IP Mobility for a Mobile Internet

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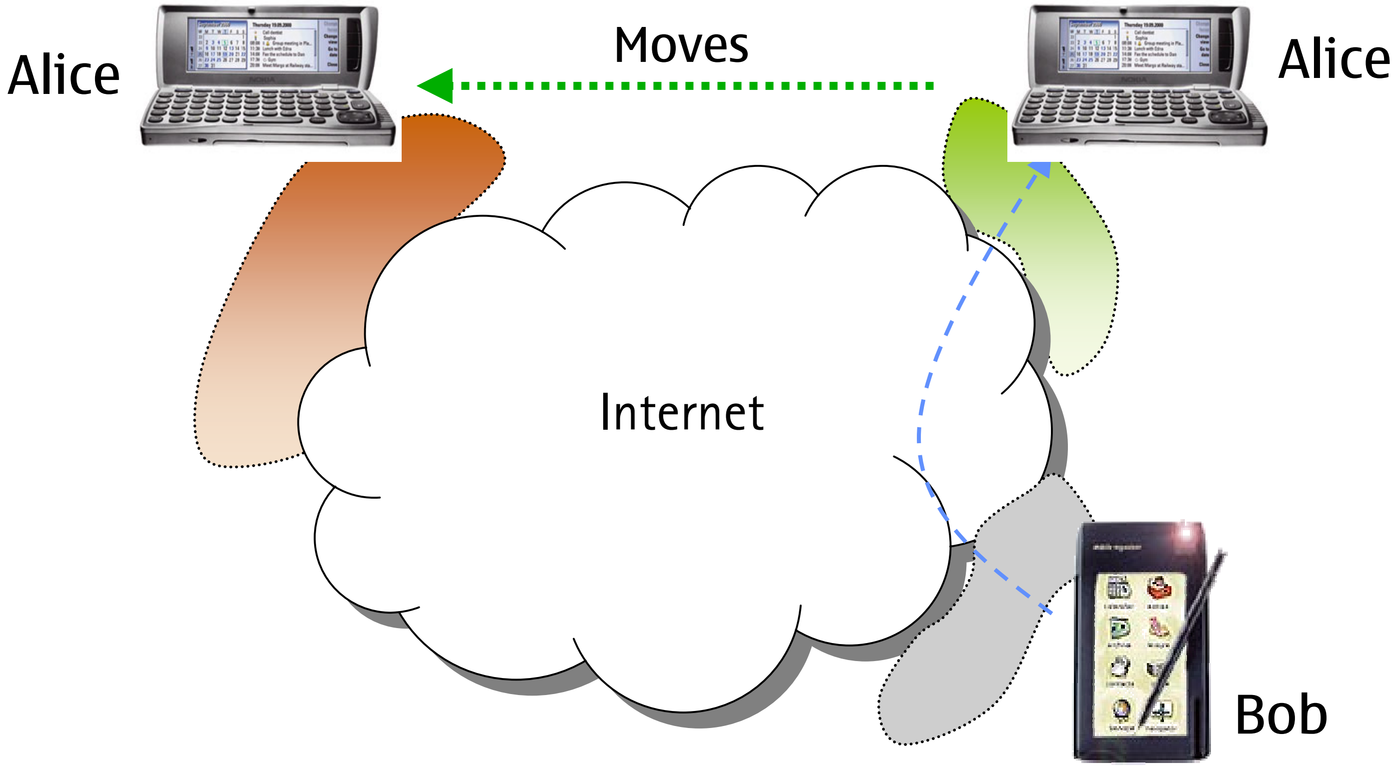
Outline

- Introduction
- Key Problems
- Solutions
- Open issues

IP Mobility: The Problem



- How can Bob reach Alice after the move ?
- How can Bob keep talking to Alice during the move ?

IP Mobility: The Problem

- An IP device moves from its existing subnet to another
- How does the device maintain
  - reachability for new communication (*roaming*),
  - its existing communication (*handover*)
- Roaming and Handover together constitute the *Mobility Problem*
- Corollary to the Mobility Problem is *Handover Performance Problem*

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IP Mobility: Drivers

- Emergence of WLAN
  - Enterprise and Campus-wide WLAN networking
  - Multiple variants of Wi-Fi

- Multiple radio access (“multi-access”) technology is here
  - Portable devices with multiple radios
  - Wide-area footprint of “wholesale” WLAN service
  - Wireless VPN access: rate and range benefits

- Success of SMS and i-Mode is paving the way for packet-data services (such as MMS, Instant Messaging, content downloading,..)
  - Emergence of SIP as a packet-data service enabler

