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無線網路多媒體系統 Wireless Multimedia System

Cellular Concepts
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Mobility Support & Channel Reuse

Mobility Support~ Handover

Channel Allocations: Reuse

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Approaches to Wireless Multiple Access

Sharing of Time-Frequency Space

- Slotted-time vs Non-Slotted Time
- Demand-based Assignment
- Contention-based
- Conflict-free
 - e.g. Token-passing & Polling

"Packet Oriented" Controlled Random Access

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Frequency Division & Time Division Duplexing

- Frequency Division Duplexing (FDD)
 - Two distinct frequency at the same time for the two directions
 - Frequency separation must be coordinated to allow cheap RF technology
 - Coordination with out-of-band users between the two bands
 - Geared towards providing individual frequencies for each user

Forward Channel Reverse Channel frequency

- Time Division Duplexing (TDD)
 - Two distinct sets of time slots on the same frequency for the two directions
 - Time latency because only quasi-duplex
 - No need for RF duplexer

Forward Channel Reverse Channel Time

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Frequency Division Multiple Access (FDMA)

- Assign different frequency bands to individual users or circuits
 - Frequency band ("channel") assigned on demand to users who request service
 - No sharing of the frequency bands: idle if not used
 - Usually available spectrum divided into number of "narrowband" channels
 - Symbol time >> average delay spread, little or no equalization required
 - Continuous transmission implies no framing or synchronization bits needed
 - Tight RF filtering to minimize adjacent band interference
 - Costly bandpass filters at basestation to eliminate spurious radiation
 - Usually combined with FDD for duplexing

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Example-AMPS Cellular System

- User FDMA/FDD
 - A channel is a pair of frequency duplexed simplex channels
 - Each simple channel is 30 kHz
 - Simple channels are separated by 45 MHz (allow cheap RF duplexers)
 - Forward link 869-894 MHz, reverse link 824-849 MHz
 - Two carriers per market share the channels
- Number of supported channels in AMPS

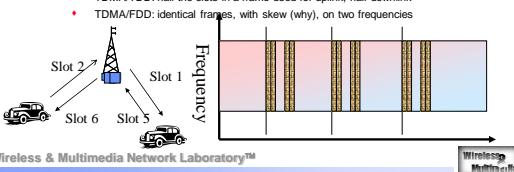
$$N = \frac{B_{\text{forward}} - 2B_{\text{guard}}}{B_{\text{channel}}} = \frac{12.5 \text{ MHz} - 2(10 \text{ kHz})}{30 \text{ kHz}} = 416$$
- Problem: set of active users is not fixed
 - How is the FDMA/FDD allocated to a user who becomes active?
 - Static multiple access is not a complete solution .. Need a separate signalling channel with "demand-access".
 - Pure FDMA is basically "dead" in the digital world

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Time Division Multiple Access (TDMA)

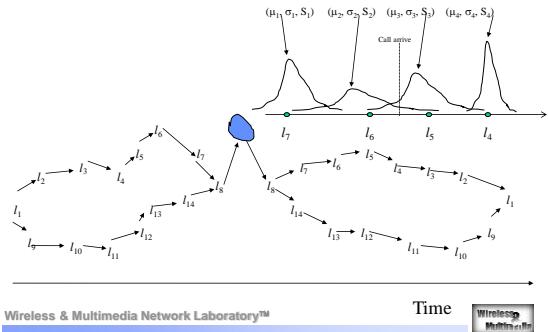
- Multiple user share frequency band via cyclically repeating "time slots"
 - "channel"=particular time slot reoccurring every frame of N slots
 - Transmission for any user is non-continuous: buffer-and-burst digital data & modulation needed, lower battery consumption
 - Adaptive equalization is usually needed due to high symbol rate
 - Larger overhead-synchronization bits for each data burst, guard bits for variations in propagation delay and delay spread
 - Usually combined with either TDD or FDD for duplexing
 - TDMA/TDD: half the slots in a frame used for uplink, half downlink
 - TDMA/FDD: identical frames, with skew (why), on two frequencies



