無線網路多媒體系統
Wireless Multimedia System

Lecture 5: Cellular Concepts

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http://wmlab.csie.ncu.edu.tw/course/wms

Mobility Support & Channel Reuse

Mobility Support~ Handover

Channel Allocations: Reuse

Channel Assignment in Cellular System

- Fundamental Problem:
- Fixed Channel Assignment
- Dynamic Channel Assignment
- Hybrid Schemes
- Whole Channel Usage (CDMA)
- Reduce the Cell Size

Hand-off in Cellular Networks

- Transfer of mobile to a new channel when it crosses cell boundary
- Handoff delay
- Prioritizing handoffs to reduce probability of dropped calls
- Handoff Strategies
- Network Controlled handoff (NCHO)
- Mobile assisted handoff (MAHO)
- Mobile controlled handoff (MCHO)

Agenda

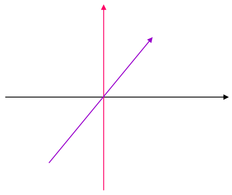
- Cellular Concepts
- Channel Assignments
- Handover
- Next Lecture: 3G WCDMA design

Reading

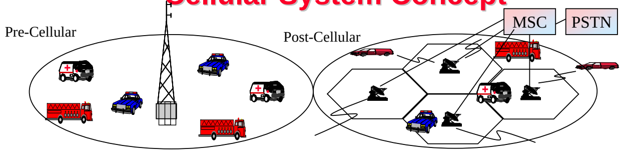
- [Katzela96]Katzela, and M. Nahgshineh,"Channel assignment schemes for cellular mobile telecommunication systems: a comprehensive survey," IEEE Personal Communications, June 1996
- [Pollinin96], G.P. Pollini, "Trends in handover design, "IEEE Communications Magazine, March 1996.

Channel Allocation

- A given Channel Spectrum (or bandwidth) can be divided into a set of disjoint or non-interfering radio channel
  - Frequency Division
    - frequency band
  - Time Division
    - time slot
  - Code Division
    - modulation code



Cellular System Concept

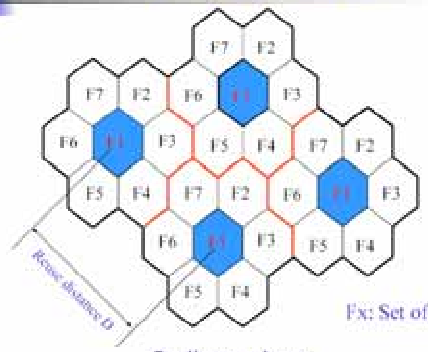


- Replace single high power transmitter covering the entire service area with low power
  - Mobiles in sufficiently distant base-stations may be assigned identical channel (frequency, time slot, & code)
  - System capacity may be increased without adding more spectrum
- Major conceptual breakthrough in spectra congestion & user capacity
  - Required relatively minor technological changes frequency reuse & co-channel interference, channel allocation, hand-offs

Cell Shape

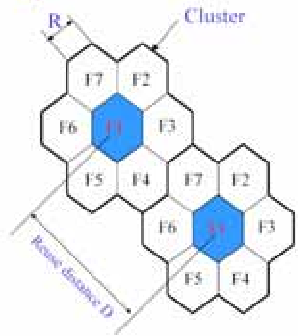
(a) Ideal cell (b) Actual cell (c) Different cell models

Frequency Reuse



7 cell reuse cluster

Reuse Distance



- For hexagonal cells, the reuse distance is given by

$$D = \sqrt{3N}\,R$$

where R is cell radius and N is the reuse pattern (the cluster size or the number of cells per cluster).

