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Configuring UDP Sockets for ECN for Common Platforms draft-ietf-tsvwg-udp-ecn-04

Abstract

Explicit Congestion Notification (ECN) applies to all transport protocols in principle. However, it had limited deployment for UDP until QUIC became widely adopted. As a result, documentation of UDP socket APIs for ECN on various platforms is sparse. This document records the results of experimenting with these APIs in order to get ECN working on UDP for Chromium on Apple, Linux, and Windows platforms.

About This Document

This note is to be removed before publishing as an RFC.

The latest revision of this draft can be found at <https://tsvwg.github.io/udp-ecn/draft-ietf-tsvwg-udp-ecn.html>. Status information for this document may be found at <https://datatracker.ietf.org/doc/draft-ietf-tsvwg-udp-ecn/>.

Discussion of this document takes place on the Transport and Services Working Group Working Group mailing list (<mailto:tsvwg@ietf.org>), which is archived at <https://mailarchive.ietf.org/arch/browse/tsvwg/>. Subscribe at <https://www.ietf.org/mailman/listinfo/tsvwg/>.

Source for this draft and an issue tracker can be found at <https://github.com/tsvwg/udp-ecn>.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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Table of Contents

| | |
|---|----|
| 1. Introduction | 3 |
| 2. Conventions and Definitions | 4 |
| 3. Receiving ECN codepoints | 4 |
| 3.1. Setting the socket to report incoming ECN codepoints . . | 4 |
| 3.1.1. Linux, Apple, and FreeBSD | 4 |
| 3.1.2. Windows | 5 |
| 3.2. Retrieving ECN codepoints on incoming packets | 5 |
| 3.2.1. Linux | 5 |
| 3.2.2. Apple and FreeBSD | 6 |
| 3.2.3. Windows | 6 |
| 4. Sending ECN codepoints | 6 |
| 4.1. On a per-socket basis | 7 |
| 4.1.1. Linux and Apple | 7 |
| 4.1.2. Windows | 7 |
| 4.2. On a per-packet basis | 7 |
| 4.2.1. Linux and Apple | 7 |
| 4.2.2. Windows | 8 |
| 5. Security Considerations | 8 |
| 6. IANA Considerations | 8 |
| 7. References | 8 |
| 7.1. Normative References | 8 |
| 7.2. Informative References | 8 |
| Acknowledgments | 10 |
| Author's Address | 10 |

1. Introduction

[RFC3168] defines a two-bit field in the IP header for Explicit Congestion Notification (ECN), which provides network feedback to endpoint congestion controllers. This has historically mostly been relevant to TCP ([RFC9293]), where any incoming ECN codepoints are internally consumed by the kernel, and therefore imply no application interface except enabling and disabling the capability.

The Stream Control Transport Protocol (SCTP) ([RFC9260]) has long supported ECN in its design. SCTP is sometimes carried over DTLS and UDP ([RFC8261]). In principle, user-space implementers might have leveraged UDP ECN APIs to deliver ECN codepoints between SCTP and the UDP socket. At the time of publication, the TSV Working Group is not aware of any such efforts.

[RFC6679] defines ECN over RTP over UDP. The Working Group is aware of a research implementation, but cannot confirm any commercial deployments.

However, QUIC [RFC9000] runs over UDP and has seen wider deployment than SCTP. The Low Latency, Low Loss, Scalable Throughput (L4S) experiment ([RFC9330]) and QUIC have combined to increase interest in ECN over UDP.

The Chromium Projects ([CHROMIUM]) provide a widely-deployed protocol library that includes QUIC. An effort to provide ECN support for QUIC on the many platforms on which Chromium is deployed revealed that many ECN-related UDP socket interfaces are poorly documented.

This informational document provides a record of that experience, to encourage further support for ECN in other QUIC implementations, and indeed any consumer of ECN codepoints that operates over UDP. It is not a standards-track document and does not bind platforms to any API, or suggest any such API.

