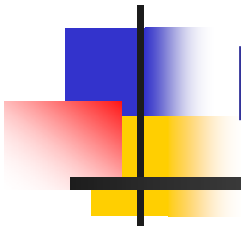
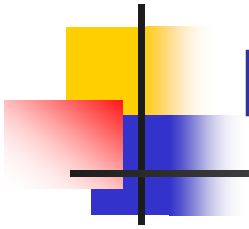


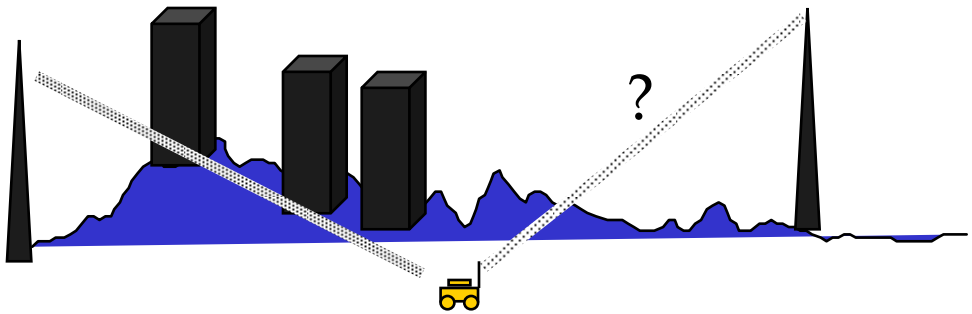
Base station selection - Handover



Radio Resource Allocation problem

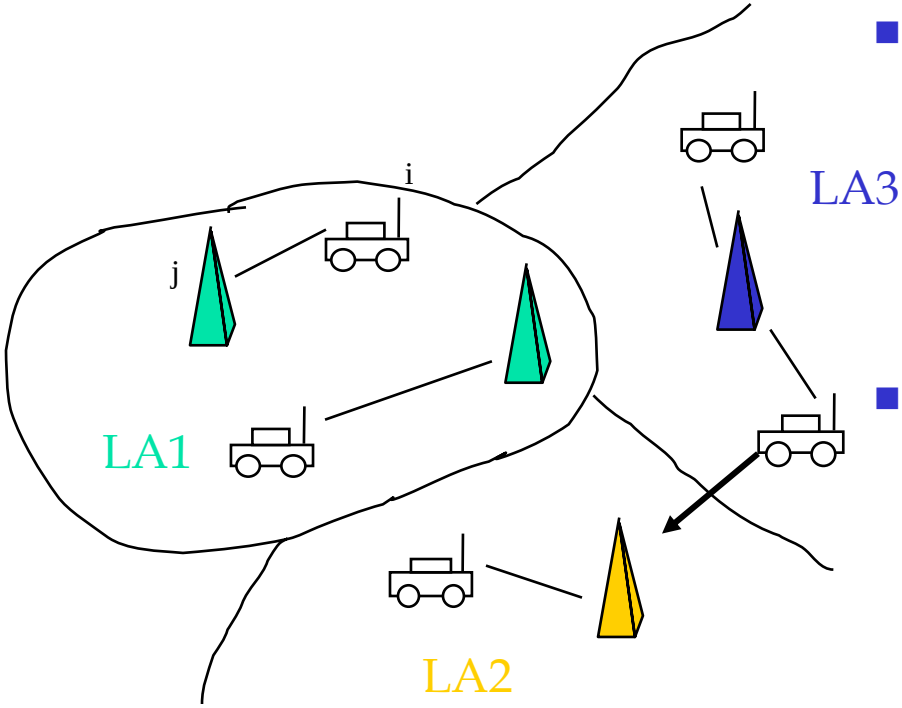
- To each active terminal assign
  - Base station
  - Waveform (“Channel”)
  - Transmitter power
- such that Link Quality & power constraints are satisfied for as many terminals as possible

Base Station Assignment

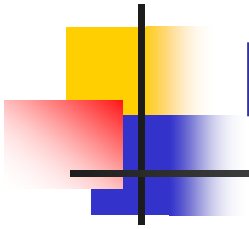


- Mobility management
  - While inactive
    - Locating
    - Paging
  - While connection in progress (Handoff)
    - Base station selection based on signal quality measurements

Mobility Management - Roaming

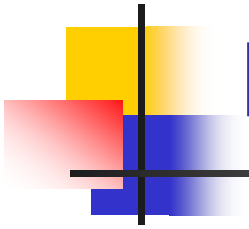


- Roaming signaling
  - Terminal On/off
  - Location area updates
  - A fixed network issue
  - Also it can be related to RRM
- Trade off
  - Large LA:s
    - Extensive paging
    - Limited update signaling
  - Small LA:s
    - Rapid, efficient paging
    - Extensive update signaling



Handoff

- Handoff decision algorithm
  - Decides when & where to handoff
  - Mobile/Network controlled decisions
- Handoff execution
  - Resource management issues
  - Handoff signaling handshaking



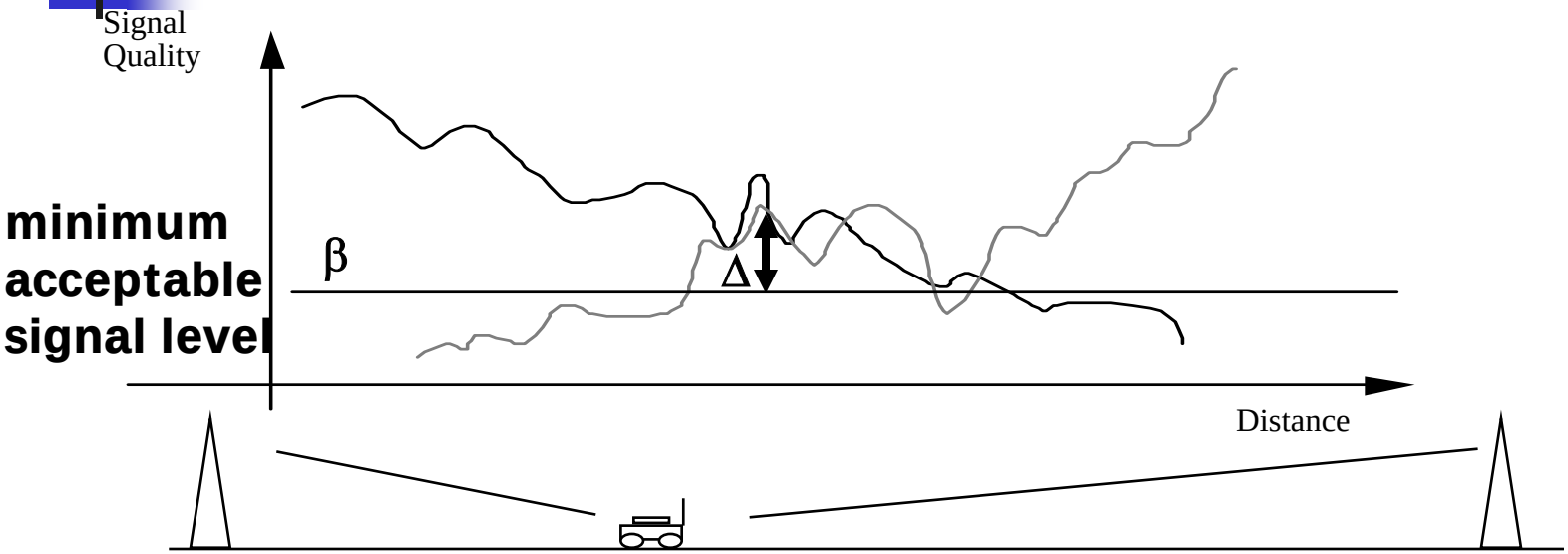
Handoff control

- Mobile Assisted Handoff (MAHO)
  - Mobile measures & reports signal quality
  - Fixed network (typically BSC) makes handoff decision and initiates handoff
- Mobile Controlled Handoff (MCHO)
  - Mobile measures & reports signal quality
  - Mobile makes handoff decision and initiates handoff

Handoff decision algorithms

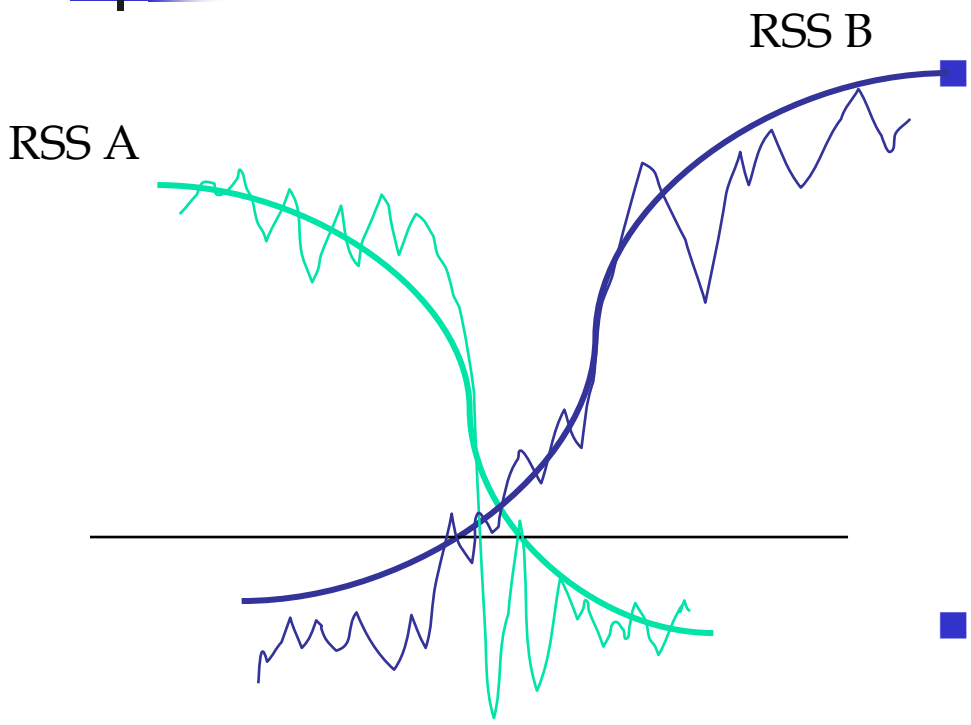
- Signal-level (RSS) based
  - “Detecting cell-boundaries”
  - Designed for low capacity macrocellular system
- C/I - based algorithms
  - Efficient in micro cell environments
  - Note: Up/Down link measurement can yield different results

RSS based handoff



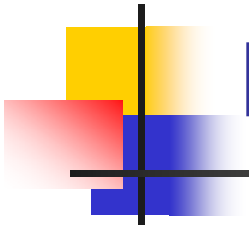
- Mobile measures & reports signal level
- Decisions based on smoothed signal recordings

RSS based Handoff (cont.)



