                   Recommended Simple Security Capabilities in
                     Customer Premises Equipment (CPE) for
                   Providing Residential IPv6 Internet Service

Abstract

   This document identifies a set of recommendations for the makers of
   devices and describes how to provide for "simple security"
   capabilities at the perimeter of local-area IPv6 networks in
   Internet-enabled homes and small offices.

Status of This Memo

   This document is not an Internet Standards Track specification; it is
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   Standard; see Section 2 of RFC 5741.

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1. Introduction

   Some IPv6 gateway devices that enable delivery of Internet services
   in residential and small-office settings may be augmented with
   "simple security" capabilities as described in "Local Network
   Protection for IPv6" [RFC4864]. In general, these capabilities cause
   packets to be discarded in an attempt to make local networks and the
   Internet more secure. However, it is worth noting that some packets
   sent by legitimate applications may also be discarded in this
   process, affecting reliability and ease of use for these
   applications.

   There is a constructive tension between the desires of users for
   transparent end-to-end connectivity on the one hand, and the need for
   local-area network administrators to detect and prevent intrusion by
   unauthorized public Internet users on the other. This document is
   intended to highlight reasonable limitations on end-to-end
   transparency where security considerations are deemed important to
   promote local and Internet security.

   The reader is cautioned always to remember that the typical
   residential or small-office network administrator has no expertise
   whatsoever in Internet engineering. Configuration interfaces for
   router/gateway appliances marketed toward them should be easy to
   understand and even easier to ignore. In particular, extra care
   should be used in the design of baseline operating modes for
   unconfigured devices, since most devices will never be changed from
   their factory configurations.

1.1. Special Language

   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].

   Additionally, the key word "DEFAULT" is to be interpreted in this
   document as pertaining to a configuration as applied by a vendor,
   prior to the administrator changing it for its initial activation.

1.2. Use of Normative Keywords

      NOTE WELL: This document is not a standard, and conformance with
      it is not required in order to claim conformance with IETF
      standards for IPv6. It uses the normative keywords defined in the
      previous section only for precision.

   Particular attention is drawn to recommendation REC-49, which calls
   for an easy way to set a gateway to a transparent mode of operation.

2. Overview

   For the purposes of this document, residential Internet gateways are
   assumed to be fairly simple devices with a limited subset of the full
   range of possible features. They function as default routers
   [RFC4294] for a single local-area network, e.g., an Ethernet network,
   a Wi-Fi network, or a bridge between two or more such segments. They
   have only one interface by which they can access the Internet service
   at any one time, using any of several possible sub-IP mechanisms,
   including tunnels and transition mechanisms.

   In referring to the security capabilities of residential gateways, it
   is reasonable to distinguish between their "interior" network, i.e.,
   the local-area network, and their "exterior" networks, e.g., the
   public Internet and the networks of Internet service providers. This
   document is concerned only with the behavior of IP packet filters
   that police the flow of traffic between the interior IPv6 network and
   the exterior IPv6 networks of residential Internet gateways.

   The operational goals of security capabilities in Internet gateways
   are described with more detail in "Local Network Protection for IPv6"
   [RFC4864], but they can be summarized as follows.

   o Check all traffic to and from the public Internet for basic
      sanity, e.g., filter for spoofs and misdirected (sometimes called
      "Martian") packets [RFC4949].

   o Allow tracking of application usage by source and destination
      network addresses and ports.

   o Provide a barrier against untrusted external influences on the
      interior network by requiring filter state to be activated by
      traffic originating at interior network nodes.

   o Allow manually configured exceptions to the stateful filtering
      rules according to network administrative policy.

   o Isolate local network DHCPv6 and DNS resolver services from the
      public Internet.

   Prior to the widespread availability of IPv6 Internet service, homes
   and small offices often used private IPv4 network address realms
   [RFC1918] with Network Address Translation (NAT) functions deployed
   to present all the hosts on the interior network as a single host to

the Internet service provider. The stateful packet filtering
behavior of NAT set user expectations that persist today with
residential IPv6 service. "Local Network Protection for IPv6"
[RFC4864] recommends applying stateful packet filtering at
residential IPv6 gateways that conforms to the user expectations
already in place.

Conventional stateful packet filters activate new states as a side
effect of forwarding outbound flow initiations from interior network
nodes. This requires applications to have advance knowledge of the
addresses of exterior nodes with which they expect to communicate.
Several proposals are currently under consideration for allowing
applications to solicit inbound traffic from exterior nodes without
advance knowledge of their addresses. While consensus within the
Internet engineering community has emerged that such protocols are
necessary to implement in residential IPv6 gateways, the best current
practice has not yet been established.

2.1. Basic Sanitation

In addition to the functions required of all IPv6 routers [RFC4294],
residential gateways are expected to have basic stateless filters for
prohibiting certain kinds of traffic with invalid headers, e.g.,
"Martian" packets, spoofs, routing header type code zero, etc. (See
Section 3.1 for more details.)

Conversely, simple Internet gateways are not expected to prohibit the
development of new applications. In particular, packets with end-to-
end network security and routing extension headers for mobility are
expected to pass Internet gateways freely.

Finally, Internet gateways that route multicast traffic are expected
to implement appropriate filters for multicast traffic to limit the
scope of multicast groups that span the demarcation between
residential networks and service provider networks.

2.2. Internet Layer Protocols

As virtual private networking tunnels are regarded as an unacceptably
wide attack surface, this document recommends that the DEFAULT
operating mode for residential IPv6 simple security be to treat
Generic Packet Tunneling [RFC2473] and similar protocols as opaque
transport layers, i.e., inbound tunnel initiations are denied and
outbound tunnel initiations are accepted.

IPsec transport and tunnel modes are explicitly secured by
definition, so this document recommends that the DEFAULT operating
mode permit IPsec. To facilitate the use of IPsec in support of IPv6

   mobility, the Internet Key Exchange (IKE) protocol [RFC5996] and the
   Host Identity Protocol (HIP) [RFC5201] should also be permitted in
   the DEFAULT operating mode.

2.3. Transport Layer Protocols

   IPv6 simple security functions are principally concerned with the
   stateful filtering of the Internet Control Message Protocol (ICMPv6)
   [RFC4443] and transport layers like the User Datagram Protocol (UDP)
   [RFC0768], the Lightweight User Datagram Protocol (UDP-Lite)
   [RFC3828], the Transmission Control Protocol (TCP) [RFC0793], the
   Stream Control Transmission Protocol (SCTP) [RFC4960], the Datagram
   Congestion Control Protocol (DCCP) [RFC4340], and potentially any
   standards-track transport protocols to be defined in the future.

   The general operating principle is that transport layer traffic is
   not forwarded into the interior network of a residential IPv6 gateway
   unless it has been solicited explicitly by interior transport
   endpoints, e.g., by matching the reverse path for previously
   forwarded outbound traffic, or by matching configured exceptions set
   by the network administrator. All other traffic is expected to be
   discarded or rejected with an ICMPv6 error message to indicate the
   traffic is administratively prohibited.

3. Detailed Recommendations

   This section describes the specific recommendations made by this
   document in full detail. Section 4 is a summary.

   Some recommended filters are to be applied to all traffic that passes
   through residential Internet gateways regardless of the direction
   they are to be forwarded. Other recommended filters are intended to
   be sensitive to the "direction" of traffic flows. Applied to
   bidirectional transport flows, "direction" has a specific meaning in
   this document.

   Packets are said to be "outbound" if they originate at nodes located
   in the interior network for exterior destinations, and "inbound" if
   they arrive from exterior sources with interior destinations.

