6. Cellular phone network: GSM, HSCSD, EDGE, GPRS

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6.1. Overview of GSM

GSM

- formerly: Groupe Spéciale Mobile (founded 1982)
- now: Global System for Mobile Communication
- Pan-European standard (ETSI, European Telecommunications Standardisation Institute)
- simultaneous introduction of essential services in three phases (1991, 1994, 1996) by the European telecommunication administrations (Germany: D1 and D2)
  ➔ seamless roaming within Europe possible
- today many providers all over the world use GSM (more than 184 countries in Asia, Africa, Europe, Australia, America)
- more than 747 million subscribers
- more than 70% of all digital mobile phones use GSM
- over 10 billion SMS per month in Germany, > 360 billion/year worldwide

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Characteristics of GSM

JS

Communication
- mobile, wireless communication; support for voice and data services

Total mobility
- international access, chip-card enables use of access points of different providers

Worldwide connectivity
- one number, the network handles localization

In Germany **networks A, B, C**
- analogue systems
- restricted functionality (e.g. location, roaming, …)

High capacity
- better frequency efficiency, smaller cells, more customers per cell

High transmission quality
- high audio quality and reliability for wireless, uninterrupted phone calls at higher speeds (e.g., from cars, trains)

Security functions
- access control, authentication via chip-card and PIN

In Germany **GSM networks D, E**
- digital systems
- so called “2nd generation”

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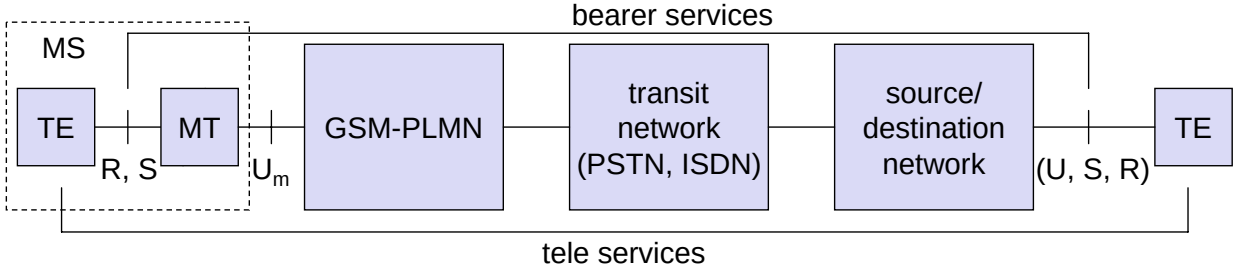
GSM: Mobile Services

JS

- **GSM offers**
  - several types of connections
    - voice connections, data connections, short message service
  - multi-service options (combination of basic services)
- **Three service domains**
  - Bearer Services
  - Telematic Services
  - Supplementary Services



TE = Terminal Equipment
MT = Mobile Termination

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6.2. Architecture of the GSM system *JS*

- **GSM is a PLMN (Public Land Mobile Network)**
  - several providers setup mobile networks following the GSM standard within each country
  - components
    - MS (mobile station)
    - BS (base station)
    - MSC (mobile switching center)
    - LR (location register)
  - subsystems
    - RSS (radio subsystem): covers all radio aspects
    - NSS (network and switching subsystem): call forwarding, handover, switching
    - OSS (operation subsystem): management of the network

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Ingredients 1: Mobile Phones, PDAs & Co. *JS*

The visible but smallest part of the network!

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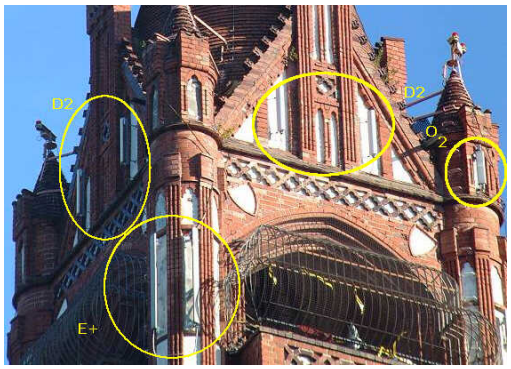
Ingredients 2: Antennas

JS



Still visible – cause many discussions…

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Ingredients 3: Infrastructure 1

JS

Base Stations

Cabling

Microwave links

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Ingredients 3: Infrastructure 2 JS

Switching units

Management

Data bases

Monitoring

Not „visible“, but comprise the major part of the network (also from an investment point of view…)

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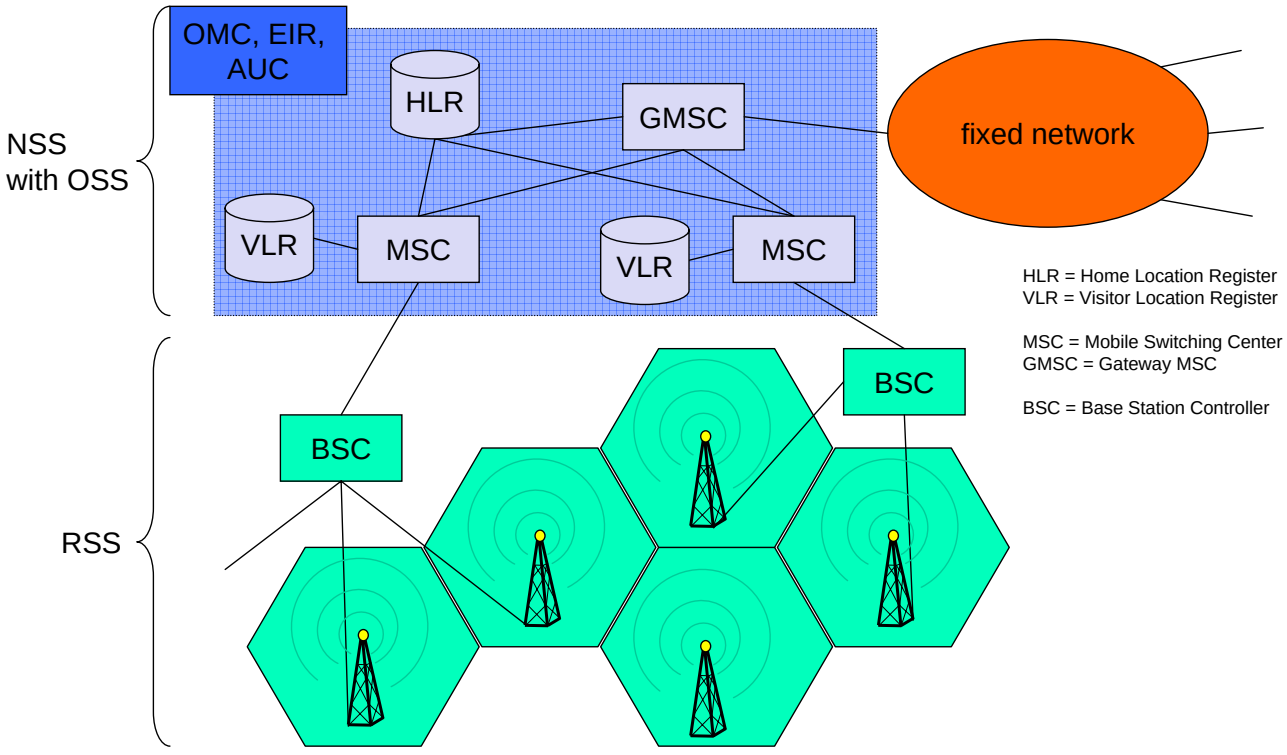
GSM Overview JS



