EEE4087F-A
Mobile and Wireless Networks

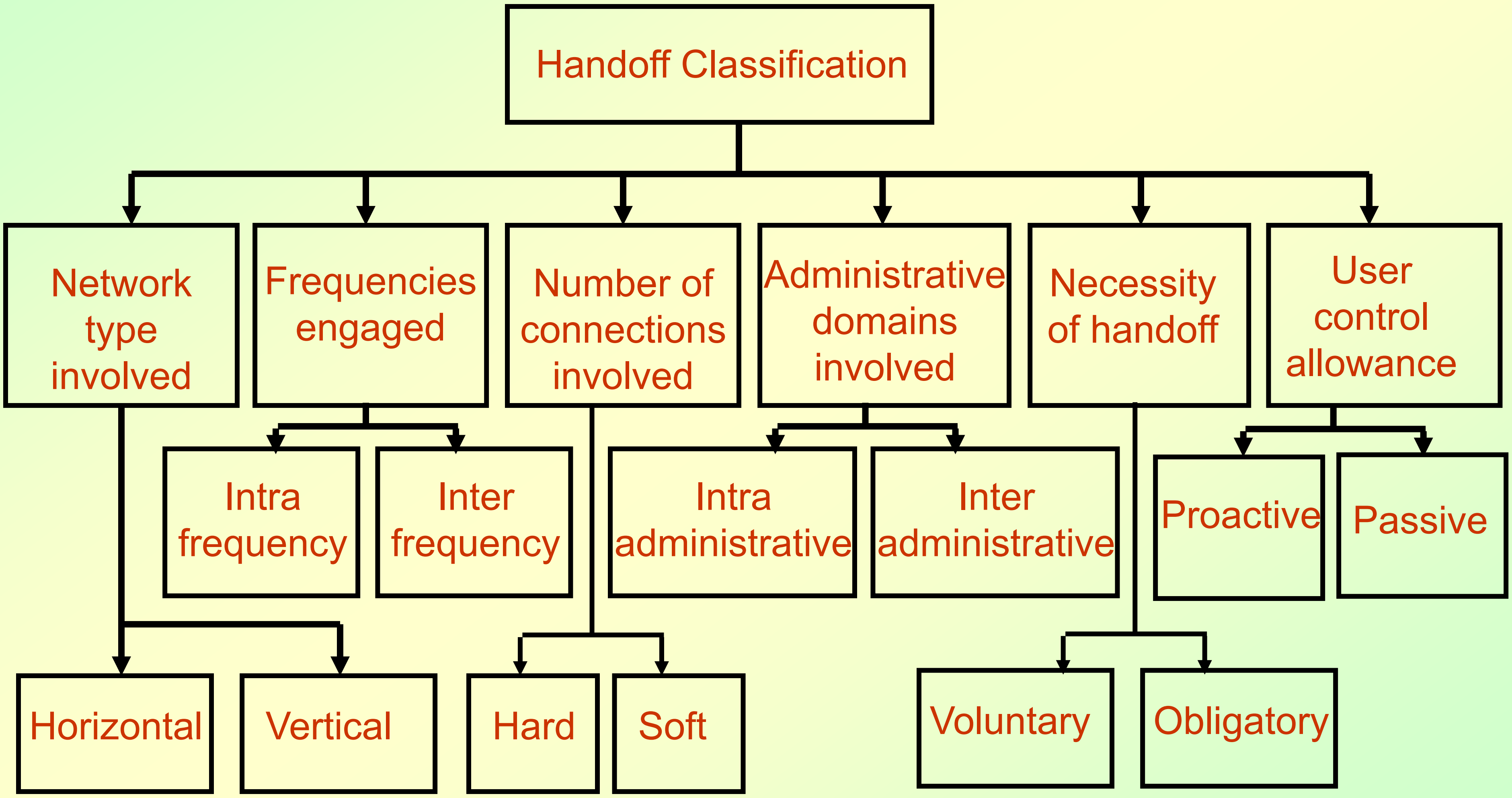
The greatest oak was once a little nut that held its ground.

Never quit!

