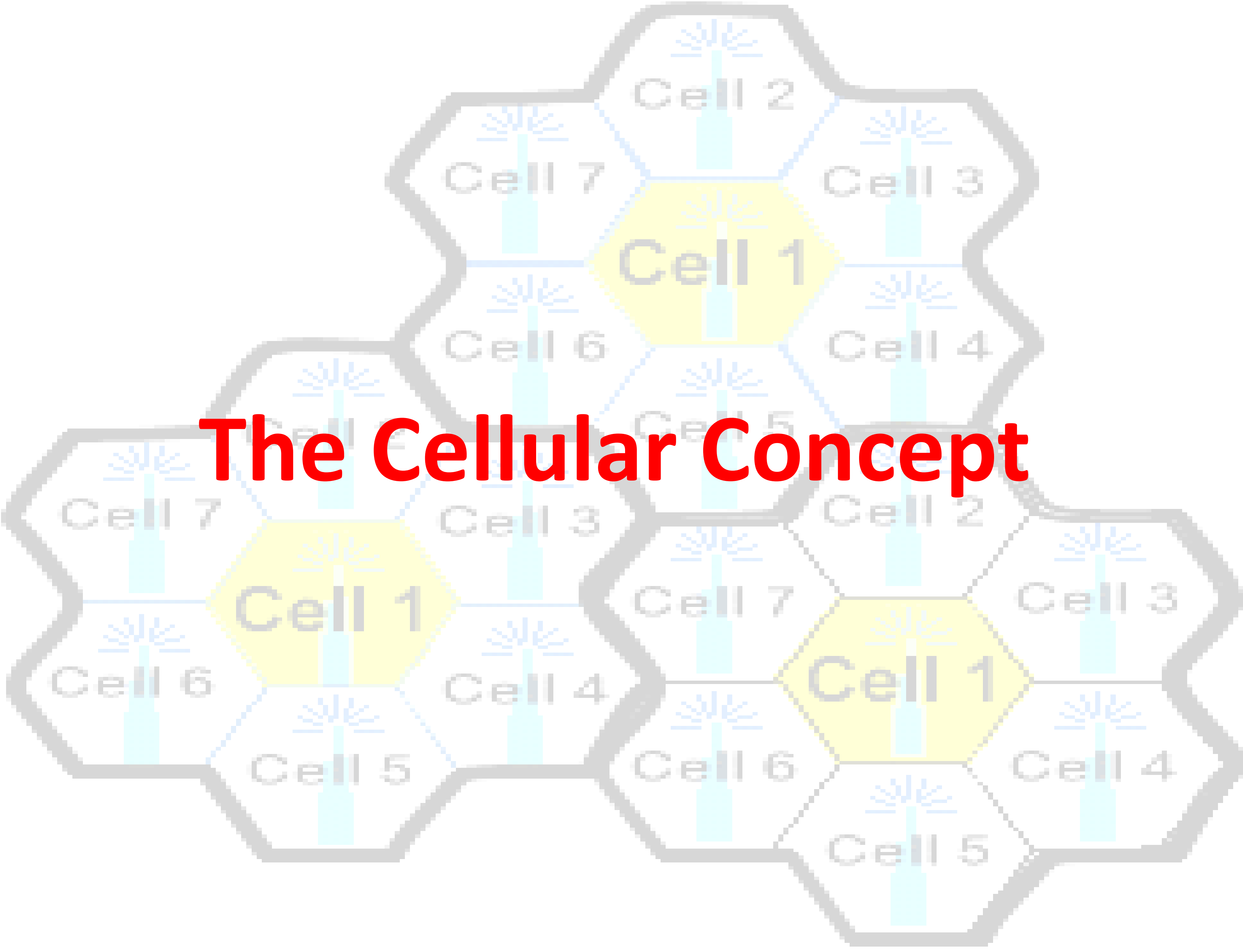
The Cellular Concept



Presentation Credits

- The material for these slides has been taken from **T. S. Rappaport's** Book: "Wireless Communications, Principles and Practice (2nd Edition)". I would like to thank the author and publishers for making the figures for this book easily accessible online.

- Animations and content for easy illustration have been prepared by **Hassan Aqeel Khan** (Lecturer CSE Dept.)

