Mobile Communication Systems

Part III- Cellular Networks

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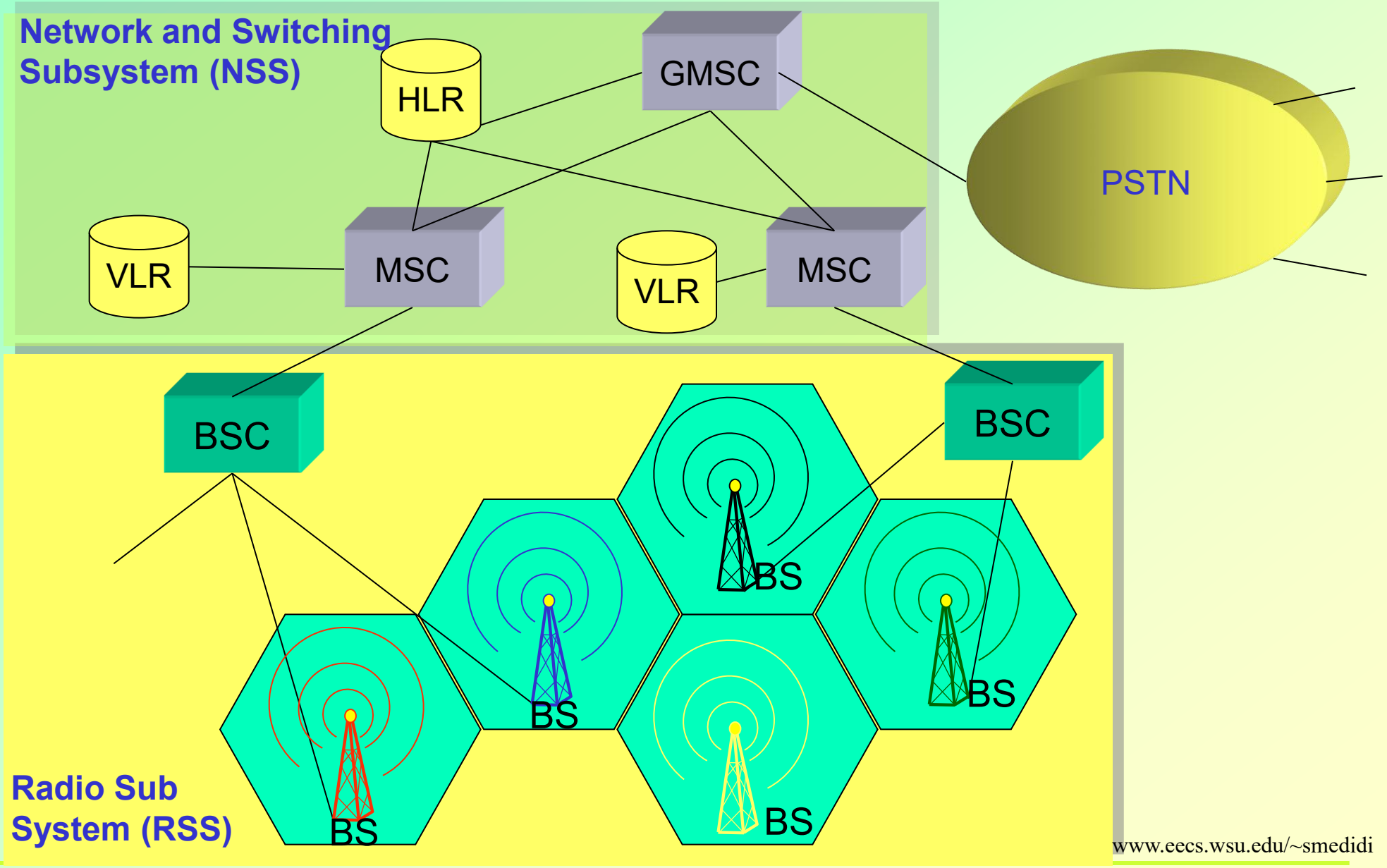
- Steps in controlled call between mobile users:
  - Handoff
- Mobile positioning
- Planning phase

Cellular Network



Cellular Network - RSS

- Base Station Subsystem (BSS):
  - Base Transceiver Station (BTS)
    - including transmitter, receiver, antenna
  - Base Station Controller (BSC)
    - switching between BTSs
    - controlling BTSs
    - network resources management
    - mapping of radio channels (U_m) onto terrestrial channels (A interface)
  - BSS = BSC + $\sum$ BTS + interconnection
- Mobile Stations (MS)

Cellular Network - Network and Switching Subsystem (NSS)

The main component of the public mobile network

- switching, mobility management, interconnection to other networks, system control

- Mobile Services Switching Center (MSC)
  - Connecting several BSC
  - Controls all connections via a separated network to/from a mobile terminal
- Home Location Register (HLR)
  - Central master database containing user data, permanent and semi-permanent data of all subscribers assigned to the HLR
- Visitor Location Register (VLR)
  - Local database for a subset of user data, including data about all user currently in the domain of the VLR