   Flows are said to be "outbound" if the originator of the initial
   packet in any given transport association is an interior node and one
   or more of the participants are located in the exterior. Flows are
   said to be "inbound" if the originator of the initial packet is an
   exterior node and one or more of the participants are nodes on the
   interior network.

3.1. Stateless Filters

   Certain kinds of IPv6 packets MUST NOT be forwarded in either
   direction by residential Internet gateways regardless of network
   state. These include packets with multicast source addresses,
   packets to destinations with certain non-routable and/or reserved
   prefixes, and packets with deprecated extension headers.

   Other stateless filters are recommended to implement ingress
   filtering (see [RFC2827] and [RFC3704]), to enforce multicast scope
   boundaries, and to isolate certain local network services from the
   public Internet.

   REC-1: Packets bearing multicast source addresses in their outer IPv6
   headers MUST NOT be forwarded or transmitted on any interface.

   REC-2: Packets bearing multicast destination addresses in their outer
   IPv6 headers of equal or narrower scope (see "IPv6 Scoped Address
   Architecture" [RFC4007]) than the configured scope boundary level of
   the gateway MUST NOT be forwarded in any direction. The DEFAULT
   scope boundary level SHOULD be organization-local scope, and it
   SHOULD be configurable by the network administrator.

   REC-3: Packets bearing source and/or destination addresses forbidden
   to appear in the outer headers of packets transmitted over the public
   Internet MUST NOT be forwarded. In particular, site-local addresses
   are deprecated by [RFC3879], and [RFC5156] explicitly forbids the use
   of address blocks of types IPv4-Mapped Addresses, IPv4-Compatible
   Addresses, Documentation Prefix, and Overlay Routable Cryptographic
   Hash IDentifiers (ORCHID).

   REC-4: Packets bearing deprecated extension headers prior to their
   first upper-layer-protocol header SHOULD NOT be forwarded or
   transmitted on any interface. In particular, all packets with
   routing extension header type 0 [RFC2460] preceding the first upper-
   layer-protocol header MUST NOT be forwarded. See [RFC5095] for
   additional background.

   REC-5: Outbound packets MUST NOT be forwarded if the source address
   in their outer IPv6 header does not have a unicast prefix configured
   for use by globally reachable nodes on the interior network.

   REC-6: Inbound packets MUST NOT be forwarded if the source address in
   their outer IPv6 header has a global unicast prefix assigned for use
   by globally reachable nodes on the interior network.

REC-7: By DEFAULT, packets with unique local source and/or
destination addresses [RFC4193] SHOULD NOT be forwarded to or from
the exterior network.

REC-8: By DEFAULT, inbound DNS queries received on exterior
interfaces MUST NOT be processed by any integrated DNS resolving
server.

REC-9: Inbound DHCPv6 discovery packets [RFC3315] received on
exterior interfaces MUST NOT be processed by any integrated DHCPv6
server or relay agent.

NOTE WELL: Nothing in this document relieves residential Internet
gateways, when processing headers to identify valid sequences of
upper-layer transport packets, from any of the requirements of the
"Internet Protocol, Version 6 (IPv6) Specification" [RFC2460],
including any and all future updates and revisions.

3.2. Connection-Free Filters

Some Internet applications use connection-free transport protocols
with no release semantics, e.g., UDP. These protocols pose a special
difficulty for stateful packet filters because most of the
application state is not carried at the transport level. State
records are created when communication is initiated and are abandoned
when no further communication is detected after some period of time.

3.2.1. Internet Control and Management

Recommendations for filtering ICMPv6 messages in firewall devices are
described separately in [RFC4890] and apply to residential gateways,
with the additional recommendation that incoming "Destination
Unreachable" and "Packet Too Big" error messages that don't match any
filtering state should be dropped.

REC-10: IPv6 gateways SHOULD NOT forward ICMPv6 "Destination
Unreachable" and "Packet Too Big" messages containing IP headers that
do not match generic upper-layer transport state records.

3.2.2. Upper-Layer Transport Protocols

Residential IPv6 gateways are not expected to prohibit the use of
applications to be developed using future upper-layer transport
protocols. In particular, transport protocols not otherwise
discussed in subsequent sections of this document are expected to be
treated consistently, i.e., as having connection-free semantics and
no special requirements to inspect the transport headers.

In general, upper-layer transport filter state records are expected
to be created when an interior endpoint sends a packet to an exterior
address. The filter allocates (or reuses) a record for the duration
of communications, with an idle timer to delete the state record when
no further communications are detected.

One key aspect of how a packet filter behaves is the way it evaluates
the exterior address of an endpoint when applying a filtering rule.
A gateway is said to have "endpoint-independent filtering" behavior
when the exterior address is not evaluated when matching a packet
with a flow. A gateway is said to have "address-dependent filtering"
behavior when the exterior address of a packet is required to match
the exterior address for its flow.

REC-11: If application transparency is most important, then a
stateful packet filter SHOULD have "endpoint-independent filtering"
behavior for generic upper-layer transport protocols. If a more
stringent filtering behavior is most important, then a filter SHOULD
have "address-dependent filtering" behavior. The filtering behavior
MAY be an option configurable by the network administrator, and it
MAY be independent of the filtering behavior for other protocols.
Filtering behavior SHOULD be endpoint independent by DEFAULT in
gateways intended for provisioning without service-provider
management.

REC-12: Filter state records for generic upper-layer transport
protocols MUST NOT be deleted or recycled until an idle timer not
less than two minutes has expired without having forwarded a packet
matching the state in some configurable amount of time. By DEFAULT,
the idle timer for such state records is five minutes.

The Internet security community is never completely at rest. New
attack surfaces, and vulnerabilities in them, are typically
discovered faster than they can be patched by normal equipment
upgrade cycles. It's therefore important for vendors of residential
gateway equipment to provide automatic software updates to patch
vulnerabilities as they are discovered.

REC-13: Residential IPv6 gateways SHOULD provide a convenient means
to update their firmware securely, for the installation of security
patches and other manufacturer-recommended changes.

Vendors can expect users and operators to have differing viewpoints
on the maintenance of patches, with some preferring automatic update
and some preferring manual procedures. Those preferring automatic
update may also prefer either to download from a vendor site or from
one managed by their network provider. To handle the disparity,
vendors are advised to provide both manual and automatic options. In

the automatic case, they would do well to facilitate
pre-configuration of the download URL and a means of validating the
software image, such as a certificate.

3.2.3. UDP Filters

"Network Address Translation (NAT) Behavioral Requirements for
Unicast UDP" [RFC4787] defines the terminology and best current
practice for stateful filtering of UDP applications in IPv4 with NAT,
which serves as the model for behavioral requirements for simple UDP
security in IPv6 gateways, notwithstanding the requirements related
specifically to network address translation.

An interior endpoint initiates a UDP flow through a stateful packet
filter by sending a packet to an exterior address. The filter
allocates (or reuses) a filter state record for the duration of the
flow. The state record defines the interior and exterior IP
addresses and ports used between all packets in the flow.

State records for UDP flows remain active while they are in use and
are only abandoned after an idle period of some time.

REC-14: A state record for a UDP flow where both source and
destination ports are outside the well-known port range
(ports 0-1023) MUST NOT expire in less than two minutes of idle time.
The value of the UDP state record idle timer MAY be configurable.
The DEFAULT is five minutes.

REC-15: A state record for a UDP flow where one or both of the source
and destination ports are in the well-known port range (ports 0-1023)
MAY expire after a period of idle time shorter than two minutes to
facilitate the operation of the IANA-registered service assigned to
the port in question.

