CS 294-7: Handoff Strategies

Prof. Randy H. Katz
CS Division
University of California, Berkeley
Berkeley, CA 94720-1776
© 1996

Technology Trends

- **Fastest way to increase network capacity is to decrease cell size**
  - **Increased cell crossings per unit time**
  - **Greater demands on switching infrastructure**
- **Quality of Service (QoS) Considerations**
  - **Rerouting connections with low latency**
  - **Minimizes co-channel interference**
  - **Rapid reallocation of network resources**
- **Multitier PCS Systems**
  - **Macrocells overlain on top of microcells**
  - **Rapidly moving mobiles assigned to the former, stationary mobiles to the latter**

Issues for Handoff

- Making handoffs "seamless"
  - Minimize handoff latency
  - Minimize frequency of handoff and its effects on QoS
  - Minimize probability of dropping connections across handoffs
  - Minimize "call blocking"/effects of admission control
- Strategies
  - Channel allocation
  - Virtual connection trees
  - Multicast routing
  - User tracking

3

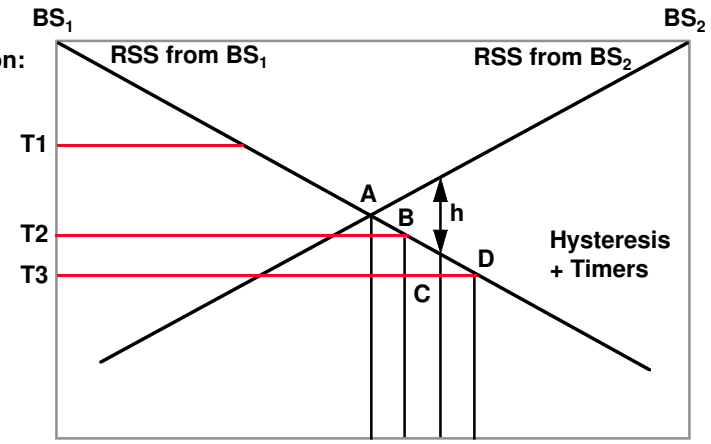
Performance Metrics

- Call blocking probability—new call attempt is blocked
- Handover blocking probability—handoff attempt is blocked
- Call dropping probability—call terminated due to failed handoff
- Probability of unnecessary handoff—handoff initiated when radio link still acceptable
- Rate of handoff—# of handoffs/unit time
- Duration of interruption—loss of communication with any base station
- Delay—distance moved before handoff occurs

4

Handoff Initiation

Handoff based on:
A: Relative SS
B: Relative SS + Threshold
C: Relative SS + Hysteresis
D: Relative SS + Hysteresis & Threshold
Predictive Techniques

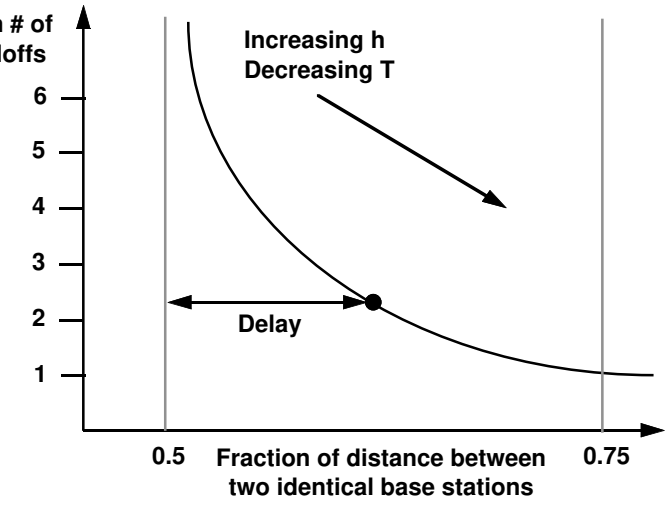


Increasing delay implies decreasing link quality and increasing dropping probability