- Reuse factor is

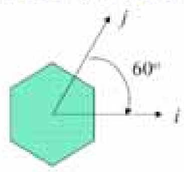
$$\frac{D}{R} = \sqrt{3N}$$

Reuse Distance (Cont'd)

- The cluster size or the number of cells per cluster is given by

$$N = i^2 + ij + j^2$$

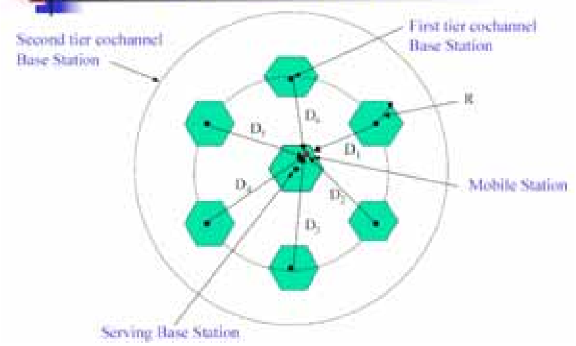
where i and j are integers.



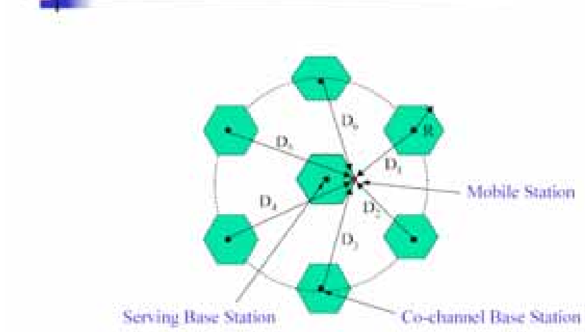
- N = 1, 3, 4, 7, 9, 12, 13, 16, 19, 21, 28, …, etc.

The popular value of N being 4 and 7.

Cochannel Interference



Worst Case of Cochannel Interference



Cochannel Interference

- Cochannel interference ratio is given by

$$\frac{C}{I} = \frac{Carrier}{Interference} = \frac{C}{\sum_{k=1}^{M} I_k}$$

where I is co-channel interference and M is the maximum number of co-channel interfering cells.

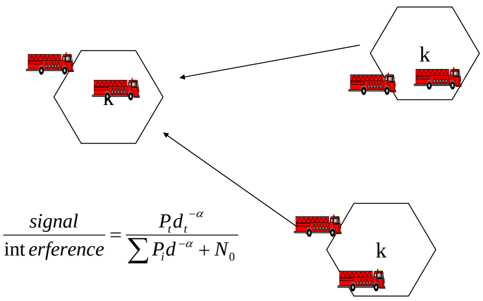
For M = 6, C/I is given by

$$\frac{C}{I} = \frac{C}{\sum_{k=1}^{6} \left(\frac{D_k}{R}\right)^{\gamma}}$$

where γ is the propagation path loss slope and $\gamma = 2\text{–}5$.

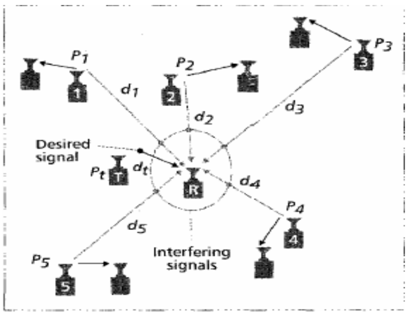
Channel Reuse

- The same channel is reused simultaneously by other sets (Co-channel)



$$CIR = \frac{signal}{interference} = \frac{P_t d_t^{-\alpha}}{\sum P_i d^{-\alpha} + N_0}$$

Interference



$$CIR = \frac{signal}{interference} = \frac{P_t d_t^{-\alpha}}{\sum_1^5 P_i d_i^{-\alpha} + N_0}$$

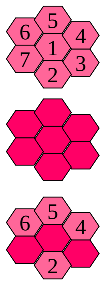
How to improve CIR (Quality)

- Increase the transmitting power (Power Control)
- Increase the separating distance (Channel Reuse)

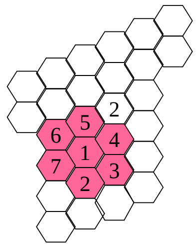
$$CIR = \frac{signal}{interference} = \frac{P_t d_t^{-\alpha}}{\sum P_i d^{\alpha} N_0}$$