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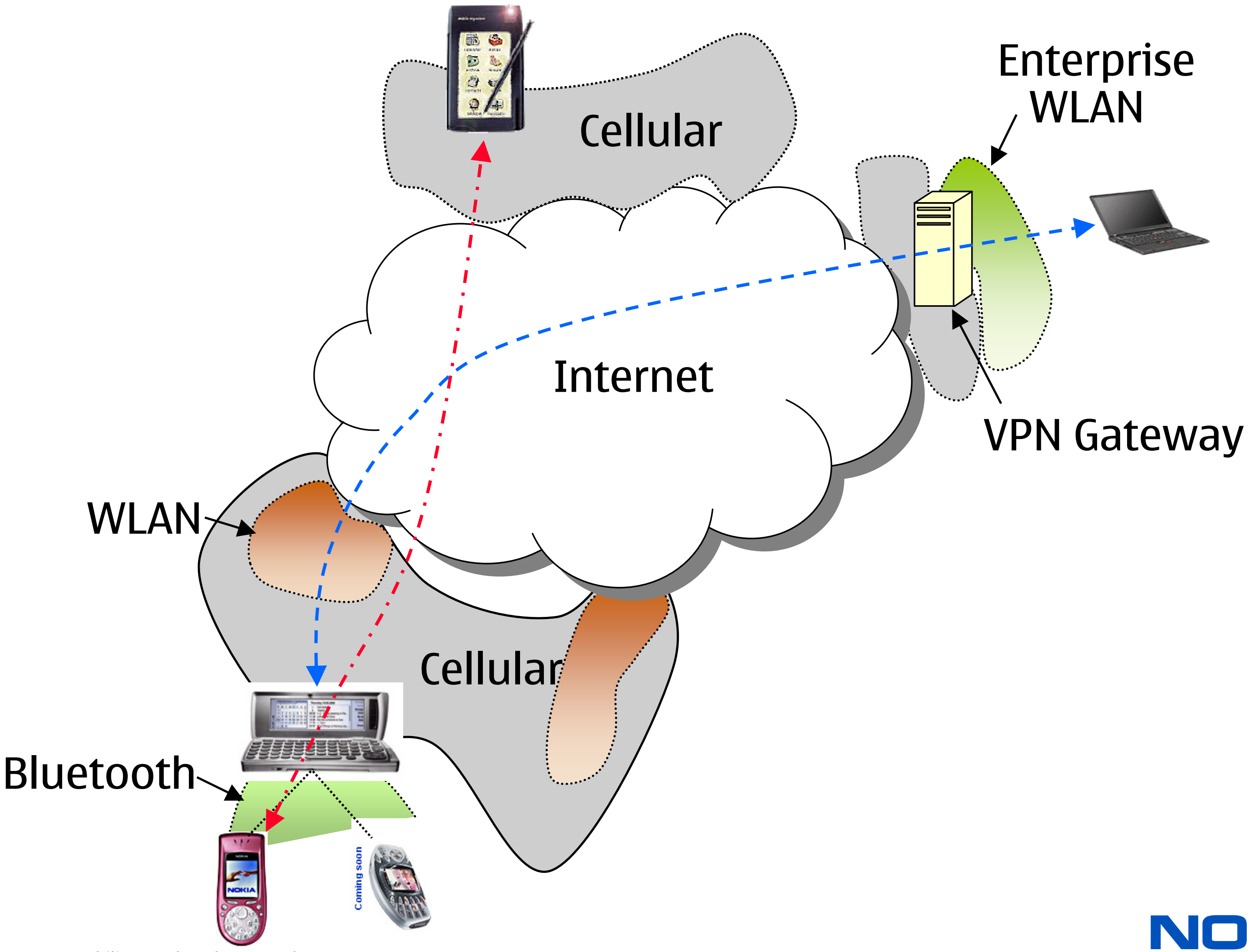
Multi-access Illustration



Mobility is not easy

- Spans multiple layers, starting from link layer to network layer to application layer
- Managing link, IP connectivity, transport protocol performance is non-trivial
- Mobility affects applications, and hence user experience
- Security: access control, access to resources are considerations in offering “seamless network roaming experience”
- Roaming is not only a technical problem

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IP Mobility: Principles

- Core network routing transparency
  - Routers and switches are un-aware of mobility
- Host-controlled location update to effect routing path change
  - Responsibility rests on the Mobile Node (MN)
- Adheres to the “end-to-end” model
  - Minimal network support
  - Intelligent host

Requirements for solutions

- Roaming: Packets need to reach the current location of a Mobile Node
- Handover:
  - Connection (session) end-point must remain constant even though the IP address changes
  - Connection end-point must be able to handle change of IP address

Principles, requirements and solutions

- Roaming:
  - MN updates namespace (DNS) upon movement
  - Application layer handles location tracking (e.g., outsource the problem to a SIP proxy)
  - An IP layer node manages location (e.g., Mobile IP Home Agent)

- Handover:
  - Each transport protocol handles mobility on its own (SIP Re-Invite, TCP Migrate, SCTP Re-associate)
  - An IP layer solution preserves connection end-point (Mobile IP Home Address)

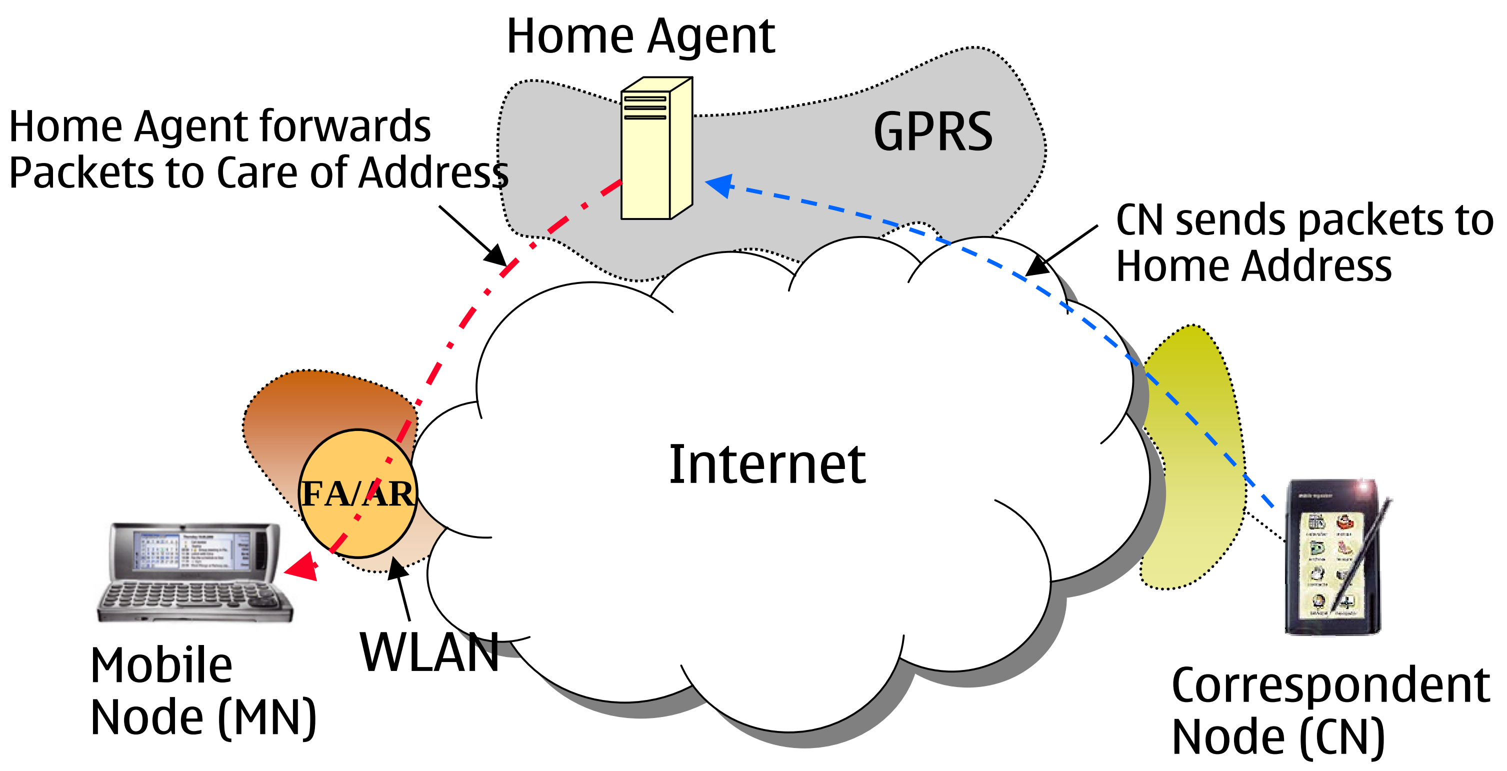
- All solutions follow, to varying degrees, the principles

