Telecommunication Systems (GSM)

Mobile Communications (Ch. 4)

John Schiller, Addison-Wesley

Wireless Communication Systems

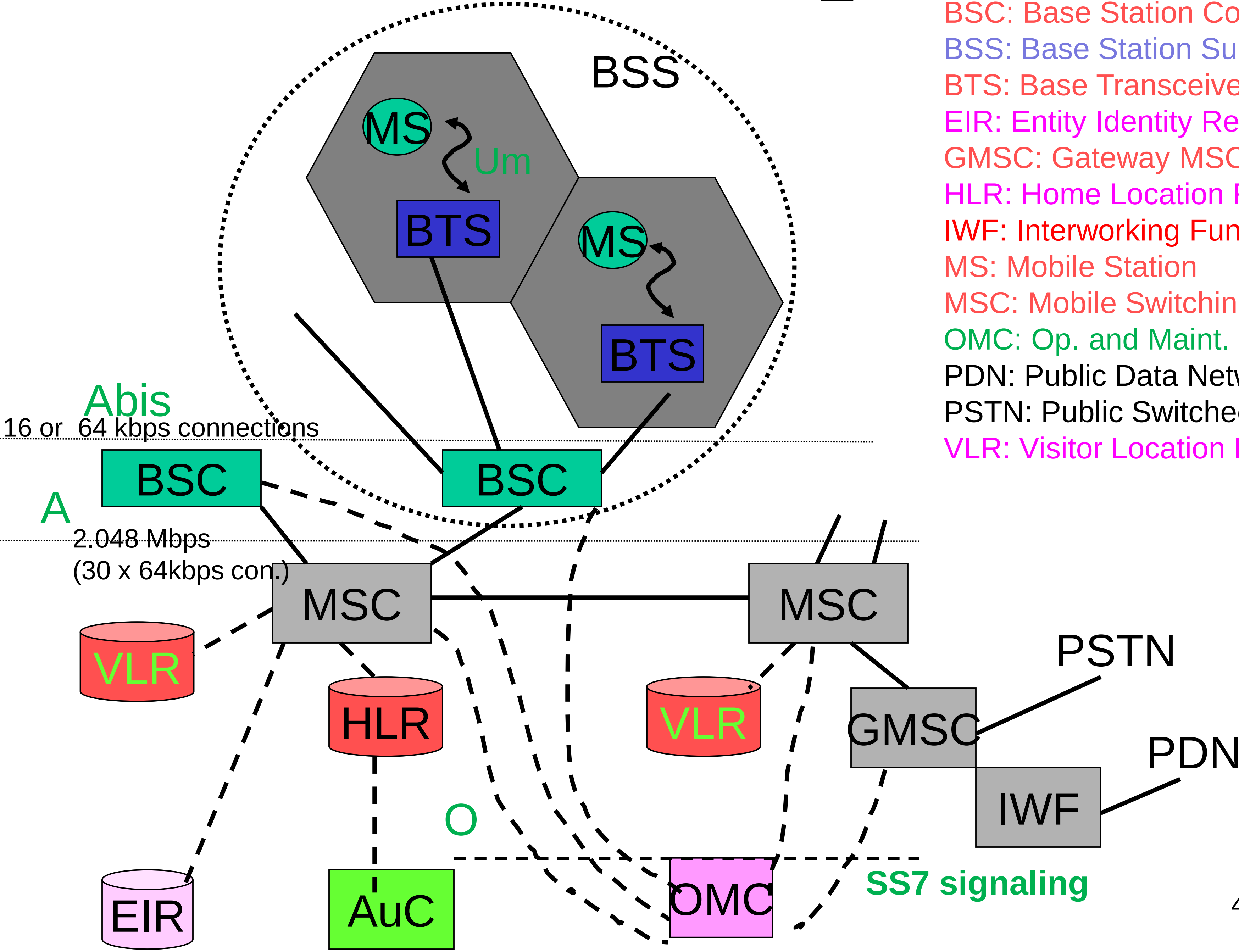
- Infrastructure-based communication
  - Wide Area Networks (**GSM**, LTE)
  - Metropolitan Area Networks (WiMAX)
  - Wireless LANs (WiFi)
- Infrastructure-less communication
  - Ad hoc, sensor, vehicular networks
- Hybrid networks
  - Combination of the above two

GSM (Global System for Mobile comm.)

- Primary goal (was): phone + roaming in Europe
- Different GSM systems
  - GSM 900
    890-915 MHz uplink, 935-960 MHz downlink
  - GSM 1800 (DCS: Digital Cellular System)
    1710-1785 MHz uplink, 1805-1880 MHz downlink
  - GSM 1900 (Personal Comm Service) ← US, Canada
    1850-1910 MHz uplink, 1930-1990 MHz downlink
- Learn two architectures
  - **Functional** and **Protocol**

Functional Architecture of GSM

AuC: Authentication Centre
BSC: Base Station Controller
BSS: Base Station Subsystem
BTS: Base Transceiver Subsys
EIR: Entity Identity Register
GMSC: Gateway MSC
HLR: Home Location Register
IWF: Interworking Function
MS: Mobile Station
MSC: Mobile Switching Centre
OMC: Op. and Maint. Centre
PDN: Public Data Network
PSTN: Public Switched Tel Net
VLR: Visitor Location Register



Interfaces

- A-interface (BSC ←→ MSC)
  - circuit switched, 2.048 Mbits/s
  - carrying up to 30 64 Kbits/s connections
- O-interface (OMC ←→ Others)
  - SS7 signaling, management data
- Abis-interface (BSC ←→ BTS)
  - 16 or 64 Kbits/s connections

Subsystems

- BSS: GSM net ➔ several BSS, 1 BSC/BSS
- BTS: radio equipment. Forms a radio cell.
- BSC
  - Reserves frequencies (**frequency/ch. assignment**)
  - Handles **handovers**
  - Performs **paging of MS**
  - **Multiplexes** radio channels onto fixed net connections.

Subsystems

- MS: User equipment and software for comm.
  - SIM (Subscriber Identity Module):
    - IMSI (Int. Mobile Sub Identity), 64 bit ID); sent from device to network; used to access the HLR
    - LAI (Location Area Identity):
      - » Mobile Country Code (3 digits) + Mobile Net Code (2 digits) + Location Area Code (16 bits)
      - » Net. periodically broadcasts LAI, and device stores it on SIM.
      - » Change in LAI ➔ Device makes a location update request
  - GSM 900: transmit power up to 2 w
  - GSM 1800: transmit power 1 w
  - Two parts: TE (Terminal Equipment) for comm with network + Services

Subsystems

- MSC
    - Manages several BSCs
    - (Gateway)MSC → other fixed network
    - Interworking Function (IWF) → data nets
    - Connection setup, release and handover
    - Supplementary services (forwarding, conf.)

Subsystems

- HLR (Home Location Register)
  - Most important database with all user relevant info.
  - Static Info.:
    - MSISDN number
      - » Mobile Station. Int. Subscriber Directory Number
    - IMSI number
    - Subscribed services (call forwarding, roaming, GPRS)
  - Dynamic Info.:
    - Current location area (LA) of the MS
    - Current MSC and VLR
    - Accounting information
  - Specialized databases to meet real-time reqs.
  - Handle millions of users.

Subsystems

- VLR (Visitor Location Register)
  - One VLR is associated with one MSC (1:1 mapping)
  - Info about <u>all users</u> in the LA associated with the MSC
  - Info per user (copied from HLR): IMSI, MSISDN, HLR address
  - Need: To avoid frequent communication with HLR
  - Large, real-time database

Subsystems

- Operation and Maintenance Centre (OMC)
  - Monitor: traffic, status of all network entities
  - Accounting and billing
- Authentication Center (AuC)
  - Contains algorithms for authentication and keys for encryption
  - Can be part of the HLR.
- Equipment Identity Register (EIR)
  - Blacklist of stolen/locked MS

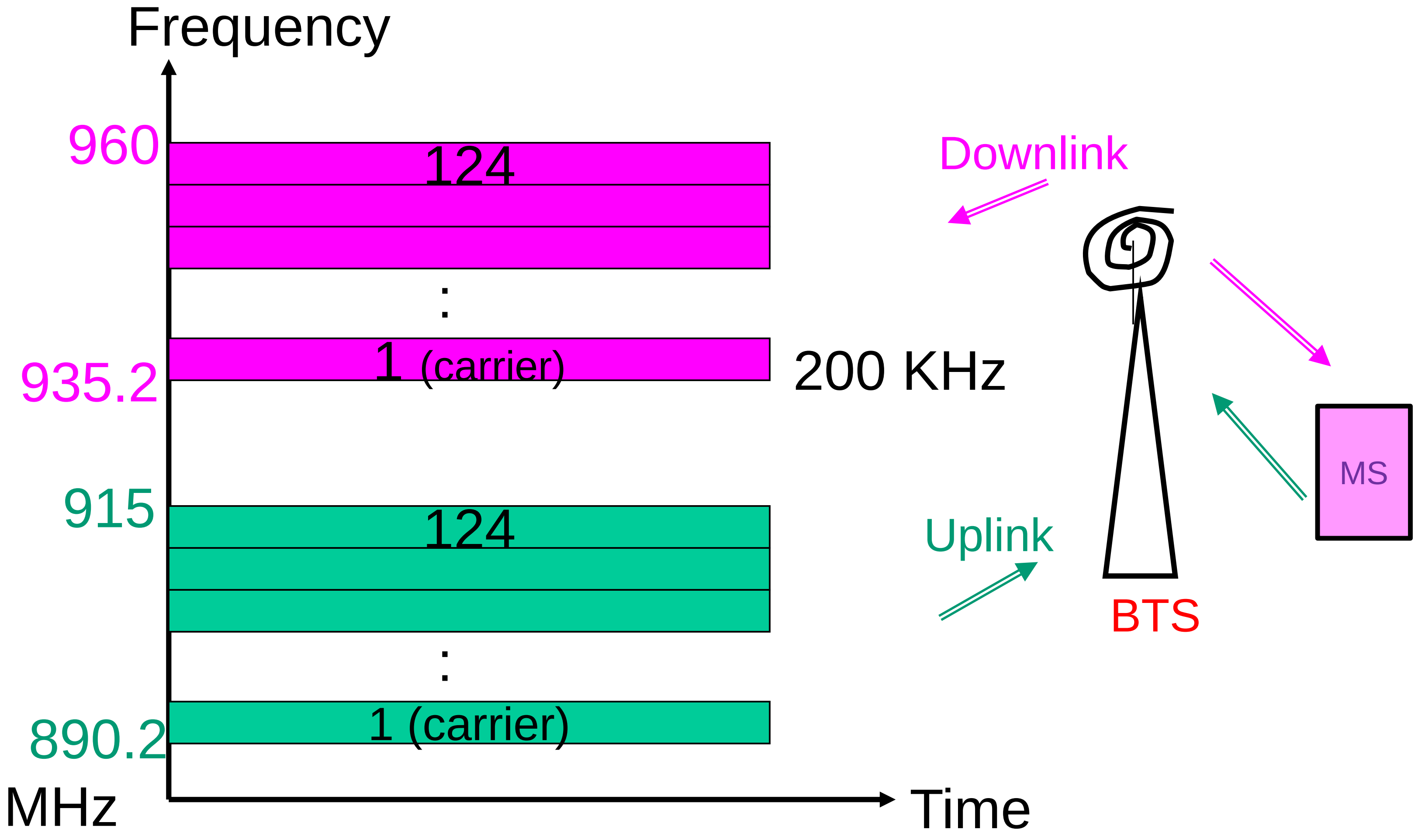
Radio Interface

- FDD (Frequency Division Duplex) is used to separate downlink & uplink.

- Media access combines TDMA and FDMA.

- GSM 900: 124 carriers, each 200 KHz wide, FDMA
  - **90** carriers to support customers
  - **32** reserved
  - **2** not used (1 and 124)

