Host and Network Mobility

Concepts, solutions and open issues

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Objectives

- Understand the motivations, needs and issues relating to host and network mobility in IP environments
- Provide an overview on Mobile IP (v4 and v6)
- Present the network mobility basic support solution (NEMO)
- Present and discuss possible solutions for NEMO route optimisation
- Identify and discuss open issues and challenges concerning mobility

Summary

- Introduction
  - Motivation
  - Enabling technologies
  - Problem statement
  - Mobility scenarios
  - Types of mobility
  - Mobility requirements
- Host mobility
  - Mobile IPv4
    - Terminology
    - Mobile IP model
    - Encapsulation
    - Dogleg routing
    - Mobile IPv4 requirements
    - Agent discovery
    - Registration

Summary (contd.)

- Mobile IPv6
  - IPv6 useful features
  - Differences in relation to MIPv4
  - Model
  - Messages
  - Home Agent discovery
  - Home Agent registration
  - Data transfer
  - Node movement
  - Route optimisation
  - Threats
- Network mobility
  - Terminology
  - NEMO basic support protocol
  - Nested NEMO
  - Network mobility concerns
  - Route optimisation issues
  - …

Summary (contd.)

- …
- Existing approaches to NEMO RO
  - Optimised Route Cache
  - Path Control Header
  - Prefix Delegation
  - Global HA to HA
  - MIRON – Mobile IPv6 Route Optimisation
- OMEN – A proposal for NEMO RO
  - Motivation
  - Overview
  - CoA discovery
  - Support for different types of MNN
  - Nested NEMOs
  - Comparison with other approaches
- Conclusion

Introduction

Motivation
Enabling technologies
Problem statement
Mobility scenarios
Types of mobility
Mobility requirements

Motivation

- Portable equipment
  - Laptop computers
  - Mobile phones
  - PDAs
  - Handheld packet radios
- Internet connectivity anytime, anywhere
  - Always connected environment
  - Pervasive computing
  - Seamless mobility

Motivation (contd.)

- Networks
  - Wireless sensor networks
  - Access networks in vehicles (bus, aircraft, taxi)
  - PANs (Personal Area Networks): emergency units, army, everyone
- Usage
  - Health-care (elderly or disabled people)
  - Transport (fleet management, navigation)
  - Emergency units (Army, Police, Fire crew)
  - Education, Journalism, Tourism

Enabling technologies

- Transmission technologies
  - Infrared
  - RF
    - FHSS
    - DSSS
    - OFDM
- Wireless LANs
  - IEEE 802.11
  - HIPERLAN
  - Other
- Cellular networks
  - GSM
  - GPRS
  - 3G networks
- WiMAX

Mobility – problem statement

- The problem
  - Change of point of attachment ⇔ change of IP subnet
  - Change of IP subnet ⇔ change of prefix and routing directive
  - Changing IP address breaks connection
  - Retaining IP address breaks routing
- Mobility support
  - Retain IP address for ongoing sessions
  - Obtain topologically correct IP address for routing
  - Use both IP addresses to communicate with others
  - Maintain ongoing sessions

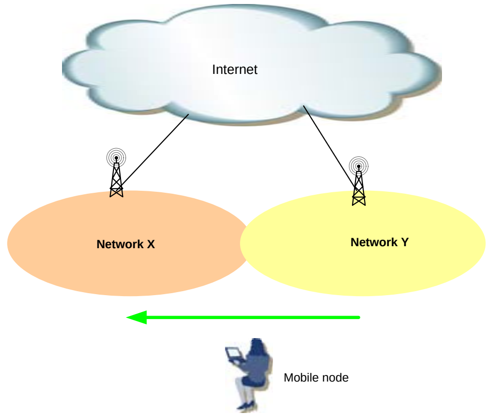
Mobility scenarios (1)

- Portable computers (laptops)
  - Connection to one of several networks, according to the user current location
  - Several possible types of connection
    - Wired LAN
    - Wireless LAN
    - Remote connection (through an access network)
  - Dynamic configuration
    - DHCP
  - Each time the user connects, he/she is assigned a different IP address
  - When the user moves from one point of attachment to another the connection is lost

Mobility scenarios (2)

- Mobile computing
  - The connection of the mobile device (laptop, PDA, phone, other) to the Internet remains active while the device moves from one network to the other (roaming)
  - The mobile node keeps the same IP address, independently of its location
    - This is required in order not to disrupt existing TCP connections
  - Typically, the network is organised into cells
    - Each cell has a base station connected to a backbone network
    - The backbone network provides access to the Internet
    - Mobile nodes identy the strongest base station through its beacon signal

Mobility scenarios (2a)



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Mobility scenarios (3)

- Network mobility
  - The whole network moves
    - The network is on a vehicle (e.g., car, train, boat, plane)
  - The nodes may be
    - Fixed relative to the mobile network
    - Move inside the network
  - Mobile networks may contain other mobile networks
    - Recursive mobility
  - Network mobility requires special care in route updates

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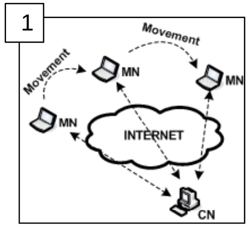
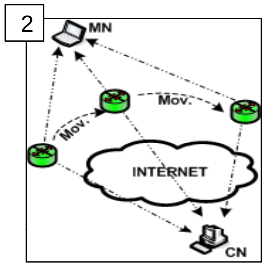
Mobility scenarios - overview

- Host mobility
  - Mobility for nodes
  - IPv4 and/or IPv6



- Network mobility
  - Mobility for networks
  - IPv4 and/or IPv6



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Types of mobility (1)

- Macro mobility
  - The mobile node (MN) traverses different mobility domains
  - This type of mobility is normally handled at the IP layer
  - Macro-mobility mechanisms
    - Must deal with the fact that although the MN is in a different IP domain, it must be reachable through its original IP address
    - Typically require tunneling
    - May not respond well in case of rapid and frequent handoffs
    - Normally lead to some loss of data during handoff

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Types of mobility (2)

- Micro mobility
  - The MN moves inside the same mobility domain
  - This type of mobility is normally handled below the IP layer
  - Micro-mobility mechanisms are optimised for rapid and frequent handoffs
  - Few or no data losses during handoff

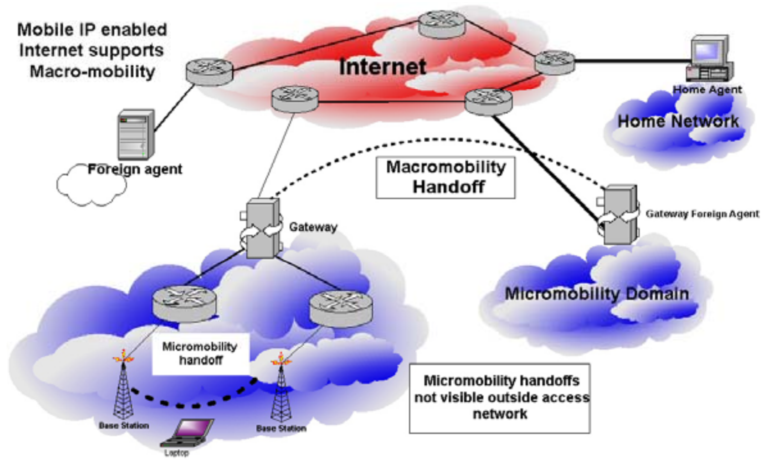
Types of mobility (3)

- Mobile IP requires that nodes report every movement
  - Signalling traffic
  - Latency
  - Data losses
- If the mobile node moves inside the same mobility domain (i.e., micro-mobility)
  - The path from the home network to the foreign network will largely coincide
  - The HA does not need to be aware of this micro-mobility
  - This leads to
    - Reduced signalling
    - Low latency
    - Few or no losses

Types of mobility (3a)

- Micro-mobility protocols do not intend to replace Mobile IP
  - They intend to complement it
- Frequent handoffs
- More efficient than macro-mobility
- Various solutions
  - Cellular IP
  - HAWAII
  - Hierarchical Mobile IP

Types of mobility - overview



Mobility requirements

- Mobile nodes must remain connected while they move from network to network
- Mobile nodes must keep their IP address
- Mobile nodes must be able to interact with existing hosts and routers, as any other node
- Mobile nodes must be able to access the same services as fixed nodes

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Mobility requirements (contd.)