Handoffs in Wireless Communications

- Mobility is the most important feature of a wireless cellular communication system
- Continuous service is achieved by supporting handoff (or handover) from one cell to another
- Handoff is the process of changing the channel (frequency, time slot, spreading code, or combination of them) associated with the current connection while a call is in progress
- Handoff algorithms can be classified in many ways

Handoff Classification



(1) Network Types Involved

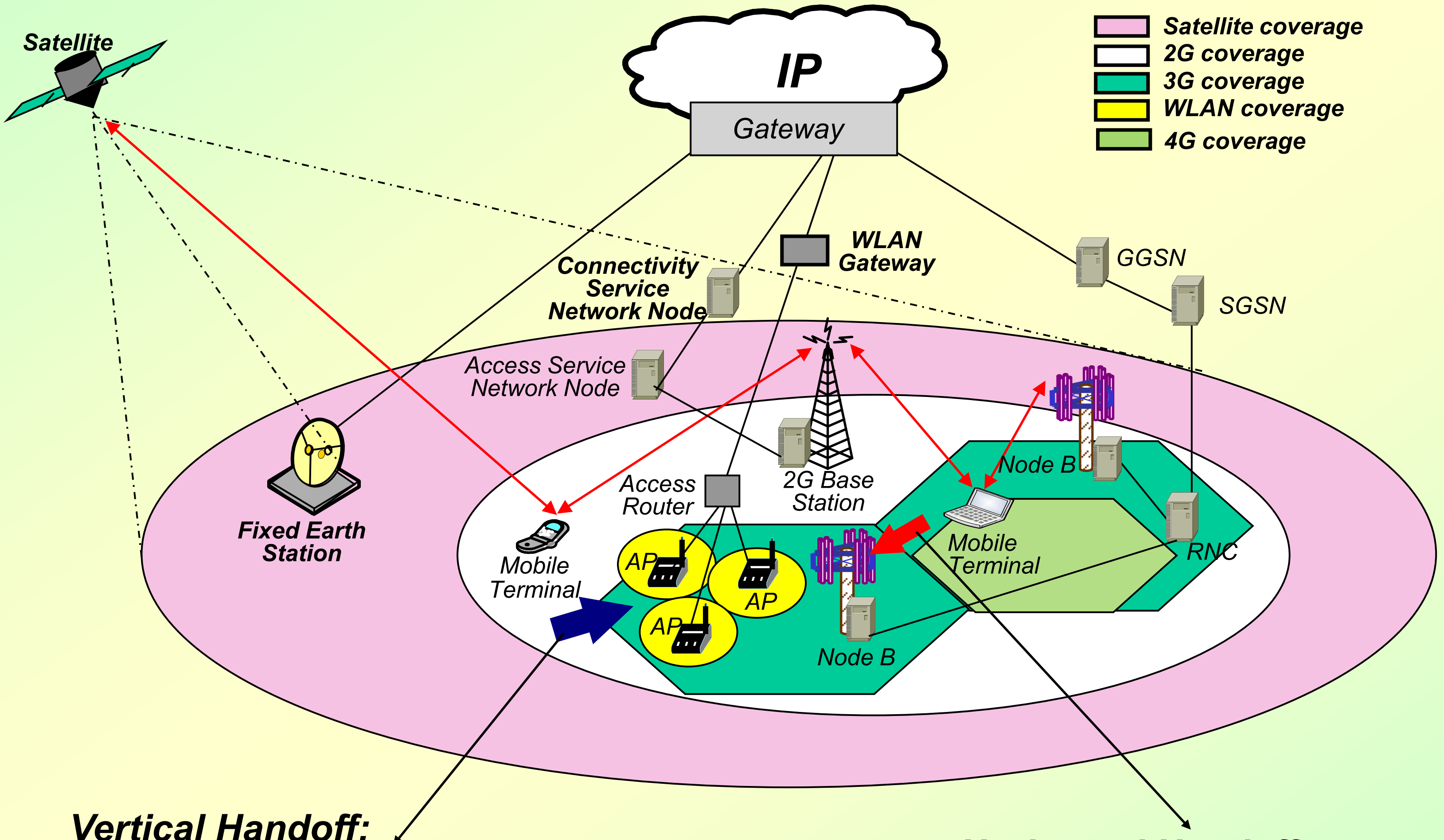
(1.1) Horizontal handoff: the handoff of a mobile terminal between access points or base stations supporting the same network technology

- For example, the handover between an IEEE 802.11ac access point and a neighboring IEEE 802.11ac access point is horizontal handoff.

