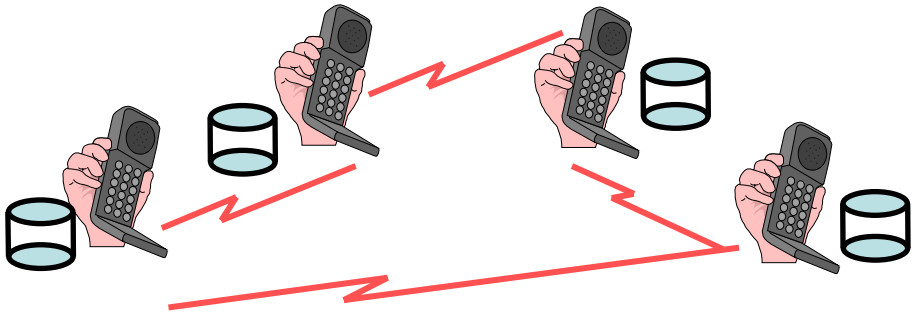
- Centralized



- Distributed
- Mobile wireless database access
  - Database access using a gizmo



- Ad-hoc database networks
  - Database on the gizmo



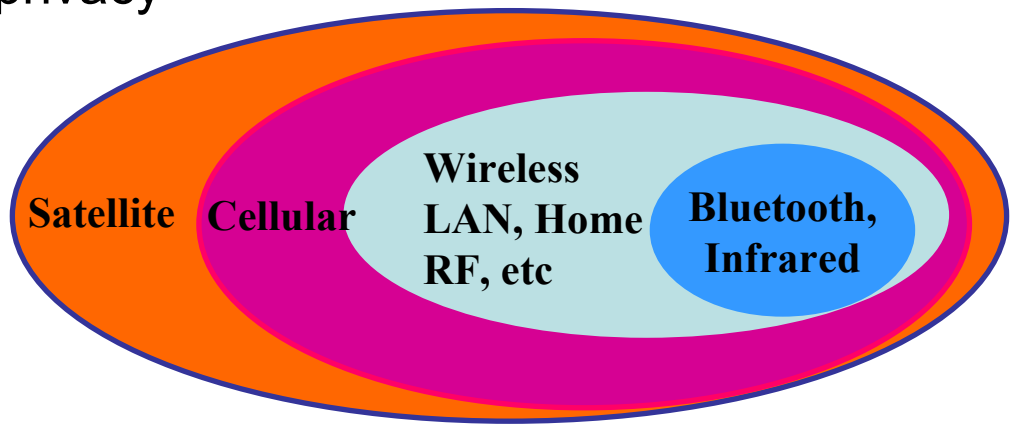
Viability

- Mobile DB market
  - Connect mobile workers to back-office enterprise servers
  - Vertical markets: Field service, transportation, retail, utilities, financial, healthcare, government
  - Gartner: $70M in 2001, Up to ~$150M in 2006 (16% CAGR)
- Need a clearer business case for further architecture evolution
  - Sensors to a DB: for niche vertical applications?
  - Pervasive and Ad-hoc networked databases?

Information management: Location, location, location

- The easiest way to add context to the user experience
- Also maybe the easiest way to add value
- Total location information management in a comprehensive multi-tier wireless network with seamless connectivity

- Location estimation
- Location (i.e. “next-cell”) prediction
- Location privacy



Location management: It's not just for gizmos anymore!

- Mobile software will become an increasingly important aspect of next generation networks and applications
  - Mobile agents, active networks, mobile code, programmable networks, etc.
- Mobile software to serve a (mobile) user
  - A user agent for personalized information retrieval, shopping, etc
  - Makes particular sense for information access over a wireless link
  - *Jain and Anjum, IEEE WCNC, 2000*
- Mobile software to serve the network provider
  - Mobile software in the network to decrease the cost of personalized information delivery to (mobile) users
  - *Shah, Jain, Rajagopalan, Anjum, 2001*
- Managing the itineraries and location of mobile software modules will be a major challenge
  - Security, cost, and efficiency implications

Database needs: gizmos as blessing (and curse ...)

