Agenda for discussion

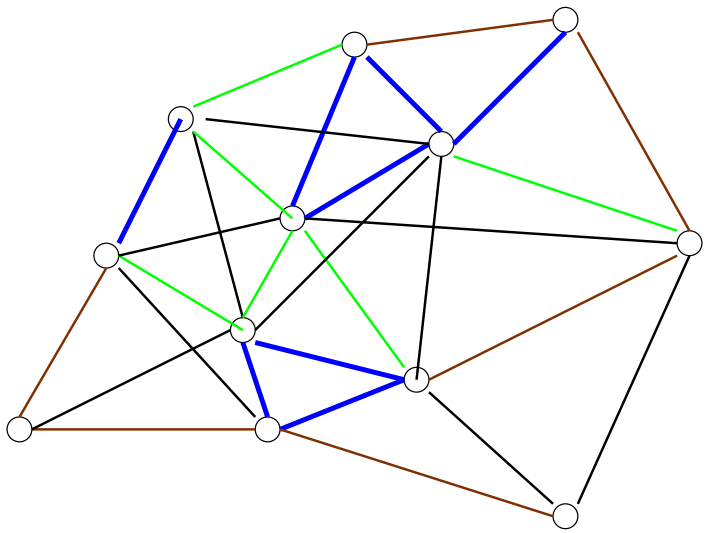
The lecture contains:

Channel assignment and support for **user mobility** in cellular system.

- Fixed channel assignments.
- Dynamic channel assignments.
- Handoffs.

Fixed channel assignment

Interference graph



Fixed channel assignment

Uniform distribution of traffic

- Used when distribution of traffic load is uniform.
- The set of available channels is partitioned into N disjoint sets. $N = \left(\frac{1}{3}\right) \times \left(\frac{D}{R}\right)^2$ Where R is range and D is reuse distance.
- The overall average call blocking probability will be same as call blocking probability in a cell.

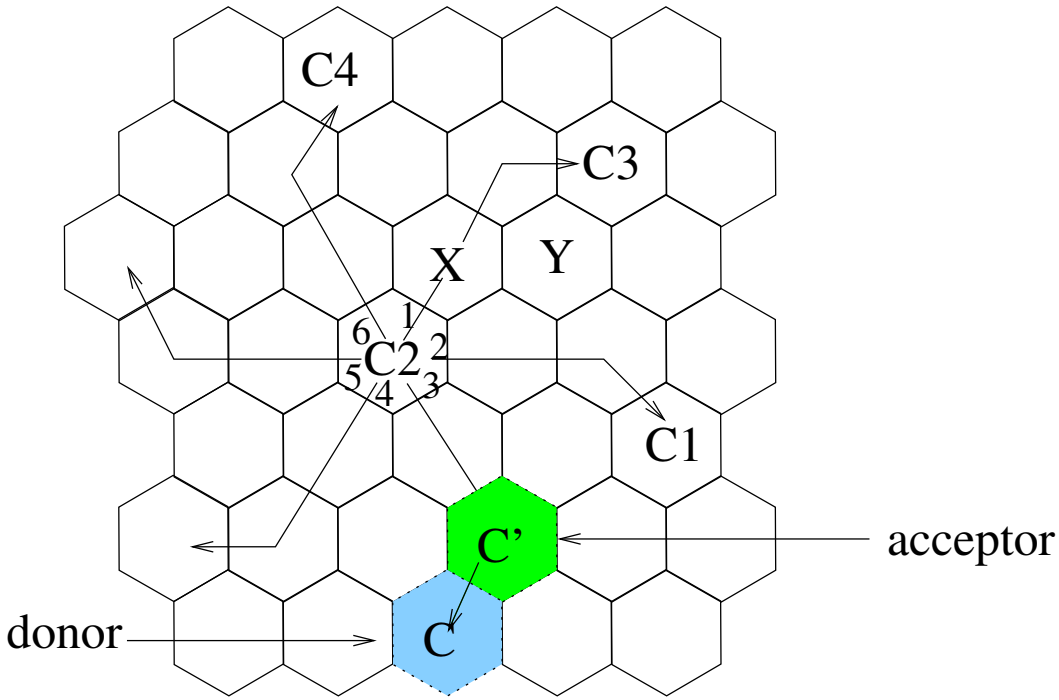
Fixed channel assignment

Borrow From Richest (BFR)

- A common sense driven approach is to borrow a free channel when no free channel is found.
- The borrower is called **acceptor**
- Lender is known as **donor**.
- Free channel should be selected in such way that:
  1. It does not affect donor cell.
  2. Does not introduce interferences on existing connections.
- By selecting the cell with largest number of free channels (BFR) as donor both conditions can be met.