Solving IP Mobility: Mobile IP approach

Base Mobility Support using Mobile IP

- Definitions:
  - *MN*: a device whose IP address changes as it moves from a network to another
  - *Home Address*: that IP address of the MN which remains constant during its movement
  - *Care of Address*: that IP address of the MN which changes from network to network, in accordance with the network prefix
  - *Home Agent*: a node, on the network where the Home Address is valid, that forwards packets to the Care of Address
  - *Foreign Agent*: a node, on the visited network, that assists the MN with connectivity

Mobile IP: Basic Protocol Overview



Mobile IP: Components

- Movement Detection
  - a MN has to determine that it has changed subnets
  - relies on Router Advertisements

- New IP Address (CoA) Configuration
  - in IPv4, either through Foreign Agent or “co-located”
  - in IPv6, either stateless or through DHCP (stateful)

- Registration with the Home Agent, Correspondent Nodes
  - inform new CoA to update [HoA, CoA] *binding*

- Datagram delivery
  - packets sent to HoA are forwarded by the HA using the binding

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Route Optimization

- In order to always use HoA, packets need to be routed through the Home Agent
  - introduces sub-optimal routing and hence potentially longer delay

- Direct communication between the MN and its correspondents should be possible

- <u>RO Problem</u>: How to prove to any arbitrary correspondent that the MN owns the HoA *and* is currently at location identified by CoA ?
  - HoA concern: a malicious node could steal an innocent node's traffic
  - CoA concern: a malicious node could spam an innocent node

Return Routability

- MN sends a *Home Address Test Init* through the HA to the CN
- MN also sends a *CoA Test Init* message directly to the CN
- CN responds to HOTI message with HOT message in which it includes a cookie (K1)
- CN responds to COTI message with COT message in which it includes a cookie (K2)
- MN generates a Key K_BU by hashing K1 and K2, and computes a MAC using K_BU on the fields in the BU
- MN sends BU

- What makes Return Routability sufficient ?

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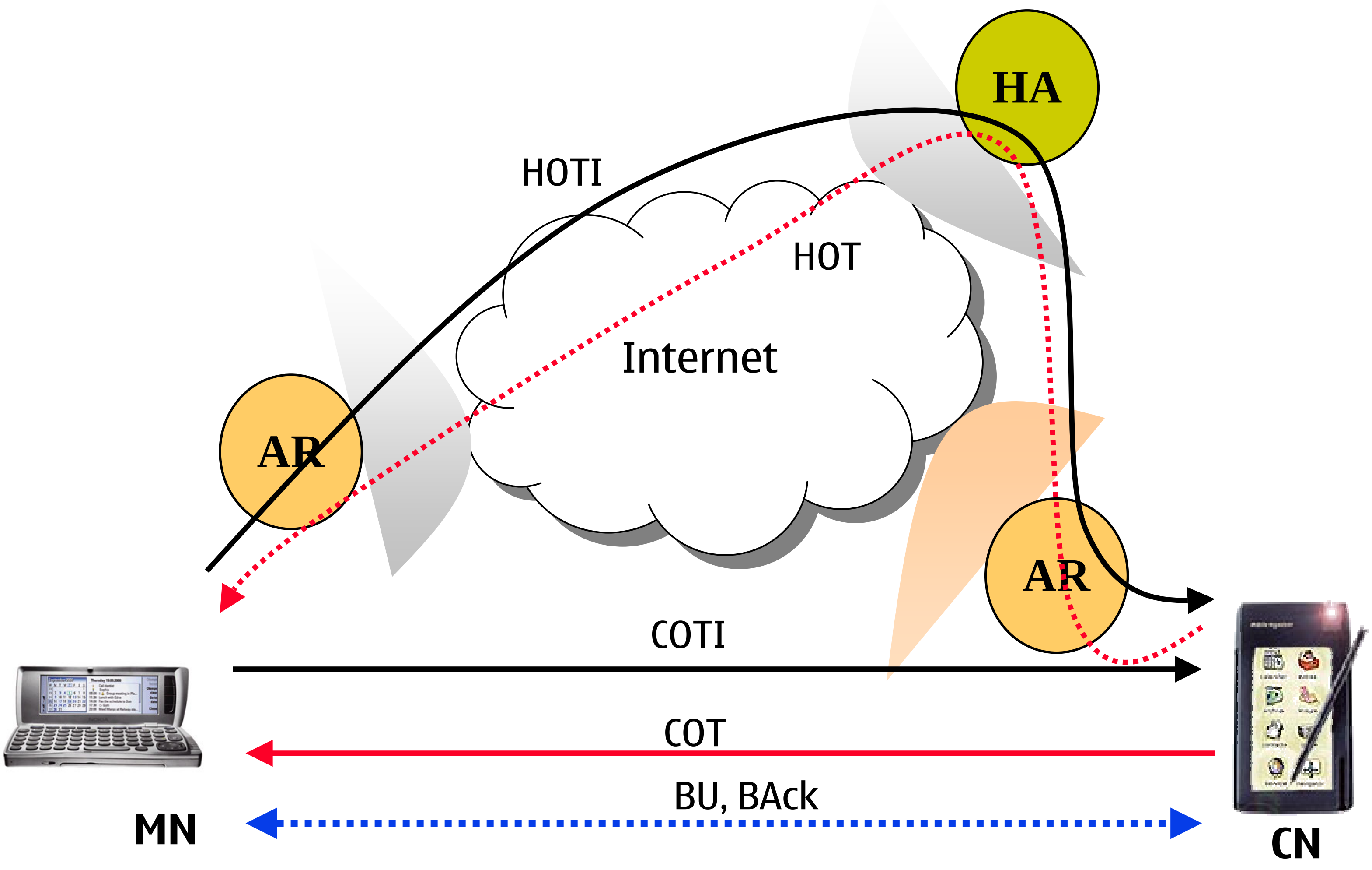
Return Routability