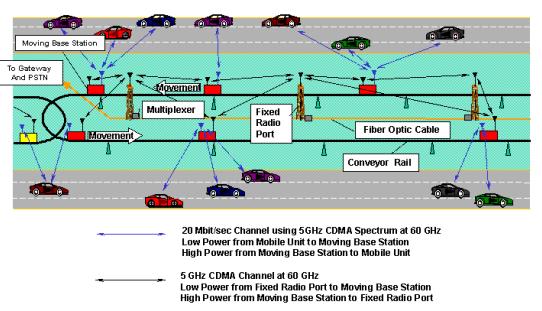
ChungLi Case Study



Moving Behavior



Mobile Broadband Infrastructure Diagram



IMS Services over HSDPA



Channel Assignment in Cellular System

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

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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)

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Agenda

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



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Reading

- [Katzela96] Katzela, and M. Nahgshineh, "Channel assignment schemes for cellular mobile telecommunication systems: a comprehensive survey," IEEE Personal Communications, June 1996
- [Pollini96], G.P. Pollini, "Trends in handover design," IEEE Communications Magazine, March 1996.

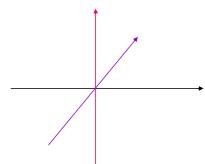


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Channel Allocation

- 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



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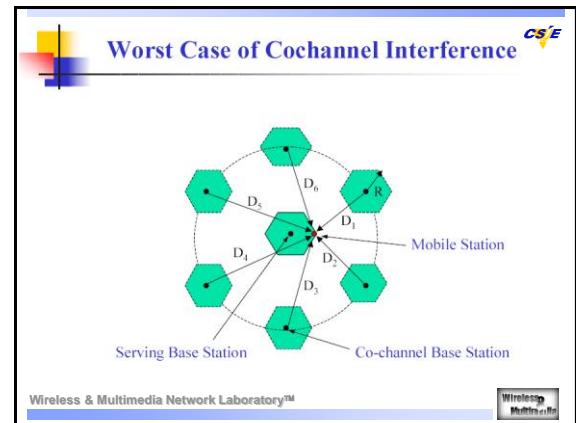
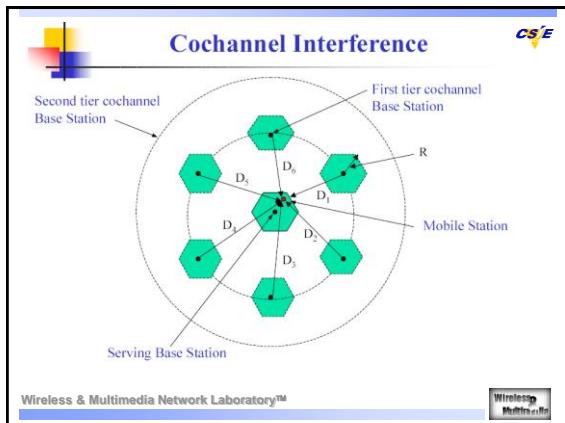
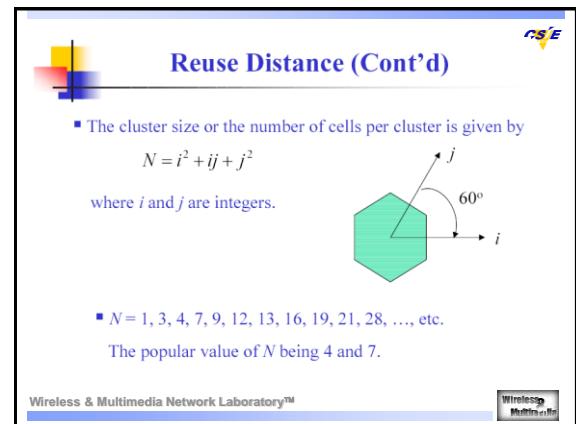
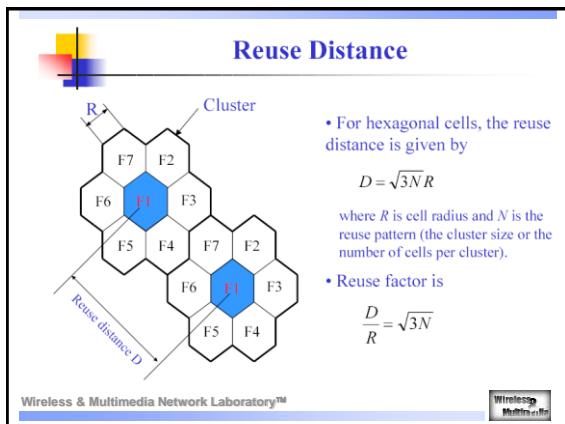
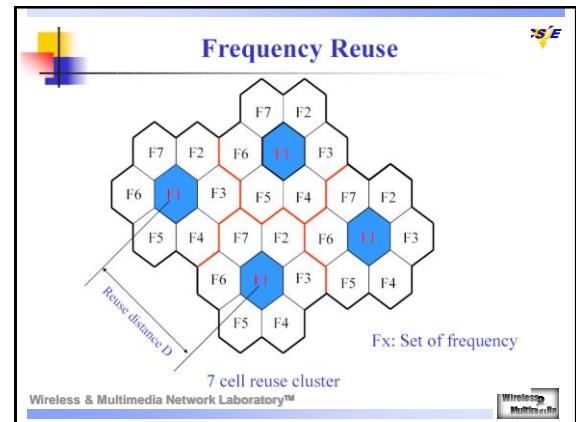
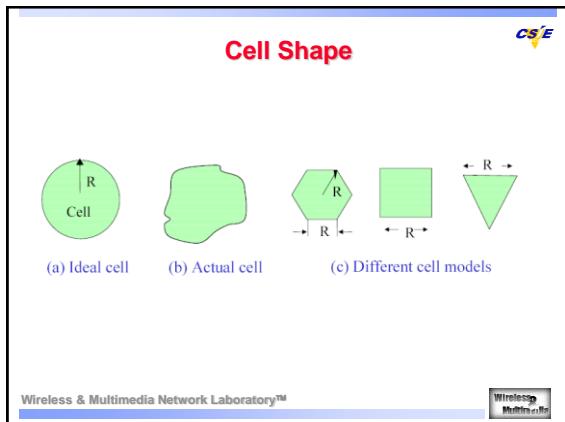