(1.2) Vertical handoff: the handoff process of a mobile terminal among access points or base station supporting different network technologies

- For example, the handover of call session from an IEEE 802.11ac access point to an overlaid 3G cellular network is considered a vertical handoff process

CAC in Heterogeneous Wireless Networks



Vertical Handoff: from 2G to 3G

Horizontal Handoff: from a 3G cell to a 3G cell

(2) Frequency Engaged

(2.1) **Intrafrequency handoff**: the handoff process of a mobile terminal across access points operating on the same frequency

- This type of handoff is present in code-division multiple access (CDMA) networks

(2.2) **Interfrequency handoff**: the handoff process of a mobile terminal across access points operating on different frequencies

- This type of handoff is present in TDMA, FDMA networks with time-division duplex (TDD) and is the only handoff type supported in GSM cellular systems

(3) Number of Connections Involved

(3.1) Hard handoff (break before make): In a hard handoff the radio link to the old base station is released before a radio link to the new base station is established

- In other words, using hard handoff, a mobile node is allowed to maintain a connection with only one base station at any given time

(3.2) Soft handoff (make before break): In a soft handoff a mobile node maintains a radio connection with no less than two base stations in an overlapping handoff region and does not release any of the signals until it drops below a specified threshold value

- Soft handoffs are possible in situations where the mobile node is moving between cells operating on the same frequency

4 Administrative Domains Involved

- An administrative domain is a group of systems and networks operated by a single organization of administrative authority

(4.1) Intra-administrative handoff: a handoff process where the mobile terminal transfers between different networks (supporting the same or different types of network interfaces) managed by the same administrative domain

(4.2) Inter-administrative handoff: a handoff process where the mobile terminal transfers between different networks (supporting the same or different types of network interfaces) managed by different administrative domains.

(5) Necessity of Handoff

(5.1) Obligatory handoff: In this situation, it is necessary for the mobile terminal to transfer the connection to another access point in order to avoid disconnection (e.g. from WLAN to 3G)

(5.2) Voluntary handoff: In this situation transfer of connection is optional (e.g. from 3G to WLAN)

(6) User Control Allowance

(6.1) Proactive handoff: In a proactive handoff, the mobile terminal's user is allowed to decide when to handoff. The handoff decision can be based on a set of preferences specified by the user

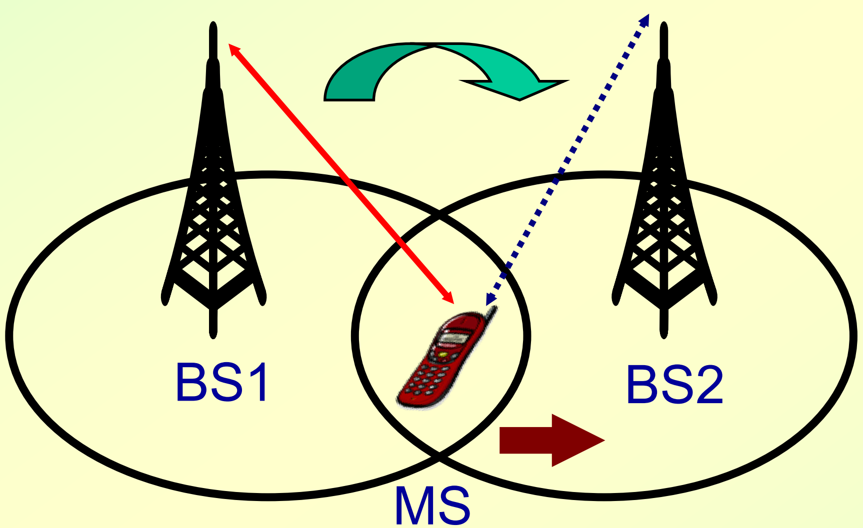
(6.2) Passive handoff: The user has no control over the handoff process. This type of handoff is the most common in first-, second-, and third-generation wireless systems

