

# Chapter 1: Introduction

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IP-Based Next-Generation Wireless Networks  
Published by John Wiley & Sons, Inc.  
January 2004

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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

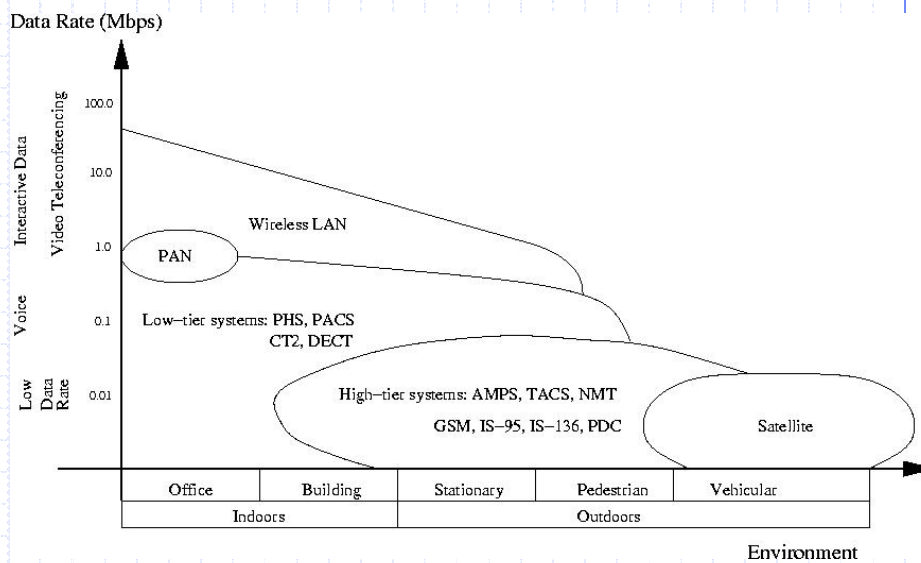
## IP-Based Wireless Networks

- ◆ 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



## 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)

## 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

## 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

## 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

## 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

## 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)

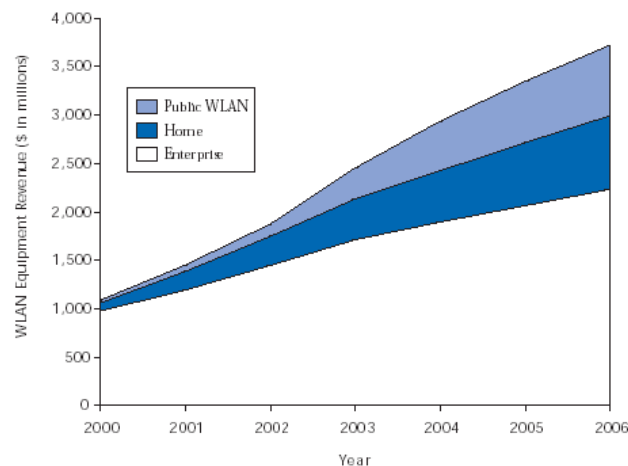
## Public WLANs

- ◆ 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



CAGR 2000 - 2006	
Enterprise	13.4%
Home	30.4%
Public WLAN	65.5%

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## 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

## 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

## 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

## 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

## 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)

## 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

## 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.

## Table 1.1 WCDMA vs. cdma2000

	WCDMA	cdma2000
Multiple Access Scheme	Frequency Division Duplex Direct-Sequence CDMA (FDD DS-SS-CDMA) and Time Division Duplex Direct-Sequence CDMA (TDD DS-SS-CDMA)	Frequency Division Duplex Multicarrier CDMA (FDD MC-SS-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