- Where is my gizmo?
  - Databases for managing the location and mobility of distributed communicating devices
- Where is the user (or object) who has my (or this) gizmo?
  - Databases for using devices and connectivity to identify, authenticate, and locate users -- as well as other devices
- What can my gizmo do for me today?
  - Databases for dynamic service discovery, download, and activation
- Why can't my one gizmo do everything?
  - Integrating database facilities with other horizontal & vertical applications
- Why can't I have a special gizmo to do this one thing I need?
  - Application-specific *micro-databases* and database micro-clients
- Why can't my gizmo and your gizmo figure things out together?
  - Database transactions across ad-hoc networks

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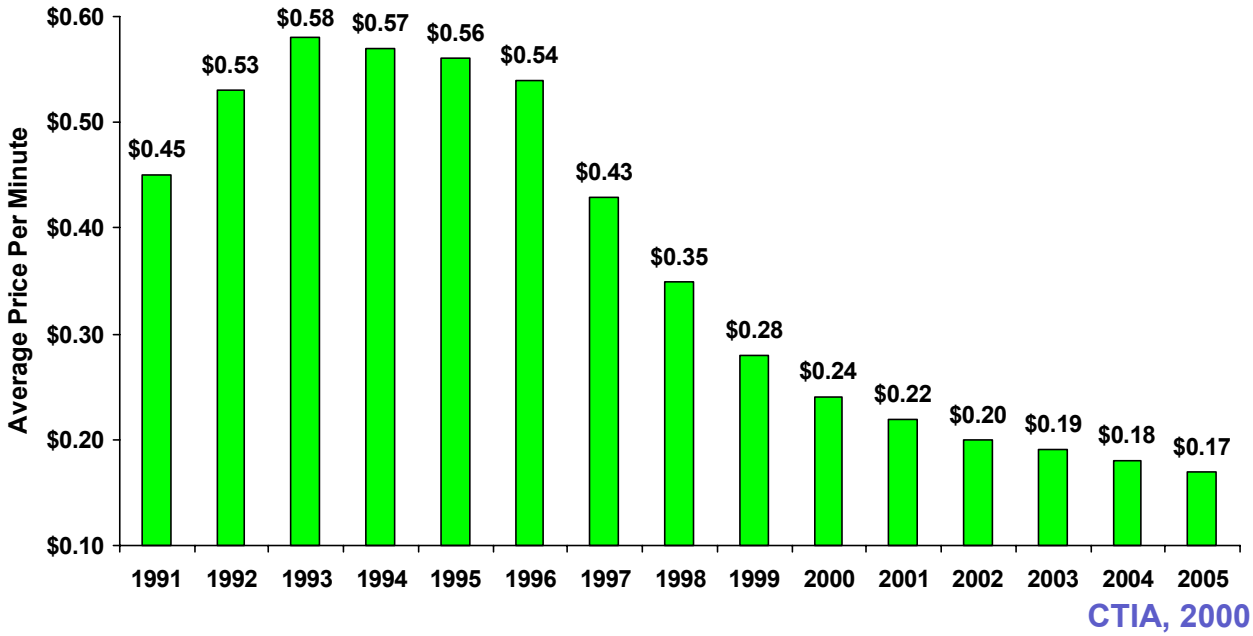
A maturing industry



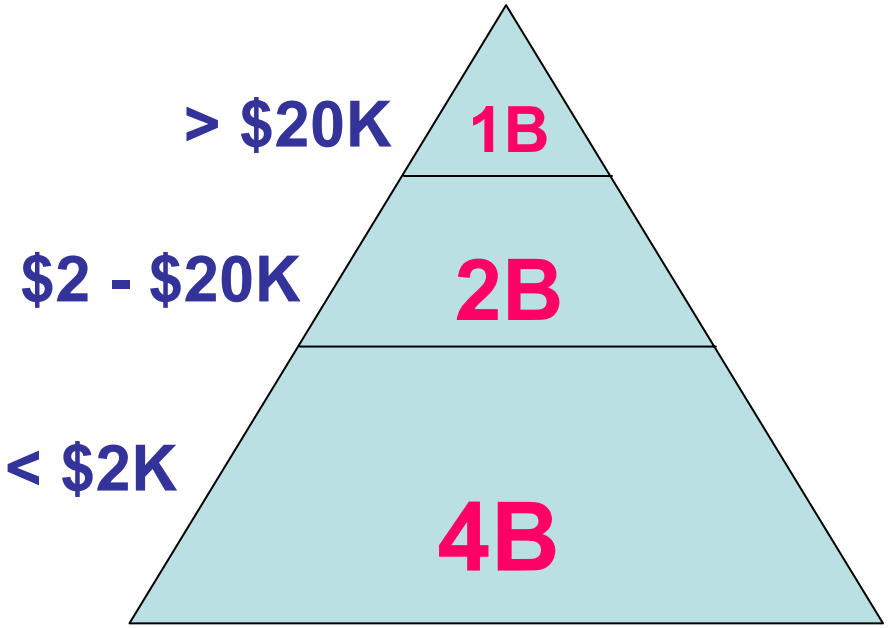
CTIA, 2000

New Challenges Require Creative Thinking

B24B

Provide useful, affordable Information Technology services to the 4 billion people on the planet earning less than $2000 *per yr*