- The security level of mobile nodes must be the same as the security level of fixed nodes
- Mobile nodes must be able to use multicast
- Privacy must be guaranteed
  - There must be a way to prevent the geographical location of mobile nodes

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Host mobility

Mobile IPv4
Terminology, Model, Encapsulation, Dogleg routing, Mobile IPv4 requirements, Agent discovery, Registration

Mobile IPv6
IPv6 useful features, Differences in relation to MIPv4, Model, Messages, Home Agent discovery and registration, Data transfer, Node movement, Route optimisation, Threats

Mobile IPv4

- Developed by the IETF to support user/host mobility
- Enhances the existing IP protocol to accommodate mobility
- Developed for the support of macro-mobility
- Defined in RFC 3344
- Leaves transport and higher protocols unaffected

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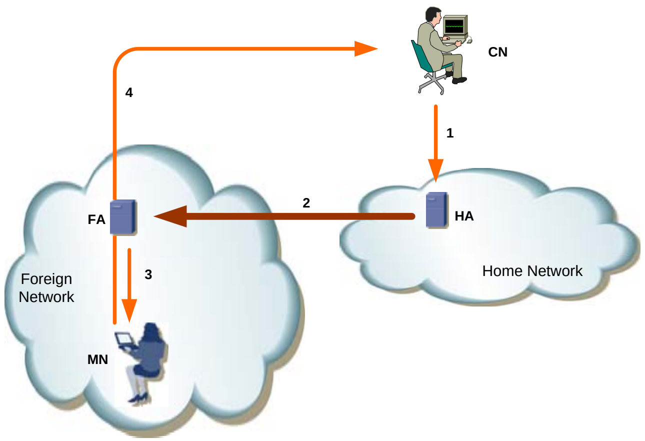
Terminology

- Home address (HoA)
  - unicast IP address assigned to a mobile node and used as a permanent IP address even when moving
- Mobile node (MN)
  - a node that can change its point of attachment from one link to another, while still being reachable via its home address
- Correspondent node (CN)
  - a peer node with which a mobile node is communicating
  - may be either mobile or stationary
- Care-of address (CoA)
  - unicast routable address associated with a mobile node while visiting a foreign link
- Home agent (HA)
  - a router on a mobile node's home link with which the mobile node has registered its current care-of address

Model

- Mobile node
  - Obtains a COA from a Foreign Agent when it moves to a foreign network
  - Registers the COA with its Home Agent
- Home Agent
  - Receives datagrams sent to the mobile node
  - Encapsulates the received datagrams and send them to the COA address (tunneling)
- Foreign Agent
  - Decapsulates the datagrams and hands them to the mobile node
- Packets sent from the MN to the CN (may) use the normal IP routing mechanism

Mobile IPv4 model (contd.)



Encapsulation (1)

- RFC 1701 – Generic Routing Encapsulation (GRE)

New IP packet

New IP header	GRE header	Original IP packet	
Source=HA, Dest=COA, Protocol=GRE (47)	Encapsulation parameters	Source=CN, Dest=MN, Protocol= TCP	TCP header + data

GRE header

Protocol type
16-bit checksum (opt)
32-bit seq no. (opt)
32-bit auth. Key (opt)
Source routing (opt)
Flags

Encapsulation (2)

- RFC 2003 – Basic encapsulation (IP within IP)

New IP packet

Source=HA, Dest=COA, Protocol= IP in IP (4)	Source=CN, Dest=MN, Protocol= TCP	TCP header + data

New IP header | Original IP packet

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Encapsulation (3)

- RFC 2004 – Minimal encapsulation

New IP packet

Source=HA, Dest=COA, Protocol= Min.Encaps. (55)	Compressed header	TCP header + data

New IP header | Original IP packet

Compressed header

Protocol type
Destination address
Source address, if diferent
16-bit checksum

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Dogleg routing

- Mobile IP can lead to considerable routing inefficiency
  - Datagrams to the MN always go through its HA, irrespectively of the location of the CN
- Example: the CN is on the network visited by the MN
  - Although the CN and MN are on the same network, the traffic from the CN to the MN has to be sent to the home network
  - Traffic from the MN to the CN follows the normal path
- This phenomenon is called 'dogleg routing'

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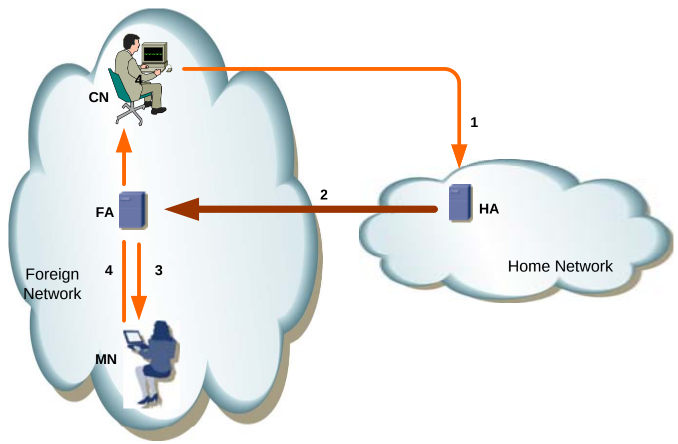
Dogleg routing (contd.)



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Mobile IPv4 requirements

- The HA must be able to announce that it is the router that gives access to the MN
  - The HA plays the role of proxy regarding the MN, or
  - The HA works as the access router to a virtual network which contains the MN
- The HA has to maintain information regarding the current location of the MN
  - The FA informs the HA, or
  - The MN informs the HA

Mobile IP requirements (contd.)

- The MN has to discover the FA of a visited network
  - The FA advertises its existence, or
  - The MN solicits a FA
- The MN must register with its HA
  - Registration via the FA, or
  - Direct registration of the MN with the HA
  - Simultaneous registration with multiple COAs is possible

Agent discovery

- Mobile Agents (HA and FA) advertise their existence using modified ICMP ‘router advertisement’ messages.
- The advertisements contain
  - Sequence number (256:65635)
    - If <256, this indicates an agent reboot
  - List of at least one COA
  - Flags
    - Ability to behave as HA and/or FA
    - Busy / Not busy
    - Type of encapsulation (minimal, IP within IP, GRE)

Agent discovery (contd.)

- If an MN starts receiving advertisements from a new agent it concludes that it has changed network
  - The MN should initiate the registration procedure with the new FA
- If an MN receives advertisements from its HA it concludes that it is back on its home network
  - The MN should cancel its registration with the HA, in order to resume normal IP routing

Agent discovery (contd.)