As [RFC4787] notes, outbound refresh is necessary for allowing the
interior endpoint to keep the state record alive. Inbound refresh
may be useful for applications with no outbound UDP traffic.
However, allowing inbound refresh can allow an attacker in the
exterior or a misbehaving application to keep a state record alive
indefinitely. This could be a security risk. Also, if the process
is repeated with different ports, over time, it could use up all the
state record memory and resources in the filter.

REC-16: A state record for a UDP flow MUST be refreshed when a packet
is forwarded from the interior to the exterior, and it MAY be
refreshed when a packet is forwarded in the reverse direction.

As described in Section 5 of [RFC4787], the connection-free semantics
of UDP pose a difficulty for packet filters in trying to recognize
which packets comprise an application flow and which are unsolicited.
Various strategies have been used in IPv4/NAT gateways with differing
effects.

REC-17: If application transparency is most important, then a
stateful packet filter SHOULD have "endpoint-independent filtering"
behavior for UDP. If a more stringent filtering behavior is most
important, then a filter SHOULD have "address-dependent filtering"
behavior. The filtering behavior MAY be an option configurable by
the network administrator, and it MAY be independent of the filtering
behavior for TCP and other protocols. Filtering behavior SHOULD be
endpoint independent by DEFAULT in gateways intended for provisioning
without service-provider management.

Application mechanisms may depend on the reception of ICMPv6 error
messages triggered by the transmission of UDP messages. One such
mechanism is path MTU discovery [RFC1981].

REC-18: If a gateway forwards a UDP flow, it MUST also forward ICMPv6
"Destination Unreachable" and "Packet Too Big" messages containing
UDP headers that match the flow state record.

REC-19: Receipt of any sort of ICMPv6 message MUST NOT terminate the
state record for a UDP flow.

REC-20: UDP-Lite flows [RFC3828] SHOULD be handled in the same way as
UDP flows, except that the upper-layer transport protocol identifier
for UDP-Lite is not the same as UDP; therefore, UDP packets MUST NOT
match UDP-Lite state records, and vice versa.

3.2.4. IPsec and Internet Key Exchange (IKE)

The Internet Protocol security (IPsec) suite offers greater
flexibility and better overall security than the simple security of
stateful packet filtering at network perimeters. Therefore,
residential IPv6 gateways need not prohibit IPsec traffic flows.

REC-21: In their DEFAULT operating mode, IPv6 gateways MUST NOT
prohibit the forwarding of packets, to and from legitimate node
addresses, with destination extension headers of type "Authentication
Header (AH)" [RFC4302] in their outer IP extension header chain.

REC-22: In their DEFAULT operating mode, IPv6 gateways MUST NOT
prohibit the forwarding of packets, to and from legitimate node
addresses, with an upper-layer protocol of type "Encapsulating
Security Payload (ESP)" [RFC4303] in their outer IP extension header
chain.

REC-23: If a gateway forwards an ESP flow, it MUST also forward (in
the reverse direction) ICMPv6 "Destination Unreachable" and "Packet
Too Big" messages containing ESP headers that match the flow state
record.

Internet Key Exchange (IKE) is a secure mechanism for performing
mutual authentication, exchanging cryptographic material, and
establishing IPsec Security Associations between peers. Residential
IPv6 gateways are expected to facilitate the use of IPsec security
policies by allowing inbound IKE flows.

REC-24: In their DEFAULT operating mode, IPv6 gateways MUST NOT
prohibit the forwarding of any UDP packets, to and from legitimate
node addresses, with a destination port of 500, i.e., the port
reserved by IANA for the Internet Key Exchange (IKE) protocol
[RFC5996].

REC-25: In all operating modes, IPv6 gateways SHOULD use filter state
records for Encapsulating Security Payload (ESP) [RFC4303] that are
indexable by a 3-tuple comprising the interior node address, the
exterior node address, and the ESP protocol identifier. In
particular, the IPv4/NAT method of indexing state records also by the
security parameters index (SPI) SHOULD NOT be used. Likewise, any
mechanism that depends on detection of Internet Key Exchange (IKE)
[RFC5996] initiations SHOULD NOT be used.

The Host Identity Protocol (HIP) is a secure mechanism for
establishing host identity and secure communications between
authenticated hosts. Residential IPv6 gateways need not prohibit
inbound HIP flows.

REC-26: In their DEFAULT operating mode, IPv6 gateways MUST NOT
prohibit the forwarding of packets, to and from legitimate node
addresses, with destination extension headers of type "Host Identity
Protocol (HIP)" [RFC5201] in their outer IP extension header chain.

3.2.5. Mobility Support in IPv6

Mobility support in IPv6 [RFC3775] relies on the use of an
encapsulation mechanism in flows between mobile nodes and their
correspondent nodes, involving the use of the Type 2 IPv6 Routing
Header, the Home Address destination header option, and the Mobility

extension header. In contrast to mobility support in IPv4, mobility
is a standard feature of IPv6, and no security benefit is generally
to be gained by denying communications with either interior or
exterior mobile nodes.

Not all usage scenarios of mobility support in IPv6 are expected to
be compatible with IPv6 simple security. In particular, exterior
mobile nodes are expected to be prohibited from establishing bindings
with interior correspondent nodes by the filtering of unsolicited
inbound Mobility Header messages, unless they are the subject of an
IPsec security policy.

REC-27: The state records for flows initiated by outbound packets
that bear a Home Address destination option [RFC3775] are
distinguished by the addition of the home address of the flow as well
as the interior care-of address. IPv6 gateways MUST NOT prohibit the
forwarding of any inbound packets bearing type 2 routing headers,
which otherwise match a flow state record, and where A) the address
in the destination field of the IPv6 header matches the interior
care-of address of the flow, and B) the Home Address field in the
Type 2 Routing Header matches the home address of the flow.

REC-28: Valid sequences of Mobility Header [RFC3775] packets MUST be
forwarded for all outbound and explicitly permitted inbound Mobility
Header flows.

REC-29: If a gateway forwards a Mobility Header [RFC3775] flow, then
it MUST also forward, in both directions, the IPv4 and IPv6 packets
that are encapsulated in IPv6 associated with the tunnel between the
home agent and the correspondent node.

REC-30: If a gateway forwards a Mobility Header [RFC3775] flow, then
it MUST also forward (in the reverse direction) ICMPv6 "Destination
Unreachable" and "Packet Too Big" messages containing any headers
that match the associated flow state records.

3.3. Connection-Oriented Filters

Most Internet applications use connection-oriented transport
protocols with orderly release semantics. These protocols include
TCP, SCTP, DCCP, and potentially any future IETF Standards-Track
transport protocols that use such semantics. Stateful packet filters
track the state of individual transport flows and prohibit the
forwarding of packets that do not match the state of an active flow
and do not conform to a rule for the automatic creation of such
state.

3.3.1. TCP Filters

An interior endpoint initiates a TCP flow through a stateful packet
filter by sending a SYN packet. The filter allocates (or reuses) a
filter state record for the flow. The state record defines the
interior and exterior IP addresses and ports used for forwarding all
packets for that flow.

Some peer-to-peer applications use an alternate method of connection
initiation termed "simultaneous-open" ([RFC0793], Figure 8) to
traverse stateful filters. In the simultaneous-open mode of
operation, both peers send SYN packets for the same TCP flow. The
SYN packets cross in the network. Upon receiving the other end's SYN
packet, each end responds with a SYN-ACK packet, which also cross in
the network. The connection is established at each endpoint once the
SYN-ACK packets are received.

To provide stateful packet filtering service for TCP, it is necessary
for a filter to receive, process, and forward all packets for a flow
that conform to valid transitions of the TCP state machine
([RFC0793], Figure 6).

