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TCP User Timeout Option
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Abstract

This document specifies a new TCP option - the TCP User Timeout Option - that allows a TCP to advertise its current user timeout for a connection. Thus, the remote TCP may modify its local user timeout based on knowledge of the peer's user timeout. The TCP user timeout controls how long transmitted data may remain unacknowledged before a connection is forcefully closed. It is a local, per-connection parameter. Increasing the user timeouts allows established TCP

connections to survive extended periods of disconnection. Decreasing the user timeouts allows busy servers to explicitly notify their clients that they will maintain the connection state only across short periods of disconnection.

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1. Introduction

The Transmission Control Protocol (TCP) specification [RFC0793]defines a local, per-connection "user timeout" parameter that specifies the maximum amount of time that transmitted data may remain unacknowledged before TCP will forcefully close the corresponding connection. Applications can set and change this parameter with OPEN and SEND calls. If a network disconnection lasts longer than the user timeout, no acknowledgments will be received for any transmission attempt, including keep-alives [TCP-ILLU], and the TCP connection will close when the user timeout occurs. In the absence of an application-specified user timeout, the TCP specification [RFC0793] defines a default user timeout of 5 minutes.

The Host Requirements RFC [RFC1122] refines this definition by introducing two thresholds, R1 and R2 (R2 > R1), on the number of retransmissions of a single segment. It suggests that TCP should notify applications when R1 is reached for a segment, and close the connection once R2 is reached. [RFC1122] also defines the recommended values for R1 (three retransmissions) and R2 (100 seconds), noting that R2 for SYN segments should be at least 3 minutes. Instead of a single user timeout, some TCP implementations offer finer-grained policies. For example, Solaris supports different timeouts depending on whether a TCP connection is in the SYN-SENT, SYN-RECEIVED, or ESTABLISHED state [SOLARIS-MANUAL].

Although some TCP implementations allow applications to set their local user timeout, there is no in-protocol mechanism to signal changes in the local user timeout to remote peers. This causes local changes to be ineffective, because the peer will still close the connection after its user timeout expires, even when the host has raised its local user timeout. The ability to suggest the remote peer a user timeout to be used for the connection can improve TCP's operation in scenarios that are currently not well supported. One example of such scenarios are mobile hosts that change network attachment points based on current location. Such hosts, maybe using

MobileIP [RFC3344], HIP [RFC4423]or transport-layer mobility mechanisms [I-D.eddy-tcp-mobility], are only intermittently connected to the Internet. In between connected periods, mobile hosts may experience periods of disconnection during which no network service is available. Other factors that can cause transient periods of disconnection are high levels of congestion as well as link or routing failures inside the network.

In scenarios similar to the ones described above, a host may not know exactly when or for how long it will be disconnected from the network, but it might expect such events due to past mobility patterns and thus benefit from using longer user timeouts. In other

scenarios, the length and time of a network disconnection may even be predictable. For example, an orbiting node on a non-geostationary satellite might experience disconnections due to line-of-sight blocking by other planetary bodies. The disconnection periods of such a node may be easily computable from orbital mechanics.

This document specifies a new TCP option - the User Timeout Option (UTO) - that allows a TCP to advertise its current local user timeout parameter. Thus, based on the information advertised by the remote TCP peer, a TCP may modify its own user timeout accordingly. This allows, for example, mobile hosts to maintain TCP connections across disconnected periods that are longer than their peer's default user timeout. A second use of the TCP User Timeout Option is advertisement of shorter-than-default user timeouts. This can allow busy servers to explicitly notify their clients that they will maintain the state associated with established connections only across short periods of disconnection.

Use of the TCP User Timeout Option could be triggered either by an API call or by a system-wide toggle. The API could be, for example, a Socket option that would need to be explicitly set by the corresponding application. This option would default to "off". A system-wide toggle would allow a system administrator to enable the use of the TCP User Timeout Option on a system-wide basis, and set the option a desired value. This system-wide toggle would allow the use of the option by application programs that have not been explicitly coded to do so. If such a system-wide toggle were provided, it would default to "off".

In all cases, use of the TCP User Timeout Option would depend on an active decision, either by the application programmer (by means of an API call), or by a system administrator (by means of a system-wide toggle).

2. Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

3. Operation

Sending a TCP User Timeout Option informs the remote peer of the current local user timeout for the connection, and suggests the TCP peer to adapt its user timeout accordingly. The user timeout value included in a TCP User Timeout Option specifies the requested user

timeout during the synchronized states of a connection (ESTABLISHED, FIN-WAIT-1, FIN-WAIT-2, CLOSE-WAIT, CLOSING, or LAST-ACK). Connections in other states MUST the default timeout values defined in [RFC0793] [RFC1122].

Note that an exchange of TCP User Timeout Options between peers is not a binding negotiation. Transmission of a TCP User Timeout Option is an advisory suggestion that the peer consider adapting its local user timeout. Hosts remain free to adopt a different user timeout, or to forcefully close or abort connections at any time for any reason, whether or not they use custom user timeouts or have suggested the peer to use them.

A host that supports the TCP User Timeout Option SHOULD include one in each packet that carries a SYN flag, but need not. [MEDINA] has shown that unknown options are correctly handled by the vast majority of modern TCP stacks. It is thus not necessary to require negotiation of the use of the TCP User Timeout Option during the three-way handshake of a connection. However, including a TCP User Timeout Option in each segment that has the SYN flag set will result in TCP being able to adopt a user timeout with knowledge of that used by the peer TCP, since the beginning of the data transfer phase.

A host that supports the TCP User Timeout Option SHOULD include it in the next possible segment to its peer whenever it starts using a new user timeout for the connection. This allows the peer to adapt its local user timeout for the connection accordingly.

When a host that supports the TCP User Timeout Option receives one, it will use the received value to compute the local user timeout for the connection. Generally, hosts should honor requests for changes to the user timeout (see Section 3.1), unless security concerns, resource constraints or external policies indicate otherwise (see Section 5). If so, hosts may use a different user timeout for the connection.

A TCP implementation that does not support the TCP User Timeout Option MUST silently ignore it [RFC1122], thus ensuring interoperability.

Hosts MUST impose upper and lower limits on the user timeouts they use. Section 3.1 discusses user timeout limits, and describes a RECOMMENDED scheme to apply them. A TCP User Timeout Option with a value of zero (i.e., "now") is nonsensical and is used for a special purpose, see Section 3.4. Section 3.1 discusses potentially problematic effects of other user timeout durations.

3.1. Changing the Local User Timeout

When a host receives a TCP User Timeout Option, it must decide whether to change the local user timeout of the corresponding connection. Application-requested user timeout values always take precedence over timeout values received from the peer in a TCP User Timeout Option. [anchor3] Consequently, unless the application on the local host has requested a specific user timeout for the connection, e.g., through the OPEN or SEND calls, hosts SHOULD adjust their local user timeout in response to receiving a TCP User Timeout Option, as described in the remainder of this section. If the local application has requested a specific local user timeout, TCP implementations MUST NOT change it in response to receiving a TCP User Timeout Option. In this case, they SHOULD, however, notify the application about the user timeout value received from the peer.

The User Timeout Option specifies the user timeout in terms of time units, rather than in terms of number of retransmissions or round-trip times (RTTs), as in most cases the periods of disconnection have to do with operation and mobility patterns, rather than with the current network conditions. Thus, the TCP User Timeout Option allows hosts to exchange user timeout values from 1 second to over 9 hours at a granularity of seconds, and from 1 minute to over 22 days at a granularity of minutes. (An option value of zero is reserved for a special purpose, see Section 3.4.)

Very short user timeout values can affect TCP transmissions over high-delay paths. If the user timeout occurs before an acknowledgment for an outstanding segment arrives, possibly due to packet loss, the connection closes. Many TCP implementations default to user timeout values of a few minutes [TCP-ILLU]. Although the TCP User Timeout Option allows suggestion of short timeouts, applications advertising them should consider these effects.

Long user timeout values allow hosts to tolerate extended periods of disconnection. However, they also require hosts to maintain the TCP state information associated with connections for long periods of time. Section 5 discusses the security implications of long timeout values.