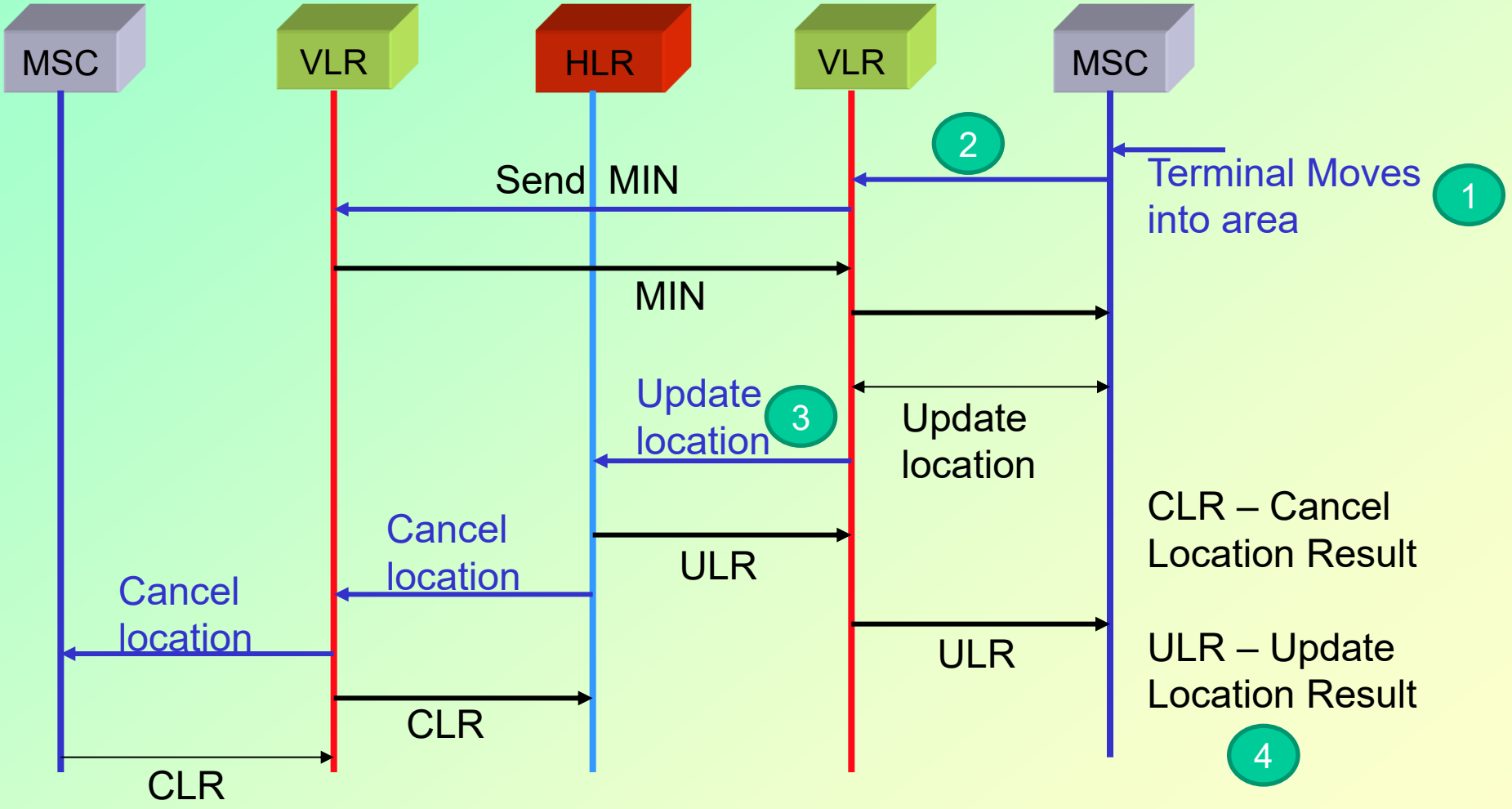
Cellular Network - MSC

- Its roles are:
  - Switching and additional functions for mobility support
  - network resources management
  - interworking functions via Gateway MSC (GMSC)
  - integration of several databases
- Its functions are:
  - 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

Cellular Network - Operation Subsystem

- Enables centralized operation, management, and maintenance of all cellular subsystems
- Authentication Center (AUC)
  - generates user specific authentication parameters on request of a VLR
  - authentication parameters used for authentication of mobile terminals and encryption of user data on the air interface within the system
- Equipment Identity Register (EIR) for Mobile Identification Number (MIN)
  - registers mobile stations and user rights
  - stolen or malfunctioning mobile stations can be locked and sometimes even localized
- Operation and Maintenance Center (OMC)
  - different control capabilities for the radio subsystem and the network subsystem

Cellular Network - Mobile Registration



Home Location Register (HLR)
Visitor Location Register (VLR)

Cellular Network - Mobile Terminated Call

1- Calling a mobile unit (MU)

