Deterministic Networking (DetNet) can provide data transmission with end-to-end bounded latency and extremely low packet loss for user’s services. In order to better control and manage deterministic network services. It is necessary to measure and monitor DetNet QoS information. As introduced in [I-D.chen-detnet-loss-delay], packet loss rates and end-to-end delay can be measured by using passive Performance Measurement (PM) in MPLS-based DetNet encapsulation.

This document implement three new QoS related attribute to support passive Performance Measurement for DetNet service.

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1. Introduction

As defined in [I-D.ietf-detnet-architecture], DetNet can provide data transmission with end-to-end bounded latency and extremely low packet loss for user’s services. In order to ensure the efficiency and accuracy of information collection and management, it is necessary to measure and monitor DetNet QoS information.

DetNet QoS information includes minimum and maximum delay, bounded jitter, packet loss ratio and an upper bound on misordering packet in general. Apart from this, link bandwidth information also play an important role in resource allocation.

As introduced in [I-D.chen-detnet-loss-delay], packet loss rates and end-to-end delay can be measured by using passive Performance Measurement (PM) in MPLS-based DetNet encapsulation. Which defines two new flags in the d-CW(control word) and three new TLVs to LM and DM messages.
Inspired by that, we implement protocol mechanisms to support passive Performance Measurement for bounded jitter, misordering packet and used bandwidth.

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 [RFC2119].

1.2. Terminology

The terminology is defined as [I-D.ietf-detnet-architecture], [RFC3270], [RFC6374], [RFC2475] and [RFC2474].

2. DetNet Control Word based PM

MPLS-based DetNet encapsulation introduces an S-Lable and a d-CW. Meanwhile [I-D.chen-detnet-loss-delay] document defines two new flags in the d-CW. Here this document defines a new flag in the d-CW (as shown in Figure 1). The B bit is defined to indicate whether the bandwidth measurement is enabled.

+-----------------+     +-----------------+
|  IP/MPLS Tunnel  |     |  Service Label  |
|                   +-----------------+     +-- Service Layer Header
|                   | +-----------------+<--/
|                   | |                   |
|                   | |                   |
|                   | |                   |
|                   | |                   |
+-----|  Control Word  |     +-- Payload     |
|      +-----------------+<--/
|      |                   |
|      +-----------------+     +-----------------+     +-----------------+     +-----------------+
|      |                   |     |                   |     |                   |     |                   |
|      |                   |     |                   |     |                   |     |                   |
|      |                   |     |                   |     |                   |     |                   |
|      |                   |     |                   |     |                   |     |                   |
|      |                   |     |                   |     |                   |     |                   |
|      +--------------------+     +--------------------+     +--------------------+     +--------------------+     +--------------------+     +--------------------+     +--------------------+     +--------------------+     +--------------------+     +--------------------+     +--------------------+
|    |0 0 0 0|L|D|B| Sequence Number   |
|    +--------------------+     +--------------------+     +--------------------+     +--------------------+     +--------------------+     +--------------------+

Figure 1: DetNet Control Word

where:

- L bit: Loss measurement indicator; 1 means the loss measurement is enabled, otherwise the loss measurement is not enabled.

- D bit: Delay measurement indicator; 1 means the delay measurement is enabled, otherwise the delay measurement is not enabled. When
a node receive a packet with D bit set, it will timestamp the packet and copy it for further PM processing.

- B bit: Bandwidth measurement indicator; 1 means the bandwidth measurement is enabled, otherwise the bandwidth measurement is not enabled.

Assume a DetNet service path between node A and node B, where node A is the ingress node, and node B is the egress node. The packets with same interval number belong to the same measurement interval.

[Editor notes: The detail of measurement interval and flags in DetNet Control Word can be found in [I-D.chen-detnet-loss-delay]]

## 2.1. Jitter

In brief, jitter can be calculated by delay. To measure the delay of a packet, the D bit of the d-CW MUST be set.

If the D bit of the d-CW is set, recording both the flow-id of DetNet flow and the node-id of node.

At the ingress node, record the time when sending the packet, with the timestamp indexed by the sequence number. At the egress node, when receiving a packet with D bit set, record the time when the packet was received, with the timestamp indexed by the sequence number.

When the measurement interval comes, all the information of node-id, flow-id, sequence number and timestamps need to be sent to the centralized controller.

The mechanism for sending information to a centralized controller is out side the scope of this document.

