Wireless and Mobile Network Architecture

Chapter 12
Third-Generation Mobile Services

Prof. **Yuh-Shyan Chen**

Department of Computer Science and Information Engineering

National Taipei University

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Introduction - **Short historical review**

- First generation – AMPS
  - Analog cellular phone service (within one country)
    - 1990, AMPS has been improved to provide roaming between US and other countries
  - cellular concept (frequency reuse, handoff)
- Second generation – GSM, IS-136, IS-95
  - Digital mobile phone service with roaming functionality
    - digital modulation
    - voice coding
    - forward error correction
    - channel equalization

Introduction - **Short historical review**

- Bridge of 2G to 3G technologies (2.5 G)
  - EDGE and GPRS
- Third generation
  - The technologies for 3G mobile systems have been significantly improved in the terms of system capacity, voice quality, and ease of use.
    - multimedia services (audio, video, and images)
    - wireless Internet access
    - better system capacity
    - higher transmission speed (vehicles 144Kbps, pedestrian 384kbps, stationary 2Mbps)

Introduction - **development of 3G**

- 1992, ITU formed Task Group (TG) 8/1
  - Renamed IMT-2000 in 1996 or 1997.
- 1994 government agents, manufacturers, operators started to anticipate
- 1996 NTT and Ericssion initiated 3G development
- 1997 U.S Telecommunications Industry Association (TIA) chose the CDMA technology for 3G
- 1998 ETSI also selected CDMA for 3G
- 1998 Wideband CDMA (W-CDMA)
  - UMTS (Universal Mobile Telecommunications System)
- 1998 cdma2000
  - TIA 45.5
- 1998 3G time division duplexing (TDD)
  - China/Europe

21.1 Paradigm Shifts in Third-Generation Systems (1/2)

- Trend
  - For wireline telecommunication in USA, data traffic already exceeds voice traffic
  - It is anticipated that the same trend will be observed in mobile telecommunications
- Two paradigm shifts
  - The shift from voice-centric traffic to data-centric traffic demands a packet-based infrastructure instead of the circuit-based infrastructure.
  - Data application continue to evolve
    - Portable terminals are usually limited by practical size, weight, power consumption, and display contraints
    - (WAP, MExE)

Cont.

- 3G wireless communication requires a very broadband spectrum and fast data rate to support high-quality Internet access and multimedia services
- Only 25 percent of the spectrum is newly created for 3G usage
  - To use the resources more efficiently, better channel and source-coding techniques, such as space-time coding and grammar-based lossless data compression
  - With toll-quality voice at a data rate much lower than 8 Kbps

21.1 Paradigm Shifts in Third-Generation Systems (2/2)

Terrestrial Spectrum Allocation for 2G and 3G

spectrum	bandwidth	systems
800MHz	50MHz	AMPA, IS-95, IS-136
900MHz	50MHz	GSM- 900
1500MHz	48MHz	Japan PDC
1700MHz	60MHz	Korean PCS
1800MHz	150MHz	GSM- 1800
1900MHz	120MHz	PCS
2100MHz	155MHz	3G

21.2 W-CDMA and cdma2000 (1/3)

- The CDMA-based 3G standards selected from numerous proposals to ITU have become the major stream for IMT 2000.
- W-CDMA and cdma 2000 are two major proposals for 3G system
- W-CDMA does not need base station timing synchronization
  - Whereas base station timing synchronization in cdma 2000 can provide decreased latency and a reduced chance of dropping calls during soft handoff

21.2 W-CDMA and cdma2000

Comparison of W-CDMA and cdma2000

TECHNOLOGY	***W-CDMA***	***CDMA2000***
Chip Rate	4.096MCps	3.6864MCps
Forward Link Pilot Structure	Dedicated Pilot with TDM	Common Pilot with CDM
Base Station Timing Synchronization	Asynchronous	Synchronous
Forward Link Modes		A multicarrier mode capable of overlay onto IS-95 carriers

21.2 W-CDMA and cdma2000 (2/3)

- Since both W-CDMA and cdma have been simultaneously adapted for the 3G standard, harmonization of these two systems becomes necessary to make IMT-2000 deployment successful.
- Harmonization of W-CDMA and cdma2000
  - Ericsson's acquision of Qualcomm's infrastructure division
  - Adoption of OHG's (Operators Harmonization Group) framework recommendations
    - To provide the foundation for accelerated growth in the 3G millennium
    - To create a **single integrated 3G CDMA specification** and process the separate W-CDMA and cdma 2000 proposals being developed by 3GPP and 3GPP2.

- OHG's efforts have resulted in
  - direct spread mode – 3.84MCps (mega chip rate) for new frequency band
  - Multicarrier mode – 3.6864MCps for operation overlaid to IS-95 signals
  - A CDM pilot added to the direct spread mode
  - A Harmonized solution for SCDMA (TDD mode proposed by China)

21.3 Improvements on Core Network (1/5)

- Harmonization for higher layer protocols
  - System module and radio access mode (IS-41, GSM-MAP, IP-based)
- Optimization of network-related procedure
  - Reduced international roaming signaling traffic
- **When a user roams to a visited network, the first registration is performed following the steps illustrated in Fig. 21.1.**

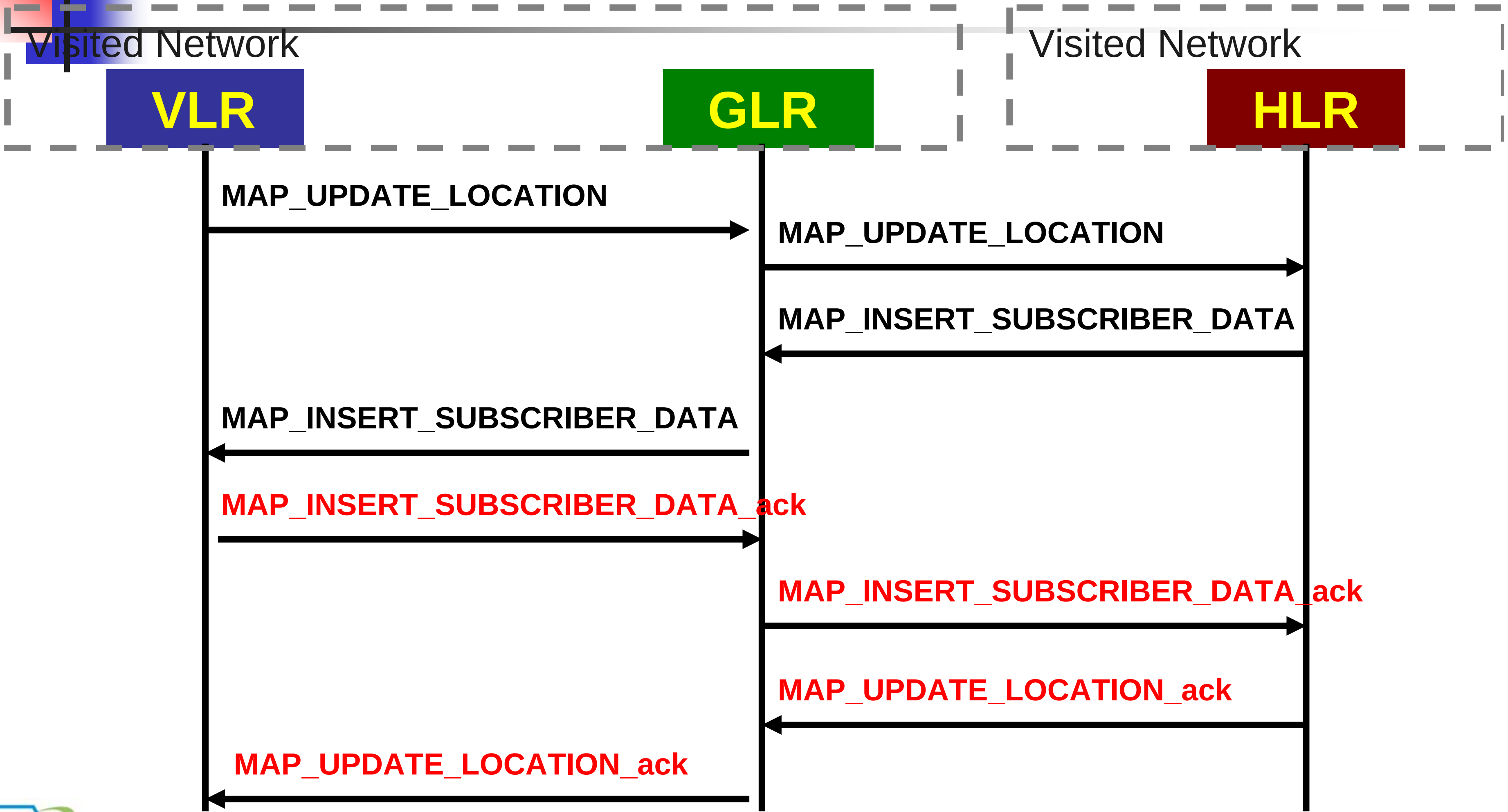
Cont.