Introduction

- **Early Mobile Radio systems:**
  - Large coverage area.
  - Single high powered transmitter on tall tower
  - Had very limited capacity since frequencies could not be reused due to interference.
- **Cellular Concept:**
  - Replace single, high power transmitter (large cell) with many low power transmitters (small cells), each providing coverage to only a small portion of coverage area.
  - Adjacent cells assigned different group of frequency channels.
  - The available channels are re-used, as long as ***interference between co-channel stations*** is kept below acceptable levels.

Frequency Reuse

- Cellular systems rely on an intelligent allocation and reuse of channels throughout a coverage region.

- Each cellular base station is allocated a group of radio channels to be used in a small geographic area called a ***cell***.

- Adjacent cells must use different channels.

Frequency Reuse

- The design process of selecting and allocating channel groups for all the cellular base stations within a system is called *frequency reuse* or *frequency planning*.

- Two main factors to consider during frequency planning:
  - Interference b/w co-channels
  - Capacity

Frequency Reuse

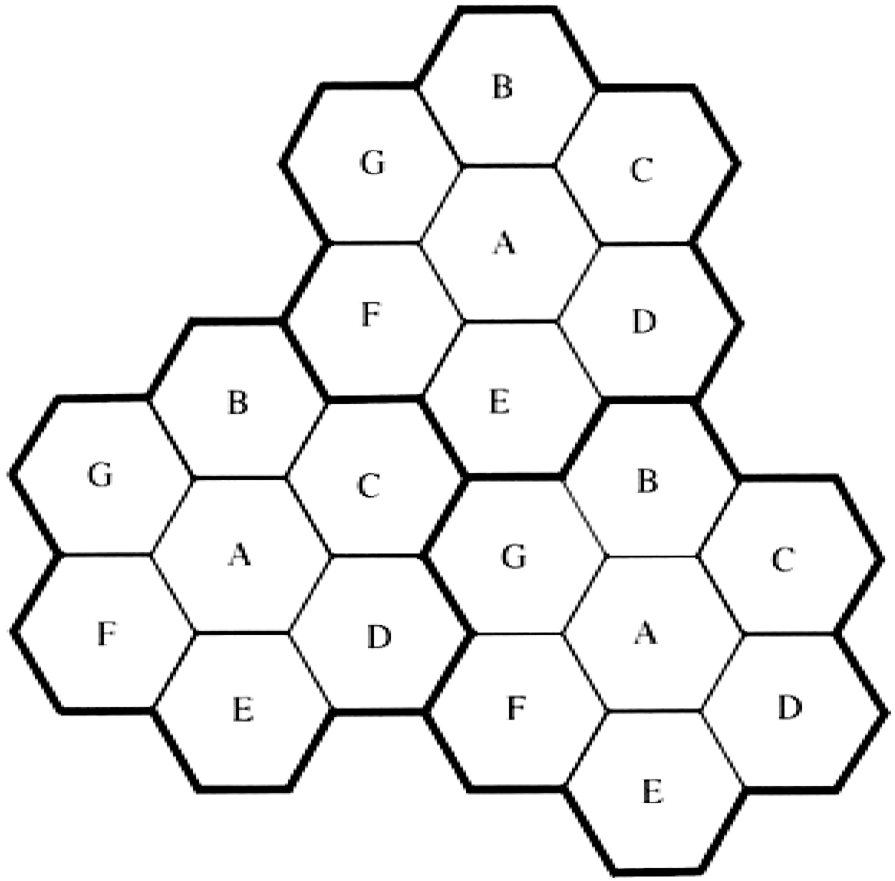


Figure 3.1 Illustration of the cellular frequency reuse concept. Cells with the same letter use the same set of frequencies. A cell cluster is outlined in bold and replicated over the coverage area. In this example, the cluster size, N, is equal to seven, and the frequency reuse factor is 1/7 since each cell contains one-seventh of the total number of available channels.