- If the advertisement sequence number is less than 256 this means that the agent has rebooted
  - All mobile nodes should re-register
- Mobile nodes may also send ‘agent solicitations’ to obtain an answer from agents
  - This speeds up the process of agent discovery, as MNs do not need to wait for agent advertisements

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Registration

- Whenever an MN detects that it has changed network, it must register its COA with its HA
  - This allows the HA to forward all datagrams destined to the MN to its current location
- If a foreign agent is being used, the registration is performed with the intervention of this FA
  - Typically, the COA is that of the FA
- If the MN can perform the functions of an FA, then it can register directly with its HA
  - The COA and source IP address of the request will be the same

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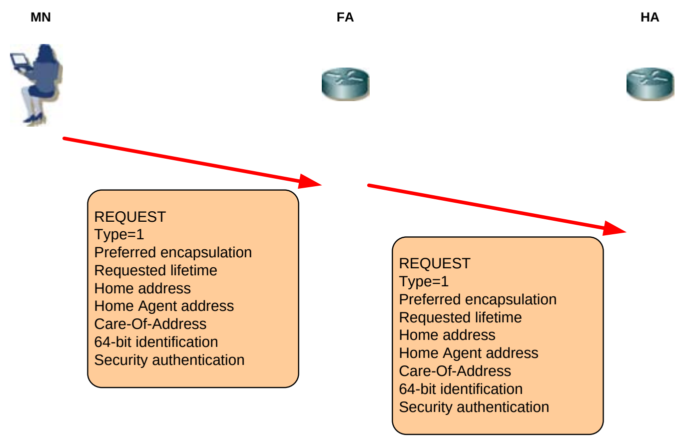
Registration request



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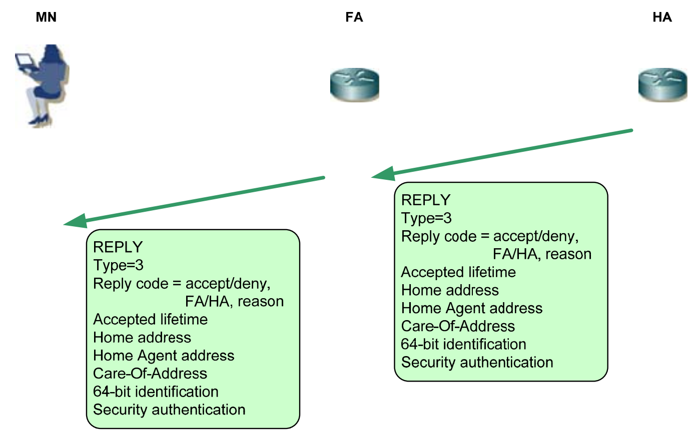
Registration response



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Registration authentication

- Mobile authentication is crucial in Mobile IP
  - Mobile IP changes the route of packets
  - Without authentication, malicious hosts could divert all traffic destined to a given MN by simply registering a fake COA
- Authentication extensions defined in Mobile IP
  - Mobile-Home authentication extension
  - Mobile-Foreign authentication extension
  - Foreign-Home authentication extension
- All registration messages (requests and replies) must contain exactly one authentication extension

Mobile IPv6

- Follows the basic design of Mobile IPv4
  - Mobile nodes reachable via their home network
  - HA sends packets to the MN's COA
  - HA encapsulates the packets sent to the MN
- IPv6 leads to considerable optimisation
  - Auto-configuration
  - Neighbour discovery
  - Route optimisation
  - Security

IPv6 useful features

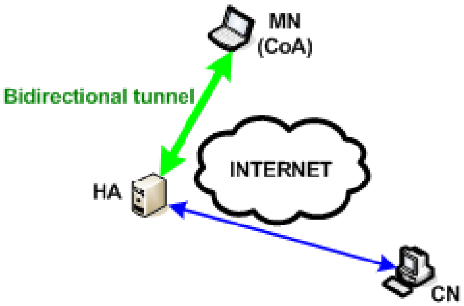
- Address Autoconfiguration
  - Stateless auto-configuratoin
    - Network Prefix + MAC address
  - Stateful auto-configuration
    - DHCPv6
- Neighbor Discovery
  - Discover each other's presence and find routers
  - Determine each other's link-layer addresses
  - Maintain reachability information
- Extension Headers
  - Routing header
    - For route optimisation
  - Destination Options header
    - For MN-originated datagrams

MIPv6 ≠ MIPv4

- No need for separate Foreign Agents
  - MNs perform the functions of FA
    - CoA (determined by the MN using auto-configuration)
    - IPv6 Decapsulation
    - Neighbor Discovery
- Packets delivery
  - MNs use CoA as source address in foreign links
    - No ingress filtering problem
  - CN uses IPv6 routing header rather than IP encapsulation
    - Natural "Route Optimisation"

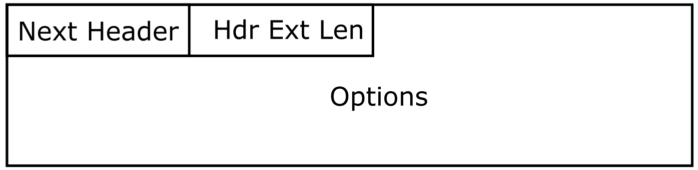
MIPv6 model

- Communication between Correspondent Node (CN) and Mobile Node (MN) traverses the Home Agent (HA)
- A bidirectional tunnel between HA and MN is used



MIPv6 messages

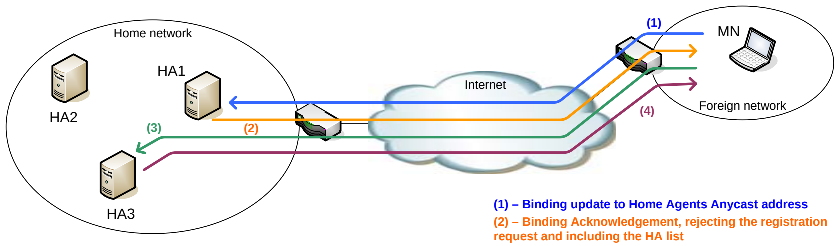
- All new messages used in MIPv6 are defined as IPv6 Destination Options
  - IPv6 Destination Options are used to carry additional information that needs to be examined only at the destination node



MIPv6 messages (contd.)

- Binding Update (BU)
  - Used by an MN to inform its HA or any CN about its current care-of address
- Binding Acknowledgement (BA)
  - Used to acknowledge the receipt of a Binding Update
- Binding Request (BR)
  - Used by any node to request an MN to send a Binding Update with the current CoA
- Home Address
  - Used in a packet sent by a mobile node to inform the receiver about the mobile node's home address

MIPv6 Home Agent discovery



(1) – Binding update to Home Agents Anycast address
(2) – Binding Acknowledgement, rejecting the registration request and including the HA list
(3) – Binding update to specific HA (HA3, in this case)
(4) – Binding acknowledgement, registration OK

MIPv6 Home Agent registration

- An MN performs address auto-configuration (stateful or stateless) to get its care-of address
- The MN registers its care-of address with its home agent on the home link
- Use “Binding Update” Destination Option
- The HA uses proxy Neighbour Discovery and also replies to Neighbour Solicitations on behalf of the MN

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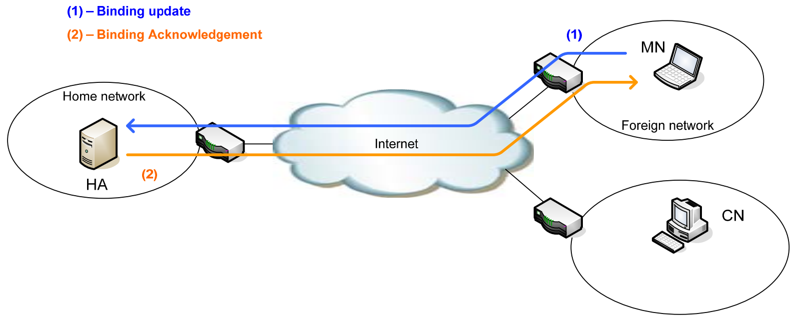
MIPv6 Home Agent registration



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MIPv6 data transfer

- Communication between CN and MN
  - A packet from CN to MN will be intercepted by the HA at the home link
  - The HA will encapsulate it in a bidirectional tunnel destined to the CoA of the MN
  - When the MN receives the packet, it decapsulates it and forwards it to the next IP layer with the original HoA
  - The response will necessarily be encapsulated to the HA, which in turn decapsulates it and forwards it to the CN

