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The Benefits to Applications of using Explicit Congestion Notification (ECN)

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Abstract

This document describes the potential benefits to applications when they enable Explicit Congestion Notification (ECN). It outlines the principal gains in terms of increased throughput, reduced delay and other benefits when ECN is used over network paths that include equipment that supports ECN-marking. The focus of this document is on usage of ECN, not its implementation in hosts, routers and other network devices.

Status of This Memo

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1. Introduction

Internet Transports (such as TCP and SCTP) have two ways to detect congestion: the loss of a packet and, if Explicit Congestion Notification (ECN) [RFC3168] is enabled, by reception of a packet with a Congestion Experienced (CE)-marking in the IP header. Both of these are treated by transports as indications of (potential) congestion. ECN may also be enabled by other transports. UDP applications may enable ECN when they are able to correctly process the ECN signals (e.g. ECN with RTP [RFC6679]).

When an application enables the use of ECN, the transport layer sets the ECT(0) or ECT(1) codepoint in the IP header of packets that it sends to indicate to routers that they may mark, rather than drop, packets in periods of congestion. This marking is generally performed by Active Queue Management (AQM) [RFC2309.bis] and may be the result of various AQM algorithms, where the exact combination of AQM/ECN algorithms is generally not known by the transport endpoints.

ECN makes it possible for the network to signal congestion without packet loss. This lets the network deliver some packets to an application that would otherwise have been dropped. This packet loss reduction is the most obvious benefit of ECN, but it is often relatively modest. However, enabling ECN can also result in a number of beneficial side-effects, some of which may be much more significant than the immediate packet loss reduction from ECN-marking instead of dropping packets.

The focus of this document is on usage of ECN, not its implementation in hosts, routers and other network devices. [RFC3168] describes a method in which a router, sets the CE codepoint of an ECN-Capable packet at the time that the router would otherwise have dropped the packet. While it has often been assumed that routers mark packets at the same level of congestion at which they would otherwise drop them, separate configuration of the drop and mark thresholds is known to be supported in some network devices and this is recommended in [RFC2309.bis].

Some benefits of ECN that are discussed rely upon routers marking packets at a lower level of congestion before they would otherwise drop packets from queue overflow [KH13].

Some of benefits are also only realised when the transport endpoint behaviour is also updated, this is discussed further in Section 5.

The remainder of this document discusses the potential for ECN to positively benefit an application without making specific assumptions about configuration or implementation.

2. ECN Deployment Scenarios / Use Cases

XXX to be written -- this section is intended to describe some specific example cases of where ECN has provided benefit XXX

3. Benefit of using ECN to avoid congestion loss

An application can benefit from using ECN in several ways:

3.1. Improved Throughput

ECN can improve the throughput performance of applications, although this increase in throughput offered by ECN is often not the most significant gain.

When an application uses a light to moderately loaded network path, the number of packets that are dropped due to congestion is small. Using an example from Table 1 of [RFC3649], for a standard TCP sender with a Round Trip Time, RTT, of 0.1 seconds, a packet size of 1500 bytes and an average throughput of 1 Mbps, the average packet drop ratio is 0.02. This translates into an approximate 2% throughput gain if ECN is enabled. In heavy congestion, packet loss may be unavoidable with, or without, ECN.

3.2. Reduced Head-of-Line Blocking

Many transports provide in-order delivery of received data to the applications they support. This requires that the transport stalls (or waits) for all data that was sent ahead of a particular segment to be correctly received before it can forward any later data. This is the usual requirement for TCP and SCTP. PR-SCTP [RFC3758], UDP, and DCCP [RFC4340] provide a transport that does not have this requirement.

Delaying data to provide in-order transmission to an application results in latency when segments are dropped as indications of congestion. The congestive loss creates a delay of at least one RTT for a loss event before data can be delivered to an application. We call this Head-of-Line (HOL) blocking.

In contrast, using ECN can remove the resulting delay for a loss that is a result of congestion:

- o First, the application receives the data normally - this also avoids dropping data that has already made it across at least part of the network path. This avoids the additional delay of waiting for recovery of the lost segment.

- o Second, the transport receiver notes the ECN-marked packets, and then requests the sender to make an appropriate congestion-response for future traffic.

3.3. Reduced Probability of RTO Expiry

ECN can help reduce the chance of the TCP or SCTP retransmission timer expiring (RTO expiry). When an application sends a burst of segments and then becomes idle (either because the application has no further data to send or the network prevents sending further data - e.g. flow or congestion control at the transport layer), the last segment of the burst may be lost. It is often not possible to recover the last segment (or last few segments) using standard methods such as Fast Recovery, since the receiver is unaware that the lost segments were actually sent.