Approaches

- Fixed no flexibility
- Dynamic complexity
- Hybrid might be ok



Frequency Reuse

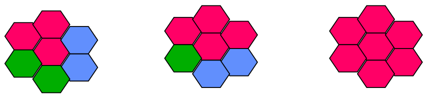


Idealized grid of Hexagonal cells

- Each BS is allocated a subset of carrier freqs
- Nearby BSs are allocated a different subset to avoid interference
- The total set is allocated to a small tesselating group of N neighboring BSs
  - Called "reuse cluster"
  - 1/N is the "reuse factor"
  - System capacity goes up by $\frac{Area_{service}}{N \times Area_{cell}}$
- Used in FDMA & TDMA based systems
  - Not required in CDMA which has universal frequency reuse
- Cells idealized as hexagons
  - Real cell footprints are amorphous
  - Hexagon close to a circle
  - Not appropriate for micro-cells, highways etc.

Reuse Cluster For Hexagonal Cells

- A tessellating group of N hexagonal cells is possibly only iff



- Frequency Reuse Distance D
  - minimum distance between centers of co-channel cells
    - Depends on # of nearby cochannel cells, terrain, antenna height, transmit power etc.
  - for hexagonal cells, $D = R\sqrt{3N}$
    - Where, R is the radius of hexagon (center to vertices)
  - Increasing N, and therefore D, reduce co-channel interference (assuming R and transmit power are invariant
  - D/R is called the co-channel reuse ratio

Determining Cluster Size

- If N is reduced while cell area is kept constant
  - more cluster needed to cover the service area
  - more channels per cell
  - more system capacity achieved
  - more co-channel interference co-channel cells are closer
- Goal is to maximize system capacity (or, capacity per unit area) subject to interference limitations
  - Minimum N such that carrier-to-interference ratio
    - $C/I \geqq (C/I)_{min}$
  - Reverse co-channel interference
    - Interference at a BS from co-channel MHs in other BSs
  - Forward co-channel interference
    - Interference at a MH from other co-channel BSs
  - Adjacent channel interference
    - From signals in adjacent channel due to imperfect filters
    - Don't assign adjacent frequencies to the same cell and if possible immediate neighbors

Determining Cluster Size N

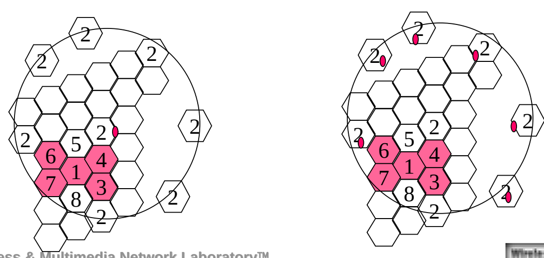
- Goal is maximize system capacity (or, capacity per unit area) subject to interference limitations
  - minimum N such that carrier-to-interference ratio
    - $C/I >= (C/I)_{min}$
  - reverse co-channel interference
    - interference at BS from co-channel MHs in other BSs
  - forward co-channel interference
    - interference at a MH from other co-channel BSs
  - adjacent channel interference
    - from signals in adjacent channels due to imperfect filters

Calculating C/I

- Let i_0 be the number of co-interfering cells, and noise be negligible

$$\frac{C}{I} = \frac{C}{\sum_{i=1}^{i_0} I_i}$$

  - C/I = Carrier / All of the co-channel interference
  - Where C is the desired carrier power and I_i is the signal power of i-th interferer



Calculating C/I

- Recall: $P_r(d) = P_r(d_0)(\frac{d}{d_0})^n$
- For equal transmit powers and path loss exponents: $\frac{C}{I} = \frac{D_0^{-n}}{\sum_{i=1}^{i_0} D_i^{-n}}$
- Assume:
  - 1. n=4
  - 2. worst case is at D_0 = R (when MH is at the fringe of its cell)
  - 3. only the six “first-tier” co-channel cells are considered
  - 4. $D_1 = D_2 = D_3 = D_4 = D_5 = D_6 = D$
- C/I~ $(D/R)^4$ / 6 depends only on the ratio D/R