FDMA in GSM 900

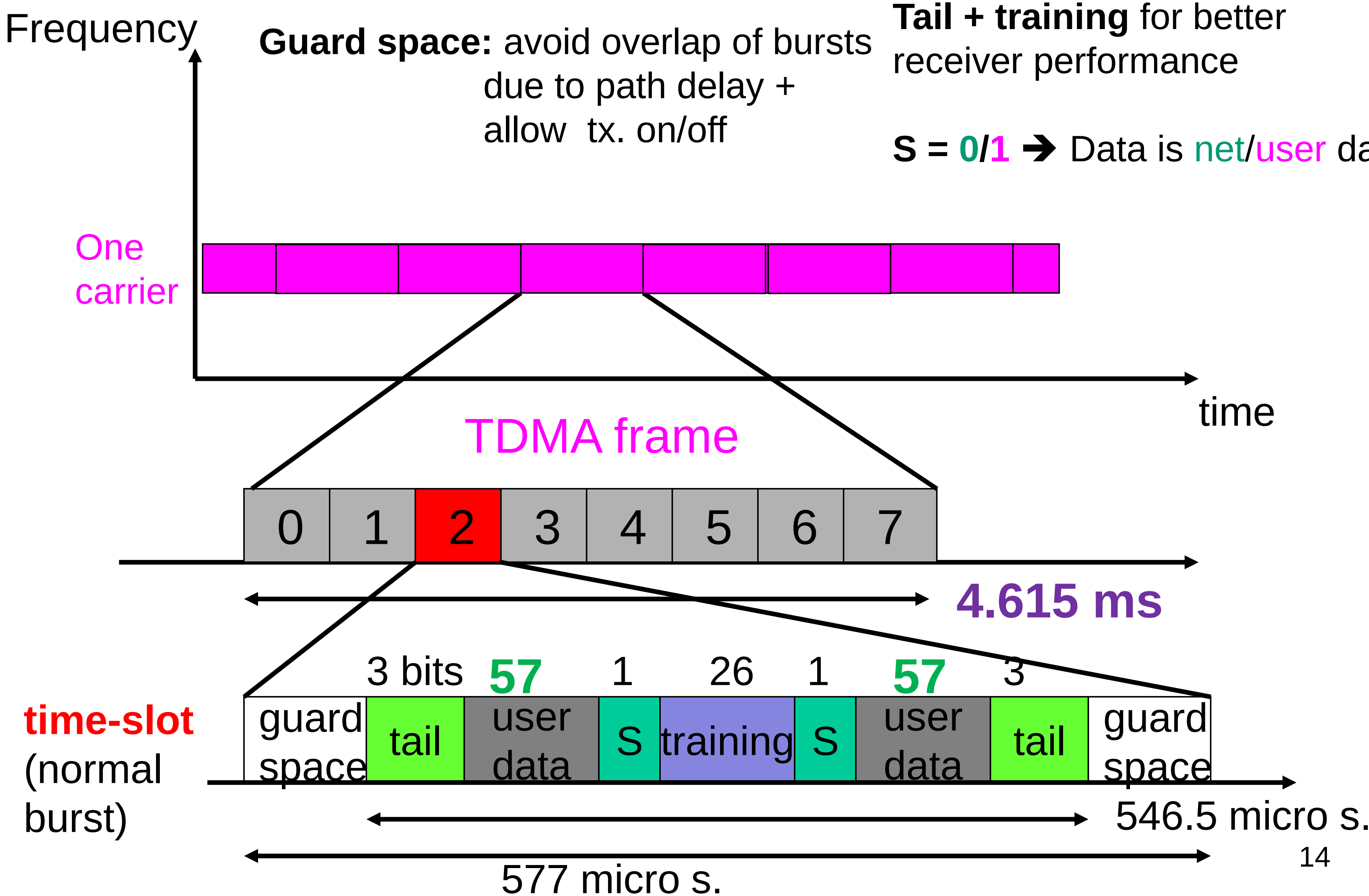


TDMA in GSM 900

Guard space: avoid overlap of bursts due to path delay + allow tx. on/off

Tail + training for better receiver performance

S = 0/1 ➔ Data is net/user data



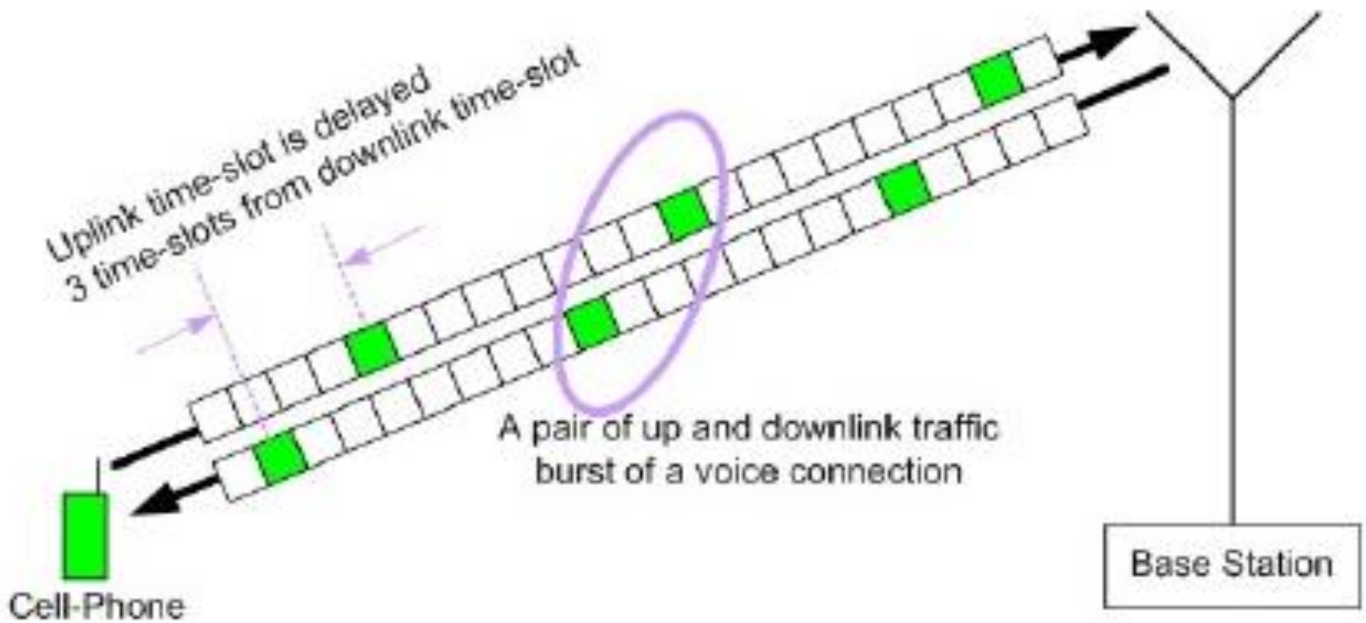
Simple MS

- TDMA frame on the uplink is **shifted by three slots** from frame on the downlink.

- If BTS sends data at t_0 in <u>slot #1</u> on the downlink, the MS accesses <u>slot #1</u> on the uplink at time t_0 + 3*577 micro sec.

➔ MS does not need a full-duplex Tx

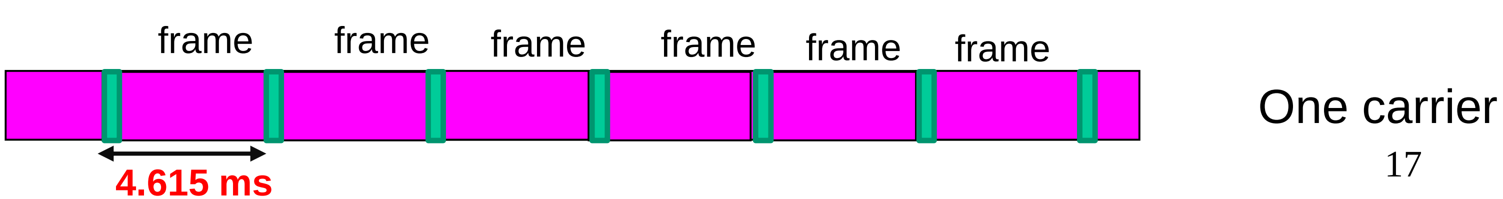
(The same radio hardware is used as a transmitter and as a receiver.)


Uplink time-slot is delayed
3 time-slots from downlink time-slot
A pair of up and downlink traffic
burst of a voice connection
Cell-Phone
Base Station

Physical and logical channels

- **Physical channel**: a slot repeated every 4.615 ms. (114 bits in 4.615 ms ➔Rate = 24.7 Kbps)
- Reality: Out of every 26 consecutive slots of a phy. ch.
  - 12 data slots + 1 signaling slot + 12 data slots + 1 unused
  - Rate of a physical channel = (24/26)*24.7 = 22.8 Kbps

- **Logical channel**: A physical channel may be split into several (logical) channels:
  - Logical channel C1: every 4th slot
  - Logical channel C2: every other slot
  - C1 and C2 could use the same physical channel with the pattern C1C2xC2C1C2xC2C1



Logical channels …

- Two basic groups of logical channels
  - Traffic channels (TCH)
  - Control channels (CCH)

- TCH
  - Carries user data (voice, fax)
  - Full-rate TCH/F: 22.8 kbits/sec
  - Half-rate TCH/H: 11.4 kbits/sec ← capacity x 2
  - Other (data)rates: TCH/F4.8, TCH/F9.6, TCH/F14.4

  (They differ in their voice coding schemes.)

Logical channels (CCH)

- CCH: for access control, ch alloc., mobility mgmnt.
  - Broadcast CCH (BCCH):
    - Slot #0 of C_0 (On the down link) C_0 is the "first" carrier in the cell
    - BTS ➔ MS: Used by BTS to send info to all MS
      - » Cell ID, options available (freq. hop), freq available
  - Common CCH (CCCH): for connection setup
    - RACH (Random Access CH): MS ➔ BTS. MS wants to make a call. Accessed by all MS in a cell. (Slotted Aloha: random access, collision)
    - Slot #0 of C_0 (On the up link)
    - AGCH (Access Grant CH): BTS ➔ MS.
      BTS tells MS to use a TCH or an SDCCH.
    - PCH (Paging CH): BTS ➔ MS for paging an MS

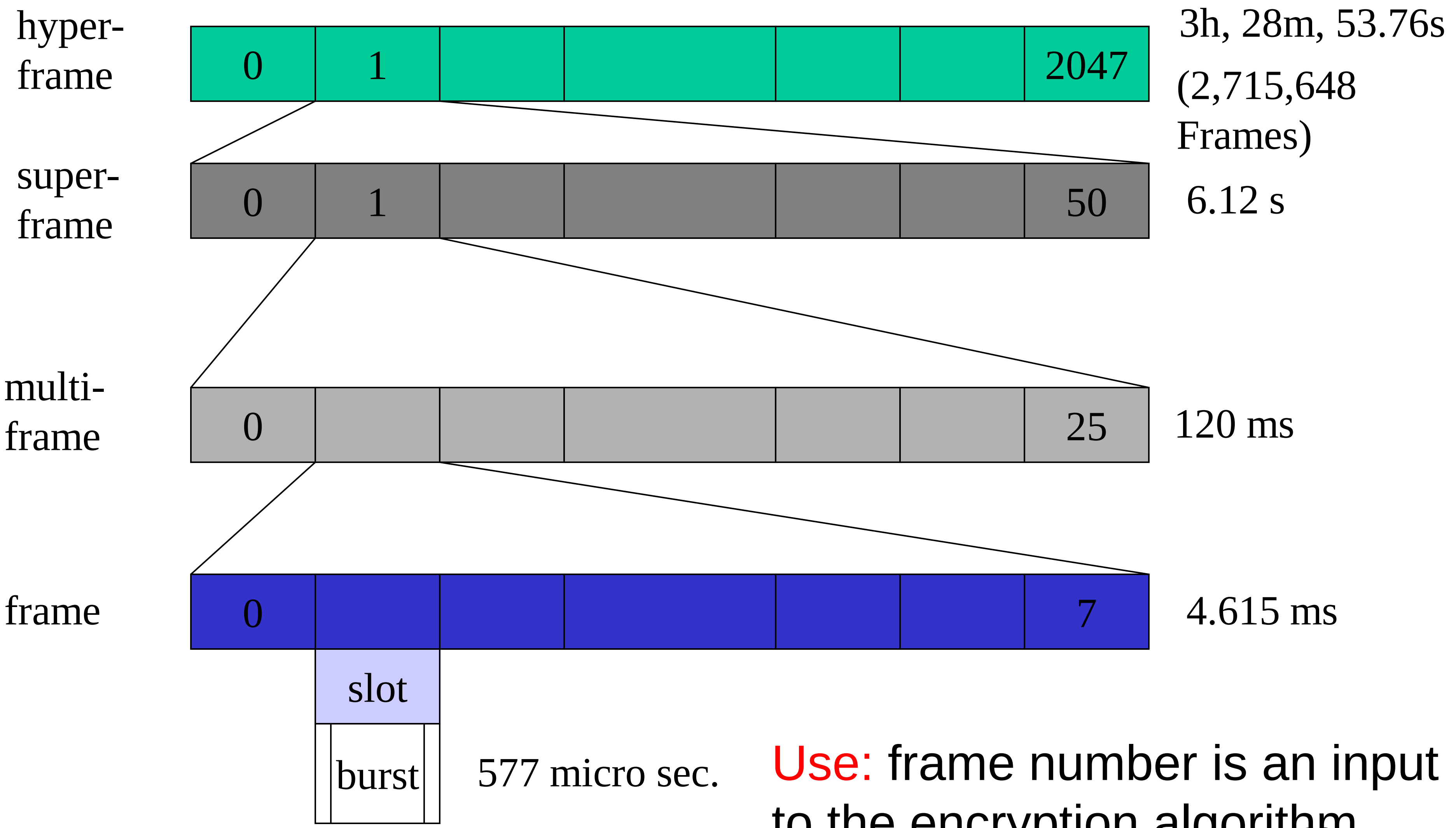
Logical channels

- Dedicated control channel (DCCH): bidirectional
  - – Stand-alone DCCH (SDCCH) is used while an MS has not established a TCH with a BTS. Time slot #1 of C_0
    - » **SDCCH** (782 bits/sec): authentication, registration, etc. needed for setting up a TCH.
  - – Slow associated-dedicated control ch (**SACCH**): Associated with each TCH. For small amount of system info: ch quality, signal power level. Time slot #1 of C_0
  - – Fast associated dedicated control ch (**FACCH**): Uses time slots from the TCH. Carries handover info.

Typical use of TCH and SACCH

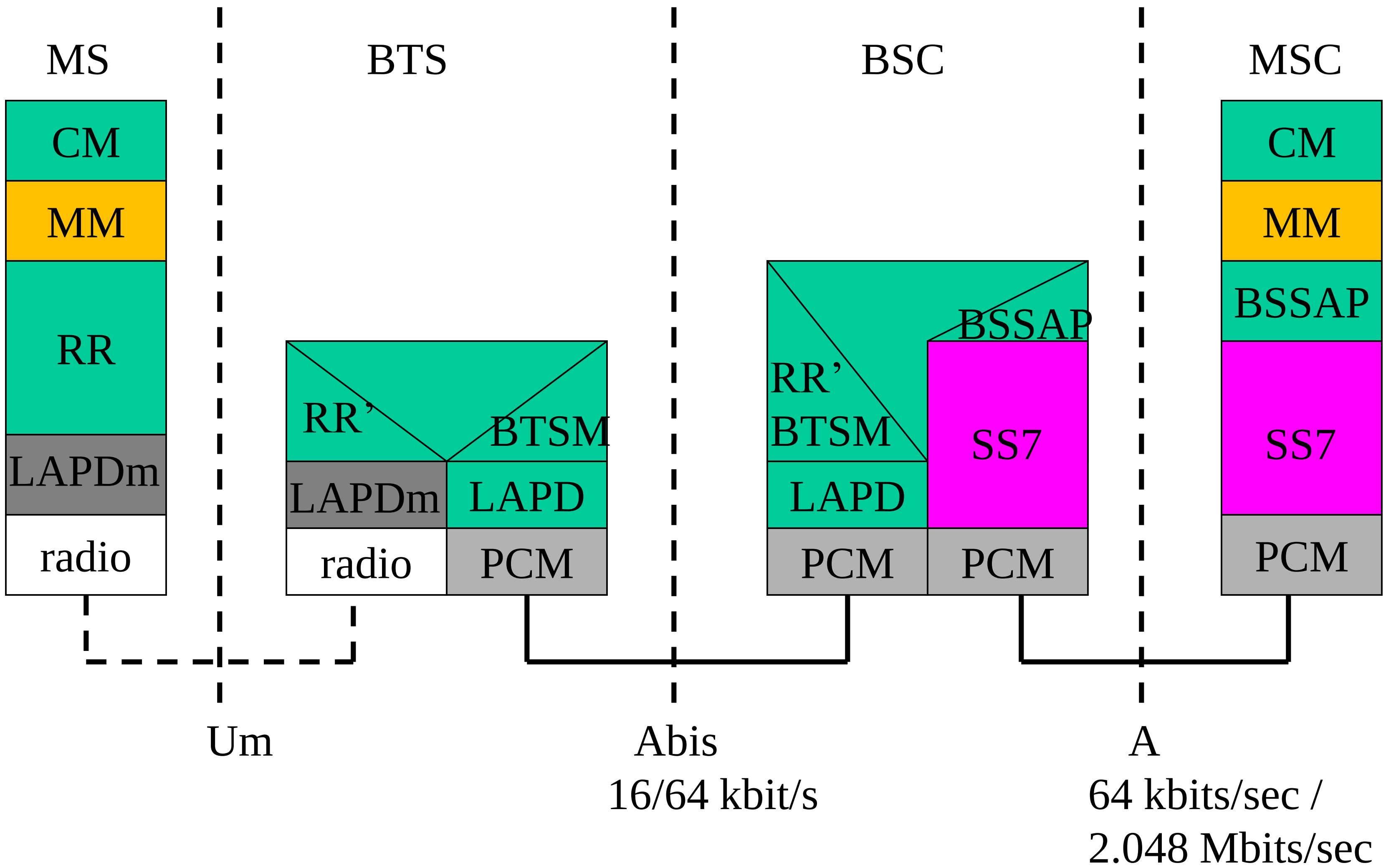
- <u>TTTTTTTTTTTT</u>**S**<u>TTTTTTTTTTTT</u>**x**
- T = user traffic in TCH/F, S = signaling
- x = unused slot
- Normal burst carries 114 bits of user data and is repeated every 4.615 ms (24.7 kbit/sec data rate)
- TCH uses 24/26 slots➔rate = 22.8 kbit/s
- SACCH: 950 bit/sec

Structuring of time using frames



Use: frame number is an input to the encryption algorithm.