2- Call forwarding 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

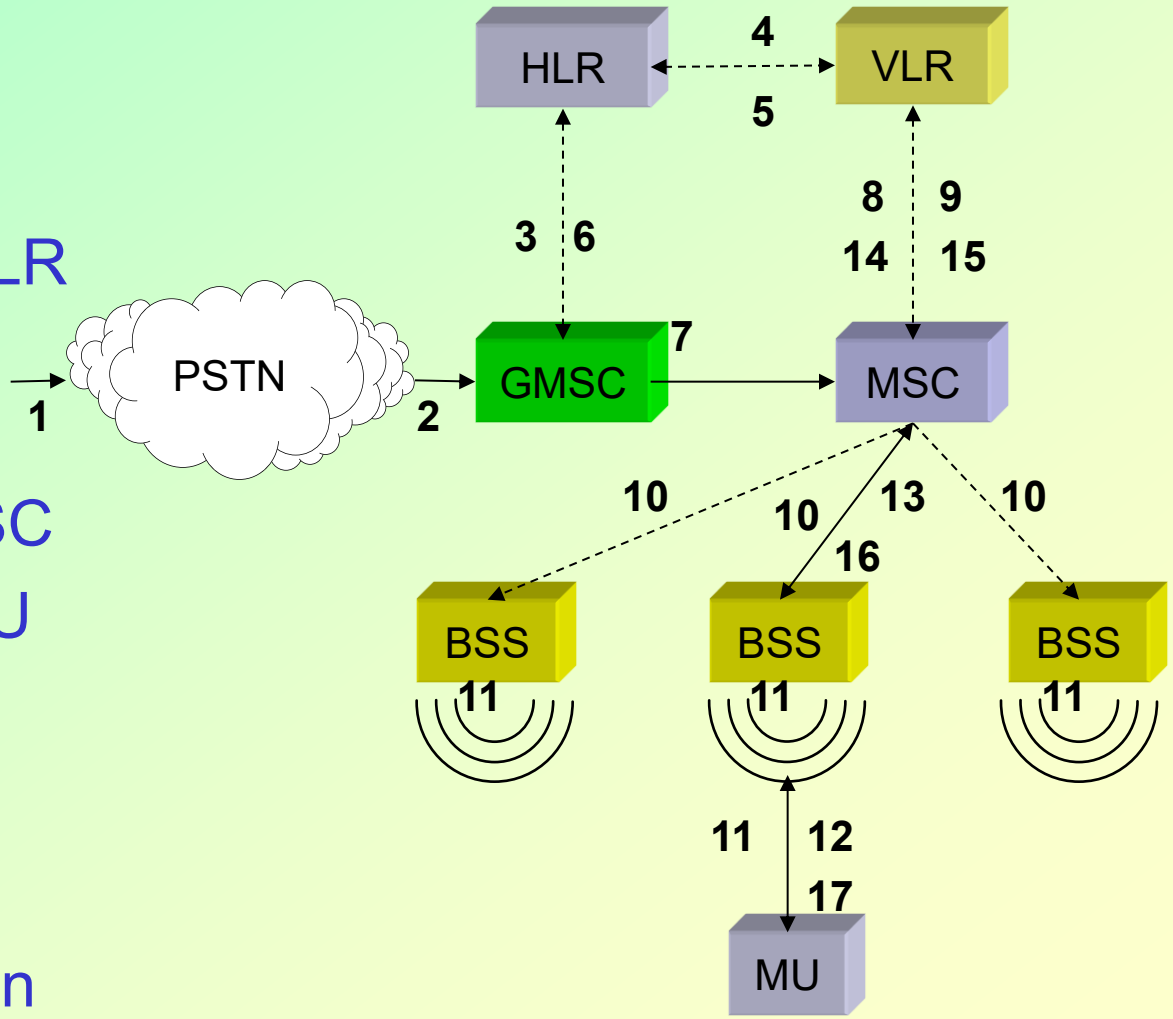
8&9- Get current status of MU

10&11- Paging of MSU

12&13- MU answers

14&15- Security checks

16&17- Call set up connection



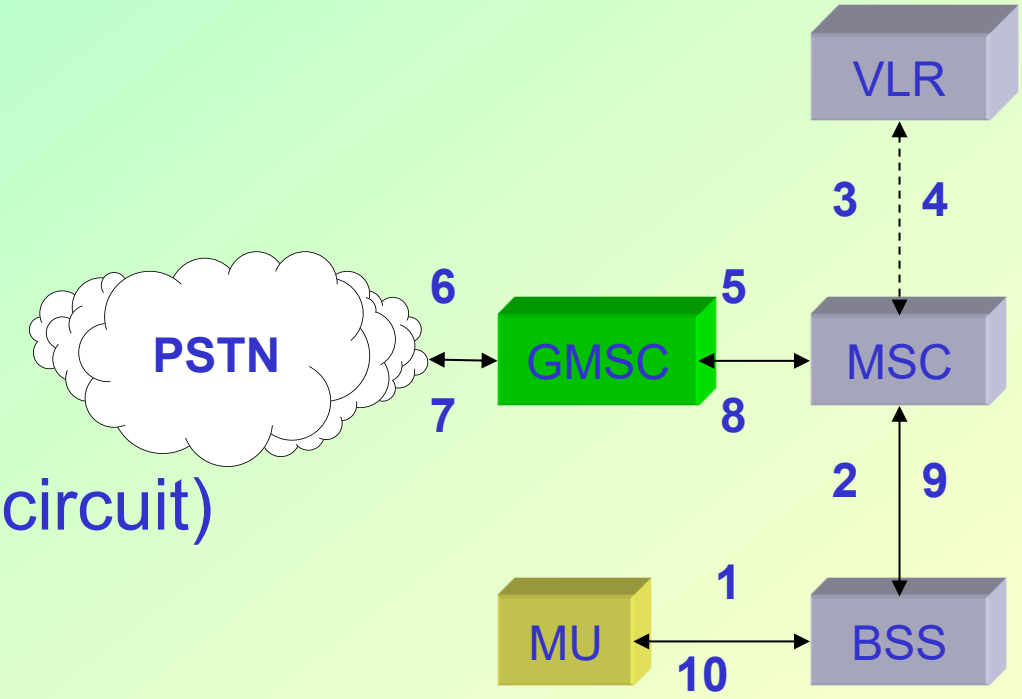
Cellular Network - Mobile Originated Call

