Chapter 1: Introduction

Jyh-Cheng Chen and Tao Zhang

IP-Based Next-Generation Wireless Networks
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Outline

1.1 Evolution of Wireless Networks

1.2 Evolution of Public Mobile Services

1.3 Motivations for IP-based Wireless Networks

1.4 3GPP, 3GPP2, and IETF

1.5 Organization of the Book

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IP-Based Wireless Networks

- ◈ More suitable for supporting the rapidly growing mobile data and multimedia applications
- ◈ Bring the globally successful Internet service creation
  - ■ provide a proven successful platform for fostering future mobile services
- ◈ Independent of the underlying radio technologies
  - ■ better suited for supporting services seamlessly over different radio technologies and for achieving global roaming

1.1 Evolution of Wireless Networks

- ◆ Personal Area Networks (PANs)
- ◆ Wireless Local Area Networks (WLANs)
- ◆ Low-tier wireless systems
- ◆ Public wide-area (high-tier) cellular radio systems
- ◆ Mobile satellite systems

Fig. 1.1 Wireless systems: bit rates vs. coverage areas

Data Rate (Mbps)
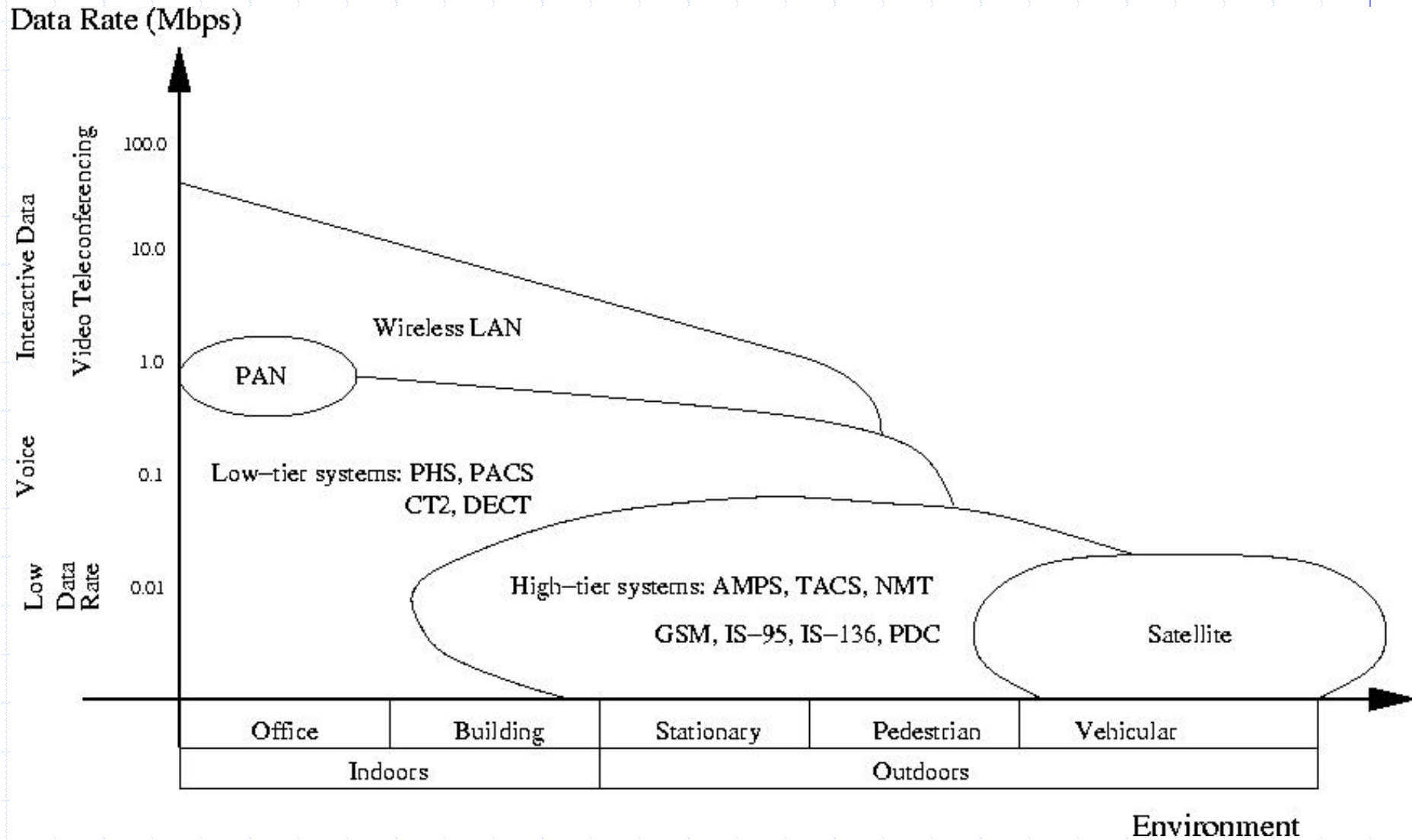
Personal Area Networks (PANs)

- Short-range low-power radios
- Bluetooth
  - three power classes with coverage ranges up to approximately 10 meters, 50 meters, and 100 meters, respectively
  - support bit rates up to about 720 Kbps
- HomeRF
- IEEE 802.15
  - support data rates over 20 Mbps

Low-Tier Wireless Systems

- ◈ Designed mainly to serve users with pedestrian moving speeds
- ◈ Coverage ranges typically are less than 500 meters outdoors and less than 30 meters indoors
- ◈ Used as wireless extensions of residential or office telephones
  - Cordless Telephone, Second Generation (CT2)
  - Digital European Cordless Telecommunications (DECT)
- ◈ Provide public services
  - Personal Access Communications Systems (PACS)
  - Personal Handyphone System (PHS)

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Cordless Telephone, Second Generation (CT2)

- Designed in the United Kingdom in 1989
- Designed for use in homes, offices, or public telephone booths
- Supports only circuit-switched voice services

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Digital European Cordless Telecommunications (DECT)

- ◆ Defined by the European Telecommunications Standards Institute (ETSI) in 1992

- ◆ Designed primarily for use in an office environment

- ◆ Supports circuit-switched voice and data services

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Personal Access Communications Systems (PACS)

- Designed by Telcordia (then, Bellcore) in the United States in 1992
- Provide wireless access to local exchange carriers (LECs)
- Radio coverage within a 500-meter range
- Support voice, data, and video
- Use in both indoor and outdoor microcells

Personal Handyphone System (PHS)

- Designed by the Telecommunications Technical Committee of Japan
- Support both voice and data services
- Support a channel rate of 384 Kbps

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Wireless Local Area Networks (WLANs)

- Typically use the unlicensed Industrial, Scientific, and Medical (ISM) radio frequency bands
- ISM bands in the United States
    - 900-MHz band (902-928 MHz)
    - 2.4-GHz band (2400-2483.5 MHz)
    - 5.7-GHz band (5725-5850 MHz)
- IEEE 802.11: the most widely adopted WLAN standard

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IEEE 802.11

- A family of standards that defines the physical layers (PHY) and the Media Access Control (MAC) layer
- IEEE 802.11:
  - infrared (IR)
  - radio frequency (RF) in the 2.4-GHz ISM band
  - 1 or 2 Mbps
- IEEE 802.11b: 11 Mbps in the 2.4-GHz ISM band
- IEEE 802.11a: 54 Mbps in the 5.7-GHz ISM band
- IEEE 802.11g: 54 Mbps in the 2.4-GHz ISM band
- IEEE 802.11i: security
- IEEE 802.11e: QoS
- IEEE 802.11f: Inter Access Point Protocol (IAPP)

Public WLANs

- ◆ Provide significantly higher data rates than wide-area wireless networks

- ◆ Could take advantages of both WLAN and wide-area radio technologies to create new services and reduce networking costs

