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One-way delay measurement method based on Digital Twin Network

Abstract

This document implements an accurate network delay measurement method based on the digital twin network. This method does not need to send measurement packets, change the physical network configuration, change the format of service packets, and do not require physical network elements to support the time synchronization protocol. Two-way delay and one-way delay measurement of any service packet.The digital twin network architecture of this document follows the NMRG working group paper draft-irtf-nmrg-network-digital-twin-arch-00.

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1. Introduction

Digital twin network is a virtual representation of the physical network. Such virtual representation of the network is meant to be used to analyze, diagnose, emulate, and then control the physical network based on data, models, and interfaces. The DTN architecture diagram is shown in Figure 1.

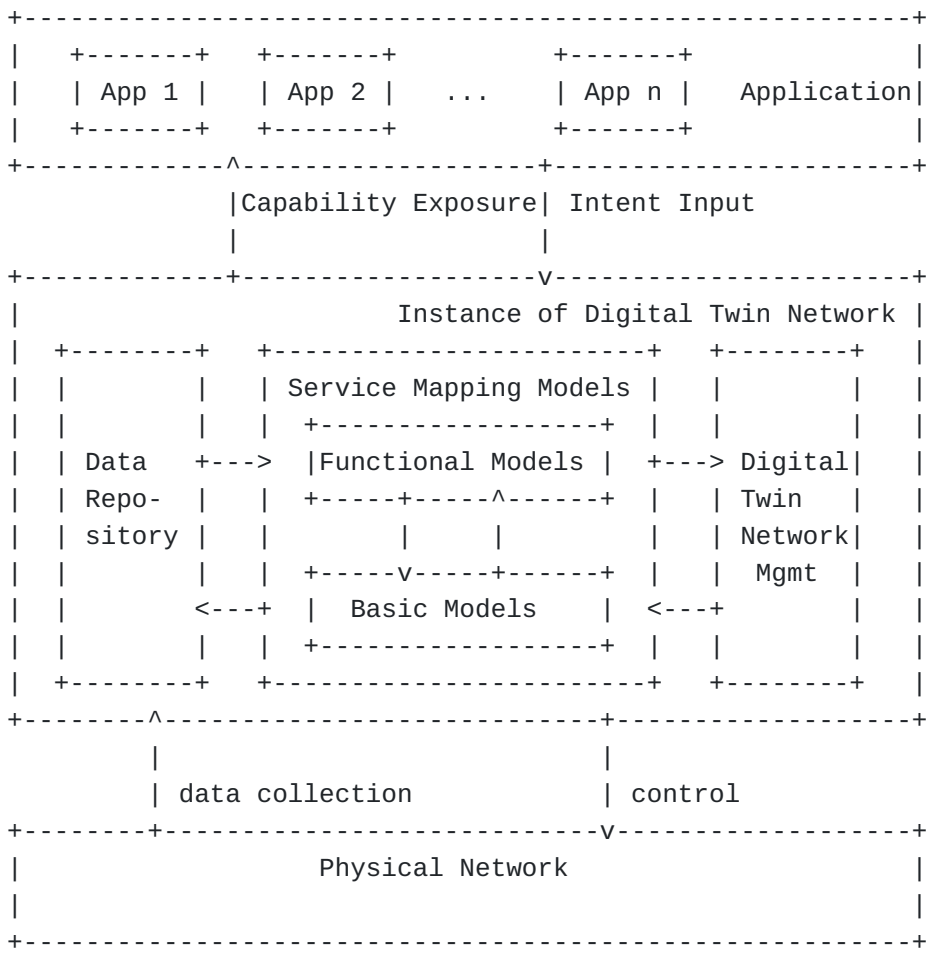

Figure 1: Figure1:Reference Architecture of Digital Twin Network

The digital twin layer forms a network element model by modeling physical network elements, and the network element model forms a twin network element through instantiation, that is, each physical network element in the physical network has a corresponding twin network element in the digital twin layer. Similarly, each physical flow of the physical network also has a corresponding twin flow at the digital twin layer.

Traditional network delay measurement methods include active measurement, passive measurement, hybrid measurement, etc., but they all have some disadvantages:

1) It is necessary to inject measurement packets into the physical network, but this will affect the forwarding behavior of actual service traffic, affect the accuracy of delay measurement, and increase the network burden and occupy network resources;

2) It is impossible to perform accurate delay measurement on the packets of all network protocols. For example, it is difficult to measure the one-way delay for UDP packets;

3) Some solutions need to change the format of service packets and insert measurement parameters, but this requires upgrading the physical network, which is difficult to implement, and affects the normal forwarding behavior of service packets and affects the measurement accuracy;

4) The time synchronization protocol is required to measure the one-way delay of the network, and the physical network is required to support this protocol, which increases the difficulty of implementing the solution.