1&2- Connection request

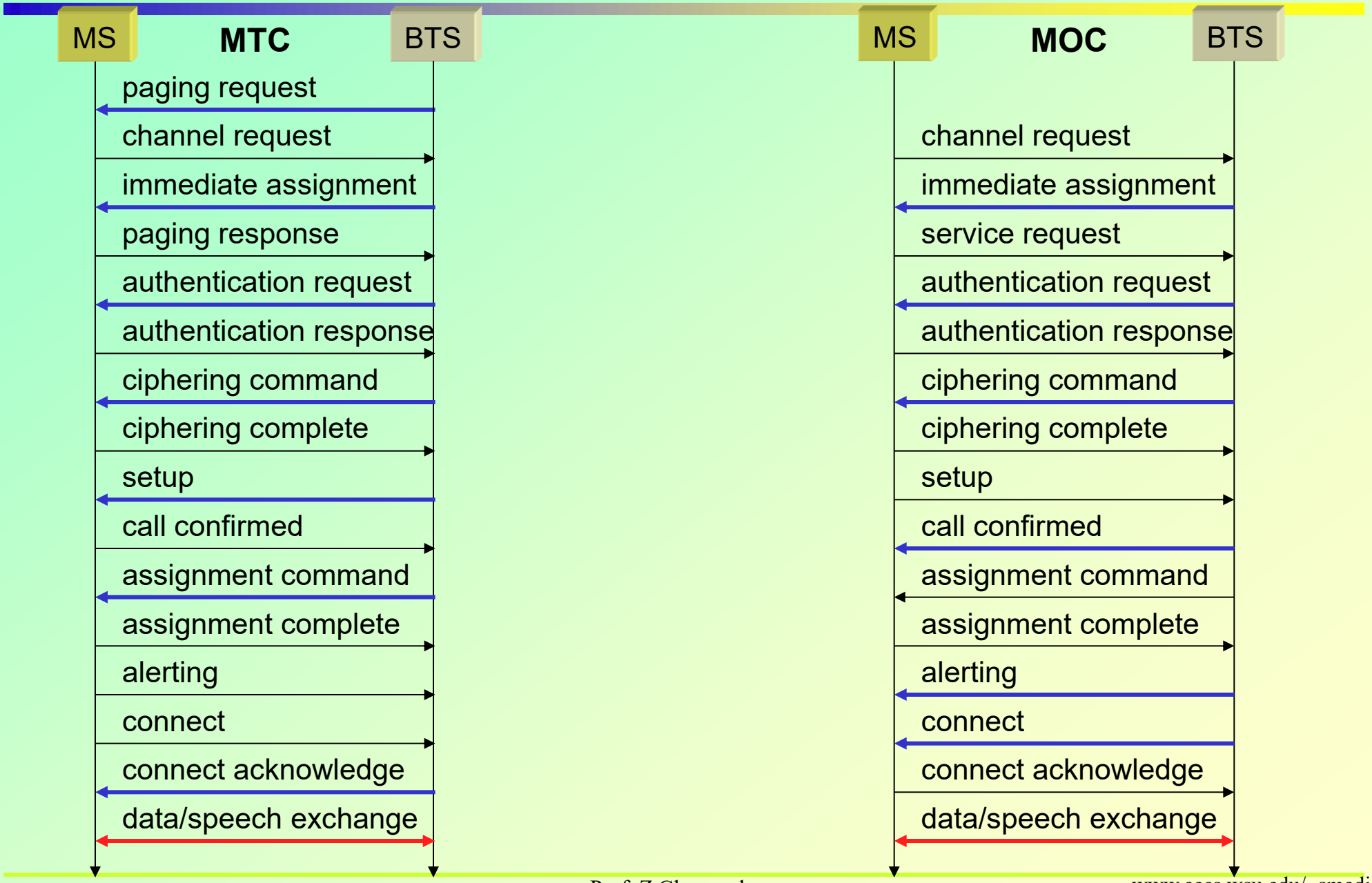
3&4- Security check

5-8- Check resources (free circuit)

9&10- Call set up



Cellular Network – MTC and MOC



Steps in Controlled Call between Mobile Users

- Mobile unit initialization
- Mobile-originated call
- Paging
- Call accepted
- Ongoing call
- **Handoff**

Additional functions

- Call blocking
- Call termination
- Call drop
- Calls to/from fixed and remote mobile subscriber

Handoff (Handover)

- In cellular networks, BSs have a limited reach, to achieve connectivity between mobile devices – which are mostly on the move – handover is necessary.
  - the base stations have to calculate exactly when a user is crossing the cell boundary.
  - Is done by mobile switching centre
  - could take **several seconds**, so if the mobile user is **moving too fast** the call will be **dropped**.
- Speed limit:
  - Analogue systems: 100 km/h
  - Digital systems: 300 km/h

  Some systems can complete handoff to the cruising speed of an airliner.

Handoff - Types

- No handoff
  - The most simple
  - A new call is made once a mobile unit has moved out of the range of a BS
  - Not common, since it takes up to 30 sec. to set up a new call
- Hard handoff
  - Mobile unit **needs to break its connection** with the BS before connecting to another BS – Channels have different frequencies. Thus, different radio channels are assigned during a handoff.
  - Not too reliable to establish a new call.
    - A cell could be already full or no cell being available at all.
    - **Repeated handoff** in areas with poor power reception within the same cell since no other BS can accept the call.
  - Results in a noticeable break in conversation especially when MU is moving fast between small cells
- Soft handoff
  - A new link is set-up with a BS in a new cell before the old one is dropped.
  - **Reliable**, calls are dropped only if MU is moving very fast.
  - A connection with two different BSs is rather difficult with existing systems. 3G overcomes this problem.