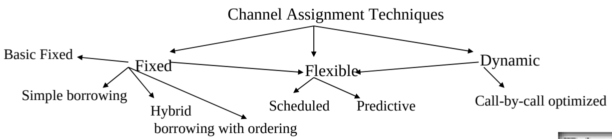
system	$(C/I)_{min}$	D/R	N
AMPS	18 dB	4.6	7
GSM	11 dB	3.0	4

Microcells-Reducing Cell Area

- IF cell area is reduced while N is kept constant
  - more clusters needed to cover the service aread
  - C/I is unchanged because D/R is unchanged
  - system capacity grows quadratically with radius scale factor
- Small cells need lower RF transmitted power
  - longer battery, smaller mobile end-points
- Small cells result in higher cell-boundary crossing
  - more signalling overhead
  - performance degradation (more disruption)

Channel Assignment in Cellular System

- Fundamental Problem
  - How to assign channels to requesting call at a BS ?
- Goal: Maximum Spectral Efficiency for a specified grade of service and a given degree of computational complexity
  - probability of new call blocking
  - probability of forced termination
  - link quality
- Maybe a “new” connection, or a connection undergoing “handoff”



Channel Assignment Techniques

- Fixed
  - Basic Fixed
  - Simple borrowing
  - Hybrid borrowing with ordering
- Flexible
  - scheduled
  - predictive
- Dynamic
  - call-by-call optimized

Fixed Channel Assignment

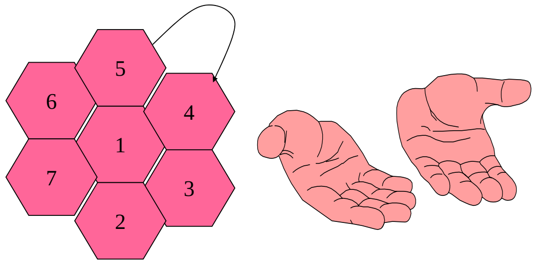
- Basic strategy
  - each cell is statically allocated a subset of channels
  - a requesting call in the cell can only use channel allocated to that cell
  - if no available channel in that cell, the call is blocked
  - MSC only informs new BS about hand-off, & keep track of serving channel

Fixed Channel Assignment

- Variation
  - borrow channel from neighboring BSs if all channels busy at BS under MSC supervision, and only if does not cause interference borrowed channels are “locked”
  - hybrid channel assignment
    - two groups of channels: fixed and borrowable
    - ratio determined a priori depending on traffic estimate
  - borrow-with-channel-ordering
    - fixed-to-borrowable channel ration varied on changing traffic condition
    - channels are rank ordered

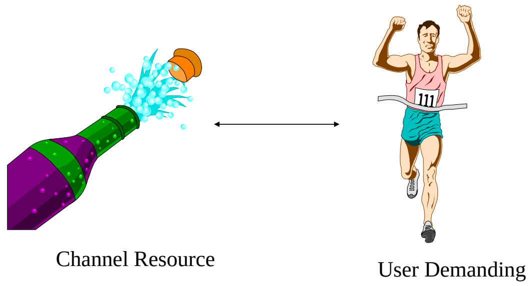
Fixed Channel Assignment

- We might borrow from neighboring cells



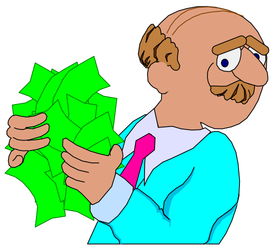
Traffic & Resource

- Uniform Distribution



Dynamic & Assignment

- Maybe I should assign you based on current condition



Issues to consider

- Selected Cost
- Blocking Probability
- Reuse Distance
- CIR
- QoS (Quality of Service)
  - current value
  - handoff value

