TCP ECN
Experience with enabling ECN on the Internet

Padma Bhooma
Apple
Using ECN from client side

• Apple enabled negotiation of TCP ECN (RFC 3168) from the client-side for the first time on iOS and macOS!

• TCP ECN negotiation is enabled on

  • 5% of randomly selected connections over Wi-Fi / Ethernet in iOS 9 and macOS El Capitan

  • 50% of randomly selected connections over Wi-Fi / Ethernet and a few cellular carriers in iOS 10 and macOS Sierra
ECN Benefits

- Reduce packet loss in the Internet
- Promote Smart Queue Management
- Reduce Buffer bloat
- Improve user experience
- Reference: draft-ietf-aqm-ecn-benefits-08
Good News!

• It works!

• No problems reported from customers after using ECN on 50% of randomly selected TCP connections on all Apple devices
Heuristics for detecting broken middle boxes

• Middle boxes could treat ECN enabled SYN or data packets differently

• Apple devices have a few heuristics to detect these anomalies

• As a fallback, devices avoid using ECN on those network attachment (path) for a limited period of time after detecting an anomaly
CE marking on every packet

• Impact: Performance degradation

• Heuristic is triggered when:
  • CE marking is seen on Non-ECN connections
  • 7 out of 10 initial packets are marked with CE on ECN enabled connections

• Frequency
  • Fixed on the ISP where it was reported initially in Germany
  • Not seen on any other ISP in the world
Packet Reordering

- Impact: Performance degradation
- Heuristic is triggered when:
  - PAWS drop (RFC 7323) is seen due to reordering
  - Reordering is detected using TCP Selective acknowledgements
TCP SYN loss

• Impact: Adds another RTO during connection establishment

• Heuristic is triggered when:
  • More than 2 successive ECN negotiating SYN are lost
  • ECN is disabled conservatively even if the SYN loss is due to other reasons
RST on first data packet

• Impact: Connection dropped

• Heuristic is triggered when:
  • More than 2 consecutive connections receive a RST for the first data packet after successfully establishing an ECN connection

• Frequency: Seen rarely, still need a metric to quantify the impact
Connection drop after multiple retransmissions

• Impact: Connection failed

• Heuristic is triggered when:
  • More than 4 successively established ECN enabled connections fail to send data after multiple retransmissions

• Frequency: Seen rarely, still need a metric to quantify the impact
More about the heuristics

• Heuristics disable ECN conservatively for limited time even if the underlying problem is not due to ECN marking

• Heuristics are triggered rarely from the data collected so far

• Later, we plan to remove all these temporary heuristics and stop trying to accommodate the few remaining defective middle boxes that mishandle the ECN bits
Networks with CE marking

- Percentage of reports that have seen any CE marking on any of the ECN enabled connections in a 12 hour period

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>0.2</td>
</tr>
<tr>
<td>China</td>
<td>1</td>
</tr>
<tr>
<td>Mexico</td>
<td>3.2</td>
</tr>
<tr>
<td>France</td>
<td>6</td>
</tr>
<tr>
<td>Argentine Republic</td>
<td>30</td>
</tr>
</tbody>
</table>

- Marking was mainly seen on the uplink
Performance comparison between ECN and Non ECN connections

• Path characteristics measured over 12 hour period

• RTT average and variance

• Percentage of out-of-order bytes

• Percentage of packet retransmissions

• Connection drops

• Percentage of reordered packets
• Every device reports these path characteristics seen on ECN and Non-ECN connections as two separate metrics during a period of 12 hours

• Our goal is to see that ECN connections perform no worse than Non-ECN connections

• Makes it safe for Apple to continue using ECN

• Offers clear competitive advantage for ISPs that do Smart queueing with support for ECN
Using Heat maps for data analysis

• Generating Heat maps with ECNOn metric on Y-axis and ECNOff metric on X-axis

• Each cell has a count of the number of reports that fall into that (ECNOff, ECNOn) values as (X,Y) co-ordinates

• Each cell is color-coded using the count of records on that cell
ECN deployment  Padma Bhooma  MAPRG  98th IETF  Chicago  March 2017

Maximum Heat

ECN Off Out of order byte percentage

Scale
1 cell = 1 percent

Color to report count mapping

<table>
<thead>
<tr>
<th>Color</th>
<th>Count Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>&lt;= 0</td>
</tr>
<tr>
<td>Dark Red</td>
<td>1 - 105</td>
</tr>
<tr>
<td>Light Red</td>
<td>106 - 1,000</td>
</tr>
<tr>
<td>Yellow</td>
<td>1,001 - 10,000</td>
</tr>
<tr>
<td>Light Green</td>
<td>10,001 - 100,000</td>
</tr>
<tr>
<td>Med Green</td>
<td>100,001 - 500,000</td>
</tr>
<tr>
<td>Green</td>
<td>500,001 - 1,000,000</td>
</tr>
<tr>
<td>Dark Green</td>
<td>1,000,001 - 10,000,000</td>
</tr>
<tr>
<td>Light Blue</td>
<td>10,000,001 - 20,000,000</td>
</tr>
<tr>
<td>Med Blue</td>
<td>20,000,001 - 50,000,000</td>
</tr>
<tr>
<td>Dark Blue</td>
<td>50,000,001 - 152,560,669</td>
</tr>
</tbody>
</table>
Comparison of Out-of-order byte percentage

- 3 Billion reports from the field were used for this data representation
- Maximum heat is around 0 - 2 percentage
- Report count (heat) is distributed evenly or symmetrically along the diagonal for 0-100 percentage points
- Indicates that the percentage of out-of-order bytes is not worse for ECN connections than it is for Non-ECN connections
ECN Off Round Trip Time

Maximum Heat

Color to report count mapping

Scale
1 cell = 10 ms

<table>
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</tr>
</thead>
<tbody>
<tr>
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<td>&lt;= 0</td>
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<tr>
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<td>1 - 772</td>
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<tr>
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<td>773 - 1,000</td>
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<tr>
<td>Med Blue</td>
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</tr>
<tr>
<td>Dark Blue</td>
<td>50,000,001 - 57,561,044</td>
</tr>
</tbody>
</table>
Comparison of Round Trip Time

• 3 billion reports from the field were used for this representation

• Maximum heat is around 40 - 50 ms

• Again, there is symmetric distribution of report counts (heat) along the diagonal for different values of RTT

• Indicates that average RTT is not any worse for ECN connections because of ECN marking
Summary

• ECN negotiation is enabled on 50% of TCP connections on all Apple devices on Wi-Fi and ethernet interfaces

• No problems reported from the customers

• Observed increasing adoption

• Now is the time for deploying SQM with ECN marking in the network and enabling ECN negotiation on all servers