Many socket APIs continue to reference the "ToS (Type of Service) byte", including the IP_TOS label, even though [RFC2474] obsoleted that in 1998. That 8-bit field now contains a 6-bit Differentiated Services Code Point (DSCP) and the 2-bit ECN field.

This document focuses on the APIs for the C and C++ languages. Other languages are likely to have different syntax and capabilities.

2. Conventions and Definitions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

This document is not a general tutorial on UDP socket programming, and assumes familiarity with basic socket concepts like binding, socket options, and common system error codes.

Throughout this document, "Apple" refers to both MacOS and iOS.

3. Receiving ECN codepoints

Network devices can change the ECN codepoint in the IP header. Since this feedback is required at the packet sender, the packet receiver needs to extract this codepoint from the UDP socket in order to report to the sender.

There are two components to this: setting the socket to report incoming ECN marks, and retrieving the ECN codepoint for each incoming packet.

Note that Apple platforms additionally provide a framework for network connections that allows receiving ECN flags when using UDP without traditional socket option semantics. When sending or receiving UDP datagrams, IP protocol metadata carries ECN information in both directions. See [APPLE-NETWORK-FRAMEWORK].

3.1. Setting the socket to report incoming ECN codepoints

3.1.1. Linux, Apple, and FreeBSD

To report ECN, applications set a socket option to true using a `setsockopt()` call.

IPv6 sockets require a socket option of level `IPPROTO_IPV6` and name `IPV6_RECVTCLASS`.

IPv4 sockets require a socket option of level `IPPROTO_IP` and name `IP_RECVTOS`.

For dual-stack sockets, on Linux hosts the application sets both the `IPV6_RECVTCLASS` and `IP_RECVTOS` options to receive ECN codepoints on all incoming packets. On Apple and FreeBSD hosts, the application only sets the `IPPROTO_IPV6`-level socket option with name

IPV6_RECVTCLASS to receive codepoints for both v4 and v6; setting an IPPROTO_IP-level socket option on an IPv6 socket results in an error. In particular this applies to the IPPROTO_IP-level socket option with the name IP_RECVTOS.

At the time of writing, an example implementation can be found at [CHROMIUM-POSIX].

3.1.2. Windows

Windows documentation recommends using the function `WSASetRecvIPEcn()` to enable ECN reporting regardless of the IP version. This function dates to Windows 10 Build 20348, according to [WINDOWS-DOC].

However, this can also be accomplished by calling `setsockopt()` and using options of level `IPPROTO_IP` and name `IP_RECVECN` for IPv4, and `IPPROTO_IPV6` and `IPV6_RECVECN` for IPv6. These options are documented at [WINDOWS-SOCKOPT].

For dual-stack sockets, `WSASetRecvIPEcn()` will not enable ECN reporting for IPv4. This requires a separate `setsockopt()` call using the `IP_RECVECN` option.

If a socket is bound to a IPv6-mapped IPv4 address (i.e. it is of the format `::ffff:<IPv4 address>`), calls to `WSASetRecvIpEcn()` return error `EINVAL`. These sockets should instead use an explicit `setsockopt()` call to set `IP_RECVECN`.

At the time of writing, an example implementation can be found at [CHROMIUM-WINDOWS].

3.2. Retrieving ECN codepoints on incoming packets

All platforms described in this document require the use of a `recvmsg()` call to read data from the socket to retrieve ECN information, because that information is encoded in the control data that is returned from that function. Those platforms all return zero or more "cmsg" that contain requested information about the arriving packet.

Examples of the technique described below can be found at [CHROMIUM-POSIX] and [CHROMIUM-WINDOWS].

3.2.1. Linux

If the incoming packet is IPv4, Linux will include a cmsg of level `IPPROTO_IP` and type `IP_TOS`. The cmsg data contains an unsigned char.

If the incoming packet is IPv6, Linux will include a cmsg of level IPPROTO_IPV6 and type IPV6_TCLASS. The cmsg data contains an int.