- Network-related procedures are optimized to reduce the signaling traffic
- To reduce the international roaming signaling traffic, 3GPP 23.119 specification proposed an approach to limit the signaling traffic between the visited mobile system and the home mobile system
  - This approach introduces a gateway location register (GLR) between VLR/SGSN and the HLR.

Cont.

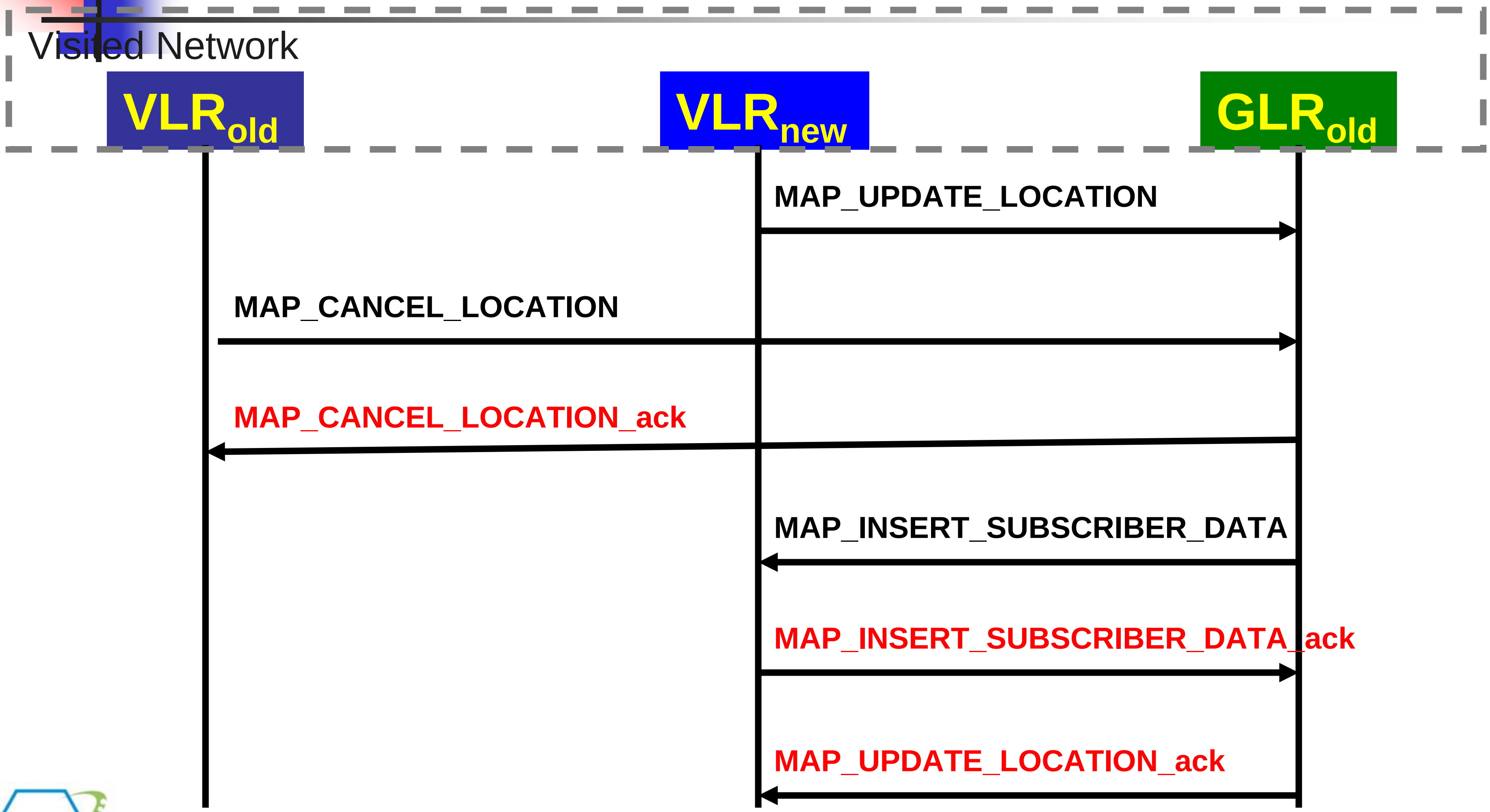
- From the viewpoint of the VLR/SGSN at the visited network
  - The GLR is treated as the roaming user's HLR located at the home network
- From the viewpoint of the HLR at the home network
  - The GLR acts as the VLR/SGSN at the visited network
- HLR communicates with GLR by D interface

21.3 Improvements on Core Network (**first registration**)



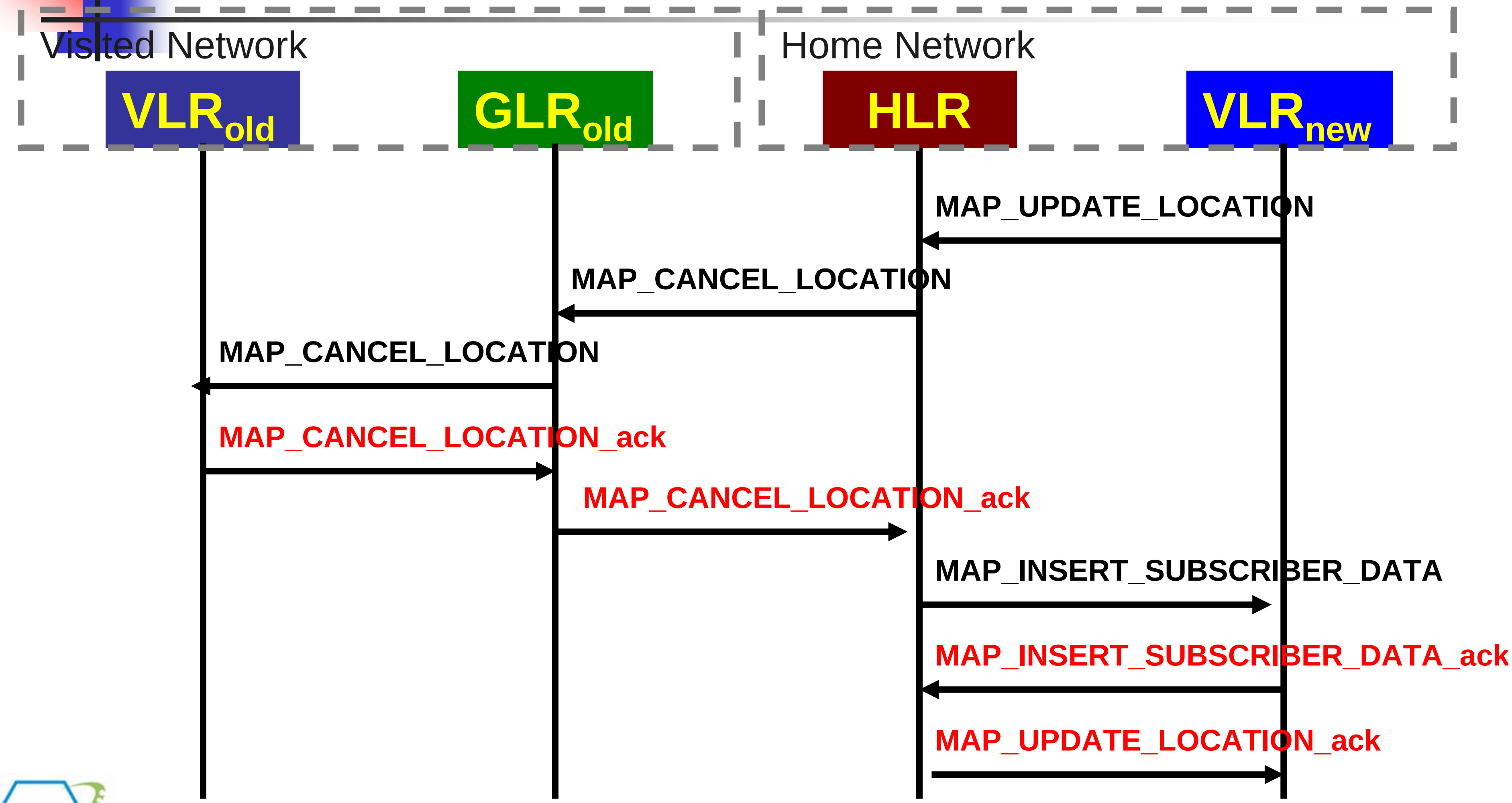
Message flow for the first registration with GLR

