Cellular Network
An Introduction

Michael Ng and Sheng Chen

Mostly using 2G or GSM as illustration

- First Principles
- History of GSM
- System Architecture
- Call set-up

The Cellular Principle

- Relies on the concept of concurrency
    - delivered through channel reuse i.e. reusing same channels in different cells
- Total coverage area is divided into cells
    - only a subset of channels available in each cell
- All channels partitioned into sets
    - sets assigned to cells
  - Rule: assign the same set to two cells that are sufficient geographically distant so that interference is small
  - Net result: increased capacity

What are channels or resources for 2G, 3G, 4G, 5G and beyond

Advantages of Cellular Networks

- More capacity due to spectral reuse
- Lower transmission power due to smaller transmitter/receiver distances
- More robust system as any Base Station fault only affects the immediate cell
- More predictable propagation environment due to shorter distances

Network densification: increase user capacity and lower transmit power

Disadvantages of Cellular Networks

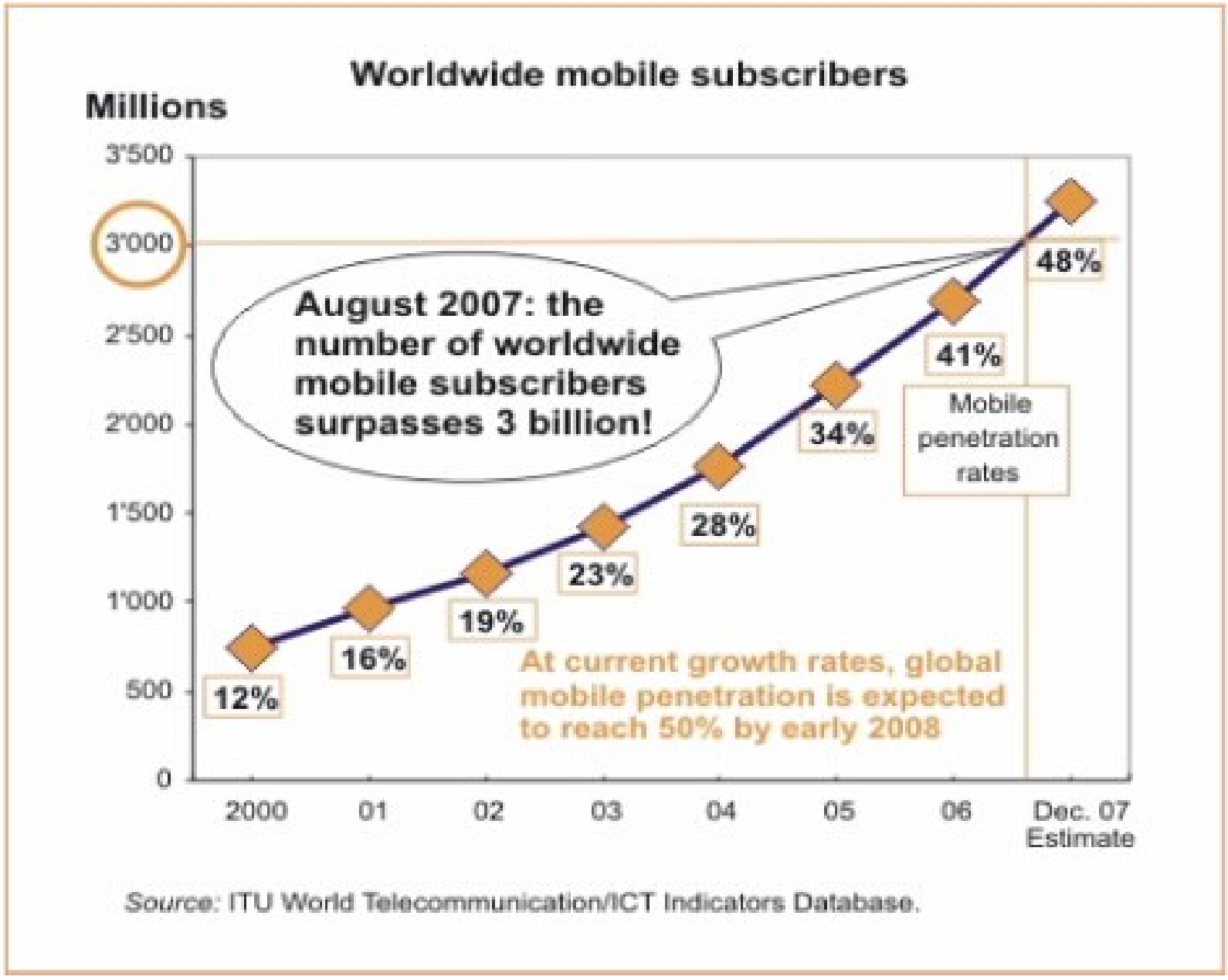
- Need for more infrastructure
- Need for fixed network (called backhaul or backbone) to connect Base Stations
- Some residual interference from co-channel cells
- Handover procedure required

Mobile network has become an integral infrastructure for our connected world, look how 5G will revolutionize our society

History of GSM

- 1982 Groupe Speciale Mobile
  - Formed to study a pan-European Cellular system
  - Good subjective speech quality
  - Low terminal service and cost
  - Support for international roaming
  - Support for a range of services
  - Spectrally efficient
  - ISDN compatibility
- 1990 GSM Phase 1 recommendations published
- 1991 DCS1800 recommendations published
- 1991 First commercial GSM networks in Europe
- 1995 GSM networks in 60 countries, 5.4m subscribers
- 2010 GSM or its successor subscribers over 3Bn worldwide