REC-31: All valid sequences of TCP packets (defined in [RFC0793])
MUST be forwarded for outbound flows and explicitly permitted inbound
flows. In particular, both the normal TCP 3-way handshake mode of
operation and the simultaneous-open mode of operation MUST be
supported.

It is possible to reconstruct enough of the state of a TCP flow to
allow forwarding between an interior and exterior node, even when the
filter starts operating after TCP enters the established state. In
this case, because the filter has not seen the TCP window-scale
option, it is not possible for the filter to enforce the TCP window
invariant by dropping out-of-window segments.

REC-32: The TCP window invariant MUST NOT be enforced on flows for
which the filter did not detect whether the window-scale option (see
[RFC1323]) was sent in the 3-way handshake or simultaneous-open.

A stateful filter can allow an existing state record to be reused by
an externally initiated flow if its security policy permits. Several
different policies are possible, as described in [RFC4787] and
extended in [RFC5382].

REC-33: If application transparency is most important, then a
stateful packet filter SHOULD have "endpoint-independent filtering"
behavior for TCP. If a more stringent filtering behavior is most
important, then a filter SHOULD have "address-dependent filtering"

behavior. The filtering behavior MAY be an option configurable by
the network administrator, and it MAY be independent of the filtering
behavior for UDP and other protocols. Filtering behavior SHOULD be
endpoint independent by DEFAULT in gateways intended for provisioning
without service-provider management.

If an inbound SYN packet is filtered, either because a corresponding
state record does not exist or because of the filter's normal
behavior, a filter has two basic choices: to discard the packet
silently, or to signal an error to the sender. Signaling an error
through ICMPv6 messages allows the sender to detect that the SYN did
not reach the intended destination. Discarding the packet, on the
other hand, allows applications to perform simultaneous-open more
reliably. A more detailed discussion of this issue can be found in
[RFC5382], but the basic outcome of it is that filters need to wait
on signaling errors until simultaneous-open will not be impaired.

REC-34: By DEFAULT, a gateway MUST respond with an ICMPv6
"Destination Unreachable" error code 1 (Communication with
destination administratively prohibited) to any unsolicited inbound
SYN packet after waiting at least 6 seconds without first forwarding
the associated outbound SYN or SYN/ACK from the interior peer.

A TCP filter maintains state associated with in-progress connections
and established flows. Because of this, a filter is susceptible to a
resource-exhaustion attack whereby an attacker (or virus) on the
interior attempts to cause the filter to exhaust its capacity for
creating state records. To defend against such attacks, a filter
needs to abandon unused state records after a sufficiently long
period of idleness.

A common method used for TCP filters in IPv4/NAT gateways is to
abandon preferentially flow state records for crashed endpoints,
followed by closed flows and partially open flows. A gateway can
check if an endpoint for a session has crashed by sending a TCP keep-
alive packet on behalf of the other endpoint and receiving a TCP RST
packet in response. If the gateway cannot determine whether the
endpoint is active, then the associated state record needs to be
retained until the TCP flow has been idle for some time.

    Note: An established TCP flow can stay idle (but live)
    indefinitely; hence, there is no fixed value for an idle-timeout
    that accommodates all applications. However, a large idle-timeout
    motivated by recommendations in [RFC1122] and [RFC4294] can reduce
    the chances of abandoning a live flow.

TCP flows can stay in the established phase indefinitely without exchanging packets. Some end-hosts can be configured to send keep-alive packets on such idle flows; by default, such packets are sent every two hours, if enabled [RFC1122]. Consequently, a filter that waits for slightly over two hours can detect idle flows with keep-alive packets being sent at the default rate. TCP flows in the partially open or closing phases, on the other hand, can stay idle for at most four minutes while waiting for in-flight packets to be delivered [RFC1122].

The "established flow idle-timeout" for a stateful packet filter is defined as the minimum time a TCP flow in the established phase must remain idle before the filter considers the associated state record a candidate for collection. The "transitory flow idle-timeout" for a filter is defined as the minimum time a TCP flow in the partially open or closing phases must remain idle before the filter considers the associated state record a candidate for collection. TCP flows in the TIME-WAIT state are not affected by the "transitory flow idle-timeout" parameter.

REC-35: If a gateway cannot determine whether the endpoints of a TCP flow are active, then it MAY abandon the state record if it has been idle for some time. In such cases, the value of the "established flow idle-timeout" MUST NOT be less than two hours four minutes, as discussed in [RFC5382]. The value of the "transitory flow idle-timeout" MUST NOT be less than four minutes. The value of the idle-timeouts MAY be configurable by the network administrator.

Behavior for handling RST packets or TCP flows in the TIME-WAIT state is left unspecified. A gateway MAY hold state for a flow in the TIME-WAIT state to accommodate retransmissions of the last ACK. However, since the TIME-WAIT state is commonly encountered by interior endpoints properly closing the TCP flow, holding state for a closed flow can limit the throughput of flows through a gateway with limited resources. [RFC1337] discusses hazards associated with TIME-WAIT assassination.

The handling of non-SYN packets for which there is no active state record is left unspecified. Such packets can be received if the gateway abandons a live flow, or abandons a flow in the TIME-WAIT state before the four-minute TIME-WAIT period expires. The decision either to discard or to respond with an ICMPv6 "Destination Unreachable" error code 1 (Communication with destination administratively prohibited) is left up to the implementation.

Behavior for notifying endpoints when abandoning live flows is left unspecified. When a gateway abandons a live flow, for example due to a timeout expiring, the filter MAY send a TCP RST packet to each

endpoint on behalf of the other. Sending a RST notification allows
endpoint applications to recover more quickly; however, notifying
endpoints might not always be possible if, for example, state records
are lost due to power interruption.

Several TCP mechanisms depend on the reception of ICMPv6 error
messages triggered by the transmission of TCP segments. One such
mechanism is path MTU discovery, which is required for correct
operation of TCP.

REC-36: If a gateway forwards a TCP flow, it MUST also forward ICMPv6
"Destination Unreachable" and "Packet Too Big" messages containing
TCP headers that match the flow state record.

REC-37: Receipt of any sort of ICMPv6 message MUST NOT terminate the
state record for a TCP flow.

3.3.2. SCTP Filters

Because Stream Control Transmission Protocol (SCTP) [RFC4960] flows
can be terminated at multiple network addresses, IPv6 simple security
functions cannot achieve full transparency for SCTP applications. In
multipath traversal scenarios, full transparency requires
coordination between all the packet filter processes in the various
paths between the endpoint network addresses. Such coordination is
not "simple", and it is, therefore, beyond the scope of this
recommendation.

However, some SCTP applications are capable of tolerating the
inherent unipath restriction of IPv6 simple security, even in
multipath traversal scenarios. They expect connection-oriented
filtering behaviors similar to those for TCP, but at the level of
SCTP associations, not stream connections. This section describes
specific recommendations for SCTP filtering for such traversal
scenarios.

An interior endpoint initiates SCTP associations through a stateful
packet filter by sending a packet comprising a single INIT chunk.
The filter allocates (or reuses) a filter state record for the
association. The state record defines the interior and exterior IP
addresses and the observed verification tag used for forwarding
packets in that association.

Some peer-to-peer SCTP applications use an alternate method of
association initiation, termed "simultaneous-open", to traverse
stateful filters. In the simultaneous-open mode of operation, both
peers send INIT chunks at the same time to establish an association.
Upon receiving the other end's INIT chunk, each end responds with an

INIT-ACK packet, which is expected to traverse the same path in
reverse. Because only one SCTP association may exist between any two
network addresses, one of the peers in the simultaneous-open mode of
operation will send an ERROR or ABORT chunk along with the INIT-ACK
chunk. The association is established at each endpoint once an
INIT-ACK chunk without an ERROR or ABORT chunk is received at one
end.