Handoff Initiation

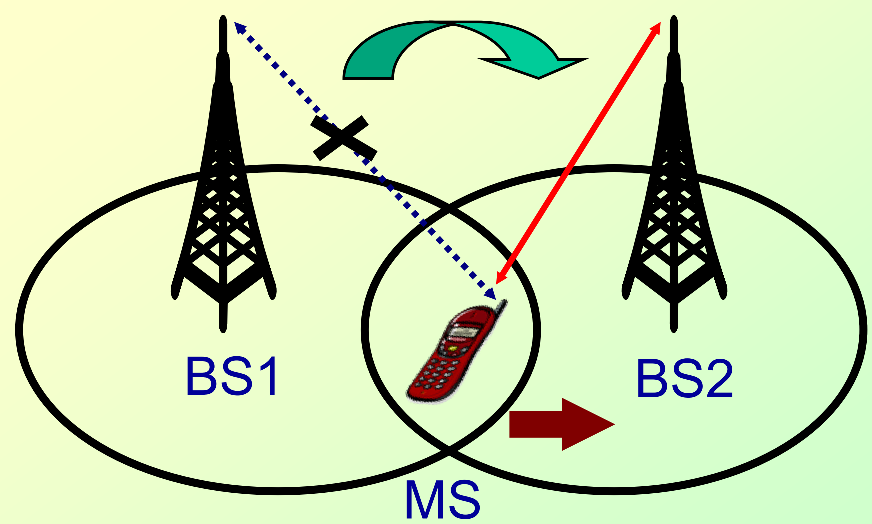
♦ **Handoff Initiations**

Horizontal handoff decisions mainly depend on the quality of the channel reflected by the received signal strength and the resources available in the target cell

Many systems are interference limited, meaning that signal strength is an adequate indication of channel quality



