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Path signals
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Abstract

TCP's state mechanics uses a series of well-known messages that are exchanged in the clear. Because these are visible to network elements on the path between the two nodes setting up the transport connection, they are often used as signals by those network elements or by administrators of these networks.

In transport protocols that do not exchange these messages in the clear, on-path network elements lack those signals. This document discusses the nature of the signals as they are seen by on-path elements and reflects on best practices for transport protocols which encrypt their state mechanics.

Status of This Memo

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This Internet-Draft will expire on June 3, 2018.

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1. Terminology

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 RFC 2119 [RFC2119].

2. Introduction

TCP [RFC0793] uses 3-way handshake messages to establish, maintain, and close connections. While these are primarily intended to create state between two communicating nodes, these handshake messages are visible to network elements along the path between them. It has been common over time for certain network elements to treat the exchanged messages as signals which related to their own functions.

A firewall may, for example, create a rule that allows traffic from a specific host IP address and port number to enter its network when the connection was

initiated by a host already within the network (Endpoint-dependent Filtering). It may subsequently remove that rule when the communication has ceased or upon the expiry of a lifetime. In the context of TCP handshake, it sets up the pinhole rule on seeing the initial TCP SYN acknowledged and then removes it upon seeing a RST or FIN & ACK exchange. Note that in this case it does nothing to re-write any portion of the TCP packet; it simply enables a return path that would otherwise have been blocked. Likewise, some translators may also follow such filtering behavior or adhere to less restrictive one such Endpoint-Independent Filtering.

When a transport protocol ~~-~~encrypts the headers it uses for state mechanics, the signal path elements inferred from examination is no longer available (e.g., initiate a connection, connection consent). Their behavior in its absence will depend on which signal is not available, on the default behavior configured by the path element administrator, and by the security posture of the network as a whole. The behavior may also depend whether an out-of-band mechanism is invoked to signal the required flow characteristics (e.g., [I-D.penno-pcp-asdn]). The document does not focus on such out-of-band signals.

3. Signals Type Inferred

The following list of signals which may be inferred from transport state messages includes those which may be exchanged during sessions establishment and those which derive from the ongoing flow. Some of these signals are derived from the direct examination of packet trains, such as using a sequence number gap pattern to infer network reliability; others are derived from association, such as inferring network latency by timing a flow's packet inter-arrival times. This list is not exhaustive, and it is not the full set of effects due to encrypting data ~~and metadata~~ in flight. Note as well that because these are derived from ~~inferenceee~~inference, they do not include any path signals which would not be relevant to the end point state machines; indeed, an inference-based system cannot send such signals.

3.1. Session ~~establishment~~Maintenance (establishment and termination)

One of the most basic inferences made by examination of transport state is that a packet will be part of an ongoing flow; that is, an established session will continue until ~~messages~~ appropriate signals are received that terminate it. On-~~Path~~ path elements may then make subsidiary inferences related to the session.

3.1.1. Session ~~identity~~Identity

On-p~~P~~ath elements that track sessions establishment will typically create

Mis en forme : Anglais (États Unis)

Commentaire [Med1]: These are data, after all.

a session identify for the flow, commonly using a transport coordinate tuple of the
visible information in the packet headers. This is then used to associate other information with the

Commentaire [Med2]: to be completed

3.1.2. ~~Routability~~ Reachability and Consent

A second common inference is that the session establishment provides ~~is~~ that the communicating pair of hosts can each reach each other and are interested in continuing communication.

The firewall example given above is a consequence of the inference of consent; because the internal host initiates the connection, it is presumed to consent to return traffic. That, in turn justifies the pinhole.

Some other on-path elements (e.g., NAT) assume that a host which asked to communicate with a remote address consents to establish incoming communications from any other host (Endpoint-Independent Mapping/ Endpoint-Independent Filtering). This is, for example, the default behavior in NAT64.

3.1.x Flow Stability

Some on-path devices that are responsible for load-sharing or load-balancing may be instructed to preserve the same path for a given flow, rather than dispatching packets belonging to the some flow on multiple paths that may presented performance distortion. For the particular case of TCP, this was critical given that firewalls that are located on distinct paths will systematically block connections if they don't observe the full 3WHS exchange.

3.1.3. Resource Requirements

An additional common inference is that network resources will be required for the session. These may be requirements within the network element itself, such as table entry space for a firewall or NAT; they may also be communicated by the network element to other systems.

For networks which use resource reservations, this might result in reservation of radio air time, energy, or network capacity.

3.2. Network Measurement

Some network elements will also use transport messages to engage in measurement to reflect the traffic performance characteristics of the paths which are used by flows on their network.
The list of measurements below is illustrative, not exhaustive.