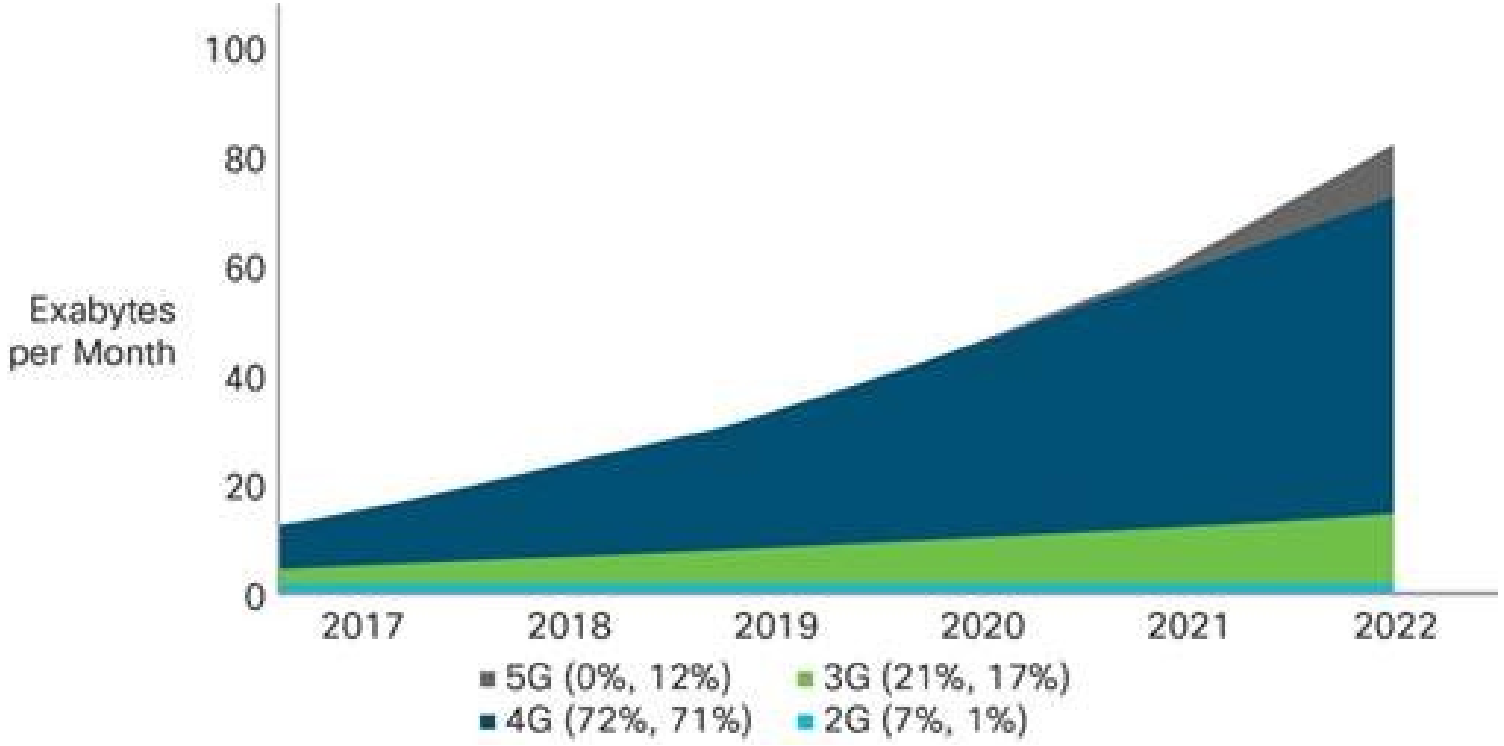
Look for history of mobile network: from 1G to 5G and beyond



Source: ITU World Telecommunication/ICT Indicators Database.

Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2017–2022 White Paper

https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-738429.html



Global Mobile Traffic by Connection Type (Prediction for 5G is likely to be wrong)

GSM Services - Phase 1

Service Category	Service	Comments
Teleservices	Speech Emergency SMS (Short Message Service) Group 3 Fax	Full Rate 13Kbps Point to Point & Cell Broadcast
Bearer Services	Asynchronous Data Synchronous Data	300 – 9600bps 300 – 9600bps
Supplementary Services	Call Forward Call Barring	Subscriber Busy, Not Reachable International & Incoming Calls

GSM Services - Phase 2

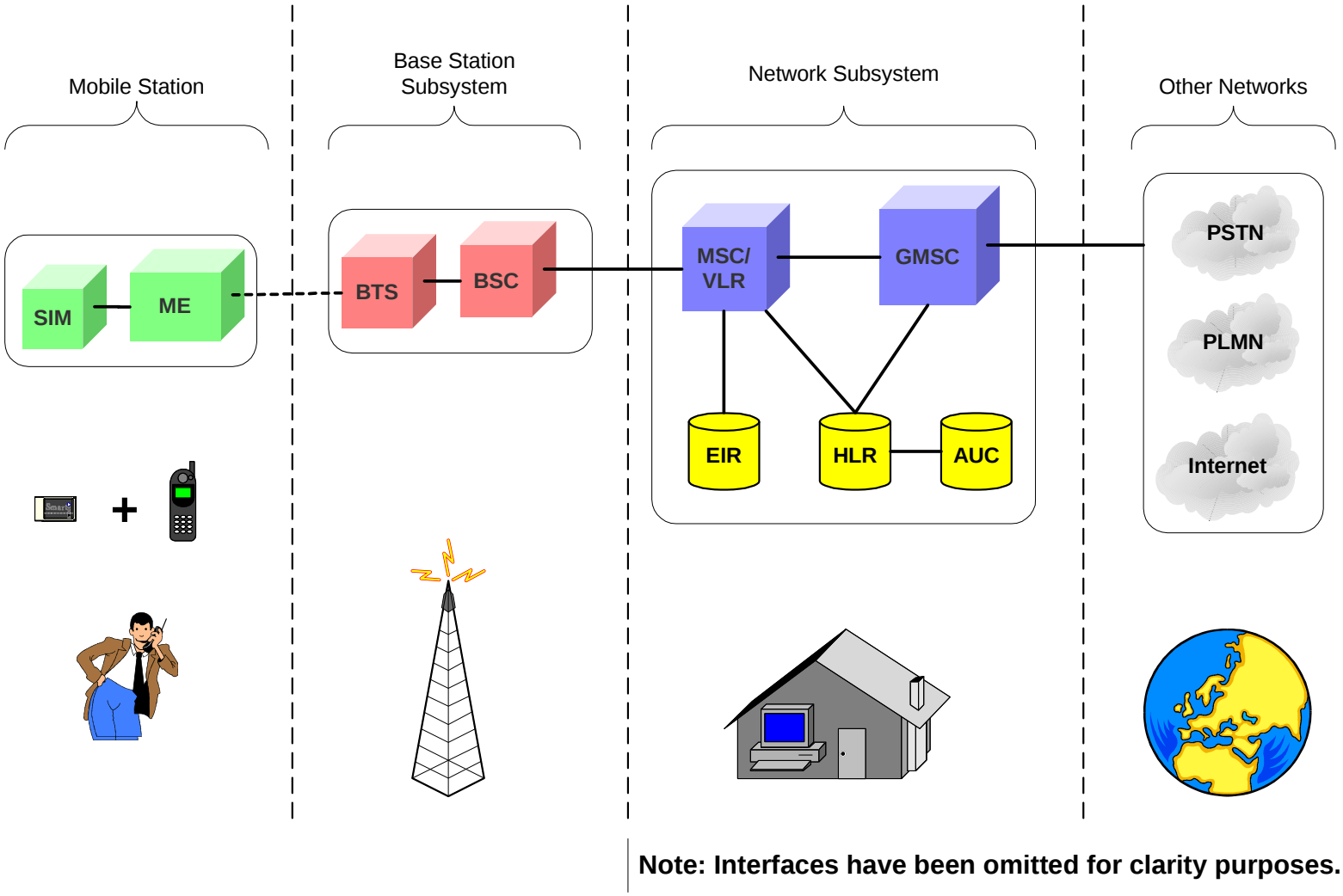
Service Category	Service	Comments
Teleservices	Speech Emergency SMS (Short Message Service) Group 3 Fax	Half Rate 6.5Kbps Point to Point & Cell Broadcast
Bearer Services	Synchronous Packet Data Access	2400 – 9600bps
Supplementary Services	CLI (Calling Line Identification) Call Waiting Call Hold Multiparty USSD (Unstructured Supplementary Service Data) Operator Barring Advice on charge	

