# One-way Delay Measurement Based on Reference Delay

draft-lyy-detnet-ref-delay-measurement-00

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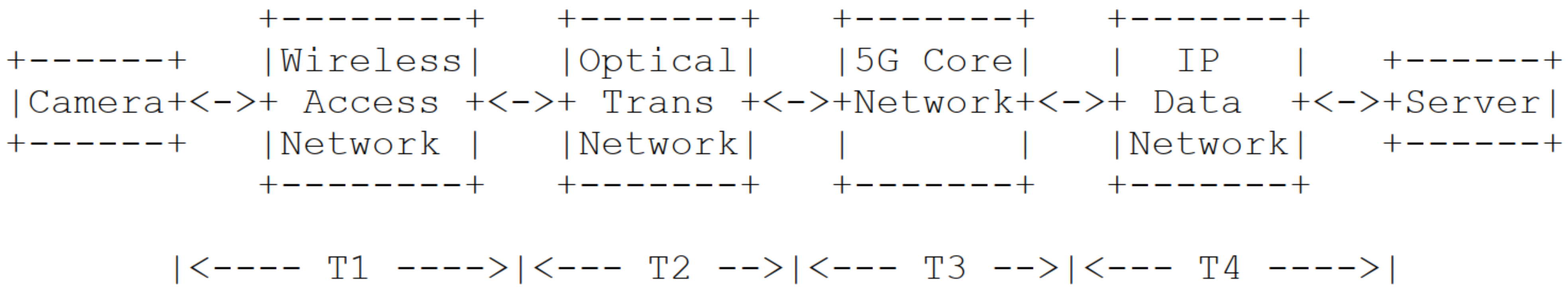
# Backgound

- End-to-end one-way delay (OWD) measurement
  - E2E OWD is an important performance indicator for SLA guarantee
  - E2E OWD measurement is of great significance
- An example: HD video surveillance service scenario in 5G network
  - The end-to-end one-way delay is the sum of T1+T2+T3+T4



```
           +--------+   +-------+   +-------+   +-------+
+------+   |Wireless|   |Optical|   |5G Core|   |  IP   |   +------+
|Camera+<->+ Access +<->+ Trans +<->+Network+<->+ Data  +<->+Server|
+------+   |Network |   |Network|   |       |   |Network|   +------+
           +--------+   +-------+   +-------+   +-------+

       |<---- T1 ---->|<--- T2 -->|<--- T3 -->|<--- T4 ---->|
```

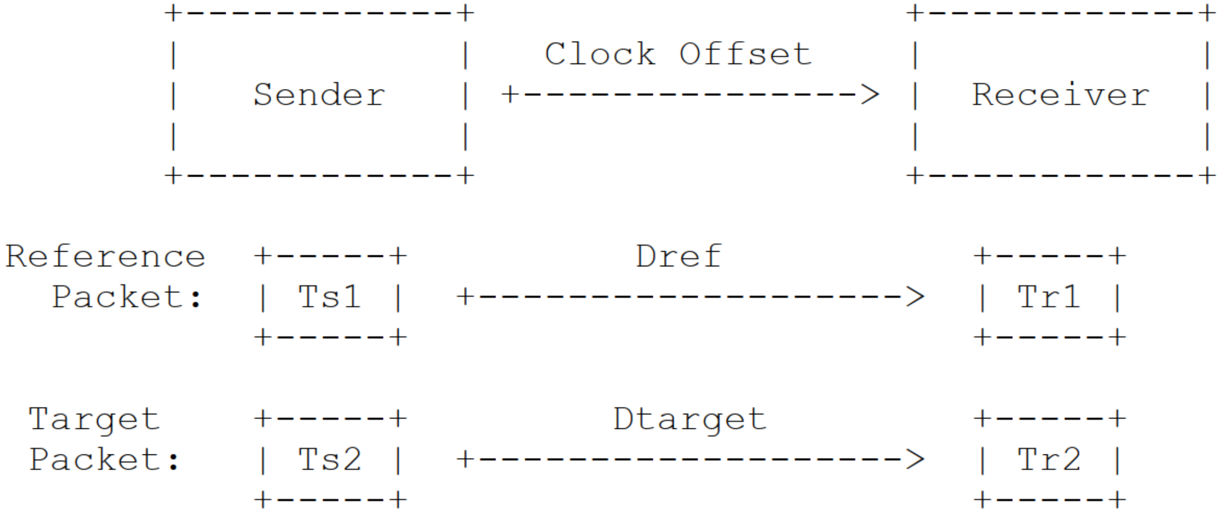
Figure 1:A Scenario for End-to-end One-way Delay

