# Wireless Network

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# Contents

**The course will mainly cover the following topics:**

- ✓ Wireless Networking
- ✓ Multiple Access techniques
  - FDMA, TDMA and CDMA systems
- ✓ Modulation Techniques
  - Analog and digital modulation techniques, Performance of various modulation techniques - Spectral efficiency, Error rate
- ✓ The Cellular Concepts and System Design Fundamentals
  - Cellular concept and frequency reuse, Channel assignment and handoff, Interface and system capacity, Trunking and Erlang capacity calculations
- ✓ Mobile Radio Propagation
  - Radio wave propagation issues in personal wireless systems, Propagation models, Multipath fading, Parameters of mobile multipath channels, Antenna systems in mobile radio.
- ✓ Cellular Wireless Networks
  - Principles of Cellular Networks
  - First-Generation Analog
  - Second-Generation TDMA
  - Second-Generation CDMA
  - Third-Generation Systems

# Outline

✓The Cellular Concepts and System Design Fundamentals

- handoff,
- system capacity, Trunking and Erlang capacity calculations

# Handover (Handoff)

***Hand-off*** is the process of switching from one frequency channel to another by the user in midst of a communication. Hand-off takes place when a user crosses the cell boundary. It Provides continuity of communication across cells. Handoffs must be performed successfully and as infrequently as possible, and be imperceptible to the users.

Process

—Received signal weakens as mobile moves out of cell .

—A slightly save signal level is used as a threshold at which a handoff is made.

—Cell site at some point requests handover to cell with stronger signal strength.

—MSC switches call to new cell after allocating channels

# Reasons for a Handoff to be conducted

**Handoff** is one of the essential features that guarantees the subscriber mobility in a mobile network, where the subscriber can move around. Maintaining connection with a moving subscriber is possible with the help of the handoff function.

✓To avoid call termination: call drops: Signal strength deterioration is the most common cause for handoff at the edge of a cell which may cause call drops.

—When the capacity for connecting new calls of a given cell is used up.

- Other reasons may include load balancing where the handoff is initiated to relieve traffic congestion by shifting calls in a highly congested cell to a lightly loaded cell.

—Interference in the channels.

—When the user behaviors change.

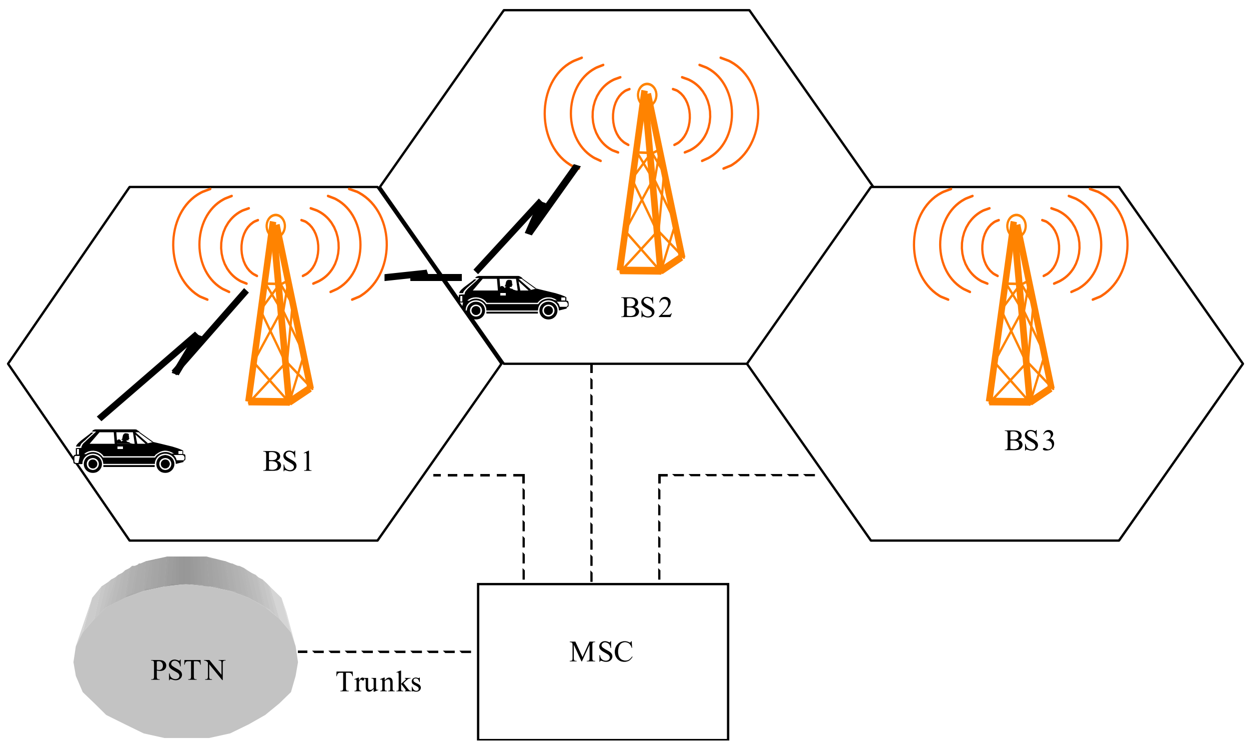
- Speed and mobility.