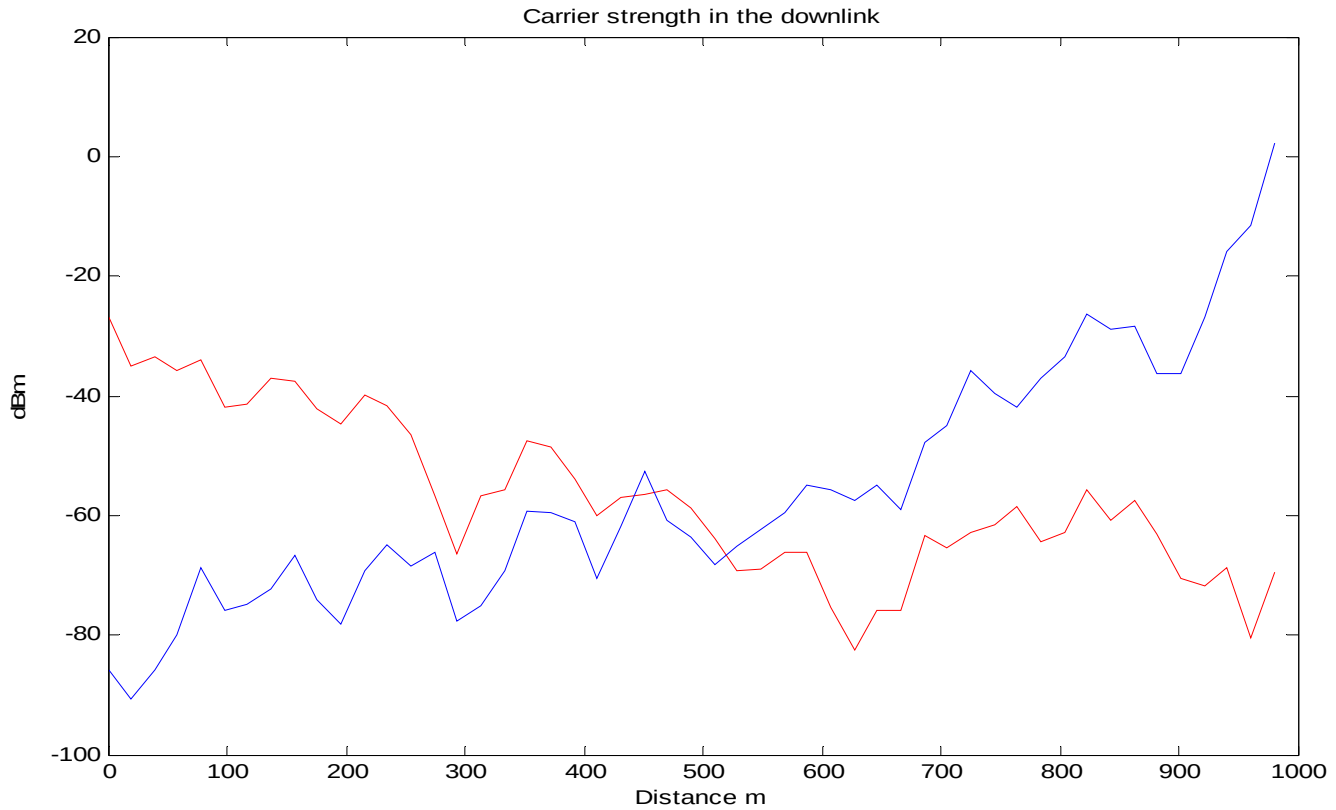
- "Smoothing"
  - + Avoids "flip-flopping"
  - (i.e. excess signaling)
  - - Slow decision process

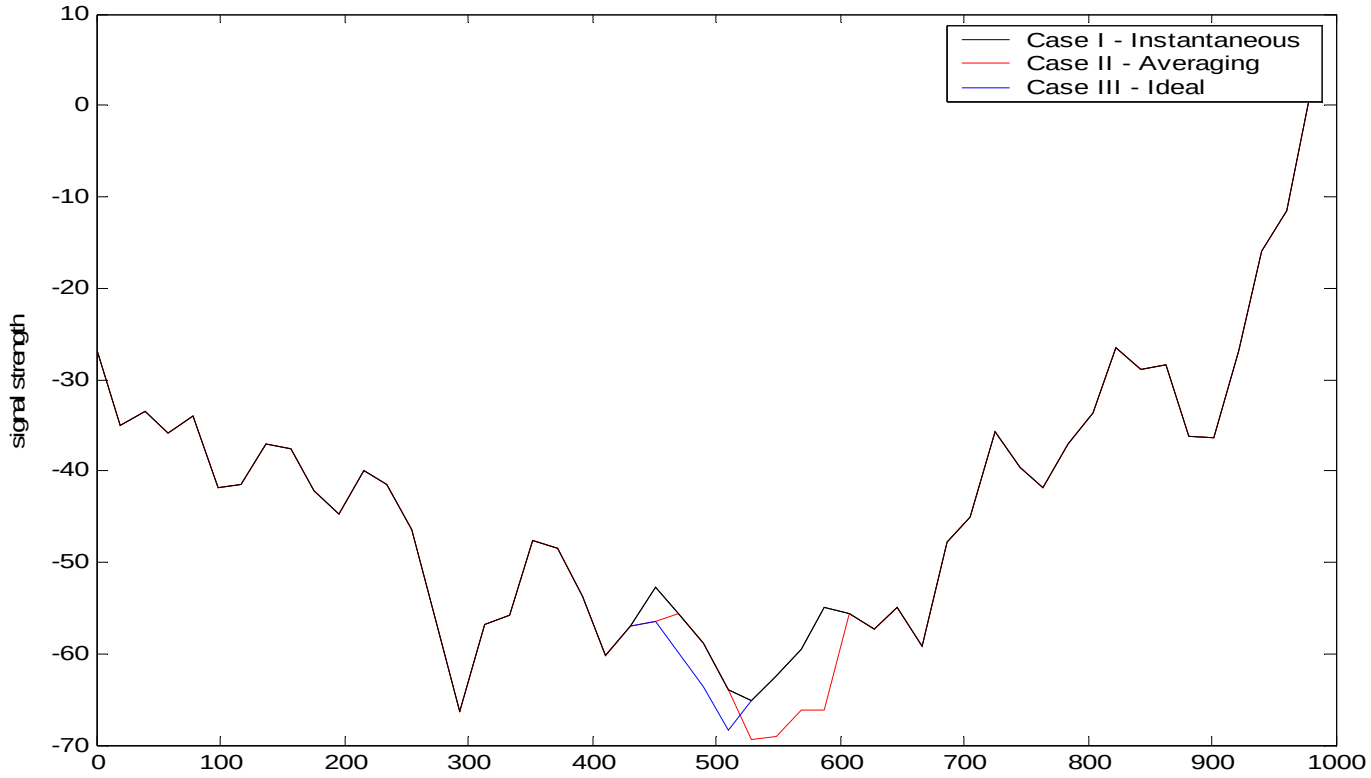
  (may miss handoff when required)
- Non-linear operations:
  - Hysteresis



Example 5.1

- I. Instantaneous handoff: The access port with the
- highest signal level is chosen in any sample point
- II. Averaging: The maximum average signal level (over the last 10 samples) determine the selected access port.
- III. “Ideal” averaging: The true expected value of the signal level is assumed to be known and the access port with the highest expected signal level is selected.

