Chapter 1: Introduction

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IP-Based Next-Generation Wireless Networks
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Outline

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1.2 Evolution of Public Mobile Services
1.3 Motivations for IP-based Wireless Networks
1.4 3GPP, 3GPP2, and IETF
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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
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.

**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)**
- **Enhanced Data Rates for Global GSM Evolution (EDGE)**
  - 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

<table>
<thead>
<tr>
<th></th>
<th>WCDMA</th>
<th>cdma2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple Access Scheme</td>
<td>Frequency Division Duplex Direct-Sequence CDMA (FDD DS-CDMA) and Time Division Duplex Direct-Sequence CDMA (TDD DS-CDMA)</td>
<td>Frequency Division Duplex Multibeam CDMA (FDD MC CDMA)</td>
</tr>
<tr>
<td>Spreading Chip Rate</td>
<td>1.2288 Mcps</td>
<td>1.2288 Mcps for 1xRTT 3 x 1.2288 Mcps for 3xRTT</td>
</tr>
<tr>
<td>Base Station Synchronization</td>
<td>Asynchronous</td>
<td>Synchronous</td>
</tr>
<tr>
<td>Network Signaling</td>
<td>GSM MAP</td>
<td>IS-41, IS-41/IS-95/1XTRA</td>
</tr>
<tr>
<td>Frame Size</td>
<td>10 ms for physical layer frames, 10, 20, 40, and 80 ms for transport layer frames</td>
<td>5 (for signaling), 20, 60 and 80 ms for physical layer frames</td>
</tr>
</tbody>
</table>

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

North America

Europe

Japan

1G

2G

3G

Beyond 3G

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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.

1.2 Evolution of Public Mobile 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

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
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

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 transparent to users.

Fig. 1.7 Growth of i-Mode subscribers

- 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

Fig. 1.8 Evolution of mobile services

- 1G: Circuit-switched voice and data
- 2G: Limited Internet access and applications (higher speeds for data services)
- 3G: Broad range of voice, data, and multimedia applications; seamless access to the Internet; seamless roaming between different radio systems

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

- IP-based wireless networks are better suited for supporting the rapidly growing mobile data and multimedia services.
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- IP-based wireless networks can integrate seamlessly with the Internet.
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1.4 3GPP, 3GPP2, AND 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

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