Frequency Reuse

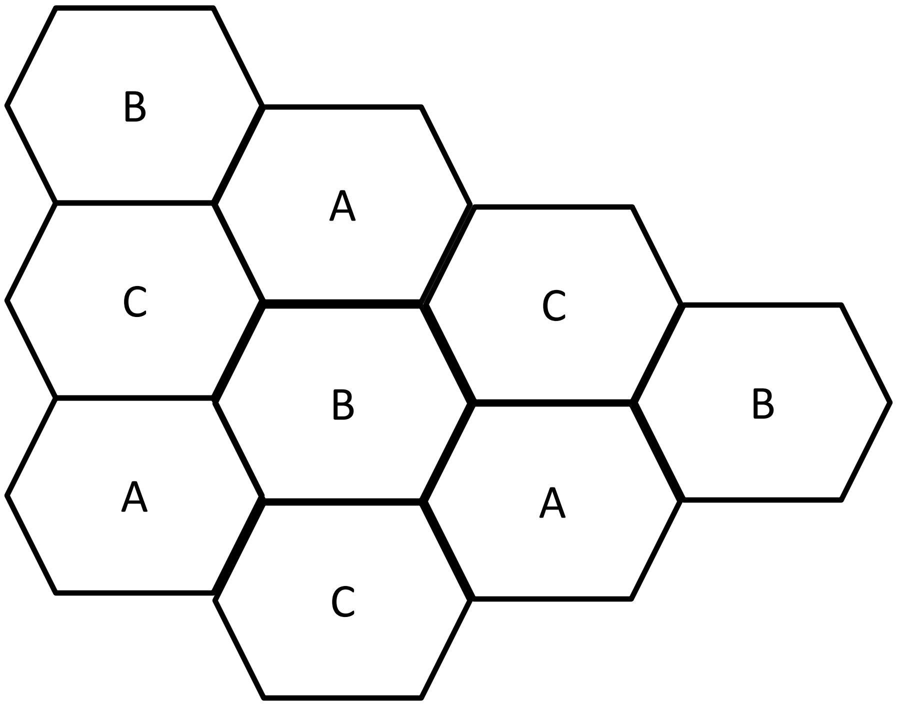


Illustration of a 3 cell cluster. In this case all the available channels are completely used up in 3 cells or *frequency reuse factor* = 1/3

Frequency Reuse

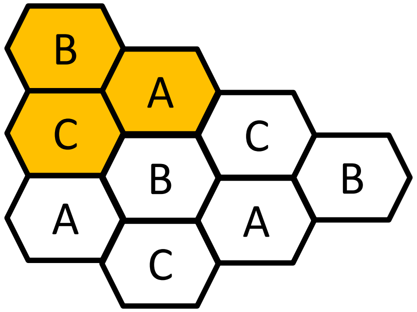
- The hexagon shape of base station coverage area is an approximation and has been adopted for easy and manageable analysis of cellular systems

- The actual coverage area of a cell is known as the *footprint* and is determined from field measurements or propagation models.

Frequency Reuse

Consider a cellular system with '*S*' duplex channels. If each cell is allocated a group of '*k'* channels (*k*<S), and if the '*S*' channels are divided among '*N*' cells into unique and disjoint channel groups which each have the same number of channels, the total number of available radio channels can be expressed as

$$S = kN \qquad (3.1)$$



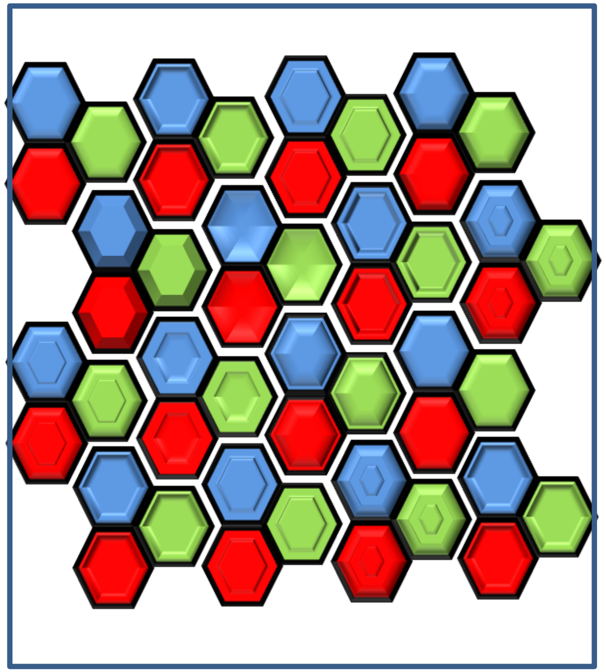
The *N* cells which collectively use the complete set of available frequencies is called a '***cluster***'. If a cluster is replicated '*M*' times within the system, the total number of duplex channels, *C*, can be used as a measure of capacity and is given by