Cellular System Concept

- 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

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Cochannel Interference

- Cochannel interference ratio is given by

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

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

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

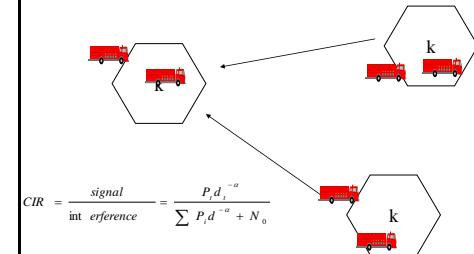
where γ is the propagation path loss slope and $\gamma = 2 \sim 5$.

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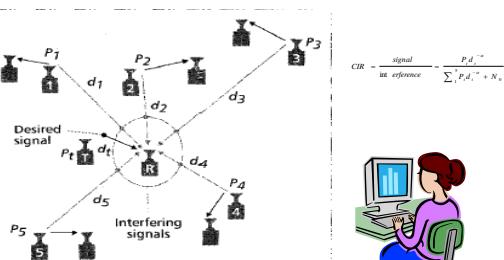
Channel Reuse

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



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Interference



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How to improve CIR (Quality)

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

$$CIR = \frac{\text{signal}}{\text{interference}} = \frac{P_i d_i^{-a}}{\sum P_j d_j^{-a} + N_0}$$

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Approaches

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



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Frequency Reuse

- 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 tessellating group of N neighboring BSs
 - Called "reuse cluster"
 - $1/N$ is the "reuse factor"
 - System capacity goes up by $\frac{\text{Area}_{\text{cluster}}}{N \times \text{Area}_{\text{cell}}}$
- 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.