GSM Services - Phase 2+

- Primarily concerned with the improvement of Bearer (data) services
  - Full data rate @ 14.4 kb/s
  - High Speed Circuit Switched Data (HSCSD)
  - General Packet Radio Service (GPRS)
- Some additional supplementary services also specified

Investigate 3G, 4G, 5G and beyond services

Architecture of GSM Network



GSM Network Architecture

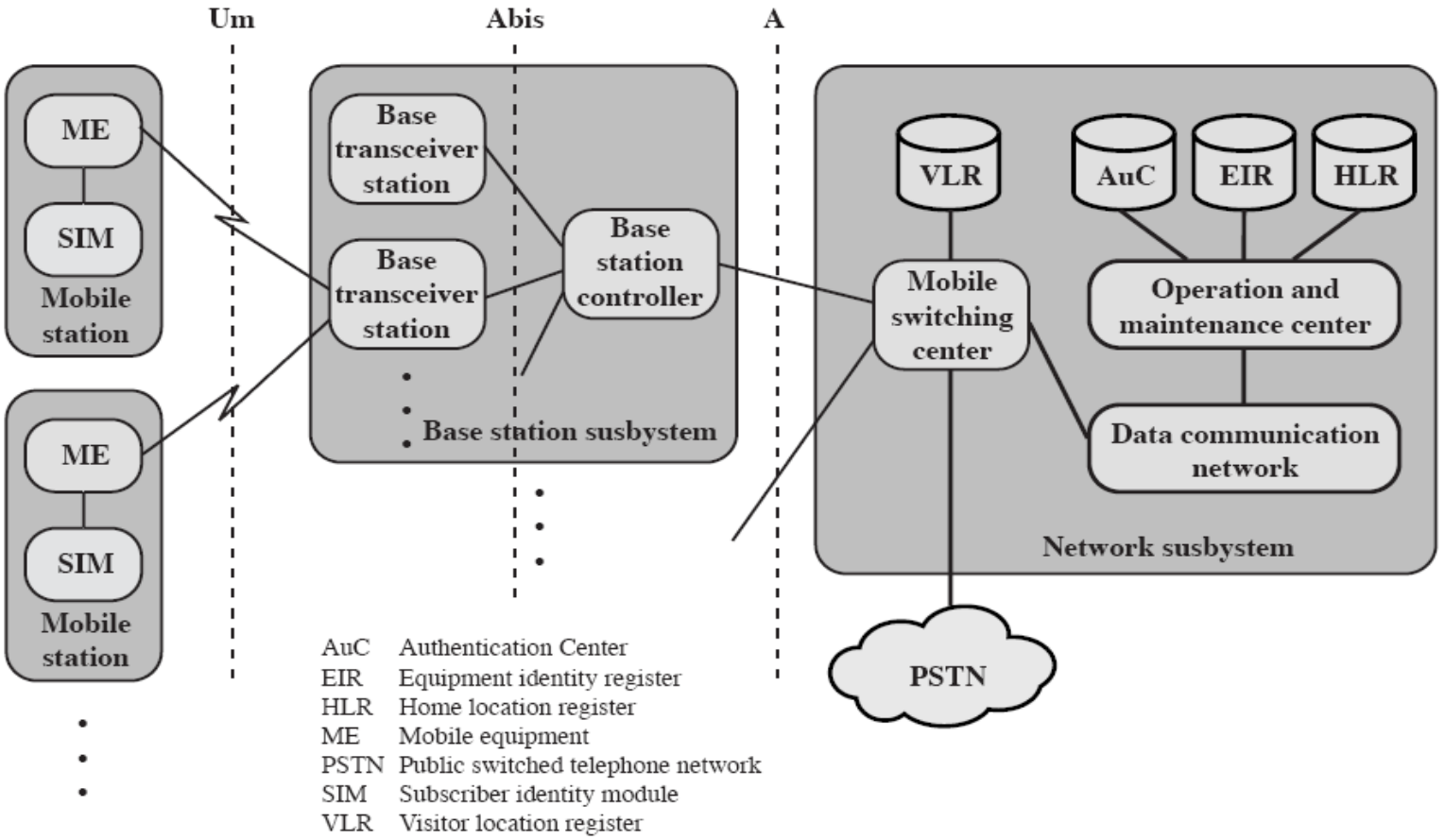


Figure 10.13 Overall GSM Architecture

Investigate Other cellular network architectures

Radio System Details

- TDMA shared carrier frequency with other users
- 200 kHz channels with 270.833 kbits/s.
- eight TDMA users
- 13kb/s vocoder, 20kb/s with overhead
- Reuse factor 3-4
- About 5 calls/MHz/cell with sectoring, or 150 calls/cell (30 MHz)

Investigate 3G, 4G, 5G and beyond radio system details

FDMA,CDMA, SDMA, orthogonal access, nonorthogonal access

Radio System Requirements

- Number of logical channels (number of time slots in TDMA frame): 8
- Maximum cell radius (R): 35 km
- Frequency: region around 900 (1800MHz PCS)
- Maximum vehicle speed (V_m):250 km/hr
- Maximum coding delay: approx. 20 ms
- Maximum delay spread (Δm): 10 μs (2 miles path difference)
- Bandwidth: Not to exceed 200 kHz (25 kHz per channel)

Investigate 3G, 4G, 5G and beyond radio systems requirements

GSM Speech Signal Processing

- RPE-LPC (Regular pulse excited Linear Predictive Coding)
- In 20 ms, 260 bits at 13kb/s
- Half-rate coded speech gives a 22.8 kbps (traffic channel)
- Interleaved over multiple slot time periods, within 20 ms protects against burst errors
- Encrypted 114 bits at a time Into time slots
- GMSK modulation

