

無線網路多媒體系統

Wireless Multimedia System

Lecture 5: Cellular Concepts
Eric Wu

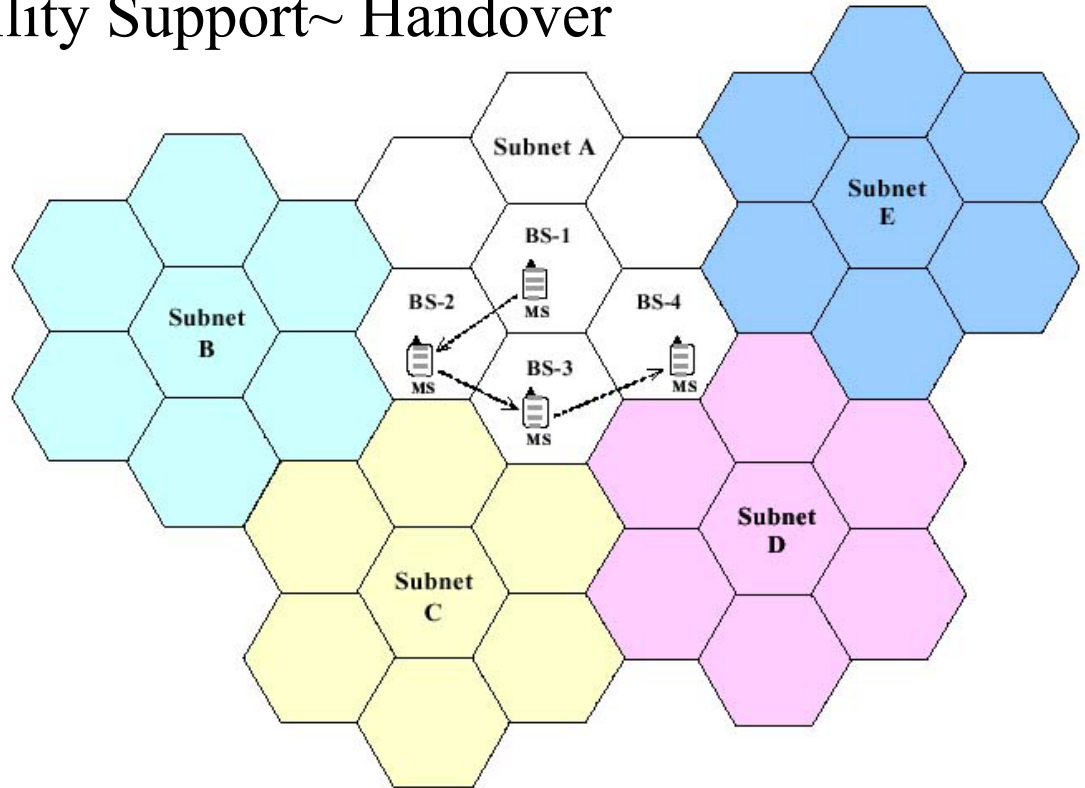
<http://wmlab.csie.ncu.edu.tw/course/wms>

We
provide
無線網路多媒體實驗室
Wireless
Wireless Network & Multimedia Laboratory
Solution

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

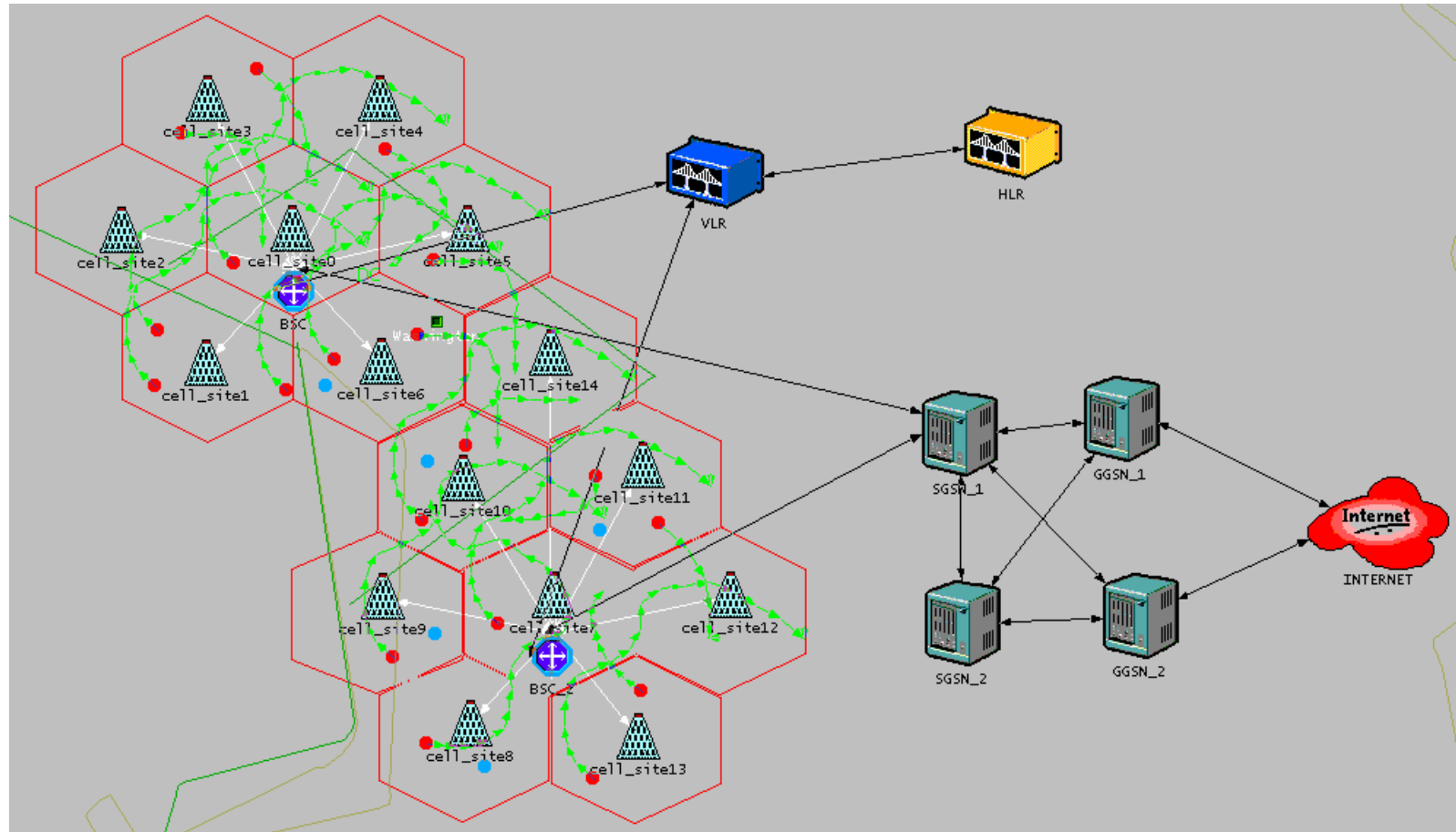
Hand-off in Cellular Networks

- ◆ 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)

