IPv6 Addressing and Implementation

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IPv6 - Agenda

• Why IPv6?
  – No business case
  – Different drivers
• IPv6 main features
• IPv6 Transition
• IPv6 Status
IPv6

- IPv4 has been the Internet Protocol for almost 30 years
- In the early nineties, IPv4 address exhaustion became a concern
- A new IP protocol was devised and standardized by IETF in 1995: IPv6
- Since then it was always predicted IPv4 address depletion in the next 3 years
- However, it has not happened so far
- And the business case has been fading
The world is changing

• More people being connected to the Internet:
  – Growth of connected population in Asia, Latin America, Africa

• Internet and connectivity is not an entertainment but an essential need
New paradigms for servers

- SaaS (Salesforce.com)
- IaaS (EC2)
- Cloud Computing
- Mega-Datacenters (tens and hundreds of thousands of commodity low-end servers)
New paradigms for servers

• Virtualization
  – Migration (MIPv6), IPv6 address

• Autonomic Computing (Self-managed systems)
  – In the server segment and client segment
  – Autoconfiguration and neighbor discovery
  – EFIPSANS www.efipsans.org
Billions of mobile devices

- Embedded systems: digital home, digital health, automotive, military, wireless sensor networks
- Ubiquitous devices: cameras, smartphones
- New form factors: netbooks, MIDs
- Always-on data connection
- Different link technologies: 802.11, 802.15.x, 3G, 4G (WiMAX, LTE), 802.21 …
- PAN, Ad-hoc networks, Wifi Direct (My Wifi)
- P2P, paging, notifications
IPv6 - Main Features

• Address size is 16 Bytes.
• Extended address hierarchy.
• New header format: 1 Base Header + n Extension Headers.
• Different support for options (comparing to IPv4).
• Support for protocol extensions (e.g. Mobility support).
IPv6 - Main Features

• Support for autoconfiguration and renumbering.
• Support for resource allocation: Flow label and service type.
• Support for authentication and privacy is specified: IPsec natively supported
IPv6 – Headers

- An IPv6 datagram has 40-octect Base Header and n Extension Headers.
- Advantages:
  - Improves performance on header processing.
  - The user can choose which extension headers to include and which to omit.
  - Flexibility for new options: more extension headers can be added.
IPv6 – Base Header

- An IPv6 datagram has 40-octect Base Header and n Extension Headers.
In order to extract any header information from an IPv6 datagram a sequential search from the base header is required. Every header has a “next header” field.

Different possibilities for datagrams with base header and n extension headers:

- Base Header NEXT=TCP
- Base Header NEXT=hbh
- Base Header NEXT=hbh

TCP segment

TCP segment

TCP segment
IPv6 – Extension Headers

• Recommended order:
  - Base header
  - Hop-by-Hop options header
  - Destination options header-1
  - Source Routing header (Type 0)
  - Type 2 routing header (for mobility)
  - Fragment header
  - Authentication header (AH).
  - Encapsulating Security Payload (ESP) header
  - Destination Options header-2
  - Upper-layer header
IPv6 – Text Representation of Addresses

• RFC 4291
• 16 Bytes: 128 bits.
• Text representation: Colon Hexadecimal Notation.

2004:FFED:01:0:0:0:0CC:A1BC
2004:FFED:1::0CC:A1BC
0:0:0:0:128:FA:1234:5678 ::128:F0A:1234:5678
::128:F0A:1234:5678
::192.168.0.5 (x:x:x:x:x:d.d.d.d for embedded IPv4 addresses)

Note: Zero compression can be applied only once.
IPv6 - Addresses
Address types

- **Unicast**: specifies a single interface (a single node).

- **Anycast**: specifies a set of interfaces (typically belonging to different nodes). They are unicast addresses assigned to different interfaces. The pkt is delivered to exactly one of them, the nearest one.

- **Multicast**: specifies a set of interfaces (typically belonging to different nodes). The pkt is delivered to all of them.

Note: broadcast is handled with multicast addresses.
<table>
<thead>
<tr>
<th>Address Type</th>
<th>Binary Prefix</th>
<th>IPv6 Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unspecified</td>
<td>00...0</td>
<td>::/128</td>
</tr>
<tr>
<td>Loopback</td>
<td>00...1</td>
<td>::1/128</td>
</tr>
<tr>
<td>Multicast Addresses</td>
<td>1111 1111</td>
<td>FF00::/8</td>
</tr>
<tr>
<td>Link-Local Unicast Addresses</td>
<td>1111 1110 10</td>
<td>FE80::/10</td>
</tr>
<tr>
<td>Unique Local IPv6 Unicast Addresses</td>
<td>1111 1100</td>
<td>FC00::/7</td>
</tr>
<tr>
<td>Global Unicast Addresses (Aggregatable)</td>
<td>everything else</td>
<td></td>
</tr>
</tbody>
</table>

IPv4-Mapped IPv6 Address: ::FFFF:d.d.d.d (used in dual-stack nodes)
IPv6 – Address Autoconfiguration

• The procedure a host follows to create its interface addresses without manual assistance.