Idealized grid of Hexagonal cells

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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

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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
 - $C/I \geq (C/I)_{\min}$
 - 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

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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
 - $C/I \geq (C/I)_{\min}$
 - reverse co-channel interference
 - interference at BS from co-channel MHS in other BSs
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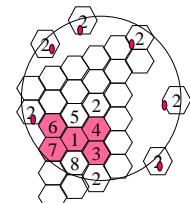
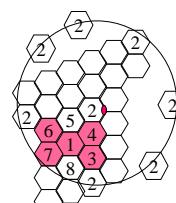
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Calculating C/I

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

$$\frac{C}{I} = \frac{C}{I_0 + \sum_{i \neq 0} I_i}$$
- Where C is the desired carrier power and I_i is the signal power of i -th interferer



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Calculating C/I

- Recall: $P_r(d) = P_t(d_0) \left(\frac{d}{d_0} \right)^{-\alpha}$
- For equal transmit powers and path loss exponents: $\frac{C}{I} = \frac{D_0^{-\alpha}}{D_1^{-\alpha} + \sum_{i \neq 0} D_i^{-\alpha}}$
- Assume:
 - $n=4$
 - 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

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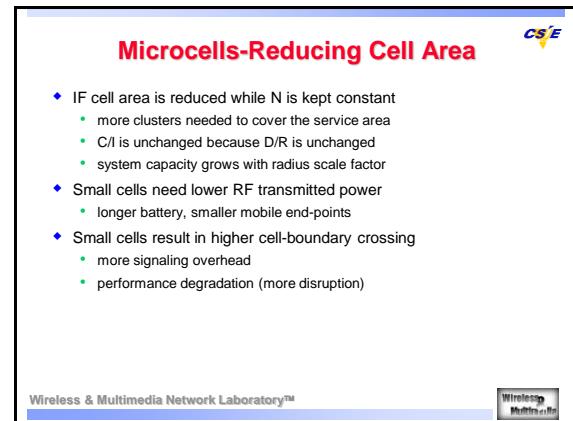
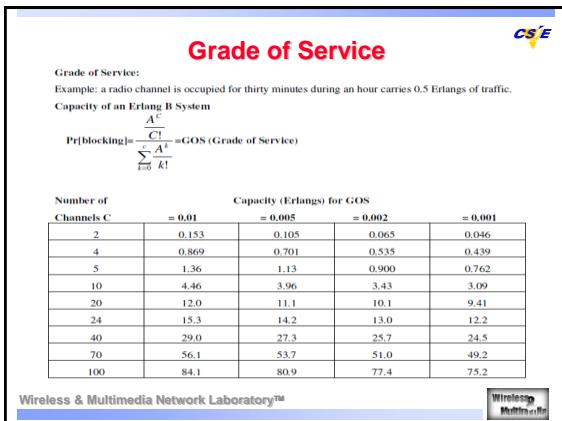
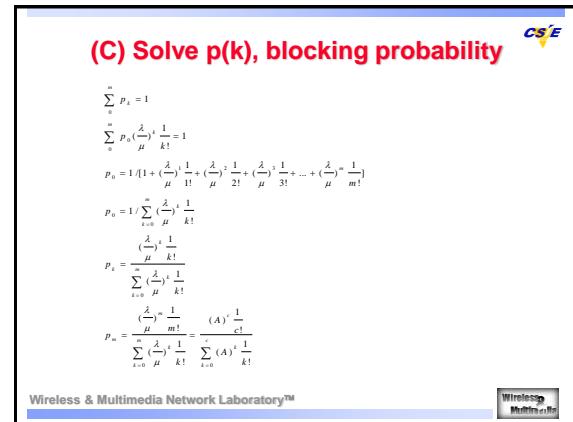
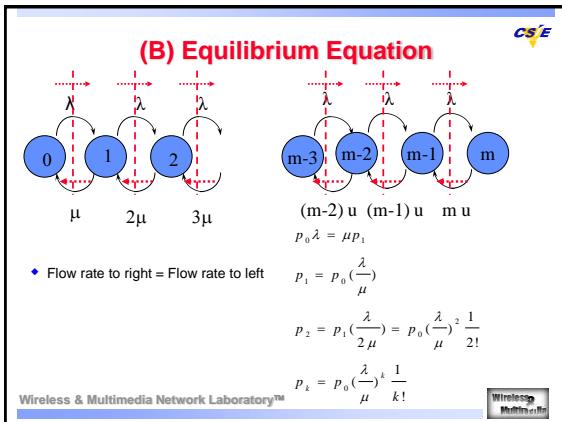
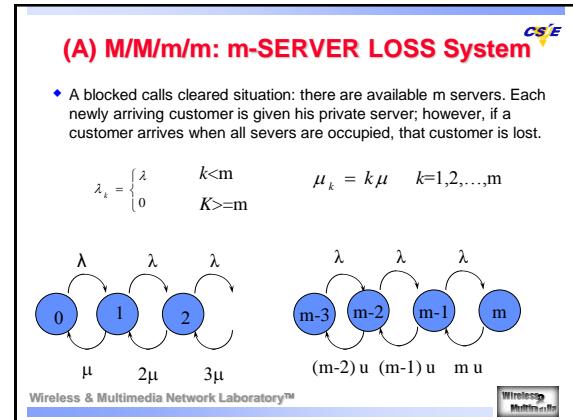
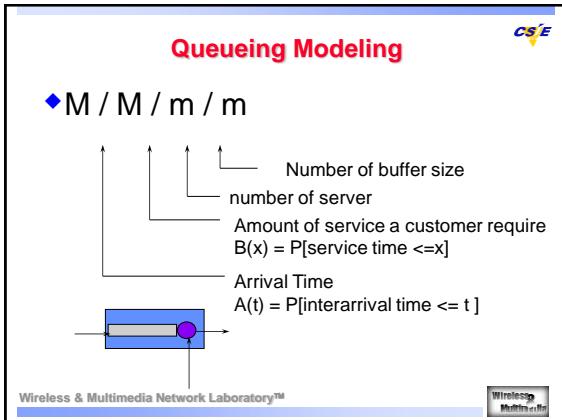
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Case study: Mobile Phone Calls for a NTU basestation



