Explicit Congestion Notification

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ECN Web Page: http://www.aciri.org/floyd/ecn.html

The ECN field in the IPv4 TOS byte

```
   0     1     2     3     4     5     6     7
+-----+-----+-----+-----+-----+-----+-----+-----+
|          DIFFSERV                 | ECT | CE  |
+-----+-----+-----+-----+-----+-----+-----+-----+
```

- ECT: ECN-Capable Transport
- CE: Congestion Experienced

The semantics of the ECN-Capable Transport (ECT) Bit:

The ECT bit can be set in the packet by the sender if the end nodes:

- use some acceptable form of congestion control
  – (i.e., together respond to packet drops by acceptably reducing the arrival rate
  of this traffic at the congested link);

and

- in terms of the response to congestion:
  – agree to respond to a single packet with the CE bit set
  as they would respond to a single packet drop.

The Semantics of the Congestion Experienced (CE) bit:

A router's response to a packet arrival at a queue:

```
IF you would normally drop this packet:
   (e.g., from active queue management such as RED)
{
    IF: queue is not full or in danger of overflowing
       AND:  packet is marked ECN-Capable Transport (ECT)

    THEN:  SET the packet's CE bit.

    ELSE:  DROP the packet.
}
```

The semantics of the Congestion Experienced (CE) bit, cont.

- For routers that already support active queue management:
  - the software modification required to support ECN would be simple.

Benefits of ECN for TCP applications:

- Reduced number of unnecessary packet drops.

- Reduced time for the TCP receiver waiting for a retransmitted packet.

- Reduced time for the TCP sender to continue sending after a congestion event:
  - No waiting for a retransmit timer to expire.
  - No waiting for the receipt of three duplicate acknowledgements.
  - Quicker to begin recovery with the reduced sending rate.

Benefits of ECN for TCP applications:
Bulk data transfers.

• "Bulk data transfers": applications that care about the total transfer time for a large transfer.

• In experiments with Reno TCP [Ahmed 99]:

– ECN flows receive 10-60% more throughput than competing non-ECN flows (for drop rates from 2% to 10%).

– The *relative* advantage of ECN increases with increasing congestion (i.e., increasing drop probabilities).

– The *absolute* advantage of ECN decreases with increasing congestion.

– The ECN flows had very few retransmitted packets.

Benefits of ECN for TCP applications:
Short transfers.

- ECN is of greatest benefit for short transfers:
  - Fast recovery requires three duplicate acknowledgements.
  - Short transfers are more likely to have to wait for a retransmit timer.
- Can TCP be made more robust for small transfers even without ECN?
  - Yes, with responses to one or two duplicate acknowledgements.
  - But it is fundamental that the absence of ECN results in greater reliance on retransmit timeouts.

Experimental results concerning short transfers:

- In experiments with Reno TCP [Ahmed 99]:
  – For short 5 KB flows, ECN allows from 10% to 70% more transactions per second (for drop rates from 2% to 10%).

- From simulations in [Krishnan 98] showing the distribution of transfer times for short transfers:

  – A small fraction of the short transfers greatly benefit from the use of ECN.

  – These are transfers that have a packet dropped without ECN.

TCP implementations that support ECN:

- Linux. (Implementation by J. Hadi Salim, B. Nandy and N. Seddigh. Pointers on the ECN Web Page.)

- FreeBSD. (Implementation by Kenjiro Cho. Pointers on the ECN Web Page.)

Simulations and Experiments:

• [Floyd 94] Floyd, S., TCP and Explicit Congestion Notification, ACM Computer Communication Review, V. 24 N. 5, October 1994, p. 10-23. (Pointers on the ECN Web Page.)

• [Krishnan 98] Hariharan Krishnan, Analyzing Explicit Congestion Notification (ECN) benefits for TCP, Master's Thesis, UCLA, 1998. (Pointers on the ECN Web Page.)

• [Ahmed 99] Uviaz Ahmed and Jamal Hadi Salim, Performance Evaluation of Explicit Congestion Notification (ECN) in IP Networks, 1999.

The future:

- ECN for unreliable unicast or multicast applications:
  - End-to-end congestion control without unnecessary packet drops.
  - Minimizes the need for Forward Error Correction.
- ECN with reliable multicast applications:
  - Fewer packet retransmissions are needed, with their nontrivial overhead, delay, and potential for wasted bandwidth.
  - Receivers receive quick and unequivocal notification of congestion.

Summary:

- It would be easy for router vendors to add support for ECN.
- It would be a moderate amount of work to add support for ECN to TCP.
- No applications would be harmed by the addition of ECN.
- Some applications could have noticeable benefit from the addition of ECN.
- ECN-capable applications would not be unfairly competing with non-ECN-capable applications.

ECN and incentives for TCP applications to ignore congestion control:

• The presence of ECN does not make it easier for TCP applications or users to disable TCP congestion control.

• ECN would make it slightly more attractive for TCP applications to disable end-to-end congestion control (or to lie about being ECN-capable):
  – given an absence of network mechanisms to encourage end-to-end congestion control.

ECN and incentives for UDP applications to ignore congestion control:

- It is already easy for UDP applications to not use end-to-end congestion control.

- ECN would make it somewhat more attractive for UDP applications to not use end-to-end congestion control:
  - given an absence of network mechanisms to encourage end-to-end congestion control.

  - And given an absence of application-level FEC.

- Because the potential benefit of ECN is higher for unreliable applications, the potential for "cheating" is also higher.