- ◆ Public WLANs are the first wave of all-IP radio access networks

- ◆ New and innovative business models for providing public mobile services

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Fig. 1.2 Worldwide WLAN sales
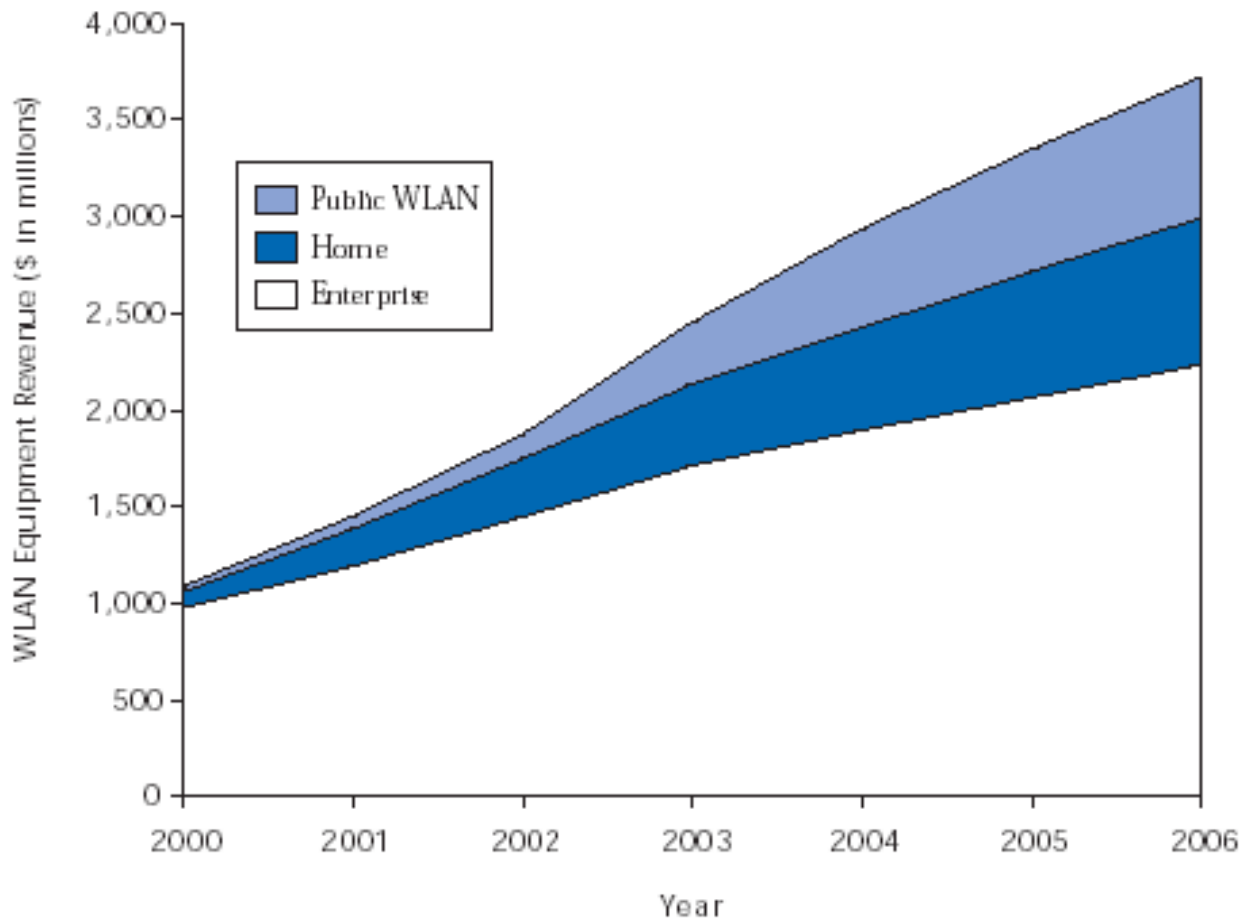
Public Wide-Area (High-Tier) Wireless Networks

- Provide public mobile services over large geographical areas to users moving on both pedestrian and vehicular speeds
- Consists of
  - Radio Access Networks (RAN): provide radio resources for mobile users to access a core network
    - a cell may exceed 10 kilometers in diameter
  - Core Network: a wireline network used to interconnect RANs and to connect the RANs to other networks
- Classified into *generations* based on the technologies they use and networking capabilities they provide

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1G Wireless Networks

- Became commercially available in the early 1980s
- Analog radio technologies and circuit-switched transmission and networking technologies
- Main service: circuit-switched voice
- Lack the ability to support roaming between different network operators
- Three main 1G radio system standards
  - Advanced Mobile Phone Systems (AMPS) in North America
  - Total Access Communications Services (TACS) in the United Kingdom
  - Nordic Mobile Telephone (NMT) in Nordic countries

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2G Wireless Networks

- Emerged in the early 1990s
- Digital signal processing and transmission technologies (increased radio capacity and spectrum utilization, enhanced voice quality, reduced power consumption, etc.)
- Standards for core networks
- In addition to circuit-switched voice, enabled the first waves of mobile data and mobile Internet services

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2G Systems in North America

- ◆ RAN
  - IS-136: Time Division Multiple Access (TDMA)
  - IS-95: Code Division Multiple Access (CDMA)
- ◆ Core Network
  - IS-41: support roaming between different network operators

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2G System in Europe

- GSM (Global System for Mobile communications): RAN and core network
- Radio frequencies
  - 900 MHz and 1800 MHz in Europe
  - 800 MHz and 1900 MHz in the United States
- Services
  - circuit-switched voice
  - 9.6 Kbps circuit-switched symmetric channel as a data connection to access the Internet
- Most widely used 2G wireless network standards in the world

2G System in Japan

- Personal Digital Cellular (PDC) network
- Services
  - circuit-switched voice
  - data services over 9.6 Kbps radio channels

2.5G Wireless Networks

- Provide higher radio system capabilities and per-user data rates than 2G systems, but do not yet achieve all the capabilities promised by 3G systems
- General Packet Radio Services (GPRS)
  - provide a packet-switched core network as an extension to GSM core networks
- Enhanced Data Rates for Global GSM Evolution (EDGE)
  - provide advanced modulation and channel coding techniques to increase the data rates of GSM radio systems
  - support data rates up to 384 Kbps (also regard as a 3G system due to its high speed)

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3G Wireless Networks

- Significantly increase radio system capacities and per-user data rates over 2G systems
- Support IP-based data, voice and multimedia services
- Enhance quality-of-service (QoS) support
- Improve interoperability

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Third-Generation Partnership Project (3GPP)

- 3G core networks will evolve the GSM core network platform to support circuit-switched mobile services and to evolve the GPRS core network platform to support packet-switched services.

- 3G radio access technologies will be based on the Universal Terrestrial Radio Access Networks (UTRANs) that use Wideband-CDMA (WCDMA) radio technologies.

Third-Generation Partnership Project 2 (3GPP2)

- 3G core networks will evolve the IS-41 core network to support circuit-switched mobile services and define a new packet core network architecture that leverages capabilities provided by the IS-41 core network to support IP services.