5

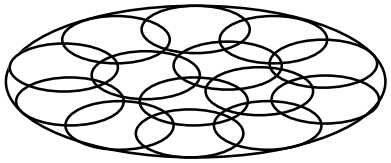
Handoff Initiation

Trade h/o delay for decreased number of handoffs



6

Macro/Micro Cell Handoffs



- **Use cell dwell times to perform cell assignment:**
  - **Move to bigger cell if user does not spend enough time in the current cell**
  - **Move to a smaller cell if the user stays there too long**

Macrocells for fast movers
Microcells for slow movers
Estimate speed via doppler frequency
Direction-based algorithms

Access Schemes:
— CDMA in macrocells, TDMA in microcells
— TDMA in macrocells, CDMA in microcells
— TDMA timeslot sharing
— Frequency splitting

CDMA/CDMA doesn't work well because of differing power levels for macro/micro cells

7

Channel Assignment

- **Channel Assignment Strategies**
  - **Fixed**
    - » **Basic Fixed**
    - » **Simple Borrowing**
    - » **Hybrid**
    - » **Borrowing with Ordering**
  - **Dynamic**
    - » **Call-by-Call Optimized**
  - **Flexible**
    - » **Scheduled**
    - » **Predictive**

8

Fixed Channel Assignment

- **Fixed Assignment**
  - Permanent assignment to all cells
  - Simple, but what happens when there are local demand hotspots?
- **Simple Borrowing**
  - MSC "borrows" unused channel from adjacent cell
  - Select cell with lowest number of in-use channels
- **Hybrid**
  - Partition channels into those that are "reserved for local use only" and those that may be borrowed on demand
  - Choose fixed partitioning based on expected traffic load
- **Borrowing with Ordering**
  - Adjust reserved/borrowable ratio based on dynamic traffic conditions

9

Dynamic Channel Assignment

- **Call-by-Call Optimized**
  - MSC assigns channels on demand to BSs under its control
  - Cost function depends on:
    - » Future blocking probability
    - » Usage frequency of channel
    - » Reuse distance of channel
    - » …
  - Other inputs to the decision process:
    - » Channel occupancy distributions
    - » Current traffic measurements
    - » Radio channel measurements

10

Flexible Channel Assignment

- MSC holds “flexible” channels in reserve in addition to channels assigned to specific cells
- MSC assigns reserve channels to cells to meet demand
  - Scheduled
    - » MSC knows in advance when peak traffic periods will arise for different cells
  - Predictive
    - » Continuous measurement of traffic intensity
    - » MSC predicts traffic changes over time and space, and makes necessary assignments of reserve channels

11

Handoff Scenarios

- Prioritize handoff requests to protect against dropped calls
- Radio channel measurements
  - Fading channel implies that loss of signal strength must persist for some threshold time before a handoff is requested
  - But perform with low latency to insure reduced probability of dropping
  - MSC must identify channel in new cell to assign to MS as it approaches the cell boundary
- Guard channels: small number of channels reserved for handoff to MS with calls in progress
  - Increases blocking probability but decreases dropping probability
  - Worse spectrum utilization

12

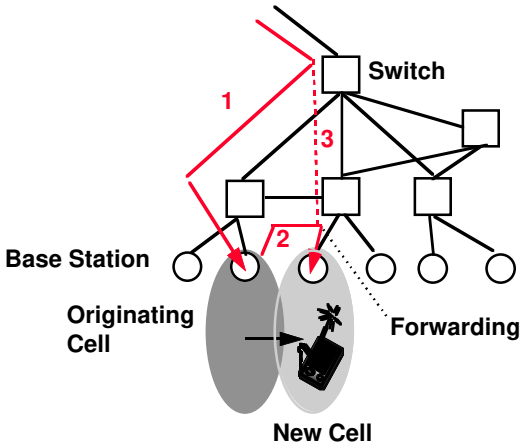
Handoff Scenarios

- **Queuing of Originating Calls**
  - Make new calls wait while giving priority to handoff connections
  - Can also queue handoffs, since there is a time interval during which the existing call connection can be retained before a new one is assigned
    - » Position in queue depends on how close the MS is to the edge of the cell
    - » Higher priority for MSs close to edge and/or moving fast
    - » Lower priority for MSs further from edge and/or moving slow