Dynamic Channel Assignment (DCA)

- Basic Features
  - channels not allocated to cells permanently
  - MSC allocated channel to a call from the global pool taking into account
  - Advantage: channel assignment may be retained across hand-off
  - Disadvantage: interruptions, deadlocks, instability

Dynamic Channel Assignment

- DCA algorithms differ in distribution of control among BSs and MSC
  - Centralized DCA
    - can do a globally optimized channel assignment and call rearrangement BSs need to communicate with MSC e.g. Maximum Packing
  - Decentralized & Fully Decentralized DCA
    - rely only on local monitoring to make channel assignments
    - require limited local communication among cluster of BSs

Flexible Channel Assignment

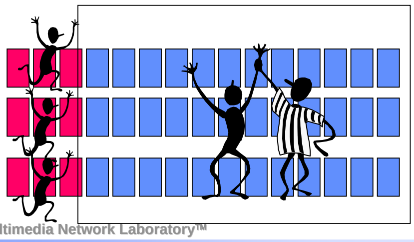
- Combine aspects of FCA and DCA
- Each cell is assigned a fixed set of channel
- Plus, a pool of channels is reserved for flexible assignment
  - MSC assigns these channels
- Flexible assignment strategies
  - Scheduled assignment: rely on known foreseeable changes in traffic pattern
  - Predictive assignment: based on measured traffic load at every BS

MSC will pick up one for MH

- Here you go !

Flexible Channel Assignment

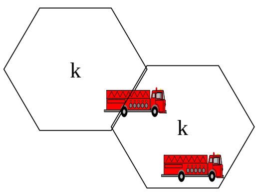
- Assign some of channel for minimum traffic requirement
- Keep all of the others in a service pool



Handoff Handling

Keep the QoS while the user moves

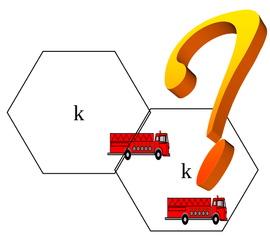
Handling Handoffs



- Handoff
  - change the radio channel
    - the same base station
    - the new base station
  - due to
    - the radio link degradation
    - channel reorder

What is going to happen ?

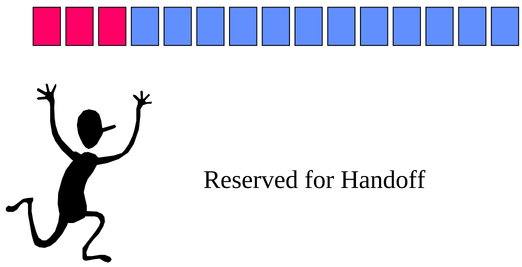
- The new cell must assign new channel
- We must reserve some hand off channel
- Some connection must be blocked !!



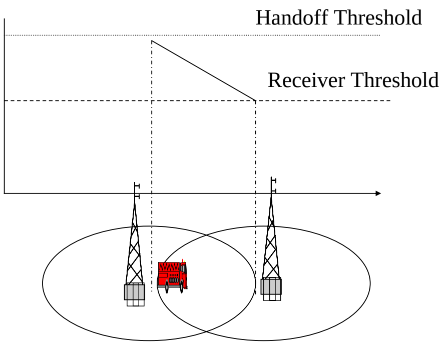
Solutions for handoff

- Handoff Priority
  - guard channel for handoff
  - how much, inefficiency
- Queueing of Handoff request
  - take a seat for future handoff