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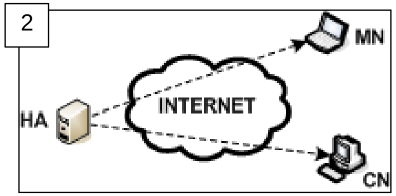
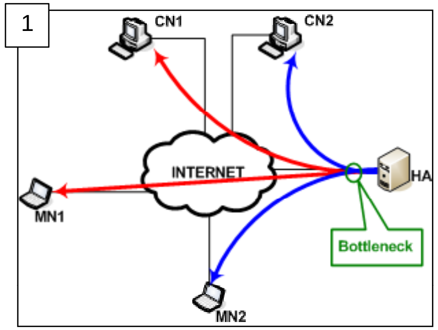
MIPv6 data transfer (contd)

- Problem
  - Every packet needs to traverse the home link and be encapsulated to the MN
    - 1) Bottleneck at home link
    - 2) Triangular routing
    - Decreased MTU





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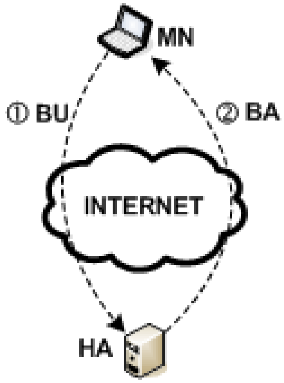
MIPv6 node movement

- Every time a node moves, it must send a Binding update (BU) to the HA with the new CoA
- The HA must answer with a Binding Acknowledge (BA) if everything is correct, and with a Binding Error (BE) if anything wrong happens



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MIPv6 node movement (contd)

- Some Binding Acknowledge message codes
  - 0 – Binding update accepted
  - 129 – Administratively prohibited
  - 131 – Home registration not supported
  - 134 – Duplicate Address detection failed
- Some Binding Error message codes
  - 1 – unknown binding for home address destination option
  - 2 – unrecognized MH (Mobile Header) type value

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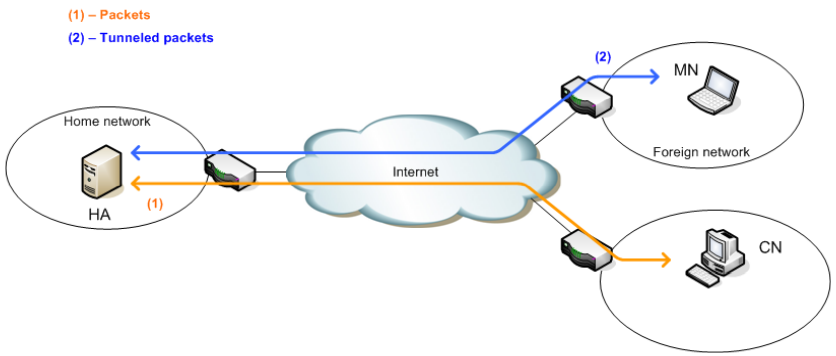
MIPv6 route optimisation

- Triangular routing



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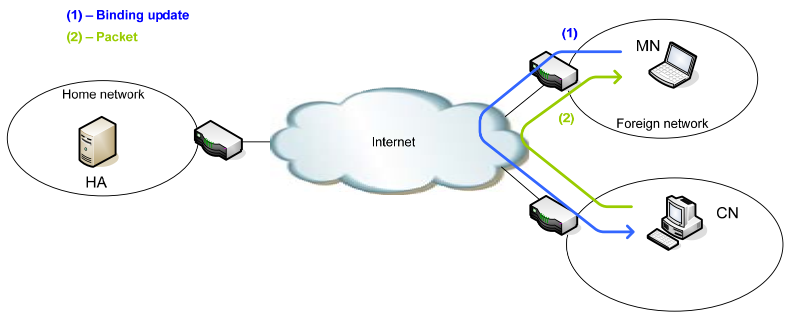
MIPv6 route optimisation (contd)



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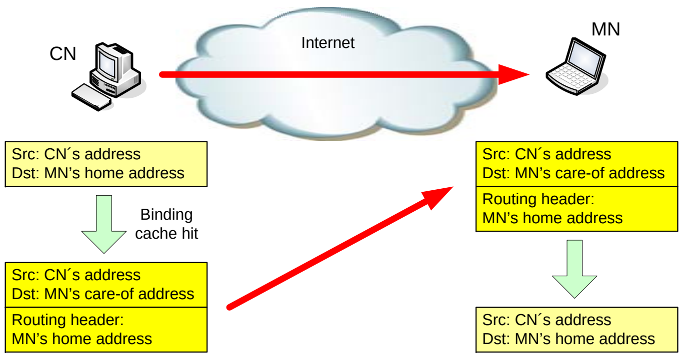
MIPv6 route optimisation (cont.)

- CN → MN packet delivery



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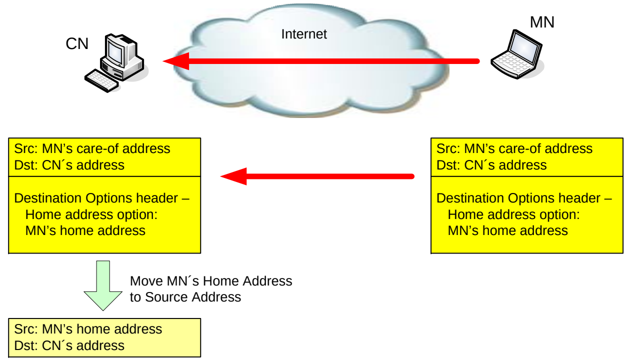
MIPv6 route optimisation (cont.)

- MN → CN packet delivery



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MIPv6 route optimisation (contd)

- Pros
  - Communication is made via the shortest path
- Cons
  - MNs and CNs must support this feature
- With RO, every time the MN moves it must
  - Contact the Home Agent to update the CoA
  - Contact all its CNs to update the CoA
    - HOW WILL IT PROVE ITS REAL IDENTITY ?

→ Return Routability

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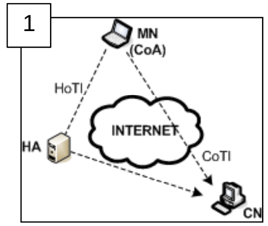
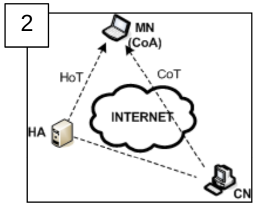
MIPv6 route optimisation (contd)

- Return Routability (RR)

1. The MN must send two packets to the CN
   - Home Test Init (HoTI) through the HA
   - Care-of Test Init (CoTI) directly to the CN



2. When the CN receives both HoTI and CoTI, it must answer with two other packets
   - Home Test (HoT) to the HoA
   - Care-of Test (CoT) to the CoA



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MIPv6: Threats

- Address stealing
  - Basic address stealing
    - If the BU is not authenticated, anyone can fabricate and spoof Binding Updates
  - Attacks against Confidentiality and Integrity
    - Man-in-the-middle attack
  - Basic Denial of Service Attacks
    - By sending spoofed binding updates, the attacker can redirect all packets sent between two IP nodes to a random or nonexistent address
    -
  - Replaying and Blocking Binding Updates
    - An attacker may be able to replay recently authenticated binding updates to the correspondent and, consequently, direct packets to the mobile node's previous location.

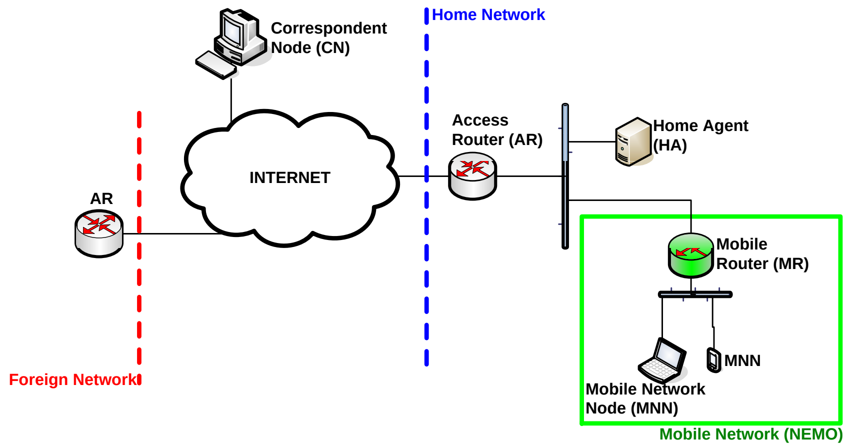
MIPv6: Threats (Contd)

- Attacks against others nodes and networks
  - By sending spoofed binding updates, an attacker could redirect traffic to an arbitrary IP address.
- Attacks against Binding Update protocols
  - Security protocols that successfully provide confidentiality and integrity can create vulnerability to denial-of-service attacks
  - The stronger the authentication, the easier it may be for an attacker to use the protocol features to exhaust the mobile's or the correspondent's resources.