Before Handoff



After Handoff

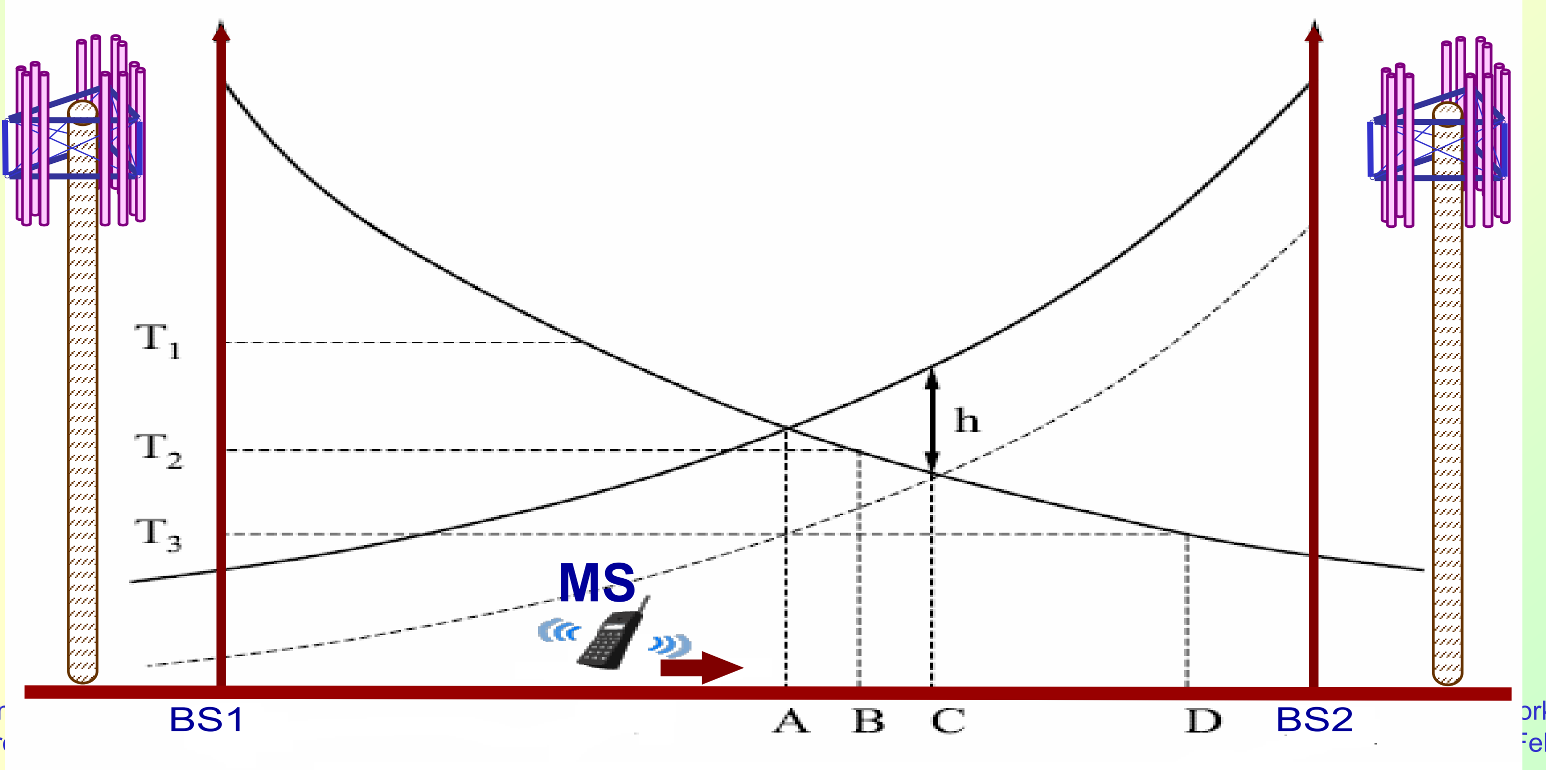
Handoff Initiation

- A hard handoff occurs when the old connection is broken before a new connection is activated
- The performance evaluation of a hard handoff is based on various initiation criteria
- It is assumed that the signal is averaged over time, so that rapid fluctuations due to the multipath nature of the radio environment can be eliminated
- Numerous studies have been done to determine the shape as well as the length of the averaging window and the older measurements may be unreliable
- Some approaches used for initiating handoff are described in the following slides

Handoff Initiation

(1) Relative Signal Strength

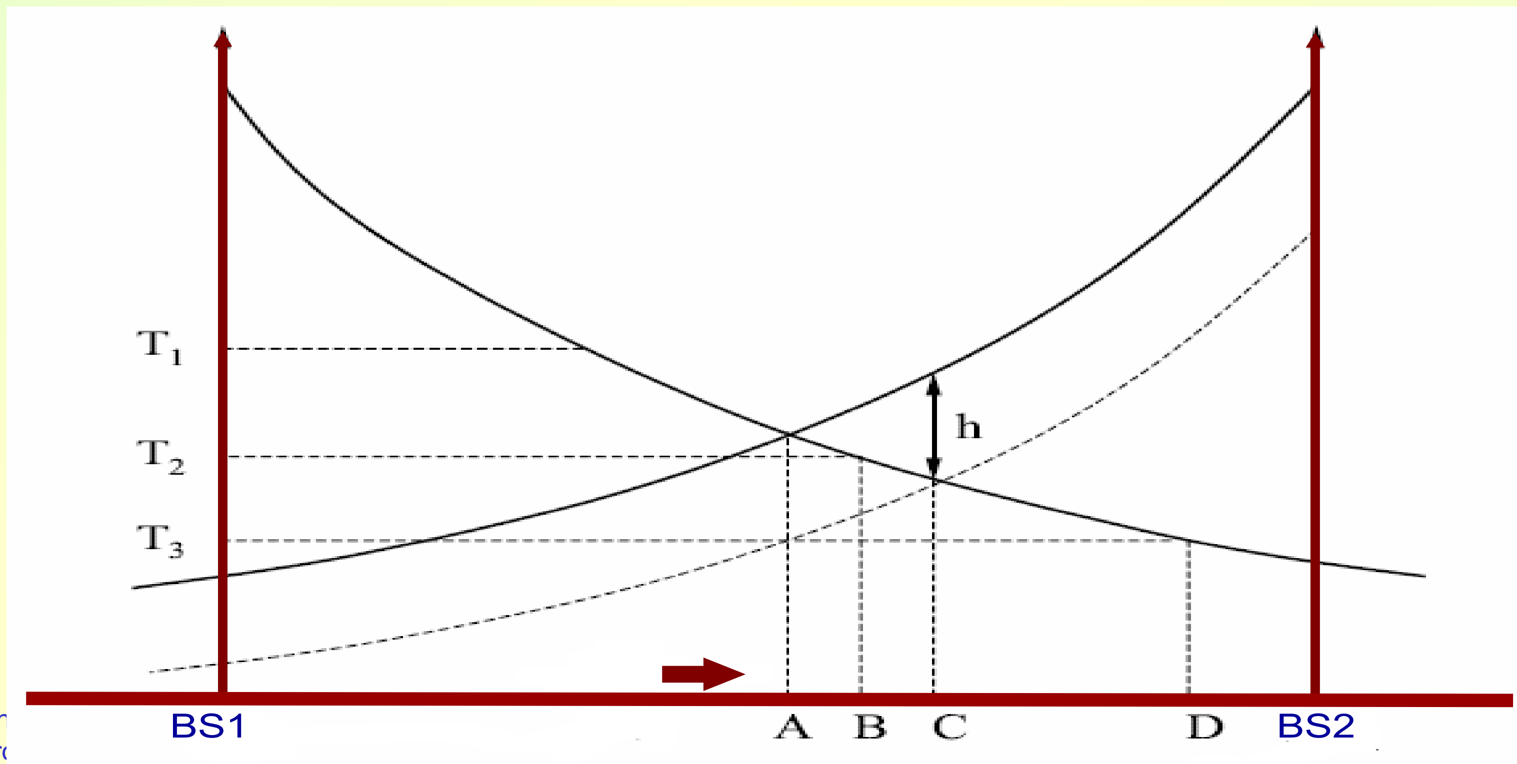
- This method selects the strongest received BS at all times
- The decision is based on a mean measurement of the received signal
- In the figure below, the handoff would occur at position **A**
- Disadvantage: It may cause too many unnecessary handoffs, even when the signal of the current BS is still at an acceptable level