Protocol Stacks in GSM Network



Protocols

- Radio
  - Creation of bursts (slots), multiplexing, sync with BTS, detection of idle channel, measurement of quality of downlink, encryption/decryption
  - Channel coding/error detection using FEC (Forward Error Correction)
    - (Alternative is retransmission. Expensive. Good for upper layers.)
  - GSM tries to correct errors, but does not deliver erroneous data.

Protocols

- LAPDm (Link Access Protocol D-channel: mobility)
  - Light weight LAPD (no sync, no checksum)
  - Flow control: Receiver controls transmissions.
  - Segmentation + reassembly
- RR (radio resource management)
  - Setup, maintenance, release of radio channels
- BTSM (BTS Management)

Protocols

- MM (Mobility Management)
  - Registration, authentication, **location updating**, temporary mobile subscriber identity (TMSI)
  - TMSI replaces IMSI to *hide the real identity* of MS
  - TMSI is valid only in current location area of a VLR

Protocols

- CM (Call Management)
  - Call Control (CC)
    - Point-to-point connection between terminals
  - Short Message Service (SMS)
    - Uses SDCCH + SACCH

Localization and calling

- Features of GSM
  - Automatic, worldwide localization of users
  - Performs periodic location update. Location is the area in all the cells under one MSC.
- Roaming
  - Changing VLRs with uninterrupted availability
    - » Within the network of one provider
    - » Between two providers in one country
    - » Between different providers in different countries

Localization and calling

- To locate/address an MS, several #s needed
  - International Mobile Equipment Identity (IMEI) ← Ai'mi
    - » Uniquely identifies an MS (device)
  - MS International ISDN number (MSISDN) ← Misden
    - » Mobile Station International Subscriber Directory Number (Telephone number to the SIM card)
    - » Country code + national destn code + subscriber num
    - » You dial this number
    - » A network can change this number → enables # portability
  - International Mobile Subscriber Identity (IMSI): 64 bits
    - » Country code + national destn code + MSIN (Mob. Sub. Identification Number: assigned by network operator)
    - » A network cannot change this number of a SIM
    - » Uniquely identifies a user
  - Note: An MS can only be operated if a SIM with a valid IMSI is inserted into a device with a valid IMEI

Examples

Canada

MCC: 302
NDC: 220 (Telus)
370 (Fido)
690 (Bell Mobility)

India

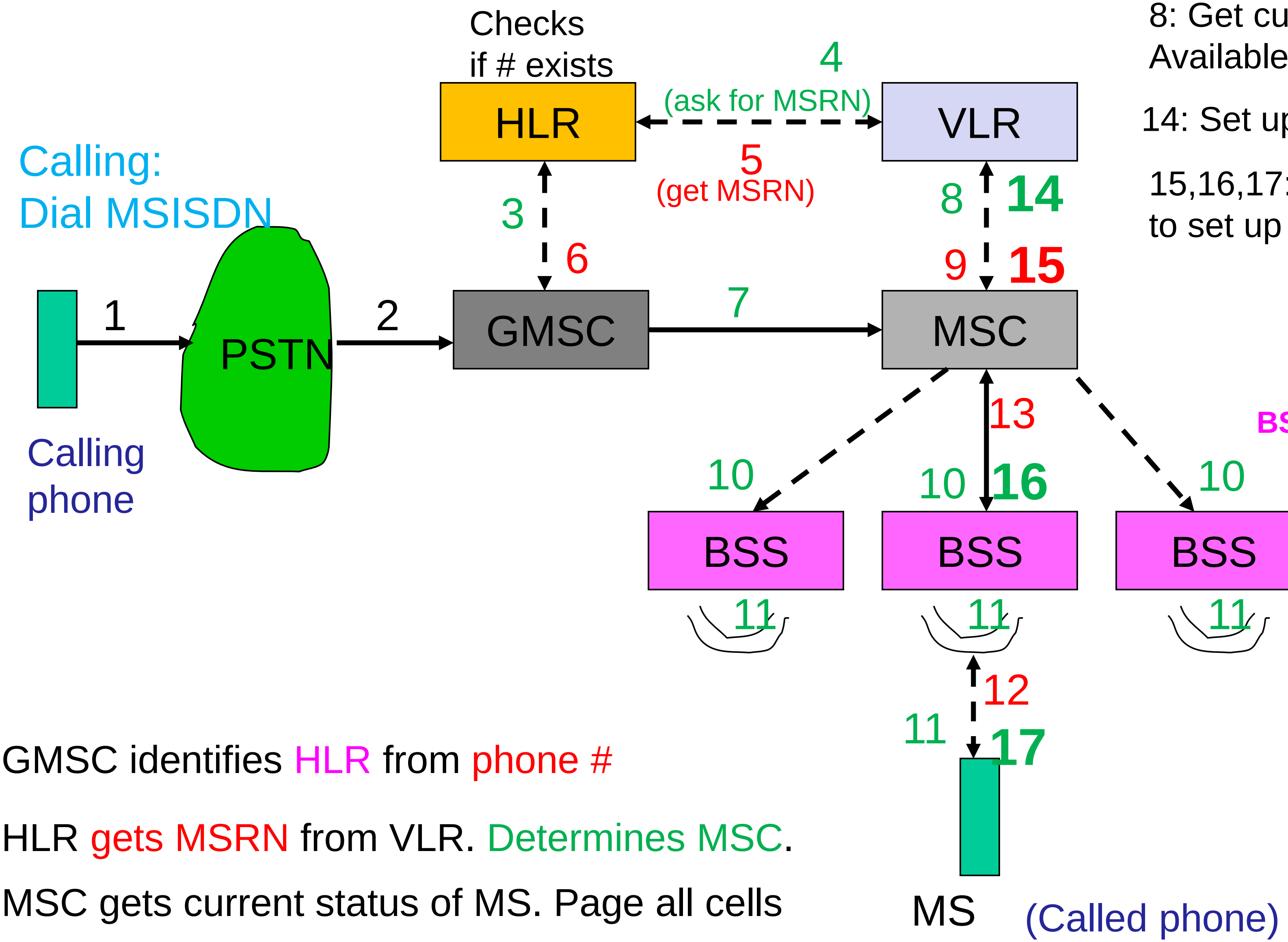
MCC: 404
NDC: 05 (Reliance Delhi/NCR)
800 (Aircel Delhi/NCR)

MNC (Mobile Network Code) is also known as National Destination Code

Localization and calling

- To locate/address an MS, several #s needed
  - Mobile Station Roaming Number (MSRN)
    - » (MSRN) is a **temporary telephone number** assigned to a mobile station which roams into another numbering area.
    - » Same structure as MSISDN
    - » Identifies the MSC as well
    - » Hides the ID and location of a subscriber
    - » Helps HLR to find a subscriber for an incoming call
  - Temporary Mobile Subscriber Identity (TMSI)
    - » Hides IMSI. Assigned by VLR. Not known to HLR.

Mobile *Terminated* Call (MTC)



8: Get current status
Available?

14: Set up encryption

15,16,17: VLR tells MSC
to set up a conn.

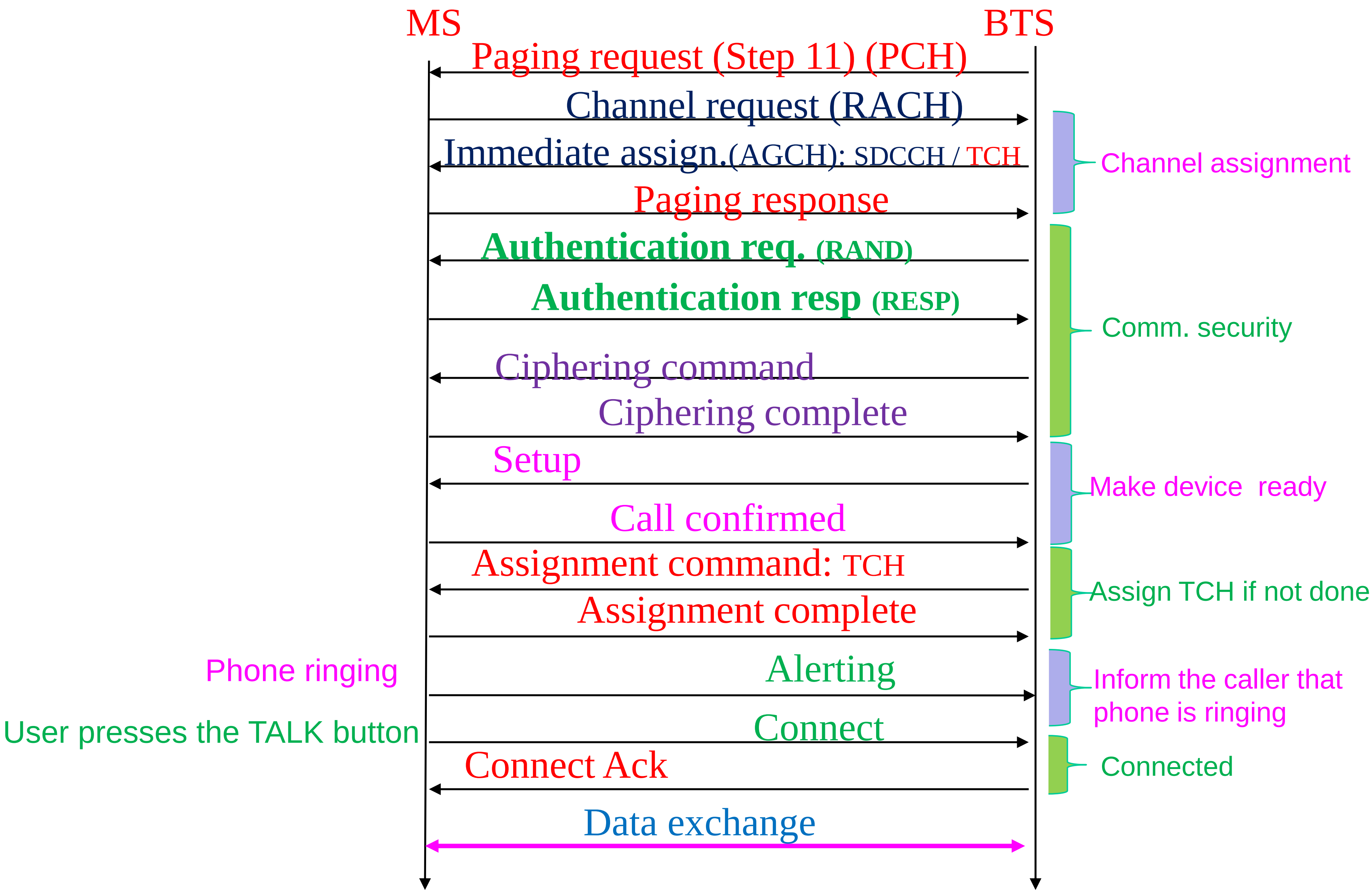
BSS: 1 BSC + many BTS

* GMSC identifies HLR from phone #

* HLR gets MSRN from VLR. Determines MSC.