WAP in NCU, Taiwan

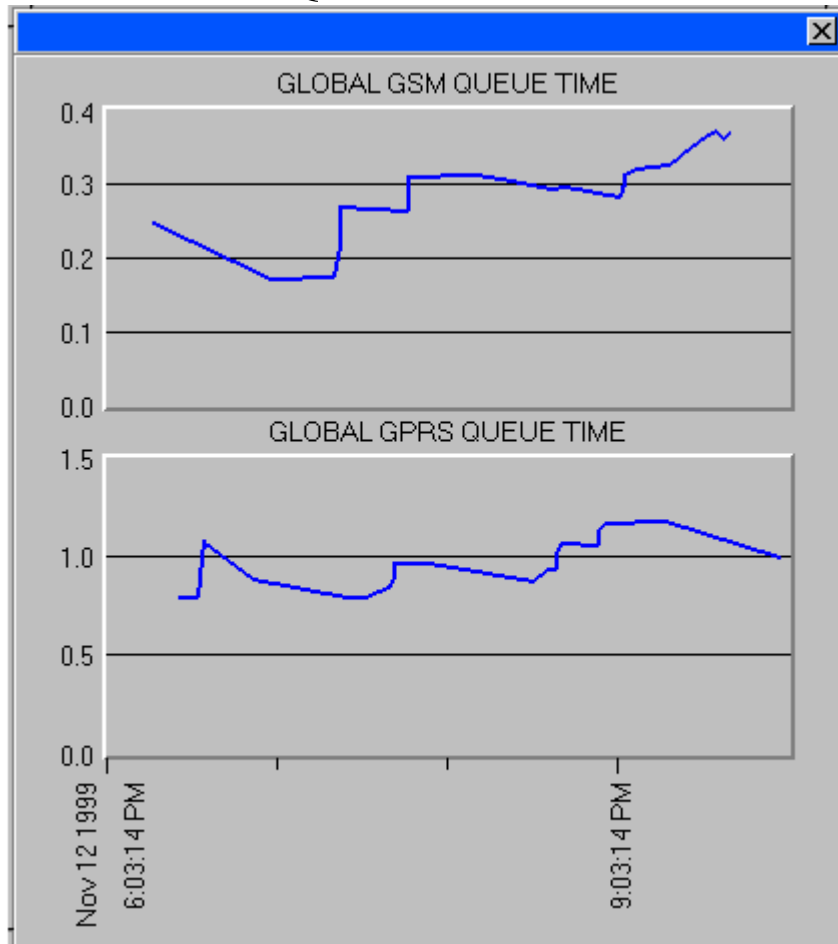


Backbone Integration



QUEUE ADVANTAGE

Queue time



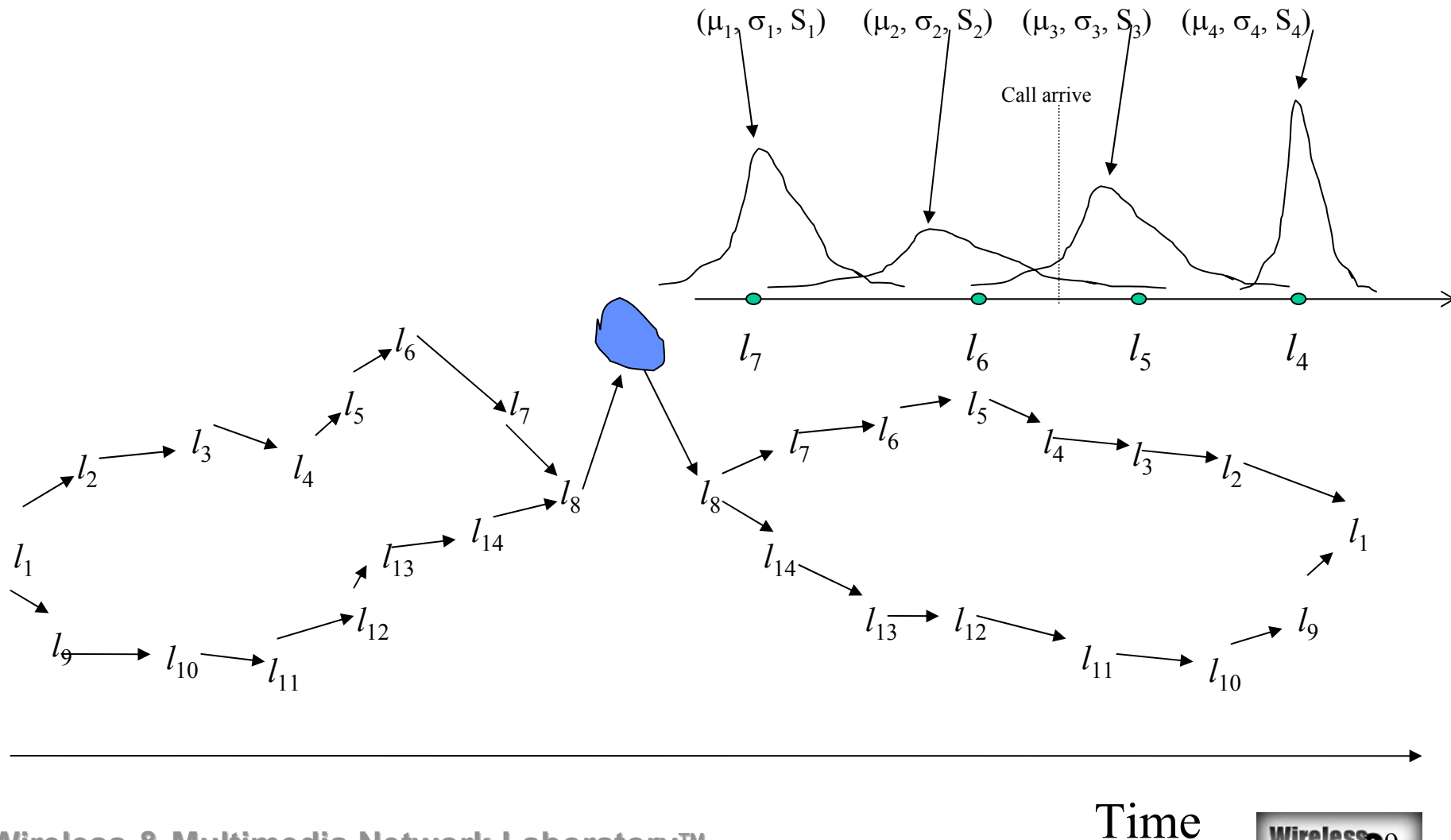
GSM SLOTS	3
GPRS SLOTS	5
e-mail portion	0.0
Real-time portion	1.0
Flow generation rate	3.0/hour
Real-time average length	3 min
Call generation rate	3.0/hour
Call average length	3 min
E-mail transmission rate	1 slot/frame
Real time transmission rate	2 slots/frame
Simulation time	4 hours

GSM nodes:6

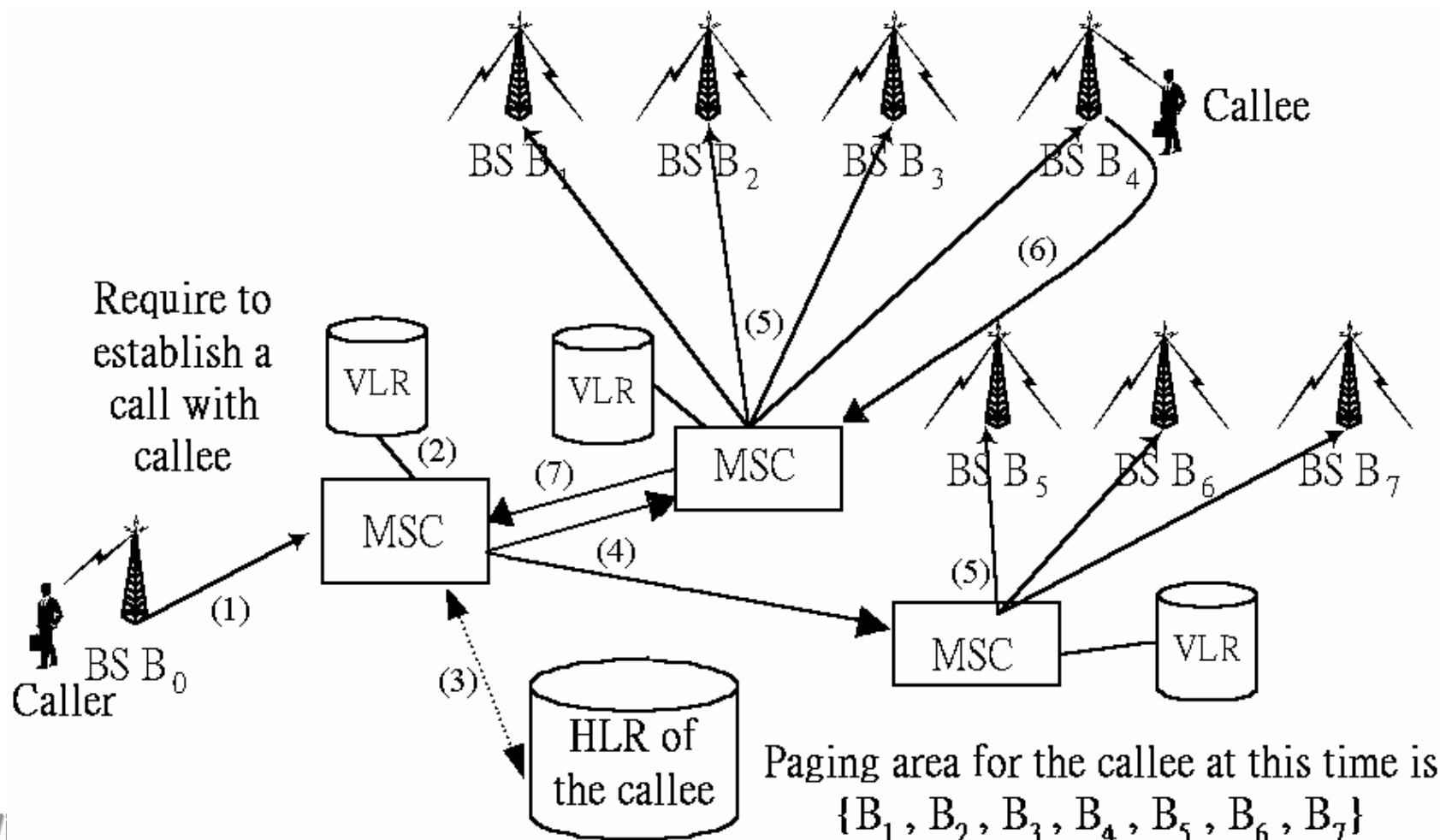
GPRS nodes:4



Moving Behavior



Paging Procedure of The Behavior-Based Strategy



Agenda

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



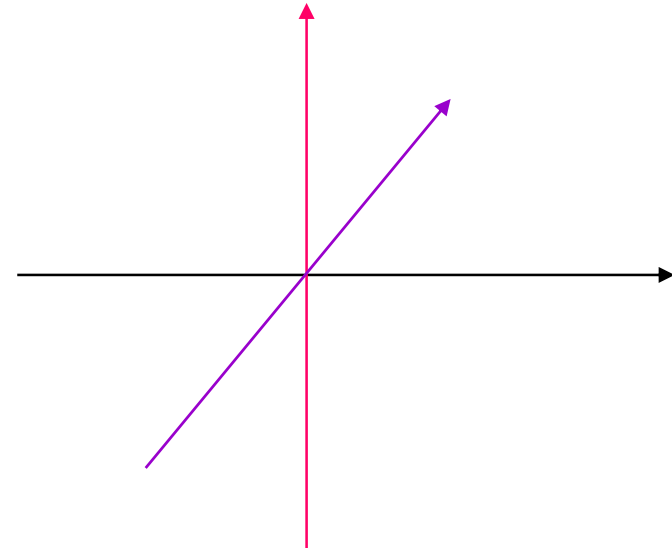
Reading

- ◆ [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.