Network Mobility

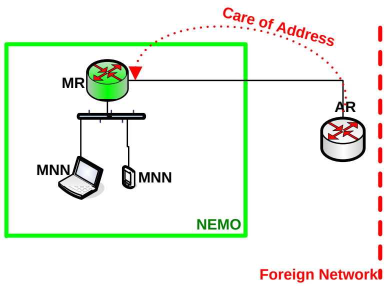
Terminology
NEMO basic support protocol
Nested NEMO
Network mobility concerns
Route Optimisation issues
Existing approaches to NEMO RO
OMEN – A proposal for NEMO RO

Terminology



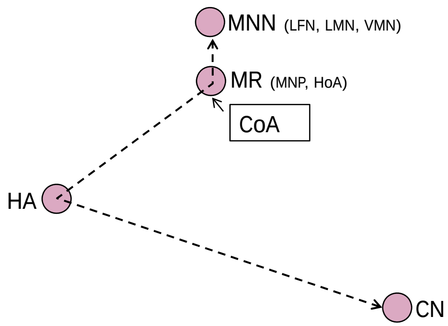
Terminology (contd)

- Home Address (HoA)
- Care-of Address (CoA)
- Mobile Network Prefix (MNP)
- Mobile Network Node types:
  - Local Fixed Node (LFN)
  - Local Mobile Node (LMN)
  - Visiting Mobile Node (VMN)
- MRHA tunnel



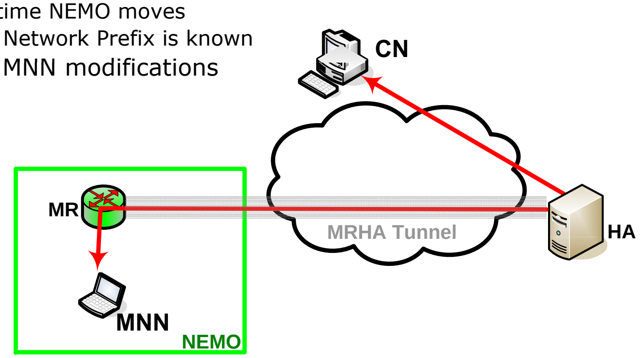
Terminology (contd)

- Simplifying …



NEMO basic support protocol

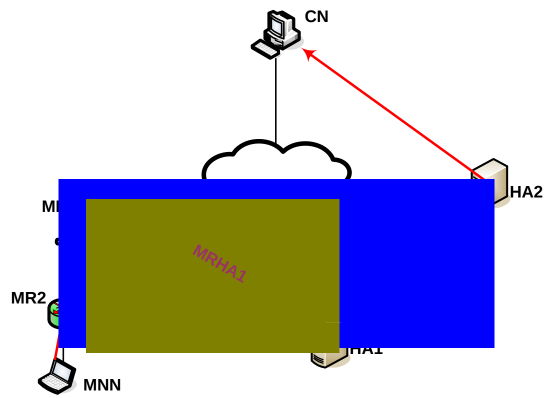
- Defined in RFC 3963
- MNN ⇔ CN communications through MRHA tunnel
- HA knows MR's CoA
  - Through Binding Update process
  - Every time NEMO moves
  - Mobile Network Prefix is known
- No CN or MNN modifications



Nested NEMO

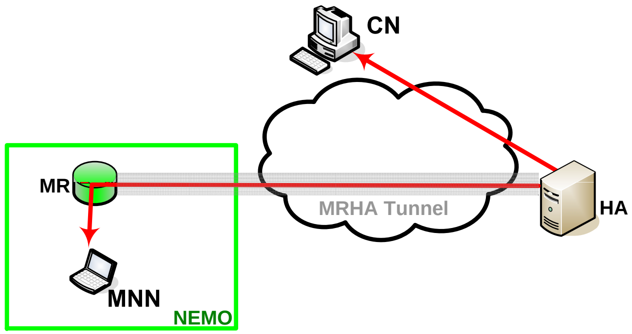
- Root-NEMO
- Parent-NEMO
- Sub-NEMO

- Root-MR (MR1)
- Parent-MR (MR1)
- Sub-MR (MR2)



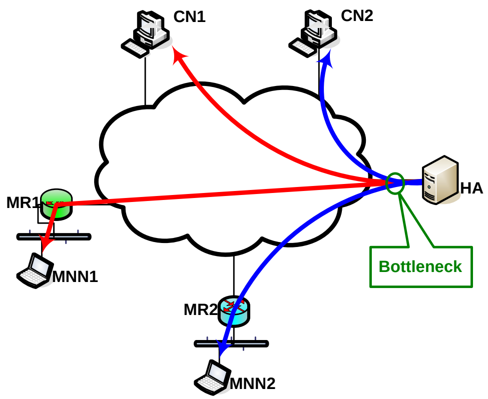
Network mobility concerns

- Sub-optimality – pinball route, triangular route



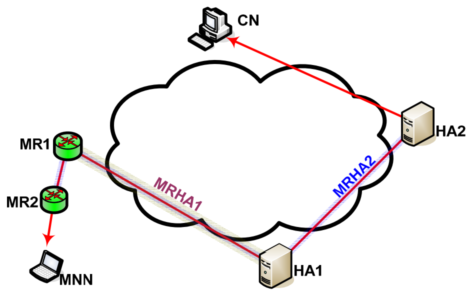
Network mobility concerns (contd)

- Bottleneck in Home Network

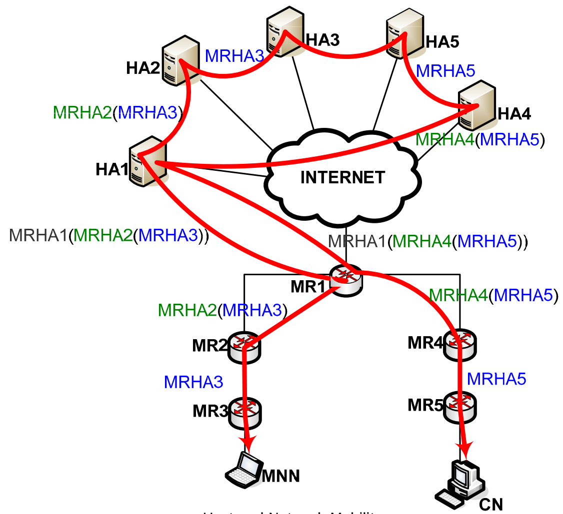


Network mobility concerns (contd)

- Amplified sub-optimality in nested Mobile Networks



Network mobility concerns (contd)



Route Optimisation issues

- (Amplified) Sub-optimality and Home Network bottlenecks clearly point to the need for route optimisation (NEMO RO)
- NEMO RO is possible, but several issues may arise
  - Additional signaling overhead
  - Extending nodes with new functionalities
  - Increased protocol complexity
  - Processing load
  - Increased delay during handoff
  - Scalability
  - Mobility transparency
  - Location privacy
  - Security considerations
  - Support of legacy nodes

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Existing approaches to NEMO RO

- ORC – Optimised Route Cache
- PCH – Path Control Header
- Prefix Delegation
- HAHA – Global HA to HA
- MIRON – Mobile IPv6 Route Optimisation

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ORC – Optimised Route Cache

- Routers on the Internet
  - Create RO tunnels with Mobile Router (MR)
  - On behalf of Correspondent Node
  - Strategically located
- MR sends Binding Router packet to the anycast address of all ORC routers.