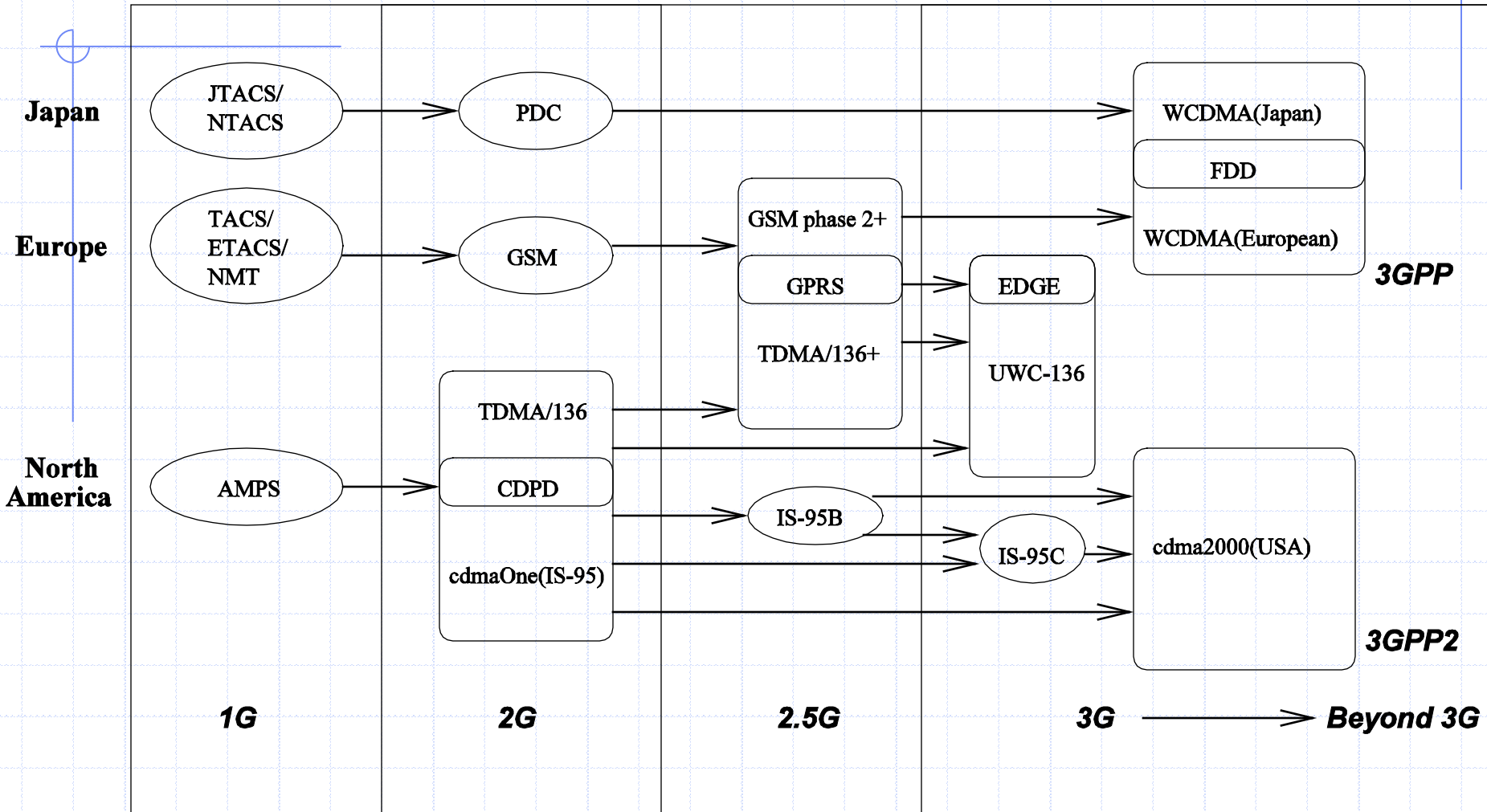- 3G radio access technologies will be based on cdma2000 radio technologies.

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Table 1.1 WCDMA vs. cdma2000

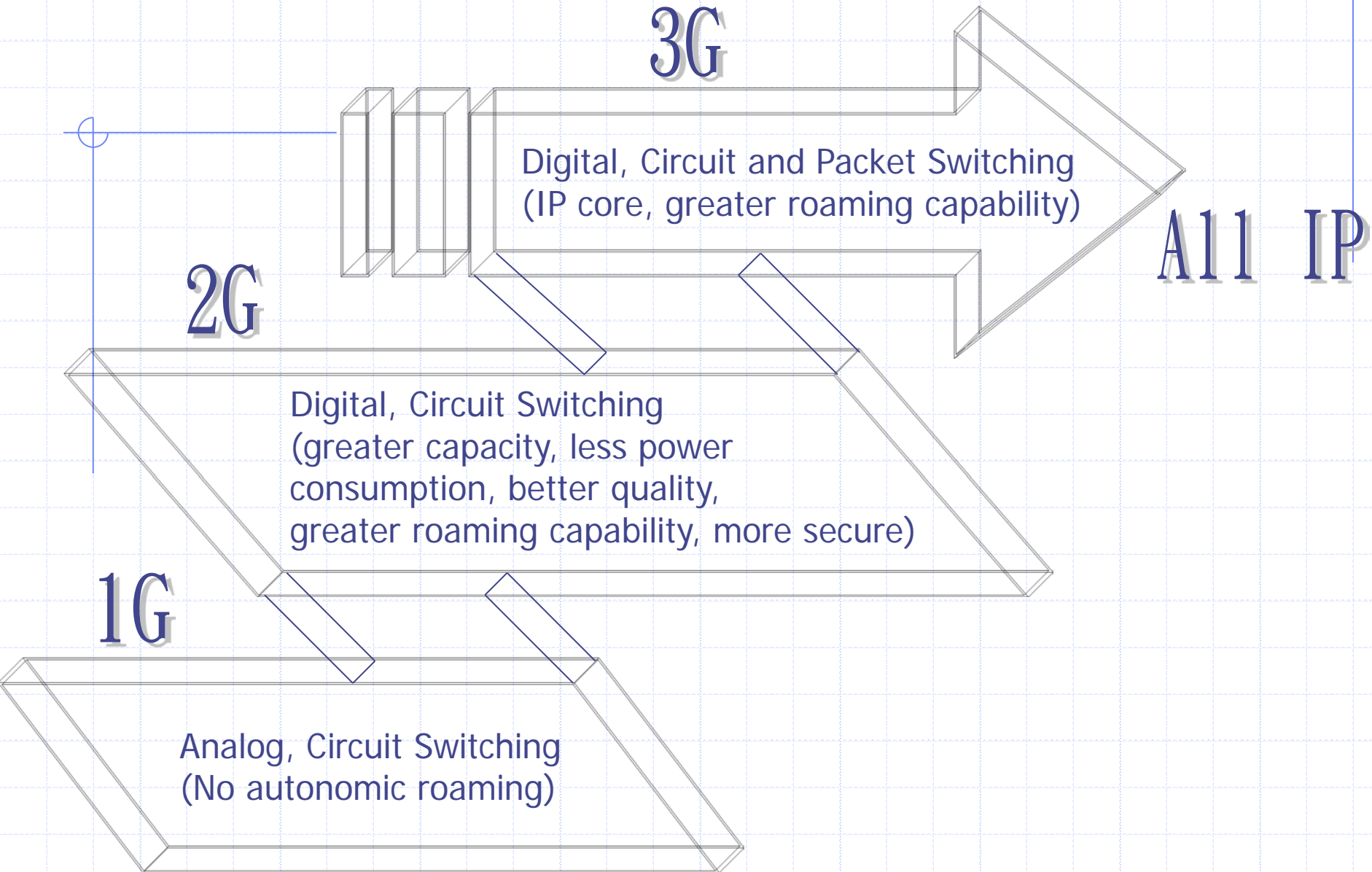|	WCDMA	cdma2000
Multiple Access Scheme	Frequency Division Duplex Direct-Sequence CDMA (FDD DS-CDMA) and Time Division Duplex Direct-Sequence CDMA (TDD DS-CDMA)	Frequency Division Duplex Multicarrier CDMA (FDD MC-CDMA)
Spreading Chip Rate	3.84 Mcps	1.2288 Mcps for 1xRTT 3 x 1.2288 Mcps for 3xRTT
Base Station Synchronization	Asynchronous	Synchronous
Network Signaling	GSM-MAP	IS-41, GSM-MAP
Frame Size	10 ms for physical layer frames 10, 20, 40, and 80 ms for transport layer frames	5 (for signaling), 20, 40 and 80 ms for physical layer frames