Subsequent registrations, follow the GSM registration



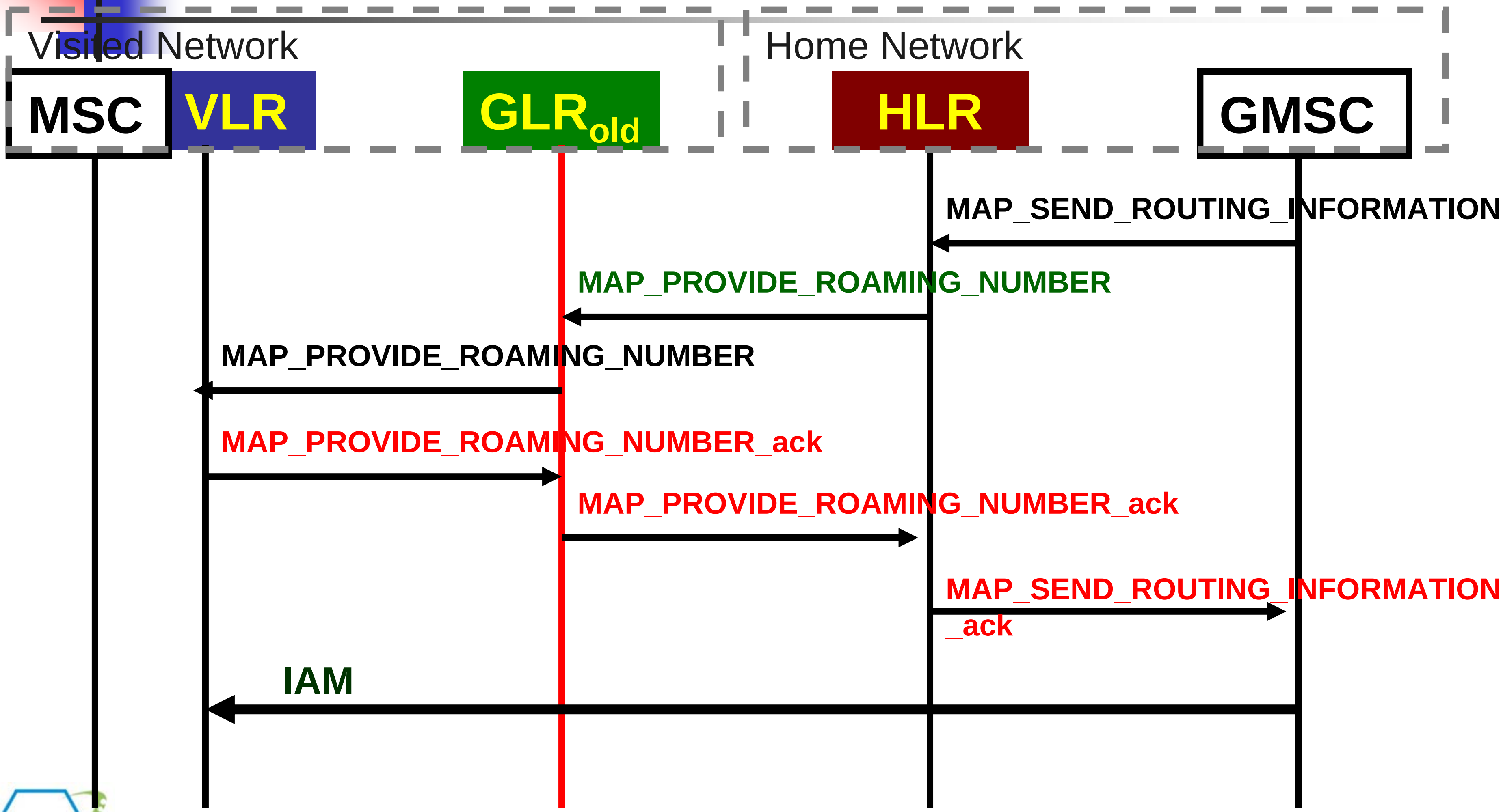
Message flow for a subsequent registration with GLR

Roamer moves to another network, the old visited network will be removed the user record at the **GLR**)



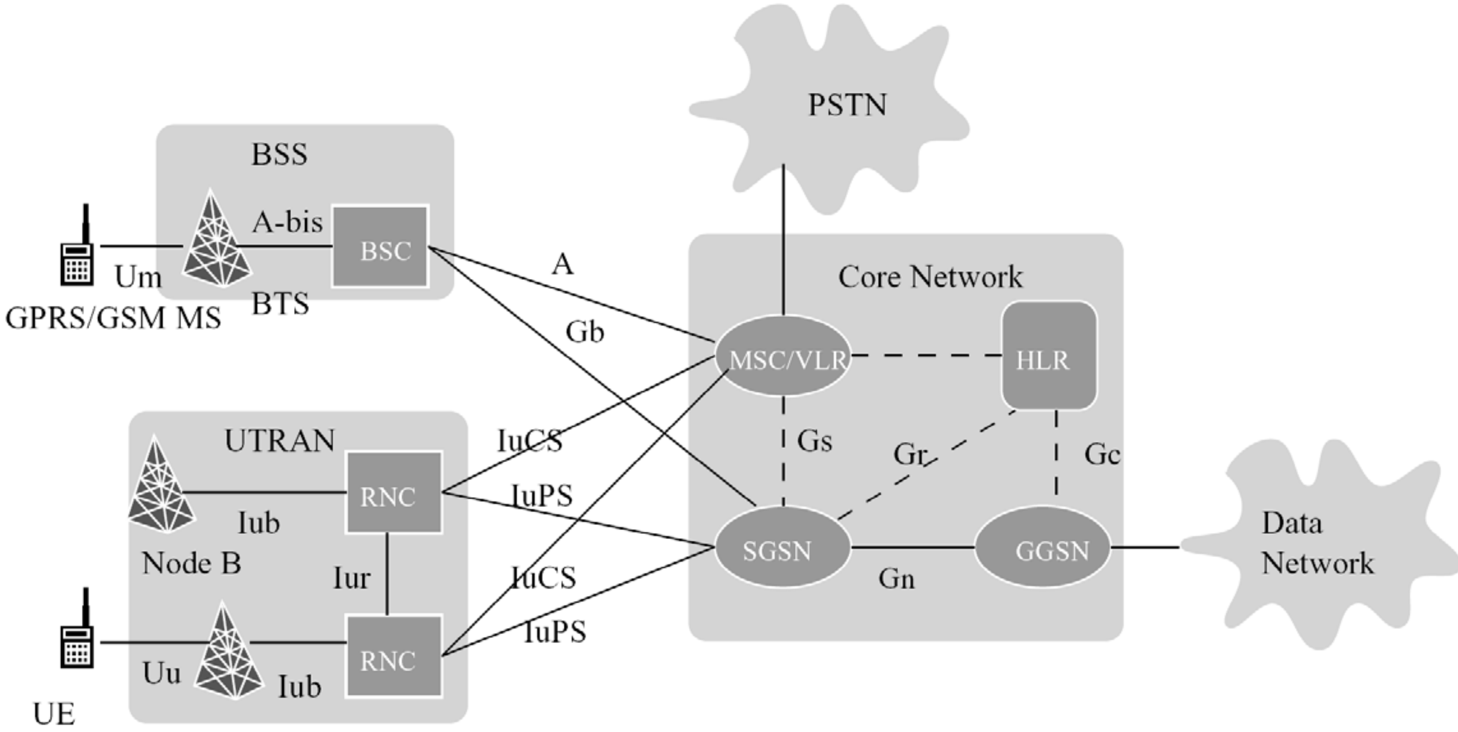
Message flow for the location cancellation with GLR

Mobile termination call



Message flow for mobile termination call with GLR

Fig. 2.1 GSM/GPRS/UMTS Network Architectures



BSS: Base Station Subsystem	BTS: Base Transceiver Station
HLR: Home Location Register	GGSN: Gateway GPRS Support Node
MS: Mobile Station	MSC: Mobile Switching Center
Node B: Base Station	PSTN: Public Switched Telephone Network
RNC: Radio Network Controller	SGSN: Serving GPRS Support Node
UE: User Equipment	UTRAN: UMTS Terrestrial Radio Access Network
VLR: Visitor Location Register	