13

Handoffs and Connections

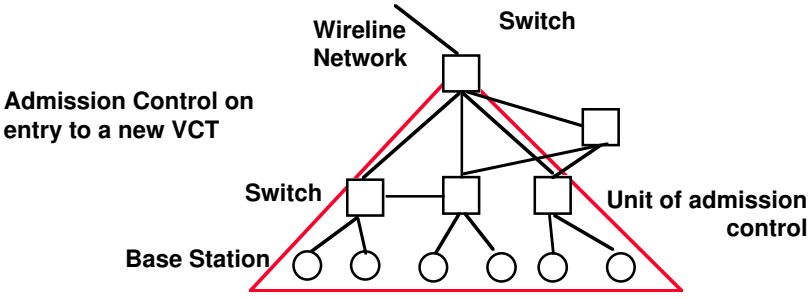
1. Connection established to originating cell
2. As mobile moves, BS in original cell forwards to new cell—latency and load on original BS and network
3. Tear up and reestablish connection tails



Beware of forwarding loops!

14

Virtual Connection Trees



Virtual Connection Numbers:

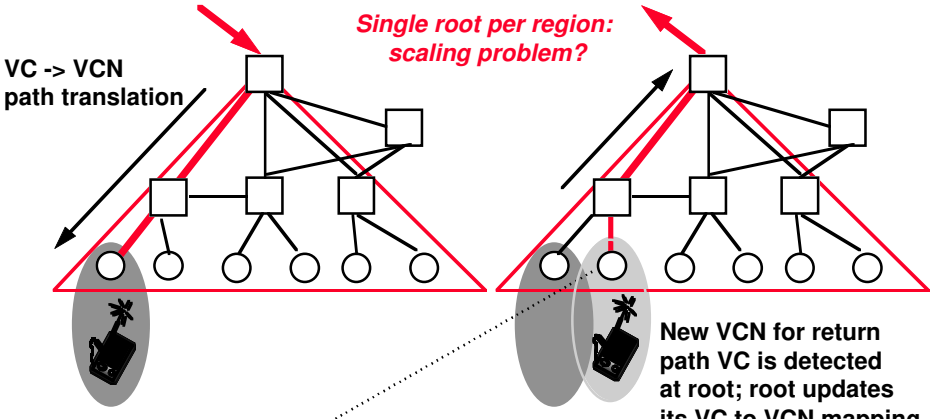
Assigned to path from root of tree to leaves of tree;
One for each possible path and each MS(!!)

Connection consists of two parts:

(1) Path from BS to root of tree
(2) Fixed virtual connection to other party in connection

15

Virtual Connection Trees



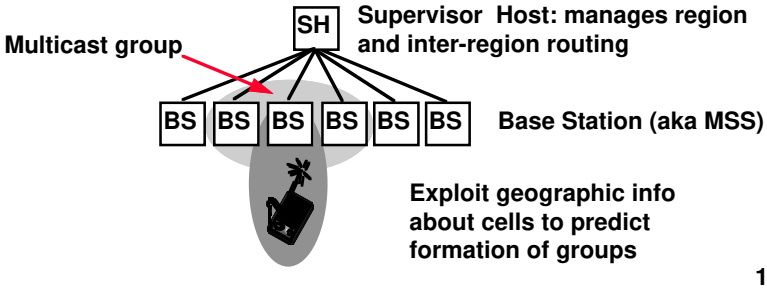
Mobile Initiated Handoff:
Access points chosen by mobile

NOTE: No discussion of forwarding!

16

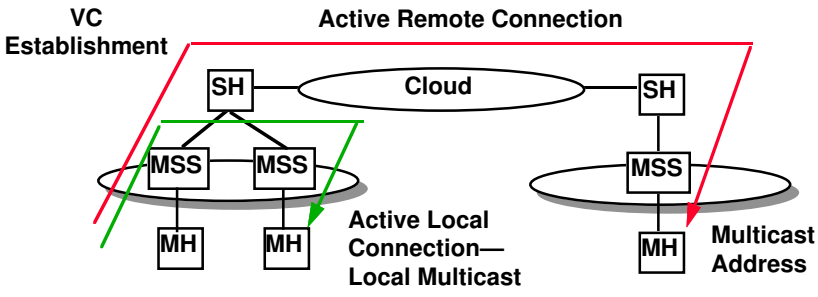
User Tracking

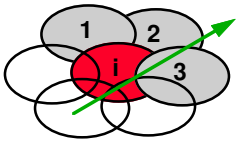
- **Picocellular systems**
  - Cell sizes on the order of 10 m diameter (pedestrian speeds are 2-3 m/second)
  - Faster inter-node mobility, greater frequency of handoffs
  - Proposed solution: local area multicast