Handover Performance: Access Network Solutions

Improving Handover Experience

- Mobile IP establishes basic routing

- Several imperfections
  - movement detection latency
  - address configuration latency
  - location update latency
  - potentially lost packets sent to previous CoA

- In addition, there may be state re-establishment overhead
  - transport protocols establish state on the access router (e.g., AAA, QoS, Header Compression)

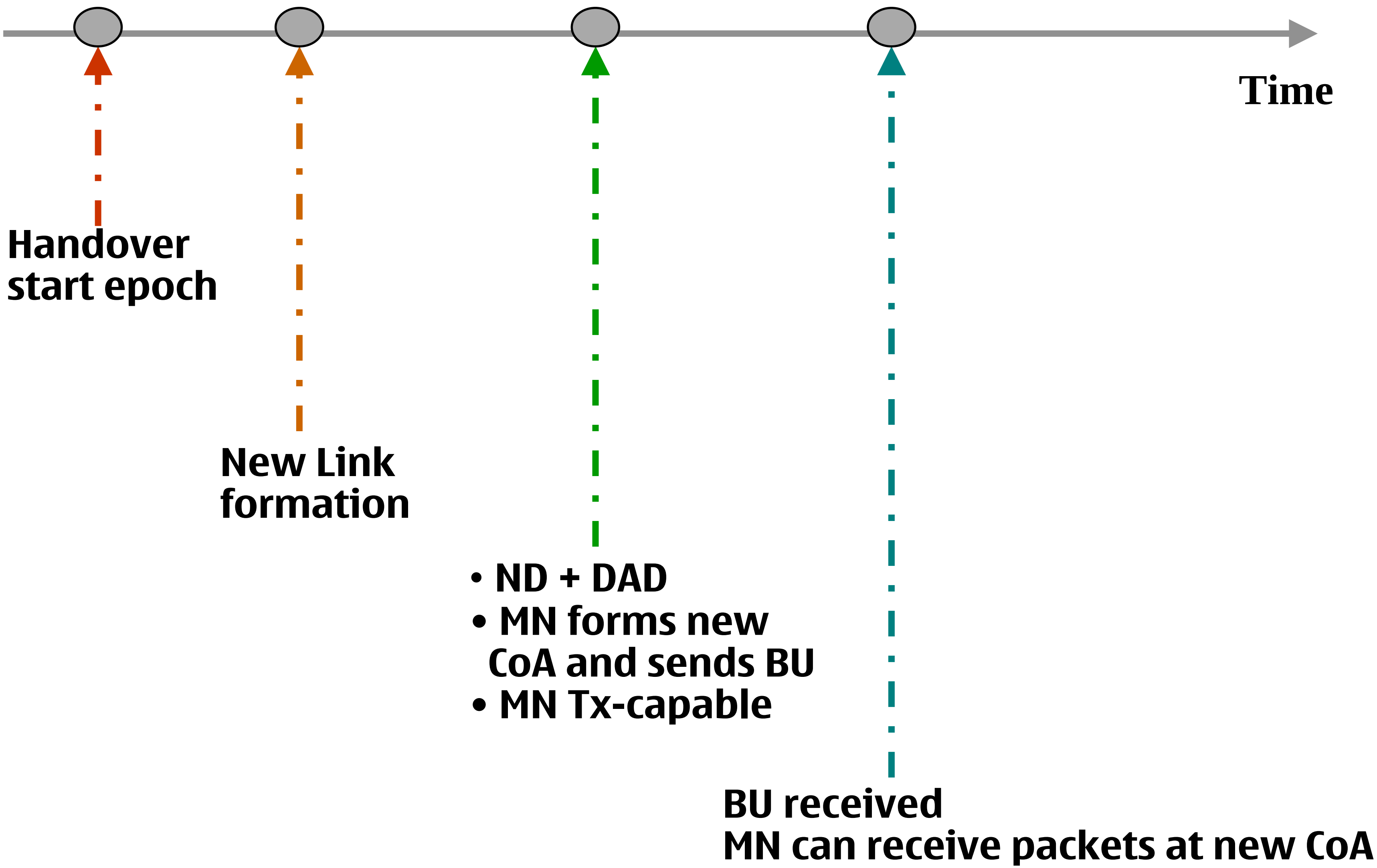
Fast Handover: Sources of delay

- a time to detect movement and formulate a new CoA at new access router (movement detection, router discovery (Neighbor Discovery: RFC 2461), and Duplicate Address Detection (RFC 2462))

- b time to receive packets at new CoA (binding update latency)

a) determines how quickly the MN can send packets, and b) determines how quickly it can receive packets at the new Care-of Address

Illustration



![NOKIA logo]