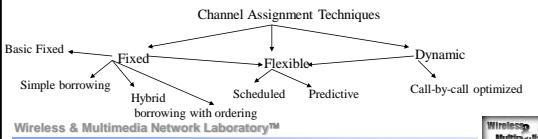
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Channel Assignment in Cellular System

- 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"



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Channel Assignment Techniques

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

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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

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Fixed Channel Assignment

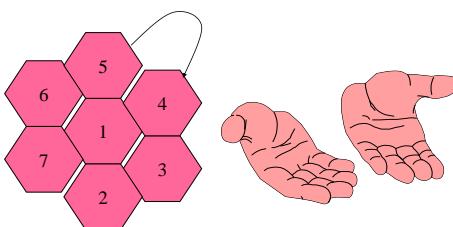
- Variation
 - borrow channel from neighboring BSs if all channels busy at BS under MSC supervision, and only if does not cause interference borrowed channels are "locked"
 - hybrid channel assignment
 - two groups of channels: fixed and borrowable
 - ratio determined a priori depending on traffic estimate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

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Fixed Channel Assignment

- We might borrow from neighboring cells

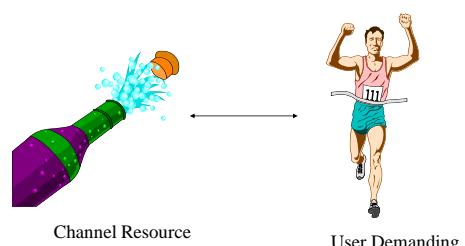


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Traffic & Resource

- Uniform Distribution



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Dynamic & Assignment

- Maybe I should assign you based on current condition



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Issues to consider



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

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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

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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

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Flexible Channel Assignment

- Combine aspects of FCA and DCA
- Each cell is assigned a fixed set of channels
- 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

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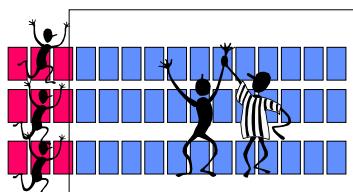
MSC will pick up one for MH

- Here you go !



