# IPv6 associated protocols

Piers O'Hanlon

# Contributions

- Main authors
  - Jean-Marc Barozet, Cisco, France
  - Faycal Hadj, Cisco, France
  - Patrick Grossetete, Cisco, France
  - Gunter Van de Velde, Cisco, Belgium
  - Bernard Tuy, Renater, France
  - Laurent Toutain, ENST-Bretagne – IRISA, France
- Contributors
  - Octavio Medina, ENST-Bretagne, France
  - Mohsen Souissi, AFNIC, France
  - Vincent Levigneron, AFNIC, France
  - Thomas Noel, LSIIT, France
  - Alain Durand, Sun Microsystems, USA
  - Alain Baudot, France Telecom R&D, France
  - Bill Manning, ISI, USA
  - David Kessens, Qwest, USA
  - Pierre-Emmanuel Goiffon, Renater, France
  - Jérôme Durand, Renater, France
  - Ben McCarthy, Dr Chris Edwards, Lancaster, UK

# New Protocols

- New features specified in IPv6 Protocol (RFC 2460 DS)
- Neighbor Discovery (ND) (RFC 2461 DS)
- Auto-configuration :
  - Stateless Address Auto-configuration (RFC 2462 DS)
  - DHCPv6: Dynamic Host Configuration Protocol for IPv6
  - Path MTU discovery (pMTU) (RFC 1981 PS)
- Mobility
  - Mobile IPv6
  - Network Mobility - NEMO
- Sensor Networks
  - 6LOWPAN

# New Protocols (2)

- Multicast Listener Discovery (MLD) RFC 2710
  - Multicast group management over an IPv6 link
  - Based on IGMPv2
  - MLDv2 (equivalent to IGMPv3 in IPv4)
- ICMPv6 (RFC 2463 DS) "Super" Protocol that :
  - Covers ICMP (v4) features (Error control, Administration, …)
  - Transports ND messages
  - Transports MLD messages (Queries, Reports, …)

# Neighbor Discovery

- IPv6 nodes which share the same physical medium (link) use Neighbor Discovery (ND) to:
  - discover their mutual presence
  - determine link-layer addresses of their neighbors
  - find routers (see autoconfiguration session)
  - maintain neighbors' reachability information (NUD)
  - not directly applicable to NBMA (Non Broadcast Multi Access) networks ➔ ND uses multicast for certain services.

# Neighbor Discovery (2)

- Protocol features:
  - Router discovery
  - Prefix(es) discovery
  - Parameters discovery (link MTU, Max Hop Limit, ...)
  - Address auto-configuration
  - Link-layer Address resolution
  - Next Hop determination
  - Neighbor Unreachability Detection
  - Duplicate Address Detection
  - Redirect

# Neighbor Discovery (3): Comparison with IPv4

- It is the synthesis of:
  - ARP
  - ICMP Router Discovery Messages RFC1256
  - ICMP redirect
  - ...

# Neighbor Discovery (4)

- ND specifies 5 types of ICMP packets :
  - Router Advertisement (RA) :
    - periodic advertisement (of the availability of a router) which contains:
      - » list of prefixes used on the link (autoconf)
      - » a possible value for Max Hop Limit (TTL of IPv4)
      - » value of MTU
  - Router Solicitation (RS) :
    - the host needs RA immediately (at boot time)

# Neighbor Discovery (5)

– Neighbor Solicitation (NS):
  – to determine the link-layer address of a neighbor
  – or to check its reachability
  – also used to detect duplicate addresses (DAD)
– Neighbor Advertisement (NA):
  – answer to a NS packet
  – to advertise the change of physical address
– Redirect :
  – Used by a router to inform a host of a better route to a given destination