—Handoff delay is much smaller (100 ms in synchronous versus 200 ms in asynchronous).

# Why should we provide a higher priority to handoff calls?

- From users' view, the dropping of handoff calls is more serious and irritating than the blocking of originating calls.
- How to provide a higher priority to handoff calls?
- One approach is reserve $S_R$ channels exclusively for handoff calls among the $S$ channels in a cell.

# Handover Process



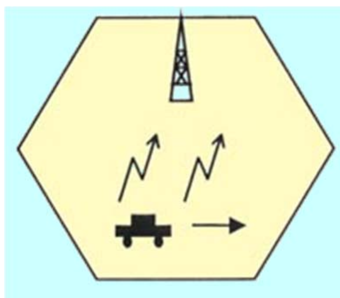
- ✓ The quality of the RSS from the mobile station is monitored by the BS. When the RSS is below a certain threshold, BS instructs the mobile station to collect signal strength measurements from neighboring BSs

- ✓ **Case 1: mobile station sends the collected information to the BS**.
  BS conveys the signal information to its parent MSC (mobile switching center) which selects the most suitable next BS for the mobile station
  Both the selected BS and the mobile station are informed when new BS assigns an unoccupied channel to the mobile station

- ✓ **Case 2: mobile station itself selects the most suitable BS.**
  The mobile station informs the current BS, who conveys information about the next BS to its MSC
  The selected BS is informed by the MSC which assigns a new channel

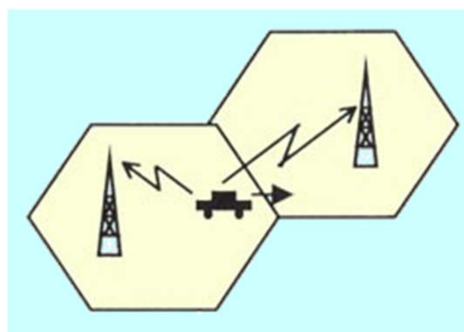
# Handoff Types

Intra-Cell

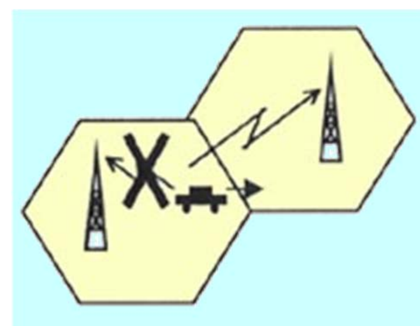


Inter-Cell

Soft Handoff



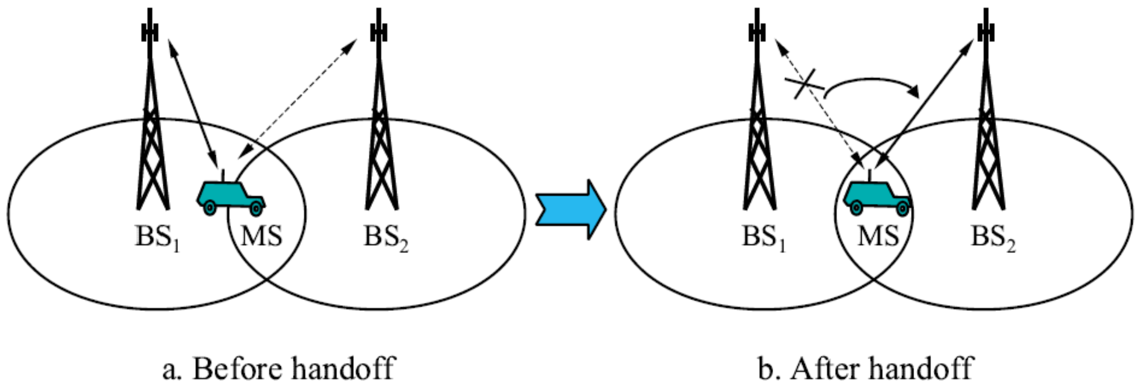
Hard Handoff



# INTER-CELL AND INTRA-CELL HANDOVER

The inter-cell handover switches a call in progress from one cell to another cell, and the intra-cell handover switches a call in progress from one physical channel of a cell to another physical channel of the same cell.