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GSM Elements and Interfaces

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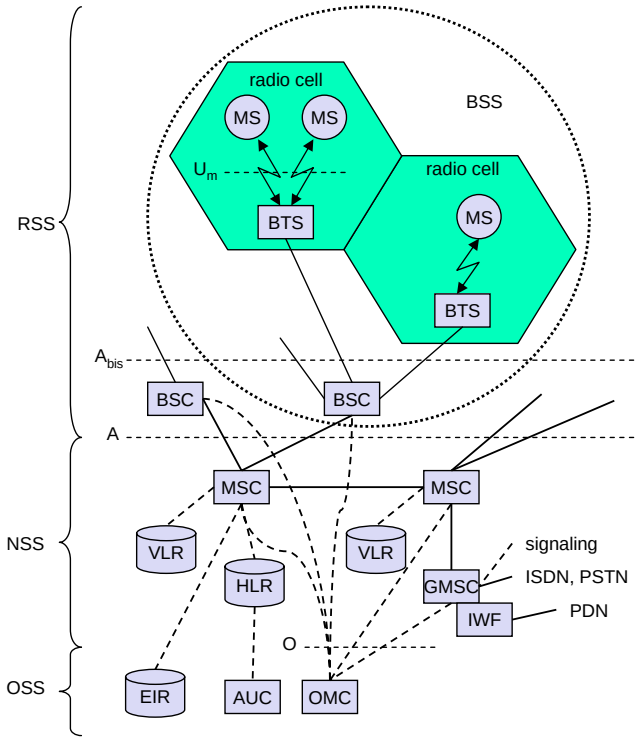

Interfaces

- U_m
- A_{bis}
- A
- O

MS = Mobile Station
BTS = Base Transceiver Station

BSC = Base Station Controller

HLR = Home Location Register
VLR = Visitor Location Register

MSC = Mobile Switching Center
GMSC = Gateway MSC
IWF = Interworking Function

details on following slides

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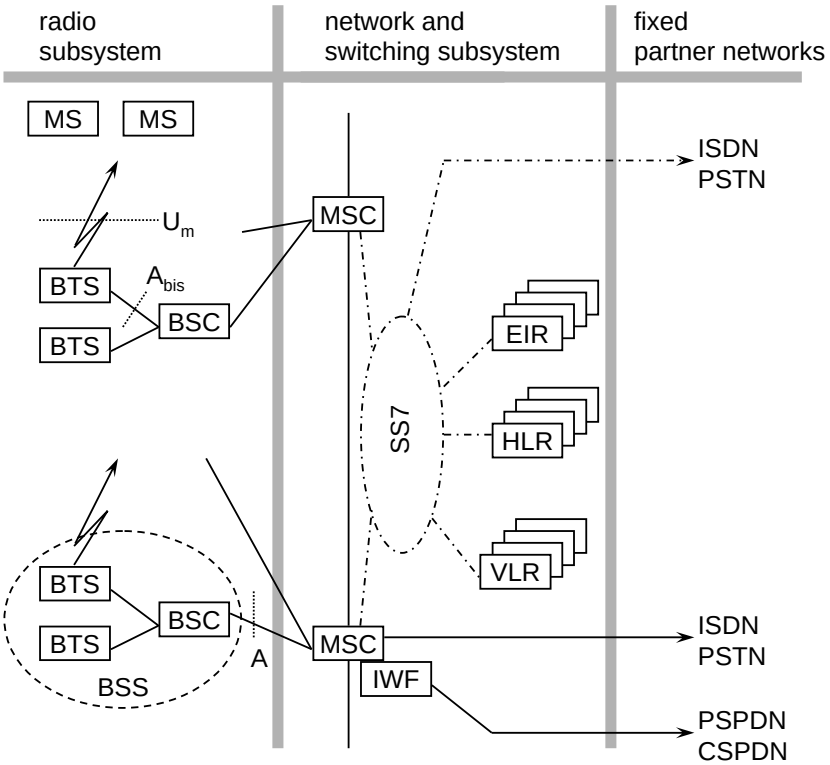
GSM System Architecture

JS



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details on following slides

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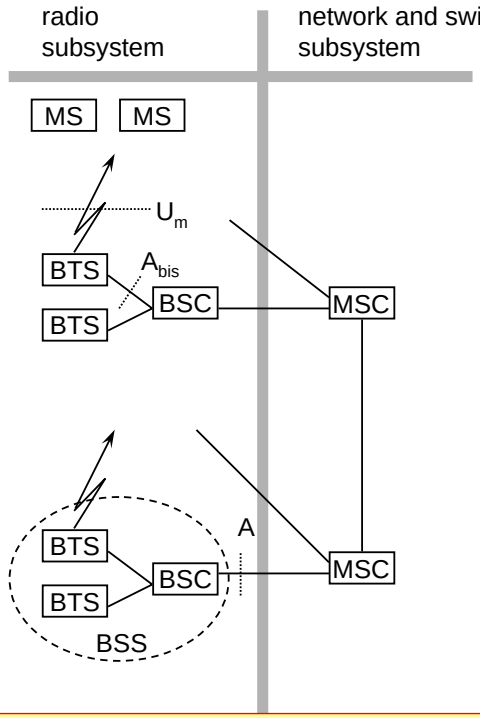
System Architecture – Radio Subsystem JS



clearly defined interfaces (open system)
compatible to ISDN (wired) telephone system

- **Components**
  - *MS* (Mobile Station)
  - *BSS* (Base Station Subsystem): consisting of
    - *BTS* (Base Transceiver Station): sender and receiver
    - *BSC* (Base Station Controller): controlling several transceivers
- **Interfaces**
  - U_m : radio interface
  - A_{bis} : standardized, open interface with 16 kbit/s user channels
  - *A*: standardized, open interface with 64 kbit/s user channels

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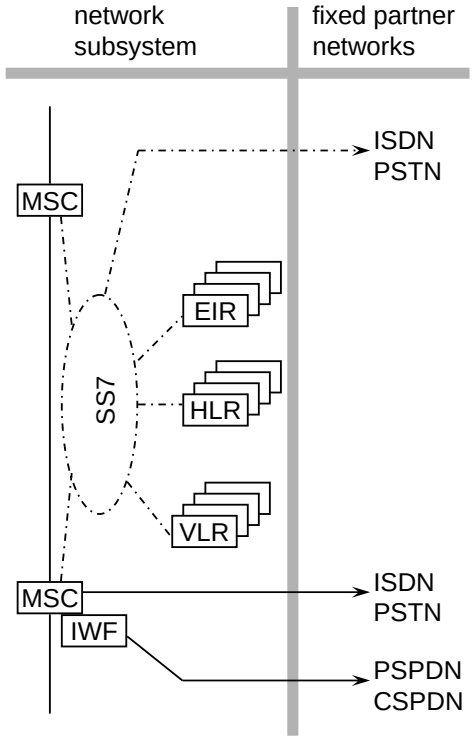
System Architecture – Network and Switching Subsystem JS



Components

- ☐ *MSC* (Mobile Services Switching Center):
- ☐ *IWF* (Interworking Functions)

- ☐ *ISDN* (Integrated Services Digital Network)
- ☐ *PSTN* (Public Switched Telephone Network)
- ☐ *PSPDN* (Packet Switched Public Data Net.)
- ☐ *CSPDN* (Circuit Switched Public Data Net.)

