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       Performance Measurement (PM) with Marking Method in Bit Index Explicit
                          Replication (BIER) Layer
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   Abstract

      This document describes the applicability of a hybrid performance
      measurement method for packet loss and packet delay measurements of a
      multicast service through a Bit Index Explicit Replication domain.

   Status of This Memo

      This Internet-Draft is submitted in full conformance with the
      provisions of BCP 78 and BCP 79.

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      material or to cite them other than as "work in progress."

      This Internet-Draft will expire on 14 July 2024.

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1. Introduction

   [RFC8279] introduces and explains the Bit Index Explicit Replication
   (BIER) architecture and how it supports the forwarding of multicast
   data packets. [RFC8296] specified that in the case of BIER
   encapsulation in an MPLS network, a BIER-MPLS label, the label that
   is at the bottom of the label stack, uniquely identifies the
   multicast flow. [RFC9341] and [RFC9342] describe a hybrid
   performance measurement method, according to the classification of
   measurement methods in [RFC7799]. The method, called Packet Network
   Performance Monitoring (PNPM), can be used to measure packet loss,
   latency, and jitter on live traffic complies with requirements R-5
   and R-12 listed in [I-D.ietf-bier-oam-requirements]. Because this
   method is based on marking consecutive batches of packets, the method
   is often referred to as a marking method. Terms PNPM and "marking
   method" in this document are used interchangeably.

   This document defines how the marking method can be used on the BIER
   layer to measure packet loss and delay metrics of a multicast flow in
   an MPLS network.

2. Conventions used in this document

2.1. Terminology

   This document uses the terms related to the Alternate Marking Method
   as defined in [RFC9341], [RFC9342]. This document uses the terms
   related to the Bit Indexed Explicit Replication as defined in
   [RFC8296].

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. OAM Field in BIER Header

   [RFC8296] defined the two-bits long field, referred to as OAM. The
   OAM field can be used for the marking performance measurement method.
   Because the setting of the field to any value does not affect
   forwarding and/or quality of service treatment of a packet, using the
   OAM field for PNPM in BIER layer can be viewed as the example of the
   hybrid performance measurement method.

   Figure 1 displays the interpretation of the OAM field defined in this
   specification for the use of the PNPM method. The context of
   interpretation of the OAM field MAY be signaled via the control plane
   or configured using an extension to the BIER YANG data model
   [I-D.ietf-bier-bier-yang]. These extensions are outside the scope of
   this document.

```
  0
  0   1
+-+-+-+-+
| S | D |
+-+-+-+-+
```

                 Figure 1: OAM field of BIER Header format

   where:

   * S - Single-Marking flag;

   * D - Double-Marking flag.

4. Theory of Operation

   The marking method can be used in the multicast environment supported
   by BIER layer. Without limiting any generality consider multicast
   network presented in Figure 2. Any combination of markings can be
   applied to a multicast flow by the Bit Forwarding Ingress Router
   (BFIR) at either ingress or egress point to perform node, link,
   segment or end-to-end measurement to detect performance degradation
   defect and localize it efficiently.

```
                                   -----
                               --| D |
                     -----    /   -----
                   --| B |--
                  /   -----   \   -----
                 /              --| E |
       -----    /                 -----
      | A |---                    -----
       -----    \              --| F |
                 \   -----    /   -----
                   --| C |--
                     -----   \   -----
                               --| G |
                                   -----
```
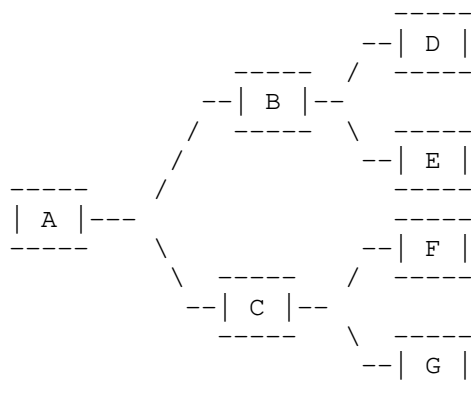
Figure 2: Multicast network

   Using the marking method, a BFIR creates distinct sub-flows in the
   particular multicast traffic over BIER layer. Each sub-flow consists
   of consecutive blocks of identically marked packets. For example, a
   block of N packets, with each packet being marked as X, is followed
   by the block of M packets with each packet being marked as Y. These
   blocks are unambiguously recognizable by a monitoring point at any
   Bit Forwarding Router (BFR) and can be measured to calculate packet
   loss and/or packet delay metrics. The marking method can be used on
   multiple flows concurrently. Demultiplexing of monitored flows might
   be achived using n-tuple, for example, two-tuple as combination of
   the values in the Entropy and BFIR-id fields [RFC8296]. Also, that
   can be achieved by using an explicit Flow Identifiier. The
   definition of the Flow Identifier is outside the scope of this
   specification. It is expected that the marking values be set and
   cleared at the edge of BIER domain. Thus for the scenario presented
   in Figure 2 if the operator initially monitors the A-C-G and A-B-D
   segments he may enable measurements on segments C-F and B-E at any
   time.