* MSC gets current status of MS. Page all cells

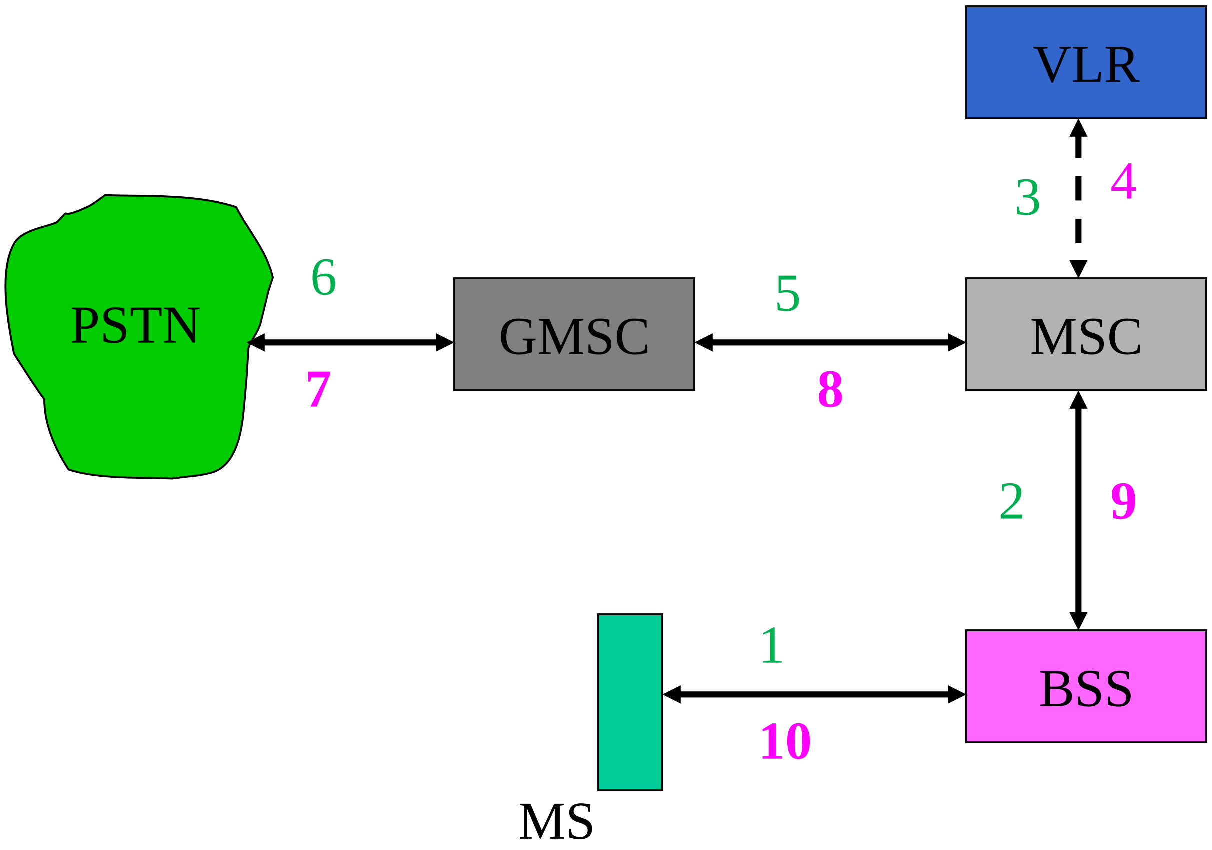
Message flow for MTC



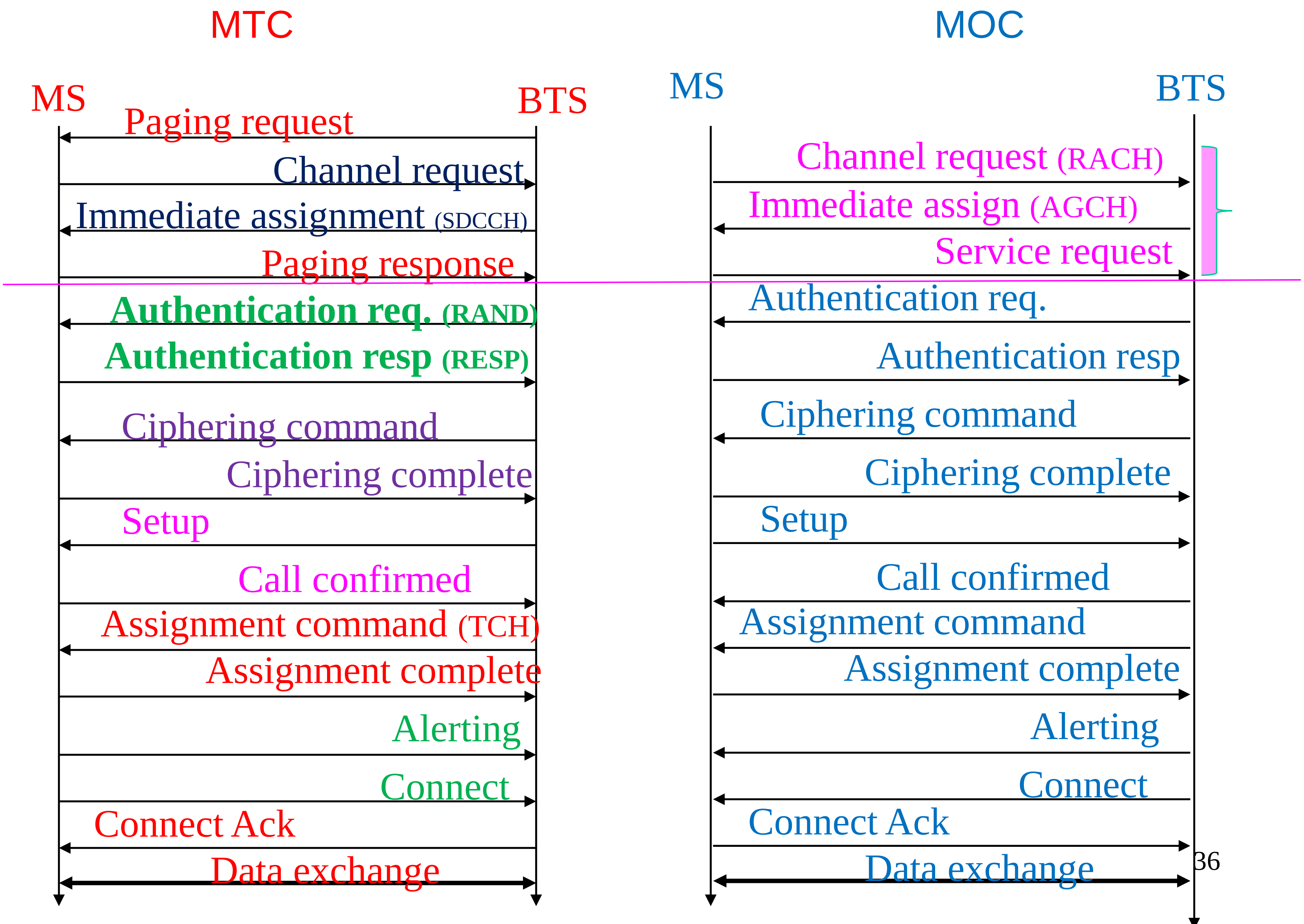
Localization and calling

- HLR
  - Checks whether the number exists and whether the user has subscribed to the service.
  - Asks for an MSRN from the VLR.
- MSC
  - Gets the current status of MS from VLR (8/9).
  - If the MS is available, start paging.
  - :
  - Ask VLR to perform security check (14).

Mobile *Originated* Call



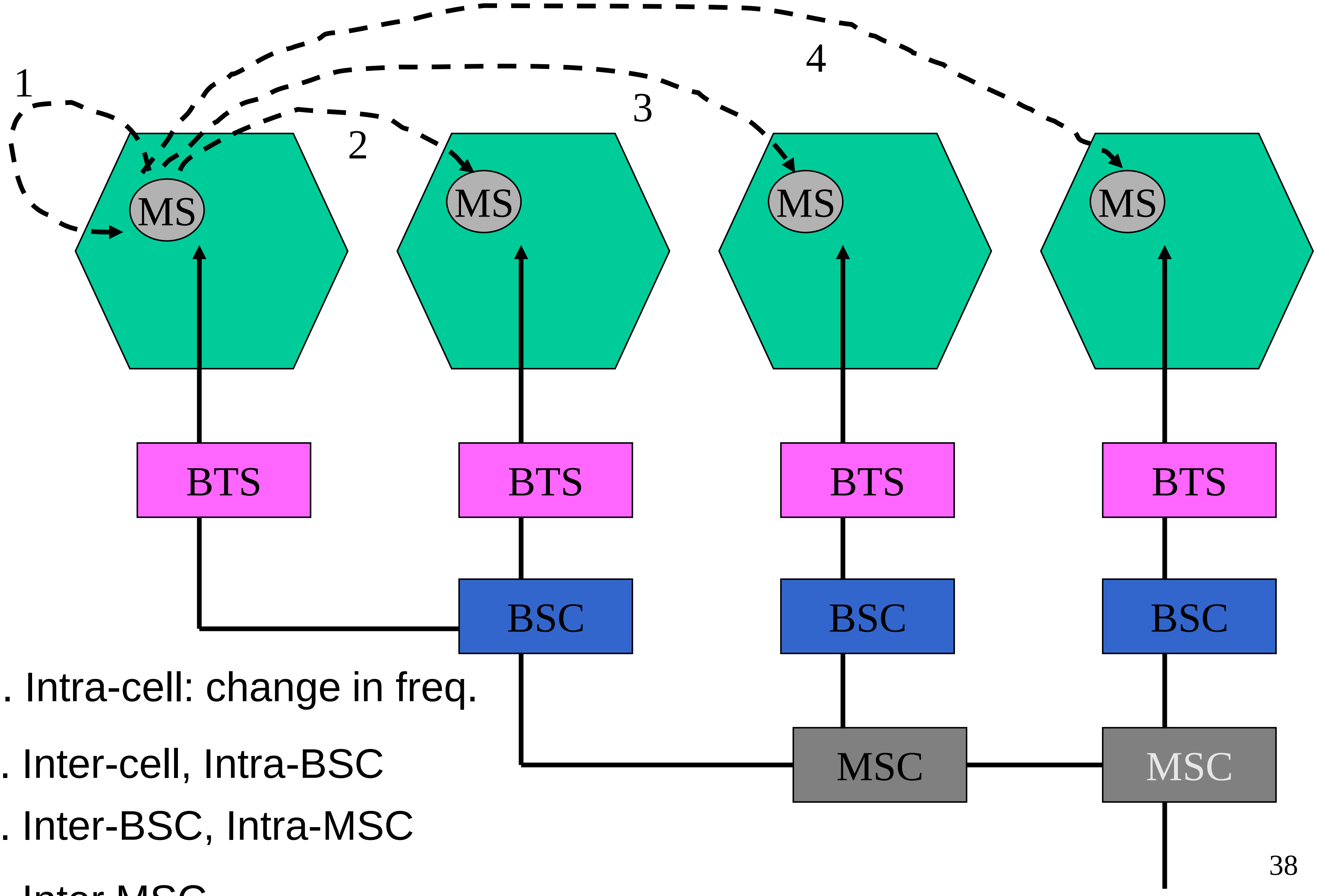
Message flow for MTC and MOC



Handover

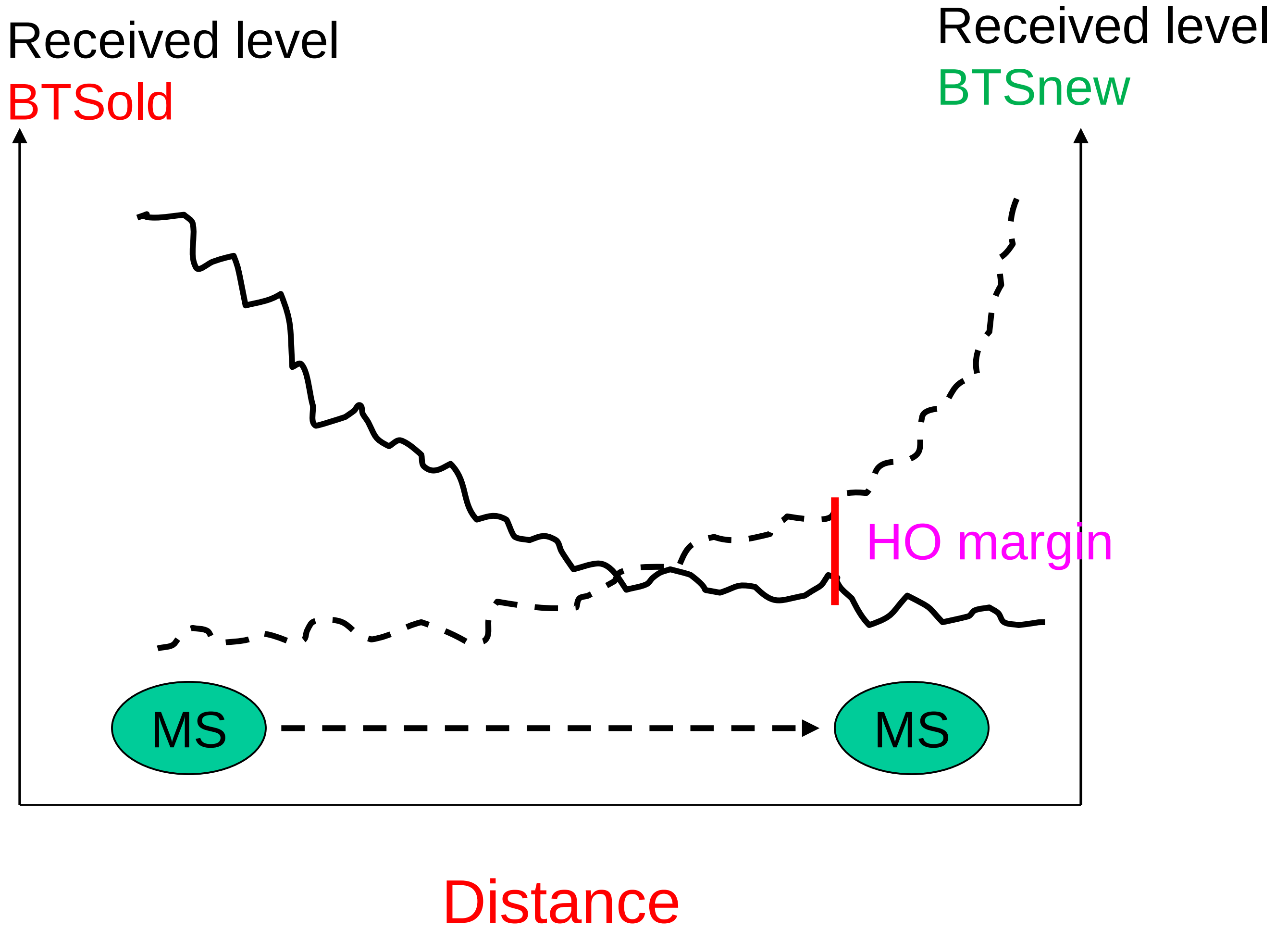
- Diminished quality of radio link
- Load balancing

Types of handovers in GSM

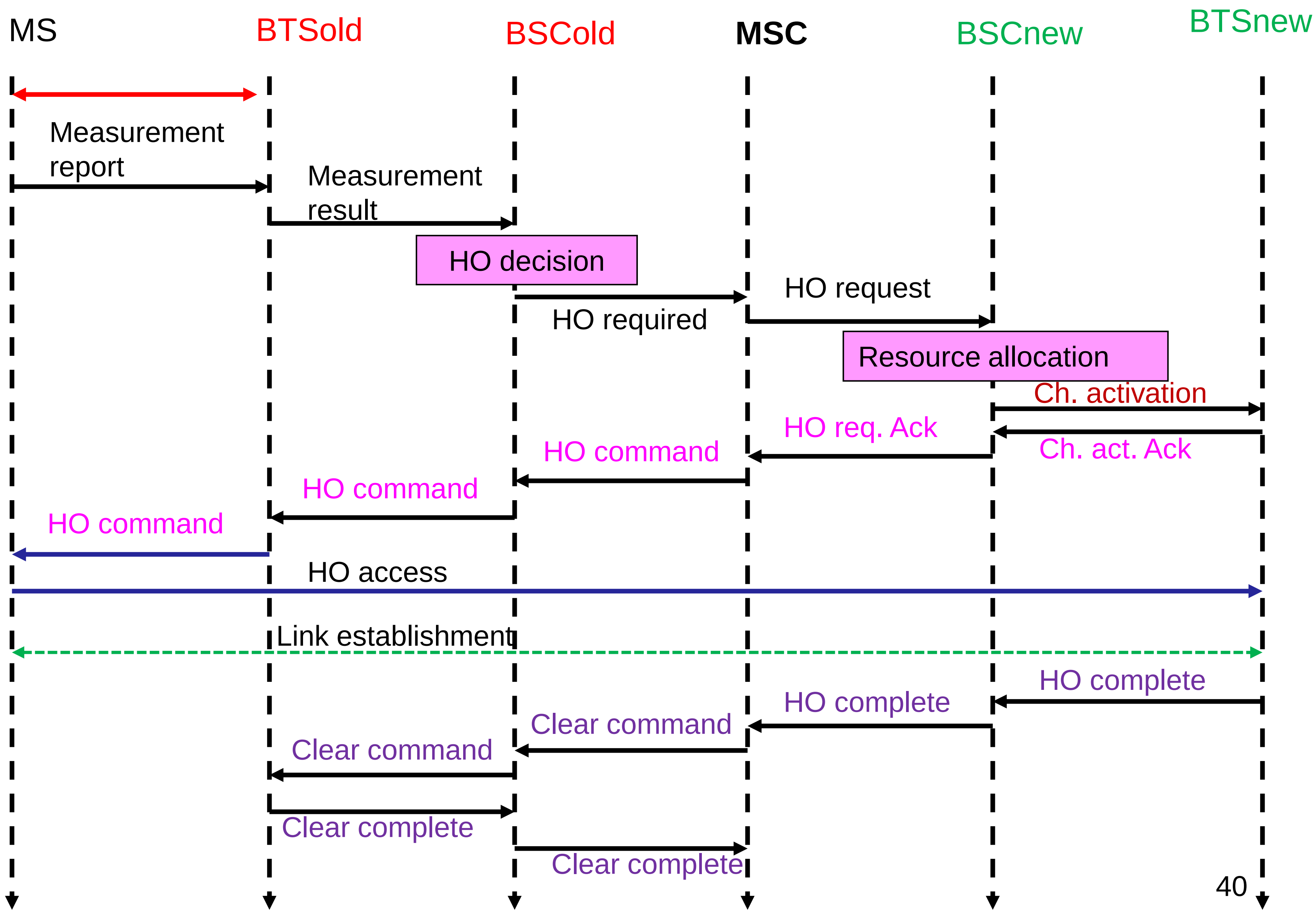


1. Intra-cell: change in freq.
2. Inter-cell, Intra-BSC
3. Inter-BSC, Intra-MSC
4. Inter MSC

Handover decision based on received signal



Intra-MSC handover



Security in GSM

Security services offered by GSM

- Access control and authentication
  - Authentication of a valid user for the SIM: The user needs a secret PIN to access the SIM
  - The next step is subscriber authentication (Fig. 4.10 in book. See message flow for MTC and MOC. Shown before.) This is based on a Challenge/Response explained on the following slide (Fig. 4.14)
- Confidentiality
  - All user data is encrypted. Shown in Fig. 4.15, on a following slide.
- Anonymity
  - All data is encrypted before transmission.
  - User identifiers are not used over air. Rather, a TMSI is transmitted. A VLR generates a new TMSI after a location update.
  - TMSI is sent to MS after authentication and encryption processes have taken place.