Databases

- ☐ *HLR* (Home Location *R*egister)
- ☐ *VLR* (Visitor Location *R*egister)
- ☐ *EIR* (Equipment Identity Register)

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Radio subsystem JS

- **The Radio Subsystem** (RSS) comprises the cellular mobile network up to the switching centers
- Components
  - **Base Station Subsystem** (BSS):
    - Base Transceiver Station (BTS): radio components including sender, receiver, antenna - if directed antennas are used one BTS can cover several cells
    - Base Station Controller (BSC): switching between BTSs, controlling BTSs, managing of network resources, mapping of radio channels (U_m) onto terrestrial channels (A interface)
    - BSS = BSC + sum(BTS) + interconnection
  - Mobile Stations **(MS)**

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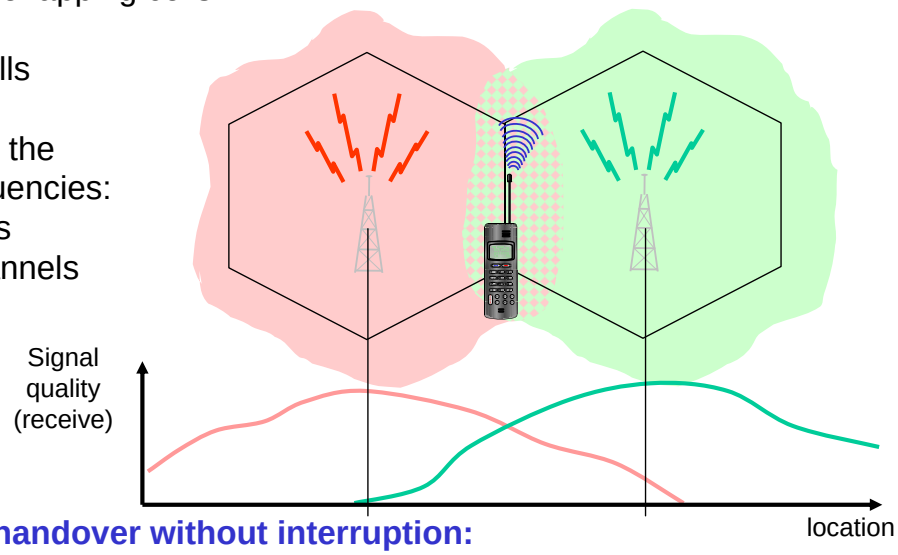
Cellular network principle

Purpose

- base station (cell) only has limited capacity
- coverage of large areas
  by using small overlapping cells
- use different frequencies
  in neighboring cells
- cellular principle reduces the number of available frequencies:
  < 125 frequencies
  < 1000 phys. channels



Overlap of cells enables handover without interruption:

MS (Mobile Station) is still in contact with old BTS (Base Transceiving Station)

- new BTS receive quality is better than from old BTS
- prepare handover with old BTS
- switch to new BTS (almost no interruption)

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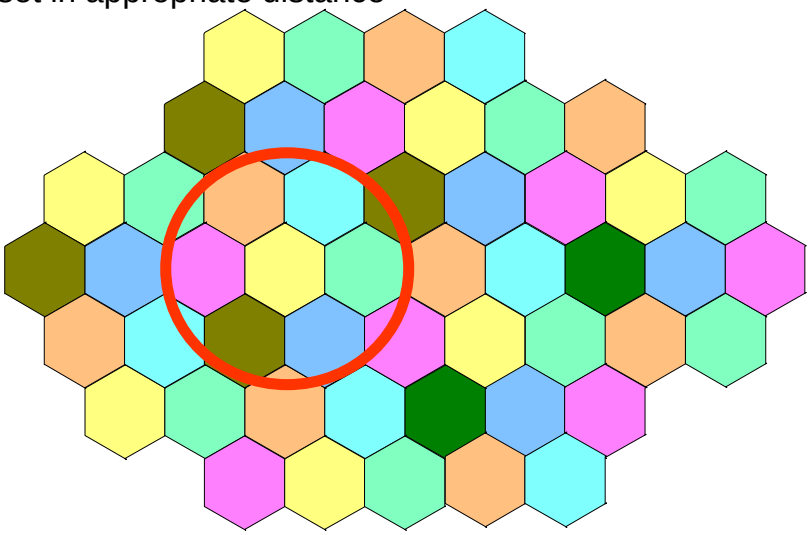
Cellular network (2)

Reuse of frequencies

- Use a subset of all available frequencies in a single cell
- all direct neighbour cells use different subset (to avoid interference)
- reuse of same frequency subset in appropriate distance



Cell clustering

- a typical representation of a cell is a hexagon
- a cluster of cells use different subsets of frequencies
- the same subsets repeat in further clusters

Typical values

- k = 7 (number of cells per cluster)
- D ≈ 4,4 • radius of cell (distance between cells with identical frequency subset)

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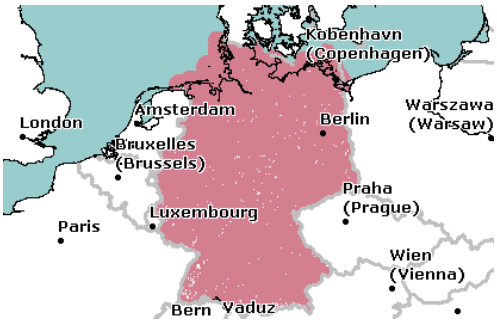
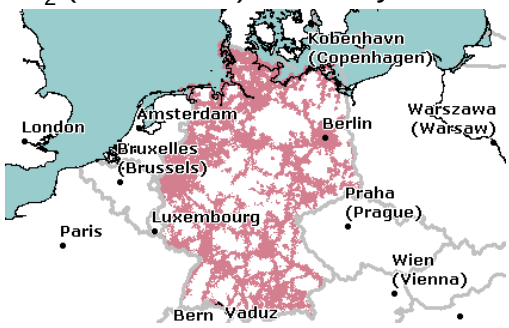
Example coverage of GSM networks (www.gsmworld.com) *JS*