Handoff - Operation

- Based on periodical measurements of the **received signal strength** and **link quality** recorded by MU and passed on to the BS
- BS reports the hand-off request to BSC, and MSC
  - In 2G systems BSC handles the handover
- BS with the highest received signal level and an ideal channel is detected
- Identifying new BS –
  - The system switches the call to a stronger-frequency channel in a new site without interrupting the call or alerting the user
- Allocation of voice and control signals to channels associated with BS.
  - During a call, two parties are on one voice channel
- If there is no new BS, the hand-off fails and the call is terminated.

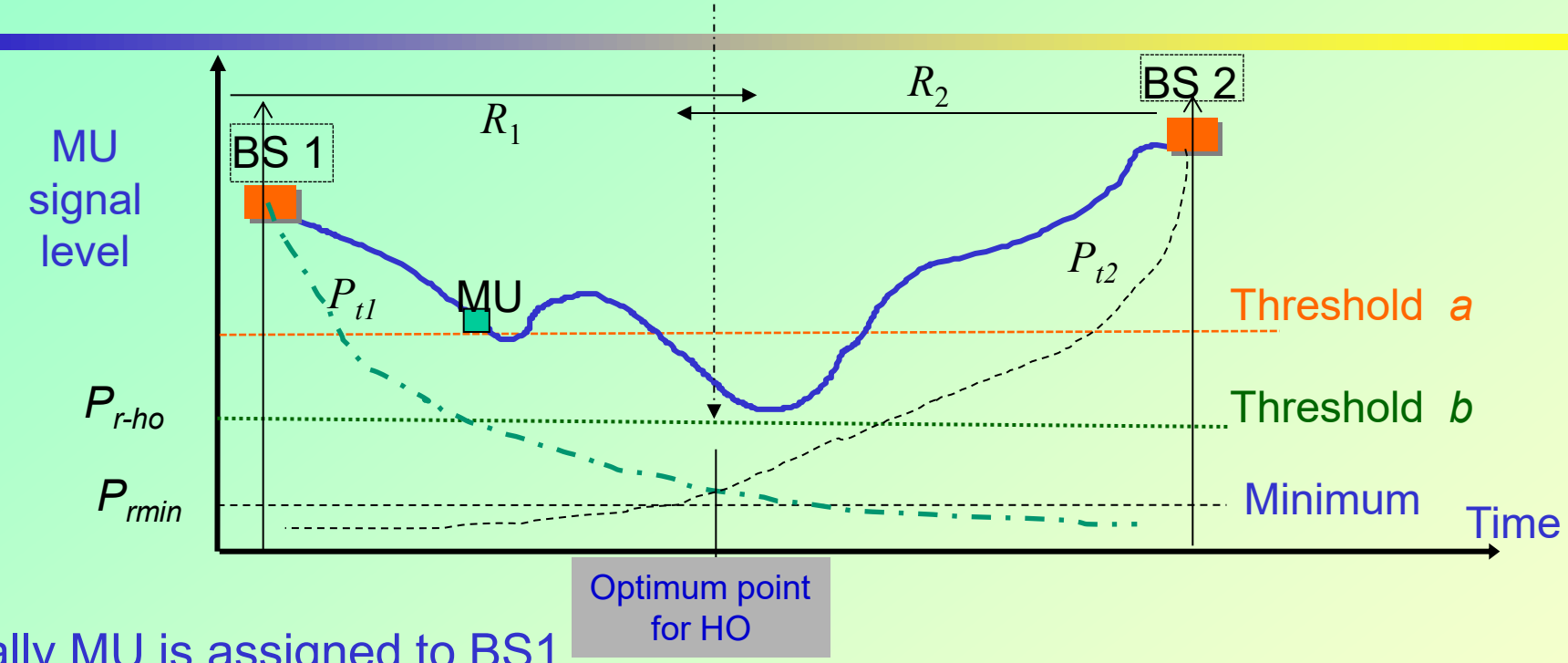
Handoff Operation - *contd.*

- Every mobile unit measures the received power from surrounding BSs and continually reports these levels to the serving BS
- Handoff is initiated when the received power from other than serving BS is higher by a certain level
- In deciding when to handoff, it is important to ensure:
  - the drop in the measured signal level is not due to momentary **FADING**
  - the mobile is moving away from the serving BS

  For this to happen the BS monitors the signal level for a certain period before a hand-off is initiated
- The length of time needed to decide if a hand-off is necessary depends:
  - on the speed at which the MU is moving

  If the slope of the short-term average received signal level in each time interval is steep, then hand-off should be made quickly