To protect against these effects, implementations MUST impose limits on the user timeout values they accept and use. The remainder of this section describes a RECOMMENDED scheme to limit user timeouts based on upper and lower limits. Under the RECOMMENDED scheme, each TCP SHOULD compute the user timeout (USER_TIMEOUT) for a connection according to this formula:

USER_TIMEOUT = min(U_LIMIT, max(LOCAL_UTO, REMOTE_UTO, L_LIMIT))

Each field is to be interpreted as follows:

USER_TIMEOUT
: Resulting user timeout value to be adopted by the local TCP for a connection.

U_LIMIT
: Current upper limit imposed on the user timeout of a connection by

the local host.

L_LIMIT
Current lower limit imposed on the user timeout of a connection by the local host.

LOCAL_UTO
Current local user timeout of this specific connection.

REMOTE_UTO
Last "user timeout" value suggested by the remote peer by means of the TCP User Timeout Option.

This means that, provided they are within the upper and lower limits, the maximum of the two announced values will be adopted for the user timeout of the connection. The rationale is that choosing the maximum of the two values will let the connection survive longer periods of disconnection. If the TCP that announced the lower of the two user timeout values did so in order to reduce the amount of TCP state information that must be kept on the host, it can, nevertheless, close or abort the connection whenever it wants.

It must be noted that the two endpoints of the connection will not necesarilly adopt the same user timeout.

Enforcing a lower limit (L_LIMIT) prevents connections from closing due to transient network conditions, including temporary congestion, mobility hand-offs and routing instabilities.

An upper limit (U_LIMIT) can reduce the effect of resource exhaustion attacks. Section 5discusses the details of these attacks.

Note that these limits MAY be specified as system-wide constants or at other granularities, such as on per-host, per-user or even per-connection basis. Furthermore, these limits need not be static. For example, they MAY be a function of system resource utilization or attack status and could be dynamically adapted.

The Host Requirements RFC [RFC1122] does not impose any limits on the length of the user timeout. However, a time interval of at least 100

seconds is RECOMMENDED. Consequently, the lower limit (L_LIMIT)

SHOULD be set to at least 100 seconds when following the RECOMMENDED scheme described in this section. Adopting a user timeout smaller than the current retransmission timeout (RTO) for the connection would likely cause the connection to be aborted unnecesarily. Therefore, the lower limit (L_LIMIT) MUST be larger than the current retransmission timeout (RTO) for the connection.

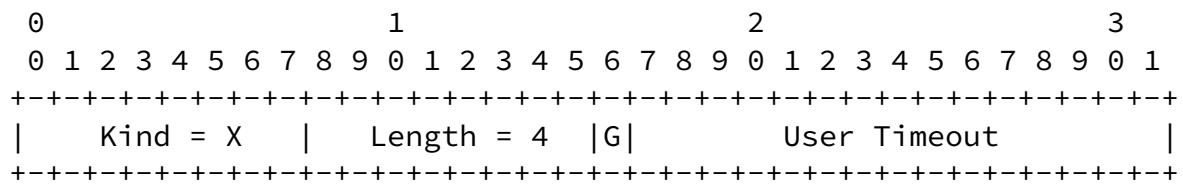
3.2. Reliability Considerations

The TCP User Timeout Option is an advisory TCP option that does not change processing of subsequent segments. Unlike other TCP options, it need not be exchanged reliably. Consequently, the specification in this section does not define a reliability handshake for TCP User Timeout Option exchanges. When a segment that carries a TCP User Timeout Option is lost, the option may never reach the intended peer.

Implementations MAY implement local mechanisms to improve delivery reliability, such as retransmitting the TCP User Timeout Option when they retransmit the segment that originally carried it, or "attaching" the option to a byte in the stream and retransmitting the option whenever that byte or its ACK are retransmitted.

It is important to note that although these mechanisms can improve transmission reliability for the TCP User Timeout Option, they do not guarantee delivery (a three-way handshake would be required for this). Consequently, implementations should not assume that a TCP User Timeout Option is reliably transmitted.

3.3. Option Format



(One tick mark represents one bit.)

Figure 1: Format of the TCP User Timeout Option

Figure 1 shows the format of the TCP User Timeout Option. It contains these fields:

Kind (8 bits)
A TCP option number [RFC0793] to be assigned by IANA upon publication of this document (see Section 6).