Fundamental Principles of 3G

- Core networks will be based on IP technologies
- Evolutionary rather than revolutionary

Fig. 1.3 Evolution of standards for wide-area radio systems

Fig. 1.4 Evolution of network technologies from 1G to 3G

3G

Digital, Circuit and Packet Switching
(IP core, greater roaming capability)

All IP

2G

Digital, Circuit Switching
(greater capacity, less power
consumption, better quality,
greater roaming capability, more secure)

1G

Analog, Circuit Switching
(No autonomic roaming)

Fig. 1.5 Wireless IP network supporting heterogeneous radio technologies
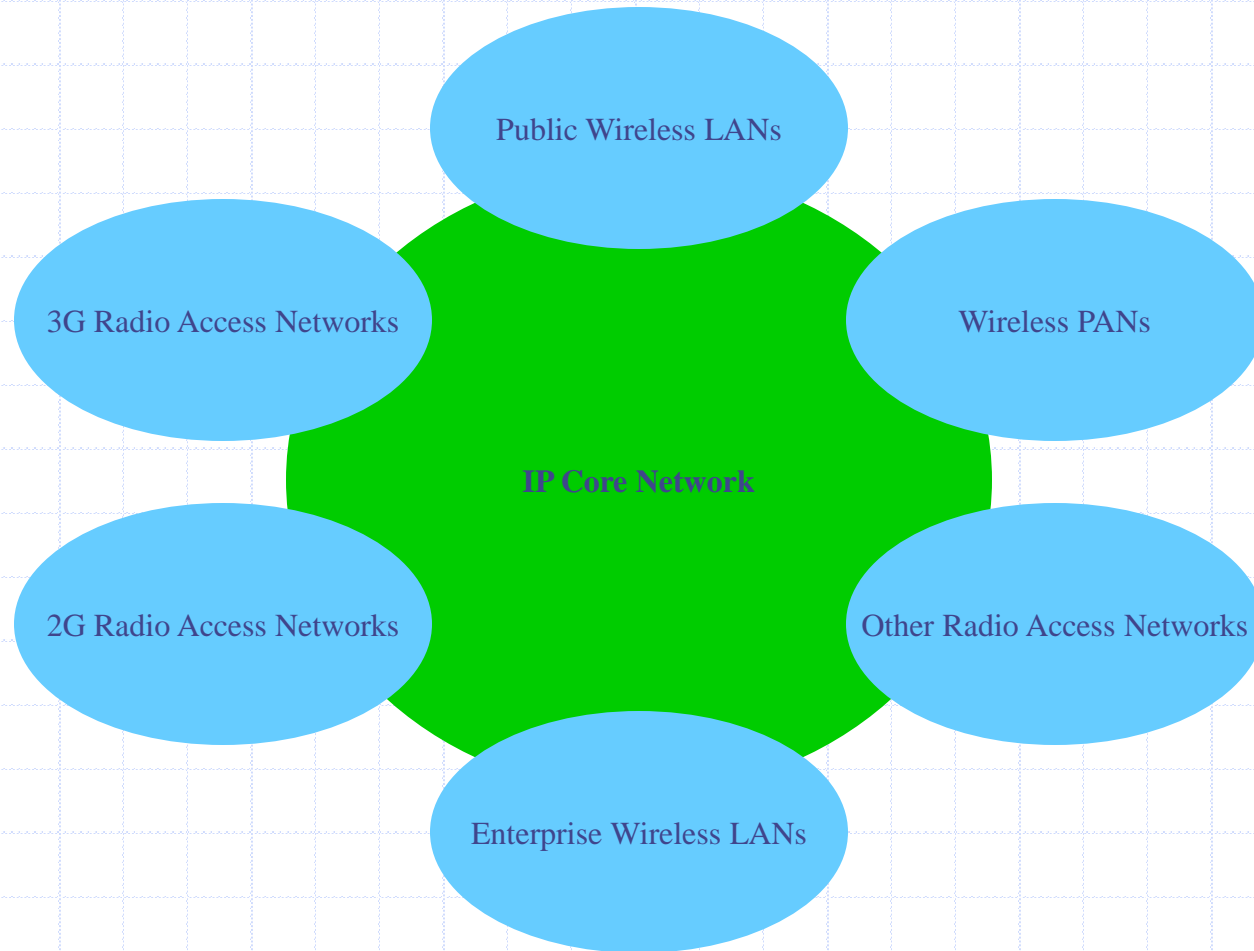
IP-Based Wireless Networks

- The core network will be based on IP technologies.
- A common IP core network will support multiple types of radio access networks.
- A broad range of mobile voice, data, and multimedia services will be provided over IP technologies to mobile users.
- IP-based protocols will be used to support mobility between different radio systems.
- All-IP radio access networks will increase over time. The first all-IP radio access networks that have emerged in public wireless networks are public WLANs.

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1.2 Evolution of Public Mobile Services

1.2.1 First Wave of Mobile Data Services: Text-based Instant Messaging

1.2.2 Second Wave of Mobile Data Services: Low-Speed Mobile Internet Services

1.2.3 Current Wave of Mobile Data Services: High-Speed and Multimedia Mobile Internet Services

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# 1.2.1 First Wave of Mobile Data Services: Text-based Instant Messaging

- ◆ SMS (Short Message Services)
  - ■ provided over the completely circuit-switched 2G networks
  - ■ delivered using Mobile Application Part (MAP) in GSM networks
- ◆ SMS allowed mobile users to become familiar and comfortable with mobile data services

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Fig. 1.6 Growth of SMS message transmissions in the United Kingdom