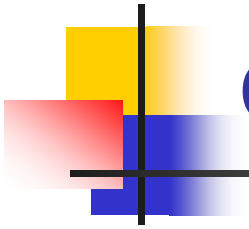

Carrier strength in the downlink
20
0
-20
-40
-60
-80
-100
dBm
0
100
200
300
400
500
600
700
800
900
1000
Distance m


Case I - Instantaneous
Case II - Averaging
Case III - Ideal
signal strength
10
0
-10
-20
-30
-40
-50
-60
-70
0
100
200
300
400
500
600
700
800
900
1000

Outage probability and expected number of handoffs

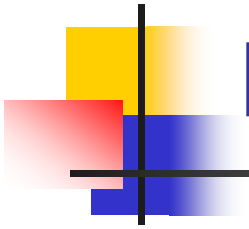
- P_{out} = the probability that the received signal is below the threshold at some point in the handoff process.
- R_{HO} = expected number of handoffs

algorithm	P_{out}			R_{HO}
	$\Delta = 10$ dB	$\Delta = 5$ dB	$\Delta = 0$ dB	
I	0.3%	2.4%	9%	7.6
II	1.4%	5%	13%	1.8
III	2.0%	6%	14%	1



Observations on Example 5.1 results

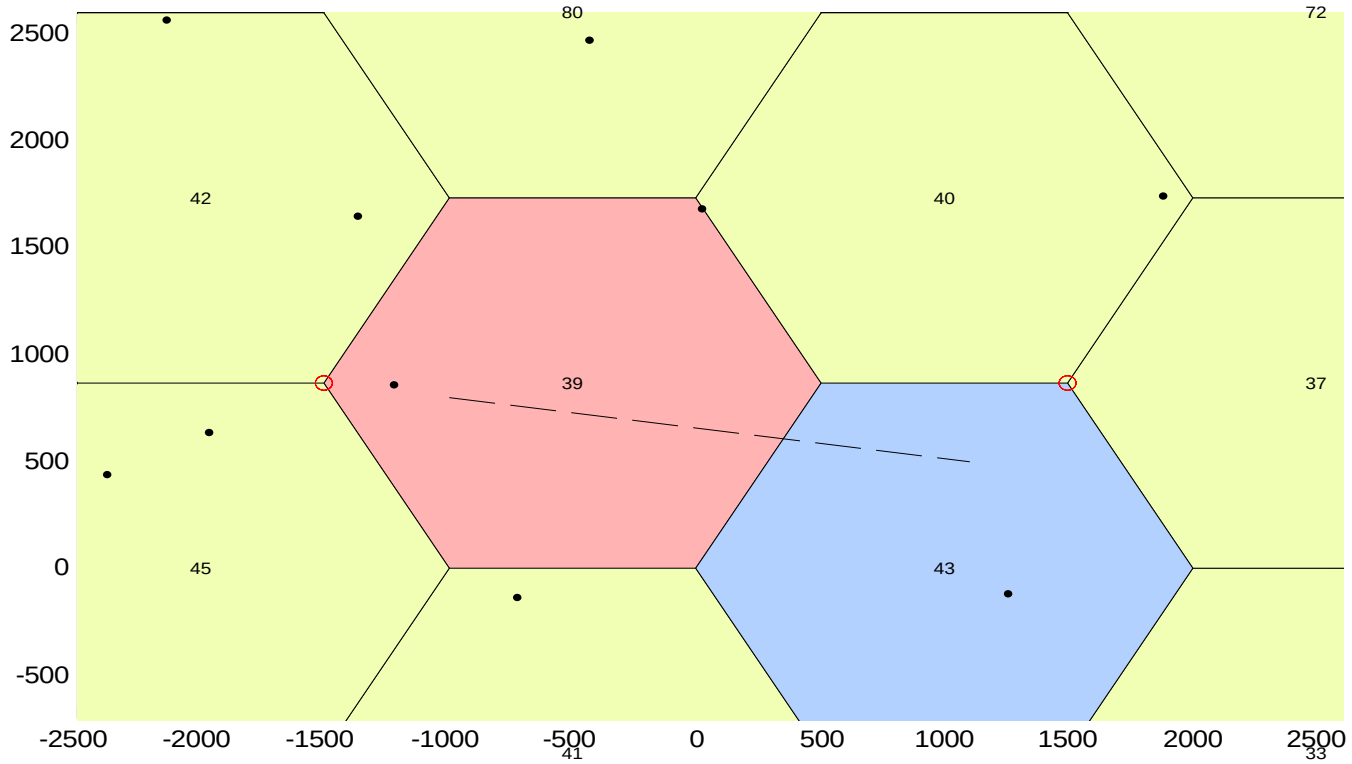
- The importance of handoff margin Δ
- The strongest instantaneous signal provides the best results
- The inversely proportional relation between P_{out} and R_{HO}
- Better signal-level estimation techniques are needed
  - A common strategy employed in the literature is to design a prediction filter to predict these situations
- High number of handoffs means flip-flopping back and forth between access ports



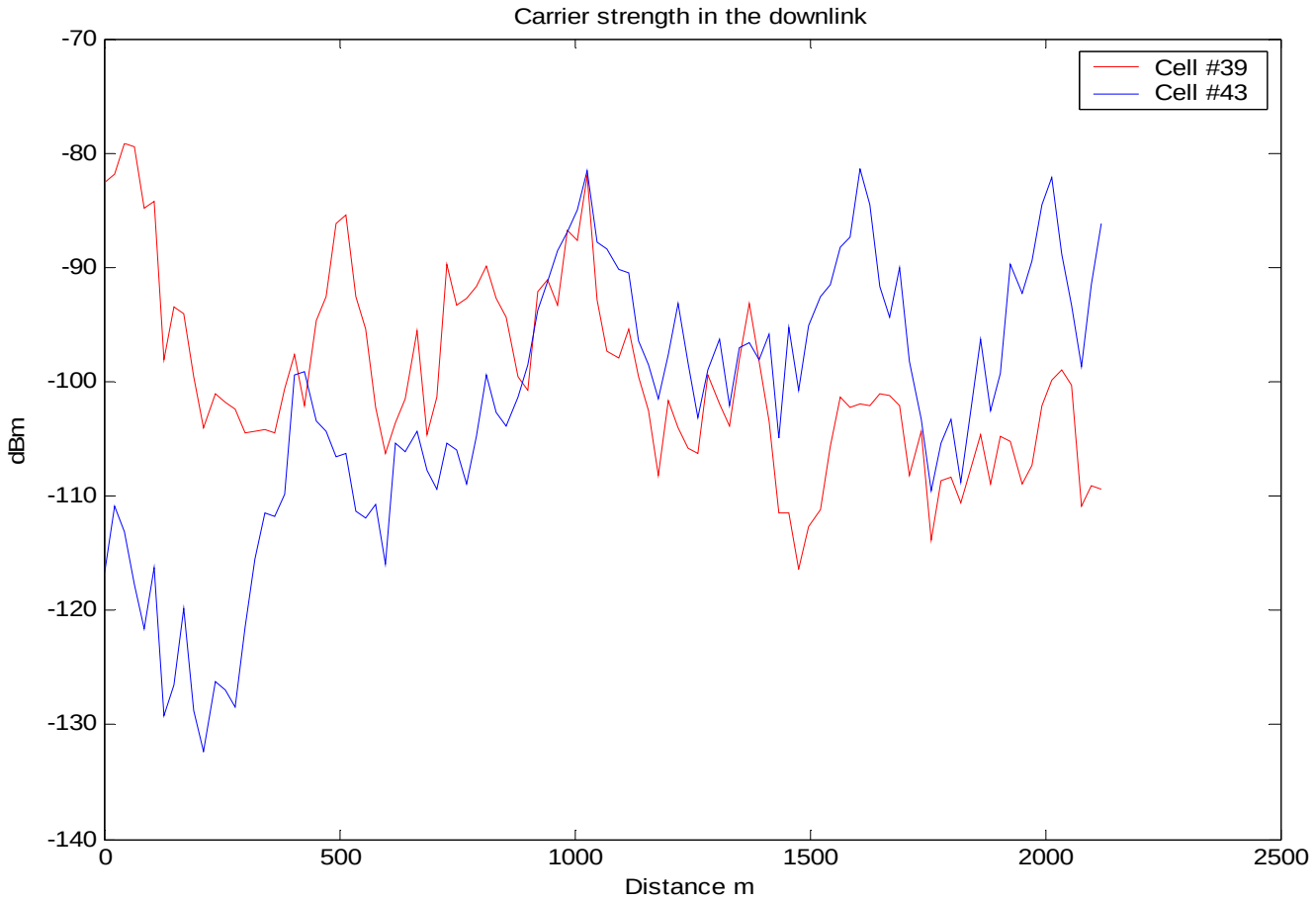
Example 5.2

- Similar to 5.1 but the trajectory is different. Also, the example sheds the light on a different handoff decision making strategy.