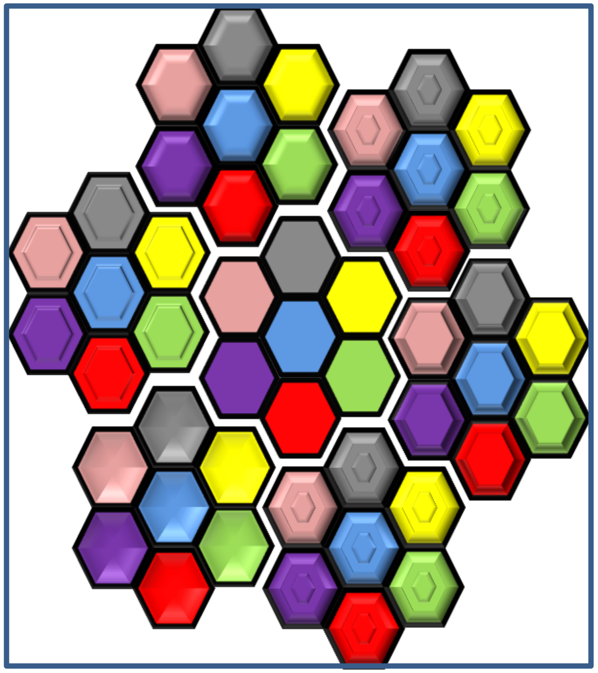
$$C = MkN = MS \qquad (3.2)$$

Frequency Reuse

- As seen from Eqn-3.2 the capacity of a cellular system is directly proportional to *M*, the number of times a cluster is replicated in a fixed service area.
- The factor *N* is called the *'cluster size'* and is typically equal to 4, 7, or 12.
- If *N* is **reduced** while the cell size is kept constant, more clusters are required to cover a given area, and hence **more capacity is achieved**.

Frequency Reuse





Total No. of cells =49(approx)
N (cluster size) = 3
Total Clusters = 16
Channels/Cluster = 100
Capacity = 100*16 = 1600 Channels

Total No. of cells =49
N (cluster size) = 7
Total Clusters = 7
Channels/Cluster = 100
Capacity = 100*7 = 700 Channels

Frequency Reuse

- Small cluster size ⇨ Small Co-channel cell separation
  (Large Capacity, High Interference Level)

- Large cluster size ⇨ Large Co-channel cell separation
  (Small Capacity, Low Interference Level)

- The value of *N* (cluster size) is a function of how much interference a mobile or base station can tolerate while maintaining a sufficient of quality of communication

- The *frequency reuse factor* of a cellular system is given by 1/N,since each cell within a cluster is only assigned 1/N of total available channels e.g. if N=4 and cellular system has total 660 channels available, so total number of channels available per cell=660/4=165 channels

Frequency Reuse

- The geometry of hexagons is such that the number of cells per cluster, *N*, can only have values which satisfy Eqn-3.3

$$N = i^2 + ij + j^2 \qquad (3.3)$$

  where i and j are non-negative integers.
- To find the nearest co-channel neighbours of a particular cell, one must do the following:
  1. Move i cells along any chain of hexagon
  2. Turn 60 degrees counter-clockwise and move j cells.
     (see Fig-3.2)

Frequency Reuse

- Move i cells along any chain of hexagon
- Turn 60 degrees counter-clockwise and move j cells.