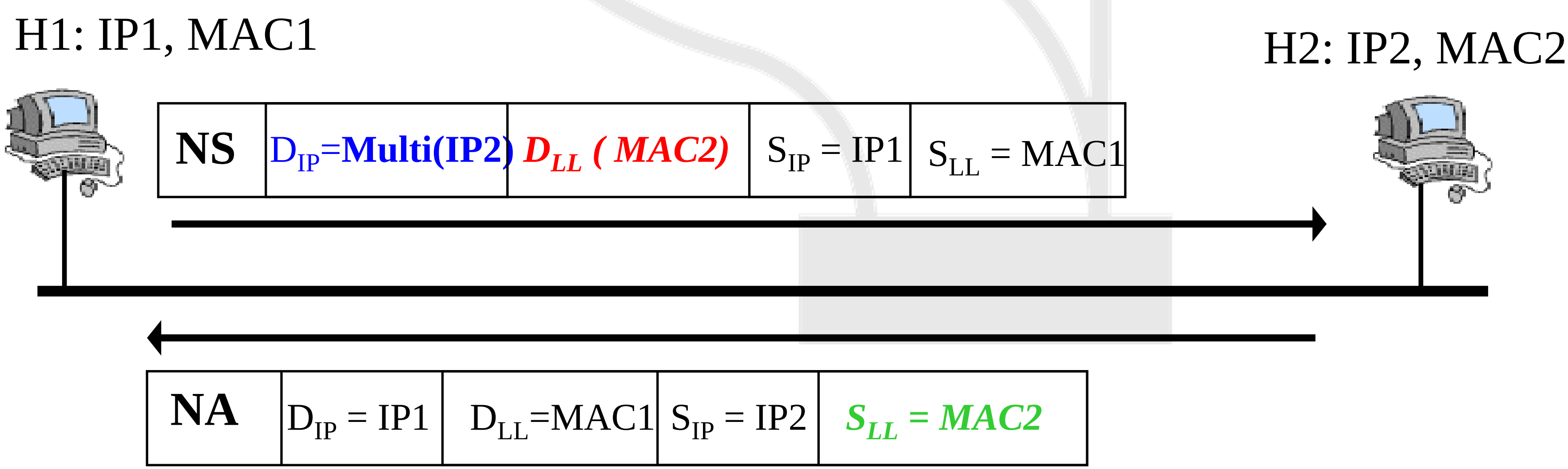
# Link-layer Address Resolution

- Find the mapping:
  - – Dst IP addr ➔ Link-Layer (MAC) addr
- Recalling IPv4 & ARP
  - – ARP Request is broadcast
    - e.g. ethernet addr : FF-FF-FF-FF-FF-FF
    - Containing the Src's LL addr
  - – ARP Reply is sent in unicast to the Src
    - Containing the Dst's LL addr

# Address Resolution (2)
# IPv6 with Neighbor Discovery

At boot time, every IPv6 node has to join 2 special multicast groups for each network interface:

- All-nodes multicast group: **`ff02::1`**
- Solicited-node multicast group: **`ff02:1:ffxx:xxxx`** (derived from the lower 24 bits of the node's address)



# Address Resolution (3)
# Solicited Multicast Address

- **Concatenation** of the prefix `FF02::1:FF00:0/104` with the last 24 bits of the IPv6 address

***Example:***

- **Dst IPv6** @: `2001:0660:010a:4002:4421:21FF:FE24:87c1`

↓

- **Sol. Mcast** @: `FF02:0000:0000:0000:0000:0001:FF24:87c1`

↓

- **Ethernet: 33-33-FF-24-87-c1**

# Path MTU discovery (RFC 1981)

- Derived from RFC 1191, (IPv4 version of the protocol)
- **Path** : set of links followed by an IPv6 packet between source and destination
- **Link MTU** : maximum packet length (bytes) that can be transmitted on a given link without fragmentation
- **Path MTU** (or pMTU) = min { link MTUs } for a given path
- Path MTU Discovery = automatic pMTU discovery for a given path

# Path MTU discovery (2)

- Protocol operation
  - makes assumption that pMTU = link MTU to reach a neighbor (first hop)
  - if there is an intermediate router such that link MTU < pMTU ➔ it sends an ICMPv6 message: "Packet size Too Large"
  - source reduces pMTU by using information found in the ICMPv6 message

=> Intermediate network element aren’t allowed to perform packet fragmentation

# Mobility Overview

- ***Mobility*** is much wider than ***"nomadism"***
- Keep the same IP address regardless of the network the equipment is connected to:
  - reachability
  - configuration
  - real mobility
- Difficult to optimize with IPv4 (RFC 3344 PS)
- Use new facility of IPv6: MIPv6