To provide stateful packet filtering service for SCTP, it is
necessary for a filter to receive, process, and forward all packets
for an association that conform to valid transitions of the SCTP
state machine ([RFC4960], Figure 3).

REC-38: All valid sequences of SCTP packets (defined in [RFC4960])
MUST be forwarded for outbound associations and explicitly permitted
inbound associations. In particular, both the normal SCTP
association establishment and the simultaneous-open mode of operation
MUST be supported.

If an inbound INIT packet is filtered, either because a corresponding
state record does not exist or because of the filter's normal
behavior, a filter has two basic choices: to discard the packet
silently, or to signal an error to the sender. Signaling an error
through ICMPv6 messages allows the sender to detect that the INIT
packet did not reach the intended destination. Discarding the
packet, on the other hand, allows applications to perform
simultaneous-open more reliably. Delays in signaling errors can
prevent the impairment of the simultaneous-open mode of operation.

REC-39: By DEFAULT, a gateway MUST respond with an ICMPv6
"Destination Unreachable" error code 1 (Communication with
destination administratively prohibited), to any unsolicited inbound
INIT packet after waiting at least 6 seconds without first forwarding
the associated outbound INIT from the interior peer.

An SCTP filter maintains state associated with in-progress and
established associations. Because of this, a filter is susceptible
to a resource-exhaustion attack whereby an attacker (or virus) on the
interior attempts to cause the filter to exhaust its capacity for
creating state records. To defend against such attacks, a filter
needs to abandon unused state records after a sufficiently long
period of idleness.

A common method used for TCP filters in IPv4/NAT gateways is to
abandon preferentially sessions for crashed endpoints, followed by
closed associations and partially opened associations. A similar
method is an option for SCTP filters in IPv6 gateways. A gateway can
check if an endpoint for an association has crashed by sending

HEARTBEAT chunks and looking for the HEARTBEAT ACK response. If the
gateway cannot determine whether the endpoint is active, then the
associated state record needs to be retained until the SCTP
association has been idle for some time.

> Note: An established SCTP association can stay idle (but live)
> indefinitely; hence, there is no fixed value of an idle-timeout
> that accommodates all applications. However, a large idle-timeout
> motivated by recommendations in [RFC4294] can reduce the chances
> of abandoning a live association.

SCTP associations can stay in the ESTABLISHED state indefinitely
without exchanging packets. Some end-hosts can be configured to send
HEARTBEAT chunks on such idle associations, but [RFC4960] does not
specify (or even suggest) a default time interval. A filter that
waits for slightly over two hours can detect idle associations with
HEARTBEAT packets being sent at the same rate as most hosts use for
TCP keep-alive, which is a reasonably similar system for this
purpose. SCTP associations in the partially open or closing states,
on the other hand, can stay idle for at most four minutes while
waiting for in-flight packets to be delivered (assuming the suggested
SCTP protocol parameter values in Section 15 of [RFC4960]).

The "established association idle-timeout" for a stateful packet
filter is defined as the minimum time an SCTP association in the
established phase must remain idle before the filter considers the
corresponding state record a candidate for collection. The
"transitory association idle-timeout" for a filter is defined as the
minimum time an SCTP association in the partially open or closing
phases must remain idle before the filter considers the corresponding
state record a candidate for collection.

REC-40: If a gateway cannot determine whether the endpoints of an
SCTP association are active, then it MAY abandon the state record if
it has been idle for some time. In such cases, the value of the
"established association idle-timeout" MUST NOT be less than
two hours four minutes. The value of the "transitory association
idle-timeout" MUST NOT be less than four minutes. The value of the
idle-timeouts MAY be configurable by the network administrator.

Behavior for handling ERROR and ABORT packets is left unspecified. A
gateway MAY hold state for an association after its closing phases
have completed to accommodate retransmissions of its final SHUTDOWN
ACK packets. However, holding state for a closed association can
limit the throughput of associations traversing a gateway with
limited resources. The discussion in [RFC1337] regarding the hazards
of TIME-WAIT assassination is relevant.

The handling of inbound non-INIT packets for which there is no active
state record is left unspecified. Such packets can be received if
the gateway abandons a live flow, or abandons an association in the
closing states before the transitory association idle-timeout
expires. The decision either to discard or to respond with an ICMPv6
"Destination Unreachable" error code 1 (Communication with
destination administratively prohibited) is left to the
implementation.

Behavior for notifying endpoints when abandoning live associations is
left unspecified. When a gateway abandons a live association, for
example due to a timeout expiring, the filter MAY send an ABORT
packet to each endpoint on behalf of the other. Sending an ABORT
notification allows endpoint applications to recover more quickly;
however, notifying endpoints might not always be possible if, for
example, state records are lost due to power interruption.

Several SCTP mechanisms depend on the reception of ICMPv6 error
messages triggered by the transmission of SCTP packets.

REC-41: If a gateway forwards an SCTP association, it MUST also
forward ICMPv6 "Destination Unreachable" and "Packet Too Big"
messages containing SCTP headers that match the association state
record.

REC-42: Receipt of any sort of ICMPv6 message MUST NOT terminate the
state record for an SCTP association.

3.3.3. DCCP Filters

The connection semantics described in the "Datagram Congestion
Control Protocol (DCCP)" [RFC4340] are very similar to those of TCP.
An interior endpoint initiates a DCCP flow through a stateful packet
filter by sending a DCCP-Request packet. Simultaneous-open is not
defined for DCCP.

In order to provide stateful packet filtering service for DCCP, it is
necessary for a filter to receive, process, and forward all packets
for a flow that conform to valid transitions of the DCCP state
machine ([RFC4340], Section 8).

REC-43: All valid sequences of DCCP packets (defined in [RFC4340])
MUST be forwarded for all flows to exterior servers, and for any
flows to interior servers that have explicitly permitted service
codes.

It is possible to reconstruct enough of the state of a DCCP flow to
allow forwarding between an interior and exterior node, even when the
filter starts operating after DCCP enters the OPEN state. Also, a
filter can allow an existing state record to be reused by an
externally initiated flow if its security policy permits. As with
TCP, several different policies are possible, with a good discussion
of the issue involved presented in [RFC4787] and extended in
[RFC5382].

If an inbound DCCP-Request packet is filtered, either because a
corresponding state record does not already exist for it or because
of the filter's normal behavior of refusing flows not explicitly
permitted, then a filter has two basic choices: to discard the packet
silently, or to signal an error to the sender. Signaling an error
through ICMPv6 messages allows the sender to detect that the
DCCP-Request did not reach the intended destination. Discarding the
packet, on the other hand, only delays the failure to connect and
provides no measurable security.

A DCCP filter maintains state associated with in-progress connections
and established flows. Because of this, a filter is susceptible to a
resource-exhaustion attack whereby an attacker (or virus) on the
interior attempts to cause the filter to exhaust its capacity for
creating state records. To prevent such an attack, a filter needs to
abandon unused state records after a sufficiently long period of
idleness.

A common method used for TCP filters in IPv4/NAT gateways is to
abandon preferentially sessions for crashed endpoints, followed by
closed TCP flows and partially open flows. No such method exists for
DCCP, and flows can stay in the OPEN phase indefinitely without
exchanging packets. Hence, there is no fixed value for an idle-
timeout that accommodates all applications. However, a large idle-
timeout motivated by recommendations in [RFC4294] can reduce the
chances of abandoning a live flow.

DCCP flows in the partially open or closing phases can stay idle for
at most eight minutes while waiting for in-flight packets to be
delivered.