Flexible Channel Assignment

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



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Handoff Handling

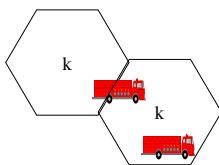


Keep the QoS while the user moves

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Handling Handoffs

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



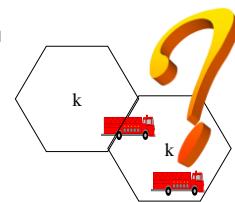
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What is going to happen ?

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



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Solutions for handoff

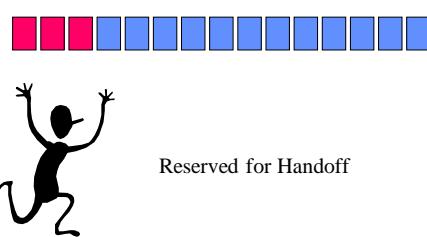
- Handoff Priority
 - guard channel for handoff
 - how much, inefficiency
- Queueing of Handoff request
 - take a seat for future handoff

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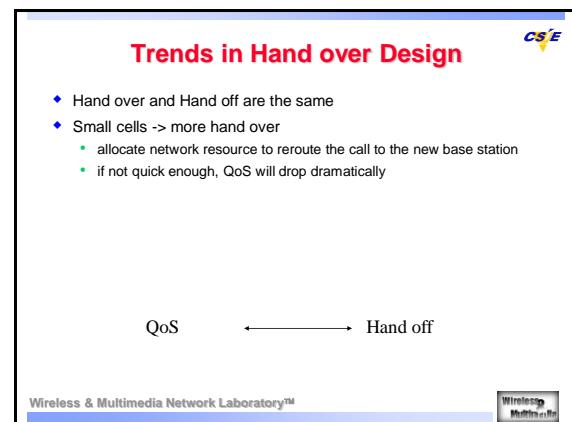
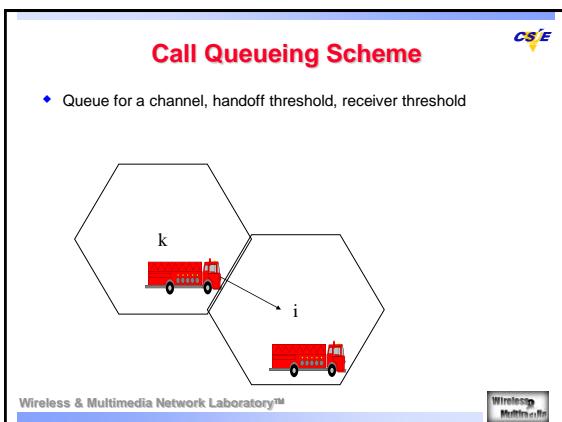
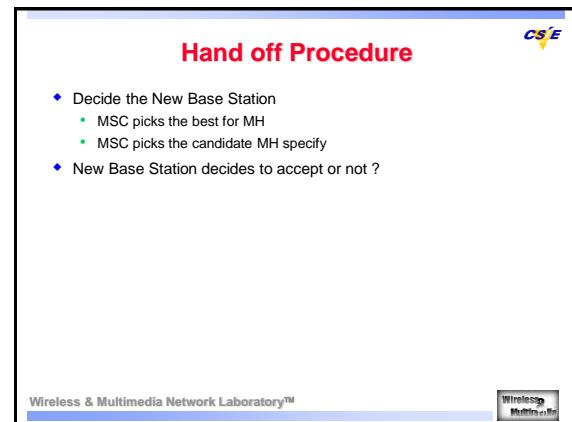
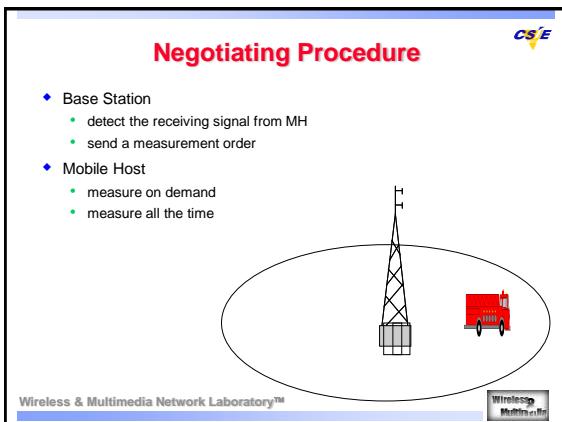
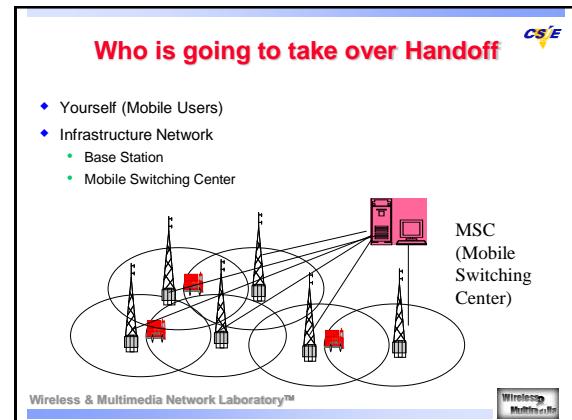
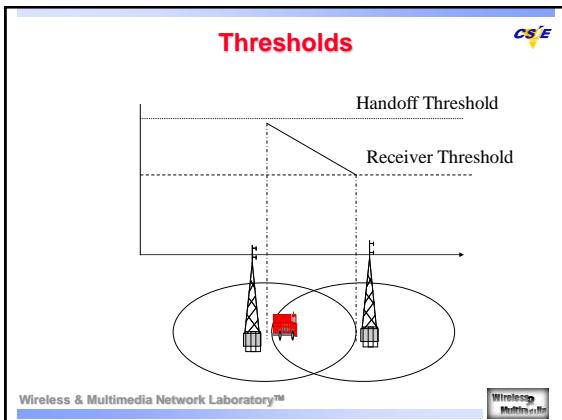
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Guard Channel



