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Using UDP Checksum Trailers in the Network Time Protocol (NTP)  
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## Abstract

The Network Time Protocol (NTP) allows clients to synchronize to a time server using timestamped protocol messages. To facilitate accurate timestamping, some implementations use hardware-based timestamping engines that integrate the accurate transmission time into every outgoing NTP packet during transmission. Since these packets are transported over UDP, the UDP checksum field is then updated to reflect this modification. This document proposes an extension field that includes a 2-octet Checksum Trailer, allowing timestamping engines to reflect the checksum modification in the last 2 octets of the packet rather than in the UDP checksum field. The behavior defined in this document is interoperable with existing NTP implementations.

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## 1. Introduction

The Network Time Protocol [NTPv4] allows clients to synchronize their clocks to a time server by exchanging NTP packets. The increasing demand for highly accurate clock synchronization motivates implementations that provide accurate timestamping.

### 1.1. Intermediate Entities

In this document we use the term 'intermediate entity', referring to an entity that reside on the path between the sender and the receiver of an NTP packet, that modifies this NTP packet en-route. Two examples of intermediate entities are presented below.

In order to facilitate accurate timestamping, an implementation MAY use a hardware based timestamping engine, as shown in Figure 1. In such cases, NTP packets are sent and received by a software layer, whereas a timestamping engine modifies every outgoing NTP packet by incorporating its accurate transmission time into the <Transmit Timestamp> field in the packet.

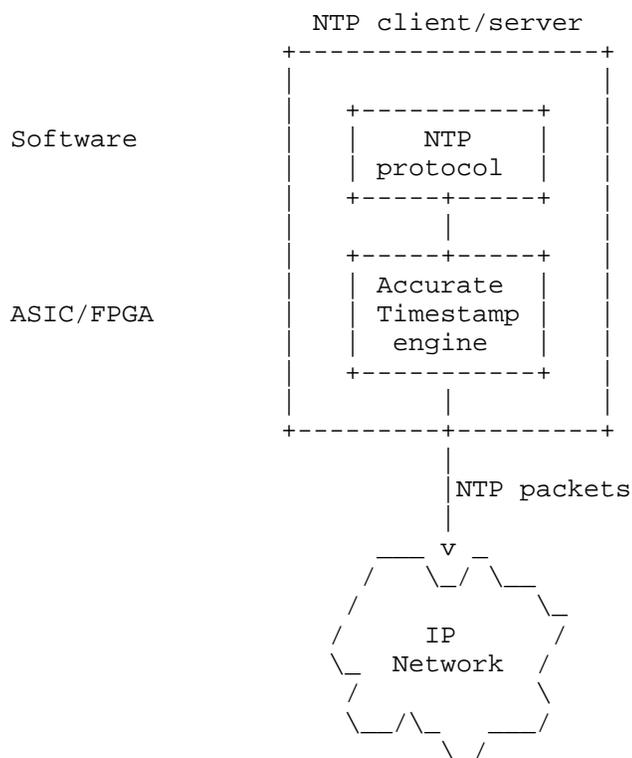


Figure 1 Accurate Timestamping in NTP

The accuracy of clock synchronization over packet networks is highly sensitive to delay jitters in the underlying network, which dramatically affects the clock accuracy. To address this challenge, the Precision Time Protocol (PTP) [IEEE1588] defines Transparent Clocks (TCs), intermediate switches and routers that improve the end-to-end accuracy by updating a "Correction Field" in the PTP packet by adding the latency caused by the current TC. In NTP no equivalent entity is currently defined, but future versions of NTP may define an intermediate node that modifies en-route NTP packets using a "Correction Field".

## 1.2. Updating the UDP Checksum

When the UDP payload is modified by an intermediate entity, the UDP Checksum field needs to be updated to maintain its correctness. When using UDP over IPv4 ([UDP]), an intermediate entity can assign a value of zero in the checksum field, causing the receiver to ignore the checksum field. UDP over IPv6, as defined in [IPv6], does not allow a zero checksum, and requires the UDP checksum field to contain a correct checksum of the UDP payload.

Since an intermediate entity only modifies a specific field in the packet, i.e. the timestamp field, the UDP checksum update can be performed incrementally, using the concepts presented in [Checksum].

A similar problem is addressed in Annex E of [IEEE1588]. When the Precision Time Protocol (PTP) is transported over IPv6, two octets are appended to the end of the PTP payload for UDP checksum updates. The value of these two octets can be updated by an intermediate entity, causing the value of the UDP checksum field to remain correct.

This document defines a similar concept for [NTP], allowing intermediate entities to update NTP packets and maintain the correctness of the UDP checksum by modifying the last 2 octets of the packet. This is performed by adding an NTP extension field at the end of the packet, in which the last two bytes are used as a checksum trailer.

The term Checksum Trailer is used throughout this document and refers to the 2 octets at the end of the UDP payload, used for updating the UDP checksum by intermediate entities.

The usage of the Checksum Trailer can in some cases simplify the implementation, since if the packet data is processed in a serial order, it is simpler to first update the timestamp field, and then update the Checksum Trailer rather than to update the timestamp and then update the UDP checksum, residing at the UDP header.