TEXT MESSAGING GROWTH (SMS): UK GSM
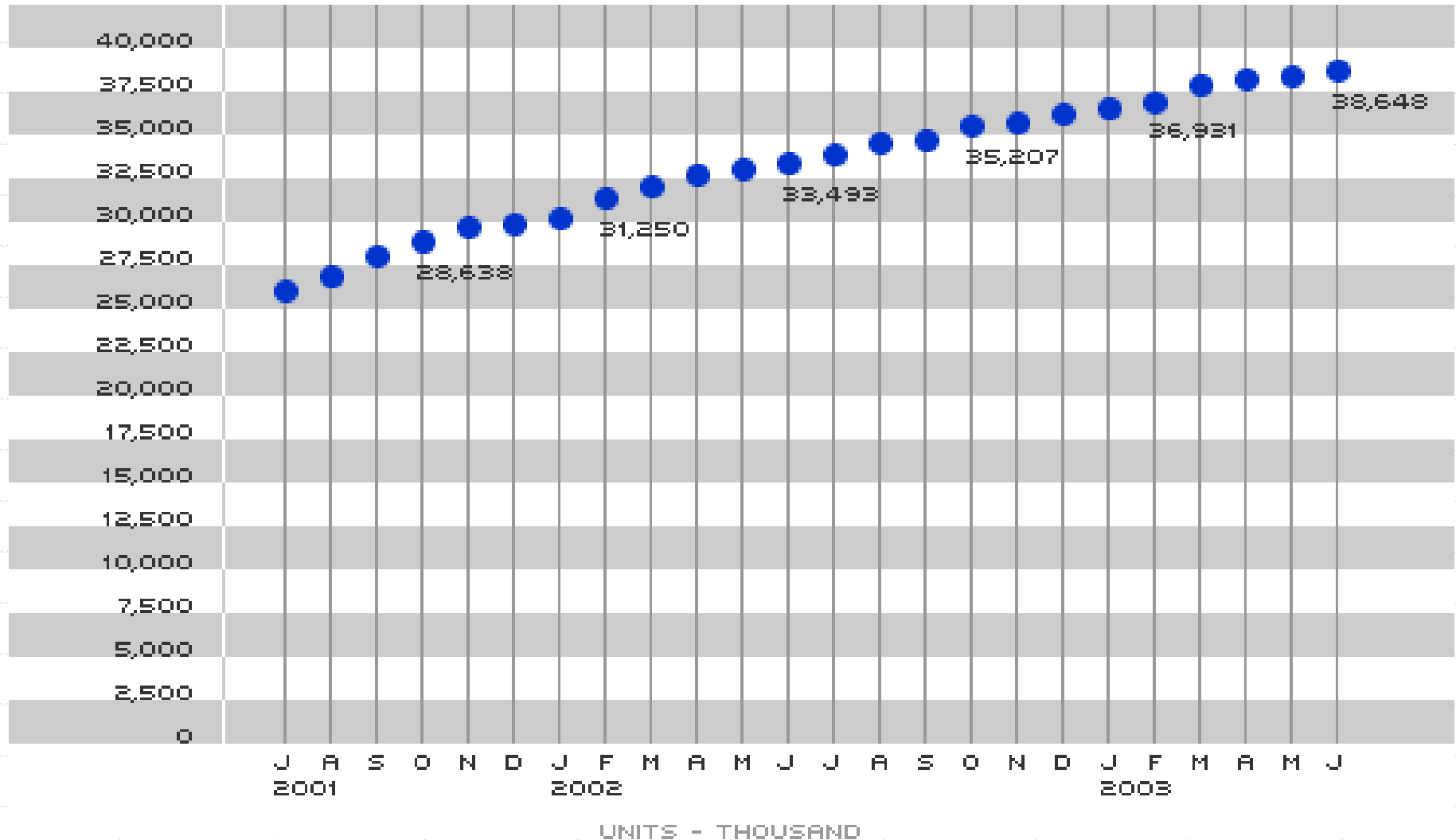NETWORK OPERATOR TOTALS
June 1998 – June 2003
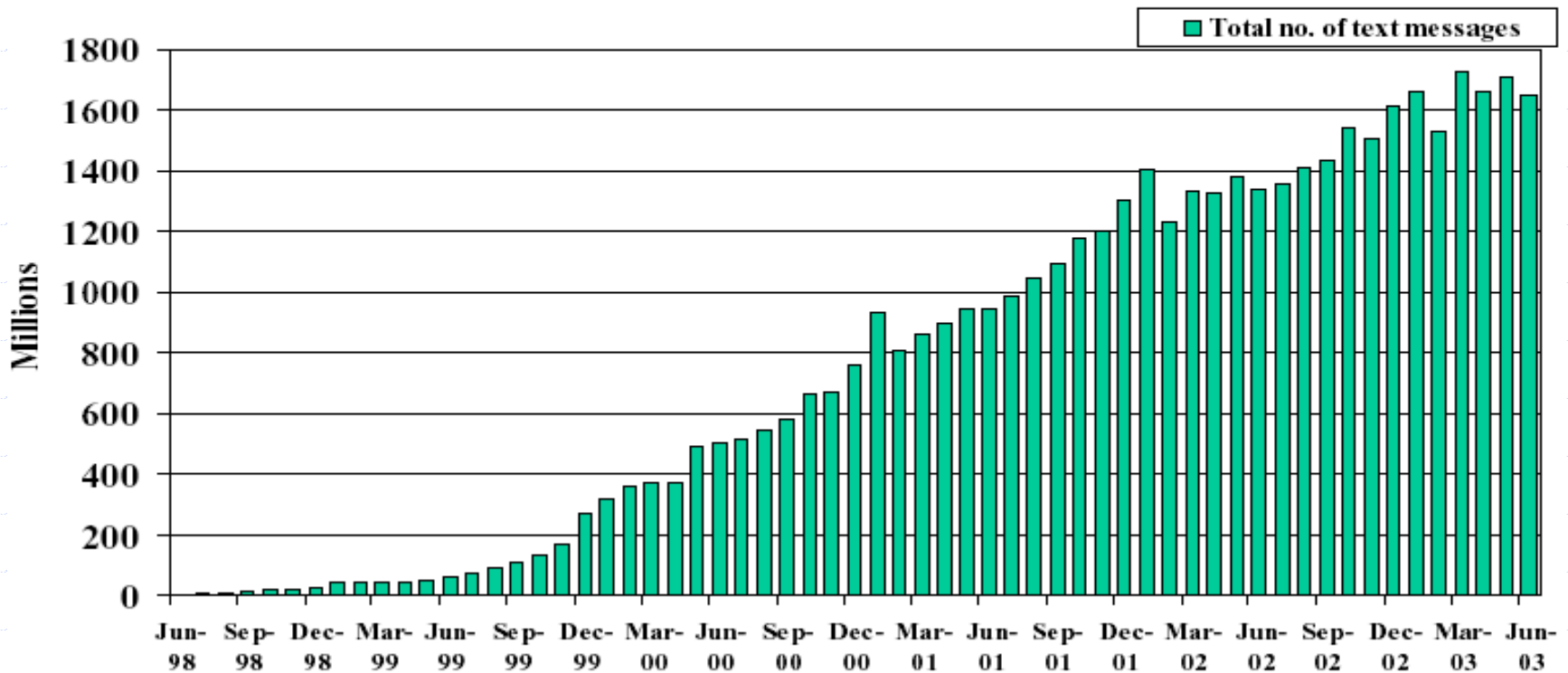
Source: MOBILE DATA ASSOCIATION

1.2.2 Second Wave of Mobile Data Services: Low-Speed Mobile Internet Services

- ◆ Interactive and information-based mobile Internet services
- ◆ i-Mode: launched by NTT DoCoMo over PDC in February 1999
  - emails and instant messages
  - commercial transactions
  - directory services
  - daily information
  - entertainment

Fig. 1.7 Growth of i-Mode subscribers

Monthly

40,000
37,500
35,000
32,500
30,000
27,500
25,000
22,500
20,000
17,500
15,000
12,500
10,000
7,500
5,000
2,500
0