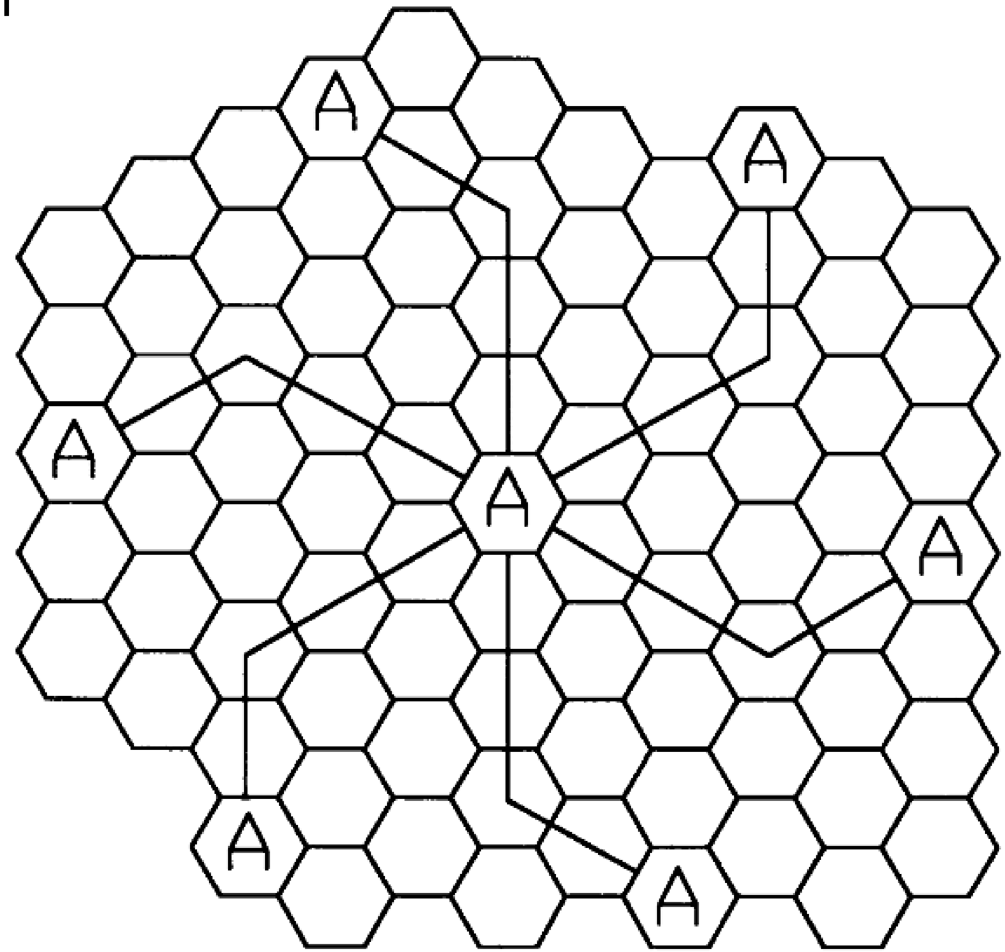


Figure 3.2 Method of locating co-channel cells in a cellular system. In this example, N = 19 (i.e., i = 3, j = 2). (Adapted from [Oet83] © IEEE.)

Channel Assignment Strategies

- A variety of channel assignment schemes have been developed to increase capacity and minimize interference.

- Channel Assignment strategies can broadly be classified as:

    1. Fixed Channel Assignment
    2. Dynamic Channel Assignment

Fixed Channel Assignment

- Each cell is allocated a predetermined set of voice channels.
- If all the channels in a cell are occupied then any call attempts from within that cell are blocked.
- One variant is *borrowing strategy*.
  - A cell is allowed to borrow channels from neighbouring cells if all of its channels are already occupied.
  - Borrowing takes place under supervision of the MSC ensuring that borrowing does not disrupt with any calls in progress in donor cell

Dynamic Channel Assignment

- Voice channels are not allocated to different cells permanently.
- Each time a call request is made, the serving base station requests a channel from the MSC.
- The MSC allocates a channel to the requested cell keeping in consideration cost functions such as:
  - The frequency of use of the candidate channel.
  - The reuse distance of the channel.
  - Likelihood of future blocking within the cell

Fixed Vs. Dynamic Assignment

- Dynamic Channel Assignment reduces the blocking probability in the system.

- Dynamic channel Assignment increases the storage and computational load on the system.