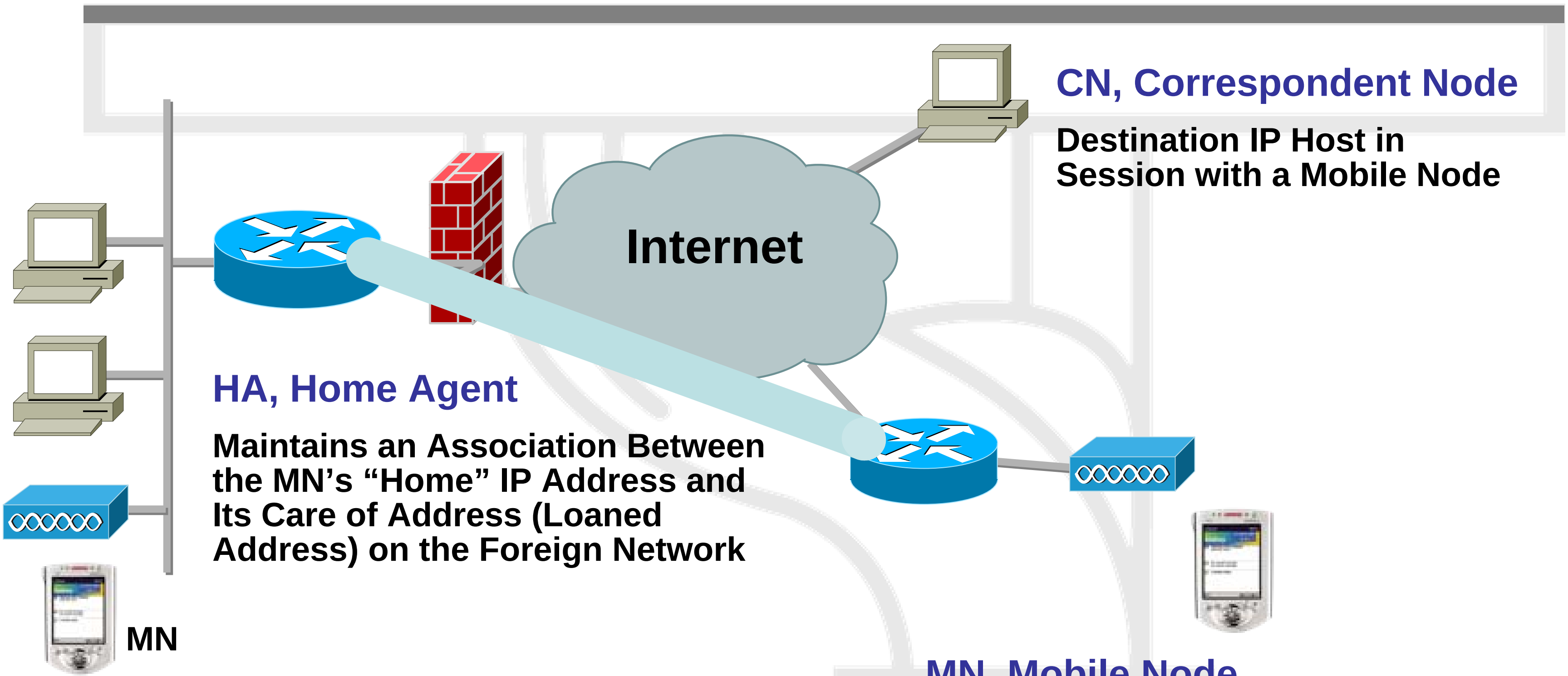
# IPv6 Mobility (MIPv6)

- IPv6 mobility relies on:
  - New IPv6 features
  - The opportunity to deploy a new version of IP
- Goals:
  - Offer the direct communication (route optimisation) between the mobile node and its correspondents
    - As opposed to triangle routing
  - Reduce the number of actors (Foreign Agent (IPv4) no longer used )
- MIPv6: RFC 3776

# General Considerations

- A globally unique IPv6 address is assigned to every Mobile Node (MN): Home Address (HA)
- This address enables the MN identification by its Correspondent Nodes (CN)
- A MN must be able to communicate with non mobile nodes
- Communications (layer 4 connections) have to be maintained while the MN is moving and connecting to foreign (visited) networks

# Mobile IPv6: Key Components




**CN, Correspondent Node**

**Destination IP Host in Session with a Mobile Node**

**HA, Home Agent**

**Maintains an Association Between the MN's "Home" IP Address and Its Care of Address (Loaned Address) on the Foreign Network**

**MN, Mobile Node**

**An IP Host that Maintains Network Connectivity Using Its "Home" IP Address, Regardless of which Link (or Network) It Is Connected to**