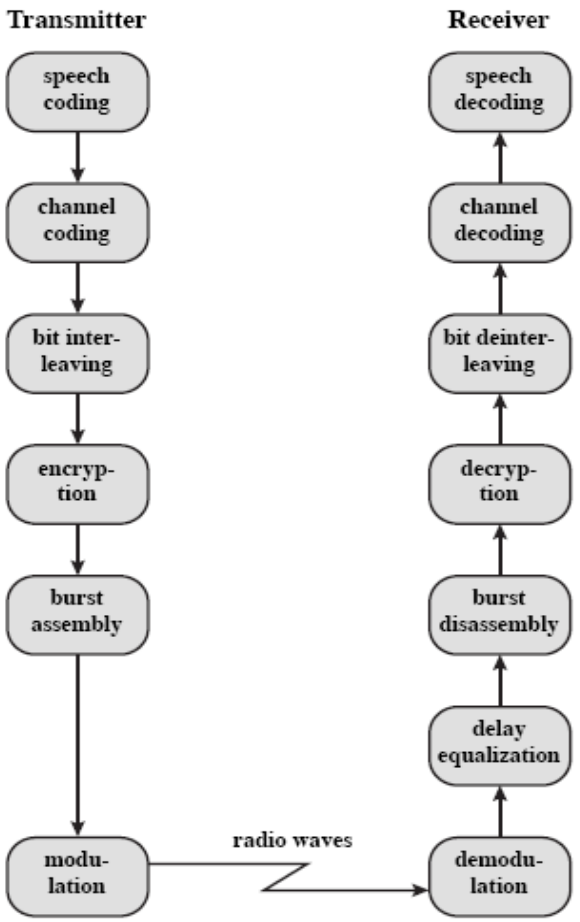


Figure 10.15 GSM Speech Signal Processing

GSM Network Architecture

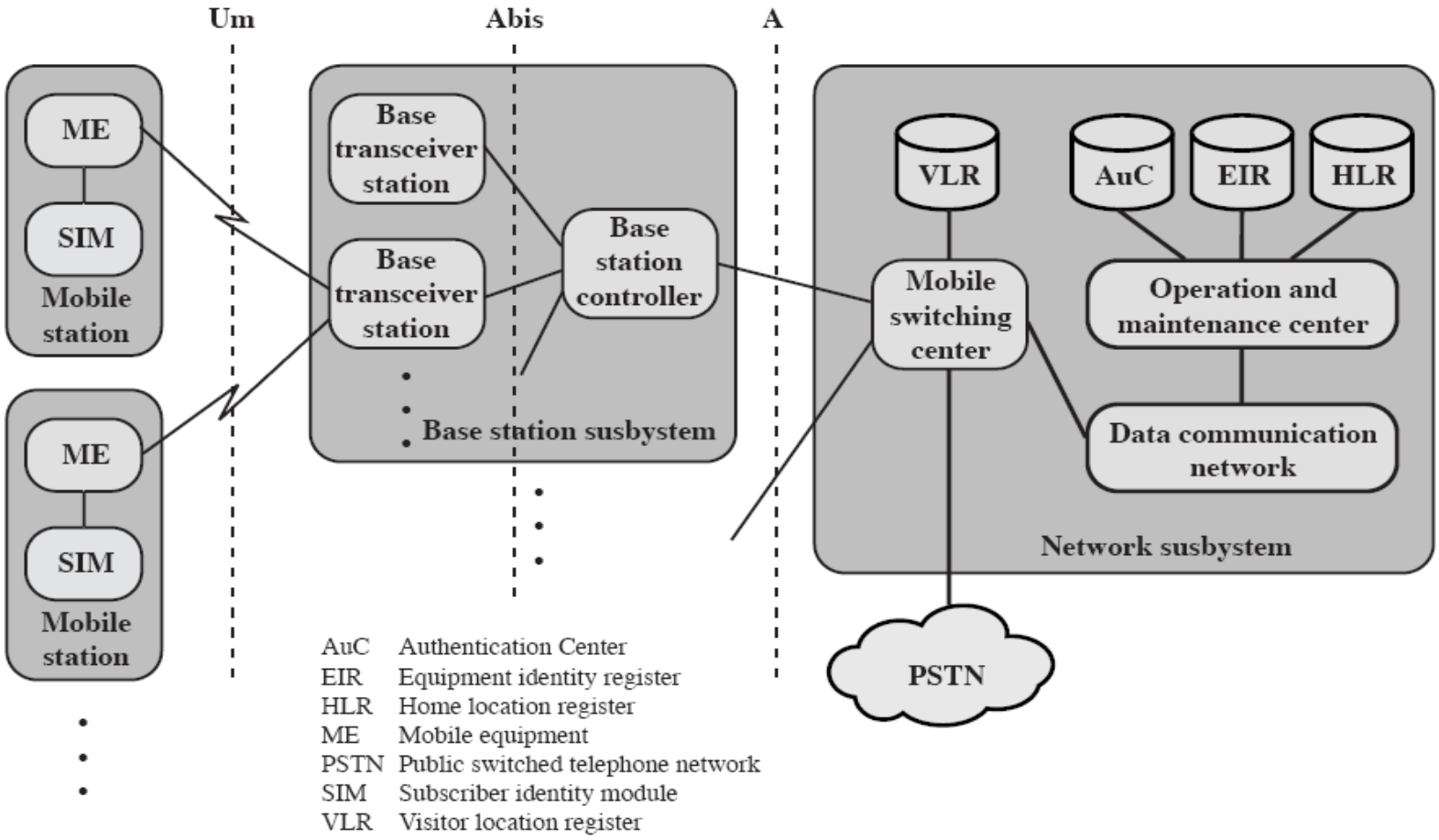
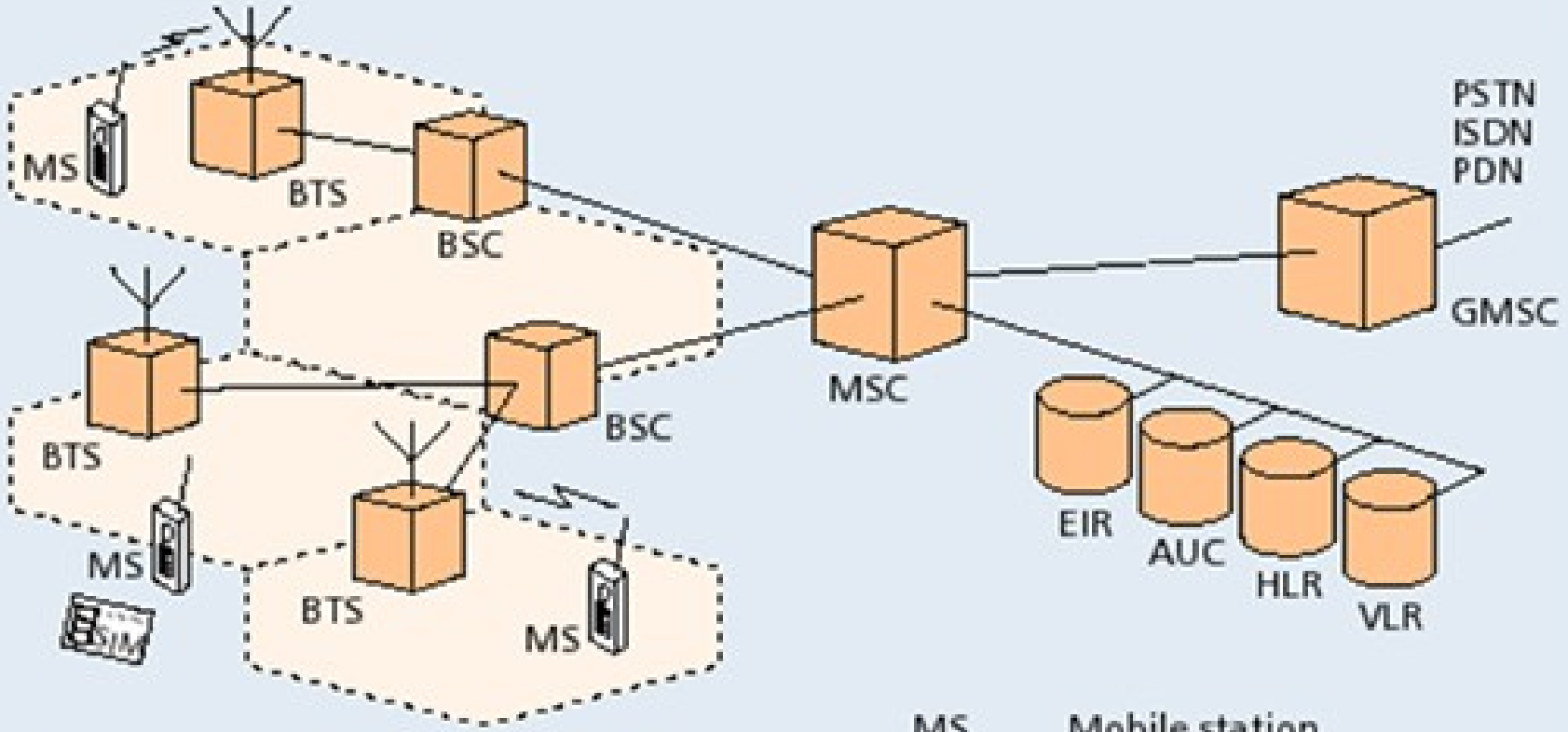