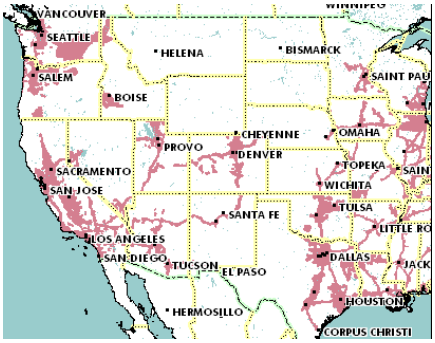
T-Mobile (GSM-900/1800) Germany



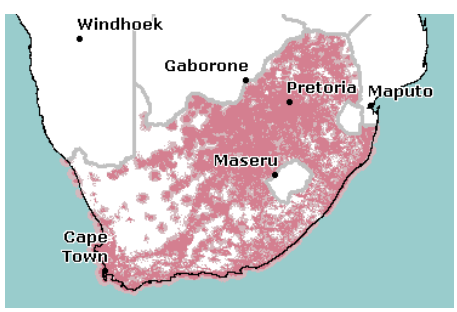
O_2 (GSM-1800) Germany



AT&T (GSM-850/1900) USA



Vodacom (GSM-900) South Africa



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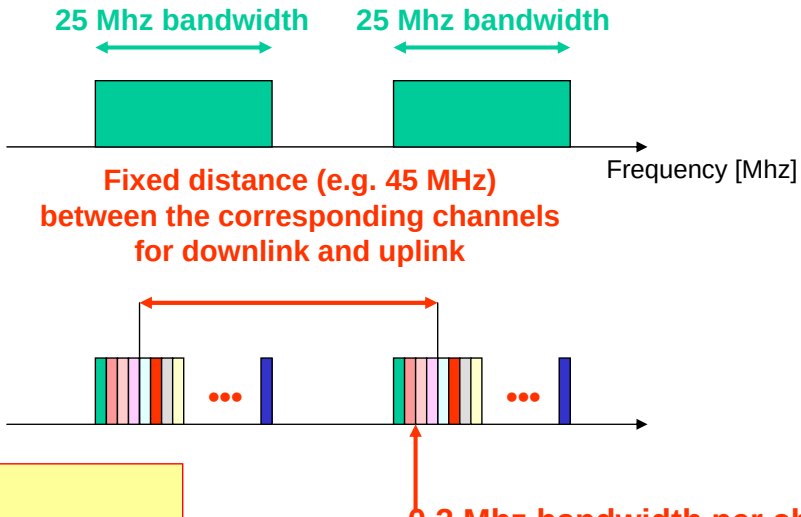
Concepts for Multiple Access: FDMA in GSM

Goal of Multiple Access: Several mobile stations intend to communicate „in parallel“ with the same base station.

The access to the shared medium „air“ (the radio frequencies) has to be coordinated in a deterministic manner (provide QoS for voice transmission, i.e. no collisions allowed)

Frequency Division Multiple Access (FDMA) in GSM:

- two bands of 25 MHz (each for uplink and downlink = Frequency Division Duplex) are divided into 125 channels of 200 kHz bandwidth



=> cf. chapter
3. Wireless Communication Basics

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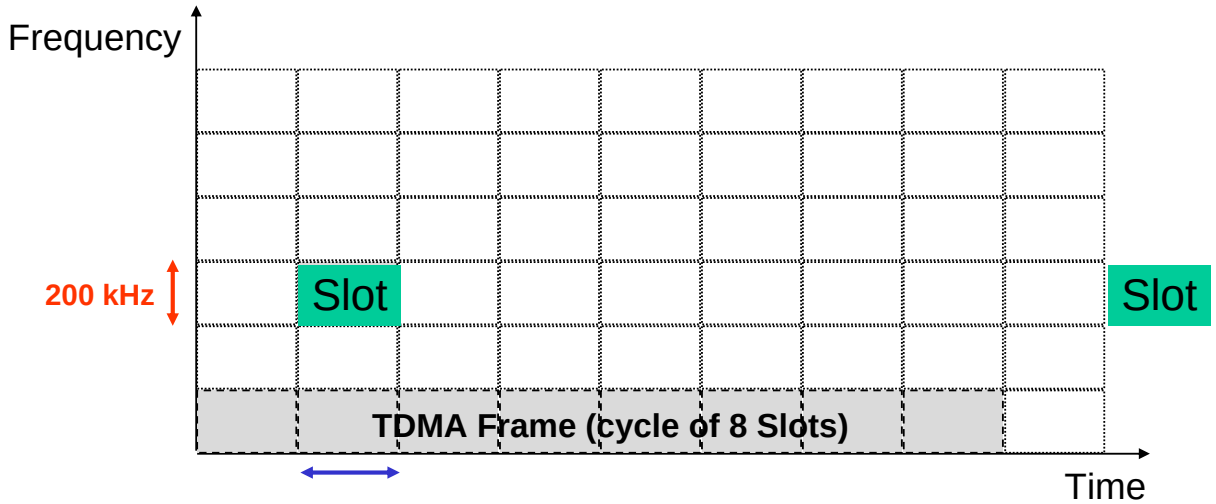
TDMA in GSM

=> cf. chapter
3. Wireless Communication Basics

Time Division Multiple Access (TDMA):

- each channel (of FDMA) is divided into 8 time slots (= 1 cycle)
- the raw datarate in a 200 kHz channel amounts to 271 kbit/s
- the raw datarate per time-slot (TDMA channel) is 33,875 kbit/s

Result: **8 physical channels** (33,875 kbit/s each) **per frequency channel**,
Altogether 125 • 8 = **1000 physical channels** in 25 Mhz



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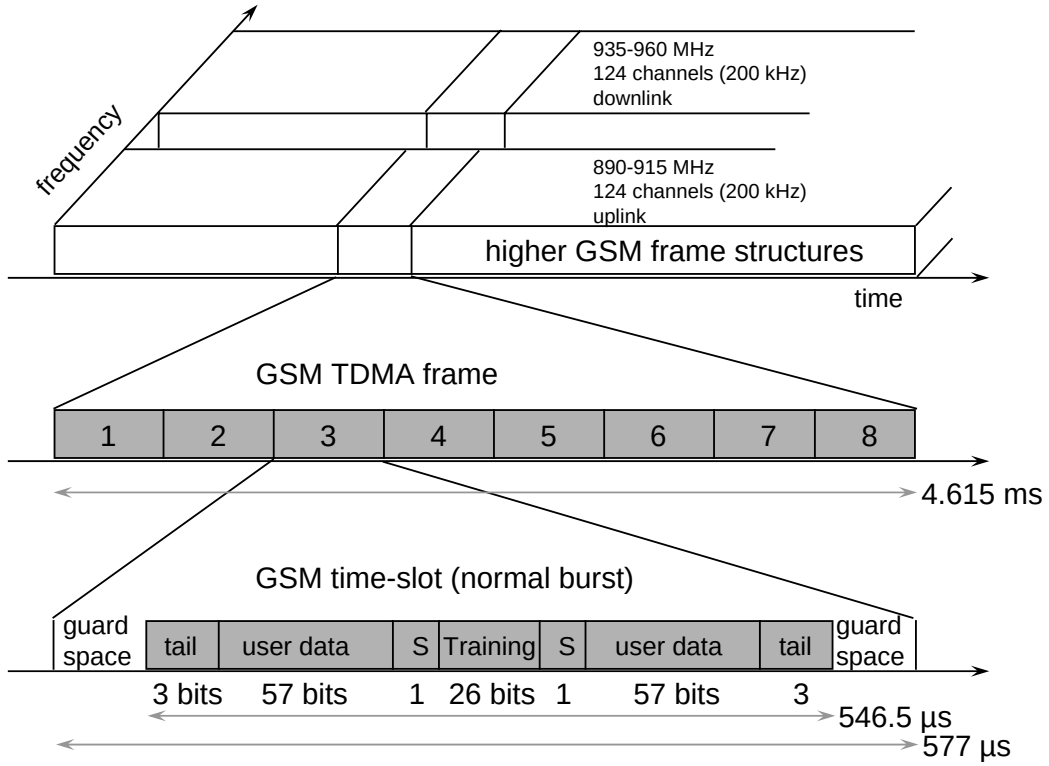
GSM – TDMA/FDMA