38,648

36,931

35,207

33,493

31,250

28,638

J A S O N D J F M A M J J A S O N D J F M A M J
2001   2002   2003

UNITS – THOUSAND

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i-Mode

- ◆ **Milestone**
  - ■ first major success in bringing Internet-based services to a large population of mobile subscribers
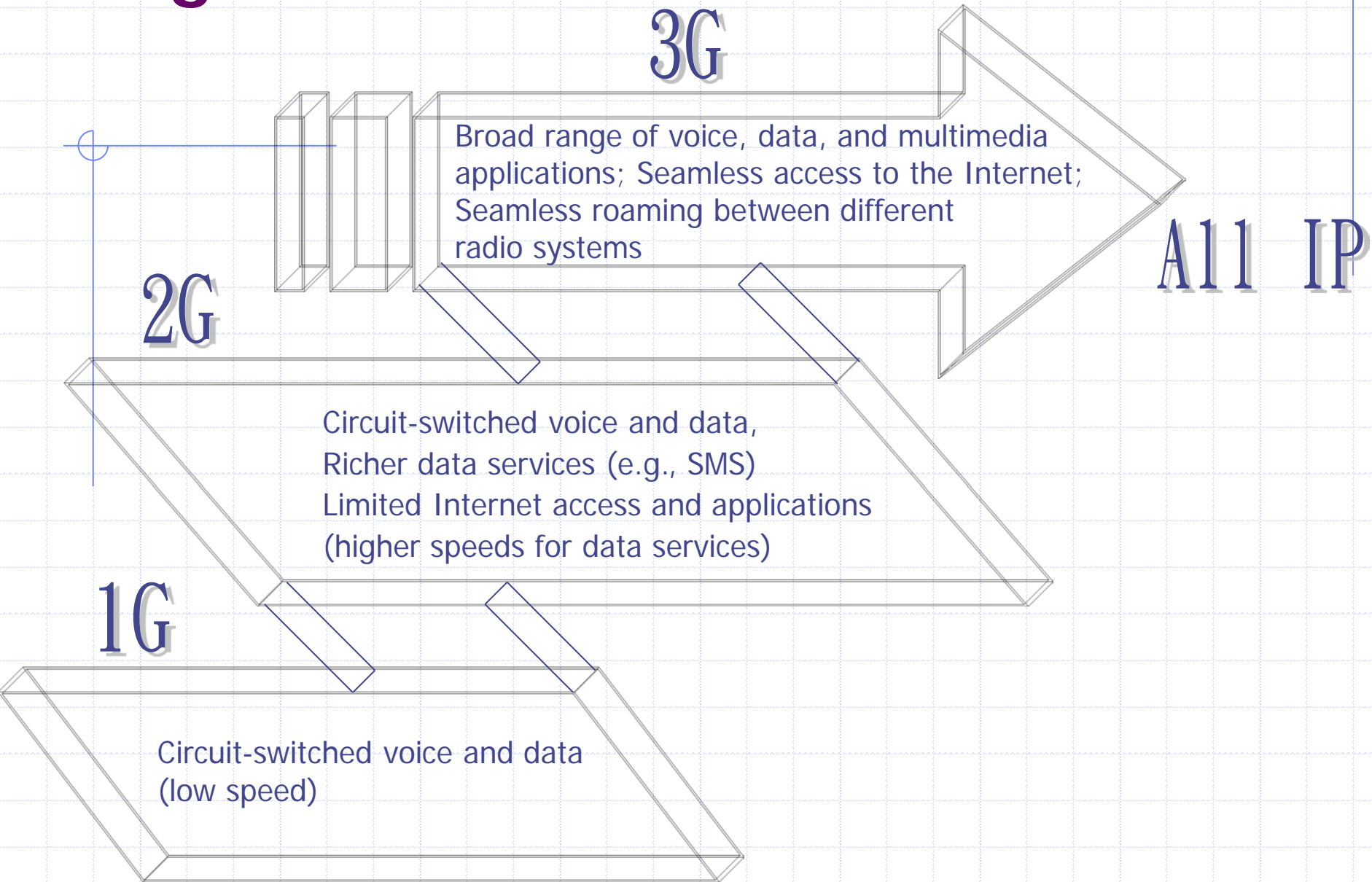 - ■ demonstrate the values and the potentials of the mobile Internet to the world
- ◆ **Limitation**
  - ■ limited by the low data rate of the PDC radio networks
  - ■ proprietary protocols developed by NTT DoCoMo, making it difficult for i-Mode to be adopted by other countries

1.2.3 Current Wave of Mobile Data Services: High-Speed and Multimedia Mobile Internet Services

- Camera phones
- Multimedia Messaging Services (MMS)
- Networked gaming
- Location-based services
- Streaming videos to mobile devices
- Vehicle information systems

Fig. 1.8 Evolution of mobile services

3G

Broad range of voice, data, and multimedia applications; Seamless access to the Internet; Seamless roaming between different radio systems

All IP

2G

Circuit-switched voice and data, Richer data services (e.g., SMS) Limited Internet access and applications (higher speeds for data services)
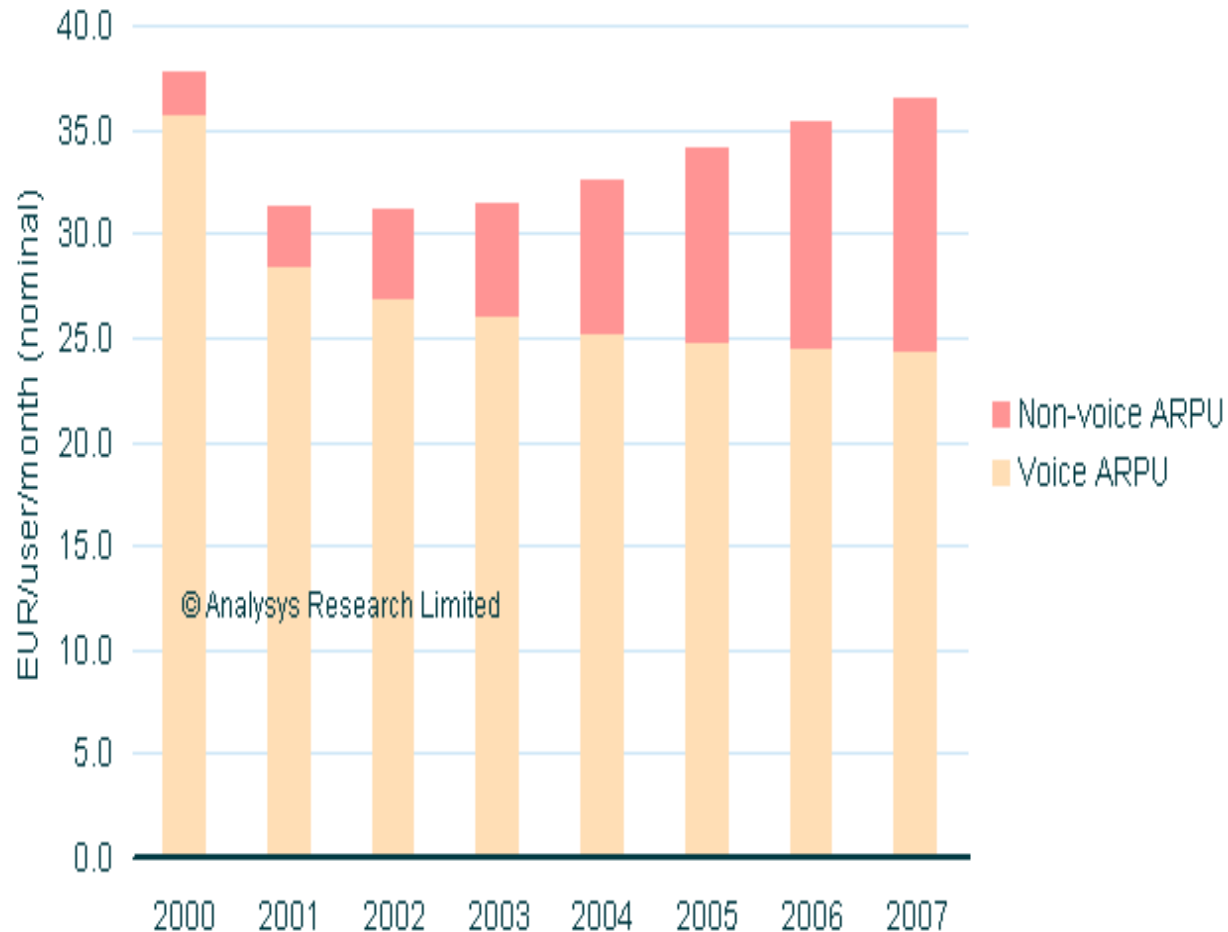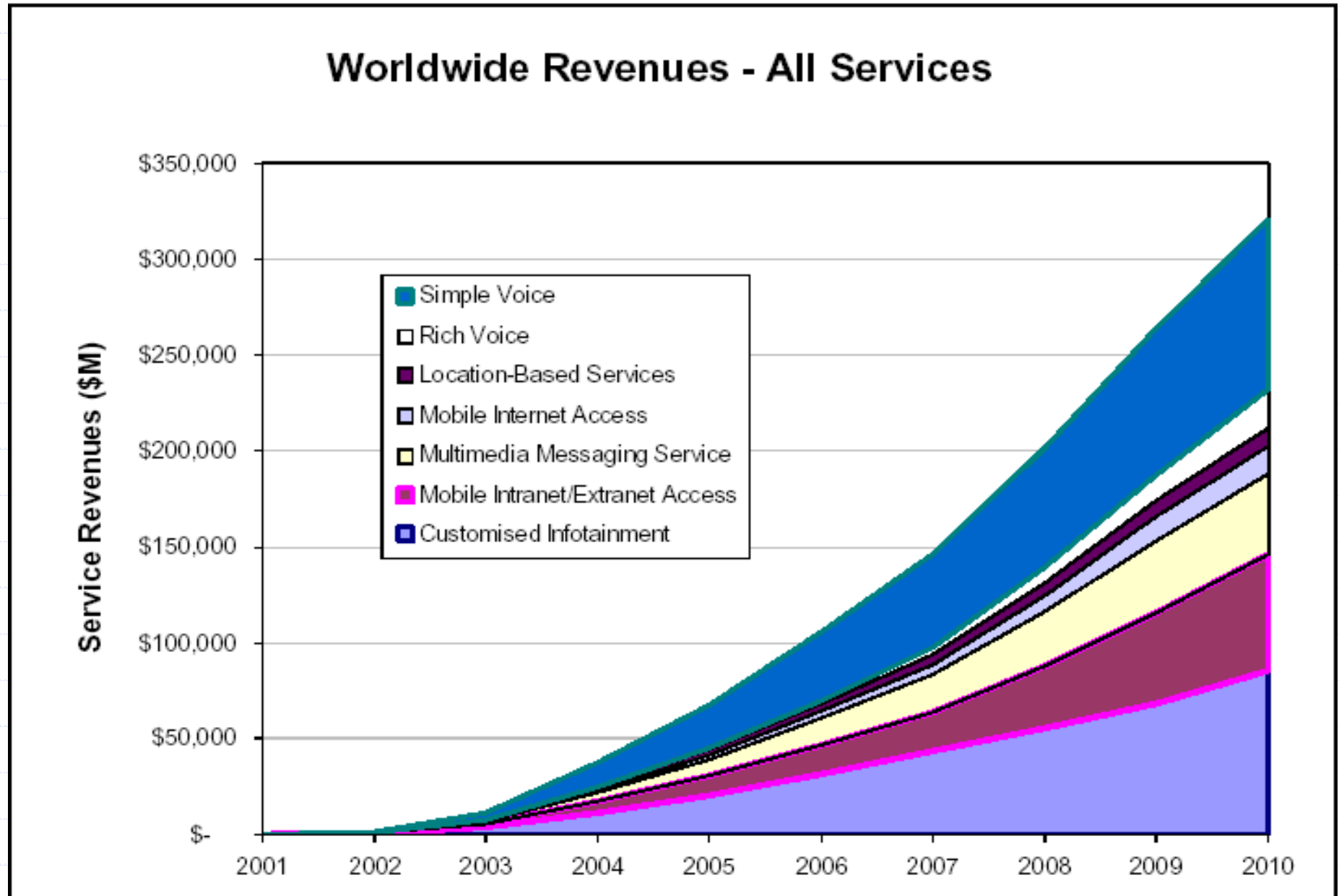
1G