Fixed channel assignment

Borrow From Richest



Fixed channel assignment

Borrow the First Available (BFA)

- Any sophisticated borrowing method will incur penalties for complex searchings.
- A simpler option is to use BFA channel.
- But, for implementing BFA, the initial channels assignment should be different from direct assignment of channels to cells.
- The set of channels is first divided into sets and each set is assigned to cells at a reuse distance D.
- Then channel ordering is used for borrowing.

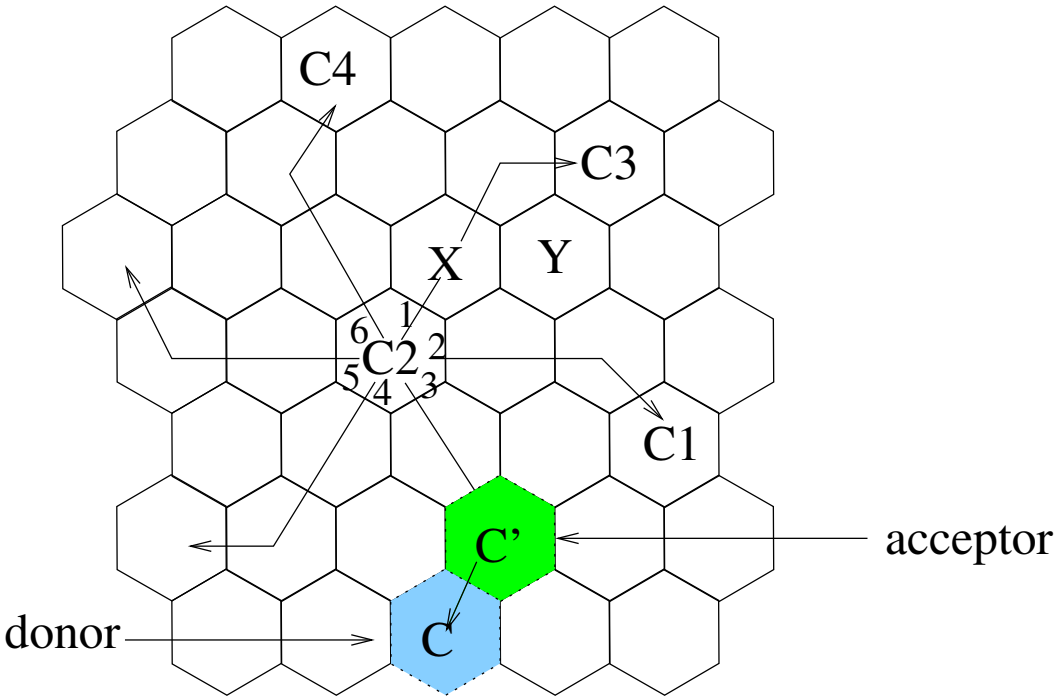
Fixed channel assignment

Borrowing with Channel Ordering (BCO)

- Channels with highest priority used for call locally.
- Channel with lowest priority is used for borrowing in neighboring cell.
- It dynamically adjusts the ratio of the channels used in cell and those lent to neighboring cells.
- Borrowed channel is locked in co-channel cells within reuse distance.

