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PHY/MAC considerations for Handoff in Packet-Switched Cellular Wireless Data Networks

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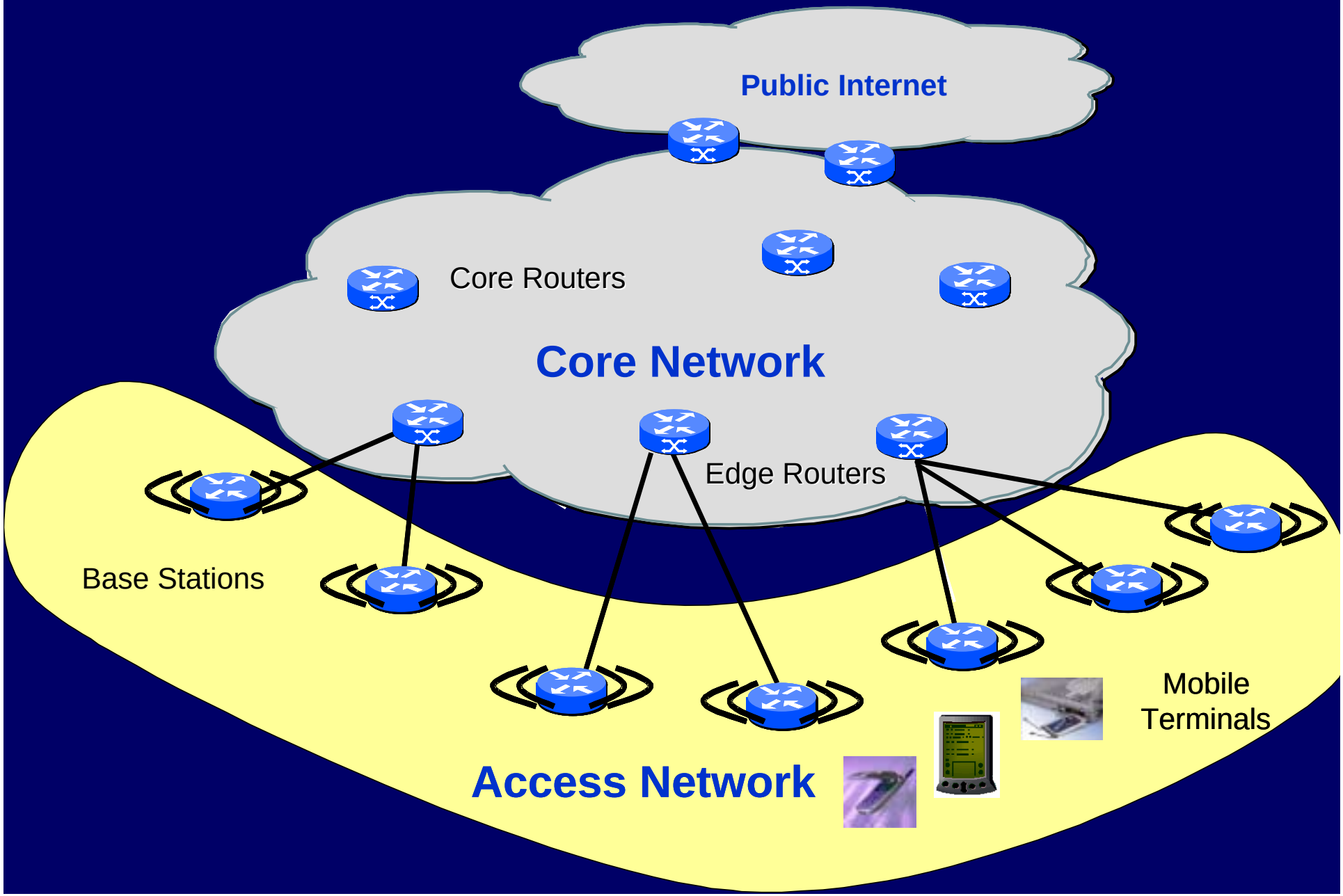
Outline