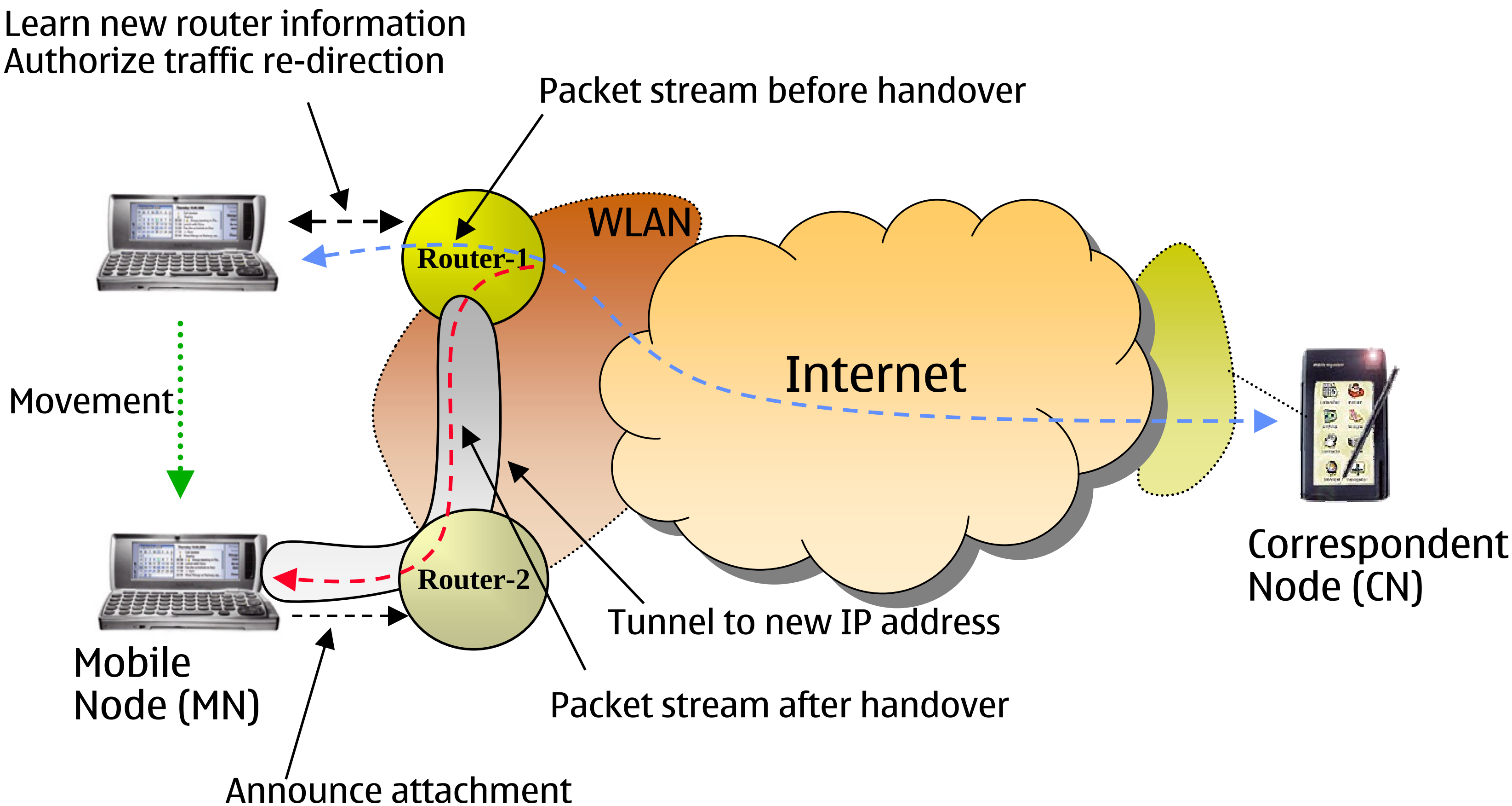
Fast Handover Protocol

- Allows a MN to learn new Router information when still attached to the current router
  - enables fast movement detection
  - expedites new address configuration
  - facilitates immediate transmission upon new link establishment

- Allows a MN to receive packets sent to its previous IP address until
  - Binding Update to Home Agent is completed
  - Binding Update to the correspondent is completed

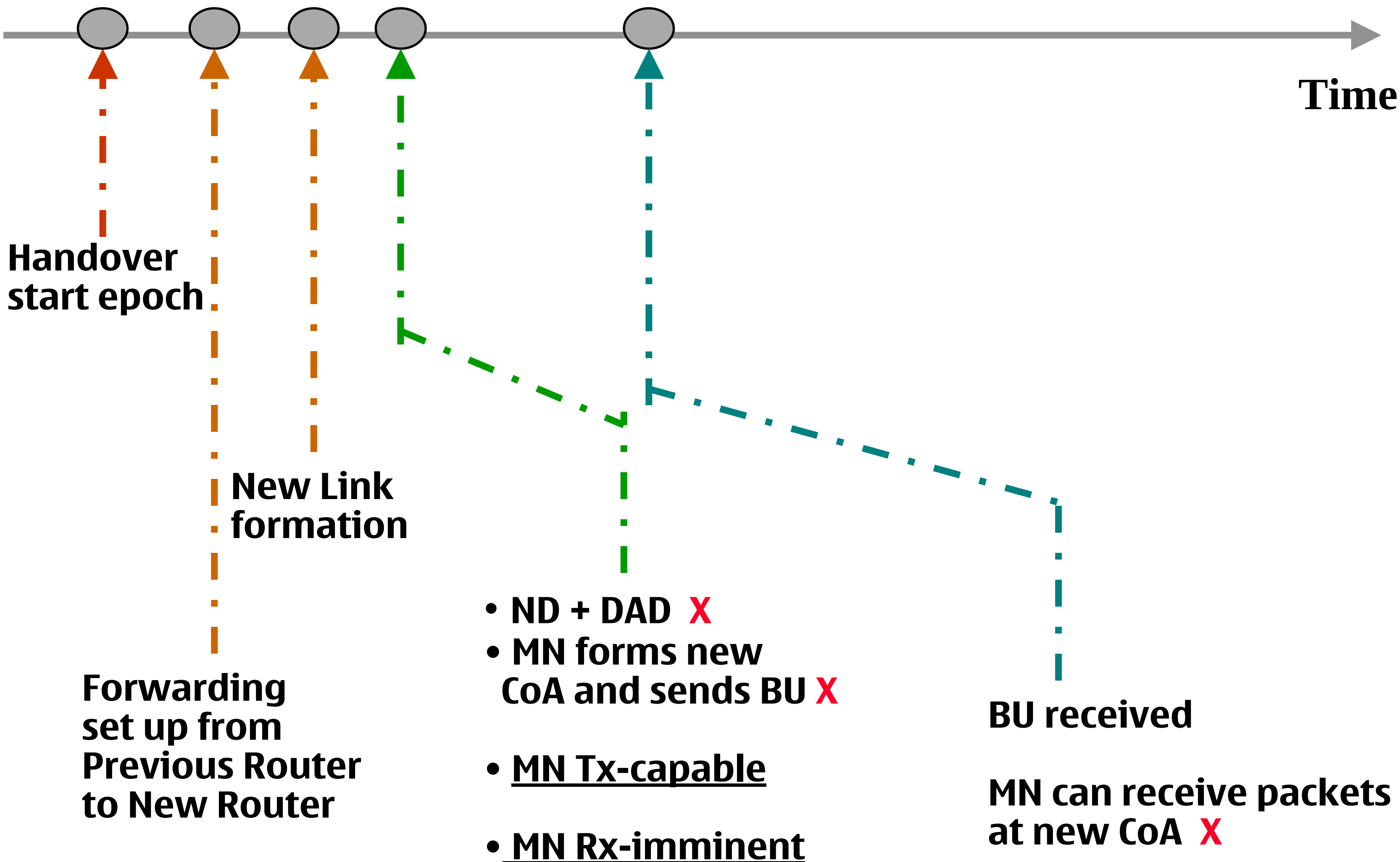
- Involves tunnel establishment triggered by MN signaling