4.1. Single-Marking Enabled Measurement

   As explained in [RFC9341], marking can be applied to delineate blocks
   of packets based either on the equal number of packets in a block or
   based on the equal time interval. The latter method offers better
   control as it allows a better account for capabilities of downstream
   nodes to report statistics related to batches of packets and, at the
   same time, time resolution that affects defect detection interval.

   If the Single-Marking measurement is used to measure packet loss,
   then the D flag MUST be set to zero on transmit and ignored by the
   monitoring point.

   The S flag is used to create sub-flows to measure the packet loss by
   switching the value of the S flag every N-th packet or at certain
   time intervals. Delay metrics MAY be calculated with the sub-flow
   using any of the following methods:

   * First/Last Packet Delay calculation: whenever the marking, i.e.,
      the value of S flag changes, a BFR can store the timestamp of the
      first/last packet of the block. The timestamp can be compared
      with the timestamp of the packet that arrived in the same order
      through a monitoring point at a downstream BFR to compute packet
      delay. Because timestamps collected based on the order of arrival
      this method is sensitive to packet loss and re-ordering of packets
      (see Section 4.3 for more details).

   * Average Packet Delay calculation: an average delay is calculated
      by considering the average arrival time of the packets within a
      single block. A BFR may collect timestamps for each packet
      received within a single block. Average of the timestamp is the
      sum of all the timestamps divided by the total number of packets
      received. Then the difference between the average packet arrival
      time calculated for the downstream monitoring point and the same
      metric but calculated at the upstream monitoring point is the
      average packet delay on the segment between these two points.
      This method is robust to out of order packets and also to packet
      loss on the segment between the measurement points (packet loss
      may cause a minor loss of accuracy in the calculated metric
      because the number of packets used is different at each
      measurement point). This method only provides a single metric for
      the duration of the block, and it doesn't give the minimum and
      maximum delay values. This limitation of producing only the
      single metric could be overcome by reducing the duration of the
      block. As a result, the calculated value of the average delay
      will better reflect the minimum and maximum delay values of the
      block's duration time.

4.2. Double-Marking Enabled Measurement

   Double-Marking method allows measurement of minimum and maximum
   delays for the monitored flow, but it requires more nodal and network
   resources. If the Double-Marking method used, then the S flag is
   used to create the sub-flow, i.e., mark blocks of packets. The D
   flag is used to mark single packets within a block to measure delay
   and jitter.

   The first marking (S flag alternation) is needed for packet loss and
   also for average delay measurement. The second marking (D flag is
   put to one) creates a new set of marked packets that are fully
   identified over the BIER network, so that a BFR can store the
   timestamps of these packets; these timestamps can be compared with
   the timestamps of the same packets on a second BFR to compute packet
   delay values for each packet. The number of measurements can be
   easily increased by changing the frequency of the second marking. On
   the other hand, the higher frequency of the second marking will cause
   a higher volume of the measurement data being transported through the
   BIER domain. An operator should consider and balance both effects.
   This method is useful to measure not only the average delay but also
   the minimum and maximum delay values and, in wider terms, to know
   more about the statistic distribution of delay values.

4.3. Operational Considerations

   For the ease of operational procedures, the initial marking of a
   multicast flow is performed at BFIR. and cleared, by way of removing
   BIER encapsulation form a payload packet, at the edge of the BIER
   domain by BFERs.

   Since at the time of writing this specification, there are no
   proposals to using auto-discovery or signaling mechanism to inform
   downstream nodes what methodology is used each monitoring point MUST
   be configured beforehand.

   Section 5 [RFC9341] provides a detailed analysis of how packet re-
   ordering and the duration of the block in the Single-Marking mode of
   the marking method impact the accuracy of the packet loss
   measurement. Re-ordering of packets in the Single-Marking mode will
   be noticeable only at the edge of a block of packets (re-ordering
   within the block cannot be detected in the Single-Marking mode). If
   the extra delay for some packets is much smaller than half of the
   duration of a block, then it should be easier to attribute re-ordered
   packets to the proper block and thus maintain the accuracy of the
   packet loss measurement.

Selection of a time interval to switch the marking of a batch of packets should be based on the service requirements. In the course of the regular operation, reports, including performance metrics like packet loss ratio, packet delay, and inter-packet delay variation, are logged every 15 minutes. Thus, it is reasonable to maintain the duration of the measurement interval at 5 minutes with 100 measurements per each interval. To support these measurements, marking of the packet batch is switched every 3 seconds. In case when performance metrics are required in near-real-time, the duration interval of a single batch of identically marked packets will be in the range of tens of milliseconds.

5. IANA Considerations

   This document sets no requirements to IANA. This section can be removed before the publication.

6. Security Considerations

   Regarding using the marking method, [RFC9341] stressed two types of security concerns. First, the potential harm caused by the measurements, is a lesser threat as [RFC8296] defines OAM field used by the marking method so that the value of "two bits have no effect on the path taken by a BIER packet and have no effect on the quality of service applied to a BIER packet." Second security concern, potential harm to the measurements can be mitigated by using policy, suggested in [RFC8296], to accept BIER packets only from trusted routers, not from customer-facing interfaces.

   All the security considerations for BIER discussed in [RFC8296] are inherited by this document.

7. Acknowledgement

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