- Design Goals
- Mobile versus Network Handoff initiation
- Handoff Types
  - Break-before-Make
  - Make-before-Break
- Handoff Situations
  - Inter-sector, inter-cell, inter-carrier, inter-technology
- Summary

True Packet-Switched Cellular Architecture



Design Goals

- Optimize exclusively for DL and UL packet-switched data traffic
  - Handoff algorithms must be “packet aware”
- Eliminate/Minimize packet loss and packet re-ordering at handoff
- Minimize MAC/Network layer signaling overhead
- Use standards-based signaling at L3 and above
- Eliminate “centralized handoff boxes” for greater scalability

Design Goals Contd.

- No PHY layer synchronization between BSs
  - Simplifies access network design and implementation
  - Only Inter-Base Station control message exchanges to expedite hand-off
- Multi-Base Station connectivity at Mobile
  - Must be able to independently scan and lock on to multiple BSs
  - Must be able to maintain packet-switched data and dedicated control channels with multiple Base Stations
- Transparent to applications

VoIP handoff is litmus test

Network versus Mobile initiated Handoffs

- Mobile and Network roles
  - Mobile-initiated and Network-assisted
  - Network-initiated and Mobile-assisted
- Mobile in best position to initiate hand-offs
  - Knows relative DL quality of various BSs
  - Base Stations assist with self or neighbor DL/UL PHY parameter information
  - Allows Mobile device differentiation
- Base Stations at Access network edge
  - Must be packet aware
  - Be decision point for network

Mobile-Initiated, Network-Assisted Handoff

- Highly scalable
- More fault tolerant
- Ideally suited for pure packet-switched Access & Core Networks with de-centralized control
- Harmonious with IP-based Mobility Mgmt protocols
- Significantly reduced overhead for Mobile to network parameter reporting

Handoff Types in Packet-Switched Access Networks

- Mobile does not have “circuits” via multiple Base Stations
- Break-before-Make Handoff
  - “Hard handoff”
  - Momentary loss in Mobile connectivity to network
- Make-before-Break Handoff
  - Not necessarily the same as traditional “Soft Handoff” in CDMA systems
  - No loss in Mobile connectivity to network

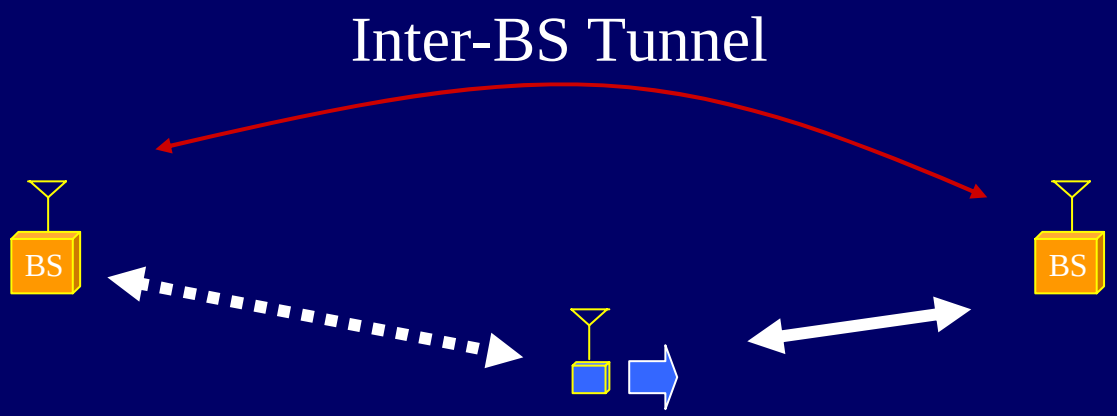
Handoff Stages

- PHY sync
  - Mobile scans, detects and locks onto new BS
- PHY Layer exchange
  - Contention based access
  - Request air-link resources
- MAC layer exchange
  - Must be contention-free
  - Mobile is allocated airlink resources, authenticated, authorized, registered
- Network Layer exchange
  - After L2 triggers. Must be contention-free
  - Mobility Management protocol (e.g., MIPv4) specific
  - Mobile prepares to send/receive IP traffic (e.g, DHCP)