Figure 10.13 Overall GSM Architecture

Mobile Station

- Mobile station communicates across Um interface (air interface) with base station transceiver in same cell as mobile unit
- Mobile equipment (ME) – physical terminal, such as a mobile phone or Smartphone
  - MS includes radio transceiver, digital signal processors (the ME) and subscriber identity module (SIM)
- GSM subscriber units are generic until SIM is inserted
  - SIMs roam, not necessarily the subscriber devices

GSM: System Architecture



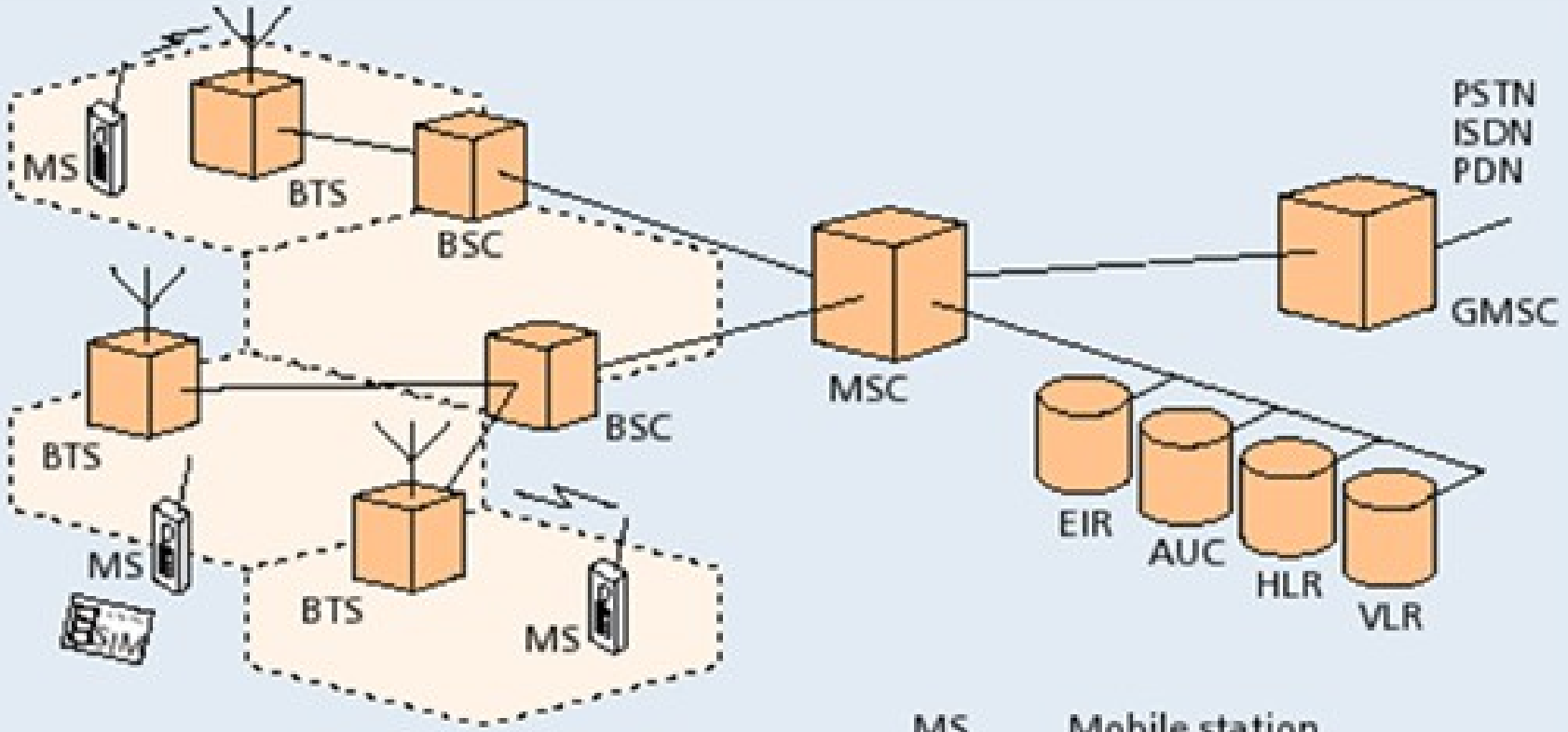
BTS	Base transceiver station
BSC	Base station controller
BSS	Base station subsystem (BTS+BSC)
MSC	Mobile switching center
GMSC	Gateway MSC

MS	Mobile station
HLR	Home location register
VLR	Visited location register
EIR	Equiment identity register
AUC	Authentication center

Base Station Subsystem (BSS)

- BSS consists of base station controller and one or more base transceiver stations (BTS)
- Each BTS defines a single cell
  - Includes radio antenna, radio transceiver and a link to a base station controller (BSC)
- BSC reserves radio frequencies, manages handoff of mobile unit from one cell to another within BSS, and controls paging

