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Y. Li
H. Yang
T. Sun
China Mobile
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One-way Delay Measurement Based on Deterministic Networking
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Abstract

One-way delay is a key indicator to measure network quality. Some applications are one-way transmission in the network, such as some high-definition video services, and are very sensitive to one-way delay. Excessive delay will affect user experience greatly. To some extent, the network can't even be used, so it is very important to accurately measure the network transmission delay. The current one-way delay measurement method has problems such as high complexity and low measurement accuracy. In order to solve the problem of high-precision one-way delay measurement, a one-way delay measurement method based on deterministic networking is proposed in this document. The method takes advantage of the delay characteristics of the deterministic networking and does not depend on precise time synchronization.The method realizes the one-way delay measurement of any service flow between any network elements. Its technical advantages are: the network does not need to send measurement packets, can test all traffic types, does not change network status, does not change the format of traffic packets, and does not require network elements to support time synchronization protocols.

Status of This Memo

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1. Introduction

One-way transmission delay is a key indicator to measure network quality. Some applications are based on one-way transmission in the network, such as some high-definition video services, and are very sensitive to one-way delay. Excessive one-way delay will affect user experience dramatically, so it is very important to accurately measure the one-way transmission delay of the network.

There are several kinds of methods to measure one-way delay. The first kind of methods is active measurement. A sender will send measurement protocol messages, such as Two-Way Active Measurement Protocol (TWAMP) [RFC8186]messages, to the network to measure the one-way delay of the sender and receiver. The advantage of active measurement is that it is flexible in application. The disadvantage is that the measurement messages cannot measure the delay of real services, and the measurement of one-way delay requires sender and receiver to support time synchronization protocol, such as NTP [RFC5905]and PTP [IEEE.1588.2008]. The first kind of methods is passive measurement. The passive measurement devices will calculate network delay by collecting actual business traffic. The advantage of passive measurement is that it can measure the one-way delay of real services. The disadvantage is that two passive measurement devices need to be deployed, and the two devices require time synchronization, which is difficult to implement. The third kind of methods is hybrid measurement. Hybrid measurement is a combination of active and passive measurements, that is, inserting some fields or flags in the service message to realize the delay measurement of the actual service. The disadvantage is that the message format of the actual service is changed, which will affect the forwarding behavior of the service and have observer effect. The network element needs to be able to recognize and forward the modified service message, and time synchronization of the network element is also required.

The above-mentioned one-way delay measurement methods have the following shortcomings. Firstly, if the measurement message is injected into actual network, it will occupy network bandwidth resources and interfere with the actual service flow, so the measured delay is not the delay of the actual service. Secondly, the measurement equipment or network elements need to support time synchronization protocols, which is difficult to implement and costly.

To address the following shortcomings of existing methods, this document presents the following technical solution. A high-precision one-way delay measurement method is proposed, which can be used to measure the one-way delay of actual service packets, without sending measurement messages, without changing the actual network status, without changing service messages, and without the need for network elements to support time synchronization protocols.

2. Conventions Used in This Document

2.1. Terminology

NTP Network Time Protocol

PTP Precision Time Protocol

TWAMP Two-Way Active Measurement Protocol

SLA Service Level Agreement

2.2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14[RFC2119][RFC8174] when, and only when, they appear in all capitals, as shown here.

3. One-way Delay Measurement Method Based on Deterministic Networking

```
+-----------------------------------------------------------+
|                 Centralized Control Node                  |
+----+-------------+---------------+---------+---------+----+
     ^             ^               ^         ^         ^
     |             |            T4 |     T3 |         | Tn
     |             |               |    +----+----+    |
     |             |               |    | Network |    |
  T1 |          T2 |  +----------------->Element 3+-+  |
     |             |  |            |    |         | |  |
     |             |  |            |    +---------+ |  |
     |             |  |            |                |  |
     |             |  |            |                |  |
     |             |  |            |                |  |
     |             |  |            |                |  |
+----+----+   +----+--+-+     +----+----+         +-v--+----+
| Network |   | Network |     | Network |         | Network |
|Element 1+--->Element 2+----->Element 4+--------->Element n|
|         |   |         |     |         |         |         |
+---------+   +---------+     +---------+         +---------+
```

Figure 1: Figure 1: A schematic diagram of the network topology structure

A schematic diagram of the network topology structure to describe the proposed method is shown in Figure 1. The network may be a SDN (Software Defined Network) or a traditional network. Whether it is SDN or traditional network, there is a centralized control node (or called a centralized management unit) for collecting network information sent by network elements and sending control information to the network. Taking SDN as an example, the centralized control node can be a SDN controller. For traditional networks, the centralized control node can be a network management system. The information from the network element to the centralized control node generally passes through the management network. In our solution, the management network from each network element to the centralized control node is required to use a delay deterministic network. As an example, the delay deterministic network may be a time sensitive network (TSN) or a deterministic Internet (Deterministic Internet

Network, DIP) [RFC8655], etc. Through the delay deterministic network, the transmission delay of the network element information from the network element to the centralized control node can be guaranteed to be fixed. T1~Tn in Figure 1 represent the network element information delay from the network element to the centralized control node of network element 1 to n respectively.

As shown in Figure 1, suppose network traffic of a real service flow passes through network element 1, network element 2, ..., network element n in turn, and the time when network traffic passes through the network element is recorded as t1, t2, ..., tn. The timestamp maybe the ingress timestamp of network traffic entering the network element or the egress timestamp of network traffic flowing out of the network element after the forwarding is completed. Each network element transmits the flow information to the centralized control node through the delay deterministic network when real traffic passes, and the transmission delays of each network element to transmit the flow information to the centralized control node through the delay deterministic network are denoted as T1, T2, ..., Tn, respectively. The timestamps when the centralized control node receives the flow information of each network element are t1', t2', ..., tn'.