Guard Channel

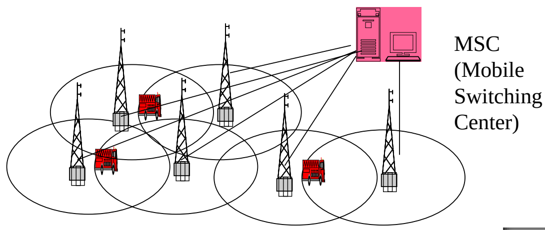


Thresholds



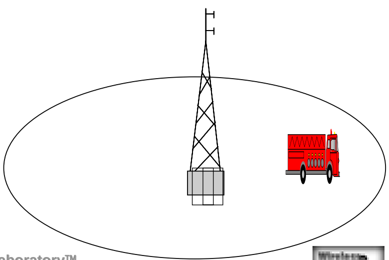
Who is going to take over Handoff

- Yourself (Mobile Users)
- Infrastructure Network
  - Base Station
  - Mobile Switching Center



Negotiating Procedure

- Base Station
  - detect the receiving signal from MH
  - send a measurement order
- Mobile Host
  - measure on demand
  - measure all the time

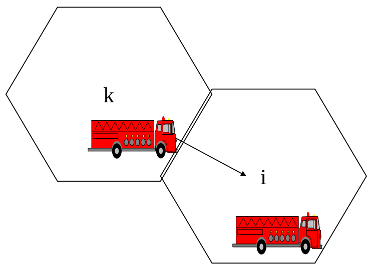


Hand off Procedure

- Decide the New Base Station
  - MSC picks the best for MH
  - MSC picks the candidate MH specify
- New Base Station decides to accept or not ?

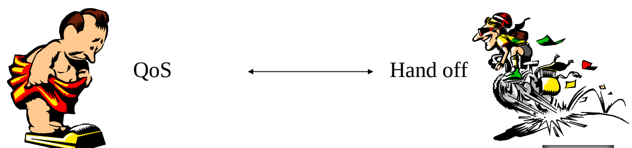
Call Queueing Scheme

- Queue for a channel, handoff threshold, receiver threshold



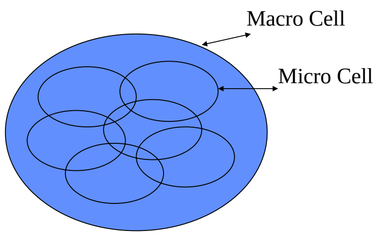
Trends in Hand over Design

- Hand over and Hand off are the same
- Small cells -> more hand over
  - allocate network resource to reroute the call to the new base station
  - if not quick enough, QoS will drop dramatically



Mobility Solution

- Multi-tiers
  - micro-cell and macro-cell
  - based on the speed
  - different schemes



Velocity Estimation

- Doppler Frequency is known -> Estimation of the velocity of the mobile users
- Mobility is estimated from the time spent in a cell

Handoff in Cellular Networks

- Transfer of mobile to a new channel when it crosses cell boundary
  - identify new base station, assign new channel
  - hand-off initiated at a carefully chosen signal level
  - avoid triggering handoff due to momentary fades

Hand-off

- Handoff delay & interruption
  - dropped (or on hold) connection if signal too low before handoff processed
  - performance degradation (disruption) in data stream
- Prioritizing handoffs to reduce probability of dropped call
  - connection dropped if no spare channels in new cell
  - guard channel : subset of channels reserved for handoff requests works well with DCA
  - handoff queuing : time interval between handoff trigger & connection drop cell overlap, speed of mobile

Handoff in Cellular Networks

- Probability of unnecessary Handoffs
- Hard vs. Soft handoff
- Hand off rate
- Handoff also triggers rerouting in the network layer
- Handoff is tightly coupled to DCA, MAC, and Networking Routing

Handoff Strategies (I)

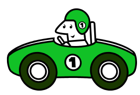
- Network controlled handoff (NCHO)
  - used in first generation analog cellular systems
  - link quality is only monitored by the serving BS and surrounding BS
  - handoff decision is made by the network (typically central agent)
  - handoff delays of several seconds (10) and infrequent link quality updates

Handoff Strategies (II)