Fixed channel assignment

Borrowing with Directional Channel Locking (BDCL)



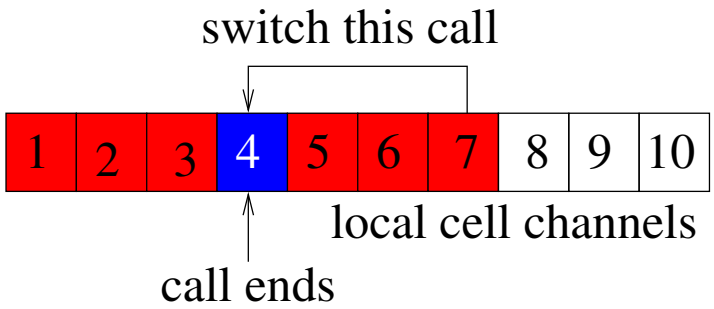
Fixed channel assignment

Returning borrowed channel

- Borrowed channel should be returned to the donor cell.
- The question is: when a borrowed channel should be returned donor cell?
- Answer depends on how it could influence systems performance.
- Performance here concerns:
  1. Inability of the system to satisfy a new connection request.
  2. The number of channel switchings for ongoing connections.
- Channel switching is not only costly but irritating.

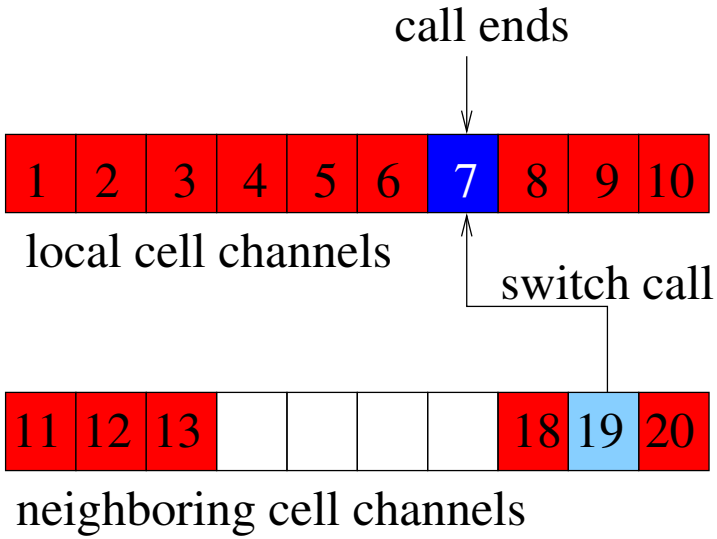
Fixed channel assignment

Channel reallocation



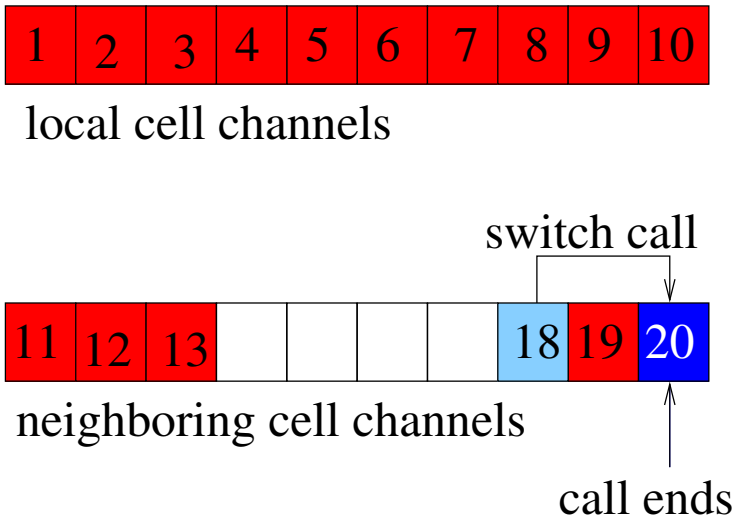
Higher order nominal channel is released then an existing call on lower order channel switched.

Fixed channel assignment



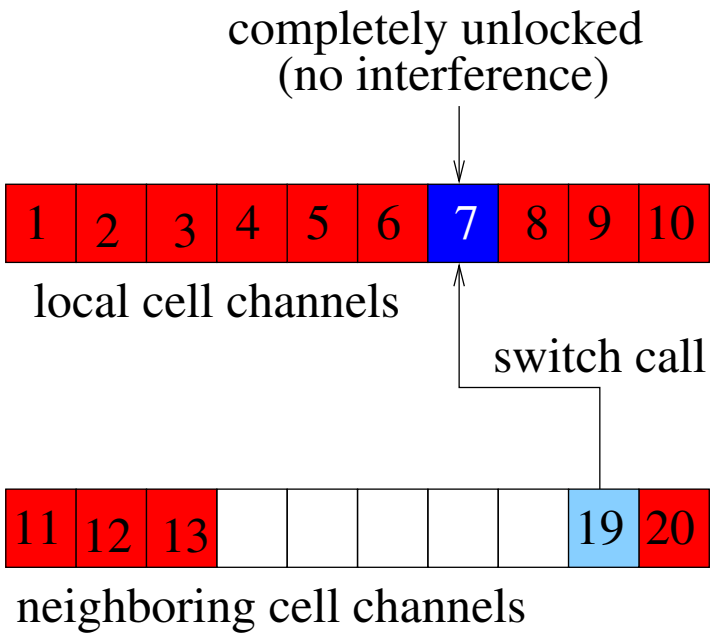
A nominal channel is released then an existing call on borrowed channel then release borrowed channel switching call to nominal channel.