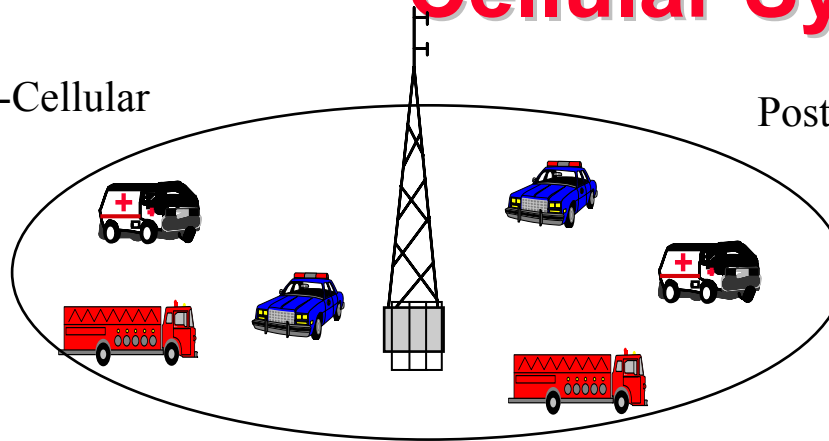
Channel Allocation

- ◆ 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

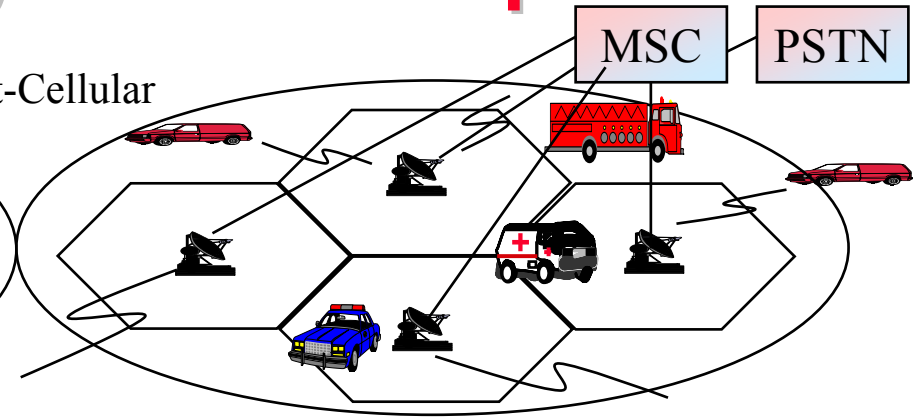


Cellular System Concept

Pre-Cellular



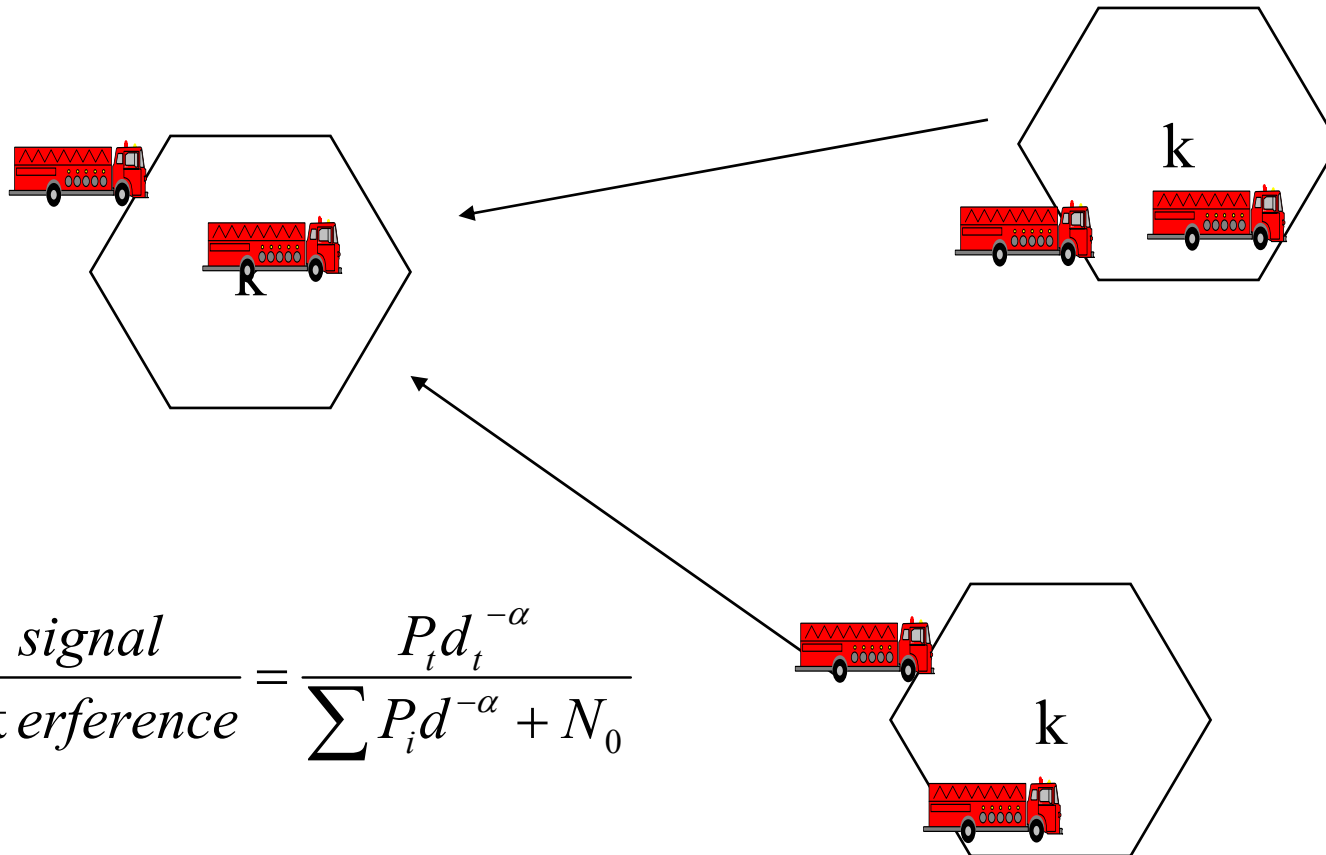
Post-Cellular



- ◆ 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

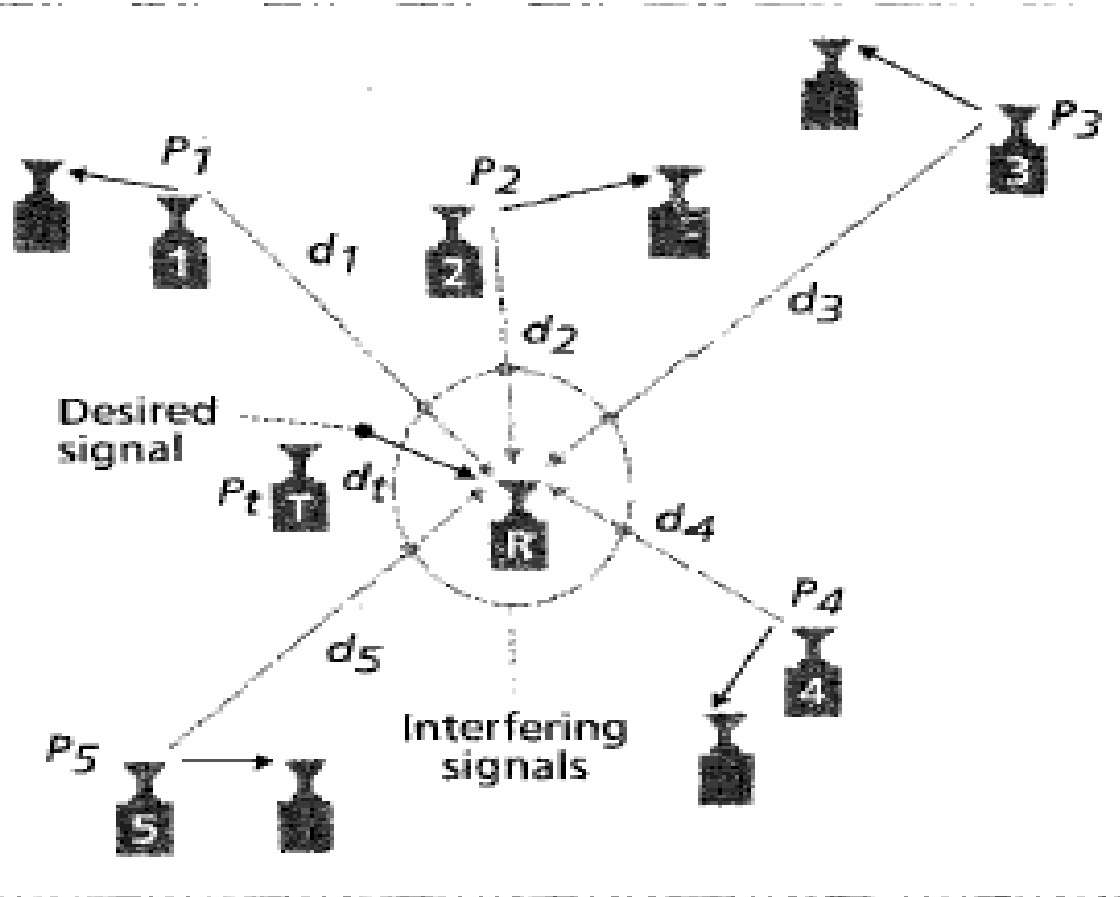
Channel Reuse

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



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

Interference



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



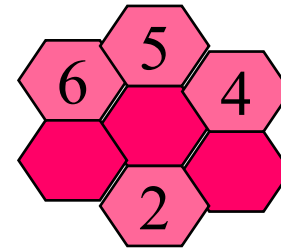
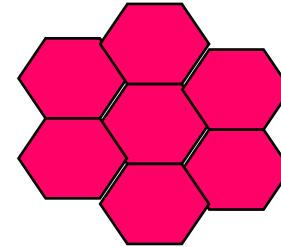
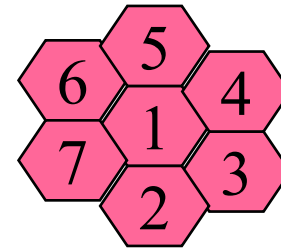
How to improve CIR (Quality)

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

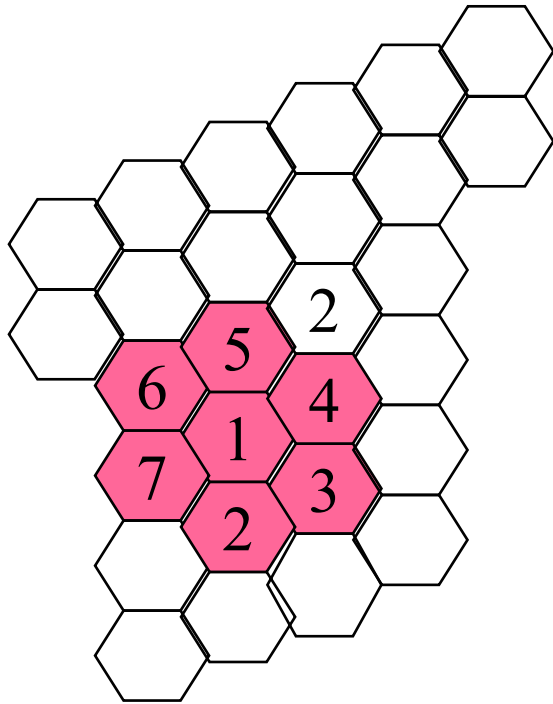
$$CIR = \frac{\text{signal}}{\text{interference}} = \frac{P_t d_t^{-\alpha}}{\sum P_i d_i^{\alpha} N_0}$$

Approaches

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



Frequency Reuse

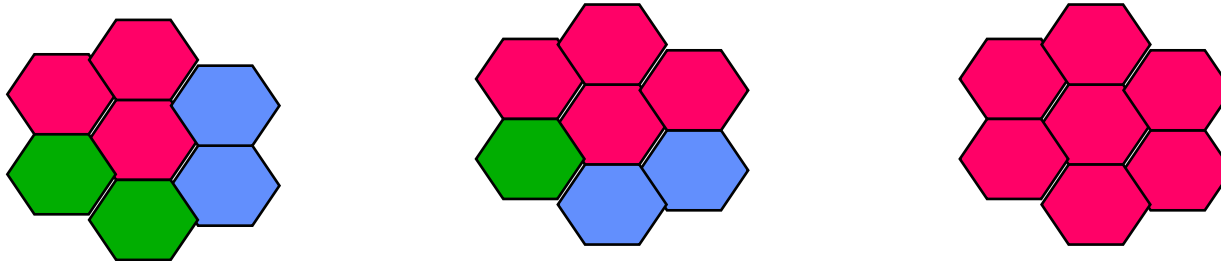


Idealized grid of
Hexagonal cells

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

Determining Cluster Size N

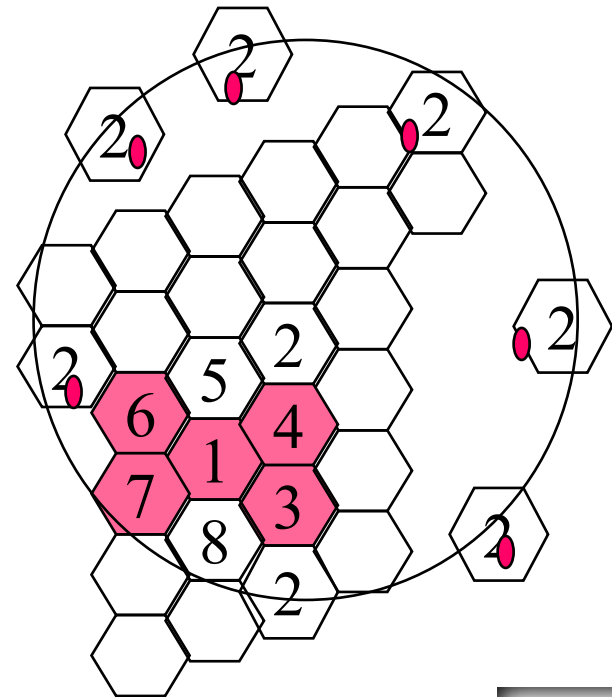
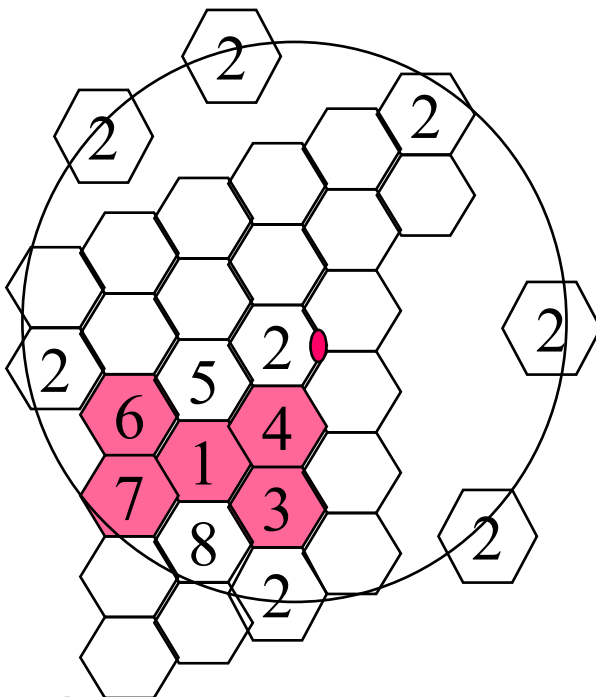
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 - ◆ interference at BS from co-channel MHs in other BSs
 - forward co-channel interference
 - ◆ interference at a MH from other co-channel BSs
 - adjacent channel interference
 - ◆ from signals in adjacent channels due to imperfect filters

Calculating C/I

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

- 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

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



Calculating C/I

- ◆ Recall: $P_r(d) = P_r(d_0) \left(\frac{d}{d_0}\right)^n$
- ◆ 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. $D_1 = D_2 = D_3 = D_4 = D_5 = D_6 = D$
- ◆ $C/I \sim (D/R)^4 / 6$ depends only on the ratio D/R