ECN provides a mitigation when the loss is a result of (mild) congestion, since a router may mark, rather than drop, these segments - which benefits the application in a way similar to above, but with the significant additional benefit that this eliminates a retransmission event. The application benefits because:

- o Data is received without HOL blocking.

- o The transport does not suffer RTO expiry with consequent loss of state about the network path it is using. This would cause it to reset path estimates such as the RTT, the congestion window, and possibly other transport state that can reduce the performance of the transport until it adapts to the path again. This can improve the throughput of the application.

The benefit of avoiding reliance on an RTO-based retransmission event can be especially significant when ECN is used on TCP SYN/ACK packets as specified in [RFC5562] because in this case TCP cannot base its RTO for these packets on prior RTT measurements from the same connection.

3.4. Applications that do not retransmit lost packets

Certain latency-critical applications do not retransmit lost packets, yet they may be able to adjust the sending rate in the presence of congestion. Examples of such applications include UDP-based services that carry Voice over IP (VoIP), interactive video or real-time data. By decoupling congestion control from loss, ECN can allow such applications to reduce their rate before experiencing significant loss. Because this reduces the negative impact of using loss-hiding mechanisms (e.g. Packet forward error correction, or data duplication), ECN can have a direct positive impact on the quality experienced by the users of these applications.

4. Benefit from Early Congestion Detection

If ECN is configured such that routers mark packets at a lower level of congestion before they would otherwise drop packets from queue overflow, an application can benefit from using ECN in the following ways:

4.1. Avoiding Capacity Overshoot

ECN can help capacity probing algorithms (such as Slow Start) from significantly exceeding the bottleneck capacity of a network path. Since a transport that enables ECN can receive congestion signals before there is serious congestion, an early-marking method can help a transport respond before it induces significant congestion. For example, a TCP or SCTP sender can avoid incurring significant congestion during Slow Start, or a bulk application that tries to increase its rate as fast as possible, may detect the presence of congestion, causing it to reduce its rate.

Use of ECN is more effective than schemes such as Limited Slow-Start [RFC3742] because it provides direct information about the state of the network path. An ECN-enabled application probing for bandwidth can reduce its rate as soon as ECN-marked packets are detected, and before the applications increases its rate to the point where it builds a router queue that induces congestion loss. This benefits the application seeking to increase its rate - but perhaps more significantly, it eliminates the often unwanted loss and queueing delay that otherwise may be inflicted on flows that share a common bottleneck.

4.2. Making Congestion Visible

A characteristic of using ECN is that it exposes the presence of congestion on a network path to the transport and network layers. This information could be used for monitoring performance of the path, and could be used to directly meter the amount of congestion that has been encountered upstream on a path; metering packet loss is harder. This is used by Congestion Exposure (CoNex) [RFC6789].

Note: traffic that observes only congestion marks and no loss implies that a sender is experiencing only congestion and not other sources of packet loss (e.g. link corruption or loss in middleboxes). The converse is not true - a mixture of ECN-marks and loss may occur during only congestion or from a combination of packet loss and congestion.

5. Other forms of ECN-Marking/Reactions

The ECN mechanism defines both how packets are marked and transports need to react to markings. This section describes the benefits when updated methods are used.

Benefit has been noted when packets are marked earlier than they would otherwise be dropped, using an instantaneous queue, and if the receiver provides precise feedback about the number of packet marks encountered, a better sender behavior is possible. This has been shown by Datacenter TCP (DCTCP) [AL10].

Precise feedback about the number of packet marks encountered is supported by RTP over UDP [RFC6679] and proposed for SCTP [ST14] and TCP [KU13]. An underlying assumption of DCTCP is that it is deployed in confined environments such as a datacenter. It is currently unknown whether or how such behaviour could be introduced into the Internet.

6. Conclusion

People configuring host stacks and network devices should enable ECN.

Application developers should where possible use transports that enable the benefits of ECN. Once enabled, the benefits of ECN are provided by the transport layer and the application does not need to be rewritten to gain these benefits. Table 1 summarises some of these benefits.

Section	Benefit
2.1	Improved Throughput
2.2	Reduced Head-of-Line
2.3	Reduced Probability of RTO Expiry
2.4	Applications that do not retransmit lost packets
3.1	Avoiding Capacity Overshoot
3.2	Making Congestion Visible

Table 1: Summary of Key Benefits

7. Acknowledgements

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Comments are welcome to the authors or via the IETF AQM or TSVWG mailing lists.

8. IANA Considerations

XXRFC ED - PLEASE REMOVE THIS SECTION XXX

This memo includes no request to IANA.

9. Security Considerations

This document introduces no new security considerations. Each RFC listed in this document discusses the security considerations of the specification it contains.

10. References

10.1. Normative References

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