Length (8 bits)
Length of the TCP option in octets [RFC0793]; its value MUST be 4.

Granularity (1 bit)
Granularity bit, indicating the granularity of the "User Timeout" field. When set (G = 1), the time interval in the "User Timeout" field MUST be interpreted as minutes. Otherwise (G = 0), the time interval in the "User Timeout" field MUST be interpreted as seconds.

User Timeout (15 bits)
Specifies the user timeout suggestion for this connection. It MUST be interpreted as a 15-bit unsigned integer. The granularity of the timeout (minutes or seconds) depends on the "G" field.

3.4. Special Option Values

Whenever it is legal to do so according to the specification in the previous sections, TCP implementations MAY send a zero-second TCP User Timeout Option, i.e, with a "User Timeout" field of zero and a "Granularity" of zero. This signals their peers that they support the option, but do not suggest a specific user timeout value at that time. Essentially, a zero-second TCP User Timeout Option acts as a "don't care" value.

Thus, the sender SHOULD adapt its local user timeout according to the peer's UTO, and the receiver SHOULD continue using its local user timeout. In order to achieve this, the receiver of a zero-second TCP User Timeout Option SHOULD perform the RECOMMENDED strategy for calculating a new local USER_TIMEOUT described in Section 3.1, with a numeric value of zero seconds for REMOTE_UTO. The sender SHOULD perform the same calculation as described in Section 3.1, with a numeric value of zero seconds for LOCAL_UTO.

A zero-minute TCP User Timeout Option, i.e., with a "User Timeout" field of zero and a "Granularity" bit of one, is reserved for future use. TCP implementations MUST NOT send it and MUST ignore it upon reception.

4. Interoperability Issues

This section discusses interoperability issues related to introducing the TCP User Timeout Option.

4.1. Middleboxes

The large number of middleboxes (firewalls, proxies, protocol

scrubbers, etc.) currently present in the Internet pose some difficulty for deploying new TCP options. Some firewalls may block segments that carry unknown options, preventing connection establishment when the SYN or SYN-ACK segment contain a TCP User Timeout Option. Some recent results, however, indicate that for new TCP options, this may not be a significant threat, with only 0.2% of web requests failing when carrying an unknown option [MEDINA].

Stateful firewalls usually reset connections after a period of inactivity. If such a firewall exists along the path between two peers, it may close or abort connections regardless of the use of the TCP User Timeout Option. In the future, such firewalls may learn to parse the TCP User Timeout Option and modify their behavior or the option accordingly.

4.2. TCP Keep-Alives

Some TCP implementations, such as the one in BSD systems, use a different abort policy for TCP keep-alives than for user data. Thus, the TCP keep-alive mechanism might abort a connection that would otherwise have survived the transient period of disconnection. Therefore, if a TCP peer enables TCP keep-alives for a connection that is using the TCP User Timeout Option, then the keep-alive timer MUST be set to a value larger than that of the adopted USER TIMEOUT.

5. Security Considerations

Lengthening user timeouts has obvious security implications. Flooding attacks cause denial of service by forcing servers to commit resources for maintaining the state of throw-away connections. However, TCP implementations do not become more vulnerable to simple SYN flooding by implementing the TCP User Timeout Option, because user timeouts exchanged during the handshake only affect the synchronized states (ESTABLISHED, FIN-WAIT-1, FIN-WAIT-2, CLOSE-WAIT, CLOSING, LAST-ACK), which simple SYN floods never reach.

However, when an attacker completes the three-way handshakes of its throw-away connections it can amplify the effects of resource

exhaustion attacks, because the attacked server must maintain the connection state associated with the throw-away connections for longer durations. Because connection state is kept longer, lower-frequency attack traffic, which may be more difficult to detect, can already cause resource exhaustion.

Several approaches can help mitigate this issue. First, implementations can require prior peer authentication, e.g., using IPsec [RFC4301], before accepting long user timeouts for the peer's

connections. Similarly, a host can start to accept long user timeouts for an established connection only after in-band authentication has occurred, for example, after a TLS handshake across the connection has succeeded [RFC2246]. Although these are arguably the most complete solutions, they depend on external mechanisms to establish a trust relationship.