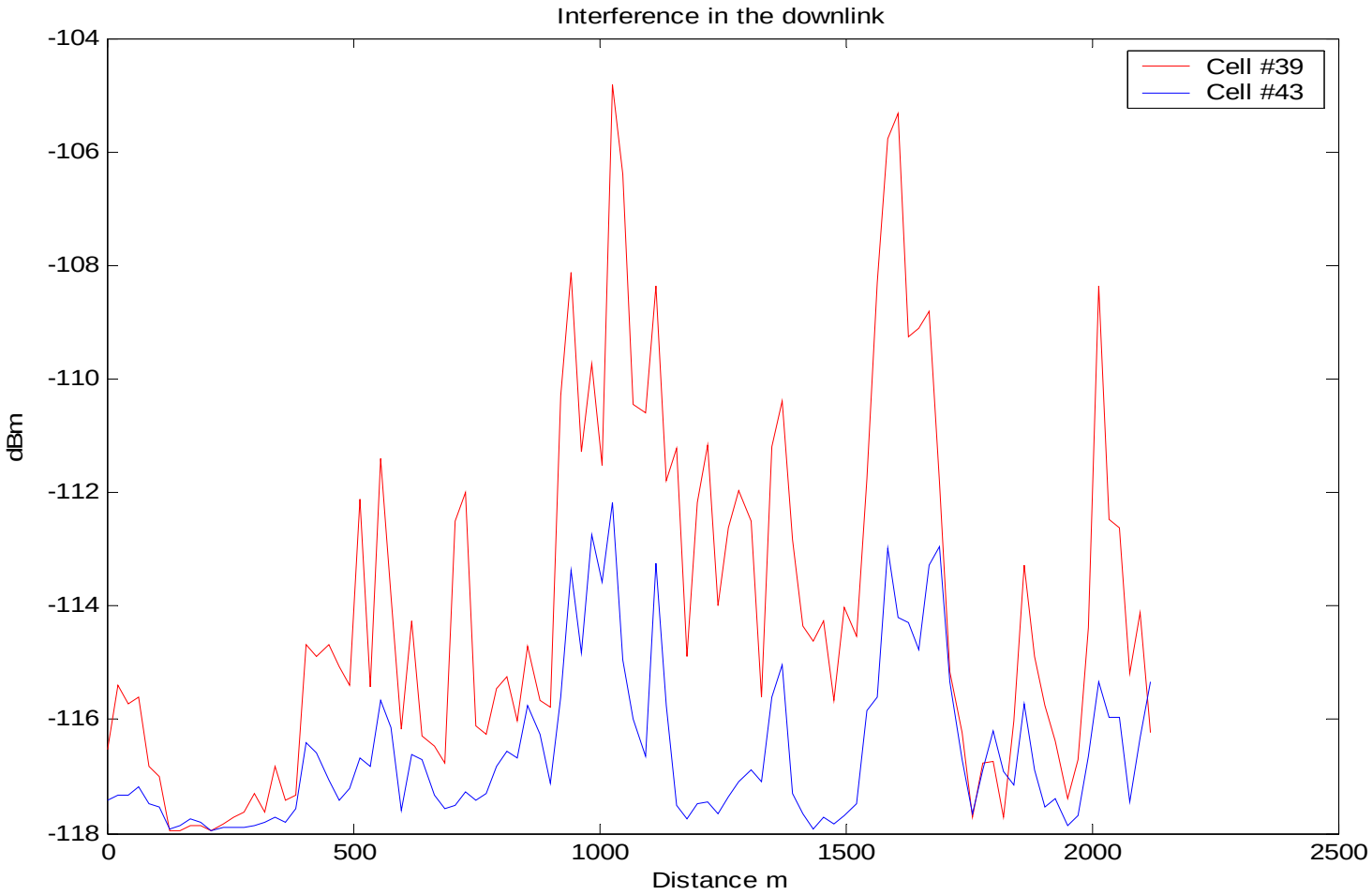
Example 5.2 Trajectory (Cont.)



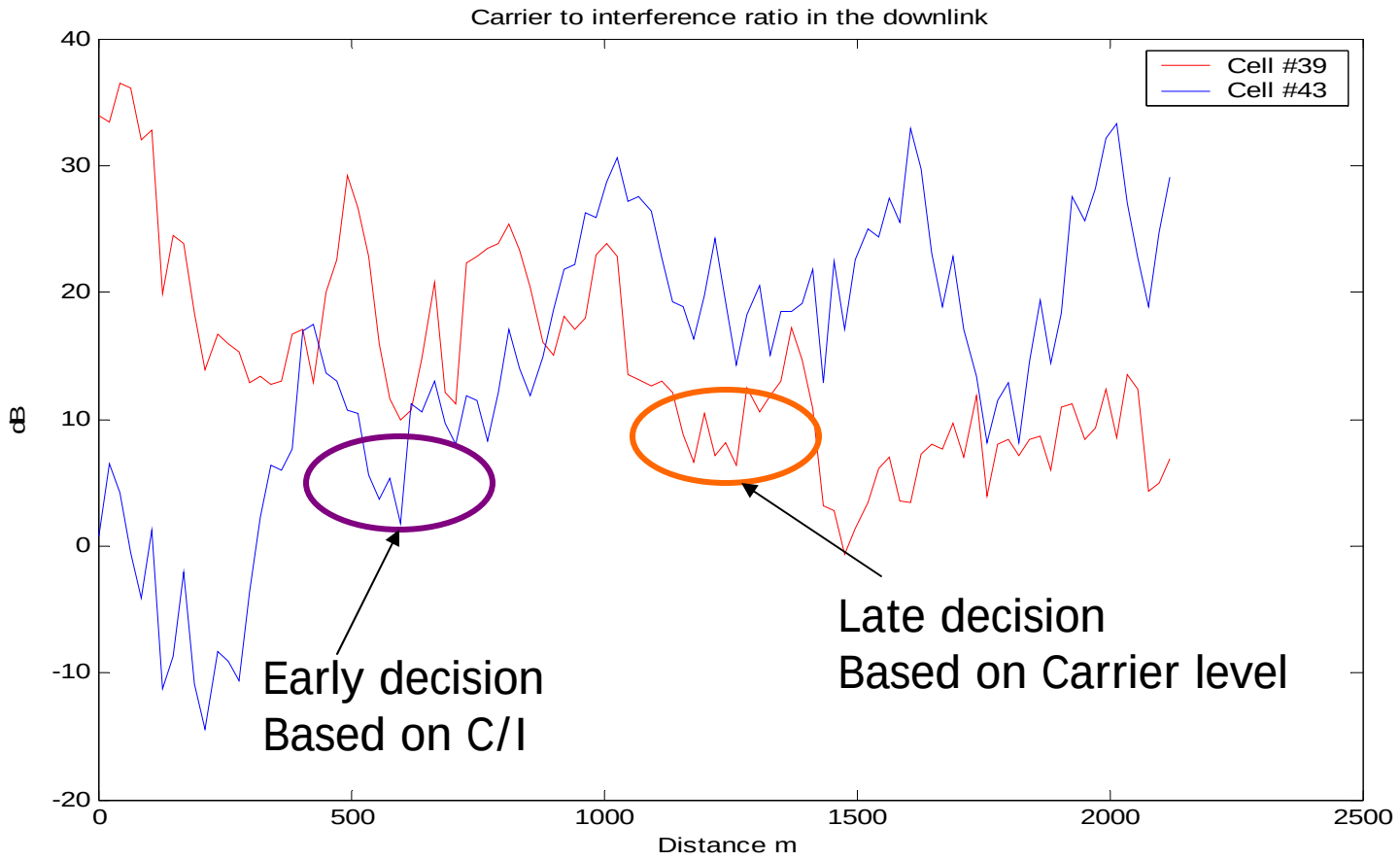
Example 5.2 (Cont.)



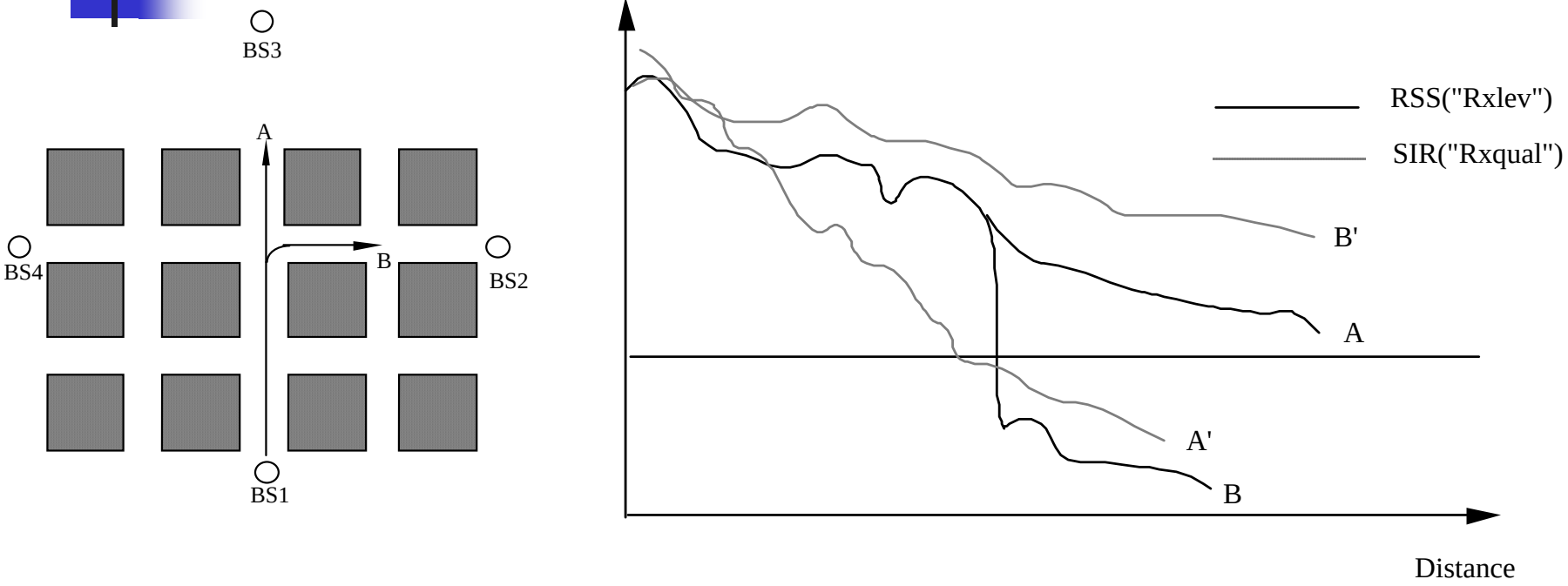
Example 5.2 (Cont.)



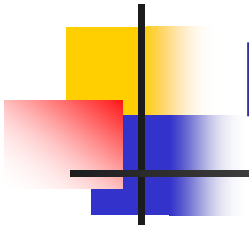
Example 5.2 (Cont.)