17

Mobility Protocol (Ghai and Singh)





Direction of Motion
Red is forwarding
Gray is buffering

How easy to predict?

18

Mobility Protocol

- **Connection Establishment**
  - MH_S to communicate with MH_D; Reflect request to MSS_S and SH_S
  - Assigns local VCN, connection is NASCENT
  - SH_S locates MH_D (VCN, ID of MH_S, ID of MH_D)
    - » Looks for MH_D within local subnet first (ACTIVE LOCAL)
    - » If no response, broadcast locate request to other SHs; When located, assign local VCN, respond to SH_S Connection status becomes ACTIVE REMOTE
  - Connection is now established
- **Connection Maintenance**
  - MSS beacon signaling: MH responds with GREET (includes ID of old MSS and SH); MSS responds with GREET_ACK
  - Same subnet: SH changes membership in MH's group
  - New subnet: new SH must inherit MH's existing connections ACTIVE_LOCAL connections become ACTIVE_REMOTE Some ACTIVE_REMOTE connections become ACTIVE_LOCAL

19

Mobility Protocol

- **Communications between MHs**
  - Same subnet: local multicast from source MSS to group members of destination MH
  - Different subnets: source SH sends packet to destination SH with appropriate local VCN
    - » At Destination SH, if connection is ACTIVE_REMOTE: Multicast the packet to the group in the local subnet
    - » If POINT, "Destination" SH forwards the packet to the current SH of the destination MH;

      Status is POINT if MH moves out of subnet after connection has been established

      Note that scheme does NOT propose how to prune these forwarding pointers

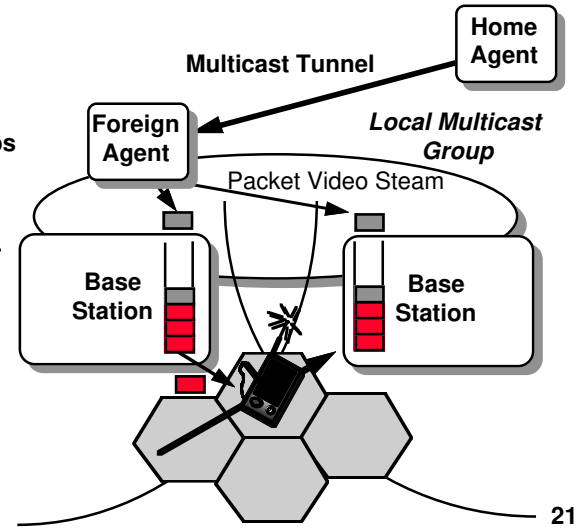
20

Low Latency Handoff

Use hints about terminal trajectory to form MC groups

Multicast packets to "regional" base stations to smooth hand-offs for R/T streams

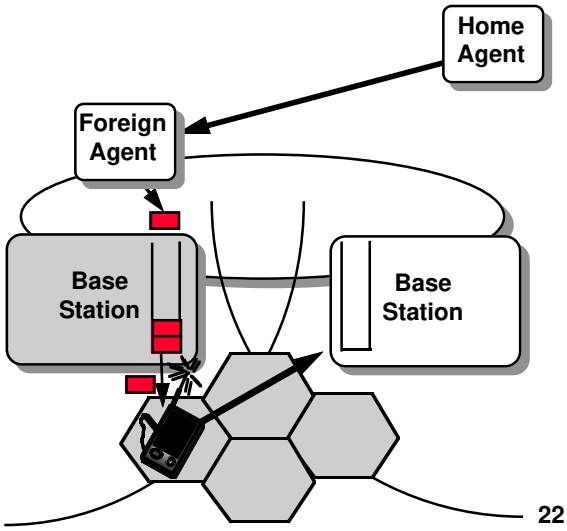
Minimize location update traffic to home agent and mobility aware CHs