Fig. 4.14: Subscriber authentication

A3: A symmetric key encryption algorithm

Mobile network

SIM

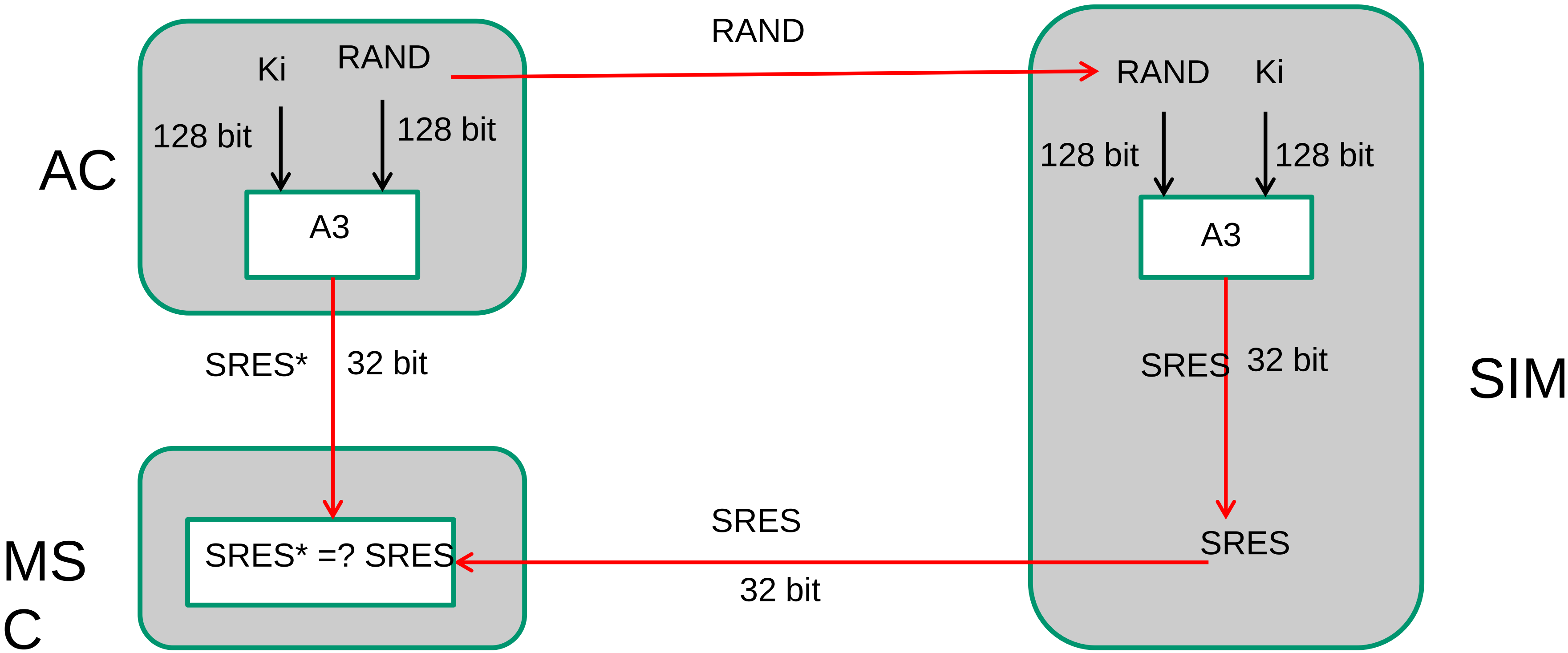
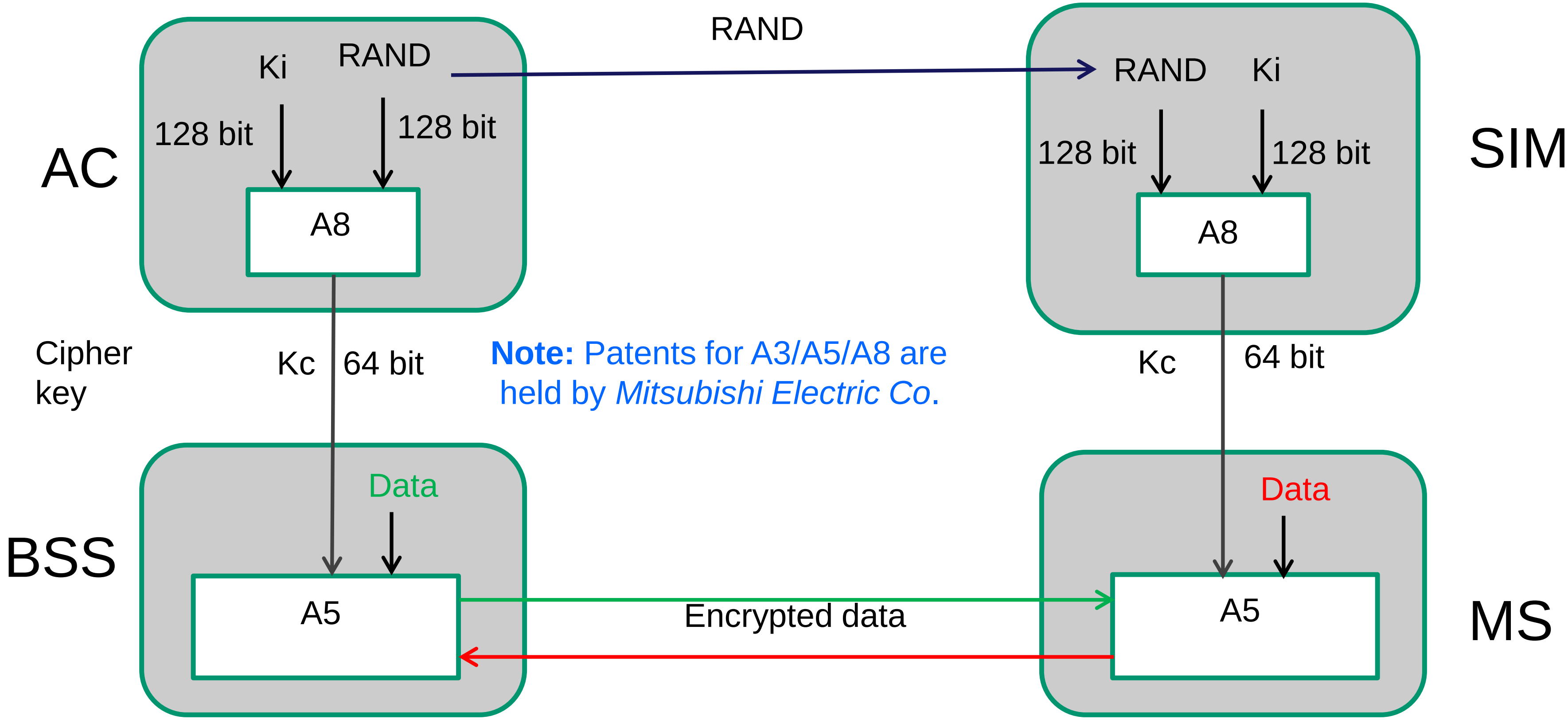


Fig. 4.15: Data encryption

A8: a key generation algorithm; A5: a symmetric-key encryption algorithm
(Example: Data Encryption Standard (DES))

Mobile network

MS with SIM



Note: Patents for A3/A5/A8 are held by *Mitsubishi Electric Co*.

Dynamic Channel (carrier) Assignment in Cellular Systems

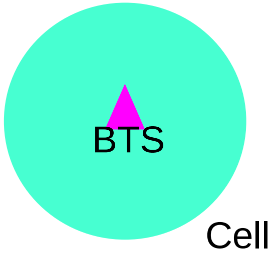
Sources: Section 2.8 (Schiller) and

A. Baiocchi, F. D. Priscoli, F. Grilli and F. Sestini, **The geometric dynamic channel allocation as a practical strategy in mobile networks**, IEEE TVT, Vol 44, No 1, Feb. 1995, pp. 14-23

Topics

- Cellular systems
- Carrier Assignment Problem
  - Static
  - Dynamic
- DCA Algorithm

Cellular Systems



- A geographic area is divided into smaller, circular areas called **cells**.
- A **base station** (transceiver) is installed at the cell’s center. Cell = radio coverage area.
- Cell radius
    - 10s of meters in buildings
    - 100s of meters in cities
    - 10s of KM in countryside

Cellular Systems

- Advantages of smaller cells
  - Higher capacity (frequency **reuse)** ← users
  - Less transmission power for MS (no BS problem)
  - Robust against failures of single components
- Disadvantages of smaller cells
  - Larger infrastructure (antennas, switches, …)
  - Frequent handover
  - Better planning: frequency assignment, etc.

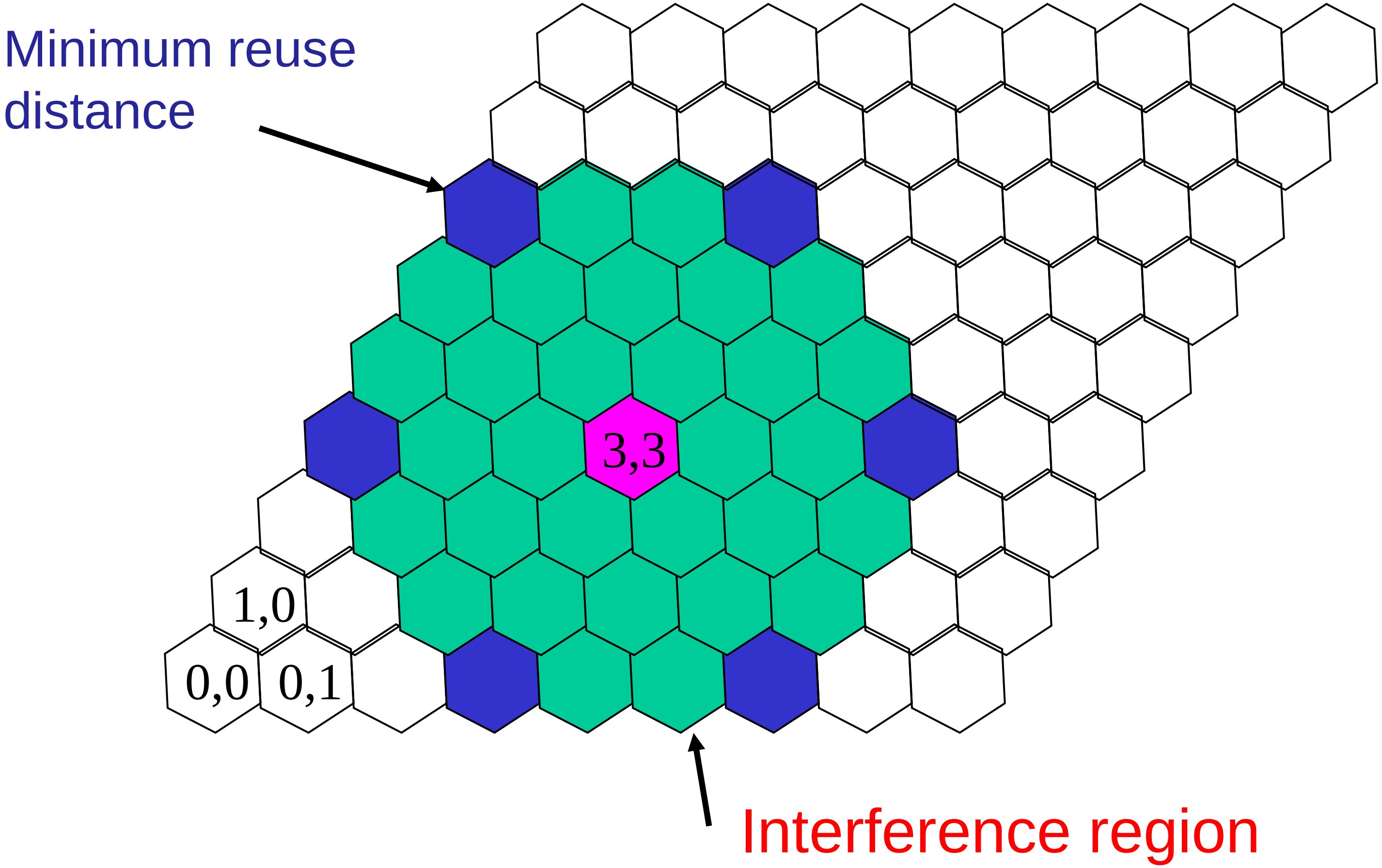
Carrier Assignment Problem

- Facts about GSM 900
  - FDM: 90 frequencies (up/down)
  - TDM: 8 slots/frequency
  - ➔ Max number of active users = 90*8
- Low capacity ➔ need for reusing carriers
  - Space division multiplexing: reuse carriers far apart
    - » To reduce interference
    - » To increase capacity (# of users)

Carrier Assignment Problem

- Problem: Given a set of carriers and a cellular system
  - How to assign carriers to cells?
  - Maximum reuse ➔ maximum capacity
  - Lower **failure rate**
    - » **Blocking rate**
      - **- What % of the new calls cannot be connected?**
    - » **Dropping rate**
      - **- What % of the on-going calls cannot be sustained?**

Cellular model



Carrier Assignment Algorithms

- **Fixed assignment** of carriers to cells
    - Use these carriers until further notice.
    - Simple to implement. No signaling load.
    - Good (bad) for low (high) traffic.

- **Dynamic assignment** of carriers to cells
    - All carriers are **“available”** in all cells.
    - Improved performance.
    - High signaling load.