## 2. Conventions used in this document

### 2.1. Terminology

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

2.2. Abbreviations

- MAC        Message Authentication Code
- NTP        Network Time Protocol
- PTP        Precision Time Protocol
- UDP        User Datagram Protocol

3. Using UDP Checksum Trailers in NTP

3.1. Overview

The UDP Checksum Trailer is a two-octet trailer that is appended at the end of the UDP payload using an NTP extension field. Figure 2 illustrates the packet format of an NTP packet with a Checksum Trailer extension. The figure illustrates an unauthenticated NTP packet. Section 3.4. provides further details about using the Checksum Trailer in authenticated packets.

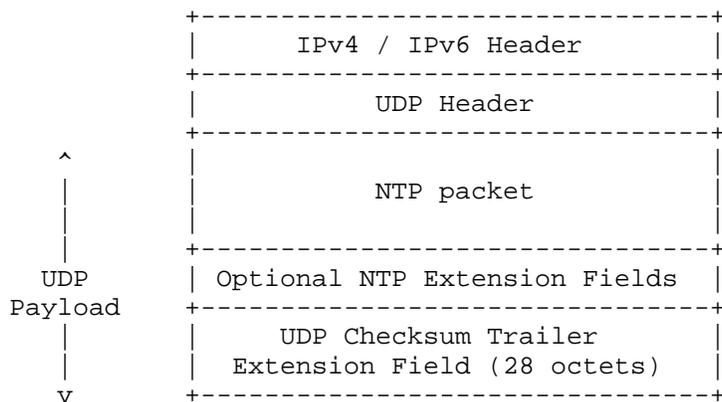


Figure 2 Checksum Trailer in NTP Unauthenticated Packets

3.2. Checksum Trailer in NTP Packets

NTP is transported over UDP, either over IPv4 or over IPv6. This document applies to both NTP over IPv4, and NTP over IPv6.



### Checksum Trailer

Includes the UDP Checksum Trailer field.

#### 3.2.1. Transmission of NTP with Checksum Trailer

The transmitter of an NTP packet MAY include a Checksum Trailer extension field.

#### 3.2.2. Intermediate Updates of NTP with Checksum Trailer

An intermediate node that receives and alters an NTP packet containing a Checksum Trailer extension MAY use the Checksum Trailer to maintain a correct UDP checksum value.

#### 3.2.3. Reception of NTP with Checksum Trailer

This document does not impose new requirements on the receiving end of an NTP packet.

The UDP layer at the receiving end verifies the UDP Checksum of received NTP packets, and the NTP layer SHOULD ignore the Checksum Trailer extension field.

#### 3.3. Interoperability with Existing Implementations

The behavior defined in this document does not impose new requirements on the reception of NTP packets. Thus, transmitters and intermediate nodes that support the Checksum Trailer can transparently interoperate with existing implementations.

#### 3.4. Using the Checksum Trailer with or without Authentication

When message authentication is used, intermediate entities that alter test packets must also re-compute the Message Authentication Code (MAC) accordingly. The MAC update typically requires the intermediate entity to store the packet, re-compute its MAC, and then forward it.

Figure 4 illustrates the format of an authenticated NTP packet with a Checksum Trailer extension.

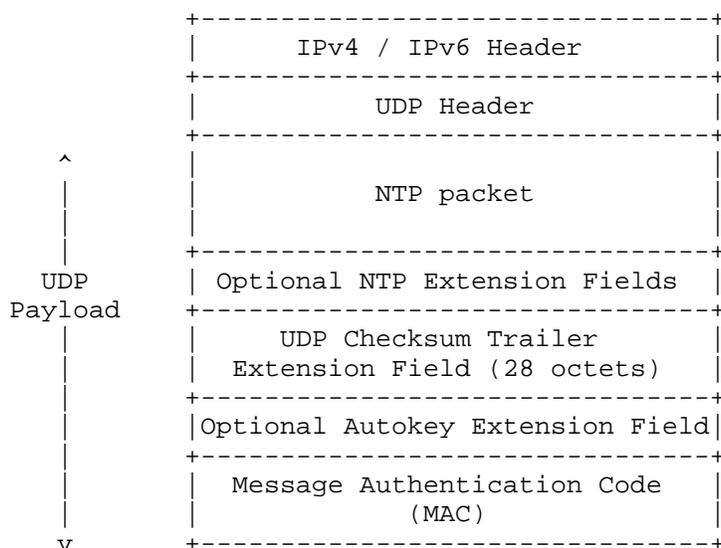


Figure 4 Checksum Trailer in NTP Authenticated Packets

While a Checksum Trailer MAY be used when authentication is enabled, in practice the Checksum Trailer is more useful in unauthenticated mode, allowing the intermediate entity to perform serial processing of the packet without storing-and-forwarding it.

#### 4. Security Considerations

This document describes how a Checksum Trailer extension can be used for updating the checksum. This concept is logically equivalent to an intermediate node that directly modifies the UDP Checksum field, and thus does not present any new security implications.

As described in Section 3.4. , the concept described in this document is especially useful for unauthenticated mode. However, this document does not make a statement about the circumstances in which authentication should or should not be used.

#### 5. IANA Considerations

IANA is requested to allocate an NTP extension Field Type value for the Checksum Trailer extension.

## 6. Acknowledgments

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

## 7. References

### 7.1. Normative References

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