Fixed channel assignment



A call on borrowed channel terminates but a call on lower order borrowed channel exits then release higher order borrowed channel switching call to lower order channel.

Fixed channel assignment



A channel is completely unlocked by termination of call in interfering cell, existing call on borrowed channel or a higher order channel is switched to this channel.

Fixed channel assignment

Channel reallocation

- Under heavy traffic conditions, different channel borrowing schemes would increase channel switchings considerably.
- In order to reduce channel switchings a comprehensive channel reallocation strategy would be needed.
- Simple FCA sometimes may provide better performance than FCA with channel borrowing.

DCA: centralized algorithms

Algorithms based on local optimizations

- First available (FA): assigns the first channel ensuring channel reuse constraints.
- Locally optimized dynamic assignment (LODA).
- Channel reuse optimization.
- Maximum use in reuse ring.
- Mean square distance.
- Nearest neighbour cell at distance $\geq D$.

DCA: centralized algorithms

1-clique scheme

- Based on global optimization.
- Builds a graph for each channel where each vertex represents a cell, and two vertices in this graph are connected by an edge if and only if the cells corresponding to the end vertices do not have co-channel interference.
- So, each graph presents channel allocations possibilities.
- Actual channel assignment is done from several possibilities so that as many vertices as possible, still remain available for allocation.

Distributed algorithms for DCA

Information on channel occupancy

- Each cell keeps track of free channels, the information stored in an augmented channel occupancy (ACO) matrix
- It is an $(M+1) \times (k_i+1)$ matrix, where M is the number of channels in the system and k_i is the number of co-channel cells.
- Last column gives number of free channels in the cell corresponding to the row.

Distributed algorithms for DCA

ACO matrix

Cells	Channel number						assignable channels
	1	2	3	4	...	M	
i		x		x	...		0
i_1	x			x	...		0
i_2		x		x	...		3
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
i_{k_i}		x		x	...		5

Distributed algorithms for DCA

ACO matrix

- The cell finds an empty column and assigns the channel corresponding to first empty column.
- If no empty column exist, the column having minimum occupancy is considered. If the cells occupying this channel have assignable channels then:
  - Those cells are requested to shift their existing call on the chosen channel to some other channel.
  - The chosen channel then becomes free for assignment.

Distributed algorithms for DCA

ACO matrix

- The issue of adjoint channel interference (ACI) can be also solved by adding extra restriction on the channel selection from ACO matrix.
- ACI effects are negligible if the minimum channel separation of N_{adj} is maintained.
- At the time of assigning a new channel c to cell i, the algorithms ensure that the channels corresponding to columns $N_{adj} - 1$ to the left and the right of column c in ACO matrix do not have entries for row i.

Distributed algorithms for DCA

Channel assignment and mutual exclusion

- Channel is a resource.
- Neighboring cells can not share this resource simultaneously.
- So, it is similar to mutual exclusion problem.
- There are differences:
  - In ME no two processes can share a resource simultaneously.
  - But in CA, channel can be used by two cell provided minimum reuse contraint is preserved.
  - In CA, a collection of resources (channels) is to be shared.
- However, techniques of ME could lead to a solution for CA.

Distributed algorithms for DCA

Channel assignment and mutual exclusion

Consider it as relaxed ME (RME). Certain pair of cells can not use while certain other pair can use the same channel simultaneously. The problems are:

- How to implement RME on single resource.
- Resolving deadlocks.
- Extending RME to multiple resources.
- Designing information structures.
- Implementing efficient channel selection strategy.