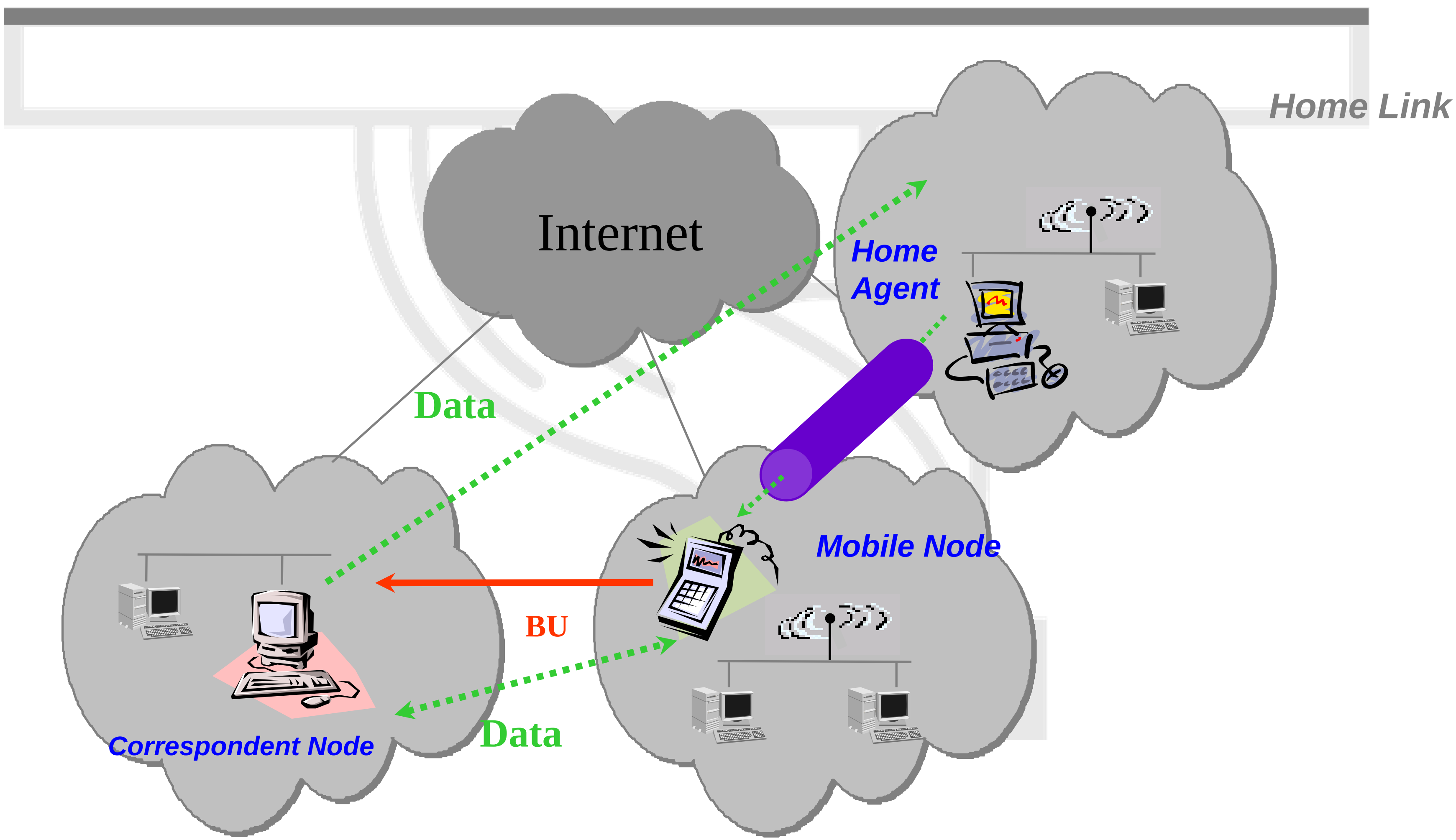
# Main features/requirements of MIPv6

- CN can:
  - Put/get a Binding Update (BU) in/from their Binding Cache
  - Learn the position of a mobile node by processing BU options
  - Perform direct packet routing toward the MN using Routing Header
- The MN's Home Agent must:
  - Be a router in the MN's home network
  - Intercept packets which arrive at the MN's home network and whose destination address is its HA
  - Tunnel (IPv6 encapsulation) those packets directly to the MN
  - Do reverse tunneling (MN → CN)

# Mobile Node Addressing

- A MN is always reachable on its Home Address
- While connecting to foreign networks, a MN always obtains a temporary address, “the Care-of Address” (CoA) by auto-configuration:
  - It receives Router Advertisements providing it with the prefix(es) of the visited network
  - It appends that (those) prefix(es) to its Interface-ID
- Movement detection is also performed by Neighbor Discovery mechanisms