Handoff Operation - *contd.*



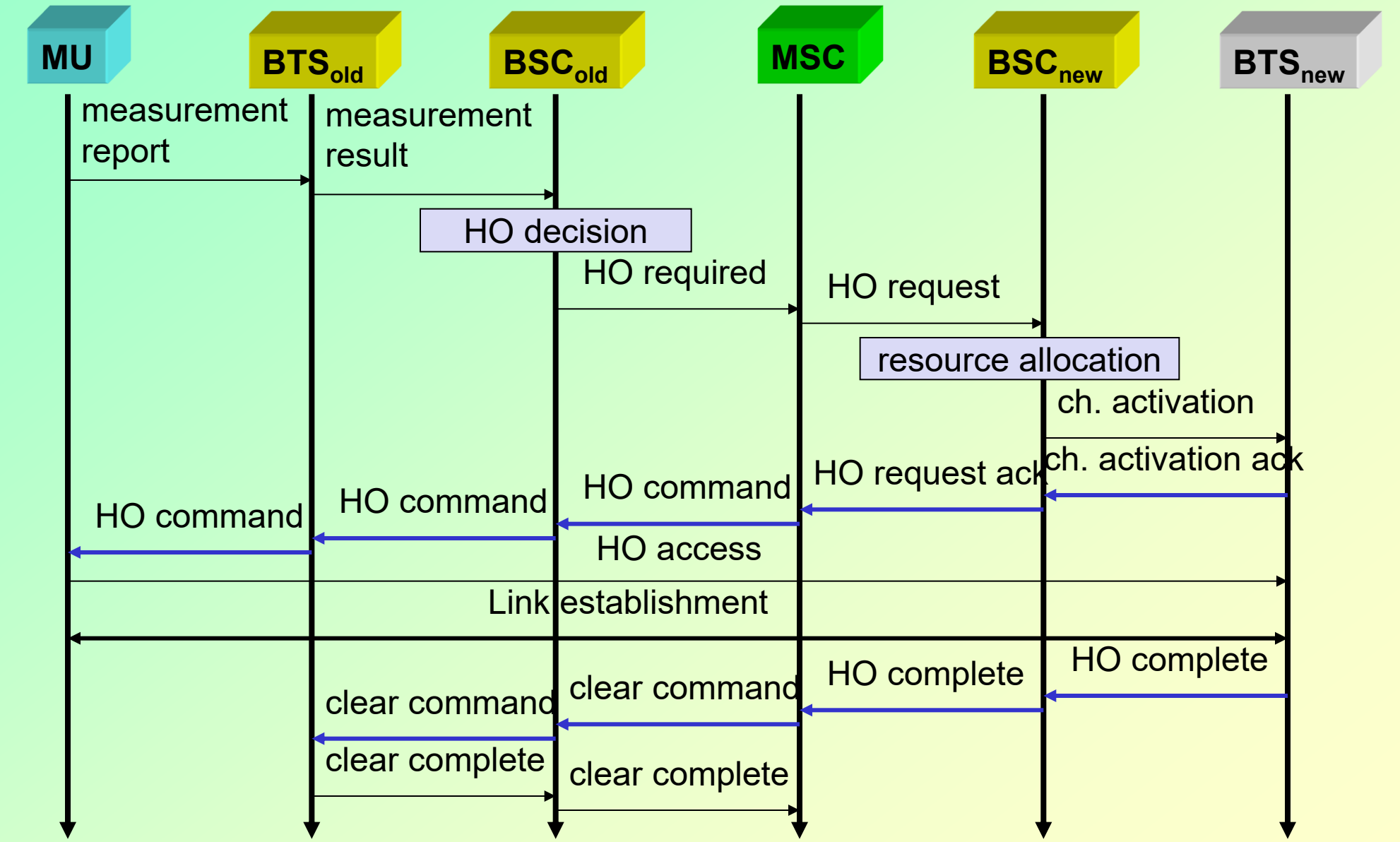
- Initially MU is assigned to BS1.
- For successful handoff an **OPTIMUM SIGNAL LEVEL** is required at which to initiate a handoff
- A call will be dropped when:
  - there is an excessive delay by the MSC in assigning a hand-off,
  - the Δ is set too small for the hand-off time in the system.

$$\Delta = P_{r\text{handoff}} - P_{r\text{min imum usable}}$$

$P_{r\text{-min}}$ = -90 dBm or -100 dBm
$P_{r\text{-hand}} > P_{r\text{-min}}$ by a few dB

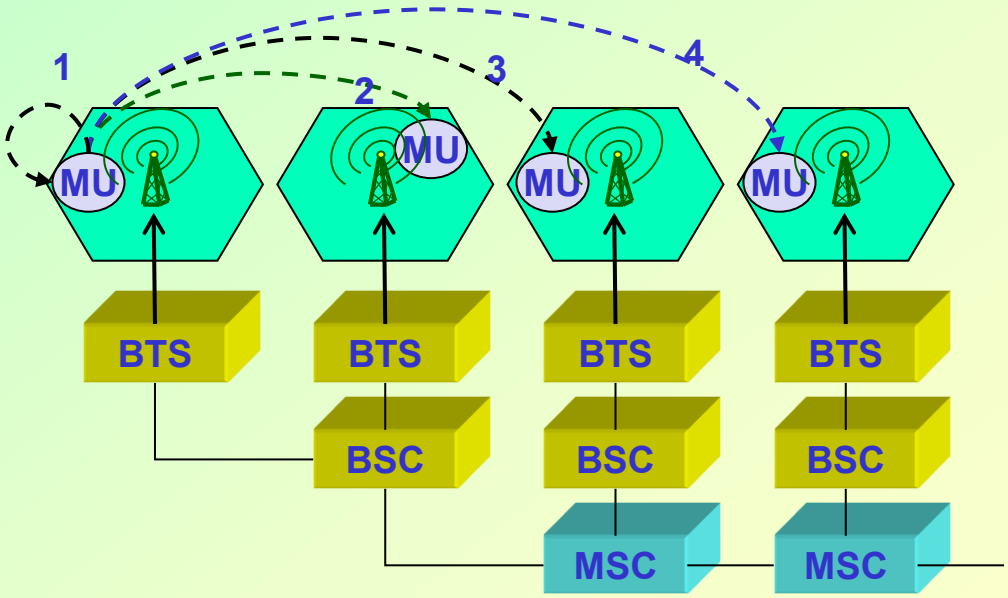
If Δ is too large, unnecessary hand-offs, which burden the MSC may occur