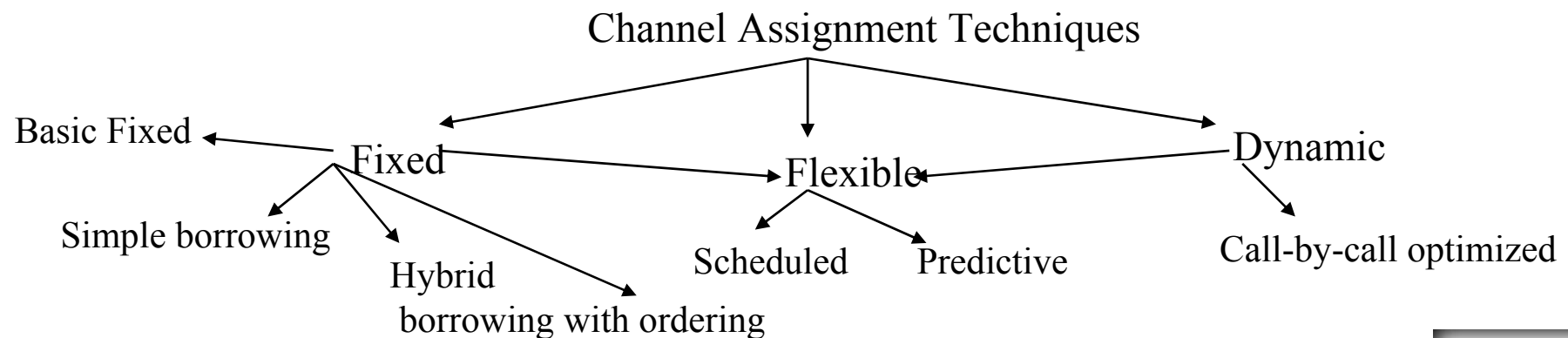
system	$(C/I)_{\min}$	D/R	N
AMPS	18 dB	4.6	7
GSM	11 dB	3.0	4

Microcells-Reducing Cell Area

- ◆ IF cell area is reduced while N is kept constant
 - more clusters needed to cover the service area
 - 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