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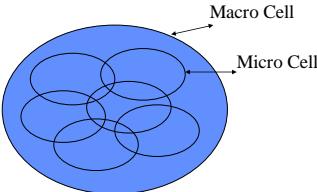
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Mobility Solution

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



Macro Cell

Micro Cell

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Velocity Estimation

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



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Handoff in Cellular Networks

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- 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

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Hand-off

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- 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

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Handoff in Cellular Networks

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- 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

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Handoff Strategies (I)

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- 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



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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



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Handoff Strategies (III)



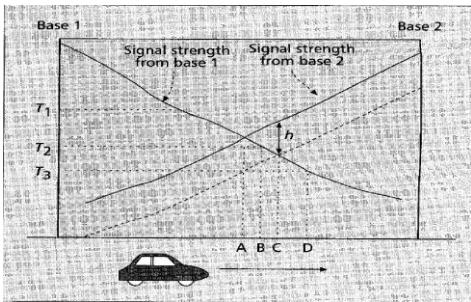
- Mobile controlled hand off
 - used in some new digital cellular systems
 - link quality measurements as in MAHO
 - serving BS relays link quality measurements to mobile
 - handoff decision is made by the mobile
 - handoff delays of about 100 ms



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Handoff Scenario



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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

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Handoff Queueing



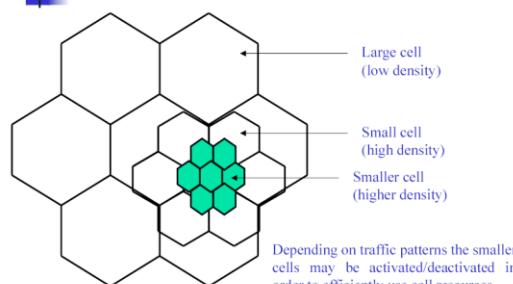
- Goal is to reduce handoff failure probability
 - Better to block a new call than to drop an existing one
 - Exploits overlap between cells to queue hand-off request in advance

- 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

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Cell Splitting



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