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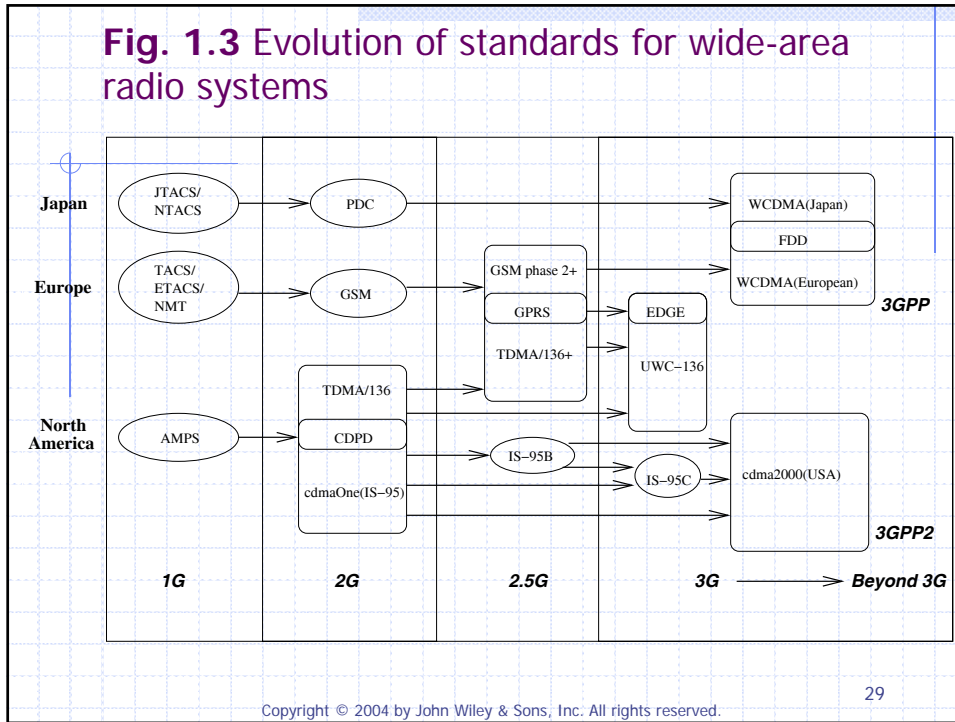
## Fundamental Principles of 3G

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

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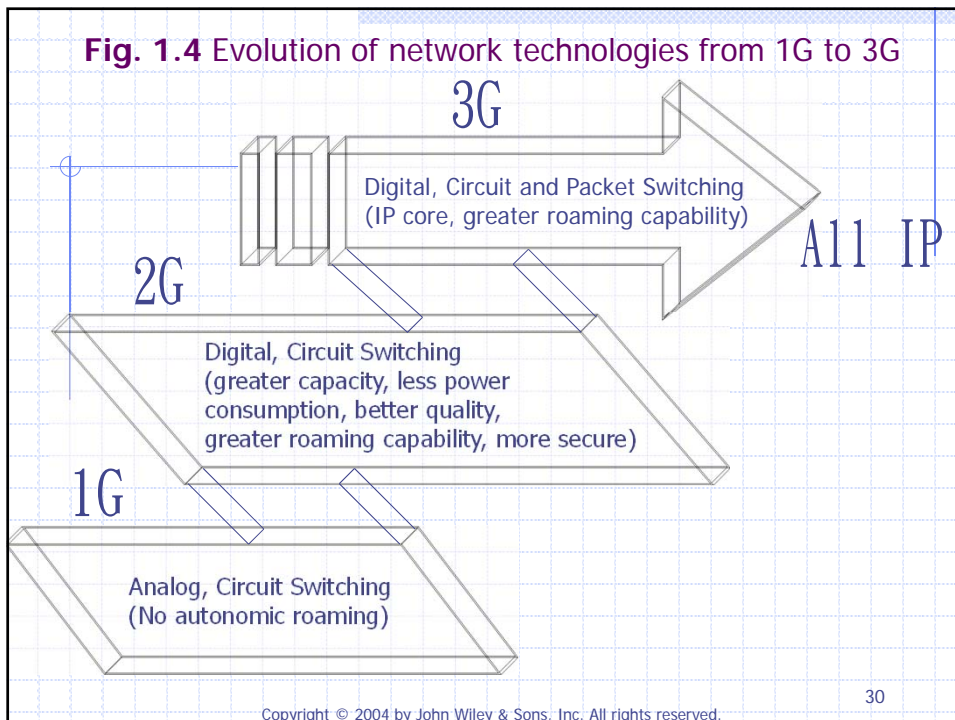
**Fig. 1.3 Evolution of standards for wide-area radio systems**