Circuit-switched voice and data (low speed)

1.3 Motivations for IP-Based Wireless Networks

◆ IP-based wireless networks are better suited for supporting the rapidly growing mobile data and multimedia services.

◆ IP-based wireless networks bring the successful Internet service paradigm to mobile providers and users.

◆ IP-based wireless networks can integrate seamlessly with the Internet.

◆ IP-based radio access systems are becoming important components of public wireless networks.

◆ IP technologies provide a better solution for making different radio technologies transparently to users.

Fig. 1.10 Growth of mobile voice and non-voice services

Fig. 1.10 Growth of mobile voice and non-voice services

Worldwide Revenues - All Services

Legend:
- Simple Voice
- Rich Voice
- Location-Based Services
- Mobile Internet Access
- Multimedia Messaging Service
- Mobile Intranet/Extranet Access
- Customised Infotainment

Y-axis: Service Revenues ($M) — $-, $50,000, $100,000, $150,000, $200,000, $250,000, $300,000, $350,000

X-axis: 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010

1.4 3GPP, 3GPP2, AND IETF

1.4.1 3GPP

1.4.2 3GPP2

1.4.3 IETF

1.4.1 3GPP

- A partnership formed in 1998 to produce international specifications for third-generation wireless networks
- Specifications include all GSM (including GPRS and EDGE) and 3G specifications

3GPP Members

- Organizational Partners
- Market Representation Partners
- Individual Members
- Observers

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3GPP Technical Specification Groups (TSGs)

- TSG CN (Core Network)
- TSG GERAN (GSM EDGE Radio Access Network)
- TSG RAN (Radio Access Network)
- TSG SA (Service and System Aspects)
- TSG T (Terminal)

3GPP Specifications

- Release: a set of Technical Specifications (TS) and Technical Reports (TR)
- Frozen: content can only be revised in case a correction is needed
- Release 99 (R99)
  - frozen in March 2000
  - focus on a new RAN based on WCDMA
  - emphasize the interworking and backward compatibility with GSM

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3GPP Specifications (Cont.)