The resulting report contains the entire IP header byte, which includes other fields. The ECN codepoint constitutes the two least-significant bits of this byte.

The same applies to the Linux-specific recvmmsg() call.

3.2.2. Apple and FreeBSD

If a UDP message (UDP/IPv4) is received on an IPv4 socket, the ancillary data will contain a cmsg of level IPPROTO_IP and type IP_RECVTOS. The cmsg data contains an unsigned char.

If a UDP message (UDP/IPv6 or UDP/IPv4) is received on an IPv6 socket, the ancillary data will contain a cmsg of level IPPROTO_IPV6 and type IPV6_TCLASS. The cmsg data contains an int.

The provided data is the entire byte from the IP header, which includes other fields. The ECN codepoint constitutes the two least-significant bits of this byte.

3.2.3. Windows

If the incoming packet is IPv4, the socket will include a cmsg of level IPPROTO_IP and type IP_ECN. The cmsg data contains an int.

If the incoming packet is IPv6, the socket will include a cmsg of level IPPROTO_IPV6 and type IPV6_ECN. The cmsg data contains an int.

The resulting integer solely consists of the ECN codepoint, and requires no further bitwise operations.

4. Sending ECN codepoints

Existing ECN specifications ([RFC3168], [RFC9330]) envision a particular connection consistently sending the same ECN codepoint. It might transition that marking after successfully completing a handshake, recognizing the path or the peer do not support ECN, or transitioning to a new path. Therefore, using a socket option to configure a consistent marking is generally more resource-efficient.

However, some server designs receive all incoming packets on a single socket. As the many connections that constitute this packet stream may have different support for ECN, it is suitable to configure outgoing ECN on a per-packet basis.

Note that Apple platforms additionally provide a framework for network connections that allows sending ECN flags when using UDP without traditional socket option semantics. When sending or receiving UDP datagrams, IP protocol metadata carries ECN information in both directions. See [APPLE-NETWORK-FRAMEWORK].

4.1. On a per-socket basis

4.1.1. Linux and Apple

Both Linux and Apple platforms set the outgoing ECN for IPv4 packets with a socket option of level IPPROTO_IP and name IP_TOS.

For IPv6 packets, they use level IPPROTO_IPV6 and name IPV6_TCLASS.

This setsockopt() call also sets the Differentiated Services Code Point (DSCP) bits that make up the rest of the header byte. Applications making this call will generally want to preserve any existing DSCP setting, which might require a getsockopt() call.

For dual-stack sockets, Linux requires an additional setsockopt() call with IP_TOS. Apple sockets do not and will return an error if this call is made.

An example of the technique described above can be found at [CHROMIUM-POSIX].

4.1.2. Windows

At the time of this writing, Windows does not provide a way to configure marking on a per-socket basis.

4.2. On a per-packet basis

Packets can be individually marked with ECN codepoints using the control information that accompanies a sendmsg() call.

4.2.1. Linux and Apple

These platforms expect a cmsg with level IPPROTO_IP and type IP_TOS if the destination is an IPv4 address, or a IPv4-mapped IPv6 address.

Otherwise, they expect a cmsg with level IPPROTO_IPV6 and type IPV6_TCLASS.

The same applies to the Linux-specific sendmmsg() call.

4.2.2. Windows

Windows uses a cmsg with level IPPROTO_IP and type IP_ECN for IPv4 packets.

Windows uses a cmsg with level IPPROTO_IPV6 and type IPV6_ECN for IPv6 packets.

An example of the technique described above can be found at [CHROMIUM-WINDOWS].

5. Security Considerations

The security implications of ECN are documented in [RFC3168] and [RFC9330]. This document is a guide to enabling these capabilities, which incurs no additional security considerations.

Note that implementing ECN capabilities on some platforms, but not others, can help peers identify the operating system in use by a host, which can have privacy implications. This document aims to mitigate that possibility.

6. IANA Considerations

This document has no IANA actions.

7. References

7.1. Normative References

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