JS



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Network and Switching Subsystem

JS

- **NSS** is the **main component** of the public mobile network GSM
  - switching, mobility management, interconnection to other networks, system control
- Components
  - **Mobile Services Switching Center** (MSC)
    controls all connections via a separated network to/from a mobile terminal within the domain of the MSC - several BSC can belong to a MSC
  - Databases (important: scalability, high capacity, low delay)
    - **Home Location Register** (HLR)
      central master database containing user data, permanent and semi-permanent data of all subscribers assigned to the HLR (one provider can have several HLRs)
    - **Visitor Location Register** (VLR)
      local database for a subset of user data, including data about all user currently in the domain of the VLR

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Mobile Service Switching Center *JS*

- The **MSC (mobile switching center)** plays a central role in GSM
  - switching functions
  - additional functions for mobility support
  - management of network resources
  - interworking functions via Gateway MSC (GMSC)
  - integration of several databases
- **Functions of a MSC**
  - specific functions for paging and call forwarding
  - termination of SS7 (signaling system no. 7)
  - mobility specific signaling
  - location registration and forwarding of location information
  - provision of new services (fax, data calls)
  - support of short message service (SMS)
  - generation and forwarding of accounting and billing information

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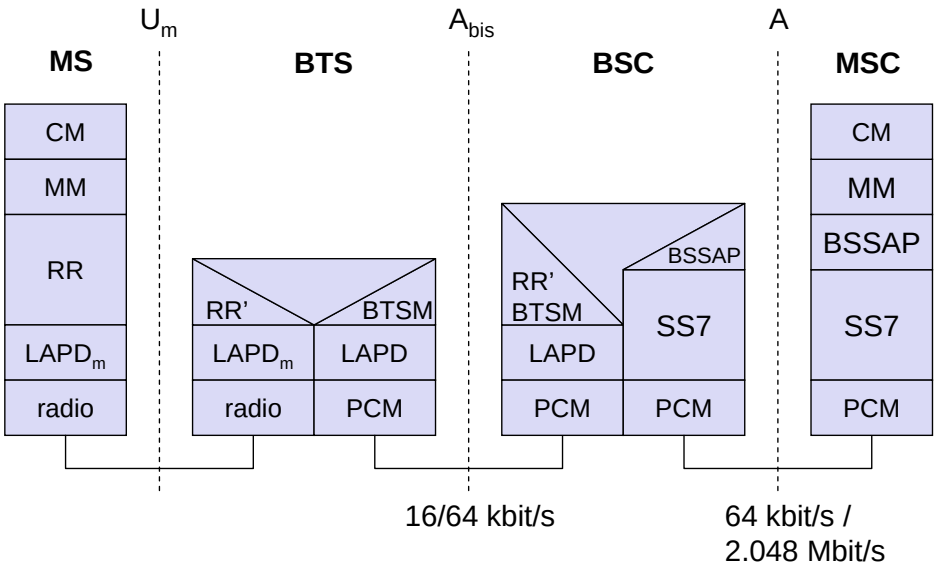
GSM Protocol Layers for Signaling *JS*



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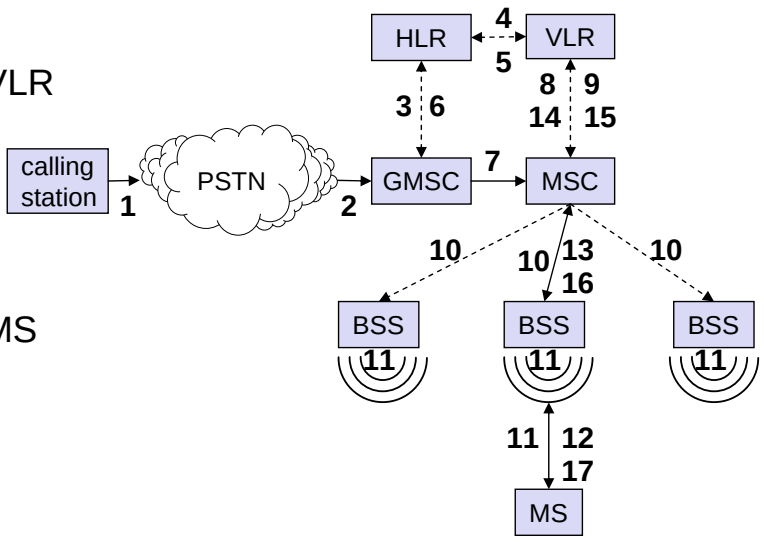
Example: Mobile Terminated Call

JS

- 1: calling a GSM subscriber
- 2: forwarding call to GMSC
- 3: signal call setup to HLR
- 4, 5: request MSRN from VLR
- 6: forward responsible MSC to GMSC
- 7: forward call to current MSC
- 8, 9: get current status of MS
- 10, 11: paging of MS
- 12, 13: MS answers
- 14, 15: security checks
- 16, 17: set up connection



Note step 4,5: MSRN = Mobile Station Roaming Number
similar to Care-of-Address in Mobile IP

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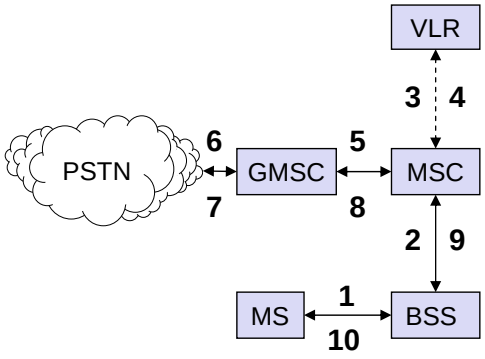
Mobile Originated Call

JS

- 1, 2: connection request
- 3, 4: security check
- 5-8: check resources (free circuit)
- 9-10: set up call



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Four Types of Handover

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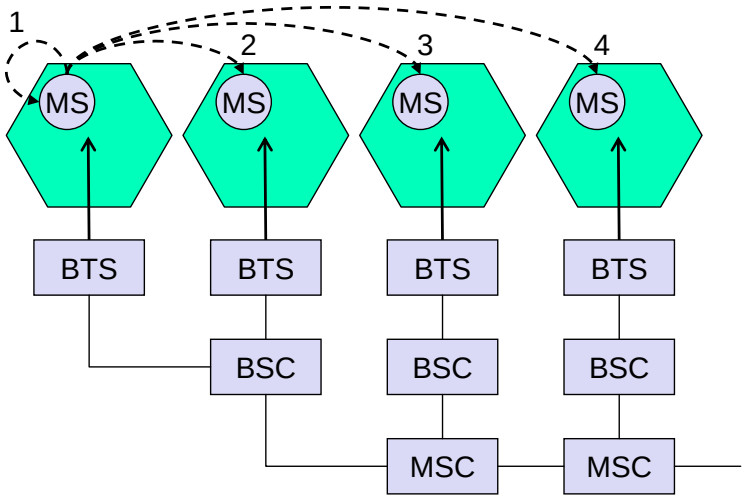