Handoff Initiation

(2) Relative Signal Strength with Threshold

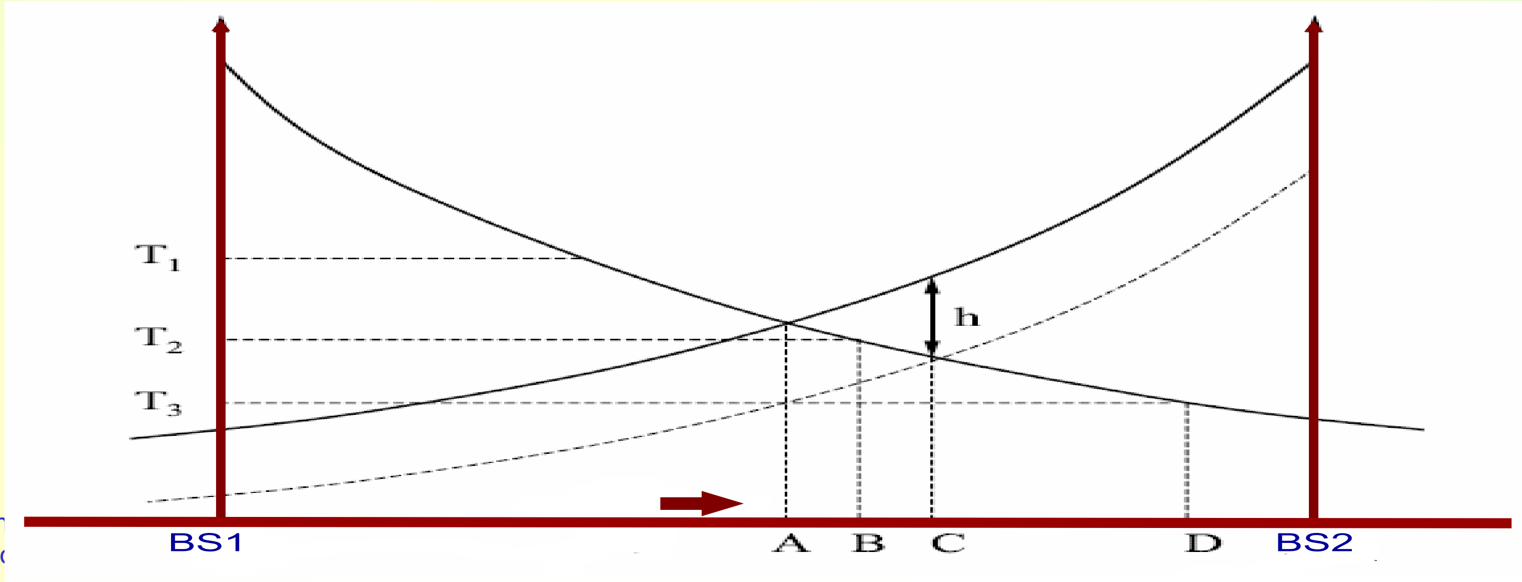
- This method allows a MS to hand off only if the current signal is sufficiently weak (less than threshold) and the other is the stronger of the two (T1, T2, T3)
- In this case handover will take place at point B.