• Autoconfiguration is performed on a per-interface basis on multicast-capable links in multicast-capable interfaces. Begins when the interface becomes enabled.
• It uses Neighbor Discovery Protocol messages.
• Address Autoconfiguration can be:
  – Stateless: without assistance of stateful servers.
  – Stateful: with assistance of a stateful server; for example DHCPv6.
• Both Stateless and Stateful are complementary.
IPv6 – Address Autoconfiguration
Address Autoconfiguration Steps – Link-Local Address

1. Interface is enabled.
2. “Tentative” link-local address is formed.
3. Duplicate Address Detection is performed: A Neighbor Solicitation is sent to Solicited-Node Multicast Address of the Target Address.
4. If the node ascertains the link-local address is unique, it is assigned to the interface.
5. The node has only link connectivity.

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IPv6 Addressing and Implementation
IPv6 – Address Autoconfiguration
Stateless Address Autoconfiguration - Next Steps

1. Routers periodically send out Router Advertisements with Prefix Information Options.
2. If a prefix published in the Prefix Information Option has the appropriate flag set, it can be used to form a Global Address or a Local Unicast Address.
3. The node has Site or Internet-wide connectivity.
Neighbor Discovery Protocol for IPv6

• This protocol is used in IPv6 to:
  – Determine neighbor’s link-layer address, i.e. address resolution (NO ARP).
  – Determine neighbor bidirectional reachability: Neighbor Unreachability Detection.
  – Discover neighboring routers.
  – Learning link specific parameters: network prefixes, MTU, etc.
  – Next-Hop determination and Redirect.
  – Duplicate Address Detection in Address Autoconfiguration.
  – Proxy support.

• Messages used in ND Protocol are part of ICMPv6.
IPv6 – ND Protocol Address Resolution

1. PC3 is to send a packet to 2002:C3D4:6EED:1:0207:A5FF:FE61:2AB8 but first it needs to know the corresponding HW address.

2. PC3 sends a Neighbor Solicitation asking for the owner of the destination address: it is sent to the solicited-node multicast address for the target addr.

3. PC1 reads the Neighbor Solicitation and responds with a Neighbor Advertisement telling its link-layer address.

4. PC3 can physically send the packet to the HW (link-layer) address of PC1.
Mobile IPv6

HA intercepts pkt y and sends it to the primary CoA by tunneling.

Correspondent Node

Core Network & UTRAN

Node-B

Mobile Node UMTS-802.11n

Home Agent

Home Network

Mobile Node UMTS-802.11n

Binding Update

11/27/2009 IPv6 Addressing and Implementation 22
Transition and co-existence

• Slow Transition:
  – IPv4 and IPv6 will co-exist for more than 10 years
• Application must be protocol agnostic
  – Use URL instead of IP address
  – Rely on dual-stack
  – Abstract from protocol-specific
• Technology transition:
  – Teredo
  – 6to4
  – ISATAP
  – Dual-stack
IPv6 Status – BGP mon [http://bgpmon.net/blog/?p=166]