- A Grand Challenge
  if there ever was one
  - *Kalil, 2002*
  - *Prahalad & Hammond,* HBR, 2002



Why?
Enlightened Self-Interest (1 of 2)

- New markets are the key to growth
  - Penetration and ARPU is saturating in the developed world
  - The economies of less developed countries are growing faster than the developed world
    - Hence less headroom for ARPU
  - The population of less developed countries is growing faster
  - The penetration of IT in less developed countries is miniscule
    - although increasing rapidly at the top of the local pyramid

Why?
Enlightened Self-Interest (2 of 2)

- "we renew our commitment to the principle of inclusion: everyone, everywhere should be enabled to participate in and no one should be excluded from the benefits of the global information society."
  - *Okinawa Charter on the Global Informaton Society,* G8 Summit in Okinawa, Japan, 2000

- In the long run, stability and prosperity everywhere is interconnected
  - "There will be no stability and prosperity in the world in the 21st Century unless the problems of Africa are resolved."
    - Japanese PM Y. Mori, Jan 2001

Frequently Raised Objections (FRO)

- The poor don't need PCs and broadband, they need food, water, power …
  - True, but only partially
  - We are not proposing PC and broadband, but IT that can help them procure their basic needs
    - Example: Price discovery for agricultural produce

FRO:
The poor don't have money to buy IT

- "The poor" are not a homogeneous mass: vast differences between urban and rural
  - Dharavi, a shantytown in Mumbai (Bombay, India)
    - Buying a house or access to indoor running water is unrealistic
    - Penetration of TV: 85%, Pressure cooker: 75%, Mixer: 75%, Gas stove: 56%

- Large amount of aggregate purchasing power
  - Grameen Telecom village phone model
  - A single entrepreneur's cell phone is used by the entire village
  - Mean ARPU = $90 (~ twice of US)
  - Max ARPU = $1000
  - Consumers willing to spend 7% of their income on phone service

FRO:
Goods must be cheap so no room for profit

- True, but only partly
- The Poverty Premium
  - Dharavi (shantytown) vs Warden Rd (upper-class suburb)
    - Water: 37X, Diarrhea medication: 10x, Rice: 1.2x
    - Phone call: 1.8x
- Cost of delivering goods to urban poor can be low
  - Most live in densely populated cities
  - Roughly half of the Bottom of the Pyramid lives in 1300 cities
  - Many of the slums of these cities have a thriving, commercial, entrepreneur-driven micro-economy

FRO:
The poor cannot use advanced technology

- All new technology requires consumer awareness and education
  - Building this, at least for the urban poor, can be less costly than in developed countries
  - A much softer sell is necessary: the technology is obviously needed
- Grameen Telecom: Poor rural women in Bangladesh easily learn to use GSM phones although may have never made a phone call in their life
- In Kenya, poor teenagers are successfully trained as Web developers

Success metrics

- Individual
  - Number of people with access to connectivity within walking distance
  - Cost equal to a cup of coffee a day
- Societal
  - Number of people who cross the poverty line
  - Improved health (education, telemedicine, etc)
  - Better preparation and response to disasters
  - Free flow of information

Technical Challenges *(1 of 2)*

- User interfaces
  - Multi-lingual
  - Cross-cultural
  - Simpler and more intuitive
- Less reliance on infrastructure
  - Ad-hoc and multi-hop networks
  - Better power usage and alternative power sources
- Better support for resource and device sharing
  - Privacy and security
  - Immediate and itemized charging, billing, and payment
  - Personalization

Technical Challenges *(2 of 2)*

- Modular, streamlined products
  - Remove the unnecessary bells and whistles
  - Allow incremental upgrade and pay-only-for-what-you-use
  - Better software and system design
- Biometric and non-linguistic security

- Be open to *Reverse Flow of Innovation*
  - Incorporate diverse feedback loops into the product process
  - Examples: handcrank radios, MiniGSM

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  - Plateau of revenue in current markets

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