3.2.1. Path Latency

There are several ways in which a network element may measure path latency using transport messages, but two common ones are examining exposed timestamps and associating sequence numbers with a local timer. These measurements are necessarily limited to measuring only the portion of the path between the system which assigned the timestamp or sequence number and the network element.

3.2.2. Path ~~reliability~~ Reliability and ~~consistency~~Consistency

A network element may also measure the reliability of a particular path segment by examining sessions which expose sequence numbers; retransmissions and gaps are then associated with the path segments on which they might have occurred.

4. Options

The set of options below are alternatives which optimize very different things. Though it comes to a preliminary conclusion, this ~~draft~~ document intends to foster a discussion of those tradeoffs and any discussion of them must be understood as preliminary.

4.1. Do not restore these signals

It is possible, of course, to do nothing. The transport messages were not necessarily intended for consumption by on-path network elements and encrypting them so they are not visible may be taken by some as a benefit. Each network element would then treat packets without these visible elements according to its own defaults. While our experience of that is not extensive, one consequence has been that state tables for flows of this type are generally not kept as long as those for which sessions are identifiable. The result is that heartbeat traffic must be maintained to keep any bindings (e.g. NAT or firewall) from early expiry. When those bindings are not kept, methods like QUIC's connection-id [I-D.ietf-quic-transport] may be necessary to allow ~~load~~ load-balancers or other systems to continue to maintain a flow's path to the appropriate peer.

4.2. Replace these with network layer signals

It would be possible to replace these implicit signals with explicit signals at the network layer. Though IPv4 has relatively few facilities for this, IPv6 hop-by-hop headers [RFC7045] might suit this purpose. Further examination of the deployability of these headers may be required.

4.3. Replace these with per-transport signals

It is possible to replace these implicit signals with signals that are tailored to specific transports, just as the initial signals are derived primarily from TCP. There is a risk here that the first transport which develops these will be reused for many purposes outside its stated purpose, simply because it traverses NATs and firewalls better than other traffic. If done with an explicit intent to re-use the elements of the solution in other transports, the risk of ossification might be slightly lower.

4.4. Create a set of signals common to multiple transports

Several proposals use UDP [RFC0768] as a demux layer, onto which new transport semantics are layered. For those transports, it may be possible to build a common signalling mechanism and set of signals, such as that proposed in "Transport-Independent Path Layer State Management" [I-D.trammell-plus-statefulness].

This may be taken as a variant of the re-use of common elements mentioned in the section above, but it has a greater chance of avoiding the ossification of the solution into the first moving protocol.

5. Recommendation

Fundamentally, this paper recommends that implicit signals should be replaced with explicit signals, but that a signal should be exposed to the path only when the signal's originator intends that it be used by the network elements on the path. For many flows, that may result in signal being absent, but it allows them to be present when needed.

Discussion of the appropriate mechanism(s) for these signals is continuing but, at minimum, any method should meet the principles set out in the security considerations below.

6. IANA Considerations

This document contains no requests for IANA.

7. Security Considerations

Path-visible signals allow network elements along the path to act based on the signaled information, whether the signal is implicit or explicit. If the network element is controlled by an attacker, those actions can include dropping, delaying, or mishandling the constituent packets of a flow. It may also characterize the flow or attempt to fingerprint the communicating nodes based on the pattern of signals.

Note that actions that do not benefit the flow or the network may be perceived as an attack even if they are conducted by a responsible network element. Designing a system that minimizes the ability to act on signals at all by removing as many signals as possible may reduce this possibility. This approach also comes with risks, principally that the actions will continue to take place on an arbitrary set of flows.

Addition of visible signals to the path also increases the information available to an observer and may, when the information can be linked to a node or user, reduce the privacy of the user.

This document recommends three basic principles:

- Cryptographic contexts should be available on any flow, derived from ubiquitous end-system cryptographic capabilities. That context should cover the portion of protocol signaling that is ~~intended~~intended for end system state machines.

- Anything exposed to the path should be done with the intent that it be used by the network elements on the path.

- Intermediate path elements should not add visible signals which identify the user, origin node, or origin network [RFC8164].

8. Acknowledgements

In addition to the editor listed above, this document incorporates contributions from Brian Trammel, Mirja Kuehlwind, and Joe Hildebrand. These ideas were also discussed at the PLUS BoF, sponsored by Spencer Dawkins. The ideas around the use of IPv6 hop-by-hop headers as a network layer signal benefited from discussions with Tom Herbert. The description of UDP as a demuxing protocol comes from Stuart Cheshire.

All errors are those of the editor.

9. References

9.1. Normative References

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9.2. Informative References

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