# Introduction

- Existing methods
  - End-to-end deployment of accurate clock synchronization, such as PTP or GPS; but the deployment cost is high.
  - Round-trip delay (RTT) is used to estimate end-to-end one-way delay; Due to the delay asymmetry of the uplink and downlink, the accuracy is low.
- **A new method**
  - This document introduces a new method to accurately measure end-to-end one-way delay using reference delay without deploying clock synchronization.
  - Reference delay is bounded and has low jitter. An example for reference delay can be found in deterministic networking[RFC8655].

# Network Topology

- Sender to Receiver Network:
  - End-to-end one-way delay from the sender to the receiver is measured.
  - Intermediate devices other than the sender and receiver are hidden for simplicity.
- Clock Offset
  - The sender and receiver do not deploy time synchronization.
  - the time deviation between the sender and receiver is the clock offset.



```
          +------------+                    +------------+
          |            |   Clock Offset     |            |
          |   Sender   | +----------------> |  Receiver  |
          |            |                    |            |
          +------------+                    +------------+

Reference    +------+          Dref             +------+
  Packet:    | Ts1  |  +--------------------->  | Tr1  |
             +------+                           +------+

 Target      +------+         Dtarget           +------+
 Packet:     | Ts2  |  +--------------------->  | Tr2  |
             +------+                           +------+
```

Figure 2:Topology of One-way Delay Measurement

# Packets Sent and Timestamps

- Reference Packet:
  - The E2E one-way delay for reference pkt is stable and bounded, denoted as Dref.
- Target Packet:
  - The E2E one-way delay for target pkt is the measurement target, denoted as Dtarget.
- Timestamping:
  - We timestamp reference and target pkt on the sender and receiver side respectively, denoted as Ts1, Ts2, Tr1 and Tr2.