Handoff Initiation

(3) Relative Signal Strength with Hysteresis

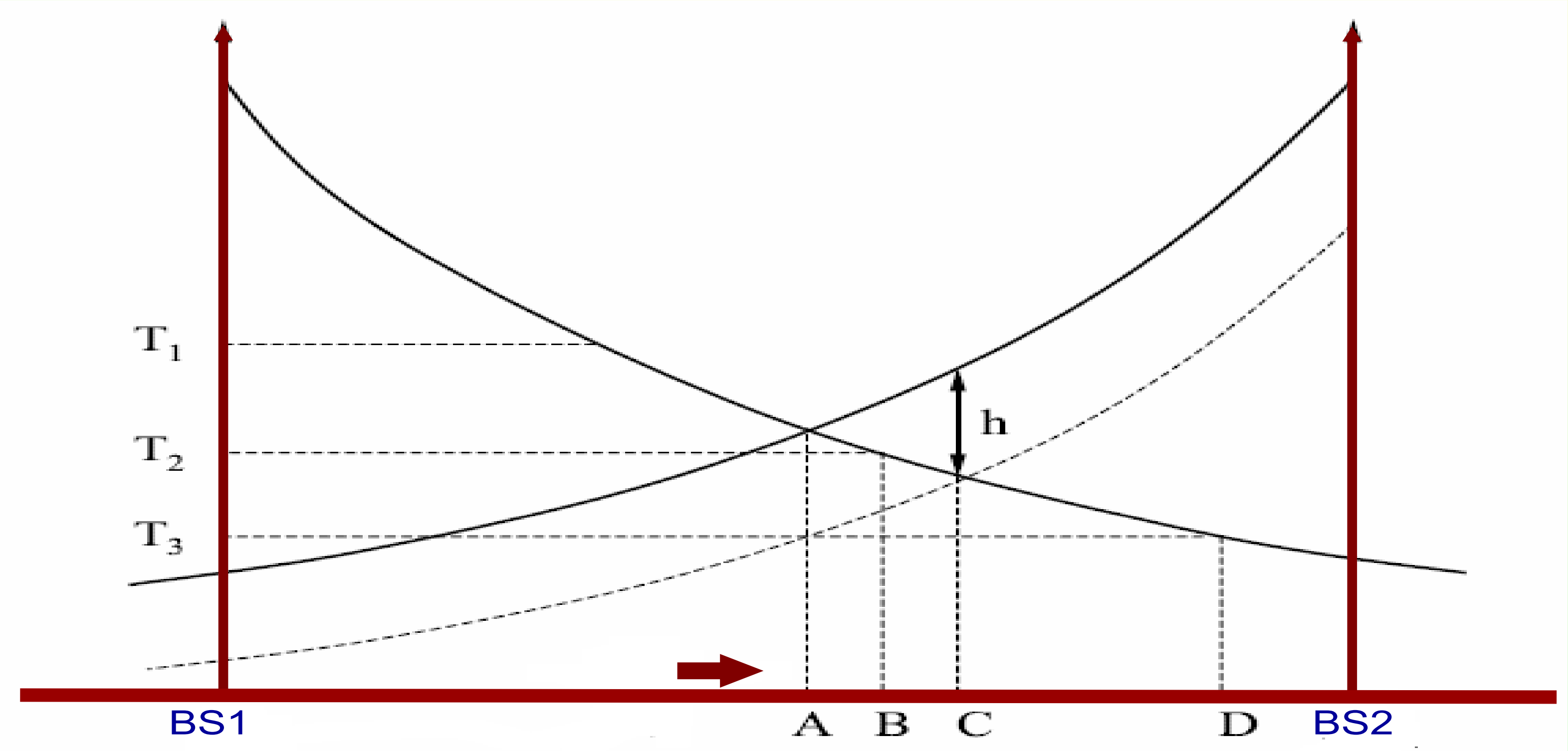
- This scheme allows a user to hand off only if the new BS is sufficiently stronger (by a hysteresis margin, h in figure below) than the current one
- In this case, the handoff would occur at **point C**
- This technique prevents the so-called ping-pong effect, the repeated handoff between two BSs caused by rapid fluctuations in the received signal strengths from both BSs



Handoff Initiation

(4) Relative Signal Strength with Hysteresis and Threshold

- This scheme hands a MS over to a new BS only if the current signal level drops below a threshold and the target BS is stronger than the current one by a given hysteresis margin
- the handoff would occur at **point D** if the threshold is T3



Handoff Initiation

(5) Prediction Techniques

- Prediction techniques base the handoff decision on the expected future value of the received signal strength
- A technique has been proposed and simulated to indicate better results, in terms of reduction in the number of unnecessary handoffs, than the relative signal strength, both without and with hysteresis, and threshold methods

Initiation of Vertical Handoff

- In vertical handoffs, many network characteristics have an effect on whether or not a handoff should take place
- The following characteristics have been proposed for making vertical handoff decisions
- **Quality of Service**

  - Handing over to a network with better conditions and higher performance

  would usually provide improved service levels.