GSM: System Architecture



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GSM Network Architecture

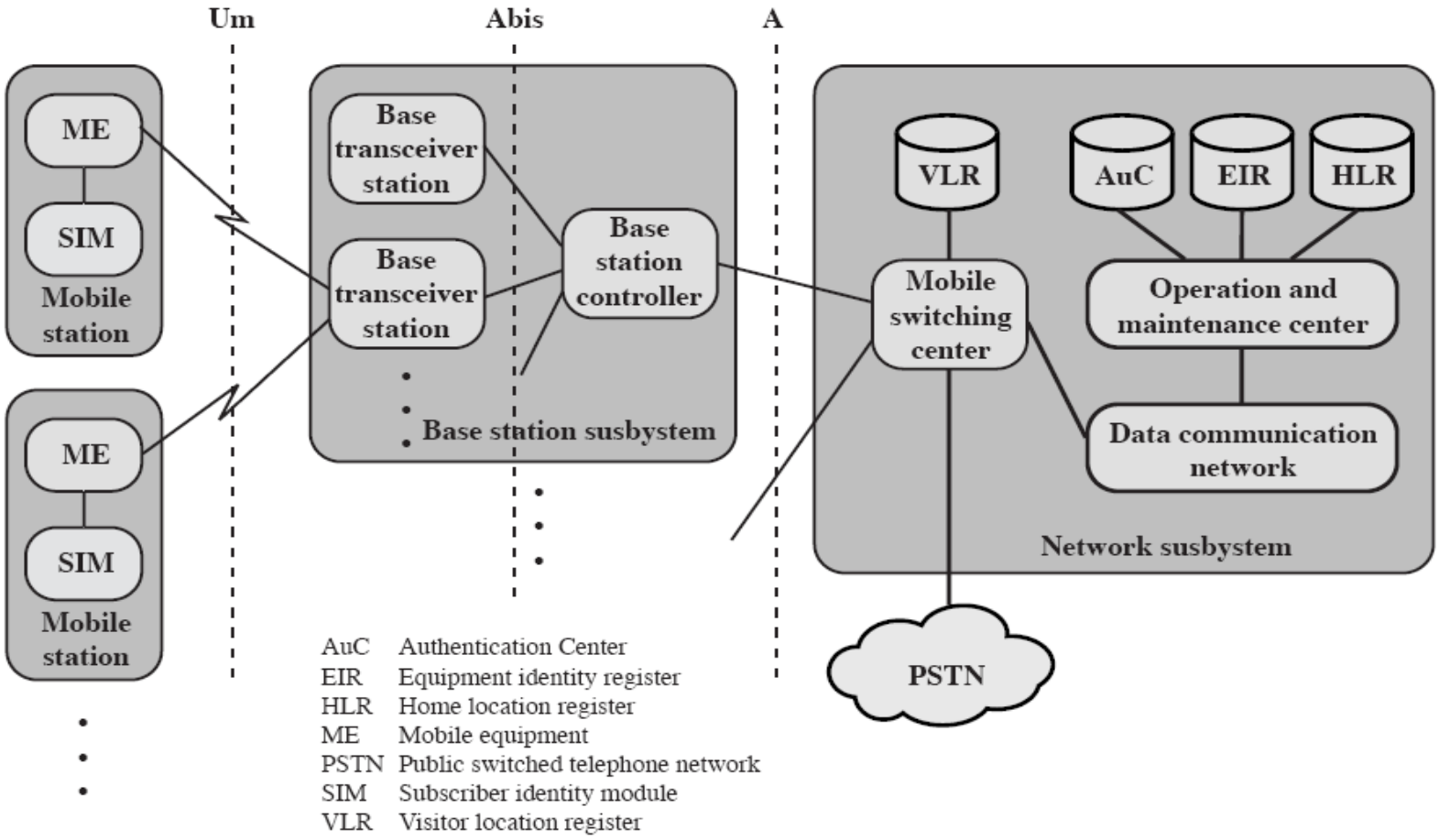
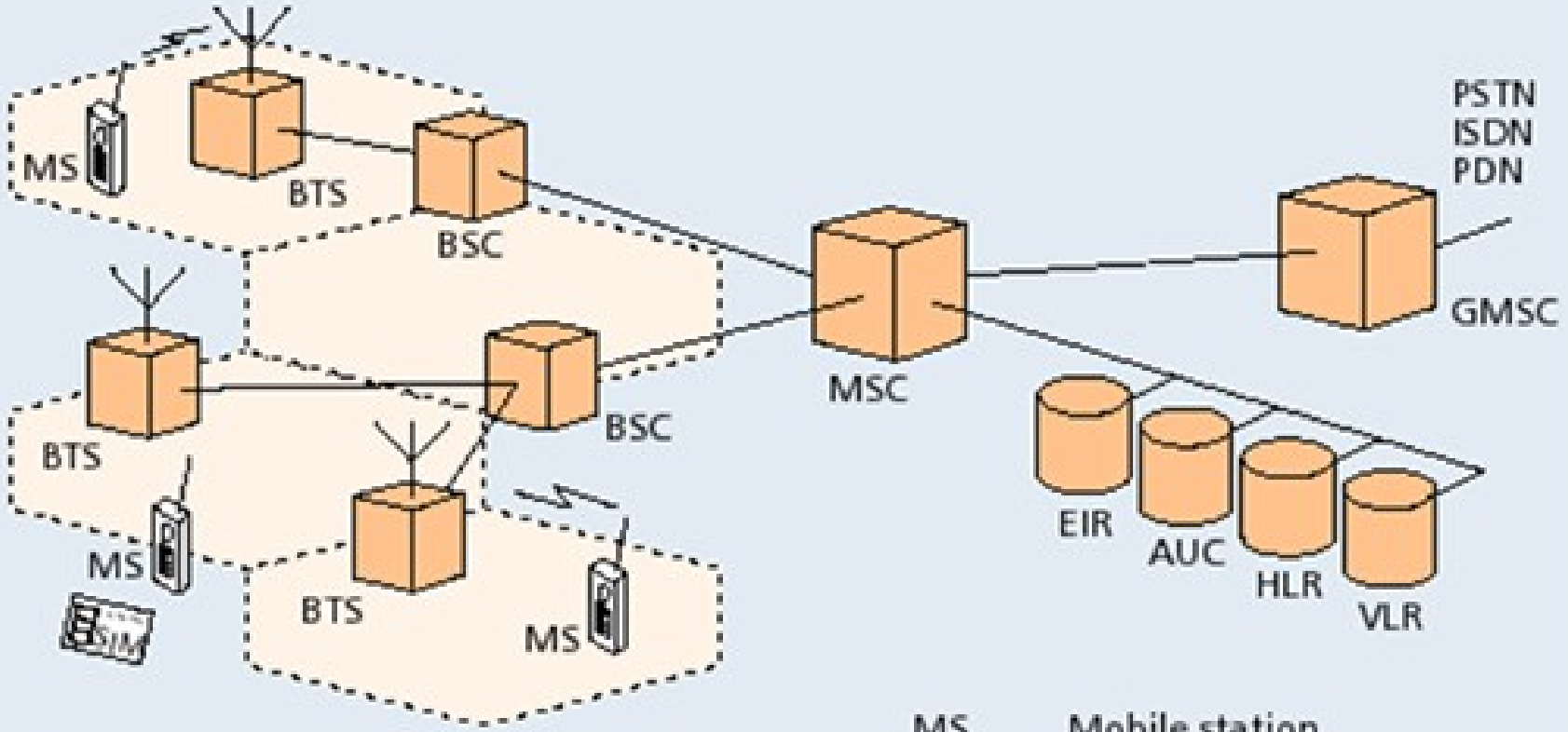


Figure 10.13 Overall GSM Architecture

Network Subsystem (NS)

- NS provides link between cellular network and public switched telecommunications networks
  - Controls handoffs between cells in different BSSs
  - Authenticates users and validates accounts
  - Enables worldwide roaming of mobile users
- Central element of NS is the mobile switching center (MSC)