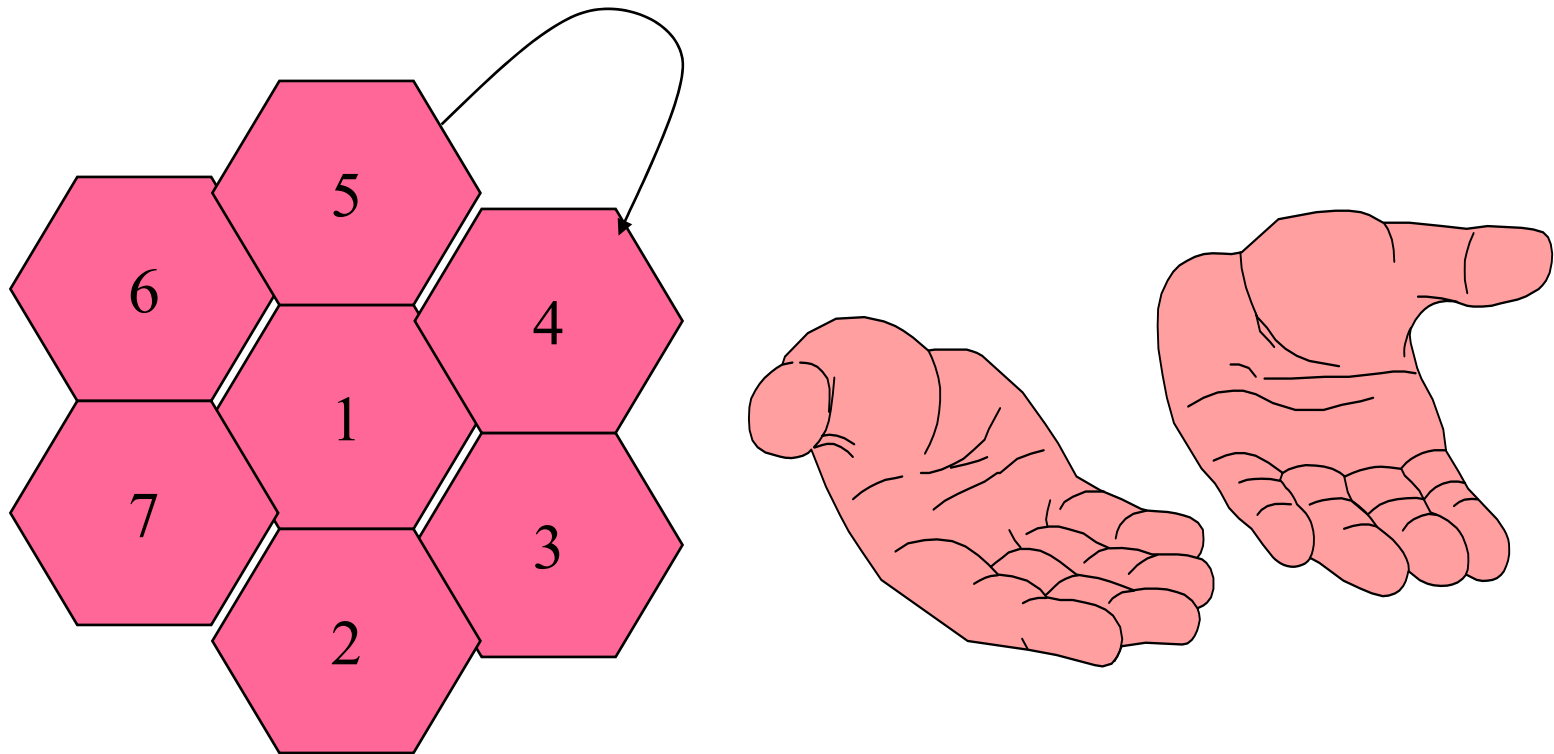
Fixed Channel Assignment

◆ 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

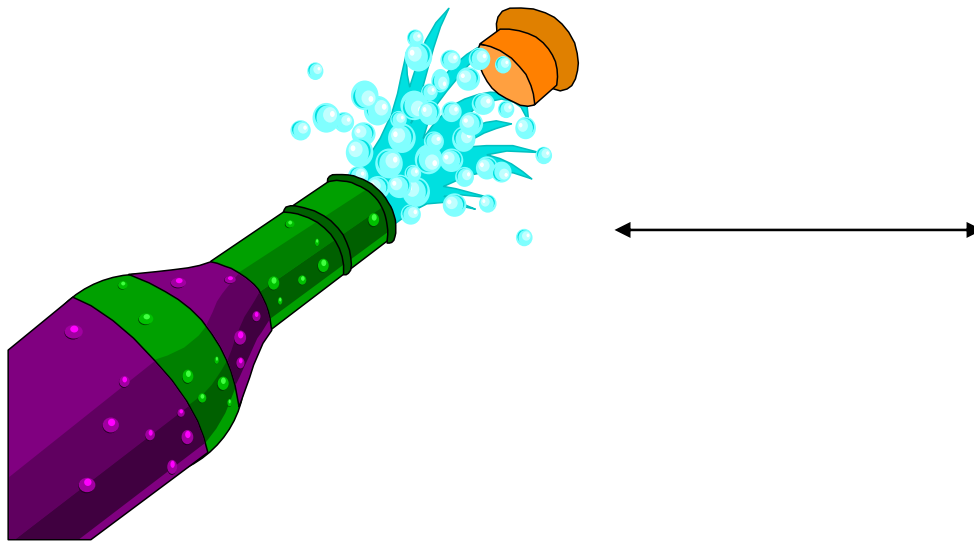
Fixed Channel Assignment

- ◆ We might borrow from neighboring cells



Traffic & Resource

- ◆ Uniform Distribution

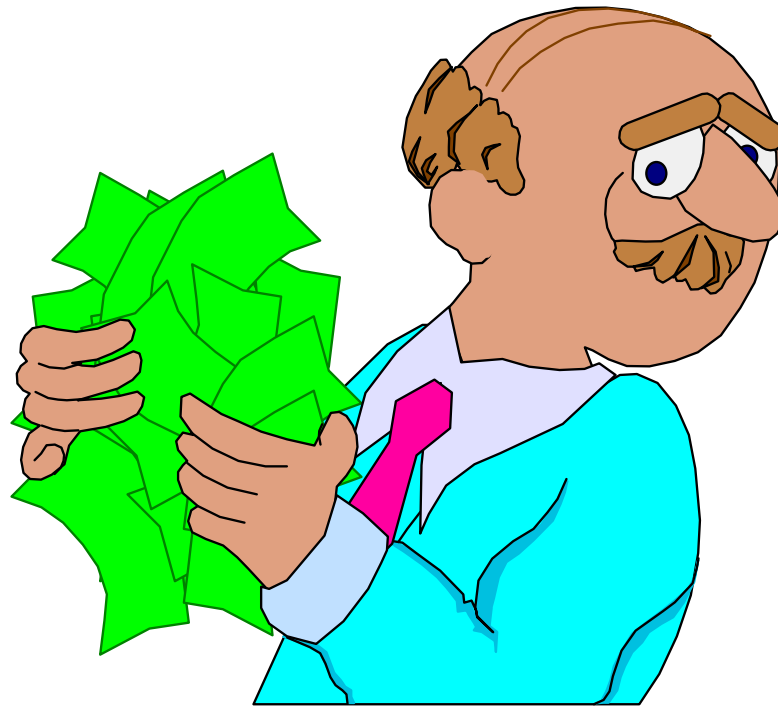


Channel Resource

User Demanding

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



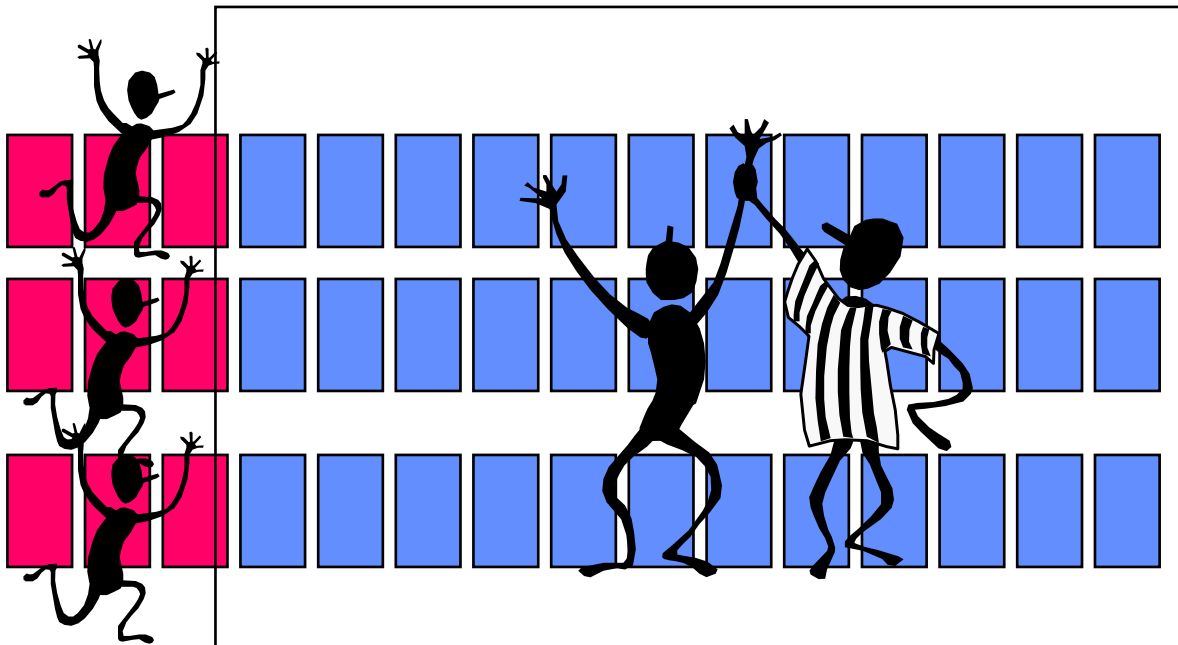
MSC will pick up one for MH

- ◆ 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