Fast Handover Protocol Illustration



draft-ietf-mipshop-fast-mip6-0X.txt

Delays with optimizations



Context Transfer Protocol

- Allows network-resident state transfer in conjunction with handover
- Eliminates the need for state re-establishment
  - handover-agnostic application execution
  - smoother operation of transport protocols
  - bandwidth savings
- Best results when synchronized with fast handover
- Example contexts include header compression, QoS, security

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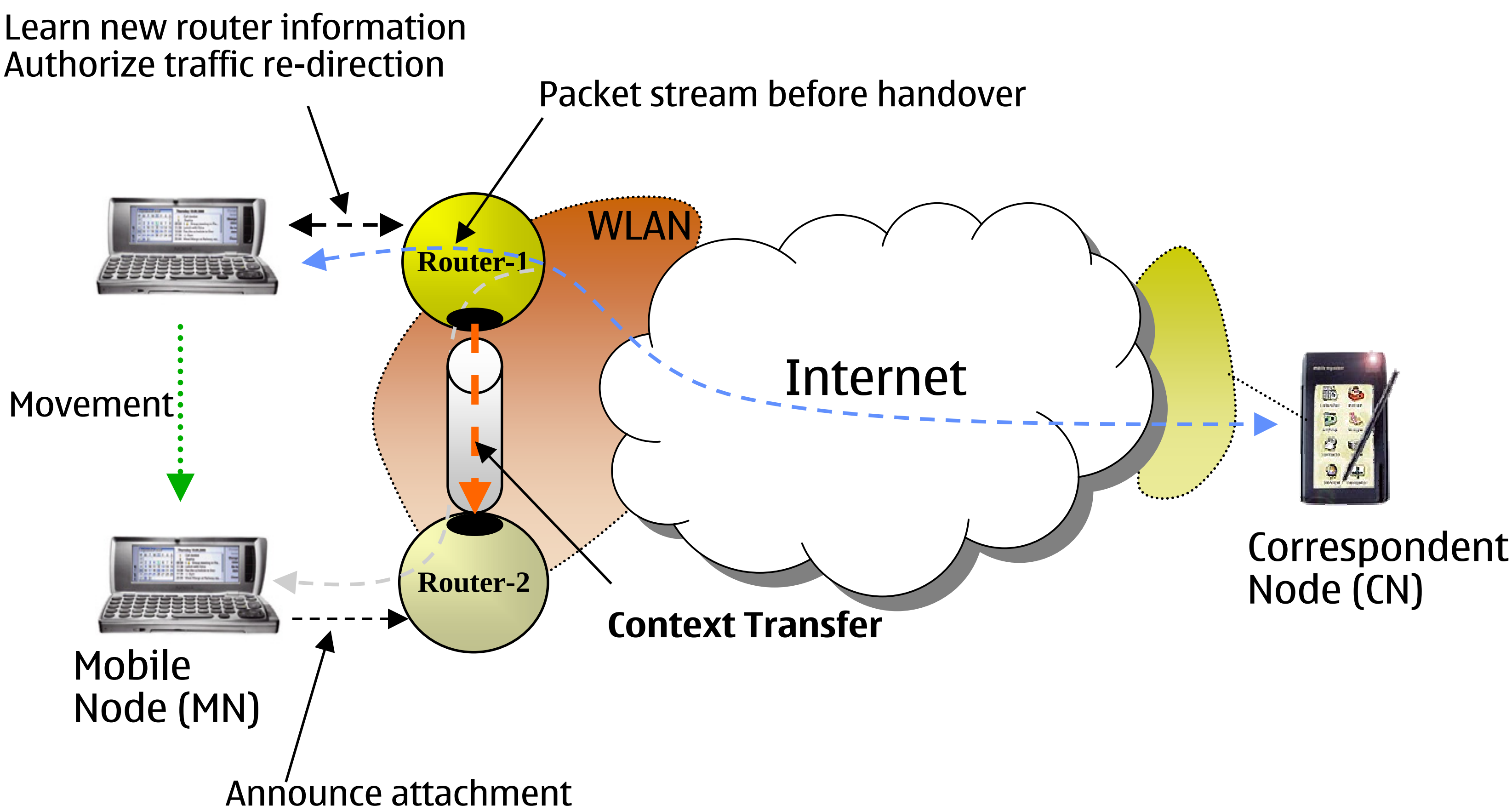
Context Transfer



Implementation

- Free-BSD derived routers, Linux MN, CN in a WLAN environment
- MN in conversation with a remote CN
- The media stream headers are compressed by the MN, and decompressed by the router
- The MN undergoes handover between routers
- Context Transfer of state corresponding to the media stream takes place in synchronization with Fast Handover

Performance Tests

- Test application: IPv6/UDP/RTP behaving according to *ON-OFF* model ("voice" source)
- Header Compression (of IPv6/MobileIPv6/UDP/RTP headers) initiated through *setsockopt()* API and MN - AR signaling
- ON period is geometrically distributed with mean λ-on
  λ-on = (1 - p) / p, where p is the probability of OFF period, a control parameter
- OFF period duration is exponentially distributed with mean λ-off
- inter-packet arrival time is 20 ms, UDP payload is 100 bytes