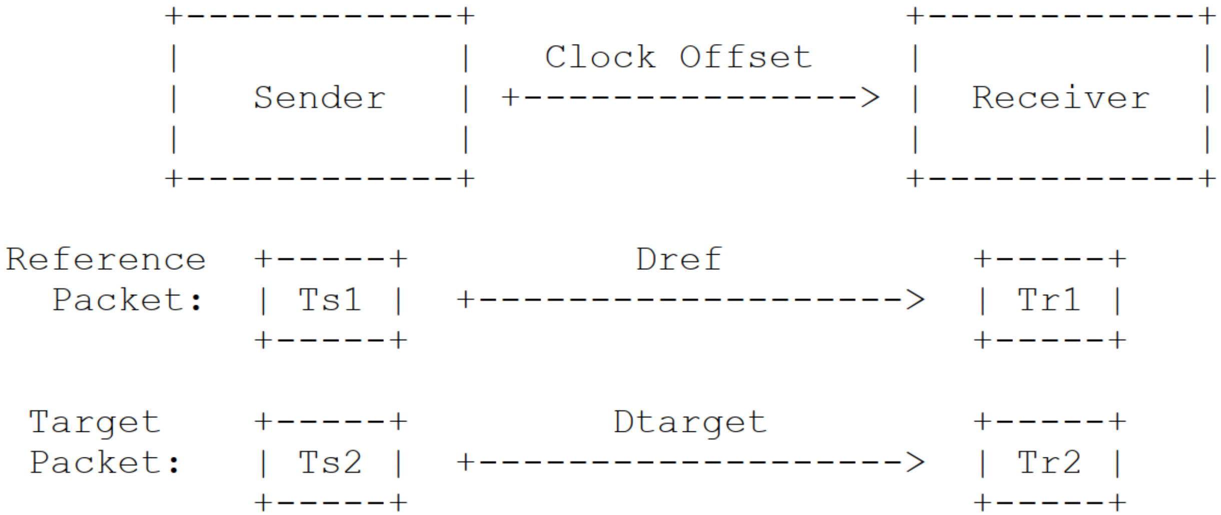


Figure 2:Topology of One-way Delay Measurement

# Proposed OWD Calculation Method

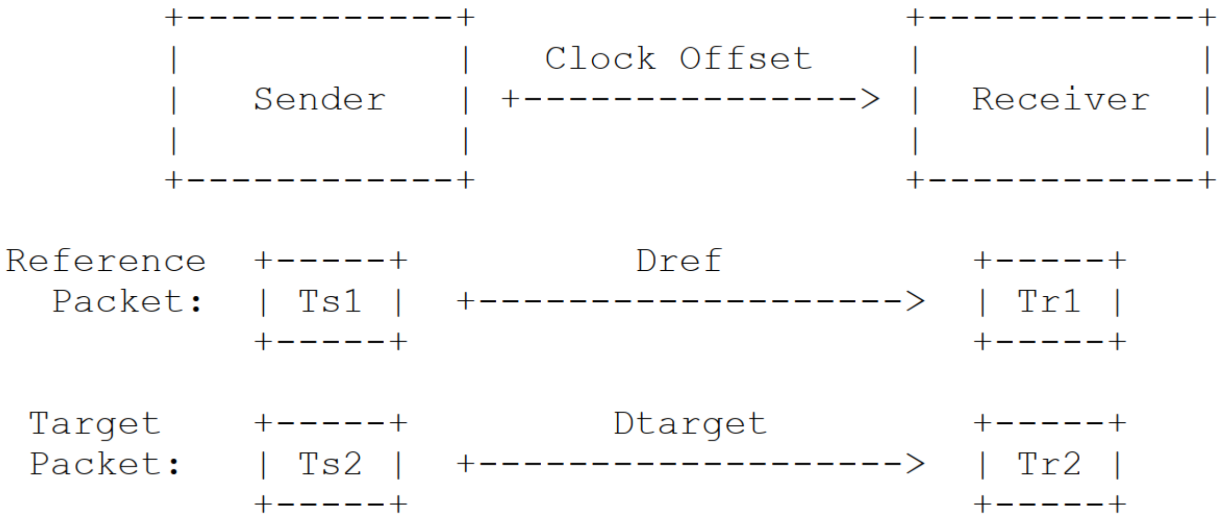
- For reference packet and target packet, we can get Equation 1 and Equation 2, respectively.

$$\mathrm{Tr1} - \mathrm{Ts1} = \mathrm{Dref} + \mathrm{Offset1} \qquad (1)$$

$$\mathrm{Tr2} - \mathrm{Ts2} = \mathrm{Dtarget} + \mathrm{Offset2} \qquad (2)$$

- When sending time interval between reference and target pkt is small, Offset1 = Offset2.
- (Equation 2 – Equation 1), we get Equation 3. Now we can calculate Dtarget.

$$\mathrm{Dtarget} = (\mathrm{Tr2} + \mathrm{Ts1}) - (\mathrm{Tr1} + \mathrm{Ts2}) + \mathrm{Dref} \qquad (3)$$