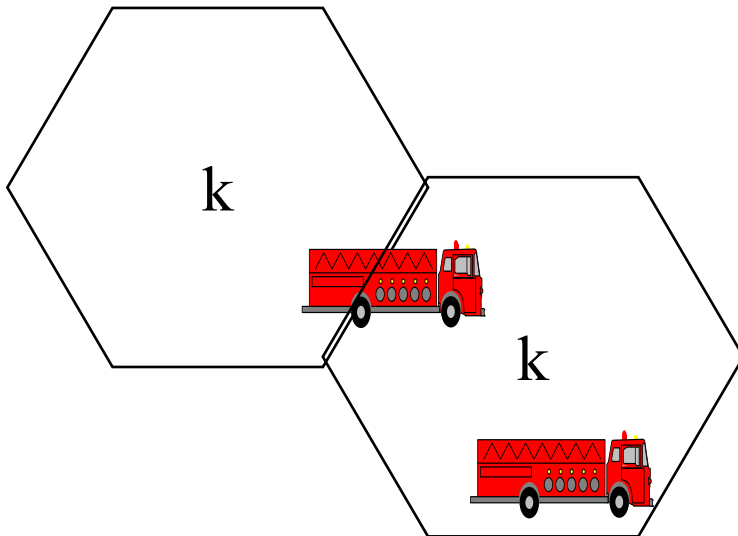


QoS Guarantee while the mobile user moves

Handling Handoffs

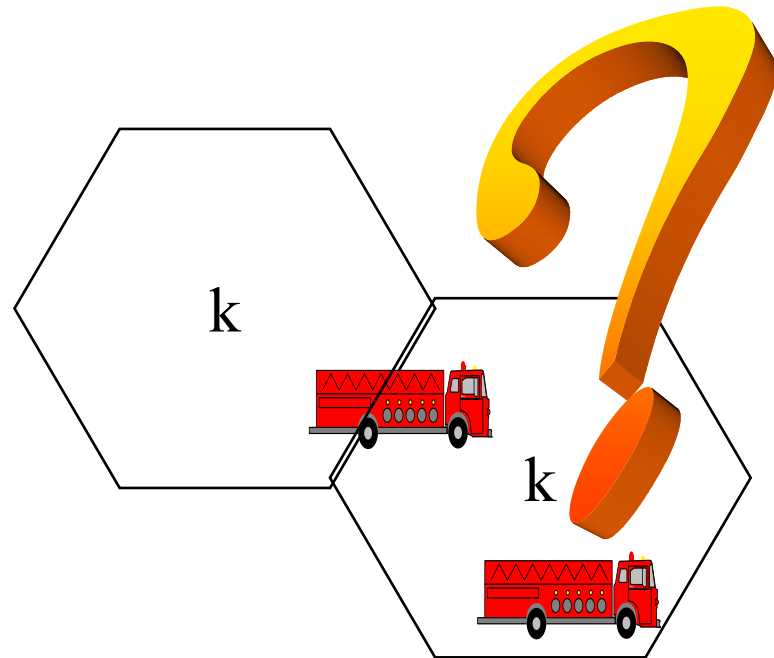
◆ Handoff

- 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 ?

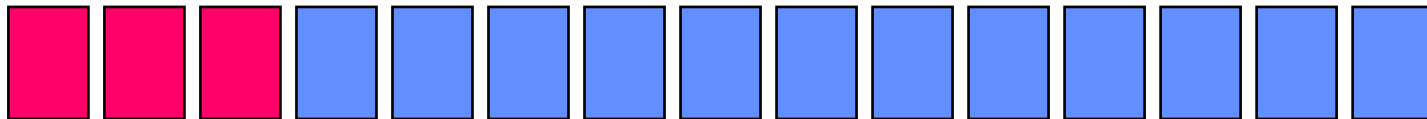
- ◆ The new cell must assign new channel
- ◆ We must reserve some hand off channel
- ◆ Some connection must be blocked !!



Solutions for handoff

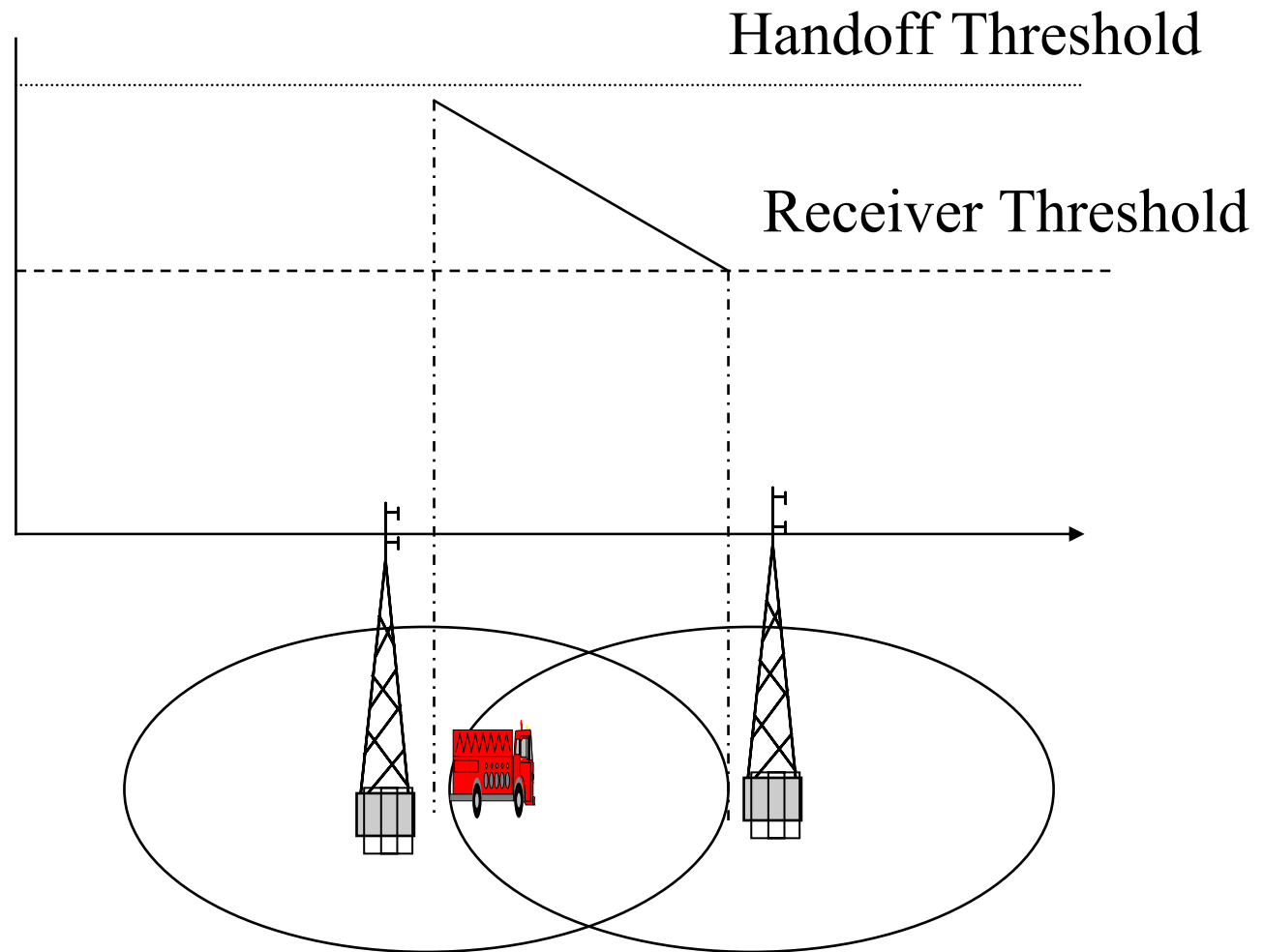
- ◆ Handoff Priority
 - guard channel for handoff
 - how much, inefficiency
- ◆ Queueing of Handoff request
 - take a seat for future handoff