The "open flow idle-timeout" for a stateful packet filter is defined
as the minimum time a DCCP flow in the open state must remain idle
before the filter considers the associated state record a candidate

for collection. The "transitory flow idle-timeout" for a filter is
defined as the minimum time a DCCP flow in the partially open or
closing phases must remain idle before the filter considers the
associated state record a candidate for collection. DCCP flows in
the TIMEWAIT state are not affected by the "transitory flow idle-
timeout" parameter.

REC-44: A gateway MAY abandon a DCCP state record if it has been idle
for some time. In such cases, the value of the "open flow idle-
timeout" MUST NOT be less than two hours four minutes. The value of
the "transitory flow idle-timeout" MUST NOT be less than eight
minutes. The value of the idle-timeouts MAY be configurable by the
network administrator.

Behavior for handling DCCP-Reset packets or flows in the TIMEWAIT
state is left unspecified. A gateway MAY hold state for a flow in
the TIMEWAIT state to accommodate retransmissions of the last
DCCP-Reset. However, since the TIMEWAIT state is commonly
encountered by interior endpoints properly closing the DCCP flow,
holding state for a closed flow can limit the throughput of flows
through a gateway with limited resources. [RFC1337] discusses
hazards associated with TIME-WAIT assassination in TCP, and similar
hazards exist for DCCP.

The handling of non-SYN packets for which there is no active state
record is left unspecified. Such packets can be received if the
gateway abandons a live flow, or abandons a flow in the TIMEWAIT
state before the four-minute 2MSL period (two times the maximum
segment lifetime [RFC4340]) expires. The decision either to discard
or to respond with an ICMPv6 "Destination Unreachable" error code 1
(Communication with destination administratively prohibited) is left
up to the implementation.

Behavior for notifying endpoints when abandoning live flows is left
unspecified. When a gateway abandons a live flow, for example due to
a timeout expiring, the filter MAY send a DCCP-Reset packet to each
endpoint on behalf of the other. Sending a DCCP-Reset notification
allows endpoint applications to recover more quickly; however,
notifying endpoints might not always be possible if, for example,
state records are lost due to power interruption.

Several DCCP mechanisms depend on the reception of ICMPv6 error
messages triggered by the transmission of DCCP packets. One such
mechanism is path MTU discovery, which is required for correct
operation.

REC-45: If an Internet gateway forwards a DCCP flow, it MUST also
forward ICMPv6 "Destination Unreachable" and "Packet Too Big"
messages containing DCCP headers that match the flow state record.

REC-46: Receipt of any sort of ICMPv6 message MUST NOT terminate the
state record for a DCCP flow.

3.3.4. Level 3 Multihoming Shim Protocol for IPv6 (Shim6)

While IPv6 simple security is applicable to residential networks with
only one Internet service provider at a time, the use of the Level 3
Multihoming Shim Protocol for IPv6 (Shim6) [RFC5533] is necessary for
communications with some multihomed exterior destinations. No
special recommendations are made in this document for processing the
Shim6 message format (protocol 140) beyond the recommendations in
Section 3.2.2. The content of the Shim6 payload extension header may
be ignored.

REC-47: Valid sequences of packets bearing Shim6 payload extension
headers in their outer IP extension header chains MUST be forwarded
for all outbound and explicitly permitted flows. The content of the
Shim6 payload extension header MAY be ignored for the purpose of
state tracking.

3.4. Passive Listeners

Some applications expect to solicit traffic from exterior nodes
without advance knowledge of the exterior addresses of their peers.
This requirement is met by IPv4/NAT gateways, typically by the use of
either the NAT Port Mapping Protocol [NAT-PMP] or the Universal Plug
and Play Internet Gateway Device [UPnP-IGD] standardized device
control protocol. On IPv4/NAT networks connected by gateways without
such services, applications must use techniques like Session
Traversal Utilities for NAT (STUN) [RFC5389] to obtain and maintain
connectivity, despite the translation and filtering effects of NAT.

While NAT for IPv6 is unlikely to be used in most residential
gateways, the simple security functions recommended by this document,
and their filtering effects, are derived from comparable functions
already in widespread use on the IPv4 Internet. A similar barrier to
communication at passive listeners is a natural outcome of the
deployment of NAT for IPv6. To avoid the need for IPv6 applications
to use techniques like STUN for opening and maintaining dynamic
filter state, something similar to NAT-PMP and UPnP-IGD, but without
actually supporting NAT, could be deployed. Alas, no consensus has
yet emerged in the Internet engineering community as to what is most
appropriate for residential IPv6 usage scenarios.

One proposal that has been offered is the Application Listener
Discovery Protocol [WOODYATT-ALD] document. It remains to be seen
whether the Internet Gateway Device profile of the Universal Plug and
Play protocol will be extended for IPv6. Other proposals of note
include the Middlebox Communication Protocol [RFC5189] and the Next
Steps in Signaling framework [RFC4080]. Until a consensus emerges
around a specific method, the following recommendations are the best
guidance available.

REC-48: Internet gateways with IPv6 simple security capabilities
SHOULD implement a protocol to permit applications to solicit inbound
traffic without advance knowledge of the addresses of exterior nodes
with which they expect to communicate.

REC-49: Internet gateways with IPv6 simple security capabilities MUST
provide an easily selected configuration option that permits a
"transparent mode" of operation that forwards all unsolicited flows
regardless of forwarding direction, i.e., not to use the IPv6 simple
security capabilities of the gateway. The transparent mode of
operation MAY be the default configuration.

In general, "transparent mode" will enable more flexibility and
reliability for applications that require devices to be contacted
inside the home directly, particularly in the absence of a protocol
as described in REC-48. Operating in transparent mode may come at
the expense of security if there are IPv6 nodes in the home that do
not have their own host-based firewall capability and require a
firewall in the gateway in order not to be compromised.

3.5. Management Applications

Subscriber-managed residential gateways are unlikely ever to be
completely zero-configuration, but their administrators will very
often possess no particular expertise in Internet engineering. In
general, the specification of management interfaces for residential
gateways is out of scope for this document, but the security of
subscriber-managed gateways merits special attention here.

REC-50: By DEFAULT, subscriber-managed residential gateways MUST NOT
offer management application services to the exterior network.

4. Summary of Recommendations

   This section collects all of the recommendations made in this
   document into a convenient list.

   REC-1   Packets bearing multicast source addresses in their outer
            IPv6 headers MUST NOT be forwarded or transmitted on any
            interface.

   REC-2   Packets bearing multicast destination addresses in their
            outer IPv6 headers of equal or narrower scope (see "IPv6
            Scoped Address Architecture" [RFC4007]) than the configured
            scope boundary level of the gateway MUST NOT be forwarded in
            any direction. The DEFAULT scope boundary level SHOULD be
            organization-local scope, and it SHOULD be configurable by
            the network administrator.

   REC-3   Packets bearing source and/or destination addresses forbidden
            to appear in the outer headers of packets transmitted over
            the public Internet MUST NOT be forwarded. In particular,
            site-local addresses are deprecated by [RFC3879], and
            [RFC5156] explicitly forbids the use of address blocks of
            types IPv4-Mapped Addresses, IPv4-Compatible Addresses,
            Documentation Prefix, and Overlay Routable Cryptographic Hash
            IDentifiers (ORCHID).

   REC-4   Packets bearing deprecated extension headers prior to their
            first upper-layer-protocol header SHOULD NOT be forwarded or
            transmitted on any interface. In particular, all packets
            with routing extension header type 0 [RFC2460] preceding the
            first upper-layer-protocol header MUST NOT be forwarded. See
            [RFC5095] for additional background.