1: Intra-Cell, Intra-BTS

2: Inter-BTS (same BSC)

3: Inter-BSC (same MSC)

4: Inter-MSC

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Handover decision

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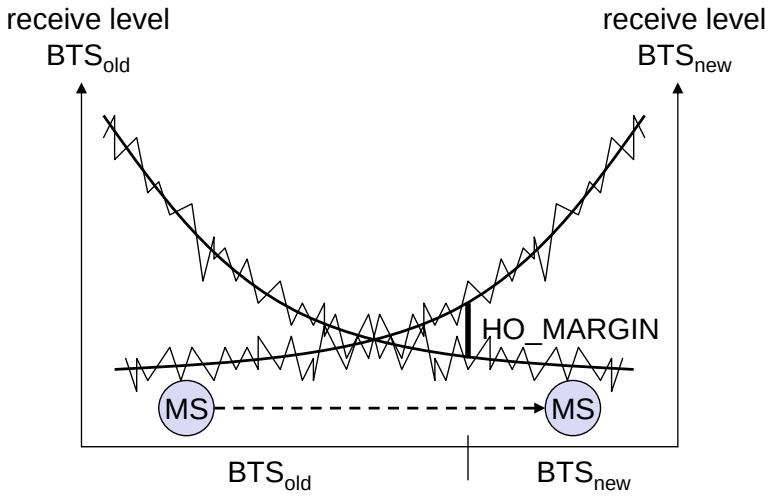

- when moving (slowly) between BTS old and new, a **"ping pong" effect** may occur
- "ping pong" = **switching back and forth** between new and old BTS (several times)
- may be prevented (or reduced) by defining a **hysteresis for handover decision** (HO_MARGIN)

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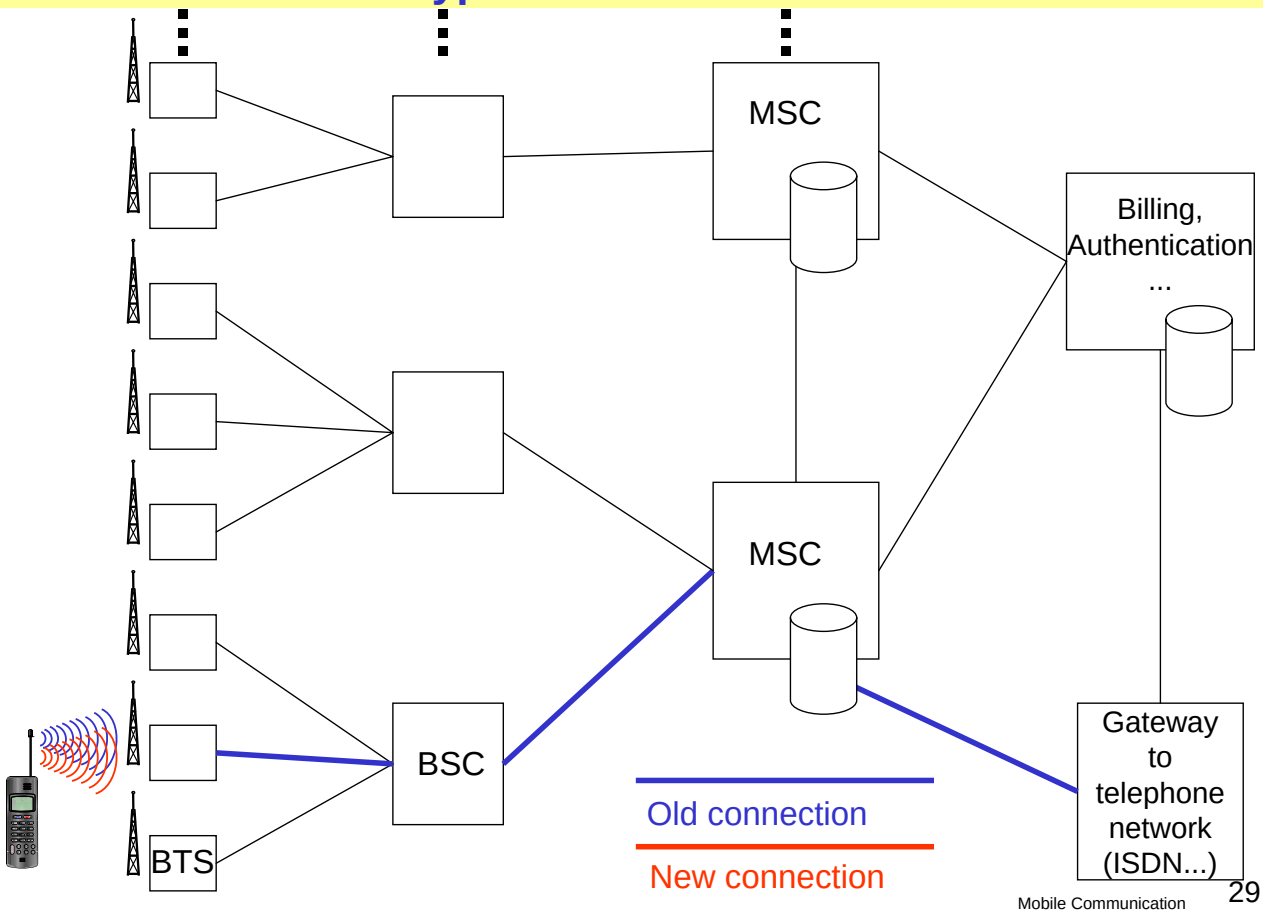
Overview handover types: Intra-Cell Handover