Handoff Procedure



Handoff - Types

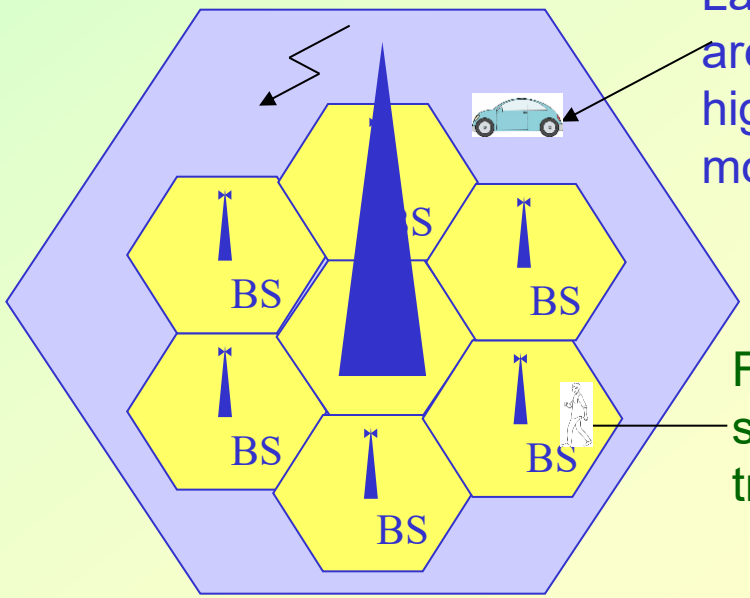
- **Intracell handover:** The mobile unit is switched from one channel to another within the cell area.
- **BTS-BTS handover:** The mobile station is switched from one Base Transceiver Station to another under the control of the same Base Station Controller.
- **BSC-BSC handover:** The mobile station switches between BTSs as well as between the BSCs at the same time. The handover is controlled by the target BSC.
- **MSC-MSC handover:** When switching between BTSs and BSCs, the mobile station may also switch from one MSC area to another. The handover is controlled by the target MSC.



Handoff - Practical Considerations

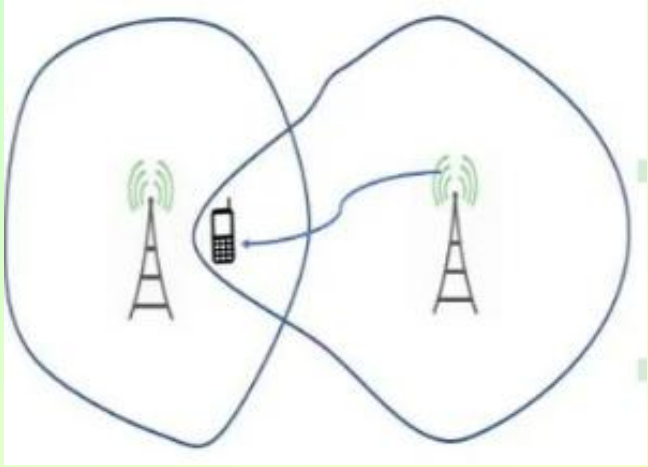
- Mobile speed throughout the coverage area
  - Cars takes seconds to pass through
  - Pedestrian may never need a handoff during a call
- Ability to obtain new cell site:
  - Service providers find it very difficult to obtain new physical cell site location in urban areas. Therefore, implement what is called the "**umbrella cell approach**", which minimizes handoffs for high-speed users

• Speed of mobile is estimated by the BS or MSC by monitoring the average signal strength
• BS may transfer high-speed mobile to the co-located microcell without MSC intervention



Handoff - Practical Considerations

- **Cell dragging**
  - Mainly in microcell systems
  - Occurs when there is a strong line-of-sight (LOS) radio path between the mobile unit and the BS, which changes slowly
  - For low-speed (people) users
  - As the mobile moves away from the BS, the average signal strength does not decay rapidly. This creates a few problems;
    - Handoff problem: The user is well outside the desired range, and with the signal strength within the cell still being strong, therefore no handoff.
    - Interference with adjacent cells and other cells
    - Management problem.



Handoff Performance Metrics

- Cell blocking probability – *probability of a new call being blocked*
- Call dropping probability – *probability that a call is terminated due to a handoff*
- Call completion probability – *probability that an admitted call is not dropped before it terminates*
- Probability of unsuccessful handoff – *probability that a handoff is executed while the reception conditions are inadequate*
- Handoff blocking probability – *probability that a handoff cannot be successfully completed*
- Handoff probability – *probability that a handoff occurs before call termination*
- Rate of handoff – number of handoffs per unit time
- Interruption duration – *duration of time during a handoff in which a mobile is not connected to either base station*
- Handoff delay – *distance the mobile moves from the point at which the handoff should occur to the point at which it does occur*

Mobile Positioning

- Mobile positioning refers to determining the position of the mobile device. Its purpose is to provide location-based services (LBS), including wireless emergency services
- Mobile location refers to the location estimate derived from the mobile positioning operation
- Methods:
  - Network based
  - Handset based positioning