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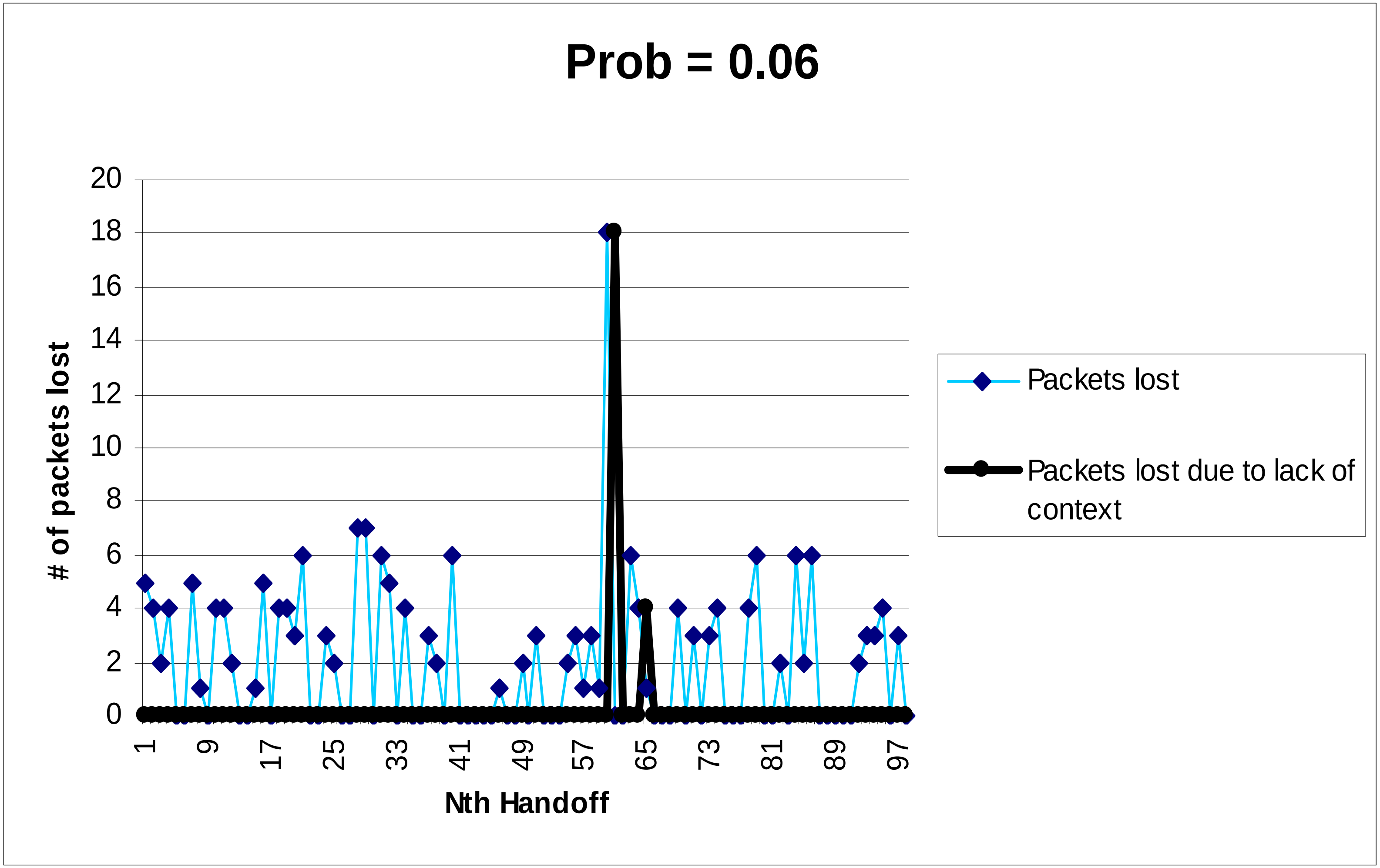
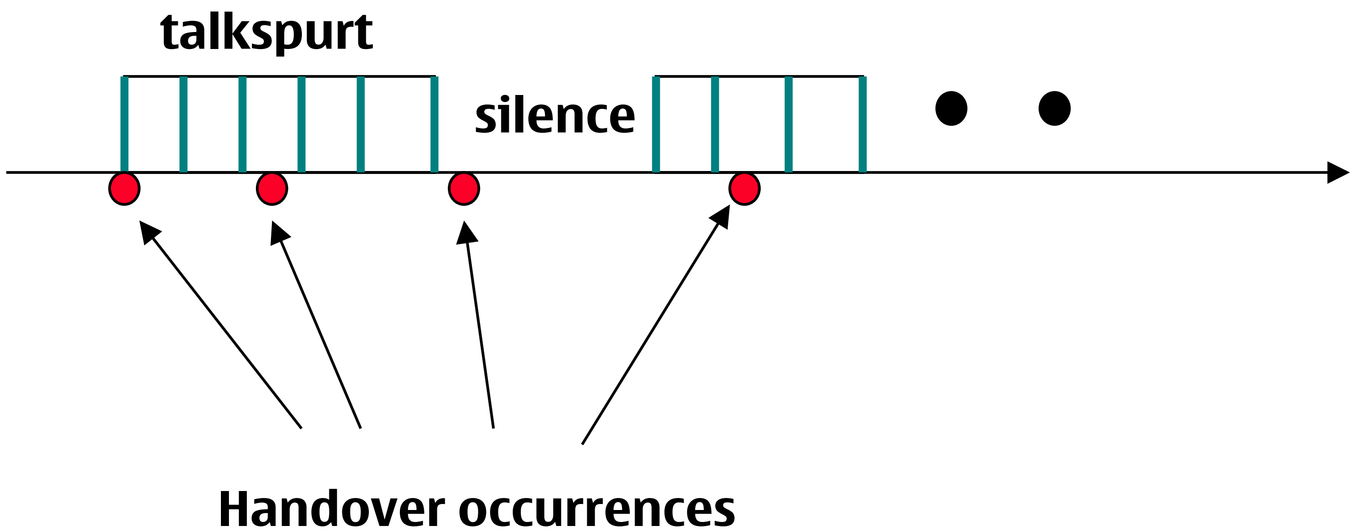