# MIPv6: IETF Model

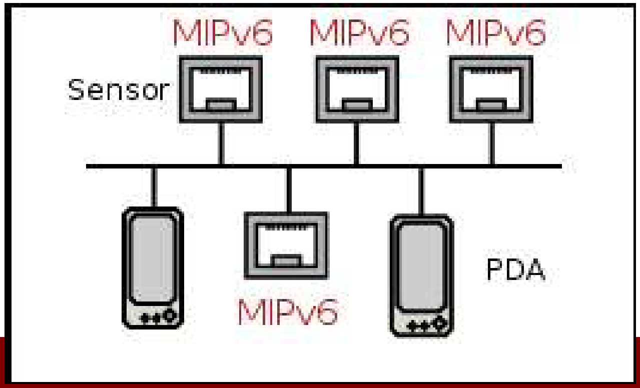


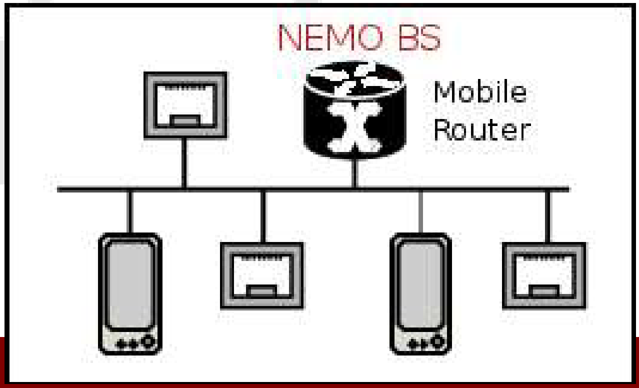
# Network Mobility

- Until now all we have considered is host mobility
  - I.e. Managing the mobility of Individual devices
- However, many scenarios exist where entire networks of mobile devices move together
  - Access networks on trains, buses or planes
  - Personal Area Networks
  - Network of In-car devices

# Network Mobility Advantages

- Consider Train-Based Access network
  - If 100's of MIPv6 devices on train
    - When the train roams, all devices must update their repective HAs (A lot of control traffic sent at once)
  - With Network Mobility, a Mobile Router (MR) manages the mobility of all the devices