Problems with RSS Handoff- Microcells



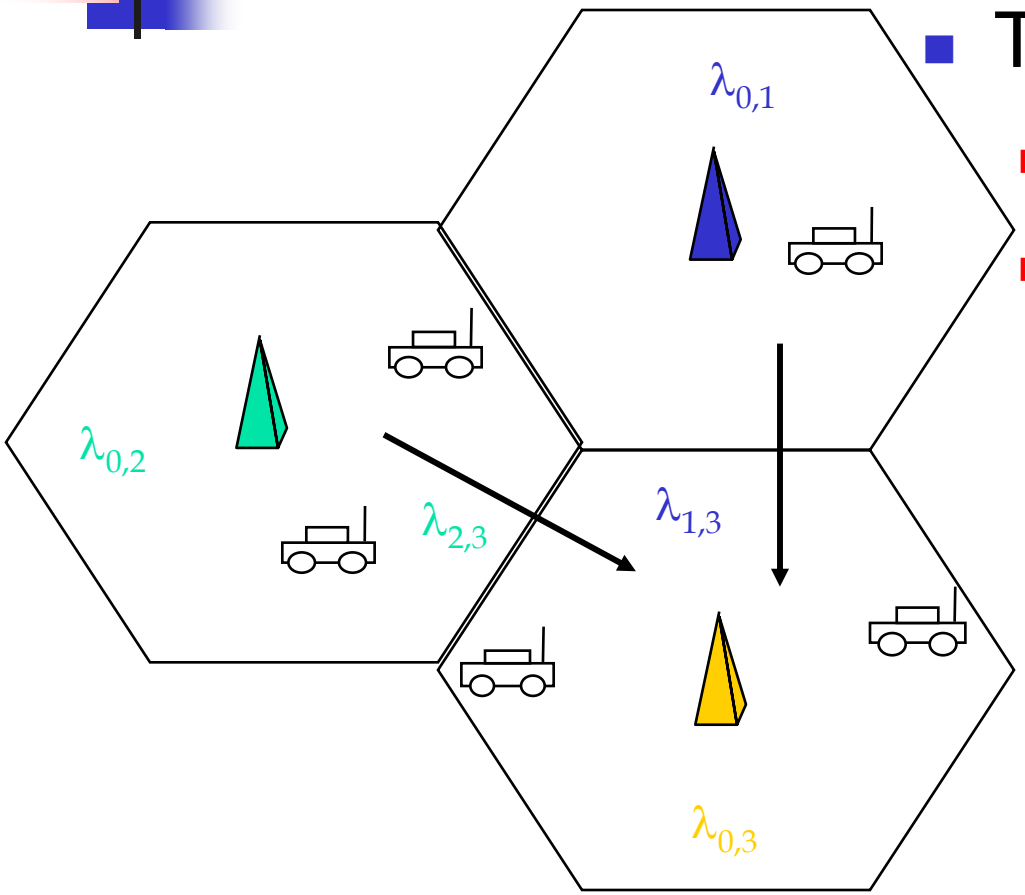
- Rapid RSS level changes at street corners
- RSS is not a good predictor for the SIR !



Handoff execution

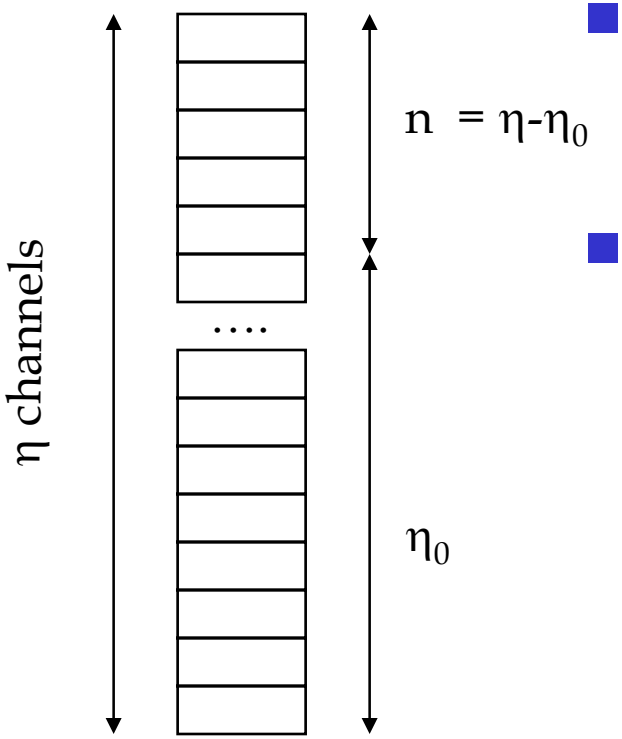
- Signaling procedure
  - Reach agreement on:
    - Which base station ?
    - Which waveform (frequency, timeslot, code etc) ?
    - Authentication
  - Fast & Reliable:
    - Performed under critical SIR conditions
    - Minimize loss of circuit switched data
- Reservation of resources for handoff
  - Is there a channel available in the receiving cell/base station

Handoff traffic



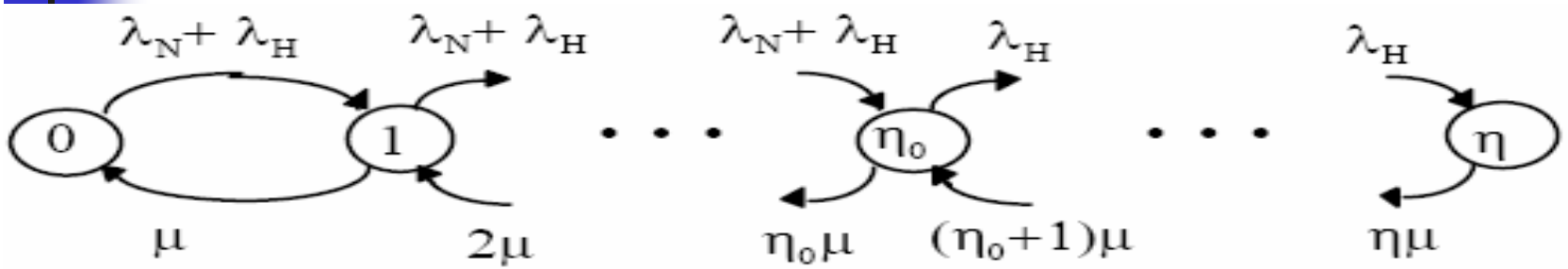
- Two fundamental issues:
  - Availability of resources
  - Effects of adding this user on the new BS traffic

Handoff Resource Management



- Priority given to
  - handoff calls before new calls
- Reservation technique:
  - Keep n channels for handoff calls only
  - Block new calls whenever only n channels remain idle

Handoff priority analysis



Local balance equation

$$(\lambda_N + \lambda_H)\, p_{k-1} = k\mu\, p_k, \quad 1 \le k \le \eta_o$$

$$\lambda_H\, p_{k-1} = k\mu\, p_k, \quad \eta_o < k \le \eta$$

solving these equations yields

$$p_k = \begin{cases} p_o \dfrac{(\lambda_N + \lambda_H)^k}{\mu^k k!}, & k \le \eta_o \\ p_o \dfrac{(\lambda_N + \lambda_H)^{\eta_o} (\lambda_H)^{k-\eta_o}}{\mu^k k!}, & \eta_o < k \le \eta \end{cases}$$

Handoff priority analysis

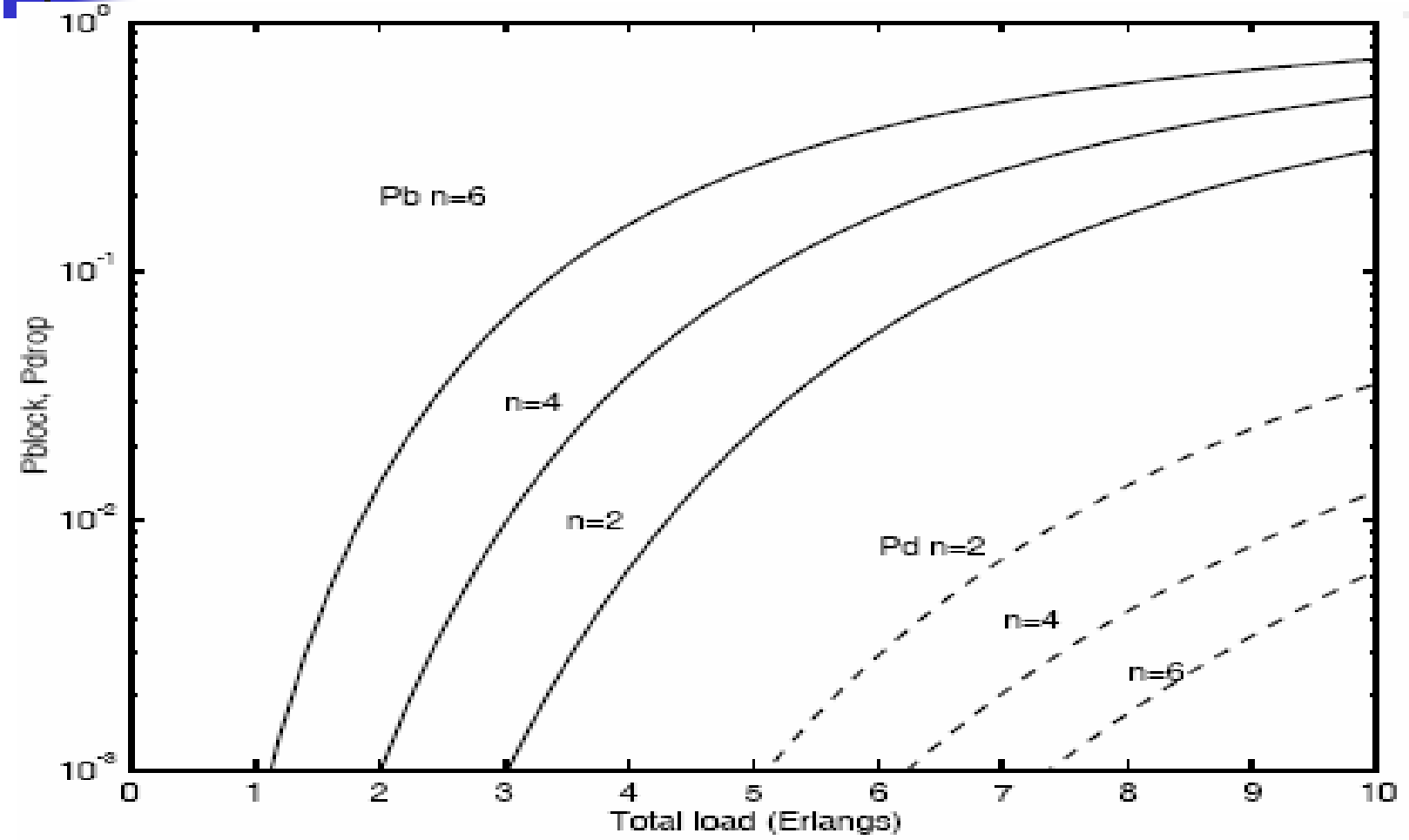
- Blocking probability:

$$P_{block} = \Pr\{ k \geq \eta_o \} = \sum_{k=\eta_o}^{\eta} p_k$$

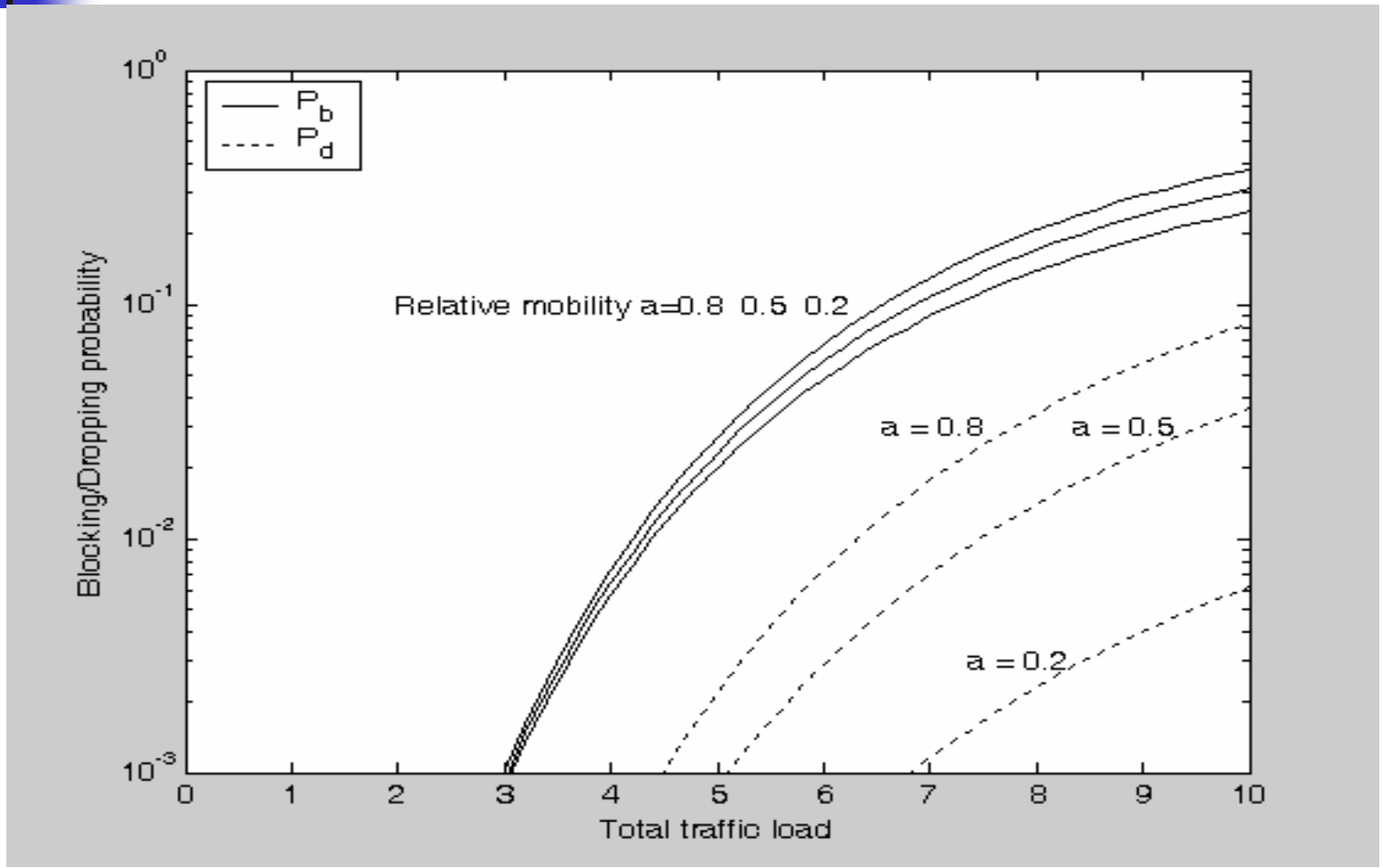
- Handoff dropping probabilities

$$P_{drop} = \Pr\{k = \eta\} = p_\eta$$

Handoff priority analysis



Handoff priority analysis



Definitions

- Relative mobility (i.e. handoffs per call)

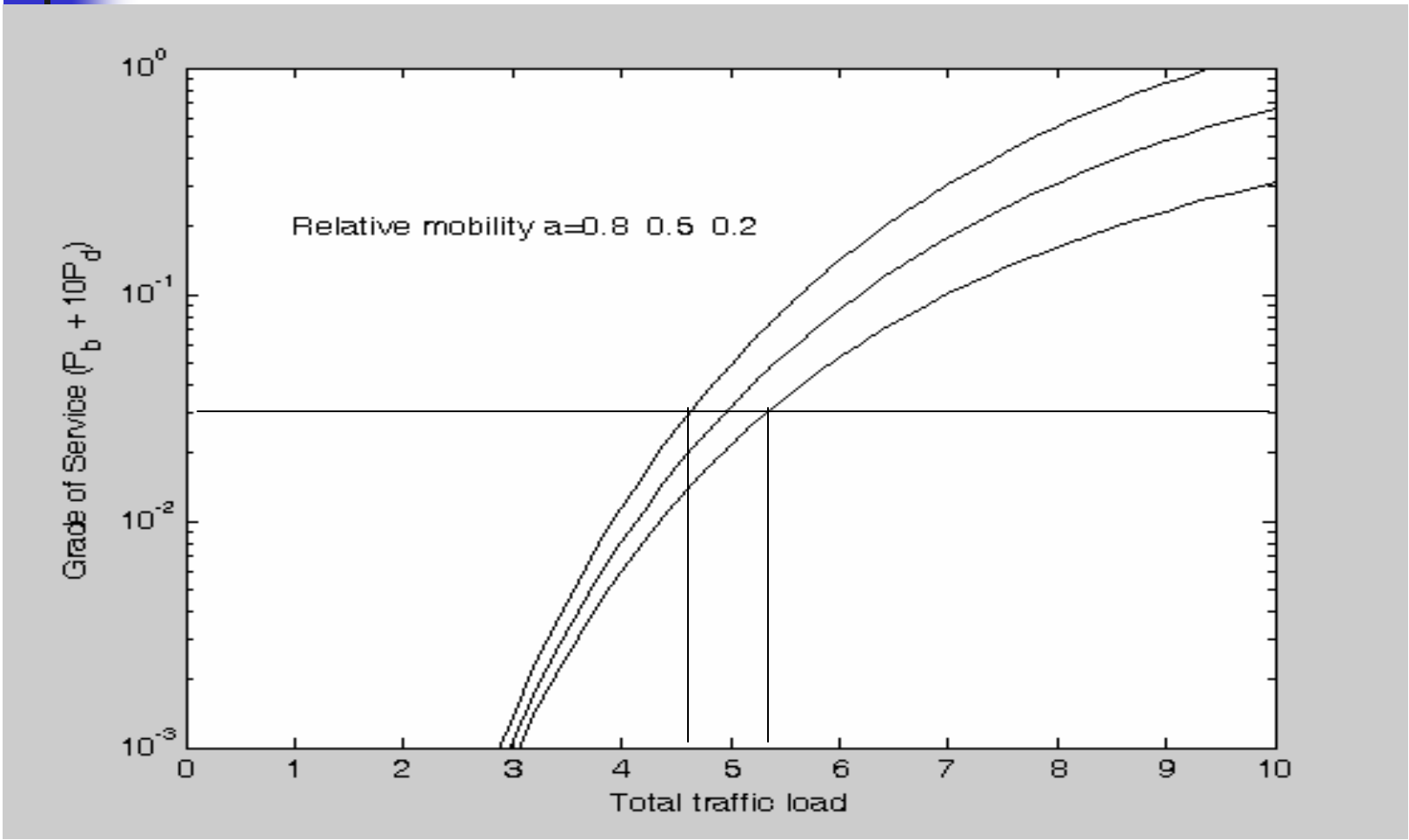
$$a = \frac{\lambda_H}{\lambda_N + \lambda_H}$$

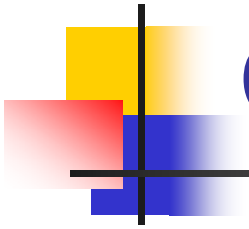
- Grade of Service (GoS)

$$GoS = P_b + \zeta P_d$$

ζ: a weighting factor

Cost of Mobility (GoS)