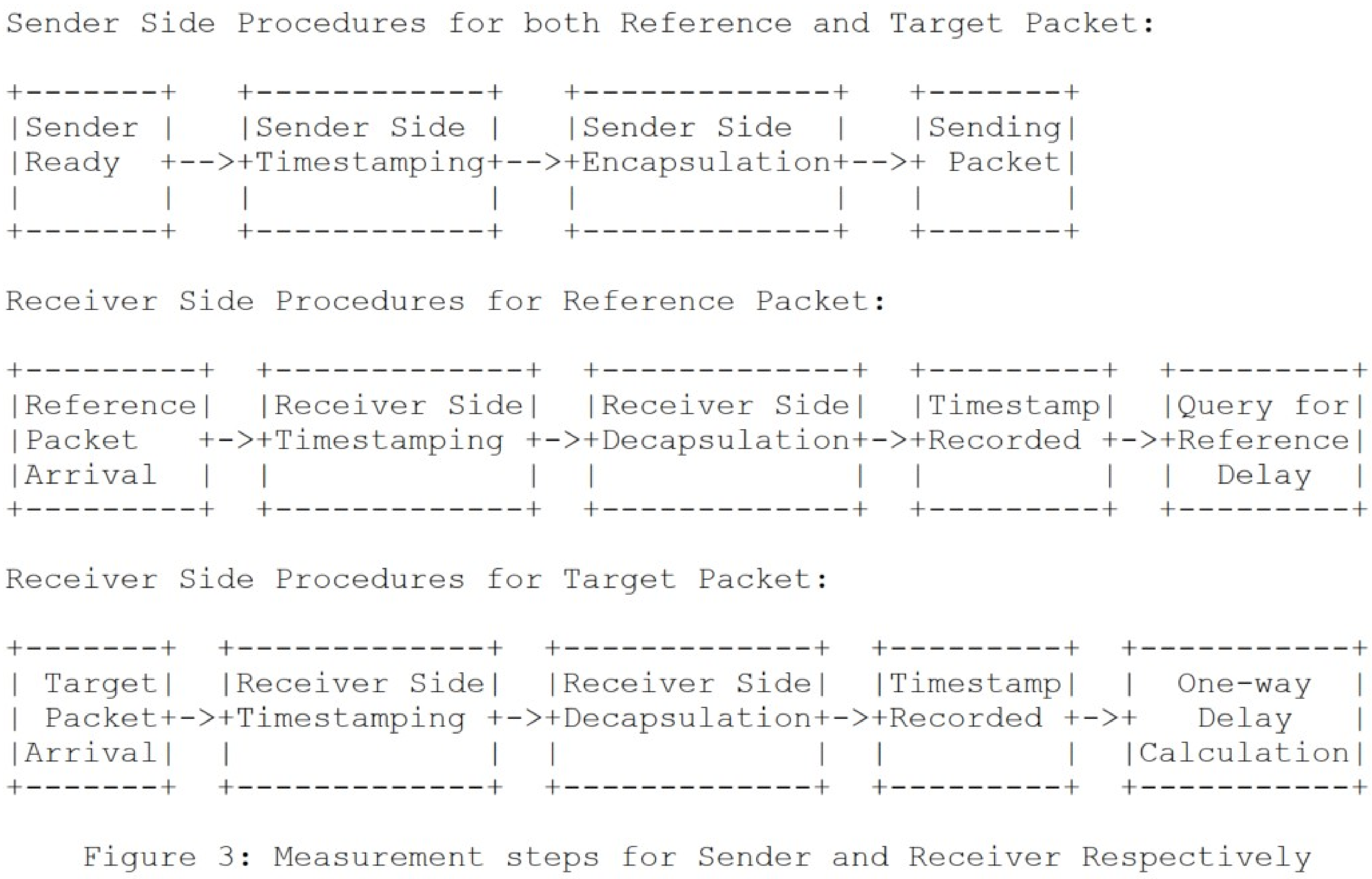
```
          +------------+                      +------------+
          |            |   Clock Offset       |            |
          |   Sender   | +----------------->  |  Receiver  |
          |            |                      |            |
          +------------+                      +------------+

Reference    +-----+           Dref              +-----+
  Packet:    | Ts1 |  +-------------------->     | Tr1 |
             +-----+                             +-----+

 Target      +-----+          Dtarget            +-----+
 Packet:     | Ts2 |  +-------------------->     | Tr2 |
             +-----+                             +-----+
```