Base Station Selection for Handoff

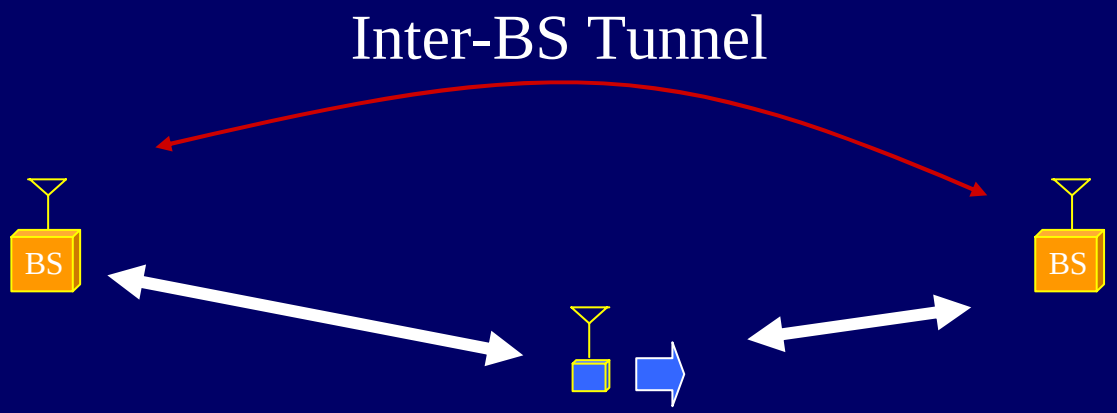
- Mobile maintains candidate Base Station Lists
- Entry and Exit criterion for list based on
  - Relative received DL powers of Base Stations
  - Time duration for power ratios
  - Hysteresis for mitigating “ping-pong” effects
- Must be flexible and configurable for variety of channel and deployment scenarios
  - Entire range of mobility classes
  - Urban, suburban, rural areas
  - Macro, Micro cells

Break-before-Make Handoff



- Mobile maintains PHY and MAC connectivity with at most one Base Station at a time
  - Overlap stages to ensure minimal “dead” time
- All latencies kept to a minimum to ensure transparency to applications
- Inter-BS data transfer and signaling protocols can ensure minimal packet loss, re-ordering or delay
  - Proper design can ensure no impact on common TCP/IP based wireless data applications

Make-before-Break Handoff



- Mobile maintains PHY and MAC connectivity with *more than one* Base Station at a time
  - Overlap stages to ensure minimal “dead” time
- DL Traffic from one BS, UL traffic to any BS
- Inter-BS data transfer and signaling protocols can ensure no packet loss, re-ordering or delay
  - Proper design can ensure no impact on all TCP/IP based wireless data applications, VoIP, Gaming etc

Handoff Situations

- Inter-cell
- Inter-sector
- Inter-carrier
  - Typically Hard-handoff
- Inter-technology
  - Handoff decision best with Mobile (multi-mode)
  - Generally policy based
  - Limited PHY/MAC involvement
  - Significant back-end involvement (billing, accounting, authentication, roaming agreements etc)

Summary

- Handoff in packet-switched wireless data systems presents a unique set of challenges and solutions
- Handoff at vehicular speeds requires
  - Make-before-Break capability with cross-layer optimizations for transparency to all applications
  - Lightweight, contention-free MAC signaling
  - Built in QoS support at the PHY/MAC layers
  - Inter-BS protocol
  - Harmonized design with Mobility Mgmt protocols such as Mobile IP