After that, the centralized controller can find the sequence number and timestamps between adjacent nodes such as AB by flow-id and node-id.

Then, with the timestamps from the ingress and egress nodes, and the sequence number, the packet delay can be calculated as below.

$$\text{Delay}[n] = \text{B_RxT}[n] - \text{A_TxT}[n]$$, where:

- \text{B_RxT}[n] identifies the timestamp at node B when receiving the No. "n" packet;
After getting multiple sets of Delay[n] information, the packet jitter in the No. \( t \) measurement interval can be calculated as below:

\[
\text{Jitter}[t] = \max(\text{Delay}[i] - \text{Delay}[j]),
\]

- Delay\([i]\) identifies the No. \( i \) packet’s delay between A and B;
- Delay\([j]\) identifies the No. \( j \) packet’s delay between A and B;

### 2.2. Used Bandwidth

To measure the used bandwidth of DetNet flows between A and B, both of the D bit and B bit of the d-CW MUST be set.

If the B and D bit of the d-CW are set, recording both the flow-id of DetNet flow and the node-id of node.

At the ingress node, record the time and accumulate the packet bytes when sending the packet, with the timestamp indexed by the sequence number. At the egress node, when receiving a packet with B and D bit set, record the time and accumulate the packet bytes when the packet was received, with the timestamp indexed by the sequence number.

When the measurement interval comes, all the information of node-id, flow-id, sequence number, timestamps and packet bytes need to be sent to the centralized controller. Then the packet bytes need to be reset to zero for next measurement interval.

After that, the centralized controller can find the sequence number, timestamps and packet bytes between adjacent nodes such as AB by flow-id and node-id.

Then, with the timestamps and packet bytes from the ingress and egress nodes, and the sequence number, the used bandwidth in No. \( t \) measurement interval can be calculated as below:

\[
\text{Bandwidth}[t] = \max(\text{A_TxB}[t], \text{B_RxB}[t]) \times \frac{8}{\text{Delay}[t]},
\]

- Delay\([i]\) identifies the No. \( i \) packet’s delay between A and B, the measurement method has been introduced in section 2.1;
- B_RxB\([n]\) identifies the total bytes received at node B in the No. \( n \) measurement interval with the same flow-id;
2.3. Misordering packets

Since the measurement of the maximum misordering packets only requires the sequence number of the DetNet flows, there is no need to additionally add a flag bit to the MPLS control word. The D bit of the d-CW can be reused.

To measure the maximum misordering packets, the D bit of the d-CW MUST be set.

At the ingress node, record the time when sending the packet, with the timestamp indexed by the sequence number. At the egress node, when receiving a packet with D bit set, record the time when the packet was received, with the timestamp indexed by the sequence number.

When the measurement interval comes, all the information of node-id, flow-id, sequence number and timestamps need to be sent to the centralized controller.

After that, the centralized controller can find the sequence number and timestamps between adjacent nodes such as AB by flow-id and node-id.

A packet can be classified as a misordering packet if it has a sequence number smaller than its predecessors.

Specifically, let M DetNet flows, denoted as \((S_1, \ldots, S_m)\), be the total number of flows sent from node A to B.

In each flow \(S_i\) consisting of \(K\) packets, we assign to each packet \(j\) a sequence number \(a_j\) which is a successive integer from 1 to \(K\) in the order of the packet emission and so we create the source sequence as \((a_1, \ldots, a_K)\). Assume an output sequence \((b_1, \ldots, b_P)\) of \(S_i\) observed at the receiving node B, where \(P \leq K\) be the total number of packets received out of the \(K\) packets sent. Due to loss, the amount \(K\) may less than \(P\).

The sequence is said to be in order if for any index \(k\) \((1 \leq k \leq P)\) holds \(b_k \leq b_q\) \((0 \leq q \leq k)\), else the flow is said to reached at the destination misordering, and the packet \(k\) is a reordered packet in the reordered flow. The total number of reordered packets in flow \(S_i\) is written as \(L_i\).
For example, for the sequence of an arrived reordered flow (1,2,3,5,4,7,6,8), there are 2 reordered packets (packet 4 and packet 6), which leads to $L = 2$. Note that in this document reordering does not correlate with loss (same as [2][8][9]). For example, a received flow (1,2,3,4,5,6,8) is considered as in order.

3. Security Considerations

TBD.

4. IANA Considerations

TBD.

5. Acknowledgements

TBD.

6. References

6.1. Informative References


6.2. Normative References


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