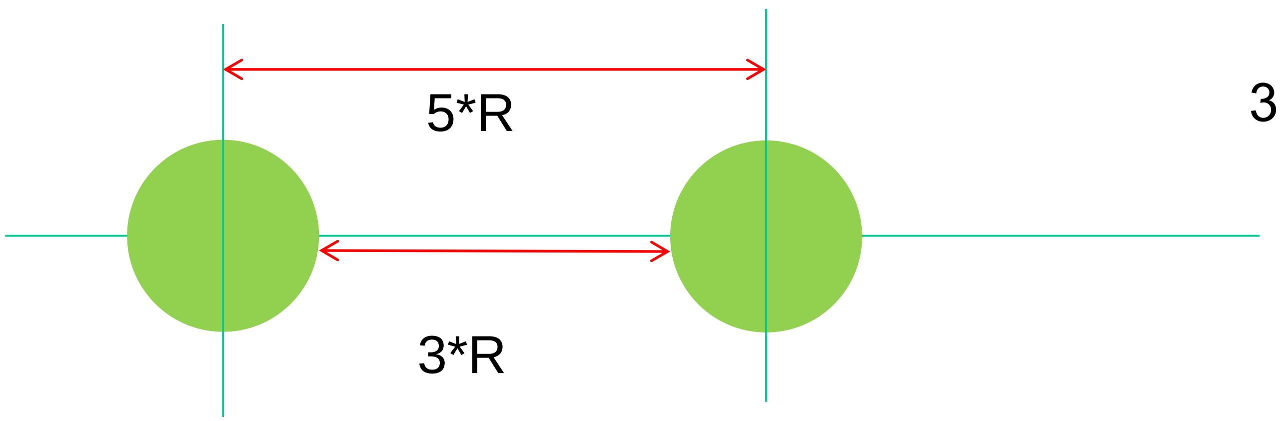
Dynamic Carrier Assignment

- (*m*, *n*): **cell** at row *m* and column *n*
- (x, y): **center** of a cell (coordinate)
- (x,y): center of cell (*m*, *n*) is computed as
  - (x,y) = (*n*, *m*) $\begin{bmatrix} \text{Sqrt(3)*R} & 0 \\ \text{Sqrt(3)*R/2} & \text{3*R/2} \end{bmatrix}$

R = cell radius

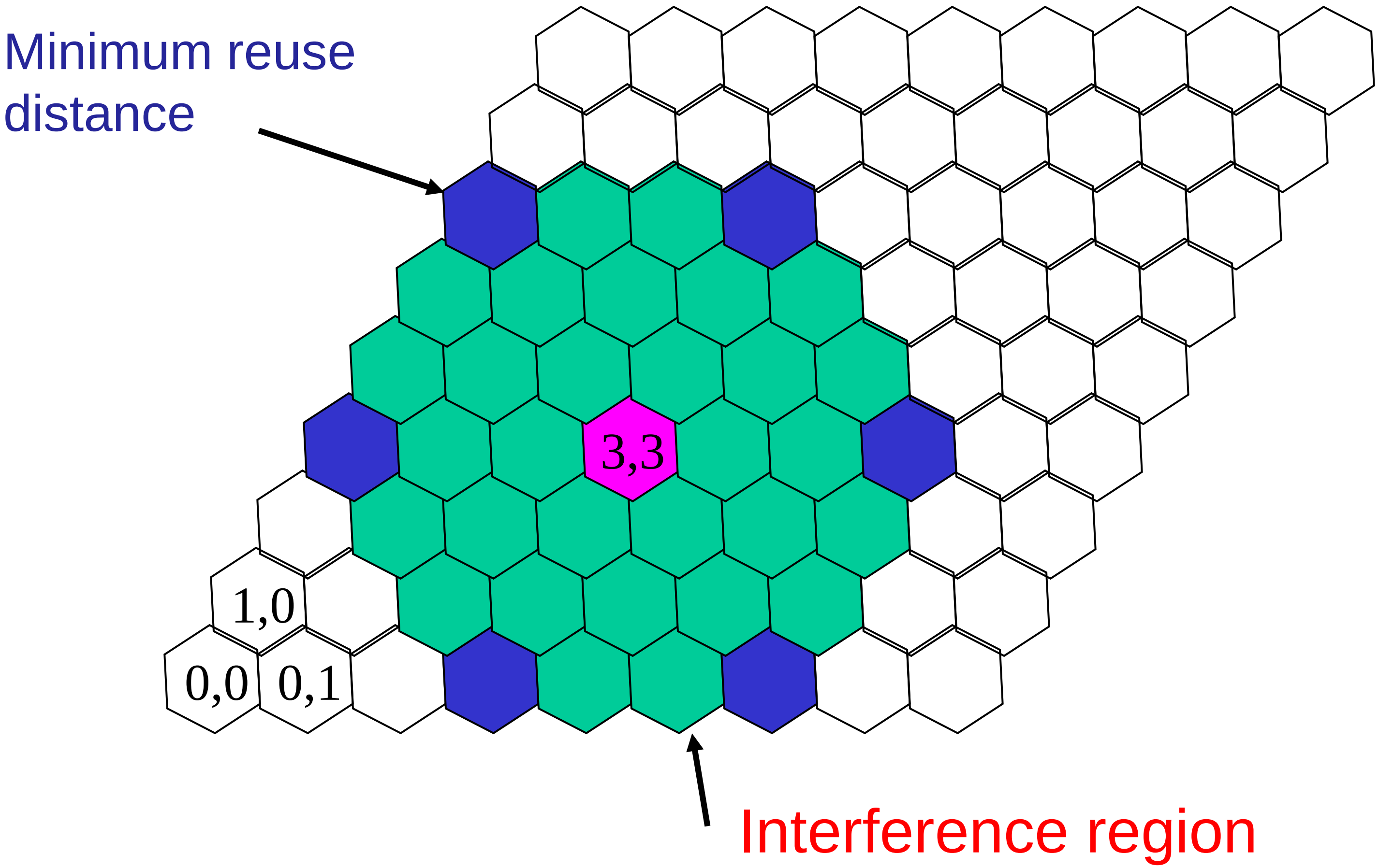
Dynamic Carrier Assignment

- Reuse condition: Two carriers can be simultaneously used in two cells only if their separation **>** D_{min}.
- Assume $D_{min} = (3*\sqrt{3})*R$
- Interference neighborhood of a cell c
  - IN(c) = {c'|dist(c, c') < D_{min} , c <> c'}
  - 30 cells
- If cell c uses a frequency, no cell in IN(c) can reuse it.



$3*\sqrt{3} \approx 5$

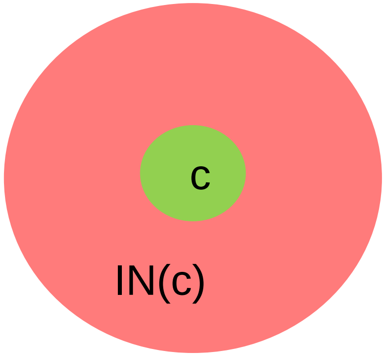
Cellular model



Dynamic Carrier Assignment

- **Status** of a carrier *r* in a cell *c*
  - **Used**: status(*r*, *c*) = UC
    - if at least one channel of *r* is currently used by some user in *c*.
  - **Interfered**: status(*r*, *c*) = IC
    - if status(*r*, *c'*) = UC for some c' in IN(c).
  - **Available**: status(*r*, *c*) = AC
    - if status(*r*, *c*) <> UC AND status(*r*, *c*) <> IC.

  ➔ cell c is not using *r* AND no cell in IN(c) is using *r*



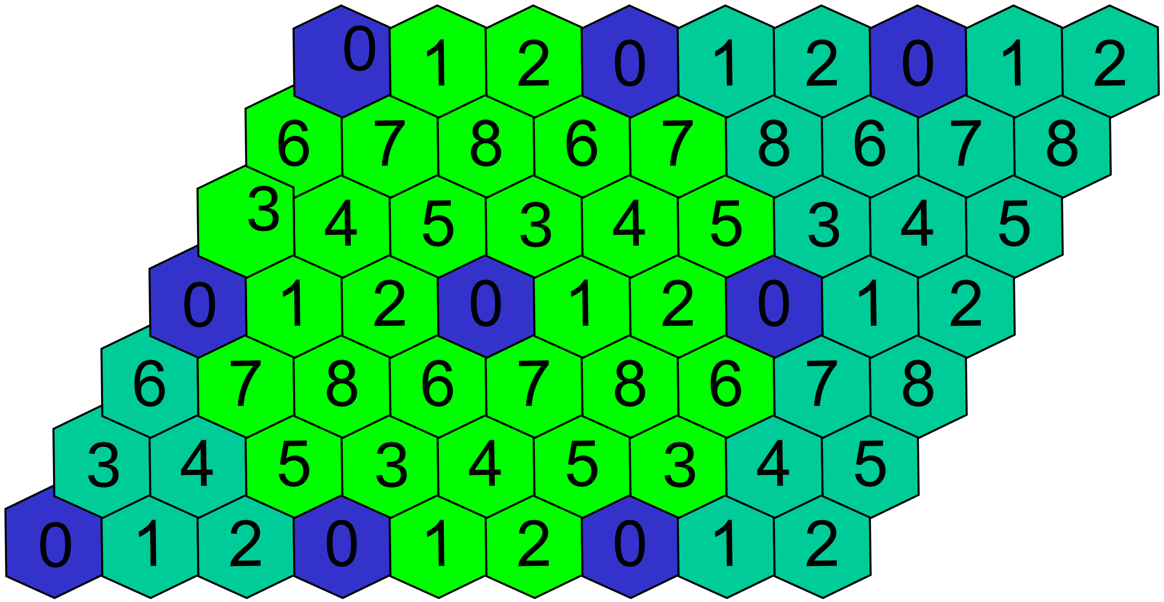
Dynamic Carrier Assignment

- **Geometric strategy**
  - ***Divide*** the **cell array** into **k groups** $S_0, S_1, \ldots, S_{k-1}$ such that distance between any pair of cells in the same group is at least D_{min}.
  - ***Split*** the **carrier set** into **k groups** $P_0, P_1, \ldots, P_{k-1}$. Carriers in each P_i is considered to be *ordered*.
  - When a cell c in $\mathbf{S_i}$ needs a carrier, it **checks the ordered lists** $\mathbf{P_i}$, $P_{i+1}, \ldots, P_0, \ldots, P_{i-1}$ in that order and **acquires** the first **available** carrier encountered.

What is the value of k?

Dynamic Carrier Assignment

For $D_{min} = (3^* \sqrt{3})^*R$, **k = 9** for max reuse



S_0 = {cell 0}

S_1 = {cell 1}

:

S_8 = {cell 8}

Dynamic Carrier Assignment

- **Performance measures**
  - **Blocking rate (Rb)**: failure to assign a channel to new calls.
  - **Dropping rate (Rd)**: failure to assign a channel to a moved-in call.
  - **Failure rate (Rf)**: Rf = Rb + (1-Rb)*Rd
- **How to obtain Rf?**
  - Analytic
  - Simulation

Dynamic Carrier Assignment

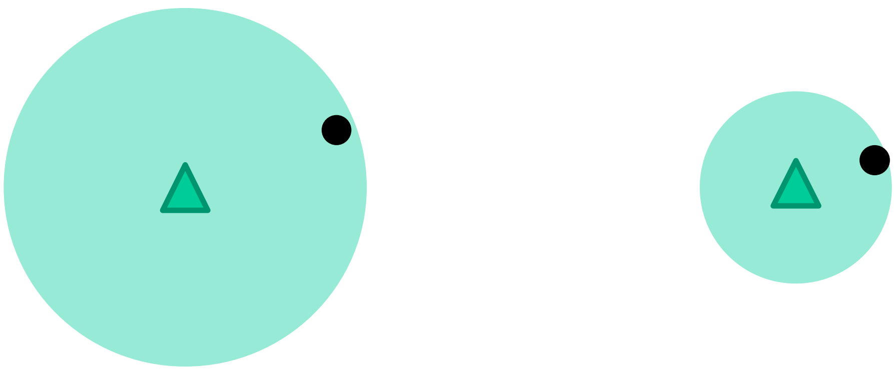
- **Simulation parameters**
  - Cell grid ← how big, wrapped around
  - Total available carriers (90 for GSM)
  - TDM slots (8/frequency) ← invisible in algorithm
  - Traffic: call arrival rate
  - Mobility: handoff rate (pattern??)
  - Mean service time
  - Uniform/non-uniform traffic (hot/normal states)

Techniques for lowering failure rates of DCAs

- Power control
- Adaptive antenna array (also, tri-sector)
- Carrier compaction
- Prioritized release
- Lower QoS (channel sub-rating)
- Call on hold
- Synchronous BTS

Techniques for lowering failure rates of DCAs

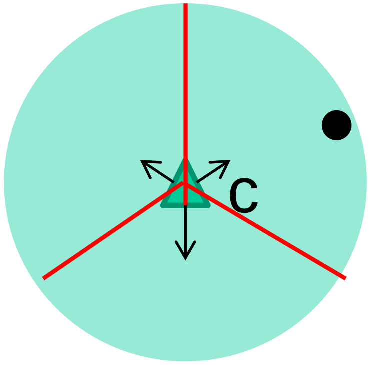
Power control: The Tx power level of BTS is adapted based on the distance of the subscriber.



Techniques for lowering failure rates of DCAs

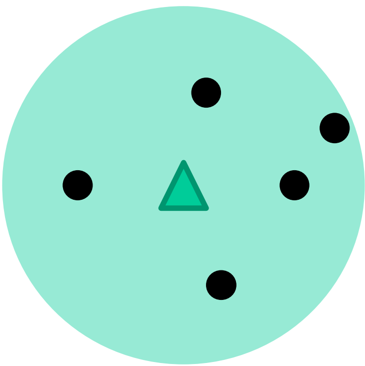
Adaptive antenna array (also, tri-sector antennas)

Reduces the size of IN(c)



Techniques for lowering failure rates of DCAs

Carrier compaction



Assume that a cell is using channels as follows:

C1: 1, 2, 7
C2: 3, 4

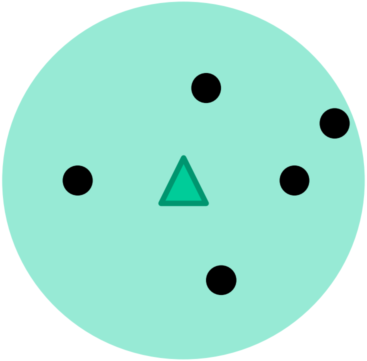
Move all the five users to one carrier:

C1: 1, 2, 3, 4, 7

to **release** one channel.

Techniques for lowering failure rates of DCAs

Prioritized release



Assume that a cell is using channels as follows:

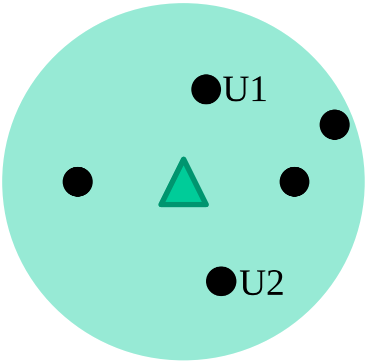
C1: 1, 2, 7
C2: 3, 4

Perform carrier compaction with the objective of making the released carrier available in the max # of cells.