Service provisioning with mobility

Continuity of service

- Provisioning continuity of service despite users' mobilities is a challenging.
- Interestingly, solution based on a simple idea of the game of football!
- The continuity can achieved by handoffs (or handovers).
- Handoff process is induced either by cell crossing, or when the quality of channel deteriorates.

Service provisioning with mobility

Reasons for service deterioration

1. Signal quality deterioration.
2. Traffic load.

Service provisioning with mobility

Keeping connection alive

- If the link to new BS is formed before or almost immediately as the link to old BS goes down.
- Thus, a handoff is the transition of signal transmission from one BS to another.
- Frequency (channel) switching may also be required when MT is moving inside cell. Eg., intra-cell handoffs discussed in channel allocation schemes.
- Our focus is on inter cell handoffs.

Service provisioning with mobility

Keeping connection alive

- Cells overlap: it means MT is within the range of multiple BSs at the boundary of a cell.
- The N/W decides which BS will handle the transmission to/from MT. The decision could be
  - With assistance of MT, or
  - Without assistance of MT.
- The critical part of the handoff: the detection of the handoff condition.
- Once an active connection is completely severed nothing can be done.

Hystersis

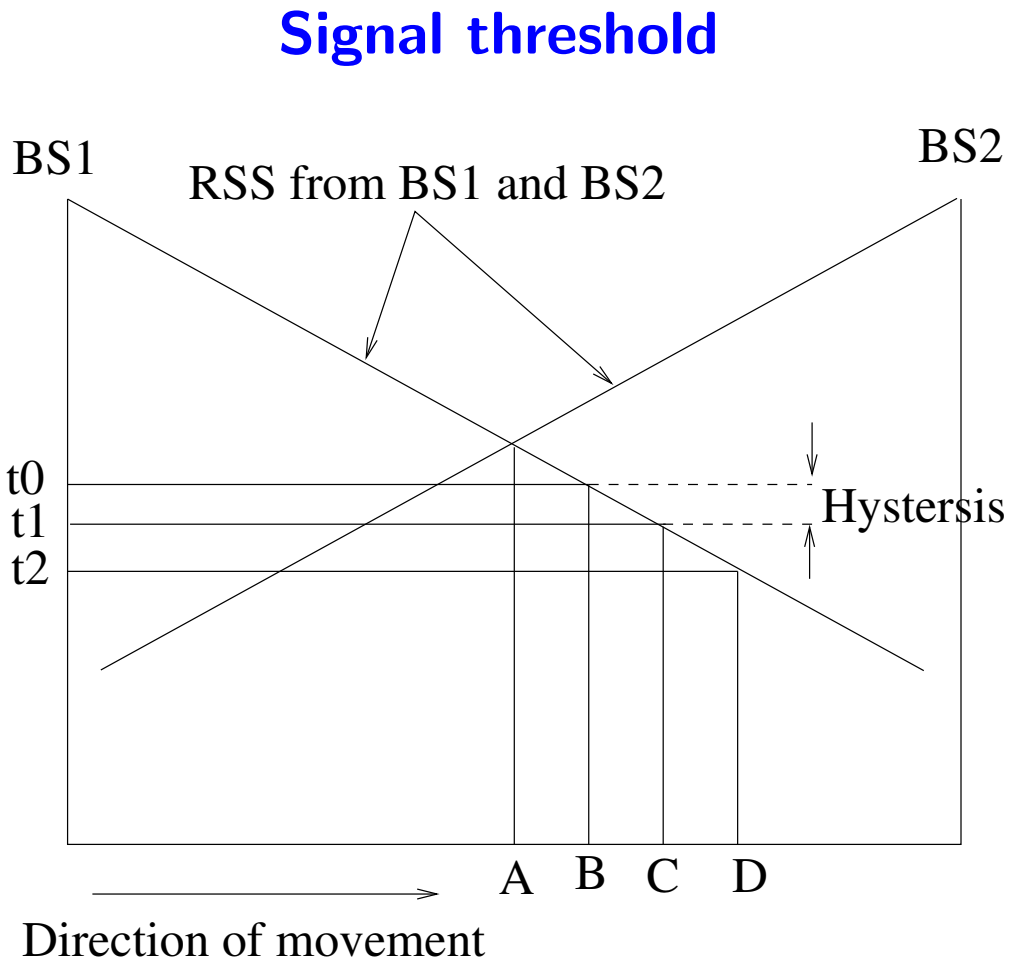
Signal threshold

- **Threshold**: signal level slightly stronger than minimum.
- **Hystersis**: the margin between the threshold and the minimum usable signal.
- Hystersis can be defined by value

$$\Delta = S_{handoff} - S_{min},$$

- Δ should not be too small or too large.