Mobile Positioning – Network Based

- Uses mobile network + network-based position determination equipment (PDE)
  - SS7 and Mobile Positioning (SS7 is a communications protocol that provides signalling and control for various network services and capabilities.
    - The easiest method
      - MSC launch a SS7 message containing the cell of origin (COO) or cell ID (of the corresponding cell site currently serving the user).
    - Covering a large area, the COO may be used by LBS to approximate the location of the user.
    - A large degree of uncertainty that should be taken into account by the LBS application in term of required quality of service (QOS).
  - Network based PDE
  - Angle of Arrival Method - between the mobile phone and the cellular antenna.
  - Time of Arrival Method - of signals between the mobile phone and the cellular antenna
  - Radio Propagation Techniques - utilize a previously determined mapping of the radio frequency (RF) characteristics to determine an estimate of the mobile device position
  - Hybrid Methods

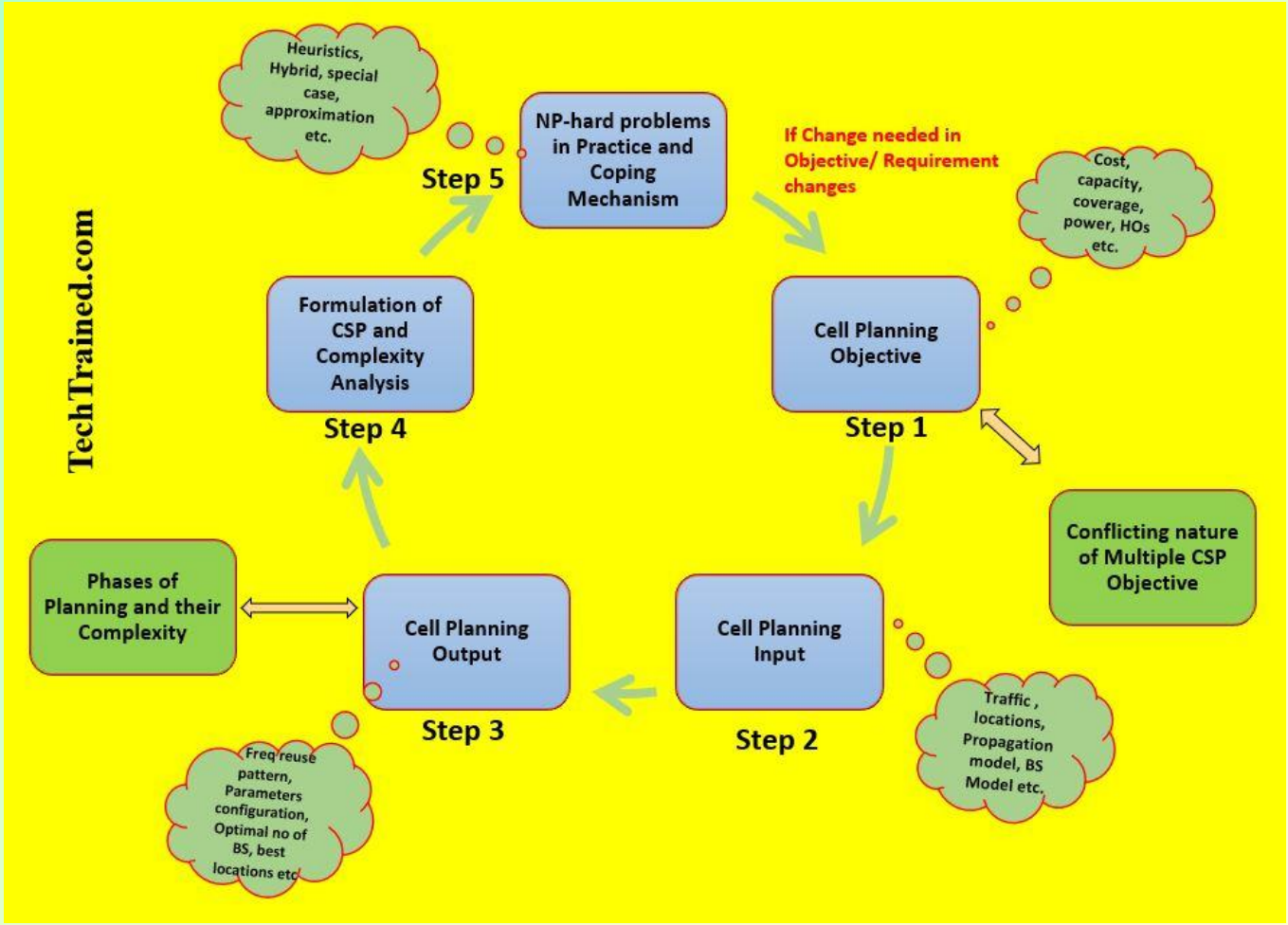
Mobile Positioning – Handset Based

- Subscriber Identity Module (SIM) Toolkit
  - Positioning information may be as approximate as COO or more precise through additional means such as use of the mobile network operation called timing advance (TA) or a procedure called network measurement report (NMR).
  - SIM toolkit is a good technique to obtain position information while the mobile device is in the idle state.
- Enhanced Observed Time Difference (E-OTD)
- Global Positioning System (GPS)
  - The most accurate (when satellites are acquired/available), but is often enhanced by additional network equipment.
- Mobile IN Technologies

Cellular Network– Planning Phases

The goal is to provide one or more of the following outputs:

- Optimal number of base stations
- Best locations to install BSs
- Types of BSs optimal for each location
- System specs.: such as:
  - antenna height
  - number of sectors
  - sector orientation
  - Tilt
  - power etc.
- Frequency reuse pattern
- Capacity dimensioning For example number of carriers or carrier components per sector



https://www.techtrained.com/what-are-the-typical-cellular-network-planning-phases/

Summary

- Cellular Networks
- Handoff Strategies
- Power allocations

Next Lecture

Interference