NTP Correction Field
draft-mlichvar-ntp-correction-field-04

Abstract

   This document specifies an extension field for the Network Time
   Protocol (NTP) which improves resolution of specific fields in the
   NTP header and allows network devices such as switches and routers to
   modify NTP packets with corrections to improve accuracy of the
   synchronization in the network.

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1. Introduction

   Processing and queueing delays in network switches and routers may be
   a significant source of jitter and asymmetry in network delay, which
   has a negative impact on accuracy and stability of clocks
   synchronized by NTP [RFC5905].

   If all network devices on the paths between NTP clients and servers
   implemented NTP and supported an operation as a server and client,
   the impact of the delays could be avoided by configuring NTP to make
   measurements only between devices and hosts that are directly
   connected to one another. In the Precision Time Protocol (PTP)
   [IEEE1588], which is a different protocol for synchronization of
   clocks in networks, such devices are called Boundary Clocks (BC).

   A different approach supported by PTP to improve the accuracy uses
   Transparent Clocks (TC). Instead of fully implementing PTP in order
   to support an operation as a BC, the devices only modify a correction
   field in forwarded PTP packets with the time that the packets had to
   wait for transmission. The final value of the correction is included
   in the calculation of the delay and offset, which may significantly
   improve the accuracy and stability of the synchronization.

   This document describes an NTP extension field which allows the
   devices to make a similar correction in forwarded NTP packets.

   To better support a highly accurate synchronization, the extension
   field also improves resolution of the receive and transmit timestamps
   from the NTP header.

1.1. Requirements 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 RFC 2119 [RFC2119].

2. Format of Correction Field

   The Correction Field is an NTP extension field following RFC 7822
   [RFC7822]. The format of the extension field is shown in Figure 1.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Field Type          |          Length (28)          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                      Origin Correction                        +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Origin ID           | Receive Corr. | Transmit Corr.|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                       Delay Correction                        +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Path ID            |      Checksum complement       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
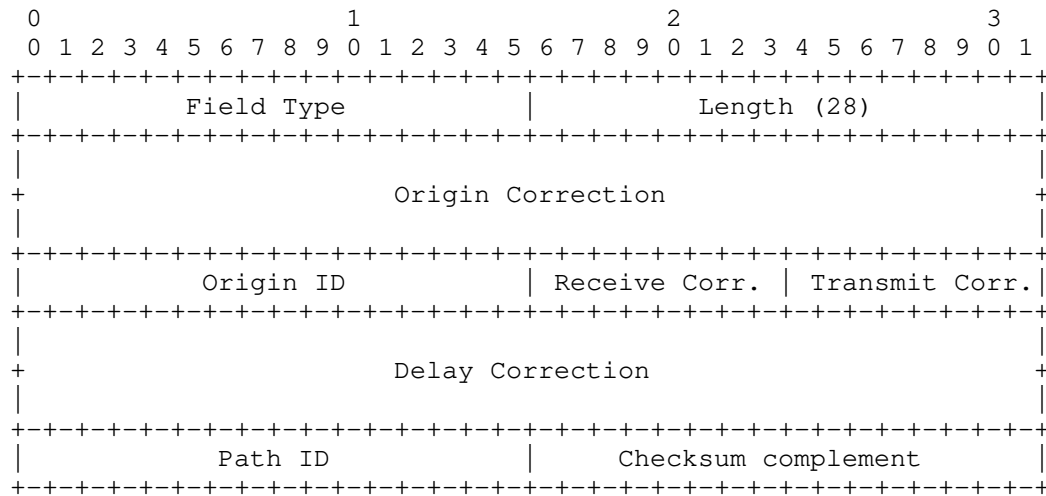
Figure 1: Format of Correction Field

The extension field has the following fields:

Field Type
       The type which identifies the Correction extension field.
       TBD

Length
       The length of the extension field, which is 28 octets.

Origin Correction
       A field which contains a copy of the final delay correction
       from the previous packet in the NTP exchange.

Origin ID
       A field which contains a copy of the final path ID from the
       previous packet in the NTP exchange.

Receive Correction
       An 8-bit extension of the receive timestamp in the NTP header
       increasing its resolution. The extended receive timestamp
       has 32 integer bits and 40 fractional bits.

Transmit Correction
       An 8-bit extension of the transmit timestamp in the NTP
       header increasing its resolution. The extended transmit
       timestamp has 32 integer bits and 40 fractional bits.

Delay Correction

A signed fixed-point number of nanoseconds with 48 integer
bits and 16 fractional bits, which represents the current
correction of the network delay that has accumulated for this
packet on the path from the source to the destination. The
format of this field is identical to the PTP correctionField.