21

Low Latency Handoff

Forwarding Base Station

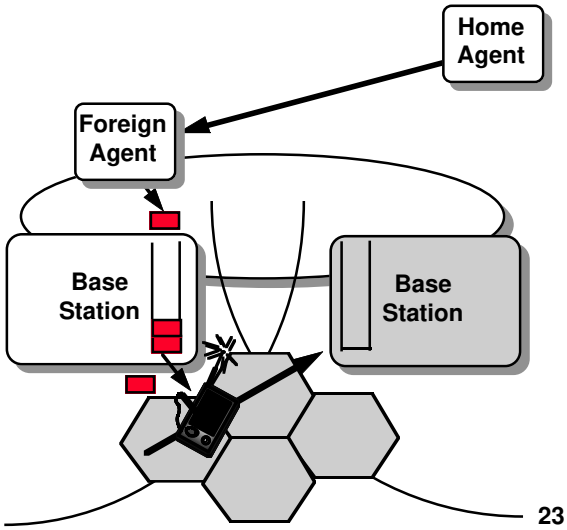


22

Low Latency Handoff

Forwarding Base Station

Buffering Base Station



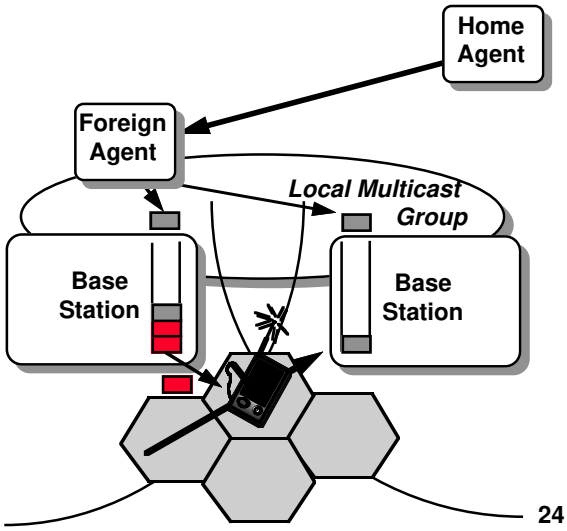
23

Low Latency Handoff

Forwarding Base Station

Buffering Base Station

Extending Multicast Group



24

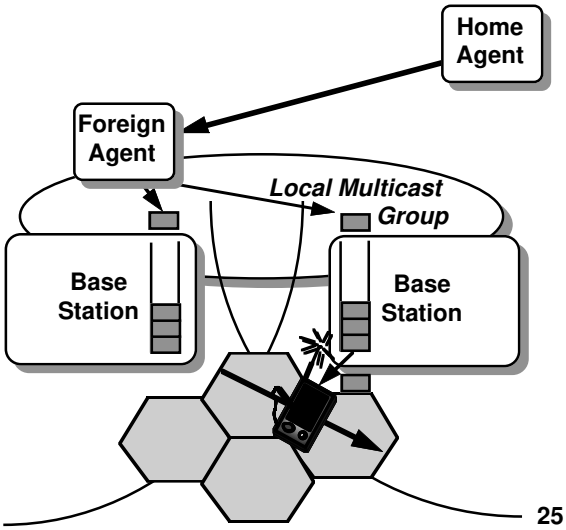
Low Latency Handoff

Forwarding Base Station