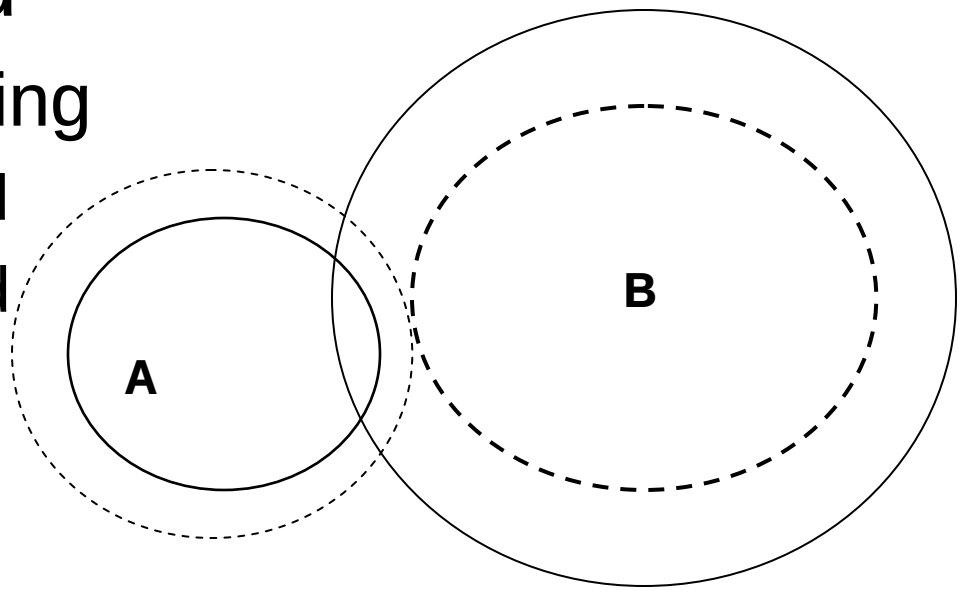


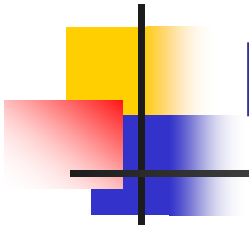
Observations

- The trade-off is clear between blocking of newly arrived users and handoff calls
  - Low P_d required → more reserved channels
  - High λ_H → more reserved channels → high P_b → low system capacity
- Reservation technique has its limitations
- Why don't include the user's QoS, signal level, etc. in the handoff decision process

Traffic Controlled Handoff (TCH)

- High traffic load BS will use high signal level threshold
- However, Low traffic load BS will use lower signal level threshold
  - Example: Cell breathing
    - Cell A is heavy loaded
    - Cell B is lightly loaded



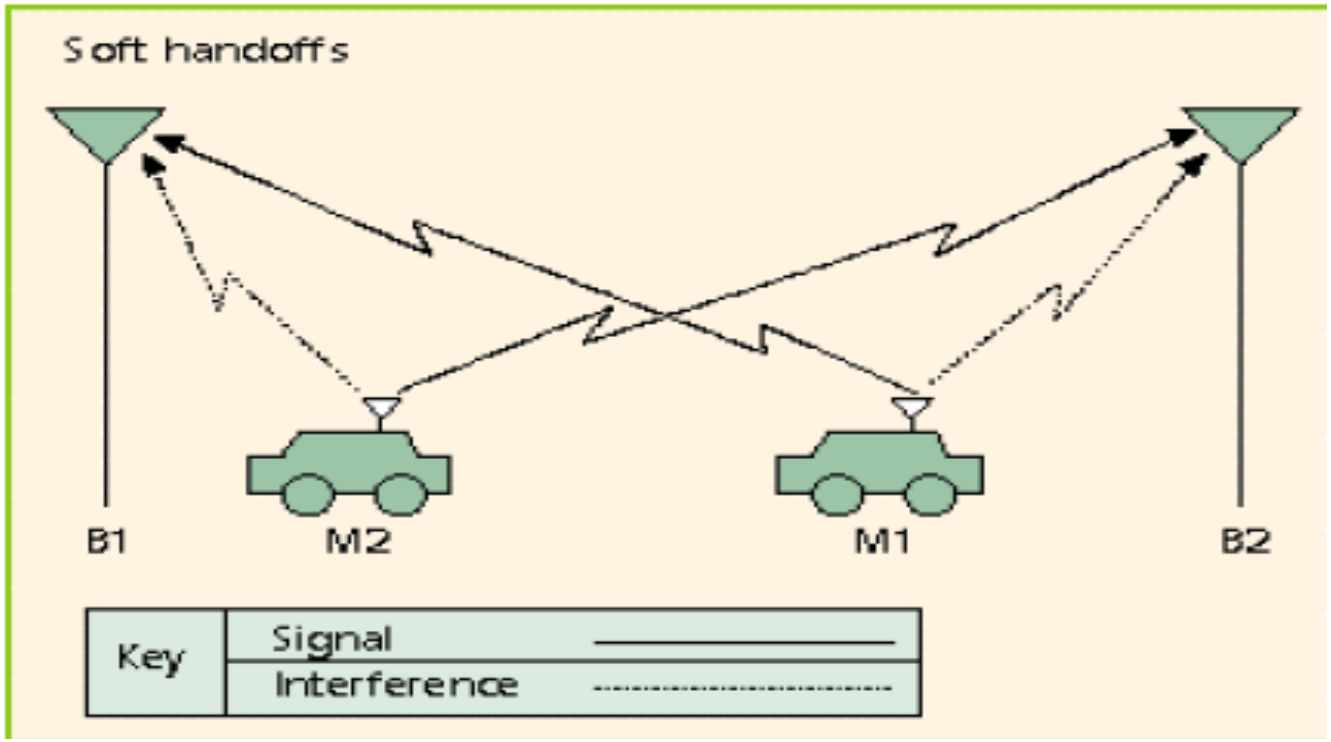


Handover in UMTS

- Hard handover
  - UTRA TDD mode: as sufficient time is available to switch cell
- Soft handover
  - UTRA FDD: A mobile communicates simultaneously with up to three sectors from different Node-B
- Softer handover
  - Same as soft handover but with the same Node-B