   REC-5   Outbound packets MUST NOT be forwarded if the source address
            in their outer IPv6 header does not have a unicast prefix
            configured for use by globally reachable nodes on the
            interior network.

   REC-6   Inbound packets MUST NOT be forwarded if the source address
            in their outer IPv6 header has a global unicast prefix
            assigned for use by globally reachable nodes on the interior
            network.

   REC-7   By DEFAULT, packets with unique local source and/or
            destination addresses [RFC4193] SHOULD NOT be forwarded to or
            from the exterior network.

REC-8   By DEFAULT, inbound DNS queries received on exterior
         interfaces MUST NOT be processed by any integrated DNS
         resolving server.

REC-9   Inbound DHCPv6 discovery packets [RFC3315] received on
         exterior interfaces MUST NOT be processed by any integrated
         DHCPv6 server or relay agent.

REC-10   IPv6 gateways SHOULD NOT forward ICMPv6 "Destination
         Unreachable" and "Packet Too Big" messages containing IP
         headers that do not match generic upper-layer transport state
         records.

REC-11   If application transparency is most important, then a
         stateful packet filter SHOULD have "endpoint-independent
         filtering" behavior for generic upper-layer transport
         protocols. If a more stringent filtering behavior is most
         important, then a filter SHOULD have "address-dependent
         filtering" behavior. The filtering behavior MAY be an option
         configurable by the network administrator, and it MAY be
         independent of the filtering behavior for other protocols.
         Filtering behavior SHOULD be endpoint independent by DEFAULT
         in gateways intended for provisioning without service-
         provider management.

REC-12   Filter state records for generic upper-layer transport
         protocols MUST NOT be deleted or recycled until an idle timer
         not less than two minutes has expired without having
         forwarded a packet matching the state in some configurable
         amount of time. By DEFAULT, the idle timer for such state
         records is five minutes.

REC-13   Residential IPv6 gateways SHOULD provide a convenient means
         to update their firmware securely, for the installation of
         security patches and other manufacturer-recommended changes.

REC-14   A state record for a UDP flow where both source and
         destination ports are outside the well-known port range
         (ports 0-1023) MUST NOT expire in less than two minutes of
         idle time. The value of the UDP state record idle timer MAY
         be configurable. The DEFAULT is five minutes.

REC-15   A state record for a UDP flow where one or both of the source
         and destination ports are in the well-known port range
         (ports 0-1023) MAY expire after a period of idle time shorter
         than two minutes to facilitate the operation of the IANA-
         registered service assigned to the port in question.

REC-16   A state record for a UDP flow MUST be refreshed when a packet
         is forwarded from the interior to the exterior, and it MAY be
         refreshed when a packet is forwarded in the reverse
         direction.

REC-17   If application transparency is most important, then a
         stateful packet filter SHOULD have "endpoint-independent
         filtering" behavior for UDP. If a more stringent filtering
         behavior is most important, then a filter SHOULD have
         "address-dependent filtering" behavior. The filtering
         behavior MAY be an option configurable by the network
         administrator, and it MAY be independent of the filtering
         behavior for TCP and other protocols. Filtering behavior
         SHOULD be endpoint independent by DEFAULT in gateways
         intended for provisioning without service-provider
         management.

REC-18   If a gateway forwards a UDP flow, it MUST also forward ICMPv6
         "Destination Unreachable" and "Packet Too Big" messages
         containing UDP headers that match the flow state record.

REC-19   Receipt of any sort of ICMPv6 message MUST NOT terminate the
         state record for a UDP flow.

REC-20   UDP-Lite flows [RFC3828] SHOULD be handled in the same way as
         UDP flows, except that the upper-layer transport protocol
         identifier for UDP-Lite is not the same as UDP; therefore,
         UDP packets MUST NOT match UDP-Lite state records, and vice
         versa.

REC-21   In their DEFAULT operating mode, IPv6 gateways MUST NOT
         prohibit the forwarding of packets, to and from legitimate
         node addresses, with destination extension headers of type
         "Authentication Header (AH)" [RFC4302] in their outer IP
         extension header chain.

REC-22   In their DEFAULT operating mode, IPv6 gateways MUST NOT
         prohibit the forwarding of packets, to and from legitimate
         node addresses, with an upper-layer protocol of type
         "Encapsulating Security Payload (ESP)" [RFC4303] in their
         outer IP extension header chain.

REC-23   If a gateway forwards an ESP flow, it MUST also forward (in
         the reverse direction) ICMPv6 "Destination Unreachable" and
         "Packet Too Big" messages containing ESP headers that match
         the flow state record.

REC-24   In their DEFAULT operating mode, IPv6 gateways MUST NOT
         prohibit the forwarding of any UDP packets, to and from
         legitimate node addresses, with a destination port of 500,
         i.e., the port reserved by IANA for the Internet Key Exchange
         (IKE) Protocol [RFC5996].

REC-25   In all operating modes, IPv6 gateways SHOULD use filter state
         records for Encapsulating Security Payload (ESP) [RFC4303]
         that are indexable by a 3-tuple comprising the interior node
         address, the exterior node address, and the ESP protocol
         identifier. In particular, the IPv4/NAT method of indexing
         state records also by security parameters index (SPI) SHOULD
         NOT be used. Likewise, any mechanism that depends on
         detection of Internet Key Exchange (IKE) [RFC5996]
         initiations SHOULD NOT be used.

REC-26   In their DEFAULT operating mode, IPv6 gateways MUST NOT
         prohibit the forwarding of packets, to and from legitimate
         node addresses, with destination extension headers of type
         "Host Identity Protocol (HIP)" [RFC5201] in their outer IP
         extension header chain.

REC-27   The state records for flows initiated by outbound packets
         that bear a Home Address destination option [RFC3775] are
         distinguished by the addition of the home address of the flow
         as well as the interior care-of address. IPv6 gateways MUST
         NOT prohibit the forwarding of any inbound packets bearing
         type 2 routing headers, which otherwise match a flow state
         record, and where A) the address in the destination field of
         the IPv6 header matches the interior care-of address of the
         flow, and B) the Home Address field in the Type 2 Routing
         Header matches the home address of the flow.

REC-28   Valid sequences of Mobility Header [RFC3775] packets MUST be
         forwarded for all outbound and explicitly permitted inbound
         Mobility Header flows.

REC-29   If a gateway forwards a Mobility Header [RFC3775] flow, then
         it MUST also forward, in both directions, the IPv4 and IPv6
         packets that are encapsulated in IPv6 associated with the
         tunnel between the home agent and the correspondent node.

REC-30   If a gateway forwards a Mobility Header [RFC3775] flow, then
         it MUST also forward (in the reverse direction) ICMPv6
         "Destination Unreachable" and "Packet Too Big" messages
         containing any headers that match the associated flow state
         records.

REC-31   All valid sequences of TCP packets (defined in [RFC0793])
         MUST be forwarded for outbound flows and explicitly permitted
         inbound flows. In particular, both the normal TCP 3-way
         handshake mode of operation and the simultaneous-open mode of
         operation MUST be supported.

REC-32   The TCP window invariant MUST NOT be enforced on flows for
         which the filter did not detect whether the window-scale
         option (see [RFC1323]) was sent in the 3-way handshake or
         simultaneous-open.

REC-33   If application transparency is most important, then a
         stateful packet filter SHOULD have "endpoint-independent
         filtering" behavior for TCP. If a more stringent filtering
         behavior is most important, then a filter SHOULD have
         "address-dependent filtering" behavior. The filtering
         behavior MAY be an option configurable by the network
         administrator, and it MAY be independent of the filtering
         behavior for UDP and other protocols. Filtering behavior
         SHOULD be endpoint independent by DEFAULT in gateways
         intended for provisioning without service-provider
         management.