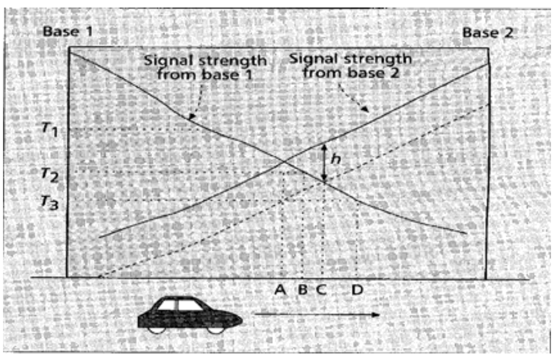
- Mobile assisted handoff
  - used in second generation digital cellular system
  - both the mobile and the serving BS measure link quality
  - only mobile measures link quality of alternate BSs
  - mobile periodically sends the link quality measurements to serving BS
  - handoff decision is made by the network
  - handoff delays of few seconds (1-2) and frequent link quality updates

Handoff Strategies (III)

- Mobile controlled hand off
  - used in some new digital cellular systems
  - link quality measurements as in MAHO
  - serving BS relays link quality measurements to mobile
  - handoff decision is made by the mobile
  - handoff delays of about 100 ms



Handoff Scenario

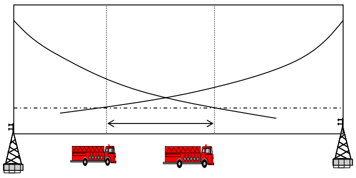


Handoff Initiation Strategies

- Relative signal strength
  - Always choose the strongest received BS
  - Too many unnecessary hand-offs
- Relative signal strength with threshold
  - Current signal < threshold,, and other BS is stronger
  - May let MH stray too far into other cell; overlapping cell coverage
  - Effectiveness depends on knowledge of cross-over signal
- Relative signal strength with hysteresis (plus optionally dwell timer)
  - Hand-off only if new BS's signal is stronger by a hysteresis margin
  - Prevents ping-pong effect from rapid fluctuations
- Relative signal strength with hysteresis & Threshold
  - Hand-off only if current BS's signal below a threshold, and new BS's signal is stronger by the hysteresis margin
- Prediction techniques
  - Decide based on expected future value of received signal strength

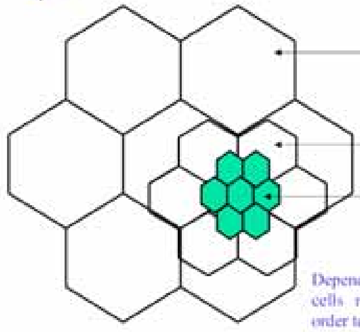
Handoff Queueing

- Goal is to reduce handoff failure probability
  - Better to block a new call than to drop an existing one
  - Exploits overlap between cells to queue hand-off request in advance



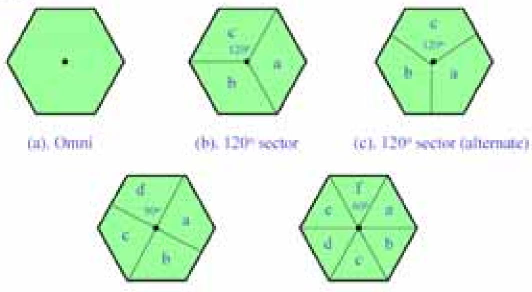
- Handoff request is issued according to handoff initiation strategy
  - Request is queued
  - Decision must be made (handoff or failure) while MH still in handoff interval

Cell Splitting



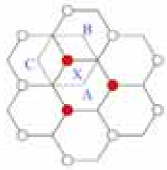
Depending on traffic patterns the smaller cells may be activated/deactivated in order to efficiently use cell resources.