21.4 Quality of Service in 3G (1/4)

- What is QoS?
- QoS's parameters
  - Maximum
  - minimum
  - guaranteed bit rate
  - delivery order
  - maximum packet size
  - reliability

21.4 Quality of Service in 3G (2/4)

- QoS control mechanism
  - Dynamically change parameters
  - Interwork with current QoS scheme
  - Present end-to-end QoS to the users with appropriate mapping

21.4 Quality of Service in 3G (3/4)

- QoS classes defined for mobile network
  - Conversational
    - Real time, highest quality control
  - Streaming
    - One-way real time video/audio
  - Interactive
    - Delay-insensitive, guarantee transfer time
  - Background
    - Delay-insensitive

21.4 Quality of Service in 3G (4/4)

- QoS's compatibility
  - 2G v.s. 3G
  - GPRS v.s. 3G

21.5 Wireless Operating System for 3G Handset

- In 2G, the major service is voice, whereas 3G supports wideband, IP, and multimedia-based communication.
- It is expected that 3G handsets will be equipped with complicated functions and features to accommodate complex information access.
- In general, a 3G handset integrates the functions of both a 2G handset and a personal data assistant (PDA).

Wireless Operating System

- A sophisticated wireless operating system is required.
- The wireless Os should satisfy the following requirements:
  - Start up time should be short.
  - The OS should be modular so that we can only install those software that we need.
  - The OS should support low-powered CPUs so that the battery life of the handset can be extended.
  - The OS should be protected in a read-only-memory chip, which implies that the size of the OS will be very limited.

21.5.1 Wireless OS Example

- WinCE OS
- EPOC OS
- Palm OS

WinCE OS

- Developed by Microsoft.
- A subset of the windows NT OS system.
- Casio and Siemens joined to develop the next-generation WinCE-enabled smart phones.

EPOC OS

- Developed by Psion.
- Symbian, (a company formed by Nokia, Ericsson, and Motorola), uses EPOC as the wireless OS platform.
- Ericsson’s R380 uses EPOC, and combines the function of a traditional mobile phone with those of a high-quality PDA.
- The R380 is equipped with an IrDA port through which a PC can make a wireless connection.

Palm OS

- Developed by 3Com's Palm Computing organizers.
- QUALCOMM has developed a PalmOS-enabled CDMA smart phone called PdQ.
- PdQ allows users to make calls, track appointments, catalog contact data, send/receive e-mails, and surf the Internet.
- Sony has licensed PalmOS to produce the next verion of PalmOS for a wider range of devices.

21.5.2 EPOC

- EPOC provides communication to the outside world through serial and sockets, dialup, TCP/IP, and PC connect.
- The EPOC core consists of the following components:
  - **Base**
  - **Engine support**
  - **Graphics**
  - System interface
  - GUI

EPOC: Base component

- Portable runtime system, kernel, file server, user library, and file server APIs; and delivers tools.
- To install EPOC on a target device requires implementing a ROM that runs E32, F32, and the text shell.
  - E32 : kernel executive and server
  - F32 : bootstrap loader, file services, file system API, and ROM testing command shell
- The kernel server is the highest-priority thread, handling requests with kernel-side resource allocation.

EPOC: Engine support component

- Provides APIs for data manipulation, an application architecture (for identifying programs to open data such as a file, an attachment, an embedded object, and so on), resource files and utilities, the standard C library, and text tools.

EPOC: Graphic component

- Provides a high-level GUI framework including drawing and user interaction, fonts, printing, views, and text entry.

Other features of EPOC

- Lightweight kernel (small amount of code to run in privileged mode).
- Preemptive multitasking, enabling context switching between threads to be done quickly.
- EPOC R5 supports fixed processes that can be swapped much more quickly than non-fixed user processes.
- A power model is used by the kernel and device drivers to turn off devices and power sources when they are not active.

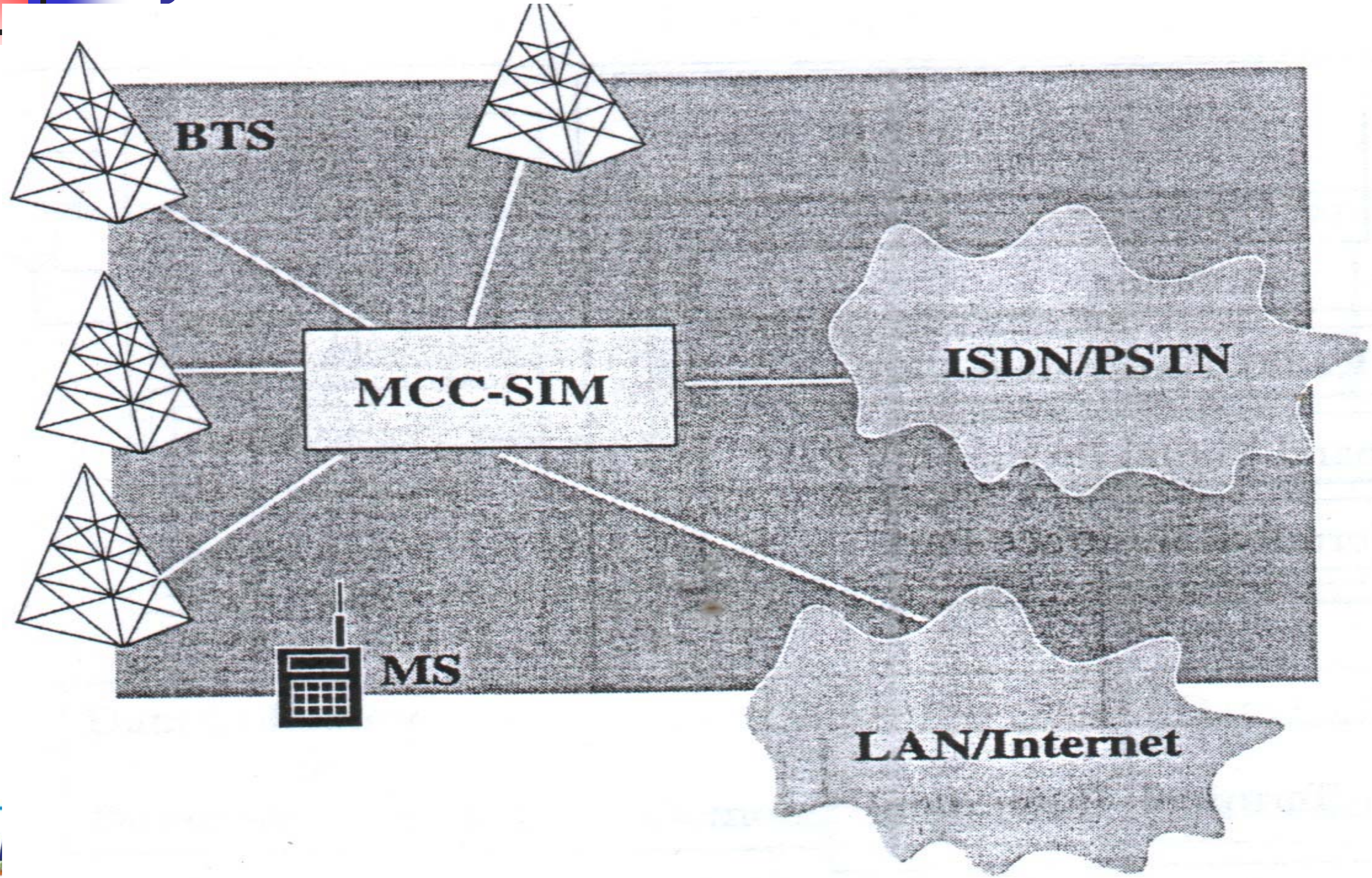
21.6 Third-Generation Systems and Field Trials

- DoCoMo W-CDMA Field Trial
- Lucent cdma2000 System

21.6.1 DoCoMo W-CDMA Field Trial

- NTT DoCoMo has promoted W-CDMA experiments since 1996. The trial architecture is shown in Fig 21.5.
- Which consists of mobile stations (MSs), a base transceiver station (BTs), and base station control equipment (MCC-SIM).