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PCH – Path Control Header

- The Mobile Router sends a special packet, PCH, destined to Correspondent Node (CN)
  - Intercepted by a router along the path
  - The router will establish a RO tunnel with MR on behalf of CN

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Prefix Delegation

- When the MR moves and gets a new prefix
  - It sends out a Router Advertisement (RA) with the new prefix
  - Each mobile node defines its Care-of-Address from delegated prefix
  - The Mobile Nodes establish RO with CN directly
- Lighter MR

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Global HA to HA

- Several Home Agents (HA) located in the Internet
  - Will interoperate with each other
  - Minimize distance between NEMO and CN
  - Ideal within large geographically area

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MIRON – Mobile IPv6 RO

- Addresses the NEMO Basic Support problems
  - Route Optimization mechanisms
  - The mechanisms depend on the type of MNN
- For Local Fixed Nodes, the MR
  - acts as a Route Optimization proxy
  - manages selected connections between MNN and CN
  - must
    - Decide which flows to optimize
    - Keep track of LFN-CN optimizations
    - Perform RO using the RR mechanism on behalf of LFN

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MIRON – Mobile IPv6 RO (contd)

- Visiting Mobile Node (VMN)
  - The MR advertises new prefix (within Foreign Network) to VMN
    - Topologically meaningful addresses
  - Renewal through PANA request
  - The MR must
    - Route packets to these nodes
    - Enable these addresses to be routable inside the NEMO
    - Perform source address routing for outgoing sending
    - Request new topologically IP addresses every time it moves
- Nested networks are treated as VMN.
  - Additionally, every MR must keep track of addresses of all nodes requesting IPv6 addresses

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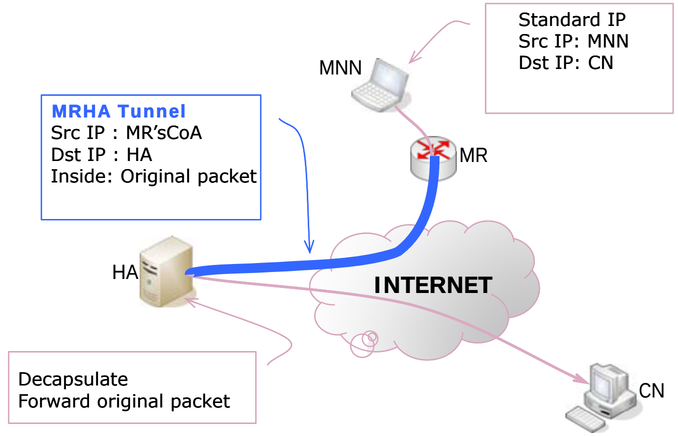
OMEN – A proposal for NEMO RO

- Motivation
  - Current NEMO RO proposals put complexity inside the network
    - Assume that nodes must not be aware of their mobility
    - Assume that no changes in the hosts are allowed
    - Consequences:
      - Complexity of the proposals
      - Changes to existing protocols
  - A paradigm shift is necessary
    - No mobility needs on the past
    - Evolve from 1970's Internet
  - Modern nodes must
    - Be aware of their mobility
    - React accordingly
  - Internet and protocols must be
    - Simple
    - Kept unchanged, as far as possible

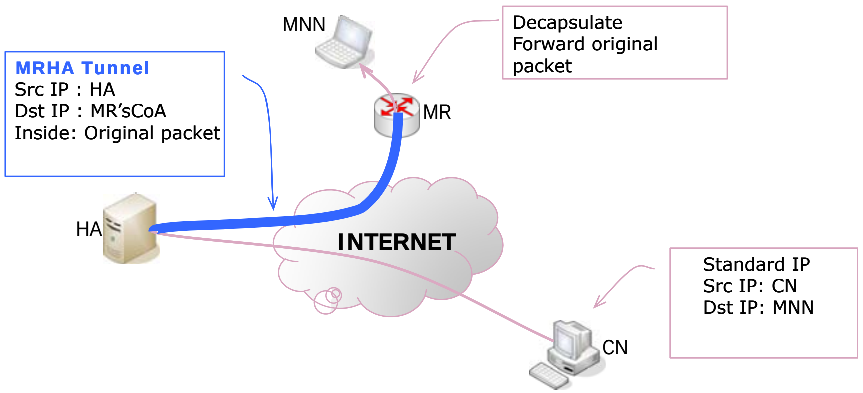
Recall NEMO Basic Support

- MNN→CN communication



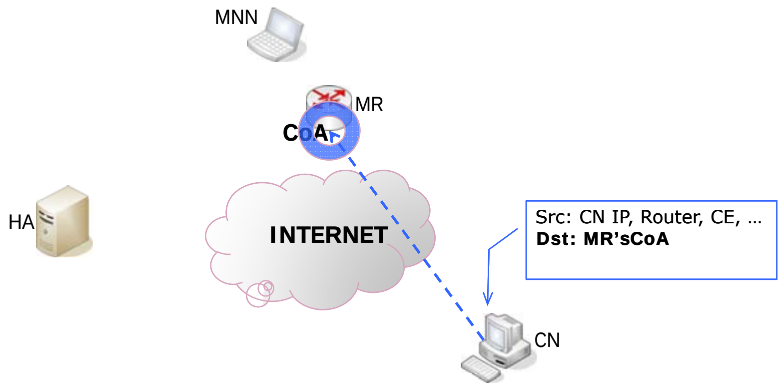
Recall NEMO Basic Support (contd)

- CN→MNN communication



Recall RO proposals

- What do they have in common?



OMEN overview

- MNNs use their MR's CoA as their own Care-of-Address
- Any node intending to optimize the route to a CN should use its MR's CoA.
- When the MR receives an optimized packet to its CoA it should
  - Check if next hop corresponds to its MNP
  - Check if next hop is registered in its routing table
  - Route packet accordingly
- The RR procedure can be carried out without problem
  - The CN→CoA and CN→HoA routes are still available
- MNNs decide when to optimize routes and can perform that optimization by themselves
  - MRs are not burdened with this task.

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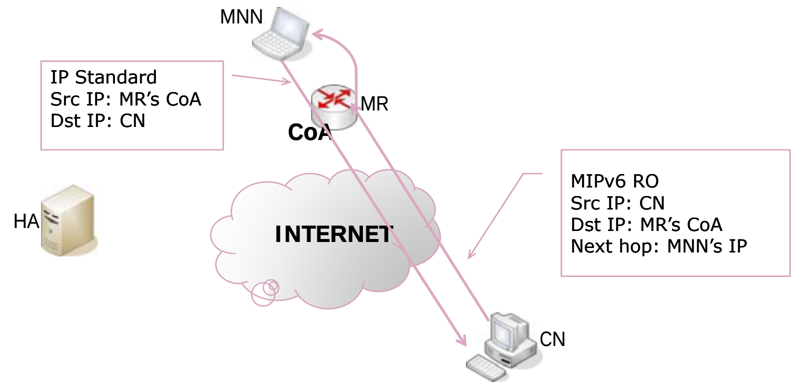
OMEN overview (contd)

- MNN MIPv6 RO is performed using the MR's CoA
- The MR forwards packets to the next hop indicated in the MIPv6 header



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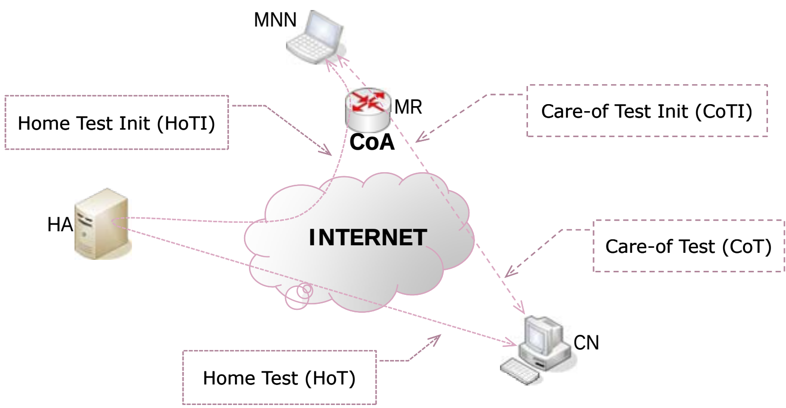
OMEN overview (contd)

- The Return Routability procedure can be carried out normally



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How do MNNs discover the CoA?