Fixed Vs. Dynamic Assignment

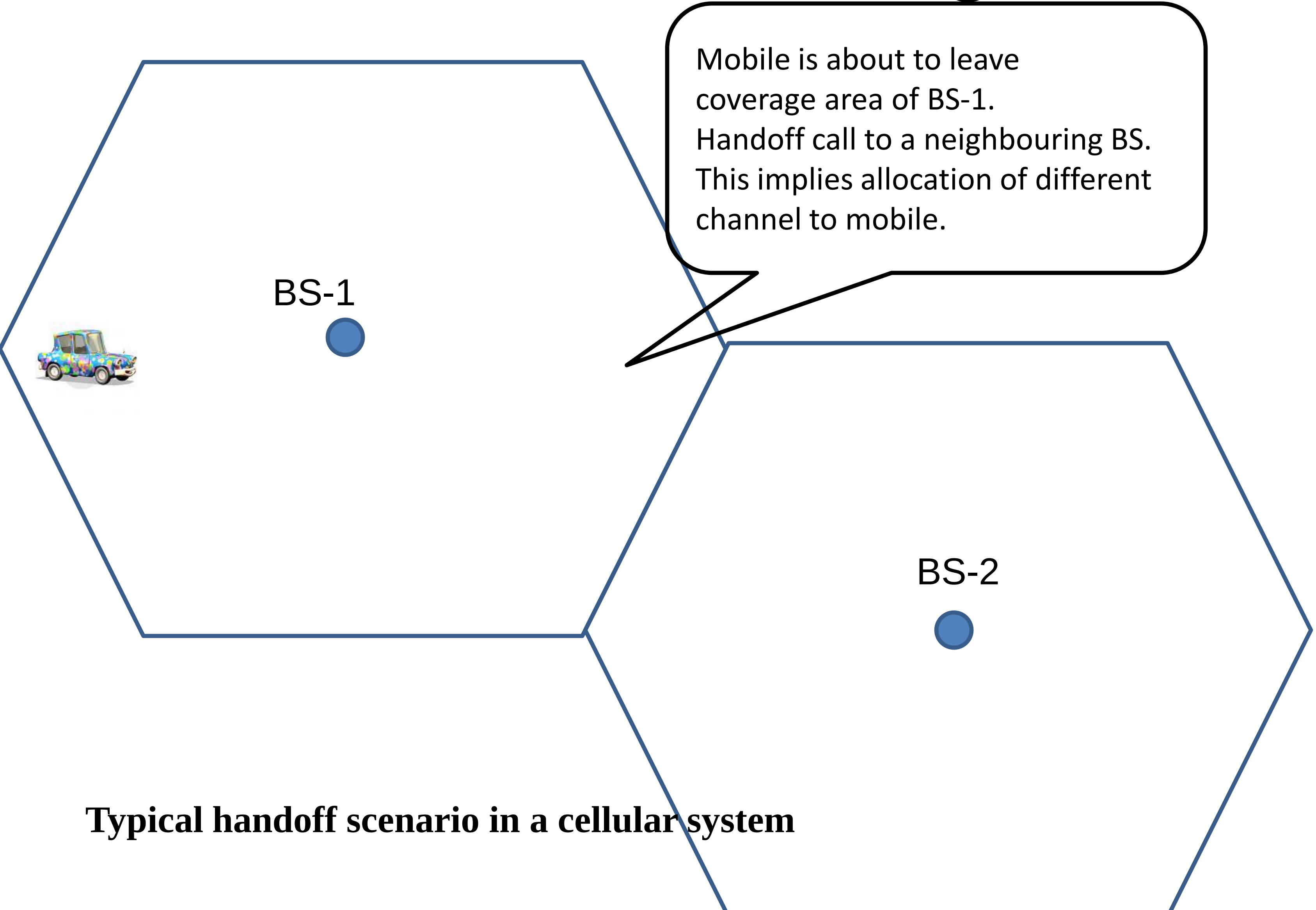
- Dynamic channel assignment strategies require the MSC to collect real-time data on:
  - Channel occupancy
  - Traffic distribution
  - *Radio signal strength indications (RSSI)* of all channels

Handoff Strategies

- What is Handoff.?

  A Handoff occurs when a mobile moves into a different cell while a conversation is in progress, the MSC automatically transfers the call to a new channel belonging to the new base station.

Handoff Strategies



Typical handoff scenario in a cellular system

Handoff Strategies

- What is Handoff.?

  A Handoff occurs when a mobile moves into a different cell while a conversation is in progress, the MSC automatically transfers the call to a new channel belonging to the new base station.

- Handoff Considerations:

  Handoffs must be performed successfully and as infrequently as possible, and be imperceptible to the users.

  Failure to perform a handoff successfully results in termination of the ongoing call.