Figure 21.5 DoCoMo W-CDMA trial system



21.6.1.1 DoCoMo W-CDMA Mobile Station

- Table 21.4

Table 21.4 DoCoMo Experimental W-CDMA Mobile Stations

MODEL	FUNCTION TEST MS	SMALL TERMINAL 1	SMALL TERMINAL 2
Weight	10 Kg	2.5 Kg	130g
Max. TX Power	4.8W	0.8W	0.3W
Data Bit Rates	64–384 Kbps	64 Kbps	Voice Only

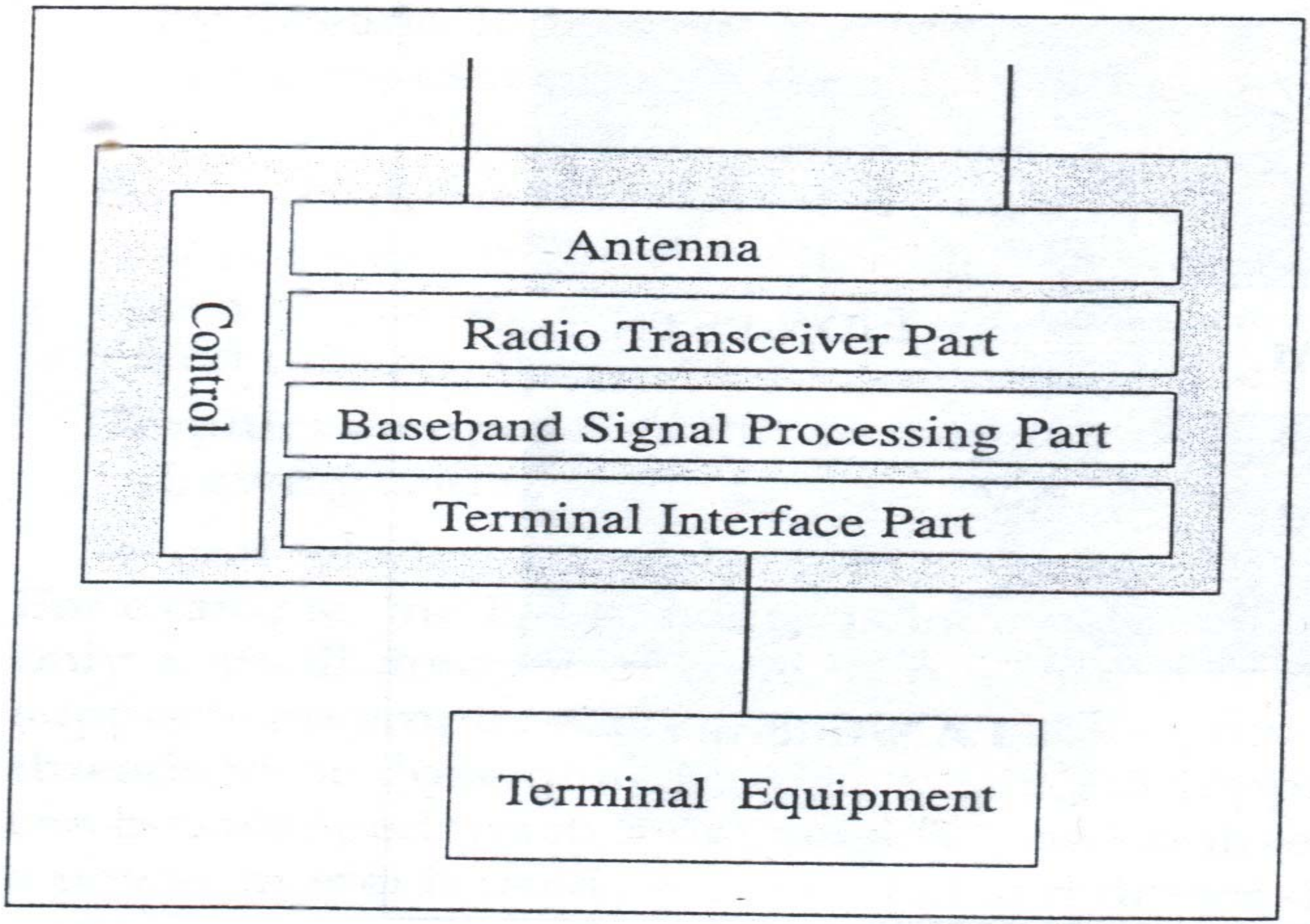
Mobile Station types

- Test Mobile Station
  - For measurement and testing
- Small Mobile Terminal 1
  - Data communication for indoor and outdoor experiments
- Small Mobile Station 2
  - Speech communication
- The experimental MS uses a real-time OS called μ I-TRON3.
- The MS includes a user identification module (UIM) that has similar functionality to the GSM SIM.

W-CDMA MS hardware (Figure 21.6)

- High-gain and high-efficiency antenna.
- Radio transceiver with high-quality linear amplifier, high adjacent channel selectivity reception, and low power consumption.
- Baseband signal processing with high integration and low power consumption.
- Terminal interface part, which supports ISDN and Ethernet interfaces (possibly through infrared or bluetooth).
- Control Part, which perform traditional MS function as well as multicall control and soft handoff control.

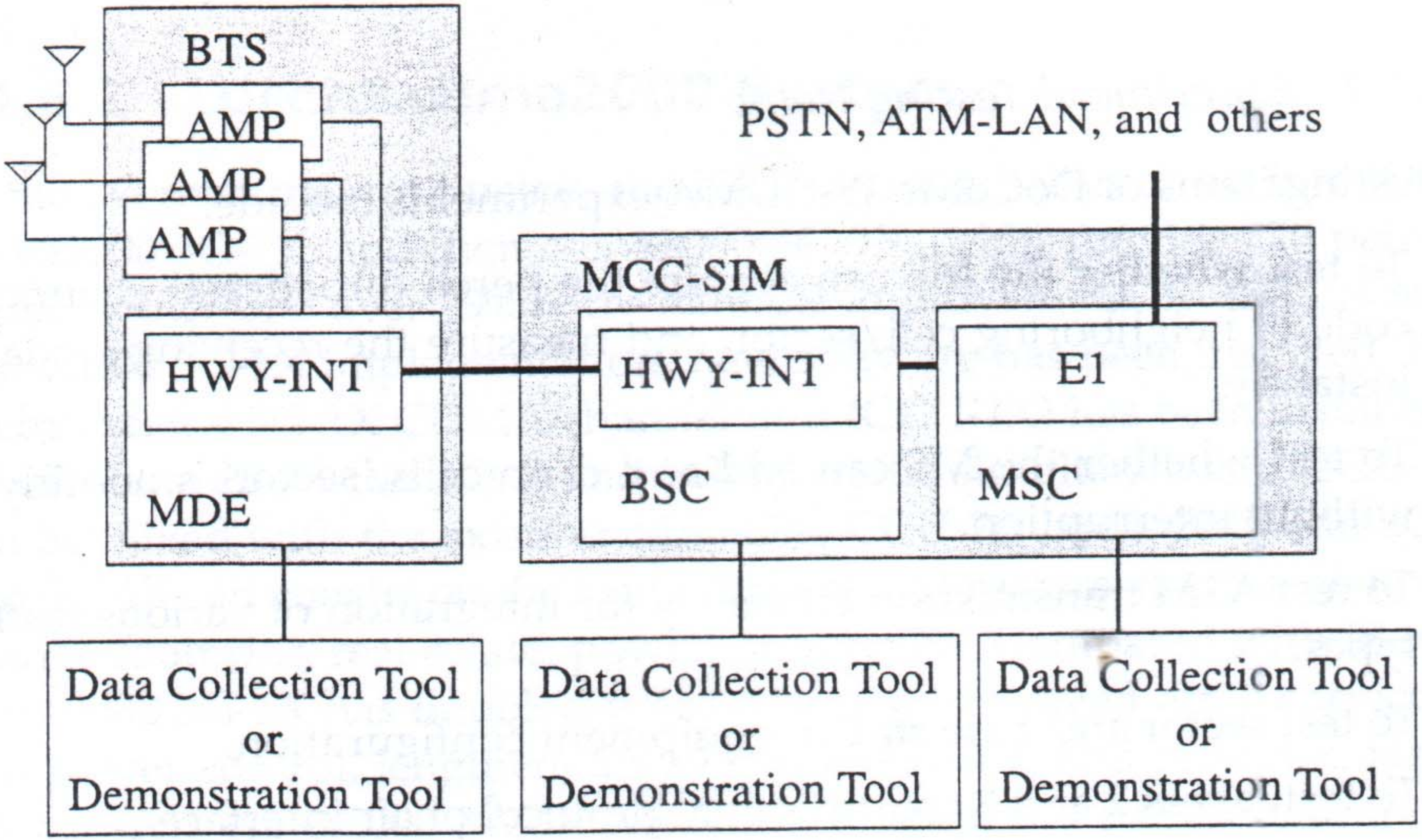
Figure 21.6 DoCoMo W-CDMA mobile station configuration



21.6.1.2 Base Station Equipment

- As shown in figure 21.7, the base station consists of a BTS and Mobile Communication Control Center-Simulator (MCC-SIM).
- It was developed by Ericsson, Fujitsu, Lucent, NEC, and Matsushita.
- The operating system is VxWorks.