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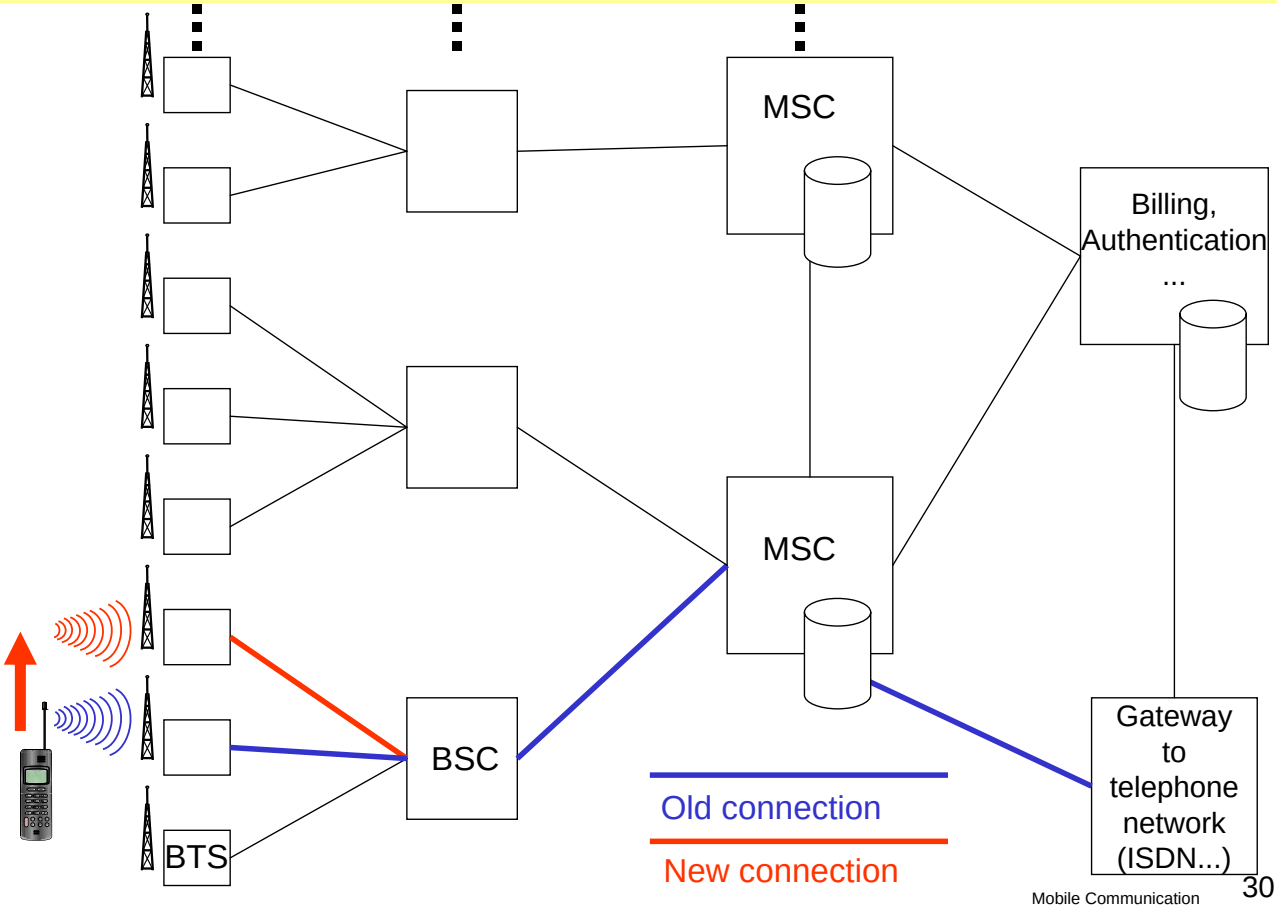
Overview handover types: BTS-BTS Handover



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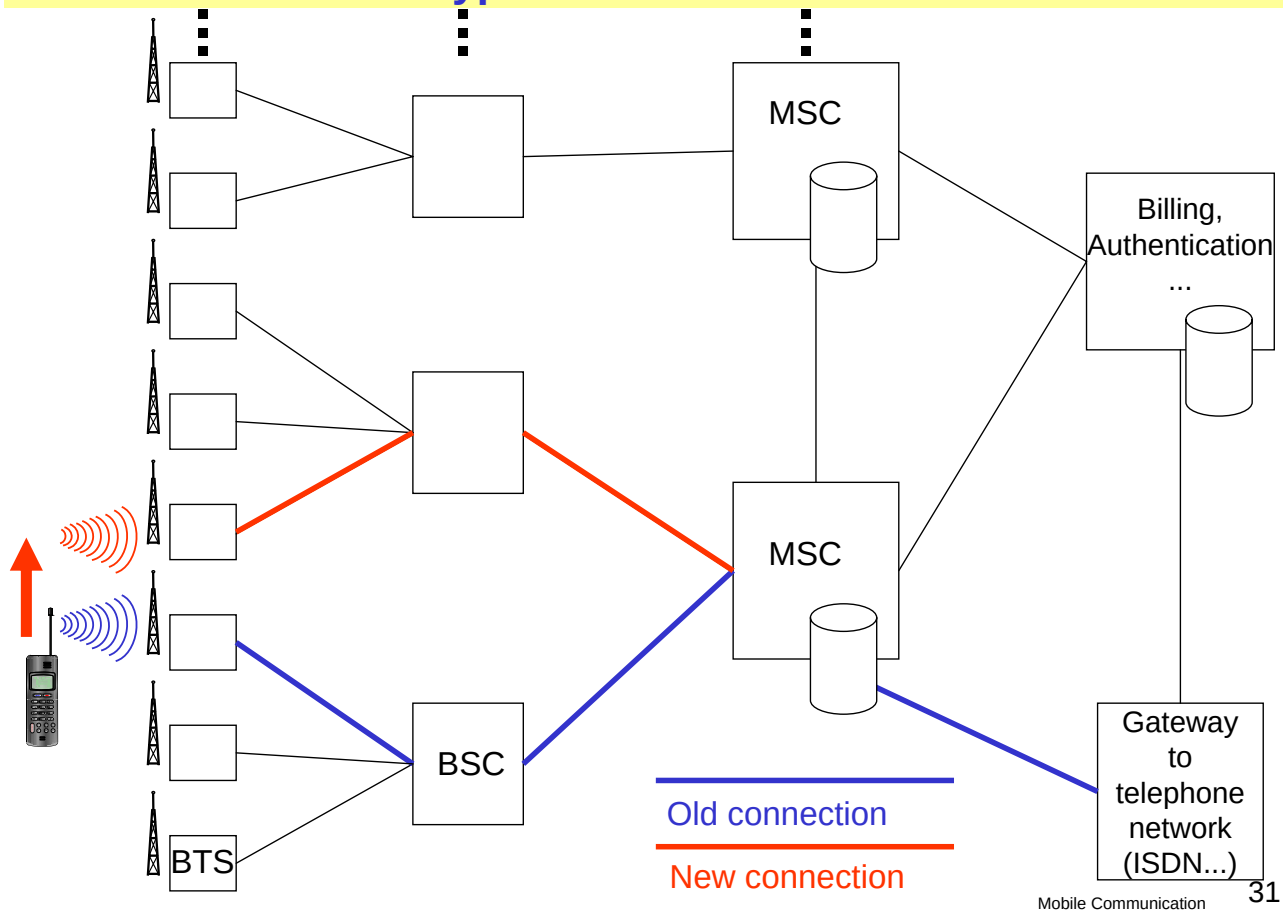
Overview handover types: BSC-BSC Handover