GSM: System Architecture



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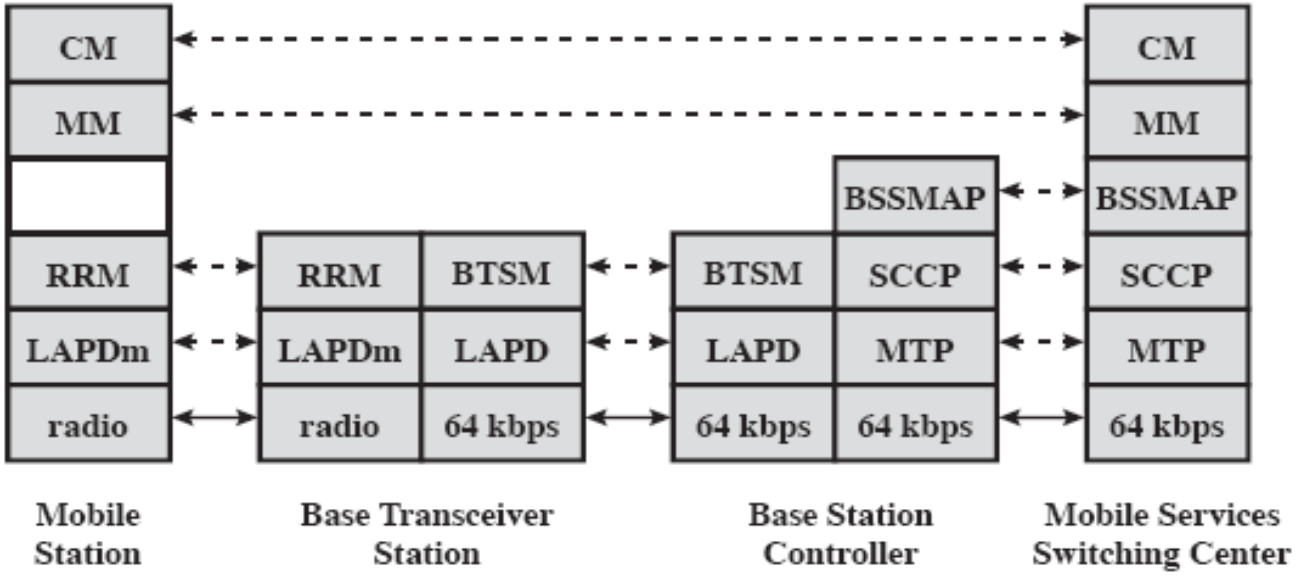
Mobile Switching Center (MSC) Databases

- Home location register (HLR) database – stores information about each subscriber that belongs to it
- Visitor location register (VLR) database – maintains information about subscribers currently physically in the region
- Authentication center database (AuC) – used for authentication activities, holds encryption keys
- Equipment identity register database (EIR) – keeps track of the type of equipment that exists at the mobile station

GSM Signaling Protocol Architecture



BSSMAP = BSS mobile application part
BTSM = BTS management
CM = connection management
LAPD = link access protocol, D channel
MM = mobility management
MTP = message transfer part
RRM = radio resources management
SCCP = signal connection control part

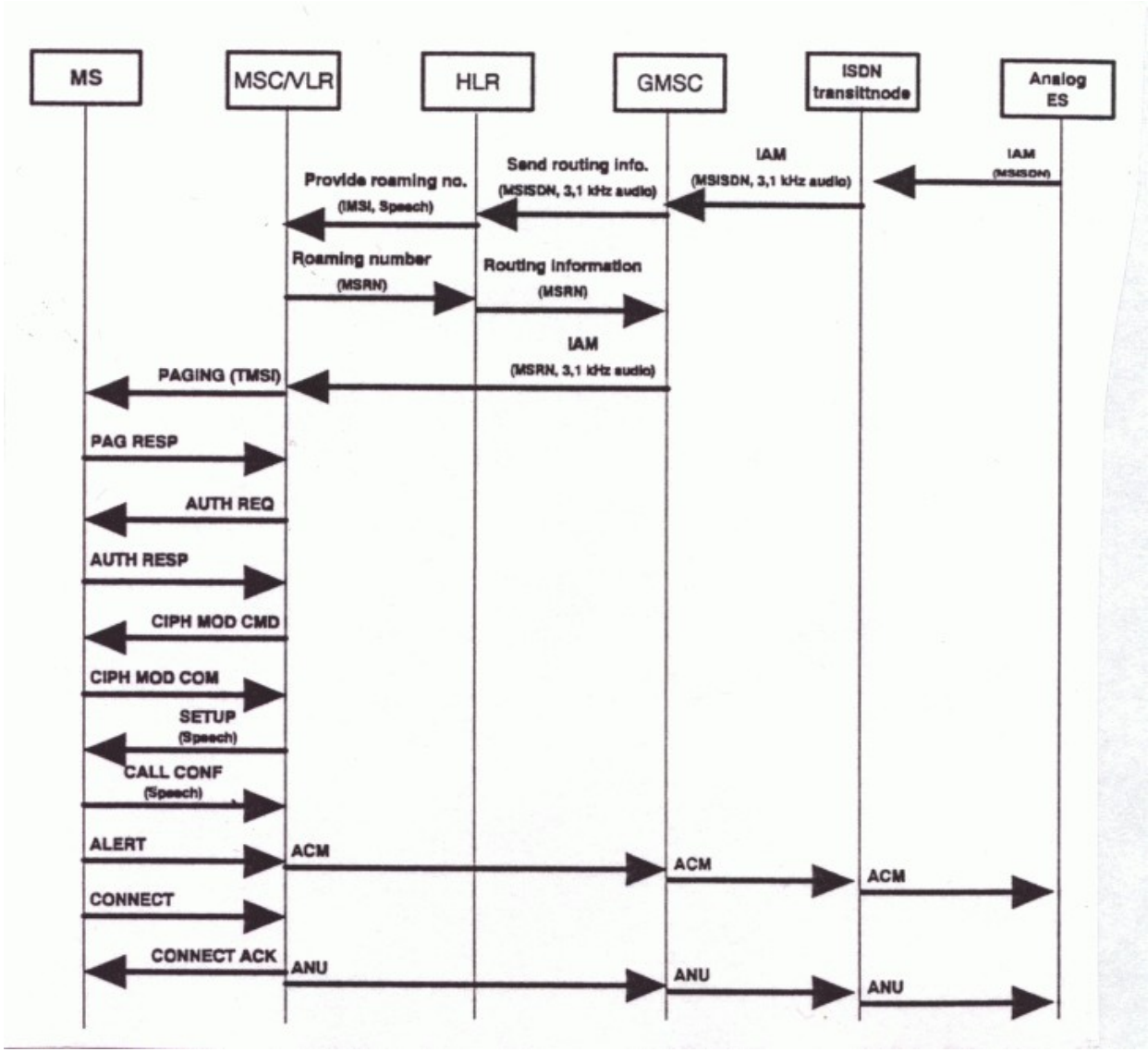
Figure 10.16 GSM Signaling Protocol Architecture

(m - modified/mobile from ISDN)
(Uses CRC, ARQ)