# Mechanism of Hard Handover




- Old connection is broken before a new connection is activated
- Primarily used in FDMA and TDMA systems (e.g. GSM)
- The base station $BS_1$ on one cell site hands off the mobile station(MS)'s call to another cell $BS_2$.
- The link to the prior base station, $BS_1$ is terminated before the user is transferred to the new cell's base station, $BS_2$.
- The MS is linked to no more than one BS at any given time.
- It is simpler as phone's hardware does not need to be capable of receiving two or more channels in parallel.

# Mechanism of Soft Handover

- The call is first connected to the new base station $BS_2$ and then it is dropped by the previous base station $BS_1$.
- The call will be established only when a reliable connection to the target cell is obtained. The MS is linked to two BS for a brief interval of time. Thus soft handover involves connection to more than one cell.
- It is commonly used in CDMA (Code-division multiple access) systems
- Technical implementation of a Soft handoff is more expensive and complex in comparison to a Hard handoff.
- It is used in sensitive communication services such as videoconferencing.

# Limited Trunk Traffic

$$P = \frac{\dfrac{A^N}{N!}}{\displaystyle\sum_{x=0}^{N} \frac{A^x}{x!}}$$

where

$A =$ offered traffic, erlangs
$N =$ number of servers
$P =$ probability of blocking (grade of service)

# Limited Trunk Traffic

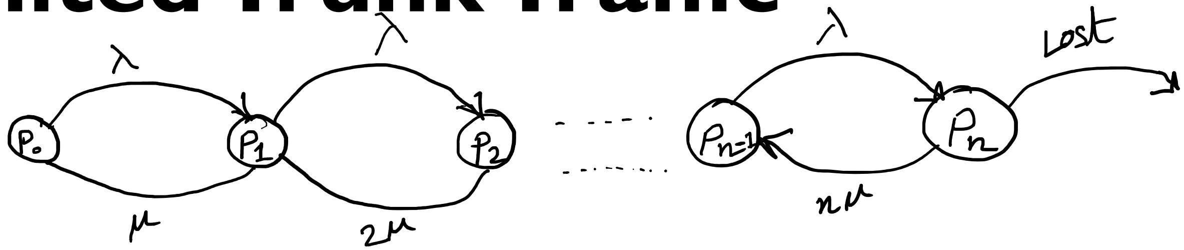



Fig: state transition of limited trunk network.

$$\sum_{i=1}^{n} P_i = 1$$

$$P_0 + P_1 + P_2 + P_3 + \cdots + P_n = 1$$

Applying cut equation bet^n $P_0$, $P_1$

$$P_0 \lambda = P_1 \mu$$

$$P_1 = P_0 \lambda/\mu = P_0 A \quad \cdots (1)$$

offered traffic

$$A = \lambda \cdot T$$

$$= \lambda \cdot \frac{1}{\mu}$$

$$A = \frac{\lambda}{\mu}$$

# Limited Trunk Traffic

Betⁿ $P_1, P_2$

$$\lambda P_1 = P_2 \times 2\mu$$

$$P_2 = \frac{\lambda}{2\mu} P_1 = \frac{1}{2} \frac{\lambda}{\mu} P_2 = \cancel{P_1} \times \frac{A}{2}$$

$$= P_0 \cdot A \cdot \frac{A}{2}$$

$$= P_0 \frac{A^2}{2!} \quad \text{--- (II)}$$

Betⁿ $P_2, P_3$

$$\lambda P_2 = P_3 \times 3\mu$$

$$P_3 = \frac{\lambda}{3\mu} P_2 = \frac{A}{3} \cdot P_0 \frac{A^2}{2} = \frac{A^3}{3!} \cdot P_0 \quad \text{--- (III)}$$

similarly

$$P_n = \frac{A^n}{n!} \cdot P_0 \quad \text{----}$$

# Limited Trunk Traffic

$$P_0 + P_1 + P_2 + P_3 + \cdots + P_n = 1$$

$$P_0 + P_0 A + P_0 \frac{A^2}{2!} + P_0 \frac{A^3}{3!} + \cdots + P_0 \frac{A^n}{n!} = 1$$