Figure 2:Topology of One-way Delay Measurement

# Detailed Measurement Procedures



Sender Side Procedures for both Reference and Target Packet:

```
+-------+   +------------+   +-------------+   +-------+
|Sender |   |Sender Side |   |Sender Side  |   |Sending|
|Ready  +-->+Timestamping+-->+Encapsulation+-->+ Packet|
|       |   |            |   |             |   |       |
+-------+   +------------+   +-------------+   +-------+
```

Receiver Side Procedures for Reference Packet:

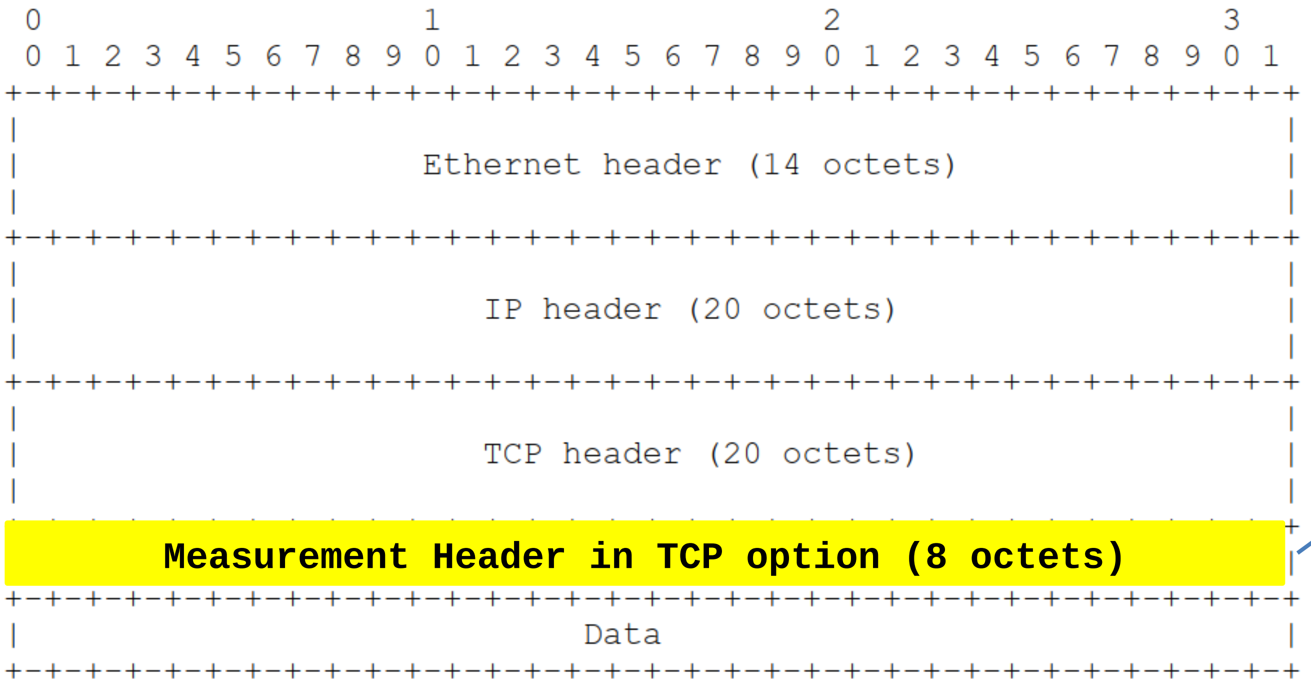
```
+---------+  +-------------+  +-------------+  +---------+  +---------+
|Reference|  |Receiver Side|  |Receiver Side|  |Timestamp|  |Query for|
|Packet   +->+Timestamping +->+Decapsulation+->+Recorded +->+Reference|
|Arrival  |  |             |  |             |  |         |  |  Delay  |
+---------+  +-------------+  +-------------+  +---------+  +---------+
```