Release C1 or C2?

Techniques for lowering failure rates of DCAs

Channel sub-rating



Assume that user U1 has been allocated a channel C1 and there is no more channel for a new user U2.

Partition C1 into two sub-rated channel C11 and C12.
Assign C11 to U1 and C12 to U2

Ex.: A 22.8 Kbps channel C1 is sub-rated into
two smaller channels C11 (11.4 Kbps) and C12 (11.4 Kbps)

Techniques for lowering failure rates of DCAs

Call-on-hold

K. Naik and D. S. L. Wei, ``Call-on-Hold for Improving the Performance of Dynamic Channel Assignment Strategies in Cellular Networks," *IEEE Trans. on Vehicular Technology*, Vol. 53, No. 6, Nov., 2004, pp. 1780-1793.

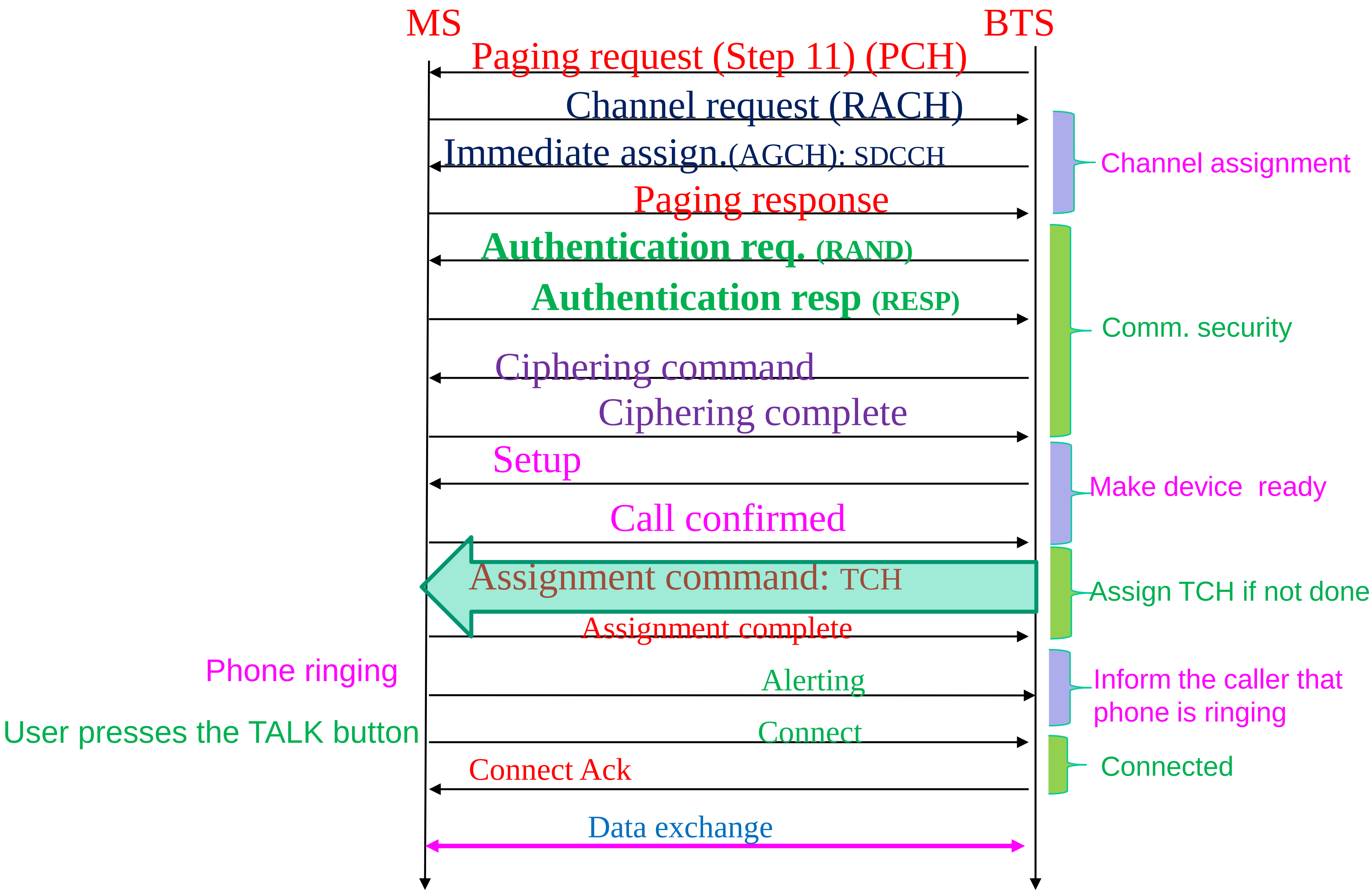
Basic idea: A small, variable delay in assigning a TCH (call-on-hold) significantly improves the performance.

Where exactly do you insert a delay?

See the next slide…

Techniques for lowering failure rates of DCAs

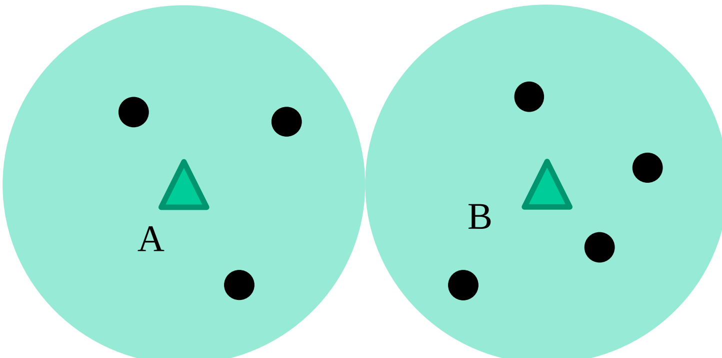
(Call-on-hold) Message flow for MTC



Techniques for lowering failure rates of DCAs

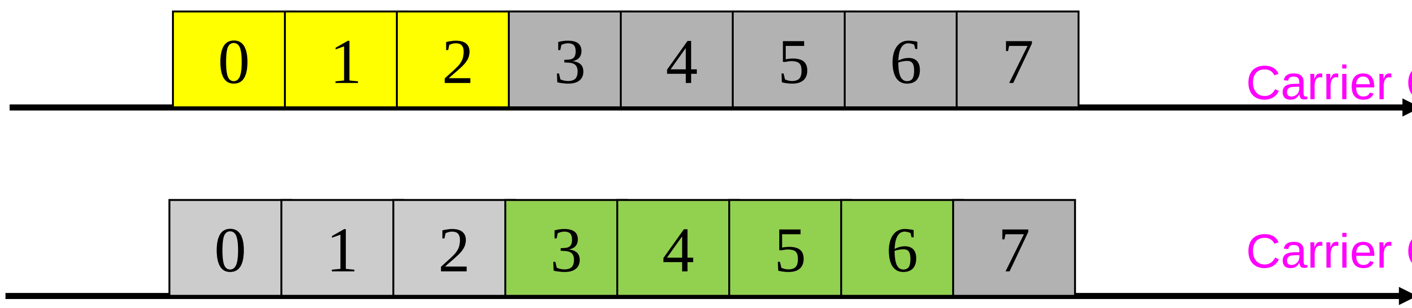
Synchronous BTS

Assume that slots of the two BTS are synchronized



K. Naik, D. S. L. Wei and S. Olariu, "Utilizing the Synchrony Among Base Stations for Better Performance of Channel Assignment Algorithms," *Computer Communications*, Vol. 31, Sept. 2008, pages 3267-3274.

We calculate the **availability of channels** in a cell, instead of availability of carriers.



Carrier C1 in A

Carrier C1 in B

Synchronized slots between A and B

GPRS: General Packet Radio Service

Wireless and Mobile Network Architectures

Yi-Bin Lin and I. Chlamtac (Wiley)

+

Schiller

GPRS

- GSM is fully circuit-switched.
  - Not suitable for Internet applications
    - Up link: Frequent Tx of small volume data
    - Down link: Infrequent Tx of small/medium volume
- Need for packet-oriented service ➔ GPRS
- Success of GPRS:
    - Packet oriented Internet
    - Different services: broadcast, multicast, unicast

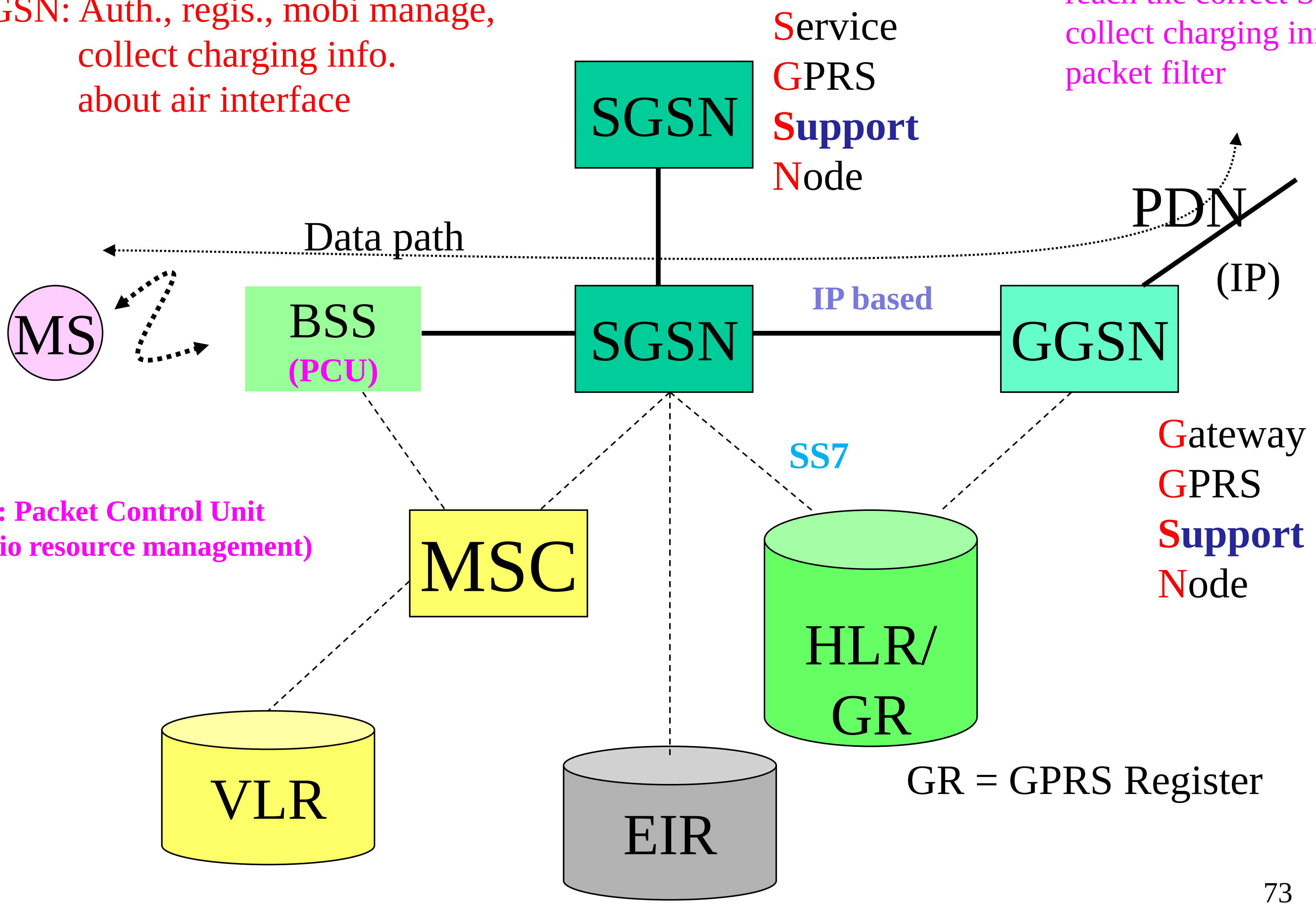
Main concepts of GPRS

- For new GPRS channels, GSM system allocates 1-8 slots in a frame.
- Time slots are allocated on demand.
- Time slots are shared by the active users.
- Allocation is based on load + op. preference.

GPRS architecture

GGSN: Routing info for MS to reach the correct SGSN, collect charging info, packet filter

SGSN: Auth., regis., mobi manage, collect charging info. about air interface



PCU: Packet Control Unit (Radio resource management)

GR = GPRS Register

Serving GPRS Support Node (SGSN)

- Equivalent of an MSC in GSM
- Supports MS (through BSS)
- Functions:
  - Requests user addresses from the GR (GPRS Register)
  - Keeps track of individual MSs' location

SGSN: Auth., regis., mobi manage,
collect charging info. about air interface

Gateway GPRS Support Node (GGSN)

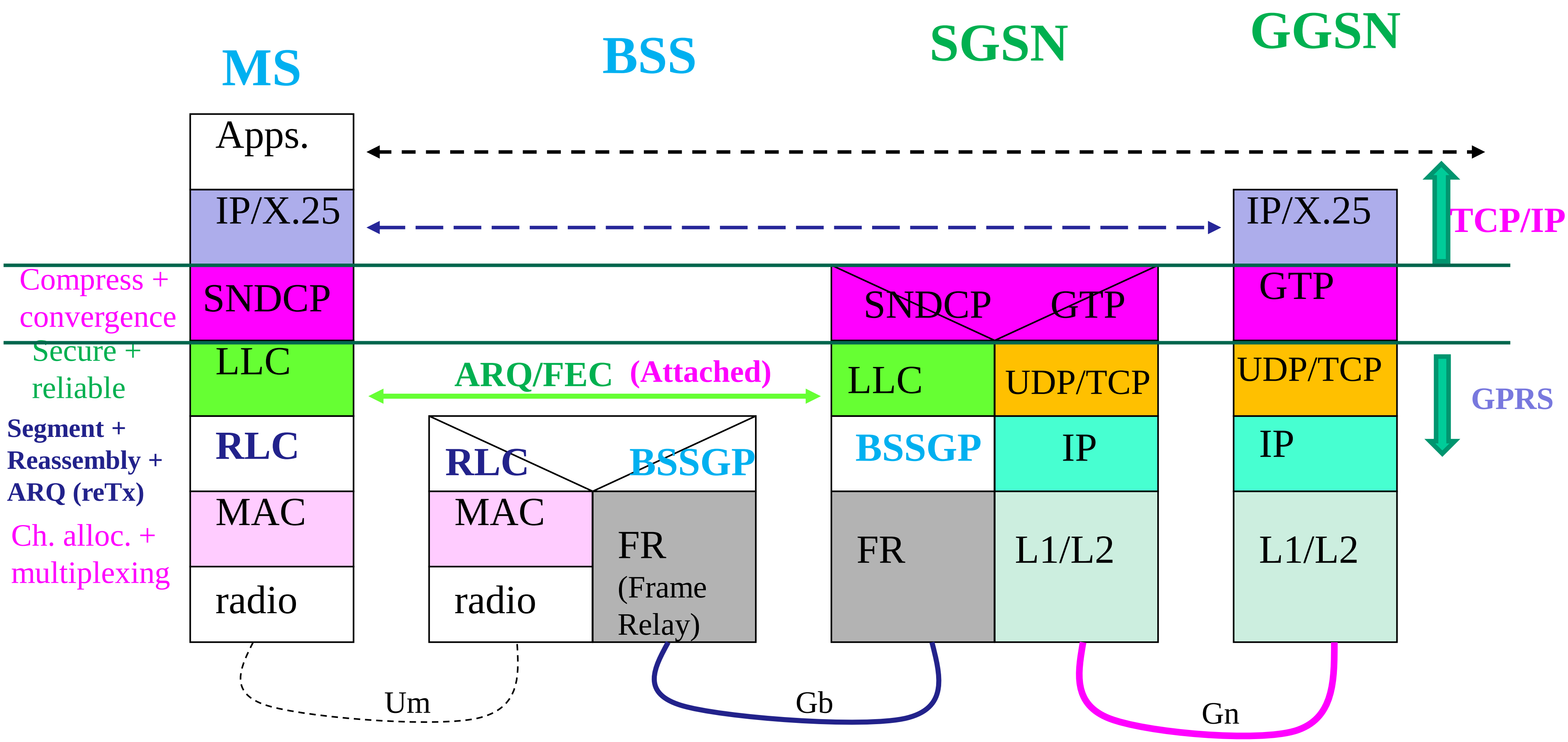
- Link between GPRS and data net (IP)
- Functions
  - routing,
  - tunneling via encapsulation to reach SGSN