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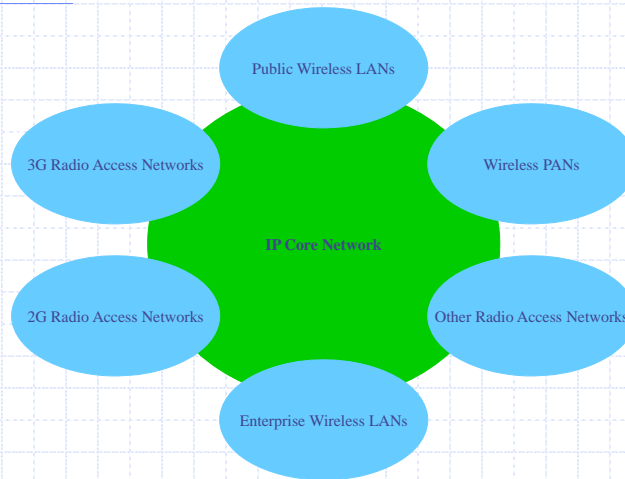
**Fig. 1.4 Evolution of network technologies from 1G to 3G**



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**Fig. 1.5** Wireless IP network supporting heterogeneous radio technologies



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## 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

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

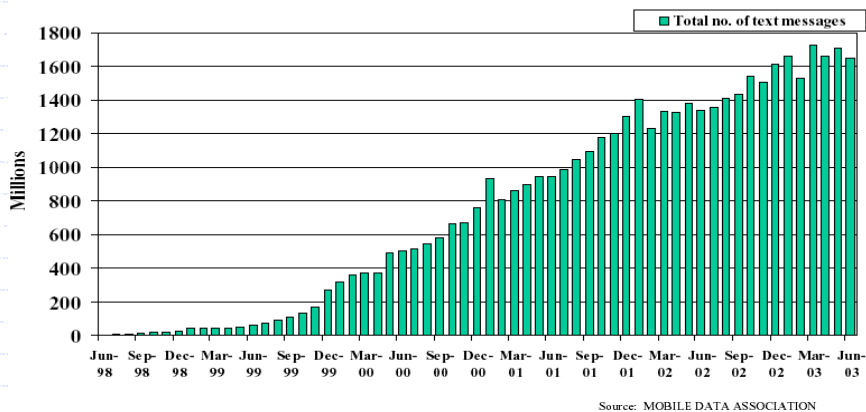
#### ◆ SMS (Short Message Services)

- 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

**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



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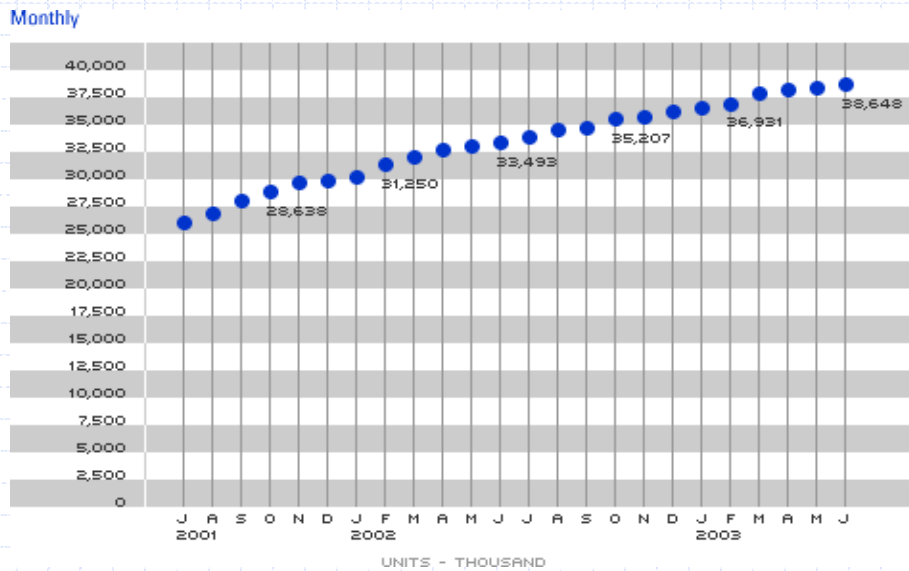
### 1.2.2 Second Wave of Mobile Data Services: Low-Speed Mobile Internet Services

- ◆ 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

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**Fig. 1.7 Growth of i-Mode subscribers**



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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