<table>
<thead>
<tr>
<th>Position</th>
<th>Country</th>
<th>Score (IPv6/IPv4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Holy See (Vatican City State) (VA)</td>
<td>100% (1/1)</td>
</tr>
<tr>
<td>2</td>
<td>Cuba (CU)</td>
<td>60% (3/5)</td>
</tr>
<tr>
<td>3</td>
<td>Fiji (FJ)</td>
<td>50% (1/2)</td>
</tr>
<tr>
<td>4</td>
<td>Uruguay (UY)</td>
<td>35% (9 / 26)</td>
</tr>
<tr>
<td>5</td>
<td>Tunisia (TN)</td>
<td>33% (1/3)</td>
</tr>
<tr>
<td>6</td>
<td>Senegal (SN)</td>
<td>33% (1/3)</td>
</tr>
<tr>
<td>7</td>
<td>Monaco (MC)</td>
<td>33% (1/3)</td>
</tr>
<tr>
<td>8</td>
<td>Mali (ML)</td>
<td>33% (1/3)</td>
</tr>
<tr>
<td>9</td>
<td>Estonia (EE)</td>
<td>28% (10/36)</td>
</tr>
<tr>
<td>10</td>
<td>Isle of Man (IM)</td>
<td>25% (1/4)</td>
</tr>
<tr>
<td>11</td>
<td>European Region (EU)</td>
<td>22% (22/99)</td>
</tr>
<tr>
<td>12</td>
<td>Madagascar (MG)</td>
<td>20% (1/5)</td>
</tr>
<tr>
<td>13</td>
<td>Bhutan (BT)</td>
<td>20% (1/5)</td>
</tr>
<tr>
<td>14</td>
<td>Luxembourg (LU)</td>
<td>19% (8/42)</td>
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<tr>
<td>15</td>
<td>Irish Republic (IE)</td>
<td>19% (30/159)</td>
</tr>
<tr>
<td>16</td>
<td>New Zealand (NZ)</td>
<td>18% (31/173)</td>
</tr>
<tr>
<td>17</td>
<td>Costa Rica (CR)</td>
<td>18% (2/11)</td>
</tr>
<tr>
<td>18</td>
<td>Cote D’Ivoire (CI)</td>
<td>17% (1/6)</td>
</tr>
<tr>
<td>19</td>
<td>Virgin Islands, U.S. (VI)</td>
<td>17% (1/6)</td>
</tr>
<tr>
<td>20</td>
<td>Qatar (QA)</td>
<td>17% (1/6)</td>
</tr>
<tr>
<td>21</td>
<td>Japan (JP)</td>
<td>15% (82 / 537)</td>
</tr>
<tr>
<td>22</td>
<td>Viet Nam (VN)</td>
<td>15% (5/34)</td>
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<tr>
<td>23</td>
<td>Taiwan, Province of China (TW)</td>
<td>15% (17 / 112)</td>
</tr>
<tr>
<td>24</td>
<td>Portugal (PT)</td>
<td>14% (10 / 70)</td>
</tr>
<tr>
<td>25</td>
<td>Netherlands (NL)</td>
<td>14% (66 / 484)</td>
</tr>
<tr>
<td>26</td>
<td>Malaysia (MY)</td>
<td>14% (9 / 64)</td>
</tr>
<tr>
<td>27</td>
<td>Mauritius (MU)</td>
<td>14% (1/7)</td>
</tr>
<tr>
<td>28</td>
<td>Liechtenstein (LI)</td>
<td>13% (2/16)</td>
</tr>
<tr>
<td>29</td>
<td>Egypt (EG)</td>
<td>11% (5/45)</td>
</tr>
<tr>
<td>30</td>
<td>Norway (NO)</td>
<td>11% (12 / 111)</td>
</tr>
<tr>
<td>31</td>
<td>South Africa (ZA)</td>
<td>11% (10 / 88)</td>
</tr>
<tr>
<td>32</td>
<td>Trinidad and Tobago (TT)</td>
<td>11% (1/9)</td>
</tr>
</tbody>
</table>
IPv6 Status

• Most OS’s: Windows Vista/7, Linux, Chrome OS
• Products: Microsoft’s DirectAccess
• Google since 2008 (http://www.google.com/intl/en/ipv6)
  – Plans to add IPv6 to YouTube
  – http://www.networkworld.com/news/2009/032509-google-ipv6-
  easy.html?page=2
• Devices connecting to Verizon’s LTE network (2010) must support IPv6
• US Government agencies are IPv6 ready since 2008
• Comcast is offering IPv6 transit services and has plans for residential IPv6 trials (2010)
• Hurricane Electric, Global Crossing, NTT America
• IPv6 at Olympics
Conclusions and Call To Action

• IPv6 is silently gaining adoption
• It is not a matter of migration but co-existence of IPv4 and IPv6
• New IPv4 addresses could be unavailable in 2011
• IPv6 is not only about more IP addresses
  – Opportunity for innovation
• Plan for IPv6 training and pilots in 2010
• IPv6 Task Force?
• GoGo6: http://www.gogo6.com
Questions
And
Answers?
Link References

- IPv6 Forum: [http://www.ipv6forum.org](http://www.ipv6forum.org)
- Argentina IPv6 Task Force: [http://www.ar.ipv6tf.org](http://www.ar.ipv6tf.org)
- IETF: [www.ietf.org](http://www.ietf.org)
- IPv4-IPv6 Transition:
  - [http://www.6journal.org/archive/00000046/01/trans_ipv6_v014.pdf](http://www.6journal.org/archive/00000046/01/trans_ipv6_v014.pdf)