2. Conventions Used in This Document

2.1. Terminology

NTP Network Time Protocol

PTP Precision Time Protocol

DTN Digital Twin Network

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. Method Introduction

The delay measurement method based on DTN is as follows:

1) According to the digital twin network architecture, build a digital twin layer, including twin network elements corresponding to physical network elements, such as twin switches, twin routers, etc.;

2) Time synchronization is maintained between each twin network element in the digital twin layer. a) If multiple twin NEs are in the same physical entity, such as the NFV-based modeling method, where multiple twin NEs are deployed in one server and share the same local clock, the twin NEs themselves is time-synchronized; b) If multiple twin NEs are deployed in different physical entities, use PTP (Precise Time Protocol) [IEEE.1588.2008]or NTP (Network Time Protocol) [RFC5905]to achieve time synchronization between physical entities to ensure time synchronization of all twin NEs;

3) The data transmission from the physical network layer to the digital twin layer uses a delay deterministic network (Detnet) to

ensure that the data transmission delay between each physical network element and the twin network element is deterministic or pre-calculable, as shown in the figure 2. T1~Tn is the delay of data transmission; the delay deterministic network can be based on TSN or DIP technology;

4) When a flow of the physical network is input from the physical network element 1, passes through the physical network elements 2 and 3, and finally is output from the physical network element n. When physical network element 1 receives the data packet, it will normally forward the data to physical network element 2 and transmit the data to twin network element 1 at the same time. At this time, the local time of the twin NE 1 is t1, and the deterministic network transmission delay is T1, then the arrival time of the traffic information recorded by the twin NE is t1-T1; similarly, the arrival time of the data packet recorded by other twin NEs is tn- Tn.

5) Finally, according to the arrival time of the data packet at the twin network elements, its one-way transmission delay between physical network elements can be calculated.

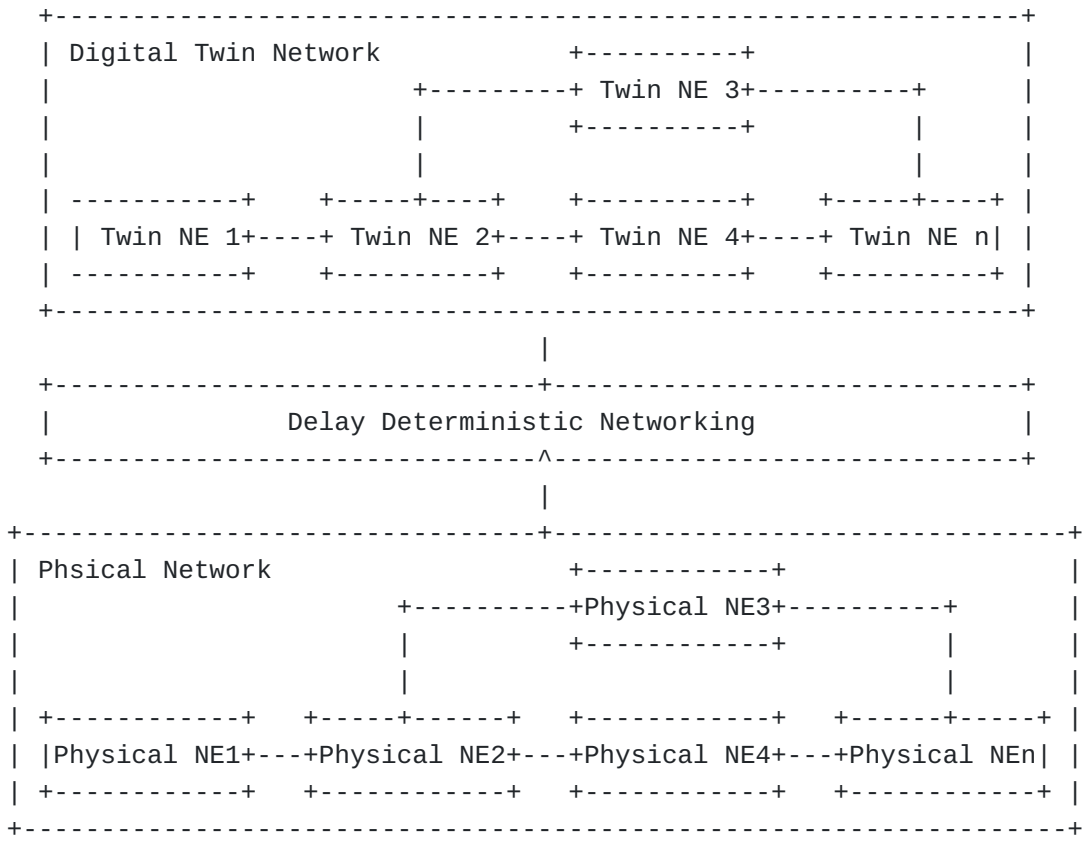

Figure 2: Figure 2: Between the physical network and the twin network is a delay deterministic network