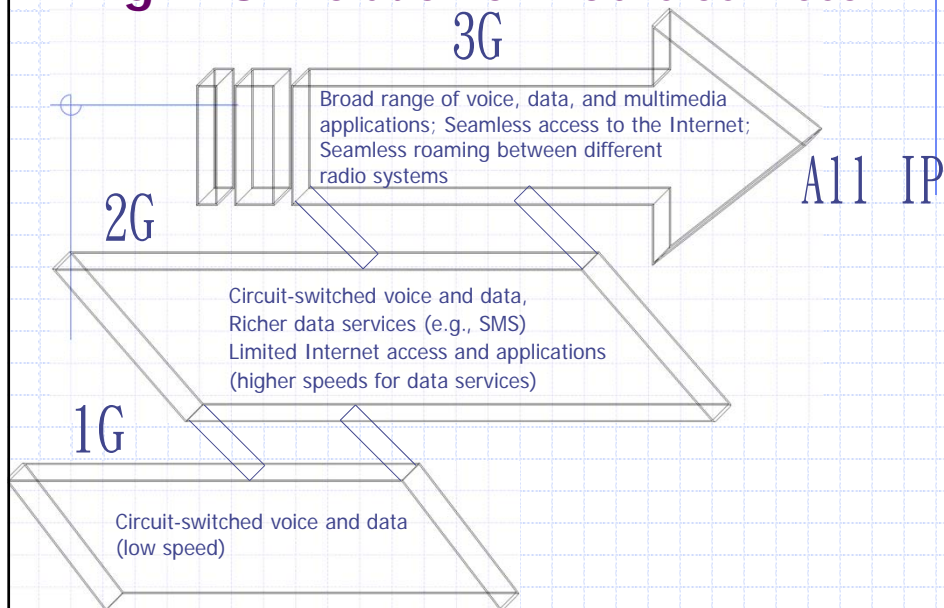
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### 1.2.3 Current Wave of Mobile Data Services: High-Speed and Multimedia Mobile Internet Services

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

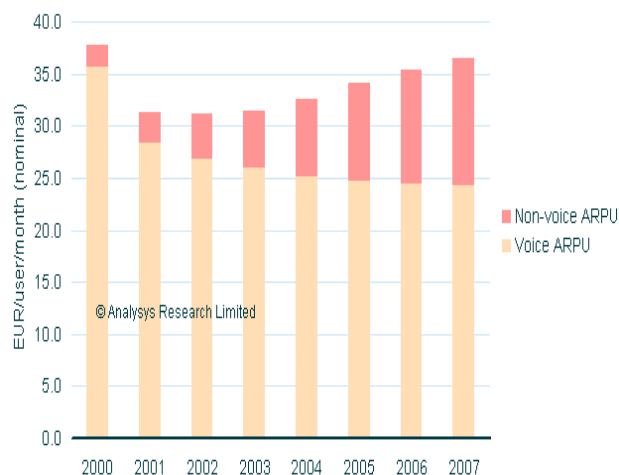
**Fig. 1.8** Evolution of mobile services



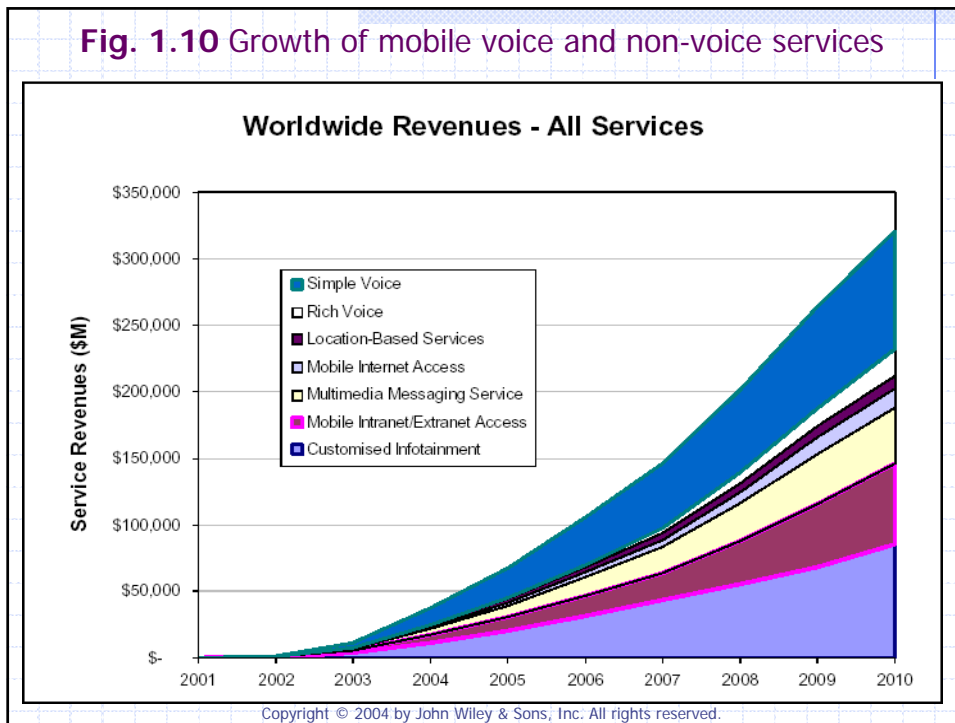
## 1.3 Motivations for IP-Based Wireless Networks