- ◆ Release 4 (R4)
  - ■ frozen in March 2001
  - ■ a minor release with some enhancements to R99
  - ■ IP transport was introduced into the core network
- ◆ Release 5 (R5)
  - ■ frozen in June 2002
  - ■ major changes in the core network based on IP protocols
  - ■ phase 1 of the IP Multimedia Subsystem (IMS)
  - ■ IP transport in the UTRAN
- ◆ Release 6 (R6)
  - ■ expected to be frozen in March 2004?
  - ■ IMS phase 2
  - ■ harmonization of IMS in 3GPP and 3GPP2
  - ■ interoperability of UMTS and WLAN
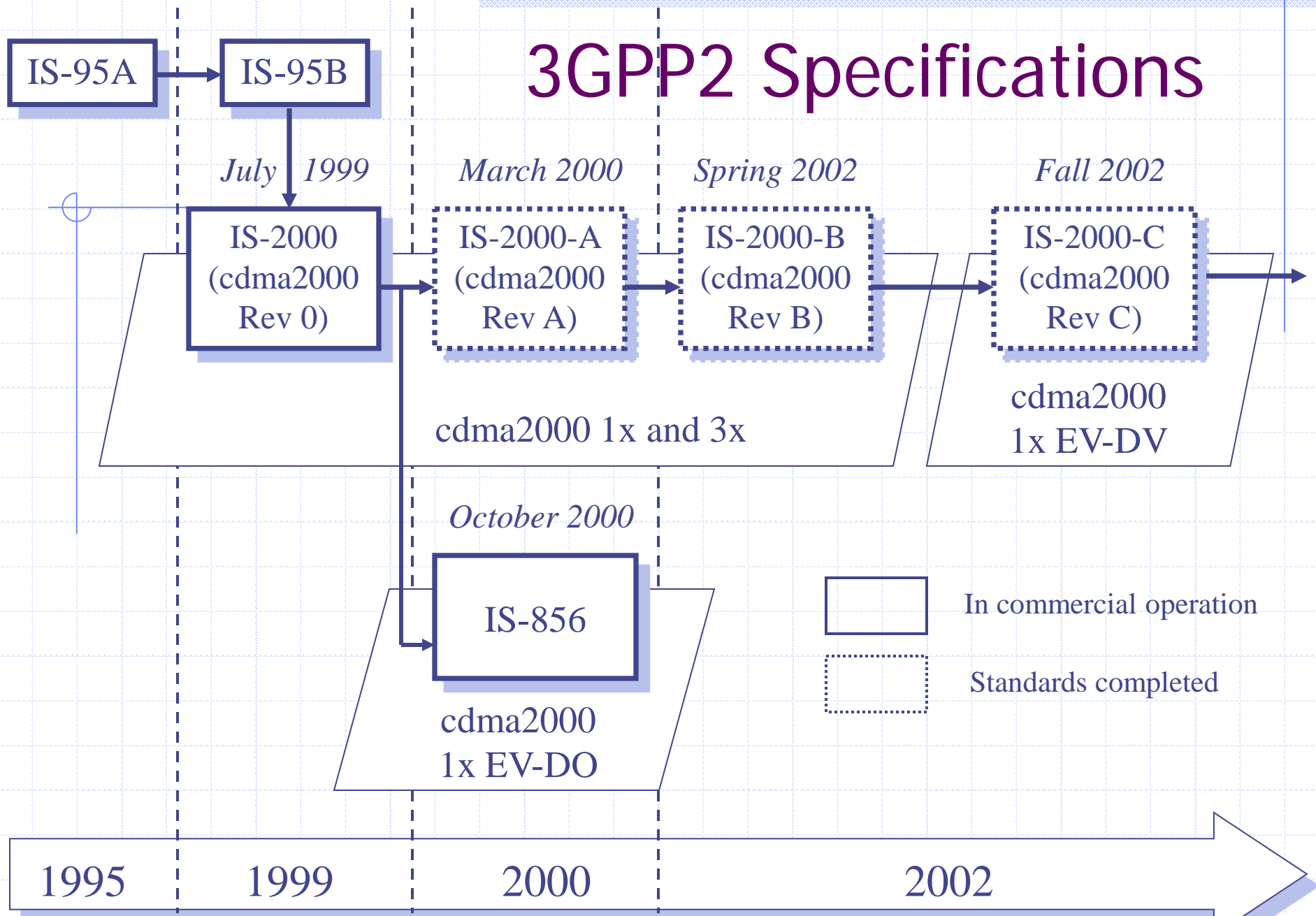 - ■ multimedia broadcast and multicast

1.4.2 3GPP2

- Formed soon after 3GPP when the American National Standards Institute (ANSI) failed to convince 3GPP to include "non-GSM" technologies in 3G standards
- Members are classified into Organizational Partners and Market Representation Partners

3GPP2 Technical Specification Groups (TSGs)

- TSG-A (Access Network Interfaces)
- TSG-C (cdma2000)
- TSG-S (Service and System Aspects)
- TSG-X (Intersystem Operations)

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3GPP2 Specifications

IS-95A → IS-95B

July 1999

IS-2000
(cdma2000
Rev 0)

March 2000

IS-2000-A
(cdma2000
Rev A)

Spring 2002

IS-2000-B
(cdma2000
Rev B)

Fall 2002

IS-2000-C
(cdma2000
Rev C)

cdma2000 1x and 3x

cdma2000
1x EV-DV

October 2000

IS-856

cdma2000
1x EV-DO

In commercial operation

Standards completed

| 1995 | 1999 | 2000 | 2002 |

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1.4.3 IETF

- A large open international community
- Internet Standards are archived and published by the IETF as *Request for Comments (RFC)*
  - Standards-track RFCs
  - Non-standards-track RFCs

RFC Categories

- Standards track
  - Proposed Standard
  - Draft Standard
 - Standard
- Non-standards track
  - Best Current Practices
  - Informational
  - Experimental
  - Historic

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IETF Working Groups

- Open to any individual
- Small focused efforts
- Preference for a limited number of options
- Mailing list and face-to-face meetings
- "Rough consensus and running code…"
  - No formal voting
  - Disputes resolved by discussion and demonstration

Working Group Creation

BOF

Chair, description, Goals and milestones

Area Director

IAB and IESG
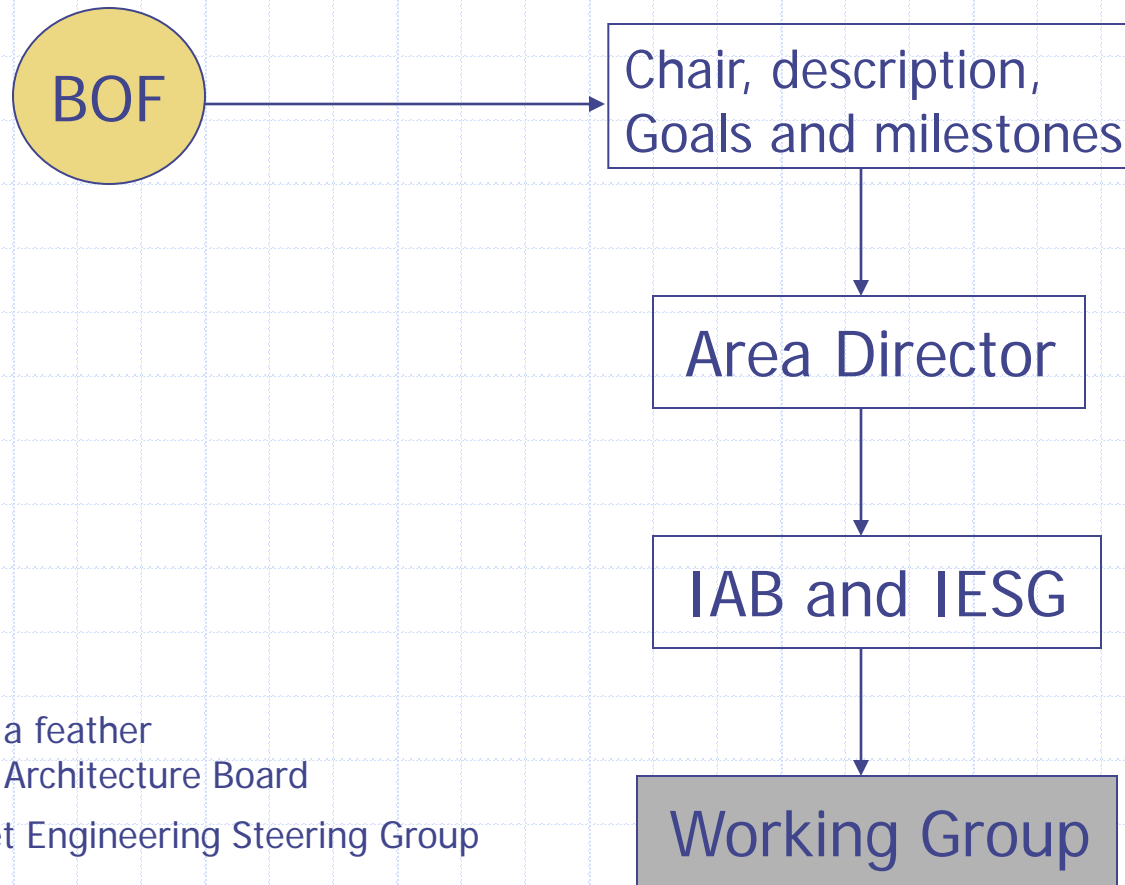
Working Group

BOF: birds of a feather
IAB: Internet Architecture Board

IESG: Internet Engineering Steering Group

1.5 ORGANIZATION OF THE BOOK

- ◆ Chapter 2: Wireless IP Network Architectures

- ◆ Chapter 3: IP Multimedia Subsystems and Application-Level Signaling

- ◆ Chapter 4: Mobility Management

- ◆ Chapter 5: Security

- ◆ Chapter 6: Quality of Service