Figure 21.7 DoCoMo W-CDMA base station equipment



BTS

- AMP
  - Provides transmission/reception amplification
- MDE
  - Is responsible for radio signaling processing

MCC-SIM

- BSC (base station controller)
  - Is responsible for radio circuit control and diversity connection.
- MSC (mobile switch center)
  - Provides switching control, error control, and interface to analog telephone, an ISDN device, ATM-LAN, and PSTN.

Diversity connection

- Diversity refers to simultaneous connection between one MS and multiple BTSs (up to three).
- 50 percent of the calls should be supported by two-BTS diversity, and 5 percent of the call should be supported by three-BTS diversity.
- The BSC is responsible for selecting and combining uplink signals from multiple BTSs.

Data Collection Tool and Demonstration Tool

- The data collection tool measures bit error rate and frame error rate characteristics, delay profiles, and data storage function.
- The demonstration tool provides display for transmission quality and the status of various controls.
- Both tools support real-time display.

21.6.1.3 Experiment Testing Items (1/2)

- To test whether the MS can acquire the perch (broadcast) channel code of neighboring cell/sector, and measure the receiving signal instantly.
- To test whether the MS can add and drop cells/sectors smoothly without interruption.
- To test ATM transmission efficiency for integration or various traffic types.
- To test sector and base station equipment configuration.

21.6.1.3 Experiment Testing Items (2/2)

- To test layers 2 and 3 control signal protocol of air interface.
- To verify the RAKE combining function of the MS when signals from multiple paths are received.
- To investigate radio transmission characteristics of various data types.
- To verify the system capacity for subscribers.

Further discussion of testing for MS

- General MS test items
  - Transmission side: transmission frequency, maximum transmission power, adjacent channel leakage power, modulation accuracy, transmission intermodulation, and so on.
  - Reception side: reception sensitivity, adjacent channel selectivity, reception intermodulation sensitivity, and so on.
- W-CDMA-specific test items
  - The fast-closed loop transmission power control test sends layer 1 signal, and a spectrum analyzer measures this control characteristic.

21.6.2 Lucent cdma2000 System (1/2)

- In the 3G road map of Lucent, the IS95A system has evolved into IS95B, cdma2000 3G-1X, and then cdma2000 3G-3X.
- Both cdmaOne and 3G-1X can coexist on the same carriers and sectors; there is no need to change footprint, real estate, power, or antenna.

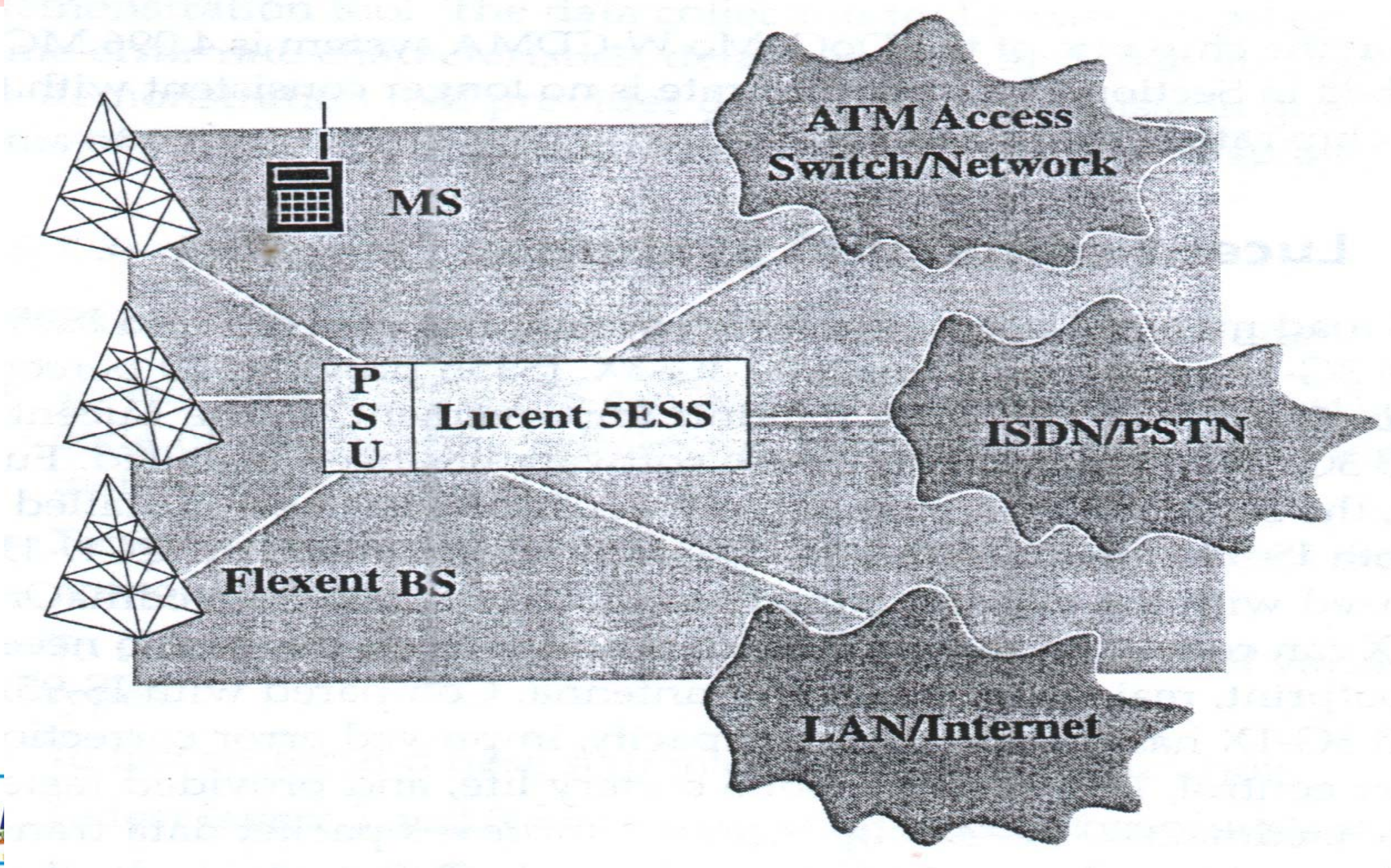
21.6.2 Lucent cdma2000 System (2/2)

- Compare with IS95A, cdma2000 3G-1X has doubled voice capacity, improved error correction and power control, lengthened mobile battery life, and provided faster pilot search.
- Cdma2000 3G-3X significantly improved packet data transmission.

Table 21.5

MODEL	3G-1X	3G-3X
Carrier Bandwidth	1.25 MHz	3.75 MHz
Ubiquitous Data Rate	144 Kbps	384 Kbps
Peak Data Rate	307.2 Kbps	1.0368 Mbps

Figure 21.8



ATM Access
Switch/Network
MS
P
S
U
Lucent 5ESS
ISDN/PSTN
Flexent BS
LAN/Internet

Base station model of Lucent cdma2000

- Flexent microcell
  - A compact and lightweight BS with flexible installation.
  - Is aimed for in-building services, RF hole filling, and hot spots.
  - Compatible with existing networks.
- Flexent CDMA module cell
  - Upgrades the Flexent microcell by accommodating next-generation CDMA radio components.
- Flexent CDMA MicroMini 5100 BS

Lucent 5ESS

- The 5ESS packet switch unit (PSU) connects to BS through frame relay.
- With wireless data IWF, the 5ESS PSU connects to dual LAN to provide Internet access.

21.7 Other Trial Systems

- Nortel W-CDMA trial system
- Ericsson W-CDMA trial system
- Motorola cdma2000 trial system

Nortel W-CDMA trial system (1/2)

- Operate at 1920-1940 MHz (uplink) and 2110-2130 (downlink).
- BTS consists of six power amplifiers.
- MCC (mobile communication control center) consists of a *radio network controller* (RNC) and an ATM swtich.
- RNC can connect up to BTSs over the A-bis interface.