Taking the calculation of the one-way transmission delay of traffic from network element 1 to network element 2 as an example, the one-way transmission delay can be calculated in the following way. Firstly, because the clocks of network element 1 and network element 2 are not synchronized, suppose the time deviation between the two is delta_t. Then the one-way transmission delay of traffic from network element 1 to network element 2 satisfies the following formula (1). Among them, Delay represents the one-way transmission delay of traffic from network element 1 to network element 2.

Formula (1): Delay = t2 - t1 - delta_t

Secondly, because the clocks between network element 1 and the centralized control node are not synchronized, assuming that the time deviation between the two is delta_t', the time for the traffic information collected from the network element 1 to reach the centralized control node through the delay deterministic network satisfies the following formula (2).

Formula (2): t1' = t1 + T1 + delta_t'

Thirdly, the clocks between network element 2 and the centralized control node are not synchronized, and the time deviation between network element 2 and the centralized control node is delta_t'-delta_t. The time t2' for the collected traffic to reach the centralized control node satisfies the following formula (3).

Formula (3): t2' = t2 + T2 + delta_t' - delta_t

Forthly, subtracting the formula (2) from the above formula (3), we can obtain the following formula (4).

Formula (4): t2 - t1 - delta_t = t2' - t1' + T1 - T2

Fifthly, substituting the above formula (4) into the above formula (1), the following formula (5) can be obtained.

Formula (5): Delay = t2' - t1' + T1 - T2

So far, the one-way transmission delay of traffic from network element 1 to network element 2 is obtained. Taking the calculation of one-way transmission delay of traffic from network element 1 to network element 3 as an example, the one-way transmission delay can be calculated in the following way: I) Referring to the above formula (5), the one-way transmission delay of traffic from network element 1 to network element 2 is: Delay12 = t2' - t1' + T1 - T2. II) Referring to the above formula (5), the one-way transmission delay of traffic from network element 2 to network element 3 is: Delay23 = t3' - t2' + T2 - T3. III) The one-way transmission delay of traffic from network element 1 to network element 3 is: Delay13 = Delay12 + Delay23 = t2' - t1' + T1 - T2 + t3' -t2' +T2 - T3 = t3' - t1' + T1 - T3. It can be seen that the one-way transmission delay between any two network elements can be calculated similarly to the above formula (5). For example, taking network element m and network element n as an example, the transmission delay of traffic from network element m to network element n is: Delay = tn' - tm' + Tm - Tn, where tn' and tm' are the time when the traffic information of network element m and network n reaches the centralized control node, and Tm and Tn are transmission delay of the traffic information from network element m and network element n to the centralized control node respectively through delay deterministic network.

4. Procedures of the One-way Delay Measurement Method

In this section, the procedures of the proposed one-way delay measurement method will be elaborated. Assume there are two network element. It is determined that the time when the centralized control node receives the first flow information is the first time, and the time when the second flow information is received by the centralized control node is determined to be the second time. The first flow information is sent to the centralized control node via delay deterministic network, and the second flow information is also sent to the centralized control node via delay deterministic network. The procedures of the one-way delay measurement method is shown in Figure 2.

```
 +-----------+  +-----------+ +---------------------+ +--------------+
 |  Network  |  |  Network  | | Delay Deterministic | | Centralized  |
 | Element m |  | Element n | |       Network       | | Control Node |
 +-----+-----+  +-----+-----+ +---------------------+ +-------+------+
       |              |                                       |
       |              |                                       |
       |              |                                       |
       |              |  The first transmission       +-------+--------+
       |              |      delay is Tm              | tm' represents |
       +----------------------------------------------> the first time |
       |              |                               +-------+--------+
       |              |                                       |
       |              |                                       |
       |              |  The second transmission      +-------+--------+
       |              |      delay is Tn              | tn' represents |
       |              +-------------------------------> the second time|
       |              |                               +-------+--------+
       |              |                                       |
       |              |                                       |
       |              |                                       |
       +              +                                       +
```

Figure 2: Figure 2: Procedures of the one-way delay measurement method

The transmission delay of traffic from the first network element to the second network element can be determined based on the first time, the second time, the first transmission delay, and the second transmission delay.

The first traffic information is sent by the first network element to the centralized control node via a delay deterministic network at the moment when the traffic passes through the first network element. And the time when the traffic passes through the first network element refers to the moment when traffic enters the first network element or the time when traffic flows out of the first network element.

The second traffic information is sent by the second network element to the centralized control node via a delay deterministic network at the moment when the traffic passes through the second network element. And the time when the traffic passes through the second network element refers to the moment when traffic enters the second network element or the time when traffic flows out of the second network element.

It is determined that the transmission delay of the first traffic information from the first network element to the centralized control node is the first transmission delay, and it is determined that the transmission delay of the second traffic information from the second network element to the centralized control node is the second transmission delay. The transmission delay of traffic from the first network element to the second network element can be determined based on the following formula: Delay=tn'-tm'+Tm-Tn. Wherein, tn' represents the second time, tm' represents the first time, Tm represents the first transmission delay, Tn represents the second transmission delay, and Delay represents transmission delay of the traffic from the first network element to the second network element. In the above method, the delay deterministic network is used to ensure that the first transmission delay and the second transmission delay are fixed delays.

5. Security Considerations

TBD.

6. IANA Considerations

TBD.

7. Normative References

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Authors' Addresses

Yang Li
China Mobile
Beijing
100053
China

Email: liyangzn@chinamobile.com

Hongwei Yang
China Mobile
Beijing
100053
China

Email: yanghongwei@chinamobile.com

Tao Sun
China Mobile
Beijing
100053
China

Email: suntao@chinamobile.com