REC-34   By DEFAULT, a gateway MUST respond with an ICMPv6
         "Destination Unreachable" error code 1 (Communication with
         destination administratively prohibited), to any unsolicited
         inbound SYN packet after waiting at least 6 seconds without
         first forwarding the associated outbound SYN or SYN/ACK from
         the interior peer.

REC-35   If a gateway cannot determine whether the endpoints of a TCP
         flow are active, then it MAY abandon the state record if it
         has been idle for some time. In such cases, the value of the
         "established flow idle-timeout" MUST NOT be less than
         two hours four minutes, as discussed in [RFC5382]. The value
         of the "transitory flow idle-timeout" MUST NOT be less than
         four minutes. The value of the idle-timeouts MAY be
         configurable by the network administrator.

REC-36   If a gateway forwards a TCP flow, it MUST also forward ICMPv6
         "Destination Unreachable" and "Packet Too Big" messages
         containing TCP headers that match the flow state record.

REC-37   Receipt of any sort of ICMPv6 message MUST NOT terminate the
         state record for a TCP flow.

REC-38   All valid sequences of SCTP packets (defined in [RFC4960])
         MUST be forwarded for outbound associations and explicitly
         permitted inbound associations. In particular, both the
         normal SCTP association establishment and the simultaneous-
         open mode of operation MUST be supported.

REC-39   By DEFAULT, a gateway MUST respond with an ICMPv6
         "Destination Unreachable" error code 1 (Communication with
         destination administratively prohibited) to any unsolicited
         inbound INIT packet after waiting at least 6 seconds without
         first forwarding the associated outbound INIT from the
         interior peer.

REC-40   If a gateway cannot determine whether the endpoints of an
         SCTP association are active, then it MAY abandon the state
         record if it has been idle for some time. In such cases, the
         value of the "established association idle-timeout" MUST NOT
         be less than two hours four minutes. The value of the
         "transitory association idle-timeout" MUST NOT be less than
         four minutes. The value of the idle-timeouts MAY be
         configurable by the network administrator.

REC-41   If a gateway forwards an SCTP association, it MUST also
         forward ICMPv6 "Destination Unreachable" and "Packet Too Big"
         messages containing SCTP headers that match the association
         state record.

REC-42   Receipt of any sort of ICMPv6 message MUST NOT terminate the
         state record for an SCTP association.

REC-43   All valid sequences of DCCP packets (defined in [RFC4340])
         MUST be forwarded for all flows to exterior servers, and for
         any flows to interior servers with explicitly permitted
         service codes.

REC-44   A gateway MAY abandon a DCCP state record if it has been
         idle for some time. In such cases, the value of the "open
         flow idle-timeout" MUST NOT be less than two hours
         four minutes. The value of the "transitory flow idle-
         timeout" MUST NOT be less than eight minutes. The value of
         the idle-timeouts MAY be configurable by the network
         administrator.

REC-45   If an Internet gateway forwards a DCCP flow, it MUST also
         forward ICMPv6 "Destination Unreachable" and "Packet Too Big"
         messages containing DCCP headers that match the flow state
         record.

REC-46 Receipt of any sort of ICMPv6 message MUST NOT terminate the
        state record for a DCCP flow.

REC-47 Valid sequences of packets bearing Shim6 payload extension
        headers in their outer IP extension header chains MUST be
        forwarded for all outbound and explicitly permitted flows.
        The content of the Shim6 payload extension header MAY be
        ignored for the purpose of state tracking.

REC-48 Internet gateways with IPv6 simple security capabilities
        SHOULD implement a protocol to permit applications to solicit
        inbound traffic without advance knowledge of the addresses of
        exterior nodes with which they expect to communicate.

REC-49 Internet gateways with IPv6 simple security capabilities MUST
        provide an easily selected configuration option that permits
        a "transparent mode" of operation that forwards all
        unsolicited flows regardless of forwarding direction, i.e.,
        not to use the IPv6 simple security capabilities of the
        gateway. The transparent mode of operation MAY be the
        default configuration.

REC-50 By DEFAULT, subscriber-managed residential gateways MUST NOT
        offer management application services to the exterior
        network.

5. Contributors

Comments and criticisms during the development of this document were
received from the following IETF participants:

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+-------------------+----------------------------+
| Jari Arkko        | Ran Atkinson               |
| Fred Baker        | Norbert Bollow             |
| Cameron Byrne     | Brian Carpenter            |
| Remi Despres      | Arnaud Ebalard             |
| Fabrice Fontaine  | Jun-ichiro "itojun" Hagino |
| Thomas Herbst     | Christian Huitema          |
| Joel Jaeggli      | Cullen Jennings            |
| Suresh Krishnan   | Erik Kline                 |
| Julien Laganier   | Kurt Erik Lindqvist        |
| Mohamed Boucadair | Keith Moore                |
| Robert Moskowitz  | Teemu Savolainen           |
| Hemant Singh      | Yaron Sheffer              |
| Mark Townsley     | Iljitsch van Beijnum       |
| Magnus Westerlund | Dan Wing                   |
+-------------------+----------------------------+
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The editor thanks them all for their contributions.

It must be noted that a substantial portion of the text describing
the detailed requirements for TCP and UDP filtering is derived or
transposed from [RFC4787] and [RFC5382]. The editors of those
documents, Francois Audet and Saikat Guha, also deserve substantial
credit for the form of the present document.

6. Security Considerations

The IPv6 stateful filtering behavior described in this document is
intended to be similar in function to the filtering behavior of
commonly used IPv4/NAT gateways, which have been widely sold as a
security tool for residential and small-office/home-office networks.
As noted in the Security Considerations section of [RFC2993], the
true impact of these tools may be a reduction in security. It may be
generally assumed that the impacts discussed in that document related
to filtering (and not translation) are to be expected with the simple
IPv6 security mechanisms described here.

In particular, it is worth noting that stateful filters create the
illusion of a security barrier, but without the managed intent of a
firewall. Appropriate security mechanisms implemented in the end
nodes, in conjunction with the [RFC4864] local network protection
methods, function without reliance on network layer hacks and
transport filters that may change over time. Also, defined security
barriers assume that threats originate in the exterior, which may
lead to practices that result in applications being fully exposed to
interior attack and which therefore make breaches much easier.

The security functions described in this document may be considered
redundant in the event that all IPv6 hosts using a particular gateway
have their own IPv6 host firewall capabilities enabled. At the time
of this writing, the vast majority of commercially available
operating systems with support for IPv6 include IPv6 host firewall
capability.

Also worth noting explicitly, a practical side-effect of the
recommendations in Section 3.2.4, to allow inbound IPsec and IKE
flows from exterior to interior, is to facilitate more transparent
communication by the use of an unauthenticated mode of IPsec, as
described in "Better-Than-Nothing-Security: An Unauthenticated Mode
of IPsec" [RFC5386], and this may be a departure from expectations of
transparency set by traditional IPv4/NAT residential gateways.

Finally, residential gateways that implement simple security
functions are a bastion between the interior and the exterior, and
therefore are a target of denial-of-service attacks against the

interior network itself by processes designed to consume the
resources of the gateway, e.g., a ping or SYN flood. Gateways should
employ the same sorts of protection techniques as application servers
on the Internet.

The IETF makes no statement, expressed or implied, as to whether
using the capabilities described in this document ultimately improves
security for any individual users or for the Internet community as a
whole.

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Author's Address

   James Woodyatt (editor)
   Apple Inc.
   1 Infinite Loop
   Cupertino, CA 95014
   US

   EMail: jhw@apple.com