Nortel W-CDMA trial system (2/2)

- The terminals can support an 8.8 Kbps voice handset, a 64 Kbps PCMCIA card, or a video phone.
- The service supported by this system include 8.8 Kbps voice, 64 Kbps circuit-switched data, and 384 Kbps packet-switched data.

Figure 21.9 Nortel W-CDMA trial system

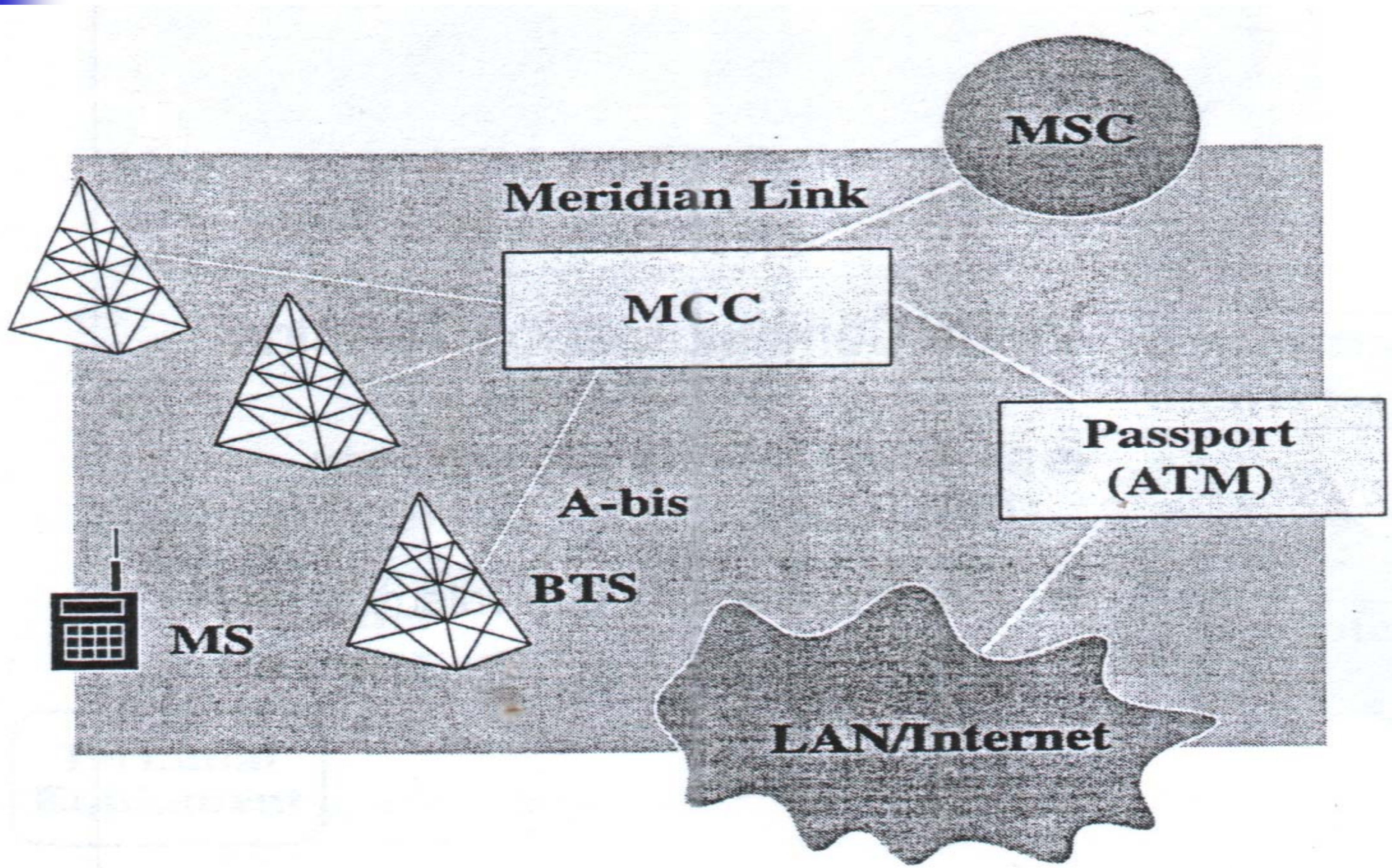
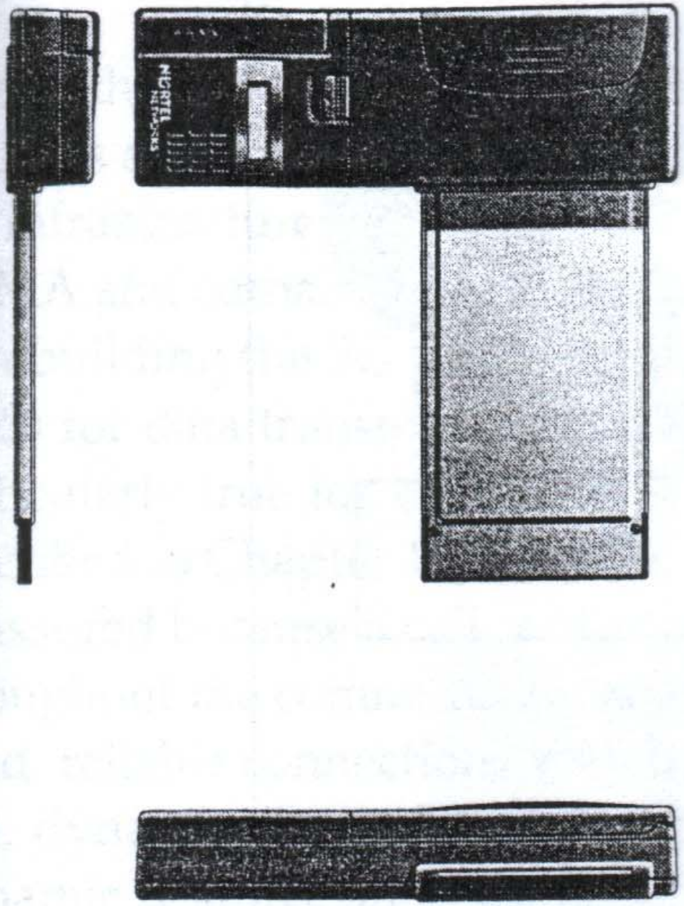


Figure 21.10 Nortel W-CDMA voice communication terminal prototype

Voice Communication Terminal (prototype)

- Small and light weight; less than 100g, 100cc
- Clear voice quality equivalent to ISDN

Figure 21.11 Nortel W-CDMA card type terminal prototype



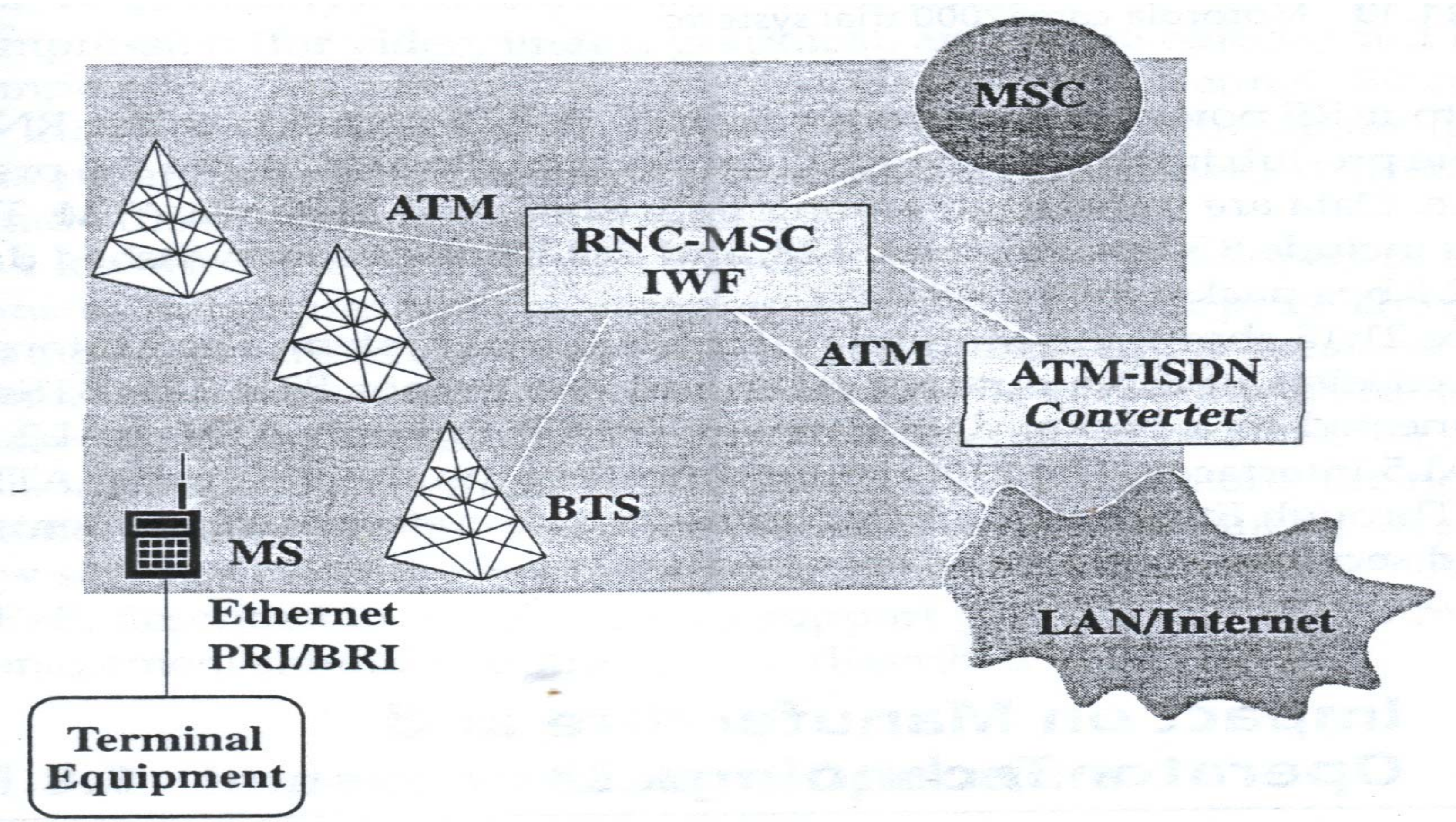
Card Type Terminal (prototype)