4. Implementation Process

The detailed calculation process is shown in Figure 3:

(1) When the traffic data to be measured reaches physical network element 1, physical network element 1 forwards the traffic to physical network element 2, but also transmits the data to twin network element 1, and the transmission delay is T1. The local time of network element 1 is t1, and the arrival time of the data recorded by twin network element 1 is t1-T1;

(2) When the data packet is forwarded to physical network element 2, physical network element 2 will also forward it to physical network element 3 normally, but also to twin network element 2, and the delay to reach twin network element 2 is T2 , at this time, the local time of twin network element 2 is t2, and the arrival time of data packet information recorded by twin network element 2 is t2-T2, then (t2-T2)-(t1-T1) is the data packet from physical network element 1 to One-way delay of physical network element 2.

(3) Similarly, when the data packet reaches the nth physical network element, the nth physical network element will also transmit the data packet to the twin network element n. The data transmission time is Tn, and the local time of the twin network element n is tn, then record tn. -Tn is the time when the packet reaches the twin network element n, then (tn-Tn)-(t1-T1) is the one-way transmission delay of the data packet from physical network element 1 to physical network element n;

So far, the one-way transmission delay of data packets between physical NEs is obtained by calculating the time when the data packet to be tested reaches the twin NEs. During the measurement process, only time synchronization between twin NEs is required, but no physical network is required. Inter-meta time synchronization. The accuracy of delay measurement depends on the time synchronization accuracy of the twin network elements and the time synchronization accuracy of the delay deterministic network. If both use the PTP synchronization protocol, the delay measurement accuracy can reach the nanosecond level.

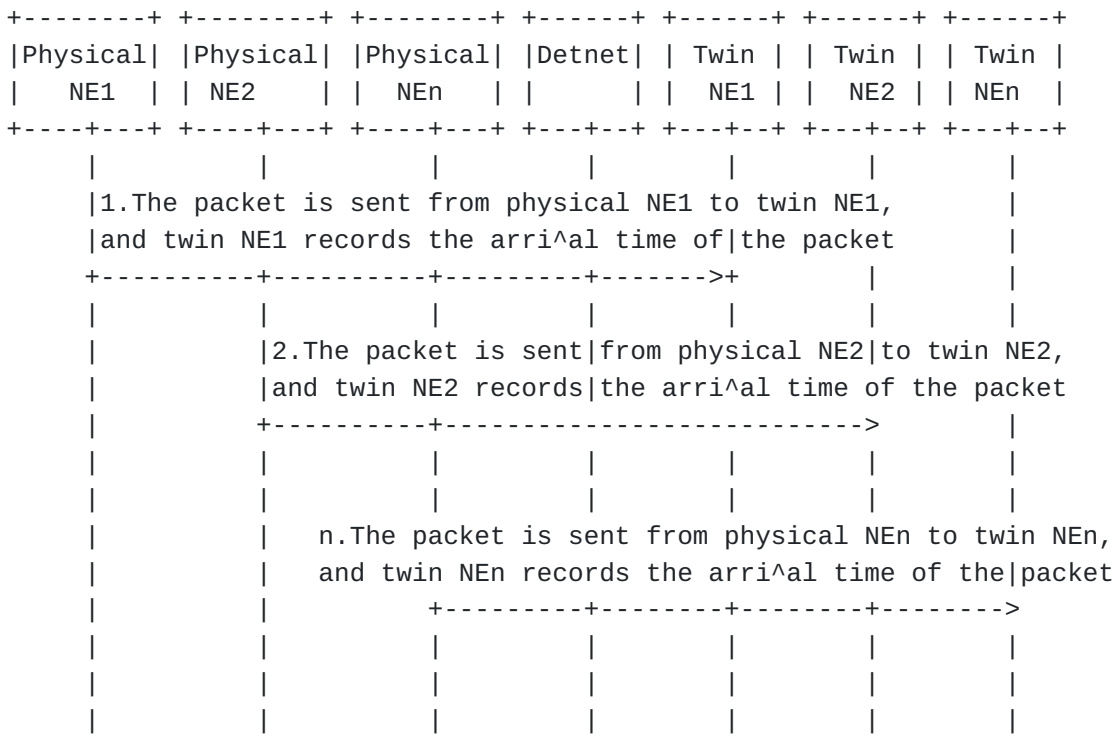

Figure 3: Figure 3: Delay Measurement Process

5. Conclusion

This method can realize segment-by-segment or end-to-end one-way delay measurement in the physical network. The advantages of this method include: no need to send measurement packets, all traffic protocol types can be measured, physical network configuration is not changed, and traffic data format is not changed. , It does not need the physical network to support the time synchronization protocol, and the measurement accuracy is high.

6. Security Considerations

TBD.

7. IANA Considerations

TBD.

8. Normative References

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