Guard Channel



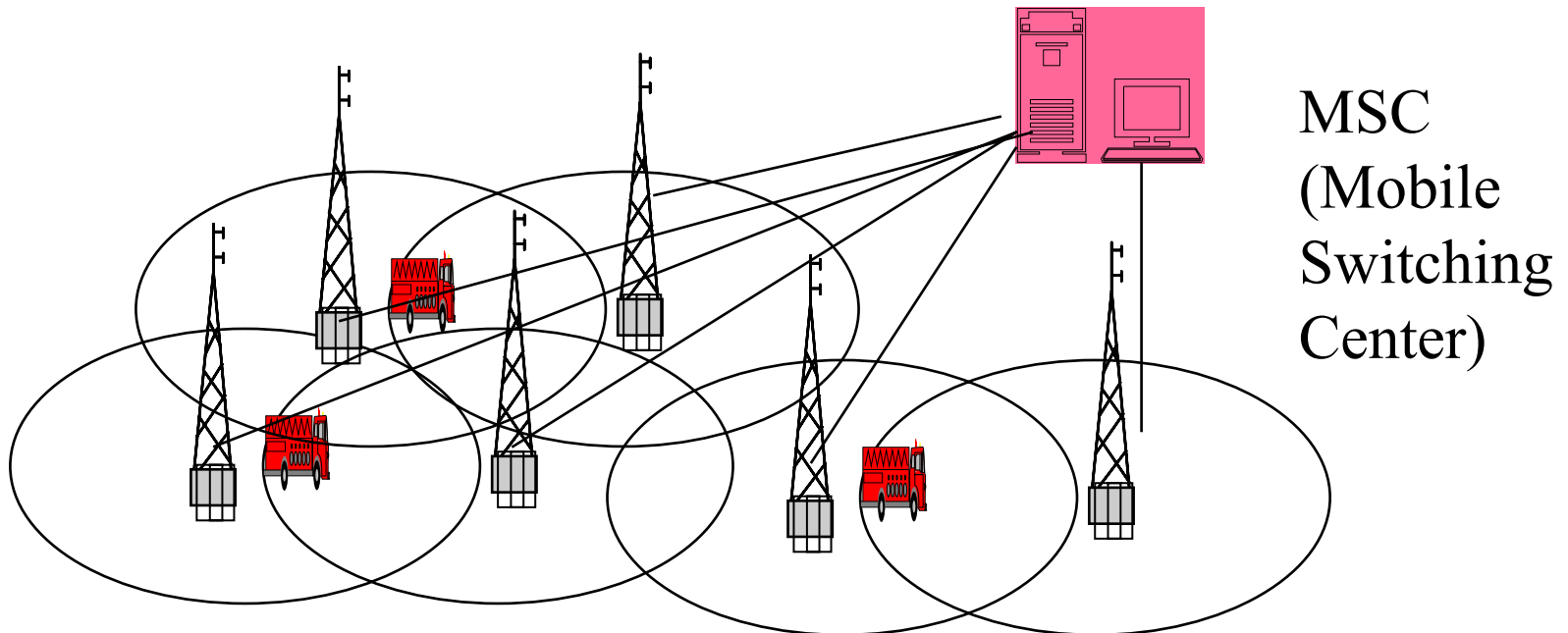
Reserved for Handoff

Thresholds



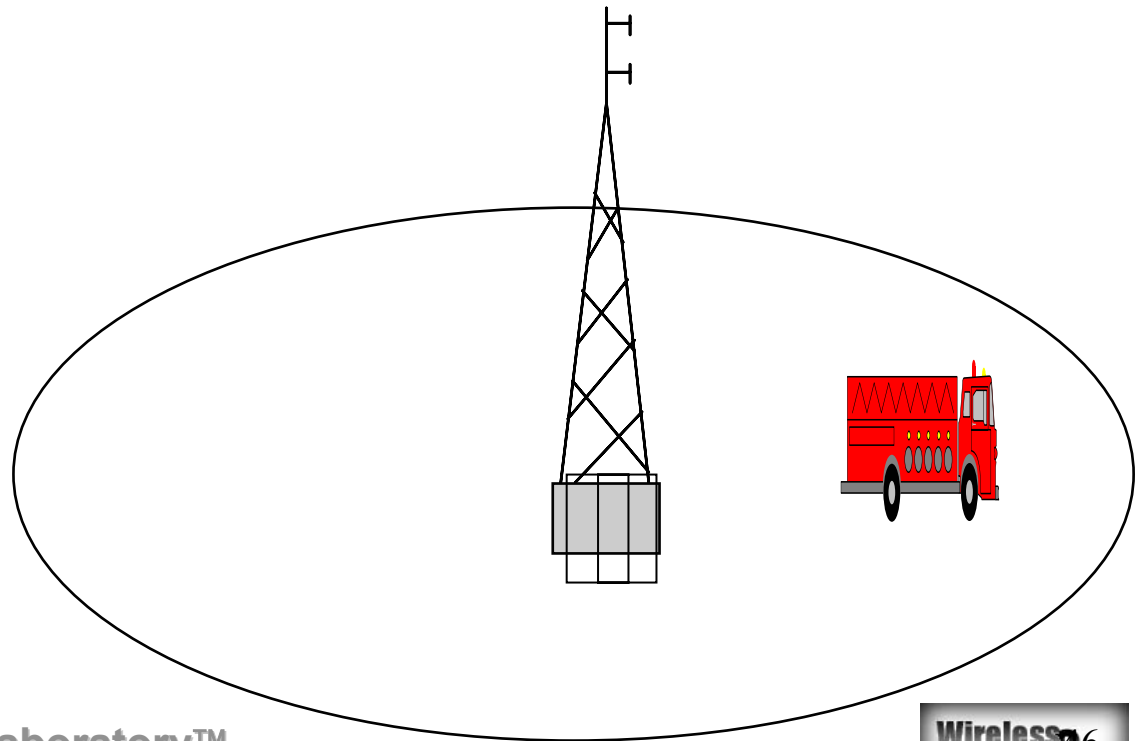
Who is going to take over Handoff

- ◆ 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

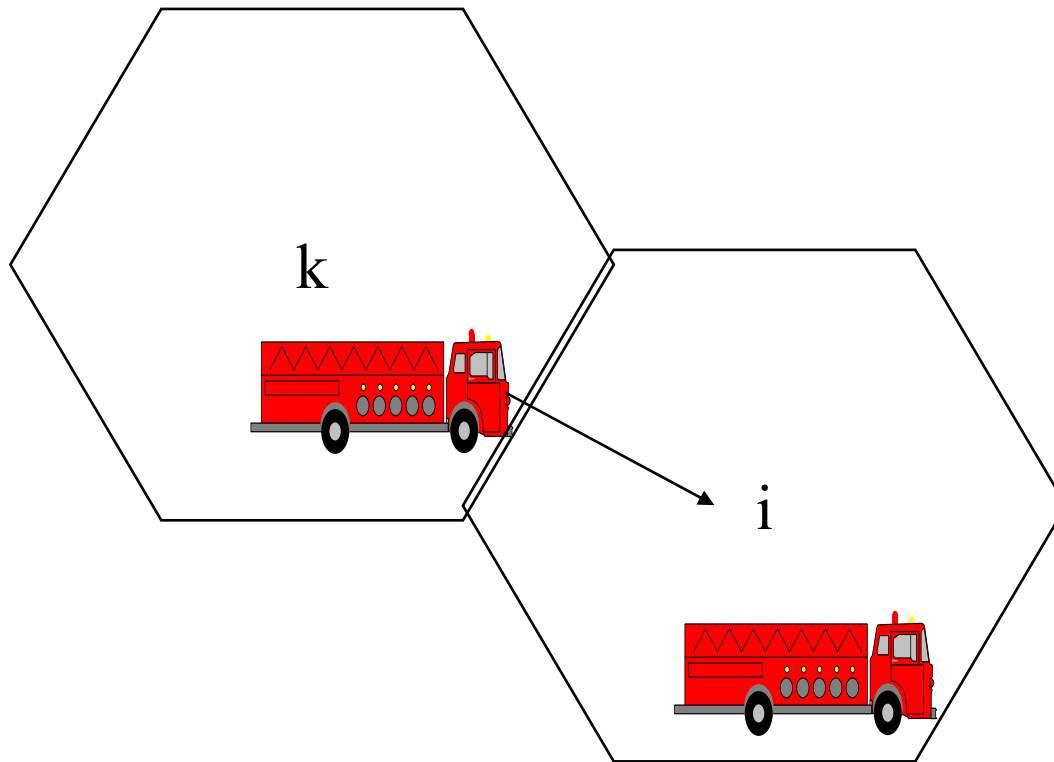


Hand off Procedure

- ◆ 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

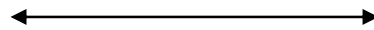


Trends in Hand over Design

- ◆ 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