Path ID
A 16-bit identification number of the path where the delay
correction was updated.

Checksum Complement
A field which can be modified in order to keep the UDP
checksum of the packet valid. This allows the UDP checksum
to be transmitted before the Correction Field is received and
modified. The same field is described in RFC 7821 [RFC7821].

3. Network devices

A network device which is forwarding a packet and supports the
Correction Field MUST NOT modify the packet unless all of the
following applies:

1. The packet is an IPv4 or IPv6 UDP packet.

2. The source port or destination port is 123.

3. The NTP version is 4.

4. The NTP mode is 1, 2, 3, 4, or 5.

5. The format of the packet is valid per RFC 7822.

6. The packet contains an extension field which has a type of TBD
    and length of 28 octets.

The device SHOULD add to the current value in the delay correction
field the length of an interval between the reception and
transmission of the packet. If the packet is transmitted at the same
speed as it was received and the length of the packet does not change
(e.g. due to adding or removing a VLAN tag), the beginning and end of
the interval may correspond to any point of the reception and
transmission as long as it is consistent for all forwarded packets of
the same length. If the transmission speed or length of the packet
is different, the beginning and end of the interval SHOULD correspond
to the end of the reception and beginning of the transmission
respectively.

If the transmission starts before the reception ends, a negative
value may need to be added to the delay correction. The end of the
reception SHOULD be determined using the length field of the UDP
header and the speed at which the packet is received.

If the device updates the delay correction, it SHOULD also add the
identification numbers of the incoming and outgoing port to the path
ID.

If the device modified any field of the extension field, it MUST
update the checksum complement field in order to keep the current UDP
checksum valid, or update the UDP checksum itself.

4. NTP hosts

When an NTP client sends a request to a server and the association is
configured to use the Correction Field, it SHOULD add the extension
field to the packet. All fields of the extension field except type
and length SHOULD be set to zero.

When the server receives a packet which includes the extension field,
the response SHOULD also include the extension field.

If the server's clock has a better precision than resolution of the
64-bit NTP timestamp format, the server SHOULD save the additional
bits in the receive and transmit correction fields and set the
precision field to the corresponding number, which is smaller than
-32. Otherwise, the receive and transmit correction fields SHOULD be
zero.

The origin correction and origin ID fields SHOULD be set to the delay
correction and path ID from the request. The other fields of the
Correction Field SHOULD be zero.

When the client receives a response which contains the extension
field, it SHOULD check the value of both the origin and delay
correction fields. If a correction is larger than a specified
maximum (e.g. 1 second), the extension field SHOULD be ignored.

The client MAY log a warning if the origin ID and path ID are not
equal, which indicates the network path between the server and client
is not symmetric.

If the client's clock has a better precision than resolution of the
64-bit NTP format and the precision field in the response contains a
number smaller than -32, the client SHOULD extend the receive and
transmit timestamp from the NTP header with the additional bits from
the receive and transmit correction fields respectively.

When the client calculates the offset and delay using the formulas
from RFC 5905, the origin correction is subtracted from the receive
timestamp and the delay correction is added to the transmit
timestamp. A conversion is necessary as the corrections are in
different units than the timestamps (nanoseconds vs seconds).

An NTP peer follows the rules of both servers and clients. It
processes Correction Fields in received packets as a client and sends
Correction Fields as a server. A packet which has a zero origin
timestamp (i.e. it is not a response to a request) SHOULD have a zero
origin correction and zero origin ID in the Correction Field.

A broadcast server using the Correction Field SHOULD always set the
origin correction and origin ID fields to zero.

5. Acknowledgements

The Correction Field extension is based on the PTP correction field
specified in IEEE 1588-2008.

The author would like to thank Tal Mizrahi and Harlan Stenn for their
useful comments.

6. IANA Considerations

IANA is requested to allocate an Extension Field Type for the
Correction Field.

7. Security Considerations

NTP packets including the Correction Field cannot be authenticated by
a legacy MAC, because the MAC has to cover all extension fields in
the packet and devices which are supposed to modify the field are not
able to update the MAC.

It is recommended to authenticate NTP packets using an authentication
extension field, e.g. the NTS Authenticator and Encrypted Extensions
[I-D.ietf-ntp-using-nts-for-ntp] extension field, and add the
Correction Field to the packet after the authentication field.

A man-in-the-middle attacker can delay packets in the network in
order to increase the measured delay and shift the measured offset by
up to half of the extra delay. If the packets contain the Correction
Field, the attacker can reduce the delay calculated by the client or
peer and shift the offset even more. The maximum correction should
be limited (e.g. to 1 second) to prevent the attacker from injecting
a larger offset to the measurements.

8. References

8.1. Normative References

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8.2. Informative References

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