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IPv4 ID Uniqueness Requirements
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Abstract

The IPv4 Identification field enables fragmentation and reassembly. This document clarifies the meaning of this field in the absence of fragmentation, based on ubiquitous current practice.

Conventions used in this document

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 [1].

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1. Introduction

In IPv4, the IP Identification (ID) field is a 16-bit value that is unique for every packet for a given source address, destination address, and protocol, such that it does not repeat within the Maximum Segment Lifetime (MSL) [2][7]. All packets between a source and destination of a given protocol must have unique ID values over a period of an MSL, which is typically interpreted as two minutes (120 seconds). This uniqueness is currently specified as required for all packets, regardless of fragmentation settings.

The uniqueness of the IP ID is a known problem for high speed devices, because it limits the speed of a single protocol between two endpoints to 6.4 Mbps for typical MTUs of 1500 bytes [4]. This strongly indicates that the uniqueness of the IPv4 ID is moot.

This document describes the current practice of relaxing the IPv4 uniqueness requirement.

2. Current Requirements

IP supports packet fragmentation, where large packets are split into smaller components to traverse links with limited maximum

transmission units (MTUs). Fragments are indicated in different ways in IPv4 and IPv6:

- o In IPv4, the header contains three fields: Identification (ID), Offset, a "Don't Fragment" flag (DF), and a "More Fragments" flag (MF) [7]

- o In IPv6, fragments are indicated in an extension header that includes an ID, Offset, and MF flag similar to their counterparts in IPv4 [3]

IPv4 and IPv6 fragmentation differs in a few important ways. IPv6 fragmentation occurs only at the source, so a DF bit is not needed to prevent downstream devices from initiating fragmentation. The IPv6 fragment header is present only when a packet has been fragmented, so the fields - notably the ID field, as will be shown later - are not present for non-fragmented packets, and thus are meaningful only for fragments. Finally, the ID field is 32 bits, and unique per source/destination address pair for IPv6, whereas for IPv4 it is only 16 bits and unique per source/destination/protocol triple.

This document focuses on the IPv4 ID field issues, because in IPv6 the field is larger and present only in fragments.

3. Uses of the ID Field in IPv4

The IPv4 ID field was originally intended for fragmentation and reassembly. Within a given source address, destination address, and protocol, fragments of an original packet are matched based on their IP ID. This requires that IDs are unique within the address/protocol triple when fragmentation is possible (e.g., DF=0).

The ID field has been discussed as useful in other ways. It can be used to detect and discard duplicate packets, e.g., at congested routers (see Sec. 3.2.1.5 of [2]).

The ID field may also be useful in tunnels. ICMP along tunnels may return only a portion of the information needed by a tunnel ingress to relay information back to the packet source. Encapsulators may retain copies of recently sent packets, to enable ICMP relaying [6].

These latter uses require that the IP ID be unique across all packets, not only when fragmentation is enabled.

4. IPv4 ID Exhaustion

With the maximum IPv4 packet size of 64KB, a 16-bit ID field that does not repeat within 120 seconds means that the sum of all TCP connections of a given protocol between two endpoints is limited to roughly 286 Mbps; at a more typical MTU of 1500 bytes, this speed drops to 6.4 Mbps [4]. This limit currently applies for all IPv4 packets, regardless of whether fragmentation is enabled, used, or inhibited.

Note that IPv6, even at typical MTUs, is capable of 18.7 Tbps when fragments are present, due to the larger 32-bit ID field. When fragmentation is not used, IPv6 speeds are not limited by the ID field uniqueness.

5. Current Practice

Wireless Internet devices are frequently connected at speeds over 54 Mbps, and wired links of 1 Gbps have been the default for several years. Although many end-to-end transport paths are congestion limited, these devices easily achieve 100+ Mbps application-layer throughput over LANs (e.g., disk-to-disk file transfer rates), and numerous throughput demonstrations have been performed with COTS systems at these speeds for over a decade. This strongly suggests that IPv4 ID uniqueness has been moot for a long time.

6. Recommended Practice

There are two kinds of packets, defined herein, for which recommended practice is described:

o Atomic packets: packets not yet having been fragmented (MF=0 and offset=0) and for which further fragmentation has been inhibited (DF=1), i.e.: ((DF==1)&&(MF==0)&&(offset==0))

o Non-atomic packets: packets which have either already been fragmented (MF=1 or offset>0 or both), or for which fragmentation remains possible (DF=0), i.e.: ((DF==0)||(MF==1)||(offset>0)), or (equivalently), ~((DF==1)&&(MF==0)&&(offset==0)).

Although at least one document suggests the ID field has other uses, it useful to confirm here that the ID field is defined only for fragmentation:

o Gateways and receiving hosts (or tunnel egresses using IP encapsulation) MUST ignore the contents of the IPv4 ID field for atomic packets.

Fragments that repeat the IP ID risk being reassembled incorrectly, especially when fragments are reordered or lost [9]. Although such errors may be detected at the transport layer, this results in excessive overall packet loss, as well as wasting network bandwidth. As a result, this document notes that:

- o IPv4 ID of non-atomic packets MUST be unique per source IP, destination IP, and protocol tuple sufficient to support reassembly.

Note that "sufficient to support reassembly" need not require unique IDs over a two minute interval. It should be sufficient that:

- o IPv4 ID of non-atomic packets MUST NOT repeat within a given source, destination, and protocol tuple over the period that the receiver experiences fragment reordering.

This suggests that the host employ rate limiting on each source/estination/protocol triple. The recommendations above are most appropriate at the host (or tunnel ingress), and can be difficult to enforce at routers. As a result, we recommend that for IPv4, as for IPv6:

- o IPv4 fragmentation SHOULD be limited to the originating source, e.g., the host or tunnel ingress. IPv4 fragmentation SHOULD NOT be performed where the IPv4 ID field is not under direct control, e.g., at routers.

Note, however, that it may not be possible for applications to know whether any of the above three requirements are satisfied at a host or on tunnels along a path (esp. those employing outer fragmentation). As a result, we recommend that:

- o Applications that cannot ensure safe IPv4 ID generation and that allow DF=0 SHOULD employ integrity checks that would detect mis-reassembled fragments, e.g, as in SEAL [10]. E.g., applications SHOULD NOT use UDP without checksums [8], and SHOULD be very careful in their use of UDP-Lite [5] in such environments, even existing UDP and TCP checksums may not be sufficient [4].

- o Applications SHOULD set DF=1 for all packets exiting a source host, regardless of whether those packets are fragmented at the source or not.

7. Security Considerations

This document attempts to address the security considerations associated with fragmentation in IPv4 [9].

When the IPv4 ID is ignored on receipt (e.g., for atomic packets), its value becomes unconstrained; that field then more easily be used as a covert channel.

8. IANA Considerations

There are no IANA considerations in this document.

The RFC Editor should remove this section prior to publication

9. Acknowledgments

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This document was prepared using 2-Word-v2.0.template.dot.

9.1. Normative References

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9.2. Informative References

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