Buffering Base Station

Extending Multicast Group

Horizontal Hand Off



25

Low Latency Handoff

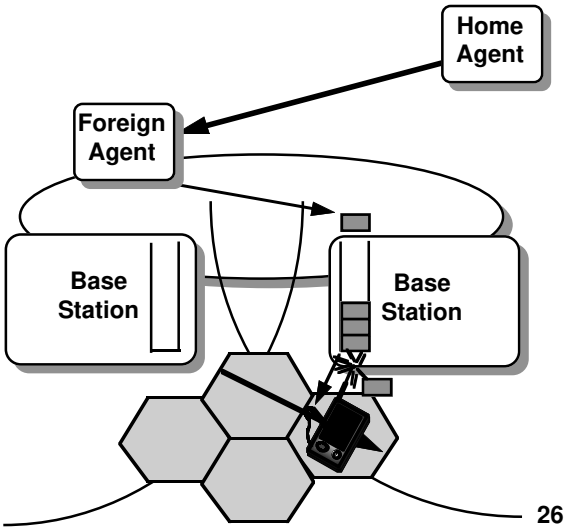
Forwarding Base Station

Buffering Base Station

Extending Multicast Group

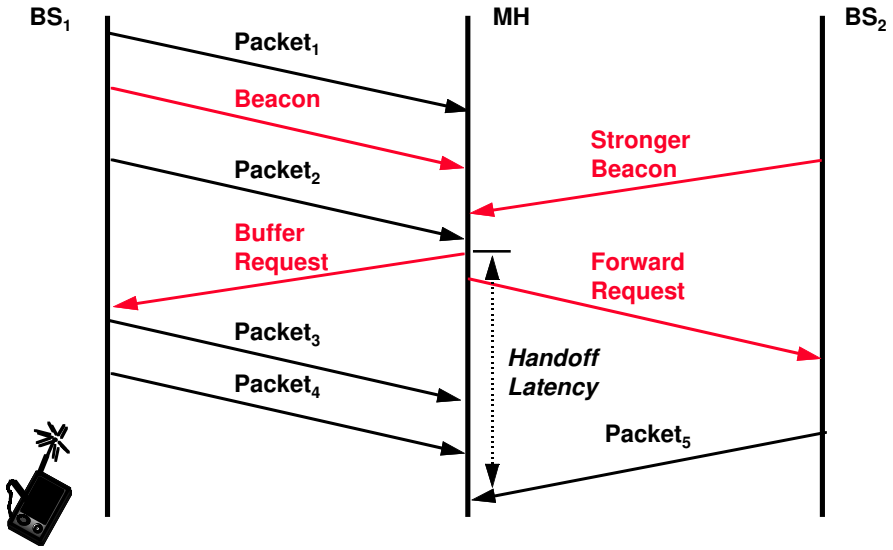
Horizontal Hand Off

Pruning Multicast Group



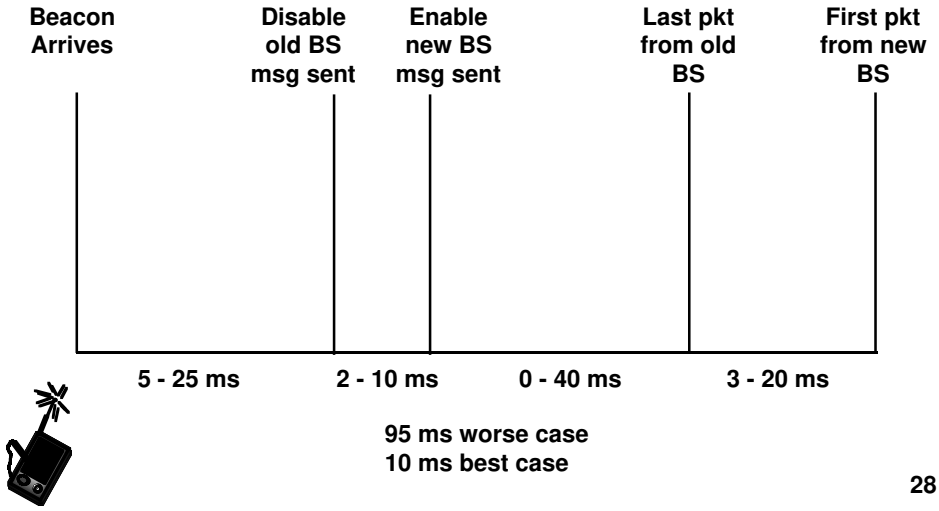
26

Typical Handoff Messaging



27

Measured Handoff Latency



28