Receiver Side Procedures for Target Packet:

```
+-------+  +-------------+  +-------------+  +---------+  +-----------+
| Target|  |Receiver Side|  |Receiver Side|  |Timestamp|  |  One-way  |
| Packet+->+Timestamping +->+Decapsulation+->+Recorded +->+   Delay   |
|Arrival|  |             |  |             |  |         |  |Calculation|
+-------+  +-------------+  +-------------+  +---------+  +-----------+
```

Figure 3: Measurement steps for Sender and Receiver Respectively

# Packet Header Format

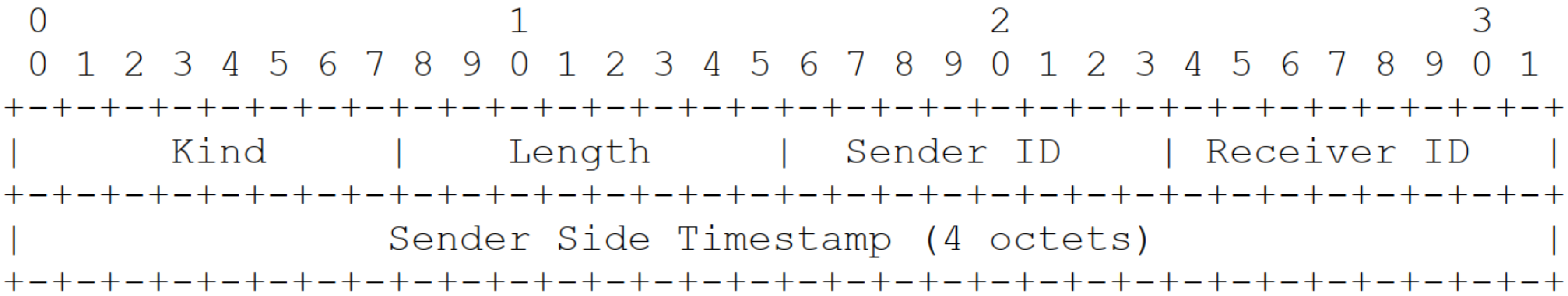


```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                    Ethernet header (14 octets)                |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                       IP header (20 octets)                   |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                       TCP header (20 octets)                  |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
        Measurement Header in TCP option (8 octets)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            Data                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: Format of Reference or Target Packet

- The sender encapsulates timestamp information and sender-receiver pair information in the Measurement Header of the sent packet.
- The position of the Measurement Header is in the option field of the TCP protocol header.

# Measurement Header Format in Detail



```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Kind     |     Length      |   Sender ID    | Receiver ID  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Sender Side Timestamp (4 octets)                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: Detailed Measurement Header Format

- The Kind value can be 253 or 254, and the Length value is 8, which is in accordance with TCP option [RFC4727].
- The sender ID is one octet, and the receiver ID is also one octet.
- The sender side timestamp is 4 octets, which can store accurate timestamp information.

# Advantages

- **No need to deploy time synchronization**
  - There is no need to deploy end-to-end accurate time synchronization, which reduces the deployment cost of accurate one-way delay measurement.
- **No impact on intermediate network devices**
  - Leveraging reference delay for assistance, only time stamping is required at the sender and receiver. So there is no extra configuration for intermediate network devices.

# Next steps

- Detailed analysis on the acquisition of reference delay.

- Consider about security issues.

- More things to be done. You are also welcome to join our work!

Thanks!