- Neighbor Discovery (RFC4861) provides the tool
  - Router advertisements carry the CoA
  - MRs can provide the CoA in response to a router solicitation or by their own initiative
- RFC4861 already allows the creation of options field
  - No need to change the protocol
  - If the MNN cannot understand this new field, it can simply ignore it

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Different types of MNNs

- OMEN uses different approaches depending on the type of MNN
- Local Fixed Nodes (LFN)
  - Legacy devices aren't supported in OMEN
    - They can simply use the NEMO Basic Support protocol
  - MIPv6-enabled LFNs can initiate and use RO in the same way as LMNs
- Local Mobile Nodes (LMN)
  - Use the MR's CoA as their own
  - Use standard MIPv6 procedures, with the new CoA
- Local Visiting Nodes (LVM)
  - Must register with the MR
  - Use the MR's CoA
  - Use standard MIPv6 procedures, with the new CoA

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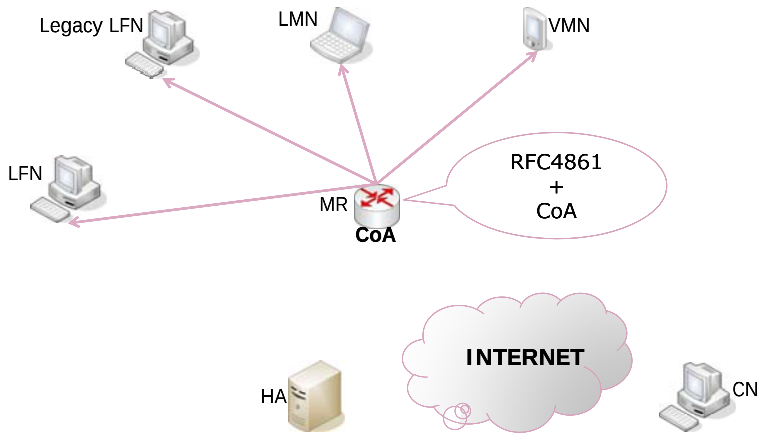
Neighbor Discovery



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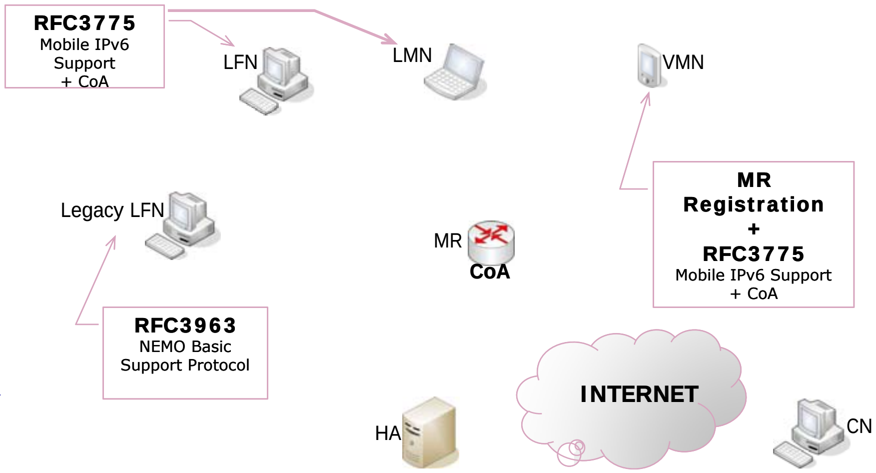
Neighbor Discovery (contd.)



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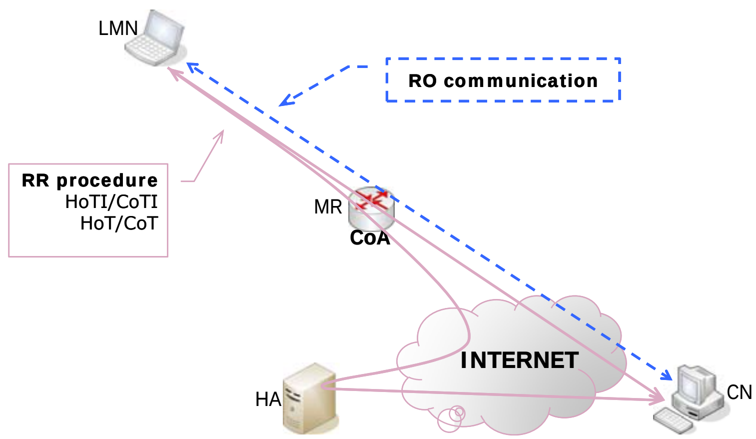
Local Mobile Node (LMN)



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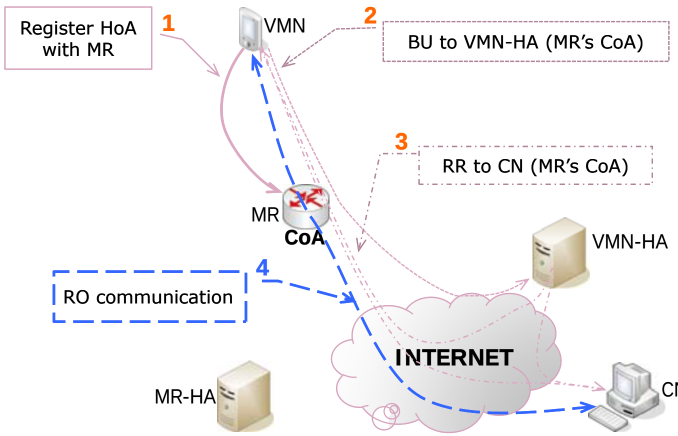
Visiting Mobile Node (VMN)



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Nested NEMO

- Nested NEMOs behave in the same way as VMN
- A sub-MR should register with its parent-root
  - The HoA of the MR's outer interface
  - The sub-MNP
  - This information should propagate up until the root-MR
- Every time a node becomes unreachable, this information should be propagated upwards to all MRs until the root-MR

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Comparison with other approaches

- OMEN was compared with
  - NEMO basic support protocol
  - MIRON
- The comparison was performed by simulation
  - A special purpose simulator was developed
- The following performance characteristics were measured for both non-nested and nested scenarios
  - RTT
  - Hand-off

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Simulator

- Simulator developed by the authors
  - Extremely flexible and light
  - Does not provide absolute values, only relative results
  - Suitable for comparison purposes only
- Few simulator definitions
  - A TCP/IP port defines a network or a host
  - The numerical difference between addresses (ports) represents the distance between networks
  - Examples:
    - Host 101 belongs to network 100
    - Host 201 belongs to network 200
    - Host 201 is nearer to host 101 than to host 501

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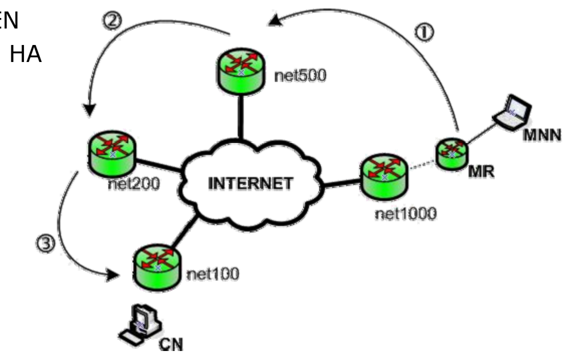
Test scenarios