Hystersis


Signal threshold
BS1
RSS from BS1 and BS2
BS2
t0
t1
t2
Hystersis
A
B
C
D
Direction of movement

Hystersis

Signal threshold

The value of Δ depends on:

- Environment.
- Speed of mobile.
- Time required to perform handoff.

Handoff protocol

Entities involved

- Entities involved are:
  1. User's mobile handset (MH),
  2. BS to which MH is currently connected and BSs in the neighborhood of MH's movements, and
  3. MSCs controlling the above group of BSs.
- Both network entities (BSs and MSCs) and MH may initiate and control a handoff.

Handoff protocol

Handoff classes

Depending on controlling entity or the entities, the handoff classified as:

1. Network controlled.
2. Mobile assisted.
3. Mobile controlled.

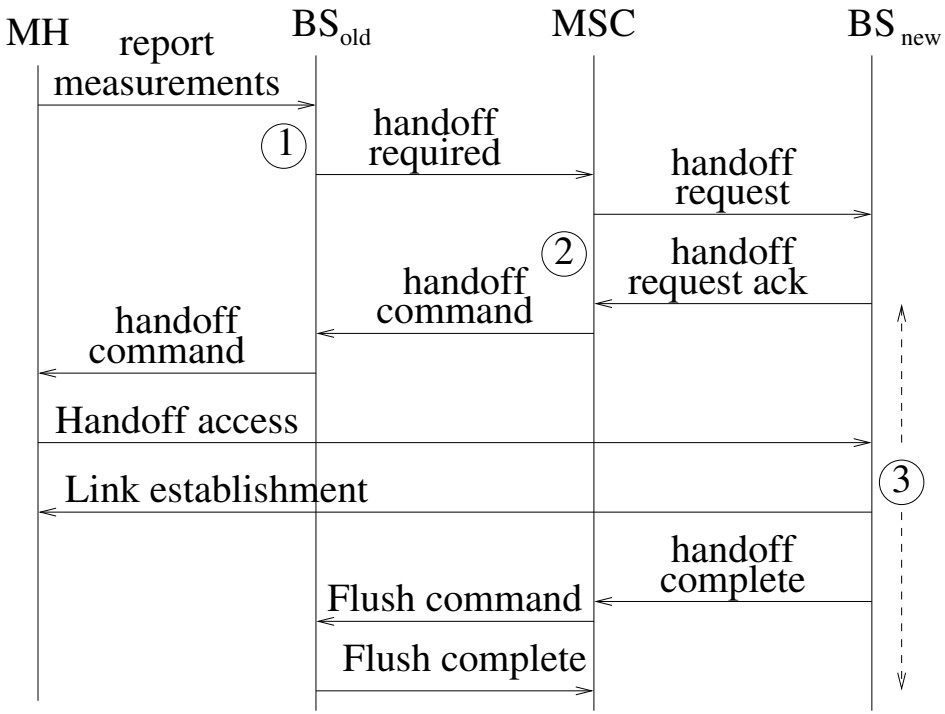
Handoff protocol

Goals of handoff protocol

1. Should be performed quickly.
2. Interruption in connection should be imperceptible to users.
3. Should be performed infrequently.
4. Should be performed successfully.

Handoff protocol

Generic procedure



① Handoff decision ② Resource allocation ③ Handoff execution

Summary

- We discussed about **channel assignments** and **handoff**.
- Channel assignment are of two types: **fixed** & **dynamic**.
- In dynamic channel assignment channels are allocated on need basis.
- Simple techniques like **borrowing** could be used for handling dynamic assignment.
- However,**DCA** is more complicated than **FCA**.
- **Handoff** is important for maintaining connectivity while user moves about.