QoS

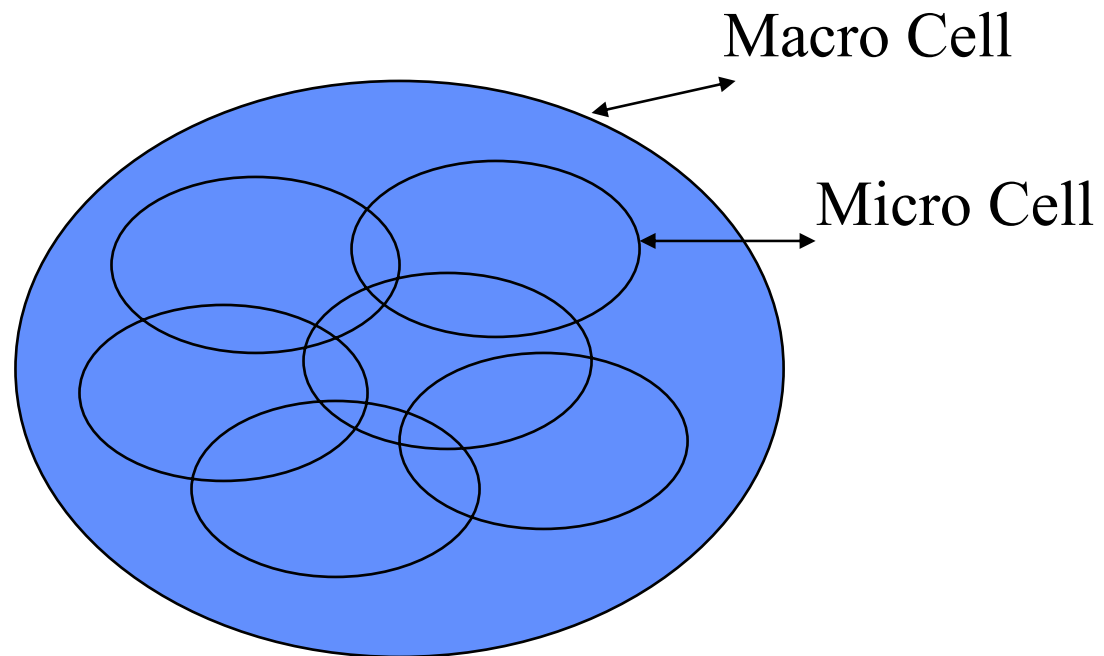


Hand off



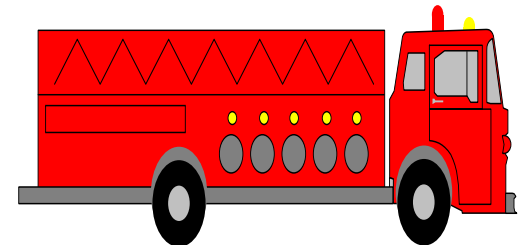
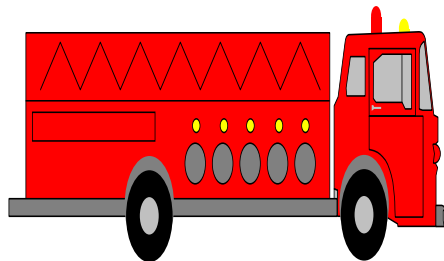
Mobility Solution

- ◆ 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

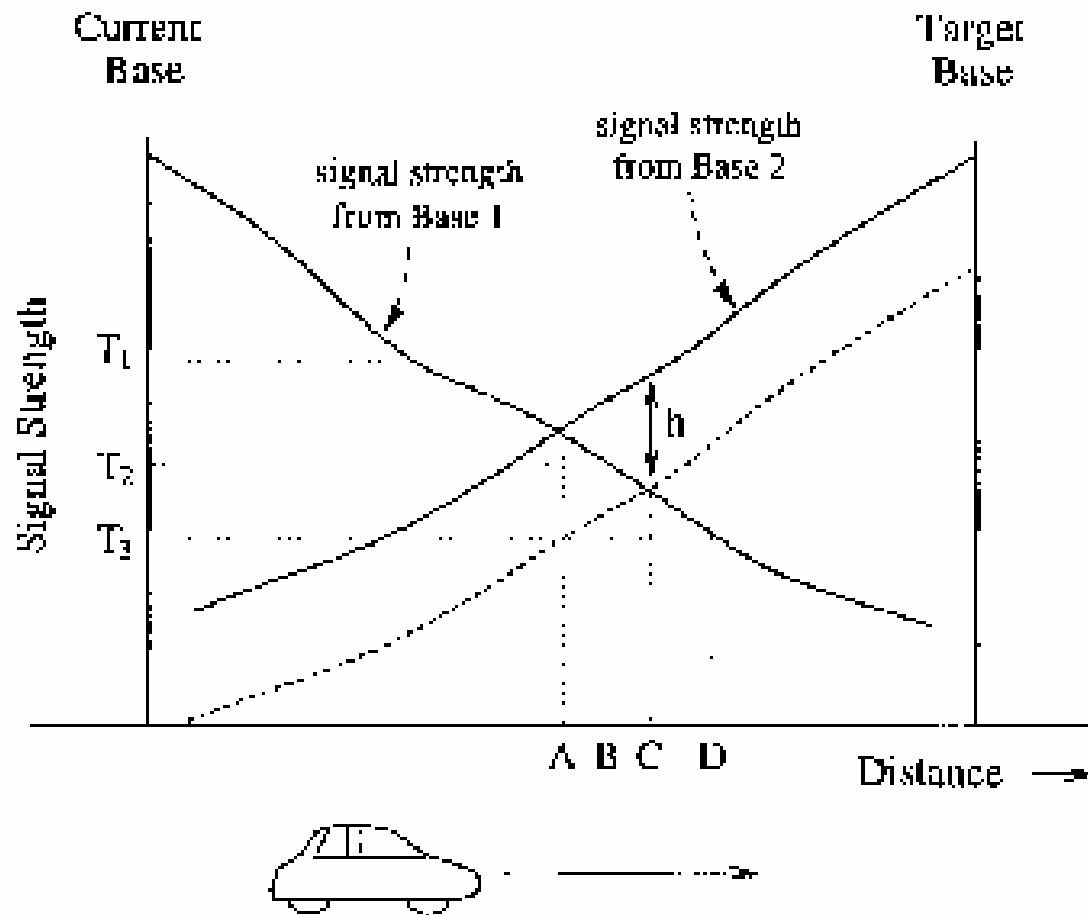
Handoff Strategies (II)

- ◆ 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

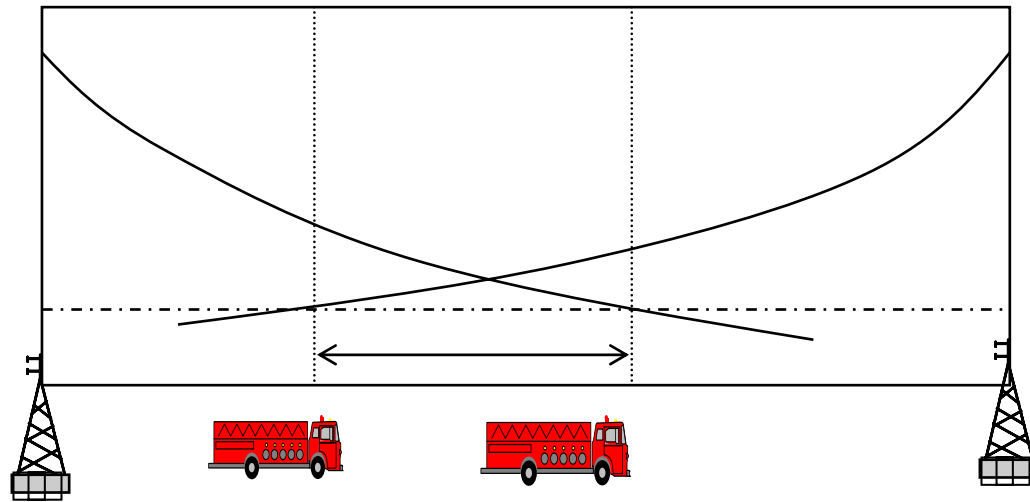


Handoff Initiation Strategies

- ◆ 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