Cell Sectoring by Antenna Design

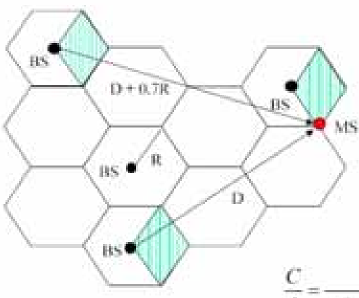


Cell Sectoring by Antenna Design

- Placing directional transmitters at corners where three adjacent cells meet

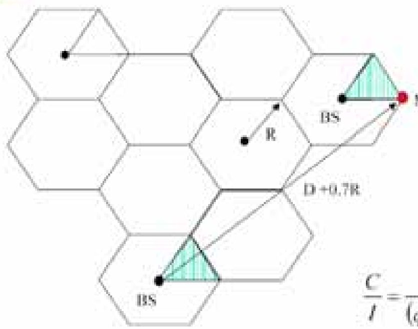


Worst Case for Forward Channel Interference in Three-sectors



$$\frac{C}{I} = \frac{C}{q^{-4} + (q+0.7)^{-4}}$$

Worst Case for Forward Channel Interference in Six-sectors



$$\frac{C}{I} = \frac{C}{(q+0.7)^{-4}}$$

Handoff Parameters

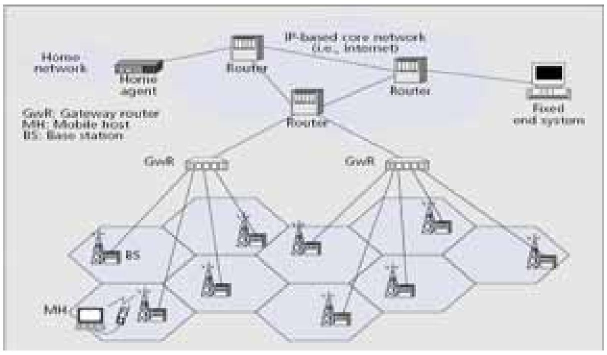
Mobility Support~ Handover

Channel Allocations: Reuse

Performance Index

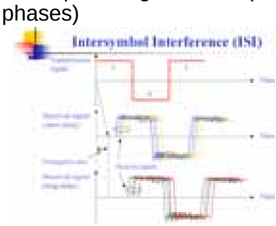
- Traffic Request: (QoS)
  - New Call Probability
  - Handoff Call Probability
  - Traffic Requirements (Bandwidth, delay)
  - Call Holding Time
  - Dwell Time (Channel Occupation) for a handoff call or new call
  - Delay/Distance/Un-necessary handoff
- Mobility:
  - Resident time in a cell
  - Hand off rate
- Channel Resource:
  - Channel assignment
  - Blocking Rate (New Call blocking rate, Handoff blocking rate)

IP-based 3G Wireless Network



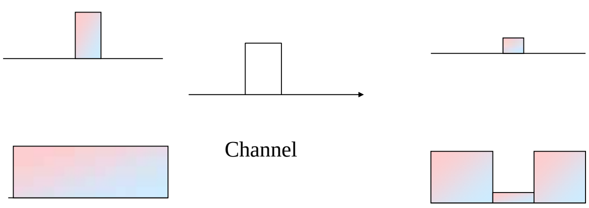
Multi-path Effect (Time)

- RMS > Symbol Duration:
  - ISI (handled by Equalizer)
- RMS < Symbol Duration:
  - More than one paths signal arrive (might have different phases)

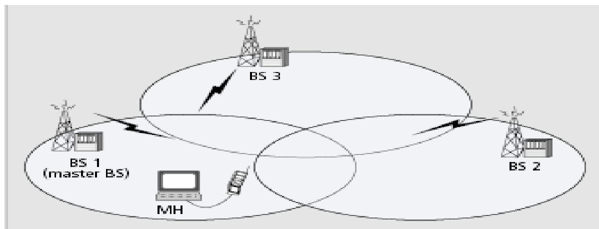


Coherence Bandwidth (Bandwidth)

- Coherence Bandwidth < BW of signal:
  - Frequency Selective Fading
- Coherence Bandwidth > BW of signal:
  - Flat Fading



BS and BS list in MS



<BS list architecture in mobile host>

IP address	Beacon signal strength
163.152.200.36	−60 dBm
163.152.19.34	−90 dBm
163.152.19.32	−80 dBm