  - Transmission rates, error rates, and other characteristics can be measured in order to decide which network can provide a higher assurance of continuous connectivity
- **Cost of Service**

  The cost of the different services to the user is a major issue, and could

  sometimes be the decisive factor in the choice of a network.
- **Security**

  Risks are inherent in any wireless technology
- **Power Requirements**
- **Velocity**

Combination of Multiple Criteria

- A major challenge in the design of multiple-criteria algorithms is how to combine many selection criteria in making decisions
- Current approaches have incorporated cost function/utility functions and computational intelligence techniques.
- Commonly used computational intelligence techniques are -
  - Fuzzy logic
  - Fuzzy-neural
  - Fuzzy MADM (Multiple Attribute Decision Making) method
  - Genetic algorithm
- Computation-intelligence-based techniques have high efficiency but are more complicated

Handoff Decision

- The decision-making process of handoff may be centralized or decentralized (i.e., the handoff decision may be made at the MS or network)

- Three different types of handoff-decision approaches are described in the following

(1) Network-Controlled Handoff

- In a network-controlled handoff protocol, the network makes a handoff decision based on the measurements of the MSs at a number of BSs.
- The handoff process takes 100–200 ms.
- Information about the signal quality for all users is available at a single point in the network that facilitates appropriate resource allocation
- Network-controlled handoff is used in first-generation analog systems such as AMPS (advanced mobile phone system), TACS (total access communication system), and NMT (advanced mobile phone system).

Handoff Decision

(2) Mobile-Assisted Handoff

- In a mobile-assisted handoff process, the MS makes measurements and the network makes the decision
- In the circuit-switched GSM (global system mobile), the BS controller (BSC) is in charge of the radio interface management
- It performs allocation and release of radio channels, and handoff management
- The handoff time between handoff decision and execution in such a circuit-switched GSM is approximately 1 second

When heaven smiles at you it does not matter who frowns.

Handoff Decision

(3) Mobile-Controlled Handoff

- In mobile-controlled handoff, each MS is completely in control of the handoff process

-This type of handoff has a short reaction time (of the order of 0.1 second)

- MS measures the signal strengths from surrounding BSs and interference levels on all channels

- A handoff can be initiated if the signal strength of the serving BS is lower than that of another BS by a certain threshold.

Class Work: Problem 1

- An urban area has a population of two million residents. Three competing mobile networks (X, Y, and Z) provide cellular service in this area. Network X has 394 cells with 19 channels each, Network Y has 98 cells with 19 channels each, and Network Z has 49 cells, each with 100 channels. Find the number of voice-service users that can be supported at 2% blocking probability if each user averages two calls per hour at an average duration of three minutes. Assuming that all three networks support only voice service and are operated at maximum capacity, compute the percentage market penetration of each cellular provider. From Erlang chart, given that at a blocking probability of 0.02

  (i) the total traffic, ***A***, carried by 19 channels is 12 Erlangs

  (ii) the total traffic, ***A,*** carried by 57 channels is 45 Erlangs

  (iii) the total traffic, ***A,*** carried by 100 channels is 88 Erlangs

Solution to Exercise 1

- Network X

Blocking probability = 0.02

Number of channels per cell, C=19

Traffic intensity per user, $A_u = \lambda H = 2*3/60 = 0.1$ Erlangs

At 0.02 blocking probability, ***A = 12***

Number of users that can be supported per cell =12/0.1 = 120

Total number of users that can be supported in Network X = 120*394= 47280

Solution to Exercise 1

- Network Y

Blocking probability = 0.02

Number of channels per cell, C=57

Traffic intensity per user, $A_u = \lambda H = 2*3/60 = 0.1$ Erlangs

At 0.02 blocking probability, ***A = 45***

Number of users that can be supported per cell =45/0.1 = 450

Total number of users that can be supported in Network Y = 450*98= 44,100

Solution to Exercise 1

- Network Z

Blocking probability = 0.02

Number of channels per cell, C=100

Traffic intensity per user, $A_u = \lambda H = 2*3/60 = 0.1$ Erlangs

At 0.02 blocking probability, ***A = 88***

Number of users that can be supported per cell =88/0.1 = 880

Total number of users that can be supported in Network Z = 880*49= 43,120

The total number of subscribers that can be supported by the three networks (X, Y, and Z) is 47,280 + 44,100 + 43,120 = 134,500 users

Solution to Exercise 1

- Total number of residents = 2,000,000
- Percentage market penetration of X = 47,280/2,000,000 =2.36%
- Percentage market penetration of Y = 44,100/2,000,000 =2.205%
- Percentage market penetration of Z = 43,120/2,000,000 =2.156%
- Percentage market penetration of the three networks = 134,500/2,000,000 = 6.725%

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