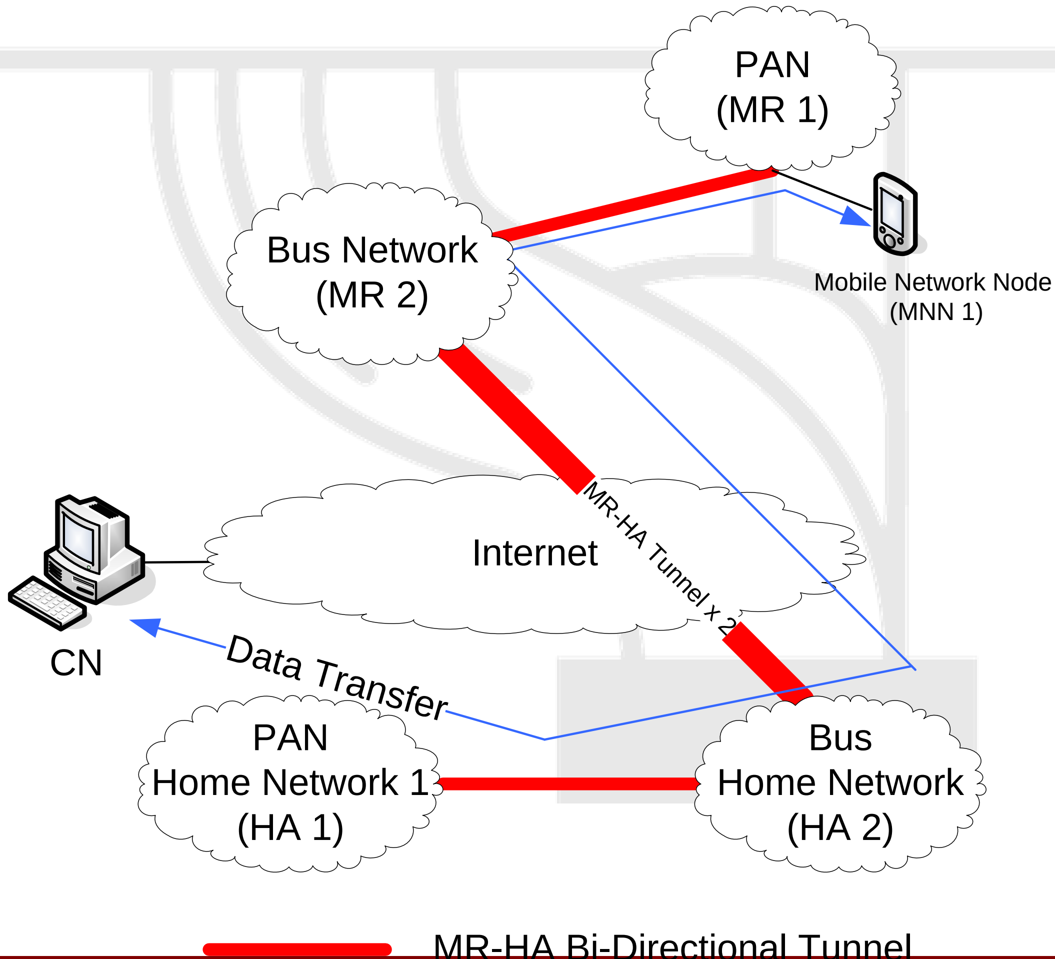
# NEMO Basic Support Protocol

- IETF's Solution to supporting Network Mobility
  - MIPv6 Extension (NEMO BS is now RFC3963)
  - HA intercepts packets for an entire IPv6 network prefix
    - i.e. 2001:630:80:10::/64
  - MR maintains Bi-directional tunnel, forwarding packets to Nodes on its Mobile Network
  - Nodes needn't be aware of their mobility
    - COTS devices need no new code

# Nested Mobile Networks

- NEMO BS introduces new scenarios (and therefore problems) not possible with MIPv6
  - Nested Mobile Networks (Nested NEMO)
- What happens if a NEMO-enabled PAN attaches to a NEMO-enabled train network?
  - Devices connected to the PAN are 2 levels deep in the Nested NEMO
  - Multiple HAs to visit
    - Produces Pinball Routing (AKA Multi-Angular Routing)
    - Latency & header size increases with every level of nesting
- Nested NEMO can be many levels deep (1 - 36)

# Nested NEMO



PAN
(MR 1)
Bus Network
(MR 2)
Mobile Network Node
(MNN 1)
Internet
MR-HA Tunnel x 2
CN
Data Transfer
PAN
Home Network 1
(HA 1)
Bus
Home Network
(HA 2)
MR-HA Bi-Directional Tunnel

# Route Optimisation

- MIPv6-Style RO cannot be applied to NEMO
  - In NEMO, Nodes behind the MR are unaware they are connected to a Mobile Network
  - Many Nodes behind the MR will be communicating with many different CNs
- MR could record packet transfers and perform RO on behalf of Nodes on the Mobile Network
  - But this solution would be unacceptable!
    - Large amount of state held in the MR
    - When MR roams: Influx of protocol data & big increase in processing
    - Still wouldn't optimise route in Nested NEMO

# 6LOWPAN

- LOWPAN: Low-power wireless personal area network
  - Devices with short range, low bit rate, low power and low cost
    - E.g. Sensor networks
  - Specifically IEEE 802.15.4-2003
- 6LOWPAN: Transport of IPv6 packets in LOWPANs
  - IETF: Transmission of IPv6 Packets over IEEE 802.15.4 Networks (draft-ietf-6lowpan-format-13)

# IPv6 transport

- IPv6 standard specifies minimum MTU of 1280 bytes
  - However LOWPANs have MTU of max 127
    - Available space of only 81 bytes
- Need to fit IPv6 packets on to LOWPAN
  - Need to specify representation
  - Typically need to compress headers
    - IPv6 Header 40 Bytes
  - Require link layer fragmentation as MTU is below 1280
    - Though not always as packets are usually small

# IPv6 packets on LOWPAN

- LOWPAN transmission
  - IEEE 802.15.4 has 4 types of frames
    - beacon frames, MAC command frames, acknowledgement frames and data frames
  - IEEE 802.15.4 defines several addressing modes
    - IEEE 64-bit extended addresses or (after an association event) 16-bit addresses unique within the PA
    - Mesh routing
- IPv6 packets are carried in data frames using all above addressing modes
  - Multicast is only available in mesh networks

# LOWPAN Adaptation Layer and Frame Format

- Uses an “Dispatch header”, which prefixes the IPv6 header.
  - Indicating compression, if used.

| Dispatch Header | IPv6 Header | Payload |
|---|---|---|

  - Additionally there maybe extra headers for fragmentation, mesh transport

| Fragment Type | Fragment header | Dispatch Header | IPv6 Header | Payload |
|---|---|---|---|---|

# Questions?