IPv6 associated protocols

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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
  – ...

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

- All-nodes multicast group: \texttt{ff02:0:1}
- Solicited-node multicast group: \texttt{ff02:1:ffxx:xxxx} (derived from the lower 24 bits of the node’s address)

**Address Resolution (2)**

IPv6 with Neighbor Discovery

<table>
<thead>
<tr>
<th>NS</th>
<th>( \text{D}_{IP} = \text{Multi}(\text{IP}2) )</th>
<th>( \text{D}_{LL} = (\text{MAC}2) )</th>
<th>( S_{IP} = \text{IP}1 )</th>
<th>( S_{LL} = \text{MAC}1 )</th>
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<tbody>
<tr>
<td>NA</td>
<td>( \text{D}_{IP} = \text{IP}1 )</td>
<td>( \text{D}_{LL} = \text{MAC}1 )</td>
<td>( S_{IP} = \text{IP}2 )</td>
<td>( S_{LL} = \text{MAC}2 )</td>
</tr>
</tbody>
</table>
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:*


    ↓

  - **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 \( \Rightarrow \) 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

**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

**CN, Correspondent Node**
Destination IP Host in Session with a Mobile Node
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

Internet

Home Link

Home Agent

Mobile Node

Correspondent Node

Data

BU
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 respective 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

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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

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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.
  - Additionally there maybe extra headers for fragmentation, mesh transport
Questions?