Prob = 0.06
# of packets lost
20
18
16
14
12
10
8
6
4
2
0
1
9
17
25
33
41
49
57
65
73
81
89
97
Nth Handoff
Packets lost
Packets lost due to lack of context


talkspurt
silence
Handover occurrences

Challenges

- Longer the delay in establishing IP connectivity, longer the effect on applications
  - better device driver, firmware greatly improve performance

- Reliability of signaling
  - if the signal from MN is lost, tunnel establishment and context transfer can only occur subsequent to new link establishment
  - even though less desirable, still better than classic Mobile IP handover

- Synchronization of multiple media streams
  - depends on the nature of the media
  - depends on how header compression impacts audio and video

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Overall Summary

- Mobility involves support for roaming and handover from a network to another
- Security is a key parameter in the host-controlled mobility model
- IP layer solution is natural for disparate access network mobility
  - Mobile IP provides the basic ingredients for supporting roaming and handover
  - Fast Handover supports real-time handovers
  - Context Transfer could smooth transport performance

Some open issues

- An (empirical and analytical) analysis of route optimization as a function of traffic pattern, topology, movement characteristics
- Comparison of end-to-end versus access-only solutions for handover performance enhancement
- IP multicast and mobility
- Evaluation of mobility as a “commodity” in IP layer versus a “rich feature” in each transport

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References

- “Fast Handovers for Mobile IPv6”, IETF [mipshop] Working Group
  http://ietf.org/html.charters/mipshop-charter.html
- “Context Transfer Protocol”, IETF [seamoby] Working Group draft
  http://ietf.org/html.charters/seamoby-charter.html
- “A Context Transfer Protocol for Seamless Mobility”, *IETF draft*
  http://people.nokia.net/~rajeev/draft-koodli-seamoby-ct-03.txt
- “Fast Handovers and Context Transfers”, Rajeev Koodli and Charles E. Perkins, *ACM Computer Communication Review*, October 2001
  http://www.acm.org/sigcomm/ccr/archive/2001/oct01/ccr-200109-koodli.html
- IPv6 Working Group in IETF, http://ietf.org/html.charters/ipv6-charter.html, RFCs 2460, 2461, 2463

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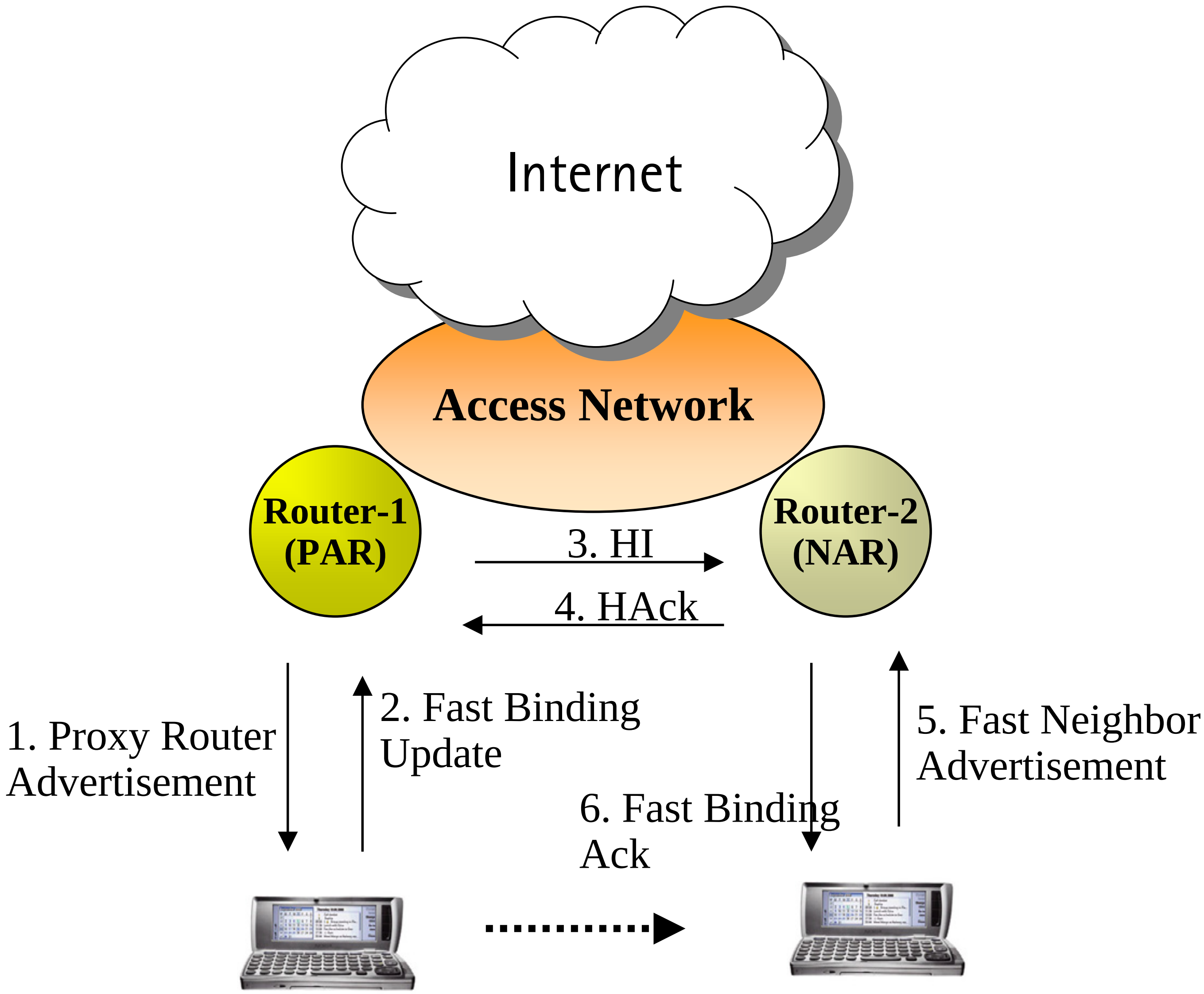
Fast Handovers: Predictive Mode



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Fast Handovers: Reactive Mode