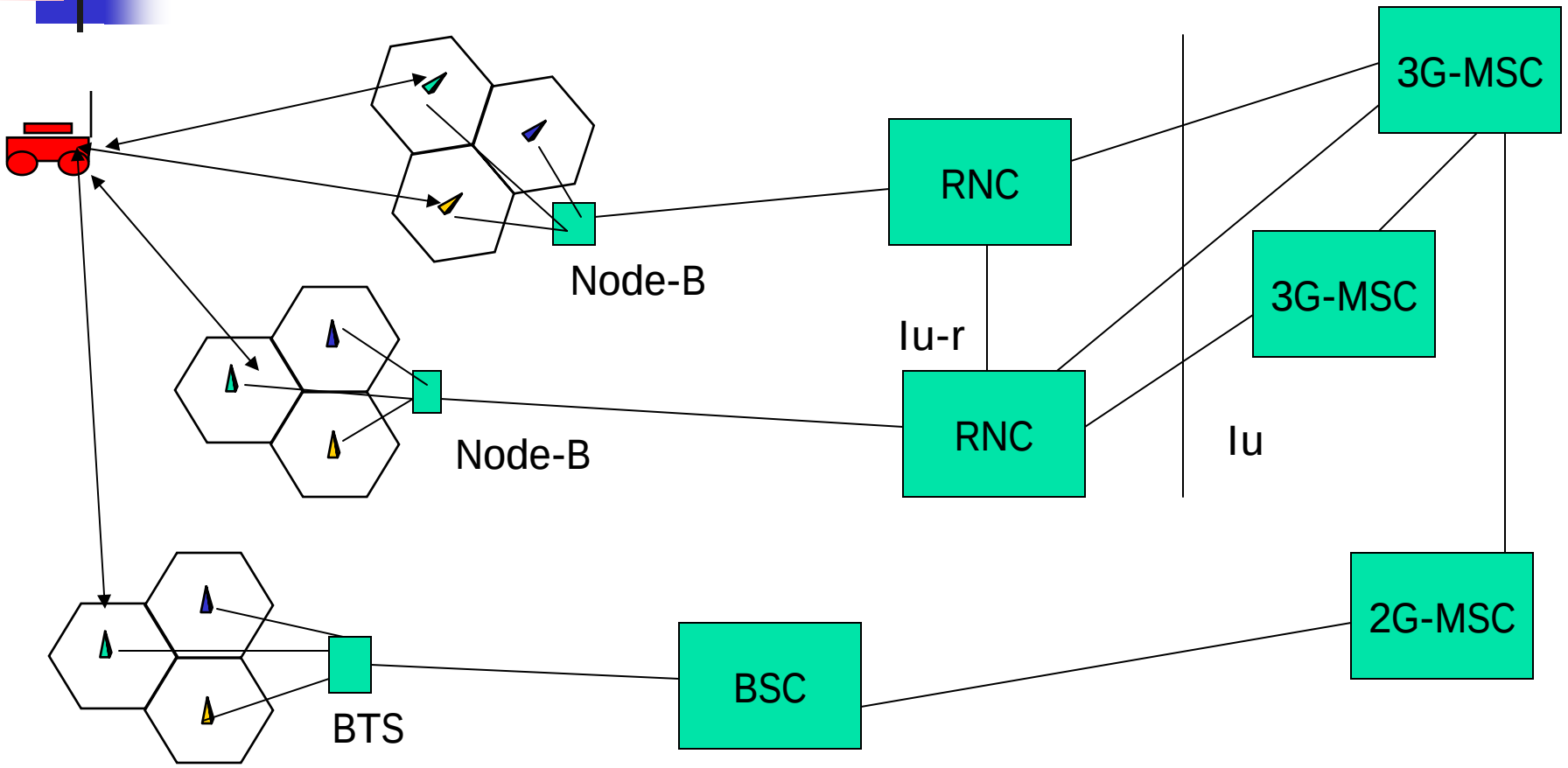
Soft Handoff

- Multiple connections to base stations

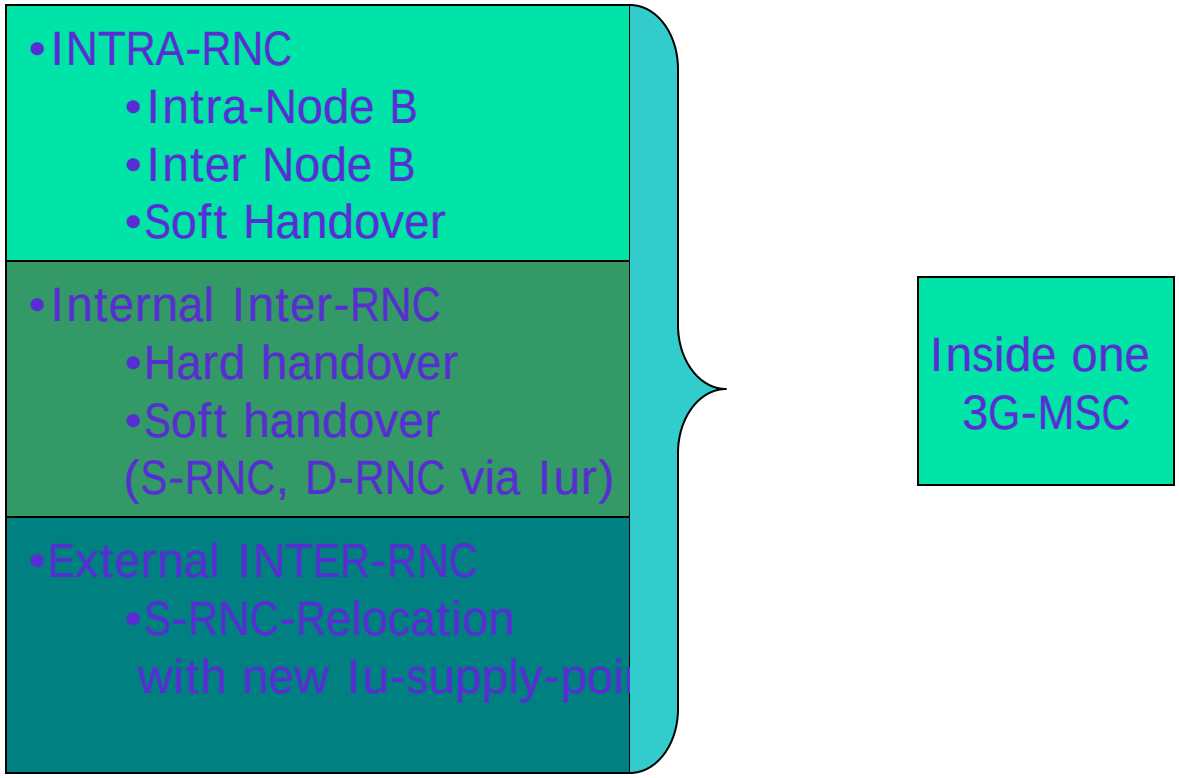


- "Ping-Pong" Effect and Hysteresis

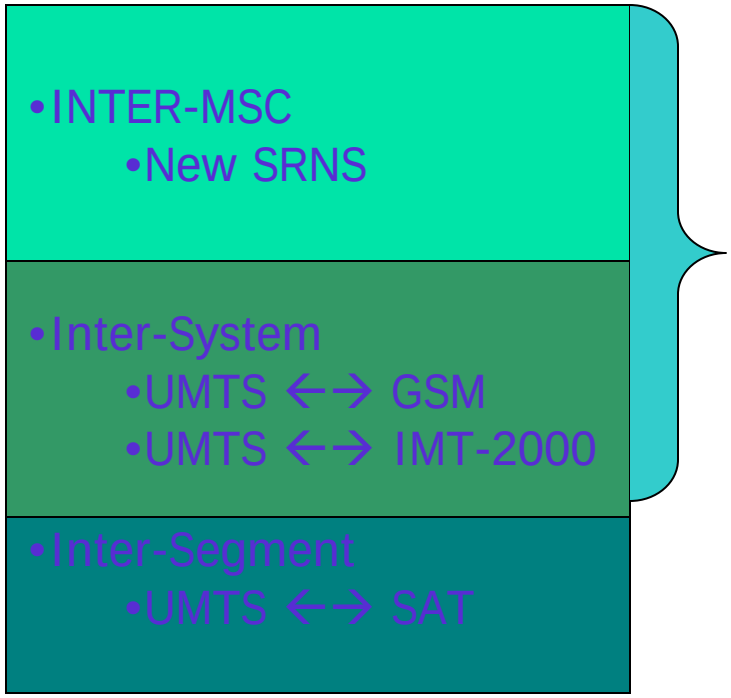
Network elements involved in handover



Handover types in UMTS

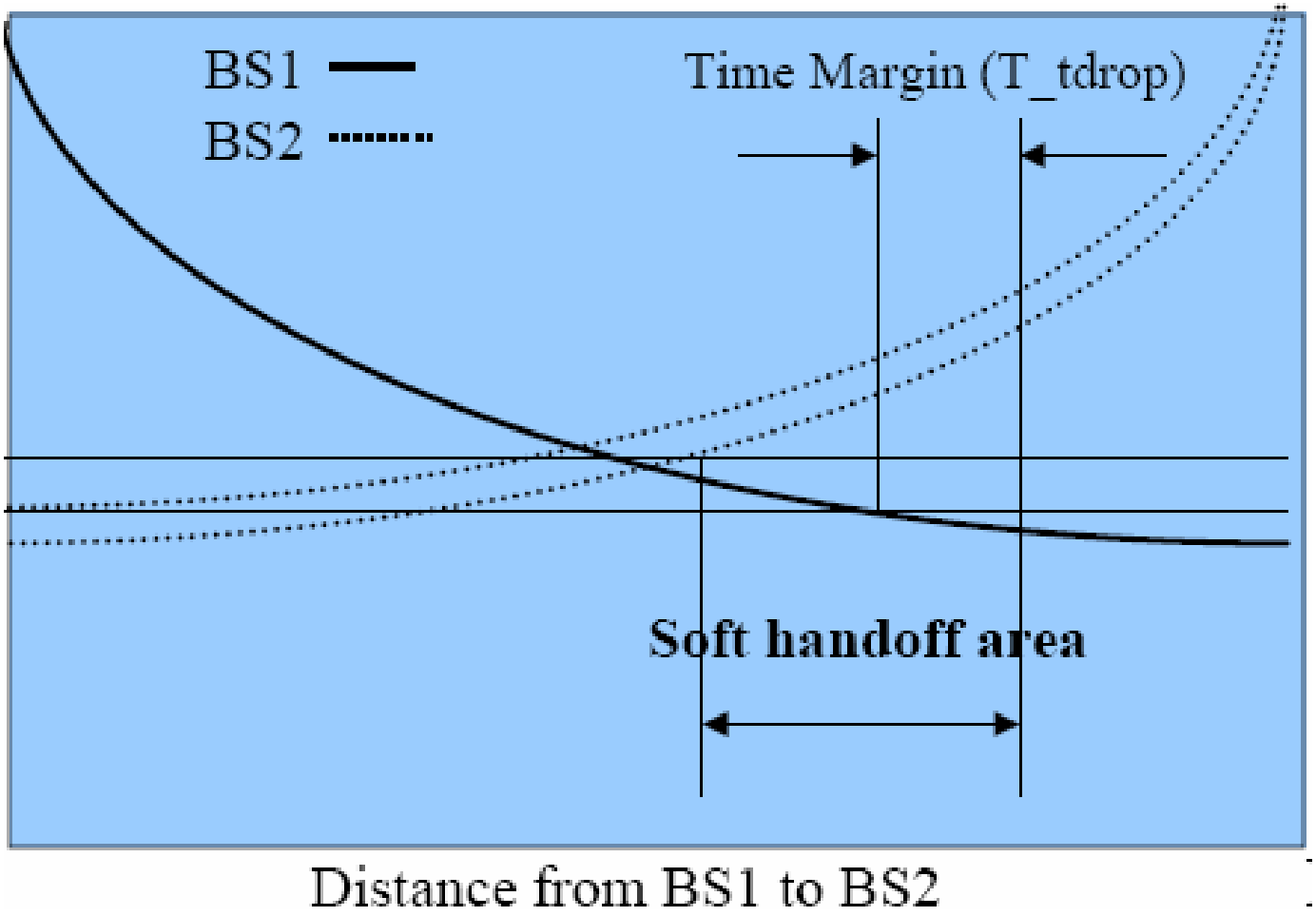


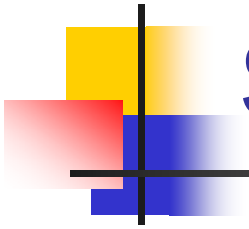
Handover types in UMTS



Between two 3G-MSC
or
between one 3G-MSC
and one GSM-MSC

Cell Breathing





Summary