- Card type terminal specialized in data communication
- PCMCIA interface

Ericsson W-CDMA trial system

- Operate in the same frequency bands as the Nortel system.
- Three BTSs and one RNC and MSC running on W-CDMA operating system (WOS)
- The services include 8 Kbps voice; 64, 128, and 384 Kbps circuit-switched data; and 472 Kbps packet-switched data.

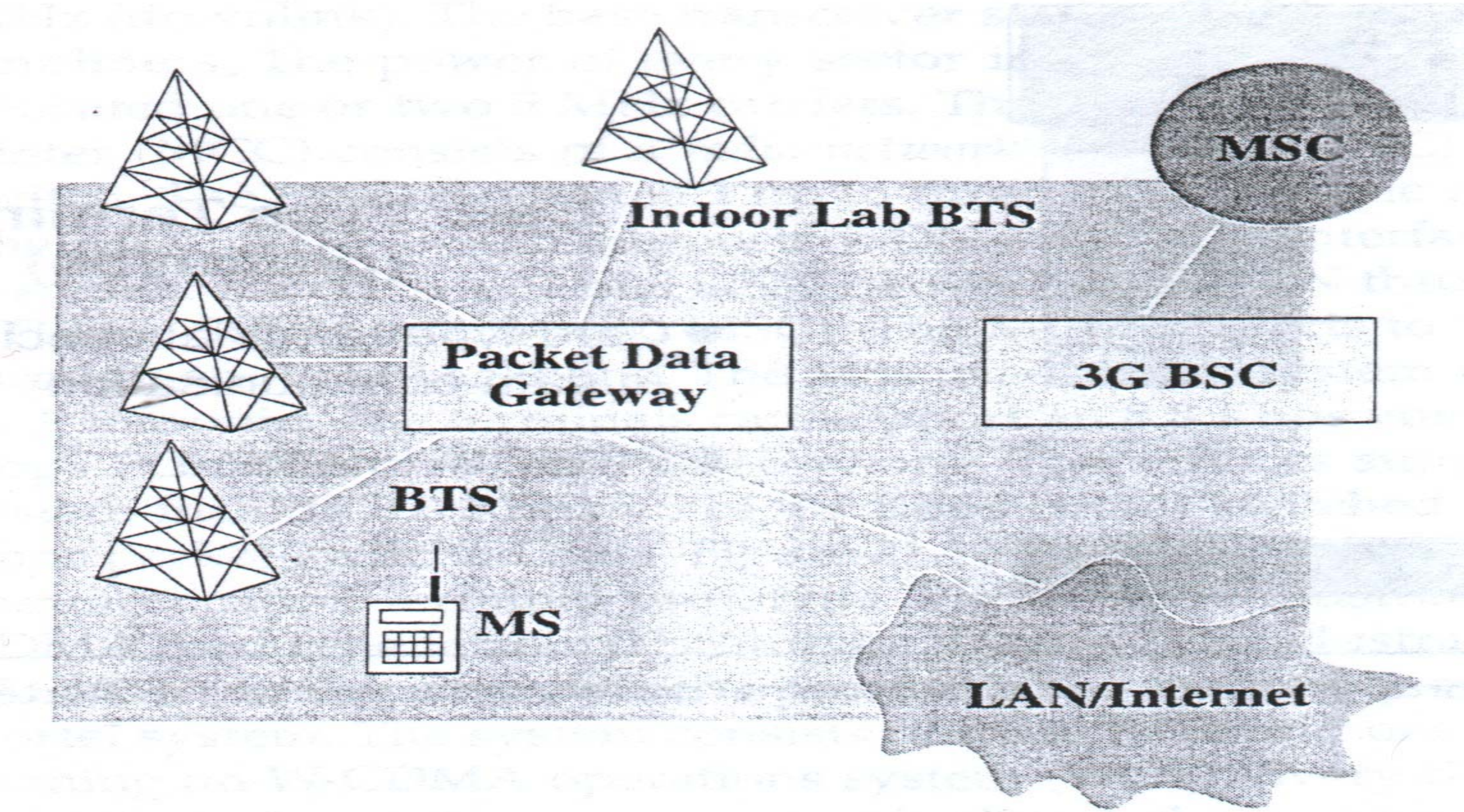
Figure 21.12 Ericsson W-CDMA trial system



Motorola cdma2000 trial system

- Three outdoor BTs and one indoor BTS.
- BTSs are connected to a packet data gateway (PDG) through ATM AAL2 and AAL5 interface.

Figure 21.13 Motorola cdma2000 trial system



21.8 Impact on Manufacture and Operator Technologies

- 21.8.1 Impact on Infrastructure Technologies
- 21.8.2 Impact on Mobile Operators

21.8.1 Impact on Infrastructure Technologies (1/2)

- In 3G packet-switched infrastructure, QoS for data transmission is one of the most important issues.
- In 2G, QoS can be assured because a call is typically assigned a fixed amount of resources throughout the communication session.
- In packet-switching, reliable connections with large bandwidth, minimized RF bit error rate, dynamic channel allocation, and smooth handoffs are desirable.

21.8.1 Impact on Infrastructure Technologies (2/2)

- Advanced data compression techniques for lossy compression, and lossless compression are essential.
- Reliable packet routing and low cost backbone equipment is needed.
- A knowledge-based 3G core network should be developed to utilize transfer techniques such as compression, caching, and prefetching.
- Network solution should provide a service platform capable of quickly deploying new services for end users (enterprise).

21.8.2 Impact on Mobile Operators (1/3)

- 3G is an emerging technology driven by the equipment suppliers, instead of bye the push from customers. This increase the risk faced by mobile operators.
- The operators want the best technologies with low cost, low risk, and high performance.
- A great challenge of 3G development for the operators is to select technical parameters so that their 2G system can evolve toward 3G services to the greatest extent possible.

21.8.2 Impact on Mobile Operators (2/3)

- In 2G, limited revenue streams are possible because mobile service providers are the only business players.
- Multiple revenue streams will emerge because mobile networks will open to content providers.
- Even though deliver of voice-based information remains the major business in the initial stage, data transmission support for Internet and multimedia applications involving content providers is essential to 3G network operation.

21.8.2 Impact on Mobile Operators (3/3)

- Service cost will experience revolutionary change from the conventional 2G charge on voice delivery.
- Typical metered-billing systems will become inapplicable.
- A billing model for customers must be flexible.
  - For example, we expect that corporate customers will accept complex billing for lower costs, while individual customers will require simple and predictable billing.

21.9 Summary

- Detail of wireless OS.
- NTT DoCoMo W-CDMA field trial 3G system.
- A small group of people have already started working on fourth-generation (4G) systems. Though their objectives have yet to be defined, unlike the 3G vendor-driven approach, most operators feel that the development of 4G systems should be public-interest driven.