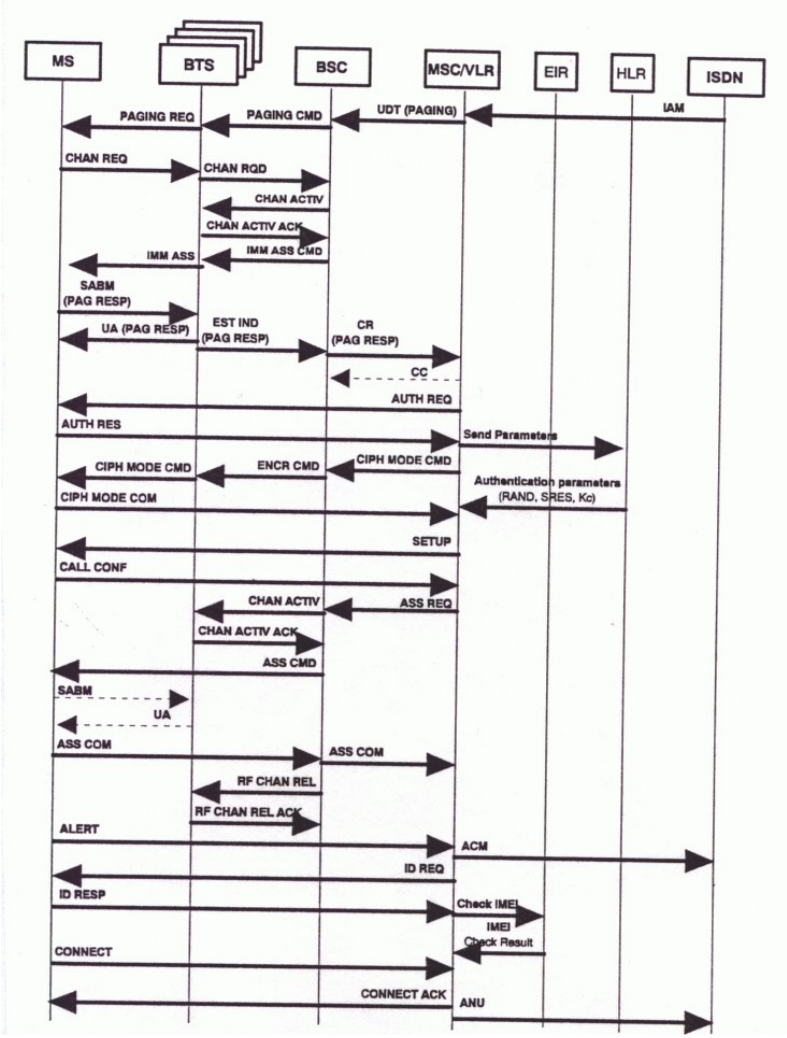
Functions Provided by Protocols

- Protocols above the link layer of the GSM signaling protocol architecture provide specific functions:
  - Radio resource management: Does radio channel management, including for handoffs
  - Mobility management: Roaming, location databases, authentication
  - Connection management: sets up calls between users
  - Mobile application part (MAP) - Core Network functions for BTS management
  - SCCP (Signal connection control part) and MTP (message transfer part) are from SS7, for control signaling

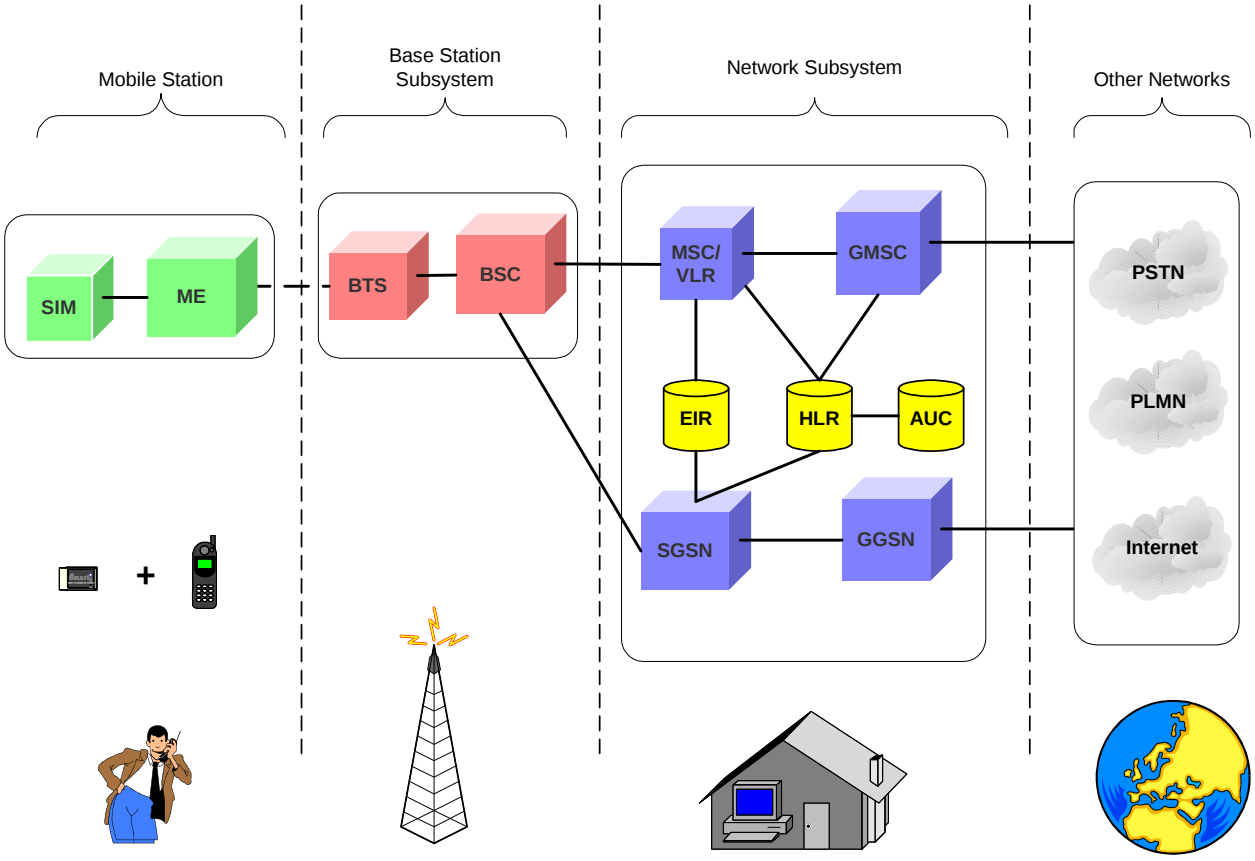
Call set-up. Landline to Mobile



Detail of MSC-BS during a call set-up



Integrating GPRS



Note: Interfaces have been omitted for clarity purposes.

Mobile Ad Hoc Network

Wireless communication network started as wireless ad hoc network (military communication network)

Very different from commercial cellular network

Mobile ad hoc network has also found its way into various commercial applications

https://en.wikipedia.org/wiki/Wireless_ad_hoc_network

Acknowledgements

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