GGSN: Allocates IP addresses,
routing info for MS to reach the correct SGSN,
collect charging info,
packet filter

GPRS protocol stack

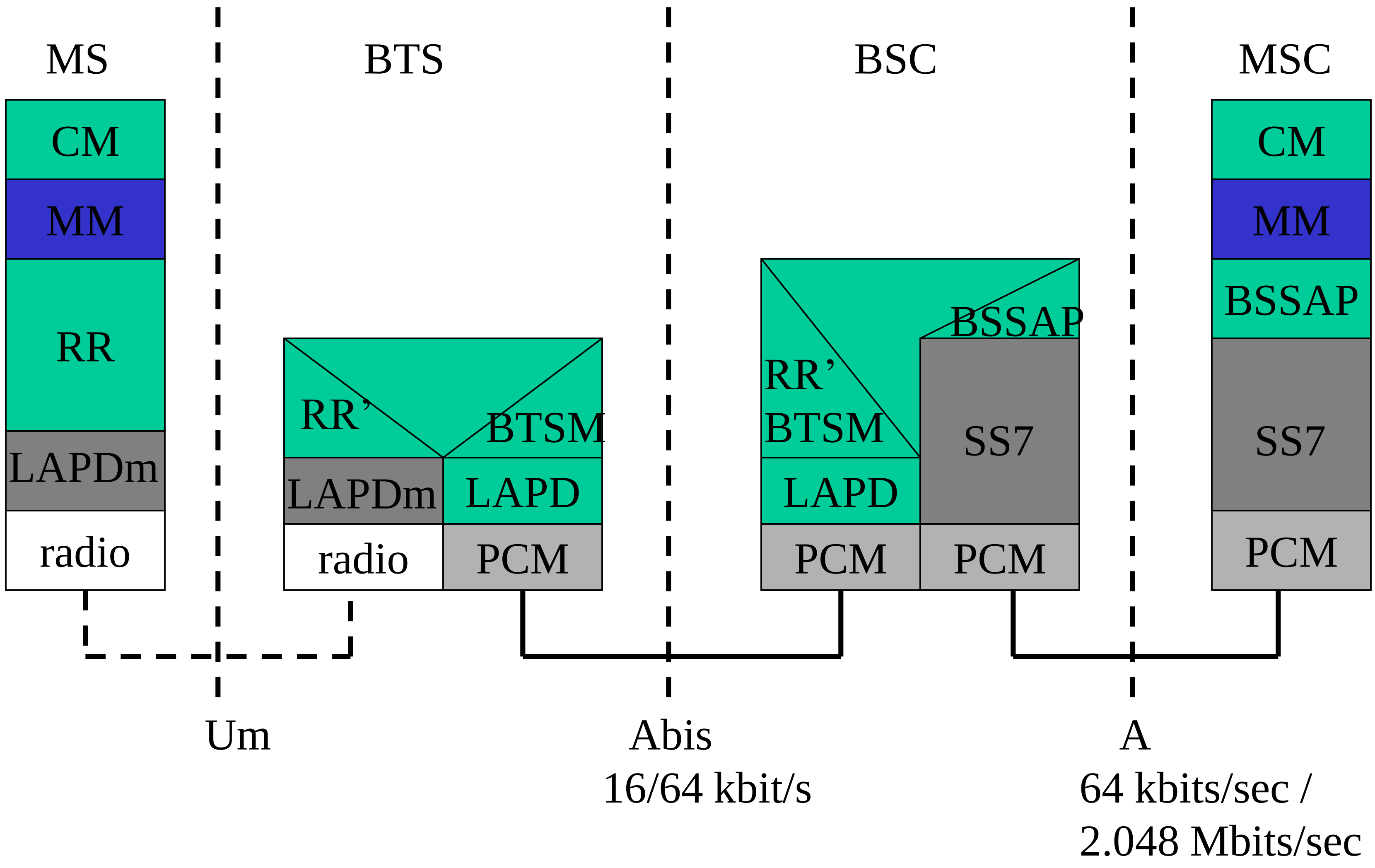
BSSGP: BSS GPRS Protocol (routing/ paging/ flow control /support QoS)

All data within GPRS backbone are transmitted using GPRS Tunneling Protocol (GTP)
Tunnel ID carries: MCC/ DNC/ MSIN/ ….



SNDCP: Sub-network Dependent Convergence Protocol

Protocol Stacks in GSM Network



Three GPRS terms

- Mobility Management context
- PDP (Packet Data Protocol) context
- QoS profile (maintained in PDP context)

MM context (MM state)

- MM state
    - IDLE: MS is not attached to the GPRS mm
    - STANDBY: Attached but has not obtained loc. info.
    - READY: Loc info has been identified on cell level

- MM context stored in MS + SGSN
- GPRS attach → (MS ←→ SGSN logical link)

PDP (packet data protocol) contexts

- Stored in MS, HLR, SGSN, GGSN
- Contain mapping and routing info for packet Tx between MS ⟷ GGSN
- After PDP context activation, MS is known to the GGSN
- As many PDP contexts as the number of IP addresses.
- ACTIVE and INACTIVE contexts

QoS profile

- QoS profile maintained in the PDP context
- Indicates radio and network resources required for data transmission.
- QoS attributes
    - Precedence class: three Tx priority levels (congestion ➔ discard)
    - Delay class: four {In 128-octet transfer, expected delays are < 0.5 s, 5 s, 50s, best effort.}

QoS profile (contd)

- Reliability classes (five) define error rate for data loss, out of sequence delivery, and corrupted data.
- Peak throughput classes (nine) specify expected max data rate from 8 Kbps to 2048 Kbps.
- Mean throughput classes (19) specify average data transmission rate.

Mobile Station (MS)

- GPRS MS = MT + TE
- MT ←→ BSS over the air.
- MT ←→ SGSN link
- TE: a computer attached to an MT
- 3 modes of MS operations
  - Class A: circuit + packet switched ← simultaneous
  - Class B: circuit OR packet switched ← one at a time, auto
  - Class C: packet ONLY

MM context info in a GPRS SIM

- IMSI ➔ uniquely identifies an MS. Used as the key to search the databases in VLR, HLR, and GSN.
- P-TMSI (similar to TMSI in GSM)
- Address of routing area (RA) where the MS resides.

PDP context in MS

- PDP type (<u>one of</u> X.25, PPP, IP)
- PDP address (e.g. IP address)
- PDP state (ACTIVE/INACTIVE)
- QoS profiles

BSS (Base Station Subsystem)

- BSS = BSC + many BTS
- BSC and BTS are modified to include a new unit: PCU (packet control unit)
- BSC
  - forwards circuit-switched data to MSC and packet-switched data to SGSN (through the PCU)
  - manage GPRS-related radio resources

BSS (some solutions)

- Nortel
  - GSM (BTS + BSC) + software upgrade
  - PCU functions are inplemented in a PCUSN.
  - PCUSN capability: 12 BSCs/cabinet
- Alcatel
  - PCU in a multifunctional server (A935 MFS)
  - Capability: 22 BSS
  - 480 activated GPRS channels/BSC
- Ericsson
  - One PCU/BSC. 512 BTS/PCU. 4K GPRS channels.

GPRS Support Node

- Serving GSN + Gateway GSN
- Functionalities of SGSN and GGSN can be
  - Combined in a physical node (Ericsson)
  - Distributed in separate nodes (Nortel, Cisco, Motorola, Alcatel)
- GSN: multiprocessor system
  - Hardware redundancy
  - Robust software ➔ uninterrupted operation

SGSN

- Role is similar to MSC/VLR in GSM.
  - Inter-SGSN routing area update, statistics collection, charging
  - Establishes an MM context (mobility info)
  - Establishes a PDP context for MS ←→ GGSN comm
  - SGSN maintains MM/PDP context info

GGSN

- Traditional gateway functionality
  - Mapping addresses, routing and tunneling packets
- GGSN maintains an activated PDP context for tunneling packets from MS to SGSN.
  - IMSI, PDP type+address, QoS profile, IP of SGSN, access point name for external data network.
- Support 5-48 K simultaneous data tunnels and 25-48 K simultaneously attached users.

GPRS Interfaces

- Um: MS ←→ BTS
- Gb: BSS ←→ SGSN
- Gn, Gp: Utilize the GPRS Tunneling Protocol (GTP)
- Gs: Databases in MSC/VLR ←→ SGSN
- Gi: GGSN ←→ PDN (IP, PPP)

Um Interface

- GPRS radio tech is based on GSM radio
- GPRS introduces a new logical ch structure.
- Radio channel structure
  - The physical channel dedicated to packet data traffic is called a packet data channel (PDCH).
  - A PDCH can be split into several packet data logical ch.
  - GPRS utilizes packet data traffic channel (PDTCH) for data transfer: 1-many and many-1 mappings.
  - Several packet common control channels (PCCCH) are introduced.

Um (Radio interface)

- PRACH (packet rand. access): MS → BTS
  - Used to initiate uplink transfer for data or signaling.
- Downlink PCCCH
  - Packet paging channel: pages an MS for both circuit and packet switched data.
  - PAGCH (access grant): for resource assignment.
  - Packet notification channel: Used to send a point-to-multipoint multicast (PTM-M) notification to a group of MSs prior to a PTM-M packet transfer
  - PBCCH (broadcast): System info specific for packet data

Um (Packet-dedicated control channels)

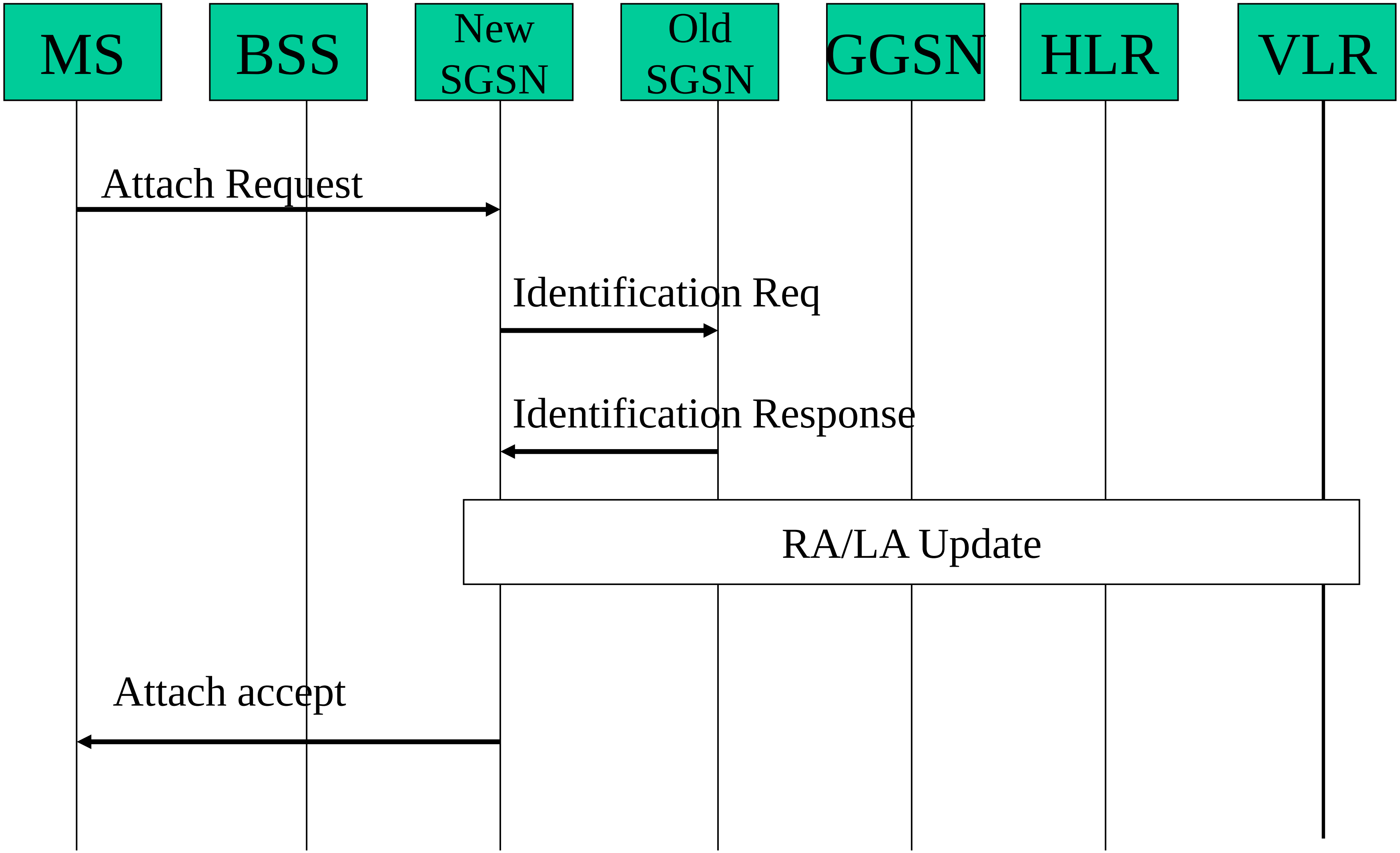
- PACCH (associated control ch):
  - Conveys signaling info: power control, resource assignment
  - MS involved in packet transfer can be paged for circuit-switched services on PACCH.

GPRS Procedures

- Attach/Detach procedures:
  - Establishes a logical link between MS ←→ SGSN
- PDP context procedures:
  - allow data transfer between MS and external world
- RA/LA update procedures
  - Tracks location of MS and reestablishes the link between MS ←→ SGSN

RA: Routing Area
LA: Location Area

Attach procedure



Detach procedure