- ◆ 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



## 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

## 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



## 3GPP Specifications (Cont.)

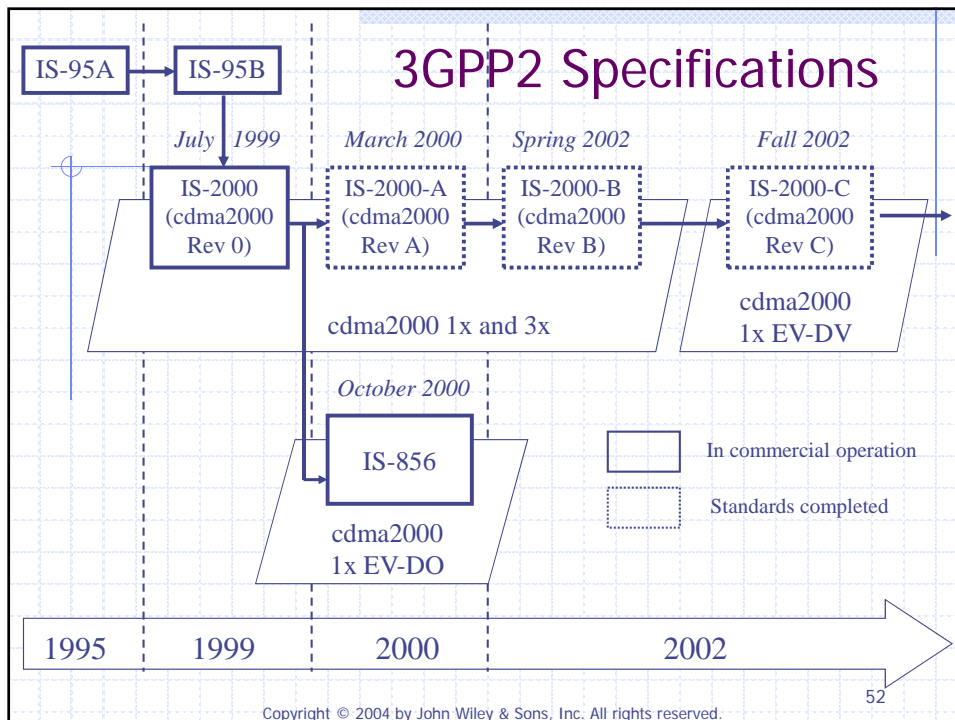
- ◆ Release 4 (R4)
  - frozen in March 2001
  - a minor release with some enhancements to R99
  - IP transport was introduced into the core network
- ◆ Release 5 (R5)
  - frozen in June 2002
  - major changes in the core network based on IP protocols
  - phase 1 of the IP Multimedia Subsystem (IMS)
  - 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)



## 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

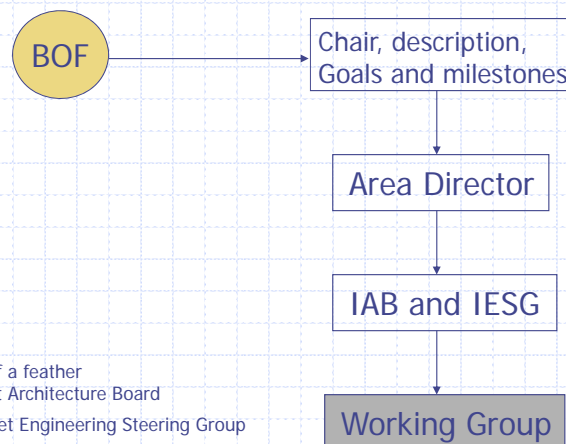
## IETF Working Groups

- ◆ 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

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## Working Group Creation



BOF: birds of a feather  
IAB: Internet Architecture Board  
IESG: Internet Engineering Steering Group

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## 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