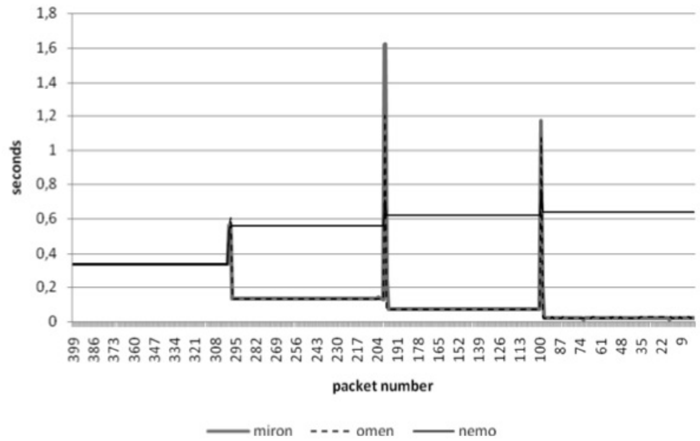
- Two different scenarios were analysed
  - Non-nested scenario
  - Nested scenario
- Each test suite comprised the measurement of the round trip time (RTT) from CN to MNN
  - A total of 240,000 packets / test suite
  - Each test suite was composed of 600 individual test runs
    - Each comprising 400 packets
  - About 4 days to complete each test suite

Non-nested scenario

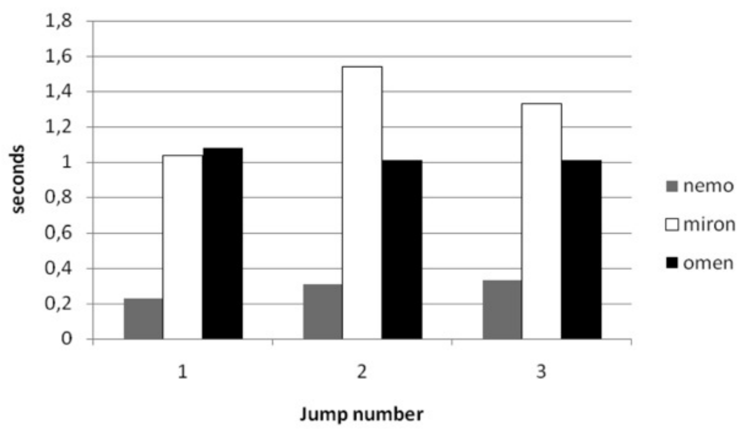
- MR travels from network to network getting closer to CN
  - On the last step (3) it jumps to the CN's network
- ≈ 100 packets sent while the MR is in each network
- Compared NEMO, MIRON and OMEN
- *Net1000* acts as HA



Non-nested results: RTT

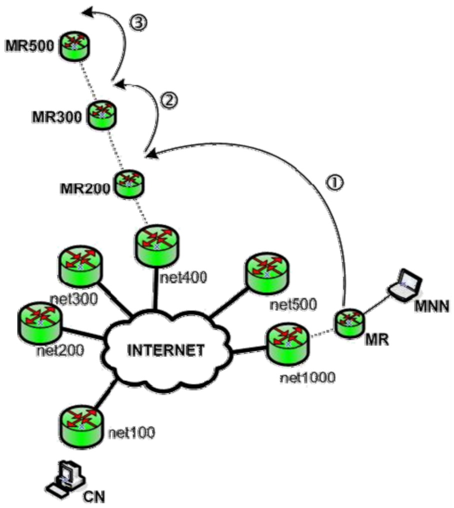


Non-nested results: Hand-off

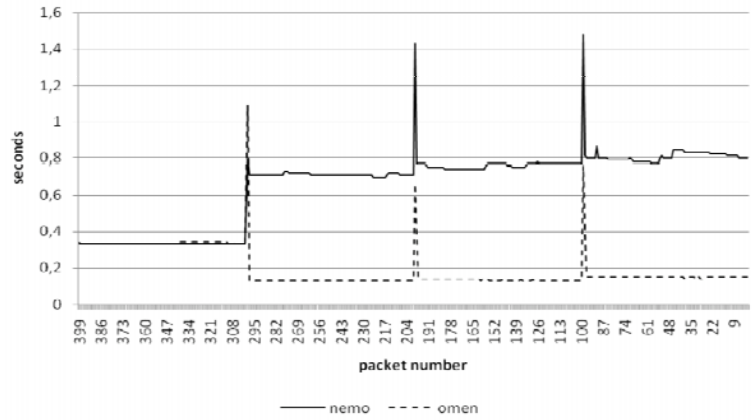


Nested scenario

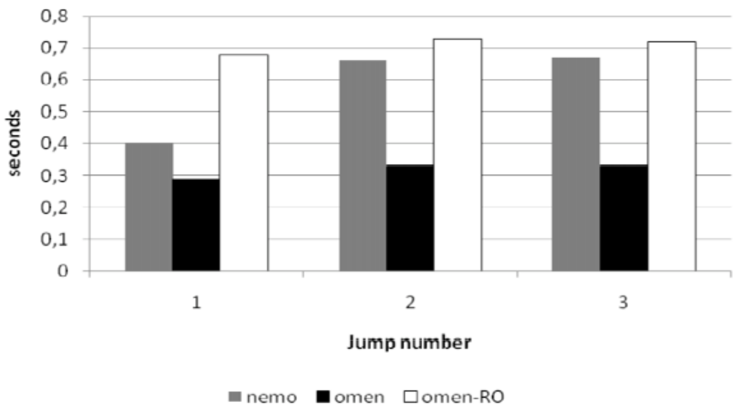
- Compared:
  - NEMO and OMEN
- *Net1000* acts as HA
- MIRON not analysed (future work!)



Nested scenario results: RTT



Nested scenario results: Hand-off



Conclusion

Mobility issues

- Mobility in IP environments is becoming crucial
  - All-IP world
  - Seamless mobility
- Macro-mobility poses several challenges, in terms of
  - Efficiency
  - Latency
  - Losses
  - Security
- In addition to host mobility, network mobility is becoming common
  - Mobility issues become even more challenging

Network Mobility

- Research interest for several years
- Related questions aren't trivial
- Nested networks add additional complexity
- RFC3963 – NEMO Basic Support protocol
  - Complete transparency
  - Lack of requirements on the nodes
  - Simplicity
    - Very basis of its weakness!

Route optimisation

- If nodes and/or networks move, correspondence between addresses and topology is broken
  - Mechanisms to 'repair' the routing function
  - Routing becomes more complex and less efficient
  - Need for Route Optimisation (RO)
- Existing RO proposals are
  - Complex
  - Inneficient
  - Based on the assumption that nodes must not be changed, even at the cost of
    - Changing existing protocols
    - Developing new protocols
    - Putting complexity inside the network as opposed to complexity in the nodes

OMEN

- Mobile Network Nodes are aware of their mobility condition
- OMEN was compared with two other key approaches: NEMO and MIRON
- OMEN benefits
  - Optimised routes are established between MNN and CN
  - MR acts as a mere routing device
  - Route Optimization decisions are taken by MNNs
  - Every time a MR acquires new CoA, nodes can be immediately informed with Neighbor Advertisement
  - VMN and Nested NEMO are greatly benefited
  - Leads to lighter mobile routers
  - Requires no changes to existing protocols
  - Better performance than NEMO Basic Support Protocol
  - Low complexity
  - No required modification to CN or other Internet devices

OMEN – future work

- Prototyping and testing in environment as real as possible
- Detailed consistency and robustness analysis
- OMEN support for MIPv6-enabled Local Fixed Nodes
- Thorough comparison between nested RO solutions and OMEN

Further reading

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- RFC 3963 – Network Mobility (NEMO) Basic Support Protocol, 2005
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Further reading (contd)

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