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Extensions to the Path Computation Element Communication Protocol (PCEP)  
for Utilizing Bit Error Rate (BER) Metrics  
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## Abstract

IGP Traffic Engineering (TE) Metric Extensions describe mechanisms with which network performance information is distributed via OSPF IS-IS, and BGP-LS, respectively. The Path Computation Element Communication Protocol (PCEP) provides mechanisms for Path Computation Elements (PCEs) to perform path computations in response to Path Computation Client (PCC) requests. This document describes the extension to PCEP to utilize Bit Error Rate (BER) and Packet Error Rate (PER) as constraints for end-to-end path computation.

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## 1. Introduction

Networks may experience transmission bit errors due to various factors, such as poor fiber quality. The bit error can be a single bit error or a burst of bit errors at a time. Bit errors include layer-2 bit errors (e.g., causing CRC errors) or layer-3 and layer-4 bit errors (e.g., causing checksum failures). It is feasible to measure Bit Error Rate (BER) and Packet Error Rate (PER) of the links using measurement packets. It is important that BER and PER metrics are also considered during the path selection process to be able to provide service level assurance.

The Traffic Engineering Database (TED) is populated with network performance information like link latency, delay variation, packet loss, as well as parameters related to bandwidth (residual bandwidth, available bandwidth, and utilized bandwidth) via TE Metric Extensions in OSPF [RFC7471] or IS-IS [RFC8570] or via a management system. [RFC7823] describes how a Path Computation Element (PCE) [RFC5440] can use that information for path selection for explicitly routed LSPs.

A Path Computation Client (PCC) can request a PCE to provide a path meeting end-to-end network performance criteria. This document extends the Path Computation Element Communication Protocol (PCEP) [RFC5440] to handle network performance constraints that also include BER and PER constraints.

## 2. Conventions Used in This Document

### 2.1. 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.

### 2.2. Abbreviations

BER: Bit Error Rate

EMA: Exponential Moving Average

IGP: Interior Gateway Protocol

IS-IS: Intermediate System to Intermediate System

OF: Objective Function

OSPF: Open Shortest Path First

PCC: Path Computation Client

PCE: Path Computation Element

PER: Rate of Packets with Bit Errors

RSVP: Resource Reservation Protocol

TE: Traffic Engineering

TED: Traffic Engineering Database

### 3. Overview

[RFC8233] defines extensions to the PCEP to compute label switched paths. This document further extends the path computation extensions defined in [RFC8233] to include Bit Error Rate (BER) and Packet Error Rate (PER) link metrics. Note that the PCEP extensions defined in this document are equally applicable to the segment routing path computation defined in [RFC8664].

Various BER metrics that can be used in path computation are:

- (1) Average BER
- (2) Maximum BER
- (3) Minimum BER
- (4) Exponential Moving Average of BER
- (5) Variance of BER (difference of minimum and average, for example)
- (6) BER anomaly state

Various PER metrics that can be used in path computation are:

- (1) Average PER
- (2) Maximum PER
- (3) Minimum PER
- (4) Exponential Moving Average of PER
- (5) Variance of PER metrics (difference of minimum and average, for example)
- (6) PER anomaly state

### 4. PCEP Extensions

This section defines PCEP extensions (see [RFC5440]) to support bit error rate based network performance aware path computation.

#### 4.1. Extensions to METRIC Object

The METRIC object is defined in Section 7.8 of [RFC5440], comprising metric-value and metric-type (T field), and a flags field, comprising a number of bit flags (B bit and P bit). This document defines the following types for the METRIC object.

- o TBA1: Path Average BER Metric
- o TBA2: Path Average PER Metric
- o TBA3: P2MP Path Average BER Metric
- o TBA4: P2MP Path Average PER Metric

The following terminology is used and expanded along the way.

- o A network comprises of a set of N links  $\{L_i, (i=1\dots N)\}$ .
- o A path P of a point-to-point (P2P) LSP is a list of K links  $\{L_{pi}, (i=1\dots K)\}$ .

#### 4.2. Path BER Metric

[RFC7471] and [RFC8570] for IS-IS define "Unidirectional Link BER". The Path BER (as a percentage) metric type of the METRIC object in PCEP encodes a function of the unidirectional BER metrics of all links along a P2P path. The end-to-end BER for the path is represented by this metric. Specifically, extending on the above mentioned terminology:

- o The percentage link BER of link L is denoted  $PR(L)$ .
- o The fractional link BER of link L is denoted  $FR(L) = PR(L)/100$ .
- o The percentage Path BER metric for the P2P path  $P = (1 - ((1-FR(L_{p1})) * (1-FR(L_{p2})) * \dots * (1-FR(L_{pK})))) * 100$  for a path P with links  $L_{p1}$  to  $L_{pK}$ .