$$\Rightarrow P_0 \left(1 + A + \frac{A^2}{2!} + \frac{A^3}{3!} + \cdots + \frac{A^n}{n!}\right) = 1$$

$$\Rightarrow P_0 \sum_{i=0}^{n} \frac{A^i}{i!} = 1$$

$$\therefore P_0 = \frac{1}{\sum_{i=0}^{n} \frac{A^i}{i!}}$$

Blocking probability

$$B_n = P_n = \frac{A^n}{n!} \cdot \frac{1}{\sum_{i=0}^{n} \frac{A^i}{i!}}$$

$$= \frac{\frac{A^n}{n!}}{\sum_{i=0}^{n} \frac{A^i}{i!}}$$

# Limited Trunk Traffic

Recurrence form of Erlang's blocking:

$$B_n = \frac{\frac{A^n}{n!}}{\sum_{i=0}^{n} \frac{A^i}{i!}} \quad --- (\mathrm{I})$$

$$B_{n-1} = \frac{\frac{A^{n-1}}{(n-1)!}}{\sum_{i=0}^{n-1} \frac{A^i}{i!}} \quad --- (\mathrm{II})$$

(I) ÷ (II)

$$\frac{B_n}{B_{n-1}} = \frac{\frac{A^n}{n!} \Big/ \sum_{i=0}^{n} A^i/i!}{\frac{A^{n-1}}{(n-1)!} \Big/ \sum_{i=0}^{n-1} \frac{A^i}{i!}} = \frac{\frac{A}{n}}{1 + \frac{A^n/n!}{\sum_{i=0}^{n-1} A^i/i!}}$$

# Limited Trunk Traffic

$$= \frac{\frac{A}{n}}{1 + \frac{A^n/n!}{\frac{A^{n-1}}{(n-1)!\, B_{n-1}}}}$$

$$= \frac{\frac{A}{n}}{1 + \frac{A B_{n-1}}{n}} = \frac{A}{n + A B_{n-1}}$$

$$\frac{B_n}{B_{n-1}} = \frac{A}{n + A B_{n-1}} \qquad \therefore \quad B_n = \frac{A\, B_{n-1}}{n + A B_{n-1}}.$$

# Limited Trunk Traffic

Example - 1

Offered traffic of a network of 5 trunk is 3.5 Erlangs. How the performance will improve or degrade with addition or removal of one trunk

Solution: $B(5, 3.5) = \dfrac{\frac{A^n}{n!}}{\sum_{i=0}^{n} A^i/i!} = \dfrac{\frac{A^5}{5!}}{1 + A + \frac{A^2}{2!} + \frac{A^3}{3!} + \frac{A^4}{4!} + \frac{A^5}{5!}}$

$= \dfrac{3.5^5}{5!} \Big/ \left(1 + 3.5 + \dfrac{(3.5)^2}{2!} + \dfrac{(3.5)^3}{3!} + \dfrac{(3.5)^4}{4!} + \dfrac{(3.5)^5}{5!}\right)$

$= 0.154$

With addition of one trunk

$$B_6 = \frac{AB_5}{6 + AB_5} = \frac{3.5 \times 0.1541}{6 + 3.5 \times 0.1541}$$

$$= 0.08247.$$

$\Rightarrow$ Performance is improved.

With removal of one trunk,

$$B_n = \frac{AB_{n-1}}{n + AB_{n-1}} \Rightarrow B_{n-1} = \frac{nB_n}{A - AB_n}$$

$$B_4 = \frac{5B_5}{3.5 - 3.5 \times B_5} = \frac{\cancel{5000} \; 5 \times 0.1541}{3.5 - 3.5 \times 0.1541} = \cancel{0.26024}$$

$$= 0.26024$$

Performance is degraded.

# Limited Trunk Traffic

A = 2 Erls traffic is offered to a link of n = 3 circuits.

Find carried traffic.

Carried Traffic $= A(1 - B_3)$

$$B_3 = \frac{A^3/3!}{\sum_{i=0}^{3} A^i/i!} = \frac{2^3/3!}{1 + 2 + \frac{2^2}{2!} + \frac{2^3}{3!}} = \frac{\frac{8}{6}}{1 + 2 + 2 + \frac{8}{6}}$$

$$= \frac{8/6}{6.33}$$

$$= 0.2105$$

Carried Traffic $= 2(1 - 0.2105) = 1.5789$ Erlangs.

# Thank You