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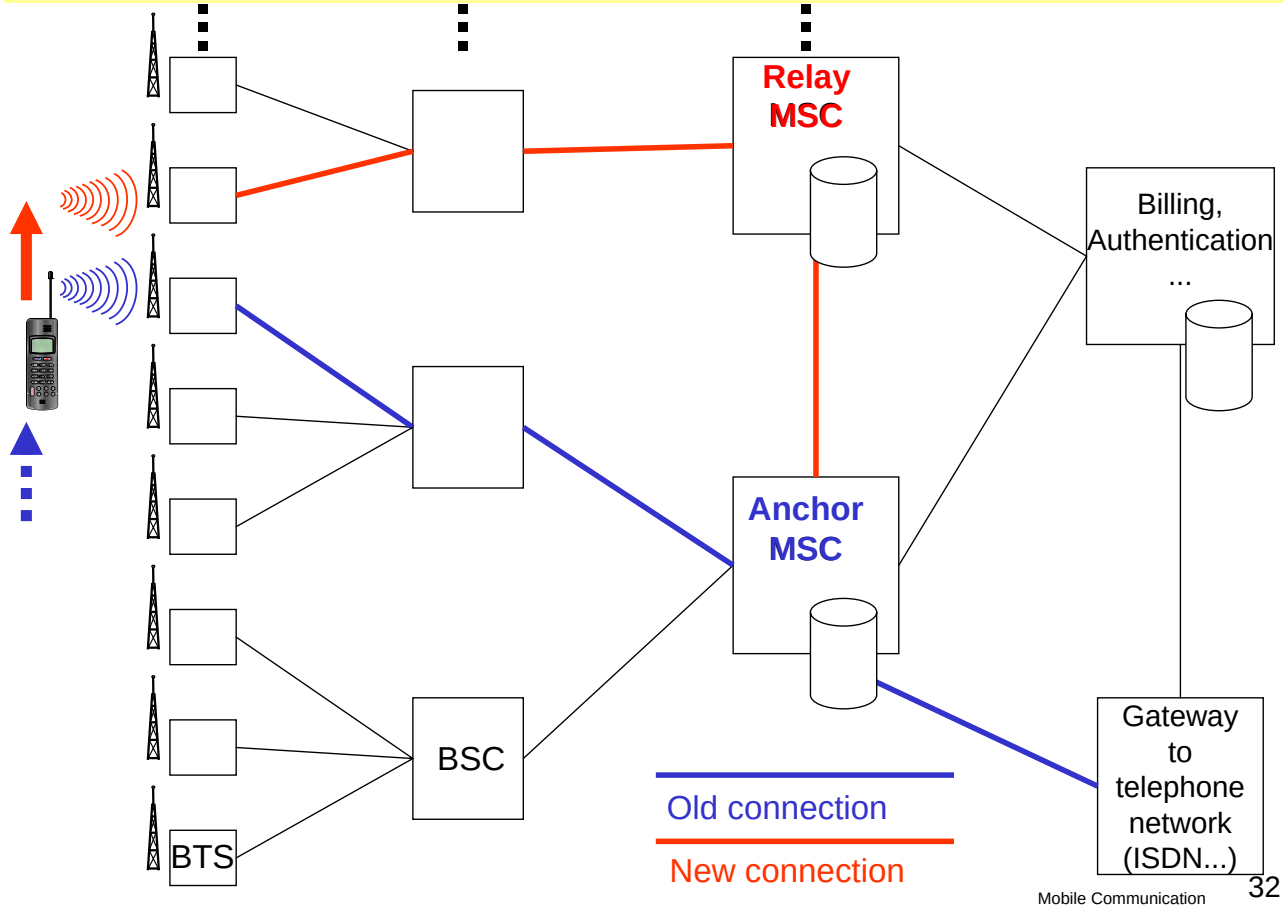
Overview handover types: MSC-MSC Handover



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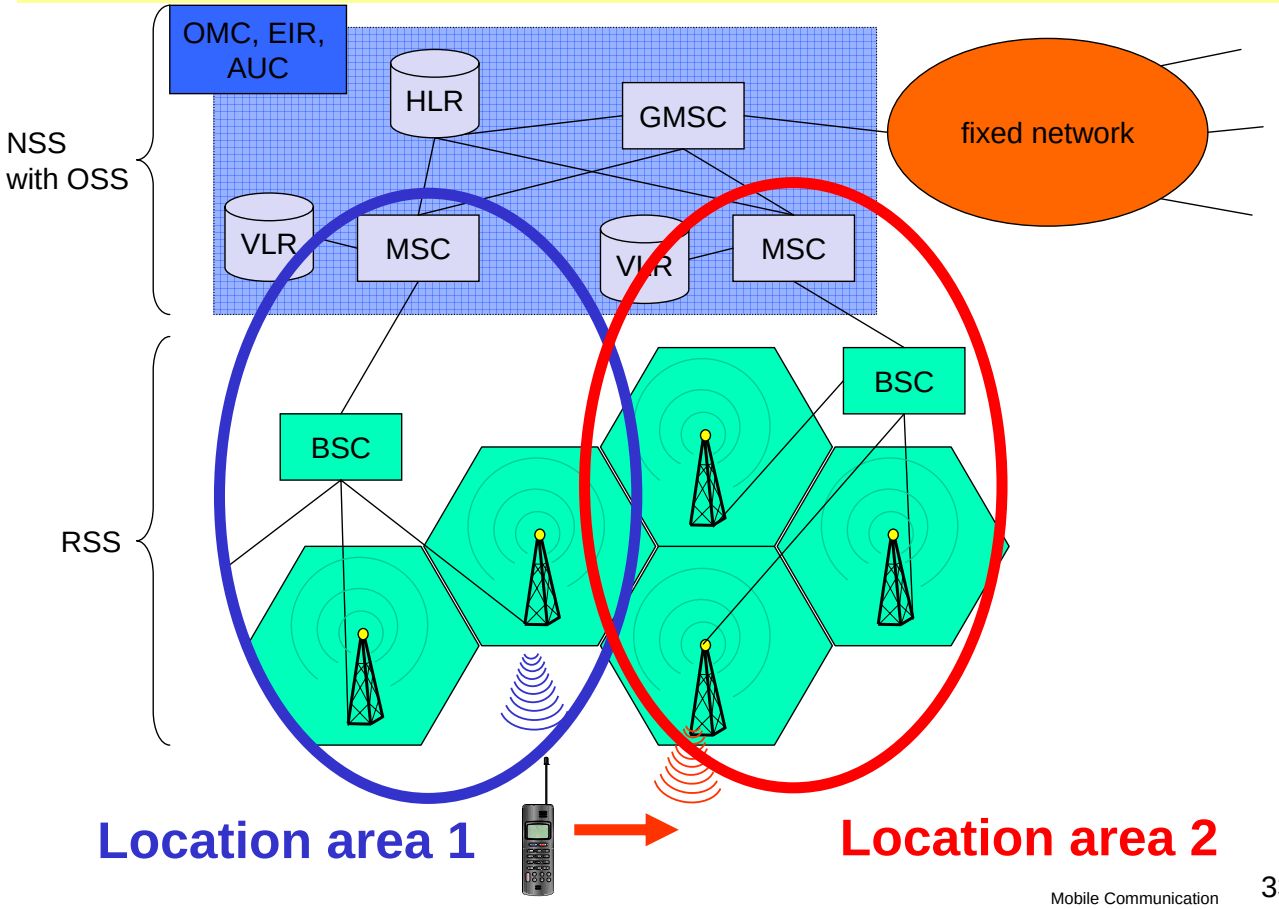
Location update overview *JS*



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Location update

Important procedure to update location information in HLR and VLR

Location update - prerequisite

- mobile station is switched on
- but MS is “idle” (= no phone call going on – in contrast to handover)

Carrying out location update

- mobile station frequently measures reception quality of BTSs
- MS decides to “camp on a cell” (select best BTS)
- MS analyses location area identity (LAI) as broadcasted from BTS

- if LAI has changed when moving from old BTS to new BTS

=> MS initiates location update

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