This is as per the composition function described in Section 5.1.5 of [RFC6049].

Metric Type T = TBA1: Path BER metric

Metric Type T = TBA2: Path PER metric

A PCC MAY use the Path BER metric in a PCReq message to request a path meeting the end-to-end BER requirement. In this case, the B bit MUST be set to suggest a bound (a maximum) for the Path BER metric that must not be exceeded for the PCC to consider the computed path as acceptable. The Path BER metric must be less than or equal to the value specified in the metric-value field.

A PCC can also use this metric to ask the PCE to optimize the path BER during path computation. In this case, the B flag MUST be cleared.

A PCE MAY use the Path BER metric in a PCRep message along with a NO-PATH object in the case where the PCE cannot compute a path meeting this constraint. A PCE can also use this metric to send the computed end-to-end BER metric to the PCC.

#### 4.3. Path BER Metric Value

The TE metrics specified in [RFC7471] for OSPF, [RFC8570] for IS-IS, and [RFC8571] for BGP are further extended to distribute "Unidirectional Link BER Sub-TLV" to advertise the link BER in percentage in a 24-bit field. [RFC5440] defines the METRIC object with a 32-bit metric value encoded in IEEE floating point format (see (IEEE.754)). Consequently, the encoding for the Path BER metric value is quantified as a percentage and encoded in IEEE floating point format.

#### 4.4. P2MP Path BER Metric

This section defines the following types for the METRIC object to be used for the P2MP TE LSPs.

The P2MP Path BER metric type of the METRIC object in PCEP encodes the path BER metric for the destination that observes the worst BER metric among all destinations of the P2MP tree. Specifically, extending on the above-mentioned terminology:

- o A P2MP tree T comprises of a set of M destinations {Dest\_j, (j=1...M)}.
- o The P2P Path BER metric of the path to destination Dest\_j is denoted by PRM(Dest\_j).
- o The P2MP Path BER metric for the P2MP tree T = Maximum {PRM(Dest\_j), (j=1...M)}.

Metric Type T = TBA3: P2MP Path BER metric

Metric Type T = TBA4: P2MP Path PER metric

#### 4.5. Objective Functions

[RFC5541] defines a mechanism to specify an objective function that is used by a PCE when it computes a path. For path BER, the following new OF is defined.

- o A network comprises a set of N links  $\{L_i, (i=1\dots N)\}$ .
- o A path P is a list of K links  $\{L_{pi}, (i=1\dots K)\}$ .
- o The percentage link BER of link L is denoted  $PR(L)$ .
- o The fractional link BER of link L is denoted  $FR(L) = PR(L) / 100$ .
- o The percentage path BER of a path P is denoted  $PR(P)$ , where  $PR(P) = (1 - ((1-FR(L_{p1})) * (1-FR(L_{p2})) * \dots * (1-FR(L_{pK})))) * 100$ .

Objective Function Code: TBA6 Name: Minimum BER Path (MBERP)

Description: Find a path P such that  $PR(P)$  is minimized.

If the objective functions defined in this document are unknown/unsupported by a PCE, then the procedure as defined in Section 3.1.1 of [RFC5541] is followed.

##### 4.5.1. TE Flex-Algorithm

New Flexible algorithm type is defined for TE that uses BER and PER metrics.

Editor's note: Additional details will be added in the future version of this document.

#### 5. Other Considerations

The new metric type and objective functions defined in this document can also be used with the stateful PCE extensions defined in RFC 8231 for PCI-initiated LSPs. The format of PCEP messages described in [RFC8231] uses (intended-attribute-list) and (attribute-list), respectively, (where the (intended-attribute-list) is the attribute-list defined in Section 6.5 of [RFC5440] and extended in this document) for BER parameters.

A stateful PCE can also determine which LSPs should be reoptimized based on network events or triggers from external monitoring systems. For example, when a particular link deteriorates and its BER increases, this can trigger the stateful PCE to automatically determine which LSPs are impacted and should be reoptimized.

## 6. Security Considerations

The security considerations specified in [RFC5440], [RFC8231], [RFC8233], and [RFC8664] apply to the procedure and extensions defined in this document.

## 7. IANA Considerations

IANA maintains the "Path Computation Element Protocol (PCEP) Numbers" registry. Within this registry, IANA maintains a subregistry for "METRIC Object T Field". New metric types are defined in this document for the METRIC object (specified in [RFC5440]). IANA is requested to allocate the values for these METRIC types.

Value	Description	Reference
TBA1	Path Average BER Metric	This document
TBA2	Path Average PER Metric	This document
TBA3	P2MP Path Average BER Metric	This document
TBA4	P2MP Path Average PER Metric	This document

Table 1: Metric Types:

Editor's note: Additional types for carrying minimum, maximum, and variance of the BER and PER metrics will be defined in the future revision of this document.

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