ICMPv6
Outline

- Purpose of ICMPv6 and the structure of all ICMPv6 messages
- ICMPv6 error messages
- ICMPv6 informational messages used for diagnostics
- Common ICMPv4 messages and their ICMPv6 equivalents
- IPv6 Path MTU discovery process
Overview of ICMPv6

- Updated and expanded version of the Internet Control Message Protocol (ICMP) for IPv6
- Reports delivery or forwarding errors and a simple echo service for troubleshooting
- Provides a framework for (later):
  - Multicast Listener Discovery (MLD)
  - Neighbor Discovery (ND) which is ?
  - IPv6 mobility
Types of ICMPv6 Messages

Error messages

- Sent for errors encountered in forwarding or delivery by the destination node or an intermediate router
- The high order bit of the Type field is set to 0
  - Type field is in the range of 0 - 127

Informational messages

- Provide diagnostic functions and additional host functionality
- The high order bit of the Type field is set to 1
  - Type field is in the range of 128 - 255
Structure of ICMPv6 Messages

<table>
<thead>
<tr>
<th>Type</th>
<th>Code</th>
<th>Checksum</th>
<th>Message body</th>
</tr>
</thead>
</table>

What are each of these?
ICMP

- Completely Changed – note new header type
- Now includes IGMP (Multicast Group Mgmt)
- Types organized as follows
  - 1 – 4 Error messages
  - 128 – 129 Ping
  - 130 – 132 Group membership
  - 133 – 137 Neighbor discovery
- General Format

<table>
<thead>
<tr>
<th>Type</th>
<th>Code</th>
<th>Checksum</th>
<th>Message Body</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Description</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Destination Unreachable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Packet Too Big</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Time Exceeded</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Parameter Problem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>128</td>
<td>Echo Request</td>
<td></td>
<td></td>
</tr>
<tr>
<td>129</td>
<td>Echo Reply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>130</td>
<td>Group Membership Query</td>
<td></td>
<td></td>
</tr>
<tr>
<td>131</td>
<td>Group Membership Report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>132</td>
<td>Group Membership Reduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>133</td>
<td>Router Solicitation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>134</td>
<td>Router Advertisement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>135</td>
<td>Neighbor Solicitation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>136</td>
<td>Neighbor Advertisement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>137</td>
<td>Redirect</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ICMPv6 Error Messages

- Destination Unreachable (Code expands error)
  - Code 0 - No route to destination
  - Code 1 - Can’t get to destination for admin reasons
  - Code 2 - Not assigned
  - Code 3 - Address unreachable
  - Code 4 - Port Unreachable

- Packet Too Big
  - Code 0 - Parameter is set to MTU of next hop, i.e., can determine MTU

- Time Exceeded

- Parameter Problem

- ICMPv6 Error messages are rate limited
  - By timer
  - By percentage of bandwidth
Error: Structure of the Destination Unreachable Message

Type = 1
Code = 0 - 4
Checksum
Parameter
Portion of discarded packet

Source can tell what destination was not reached
**Error: Structure of the Packet Too Big**

*Message*

- **Type**: 2
- **Code**: 0
- **Checksum**
- **(needed) MTU**
- **Portion of discarded packet** . . .
Error: Structure of the Time Exceeded Message

Type = 3
Code = 0 or 1
Checksum
Unused
Portion of discarded packet...
**Error: Structure of the Parameter Problem**

**Message – Error in Packet Structure**

- **Type**: 4
- **Code**: 0 - 2
- **Checksum**: ... (where pkt went bad)
- **Pointer**: Portion of discarded packet...

---

v6 ICMP  Slide: 12
ICMPv6 Informational Messages

- Echo Request
- Echo Reply
- Additional informational messages for
  - ND (Neighbor Discovery),
  - MLD (Multicast Listener Discovery), and
  - IPv6 mobility
Info: Structure of the Echo Request

**Msg**

<table>
<thead>
<tr>
<th>Type</th>
<th>Code</th>
<th>Checksum</th>
<th>Identifier</th>
<th>Sequence Number</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Type = 128
Code = 0

Match response

...
Info: Structure of the Echo Reply Message

Just Turn the message around
### ICMPv4 Messages and their ICMPv6 Equivalents

<table>
<thead>
<tr>
<th>Common ICMPv4 Message</th>
<th>ICMPv6 Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Destination Unreachable- Network unreachable (Type 3, Code 0)</td>
<td>Destination Unreachable-No route to destination (Type 1, Code 0)</td>
</tr>
<tr>
<td>Destination Unreachable-Protocol unreachable (Type 3, Code 2)</td>
<td>Parameter Problem-Unrecognized Next Header field (Type 4, Code 1)</td>
</tr>
<tr>
<td>Destination Unreachable-Port unreachable (Type 3, Code 3)</td>
<td>Destination Unreachable-Port unreachable (Type 1, Code 4)</td>
</tr>
<tr>
<td>Destination Unreachable-Fragmentation needed and DF set (Type 3, Code 4)</td>
<td>Packet Too Big (Type 2, Code 0)</td>
</tr>
<tr>
<td>Time Exceeded-TTL expired (Type 11, Code 0)</td>
<td>Time Exceeded-Hop Limit exceeded (Type 3, Code 0)</td>
</tr>
<tr>
<td>Parameter Problem (Type 12, Code 0)</td>
<td>Parameter Problem (Type 4, Code 0 or 2)</td>
</tr>
<tr>
<td>Source Quench (Type 4, Code 0)</td>
<td>This message is not present in IPv6.</td>
</tr>
<tr>
<td>Redirect (Type 5, Code 0)</td>
<td>Neighbor Discovery Redirect message (Type 137, Code 0).</td>
</tr>
</tbody>
</table>
**Path MTU Discovery**