A second alternative that does not depend on external mechanisms would introduce a per-peer limit on the number of connections that may use increased user timeouts. Several variants of this approach are possible, such as fixed limits or shortening accepted user timeouts with a rising number of connections. Although this alternative does not eliminate resource exhaustion attacks from a single peer, it can limit their effects. Reducing the number of high-UTO connections a server supports in the face of an attack turns that attack into a denial-of-service attack against the service of high-UTO connections.

Per-peer limits cannot protect against distributed denial of service attacks, where multiple clients coordinate a resource exhaustion attack that uses long user timeouts. To protect against such attacks, TCP implementations could reduce the duration of accepted user timeouts with increasing resource utilization.

TCP implementations under attack may be forced to shed load by resetting established connections. Some load-shedding heuristics, such as resetting connections with long idle times first, can negatively affect service for intermittently connected, trusted peers that have suggested long user timeouts. On the other hand, resetting connections to untrusted peers that use long user timeouts may be effective. In general, using the peers' level of trust as a parameter during the load-shedding decision process may be useful.

Note that if TCP needs to close or abort connections with a long TCP User Timeout Option to shed load, these connections are still no worse off than without the option.

Finally, upper and lower limits on user timeouts, discussed in Section 3.1, can be an effective tool to limit the impact of these sorts of attacks.

6. IANA Considerations

This section is to be interpreted according to [RFC2434].

This document does not define any new namespaces. It uses an 8-bit TCP option number maintained by IANA at http://www.iana.org/assignments/tcp-parameters.

7. Acknowledgments

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8. References

8.1. Normative References

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Editorial Comments

[anchor3] Without this, UTO would modify TCP semantics, because application-requested UTOs could be overridden by peer requests.

Appendix A. Alternative solutions

The same benefits could be obtained through an application-layer mechanism, i.e., exchanging user timeout information via application messages and having the application adjust the user timeouts through the TCP API on both sides of a connection. This approach would not require a new TCP option, but would require changing all application implementations that desire to tolerate extended periods of disconnection, and in most cases would also require a modification to the corresponding application layer protocol. With the proposed TCP option, application changes may not be necessary at all, or may be restricted to sender- or receiver-side only, and there is no need to modify the corresponding application protocol.

A different approach to tolerate longer periods of disconnection would be to simply increase the system-wide user timeout on both peers. This approach has the benefit of not requiring a new TCP option or application changes. However, it can also significantly increase the amount of connection state a busy server must maintain, because a longer global timeout value would apply to all its connections.

The proposed TCP User Timeout Option, on the other hand, allows hosts to selectively manage the user timeouts of individual connections,

reducing the amount of state they must maintain across disconnected periods.

Appendix B. Document Revision History

To be removed upon publication

Revision	Comments

03	Corrected use of RFC2119 terminology. Clarified how use of the TCP UTO is triggered. Clarified reason for sending a UTO in the SYN and SYN/ACK segments. Removed discussion of the SO_SNDTIMEO and SO_RCVTIMEO options. Removed text that suggested that a UTO should be sent upon receipt of an UTO from the remote peer. Required minimum value for the lower limit of the user timeout. Moved alternative solutions to appendix. Miscellaneous editorial changes.
02	Corrected terminology by replacing terms like "negotiate", "coordinate", etc. that were left from pre-WG-document times when the UTO was a more formalized exchange instead of the advisory one it is now. Application-requested UTOs take precedence over ones received from the peer (pointed out by Ted Faber). Added a brief mention of SO_SNDTIMEO and a slightly longer discussion of SO_RCVTIMEO.
01	Clarified and corrected the description of the existing user timeout in RFC793 and RFC1122. Removed distinction between operating during the 3WHS and the established states and introduced zero-second "don't care" UTOs in response to mailing list feedback. Updated references and addressed many other comments from the mailing list.
00	Resubmission of draft-eggert-gont-tcpm-tcp-uto-option-01.txt to the secretariat after WG adoption. Thus, permit derivative works. Updated Lars Eggert's funding attribution. Updated several references. No technical changes.

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