- For a given flow, the source host assumes that the path MTU is the MTU of the first link.
- If a packet reaches a link with a smaller MTU, that router discards it and returns an **ICMP** error message along with that link’s MTU.
- This continues until the packet reaches the destination.
- The source host caches the smallest link MTU as the “Path MTU” for that flow.
Path MTU Discovery

Source Host

1500 Byte Packet

MTU = 1500

Path MTU = 1500

Router 1

Router 2

Destination Host

4/7/14
Path MTU Discovery

Source Host

MTU = 1500
Path MTU = 1000

Router 1

ICMP "Pkt Too Big" (MTU = 1000)

MTU = 1000

Router 2

Destination Host

4/7/14
Path MTU Discovery

Source Host

500 Byte Frag ➔ 1000 Byte Fragment ➔ Router 1

MTU = 1500

Router 1

Path MTU = 1000

MTU = 1000

Router 2

Destination Host

4/7/14
Path MTU Discovery

Source Host

MTU = 1500
Path MTU = 1000

Router 1

Router 2

Destination Host

MTU = 1000

500 Byte Frag

1000 Byte Fragment

1000 Byte Fragment

500 Byte Frag
Path MTU Discovery

Source Host

MTU = 1500

Path MTU = 500

Router 1

MTU = 1000

Router 2

MTU = 500

Destination Host

ICMP "Pkt Too Big" (MTU = 500)
Path MTU Discovery

Source Host

500 Byte Frag ➔ 500 Byte Frag ➔ 500 Byte Frag ➔ Router 1

MTU = 1500

Path MTU = 500

Router 2

MTU = 500

Router 1

MTU = 1000

Destination Host

MTU = 500

4/7/14
Path MTU Discovery

Source Host

VMU = 1500

Path MTU = 500

Router 1

500 Byte Frag ➔ 500 Byte Frag ➔ 500 Byte Frag ➔ Destination Host

MTU = 1000

Router 2

MTU = 500

4/7/14
Changes in PMTU – Path MTU

Set PMTU to destination to link MTU.

Send packet at PMTU size.

ICMPv6 Packet Too Big message received?

Yes

Set PMTU to destination to the value of the MTU field in the Packet Too Big message.

No

Is PMTU to destination less than the link MTU?

Yes

Has PMTU timer expired?

Yes

Advantage of Flowchart?

No

No
Consequences of New Fragmentation Method

- Improved router performance (since routers don’t fragment), but must handle ICMP error packet
- No more “fragments of fragments”
- Hosts that do not support Path MTU discovery must limit packet size to 576 bytes
- All links must support a MTU of at least 576 bytes or do “local” fragmentation (a la ATM AAL5)
- This makes dynamic route changes problematic, since the new path may include a smaller MTU
  - QoS promises associated with flows cause the same problem
  - Result: no dynamic path changes in IPv6, which means no longer best effort on a random path of routers
## IPv6 Fragment Extension Header

<table>
<thead>
<tr>
<th></th>
<th>Next Header</th>
<th>Reserved</th>
<th>Fragment Offset</th>
<th>Res</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Measurement</td>
<td></td>
<td>Identification</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Fragment Offset** - offset of data in this packet, from the start of the original packet (counted in 8-byte units)
- **M Flag** - Set to 1 if more fragments coming, set to 0 if this is the last fragment
- **Identification** - a value unique to the original packet and common to all fragments
### IPv4 Fragmentation-Related Fields

<table>
<thead>
<tr>
<th>Field</th>
<th>Bit Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version</td>
<td>0-3</td>
</tr>
<tr>
<td>Hdr Len</td>
<td>4-7</td>
</tr>
<tr>
<td>Type of Service</td>
<td>8-11</td>
</tr>
<tr>
<td>Total Length</td>
<td>12-15</td>
</tr>
<tr>
<td>Identification</td>
<td>16-19</td>
</tr>
<tr>
<td>Flags</td>
<td>20-23</td>
</tr>
<tr>
<td>Fragment Offset</td>
<td>24-31</td>
</tr>
<tr>
<td>Time To Live</td>
<td>0-7</td>
</tr>
<tr>
<td>Protocol</td>
<td>8-15</td>
</tr>
<tr>
<td>Header Checksum</td>
<td>16-23</td>
</tr>
<tr>
<td>Source IP Address</td>
<td>24-31</td>
</tr>
<tr>
<td>Destination IP Address</td>
<td>0-31</td>
</tr>
<tr>
<td>Options (If Used)</td>
<td>0-20</td>
</tr>
<tr>
<td>Padding</td>
<td>21-31</td>
</tr>
<tr>
<td>Payload</td>
<td>0-65535</td>
</tr>
</tbody>
</table>

4/7/14
**IPv6 Fragmentation Example**

The Unfragmentable Part contains the IPv6 base header plus any extension headers that must be processed en route to the destination. The remainder of the original packet is the Fragmentable Part (which may include additional extension headers, along with the payload).
Summary

- Structure of all ICMPv6 messages
- ICMPv6 error messages
- ICMPv6 informational messages used for diagnostics
- Common ICMPv4 messages and their ICMPv6 equivalents
- IPv6 Path MTU discovery process