

Network Working Group  
Internet-Draft  
Intended status: Standards Track  
Expires: 5 September 2022

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4 March 2022

Precision Availability Metrics for SLO-Governed End-to-End Services  
draft-mhmcsfh-ippm-pam-00

## Abstract

This document defines a set of metrics for networking services with performance requirements expressed as Service Level Objectives (SLO). These metrics, referred to as Precision Availability Metrics (PAM), can be used to assess the service levels that are being delivered. Specifically, PAM can be used to determine the degree of compliance with which service levels are being delivered relative to pre-defined SLOs. PAM can be used to provide a service according to its SLO as part of accounting records, to account for the actual quality with which services were delivered and whether or not any SLO violations occurred. Also, PAM can be used to continuously monitor the quality with which the service is delivered.

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This Internet-Draft will expire on 5 September 2022.

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PAM for Multi-SLO

March 2022

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[1.](#) Introduction

Network operators and network users often need to assess the quality with which network services are being delivered. In particular in cases where service level guarantees are given and service level objectives (SLOs) are defined, it is essential to provide a measure of the degree with which actual service levels that are delivered comply with SLOs that were promised. Examples of service levels

include end-to-end latency and packet loss. Simple examples of SLOs associated with such service levels would be target values for the maximum end-to-end latency or maximum amount of loss that would be deemed acceptable.

To express the quality of delivered networking services versus their SLOs, corresponding metrics are needed that can be used to characterize the quality of the service being provided. Of concern is not so much the absolute service level (for example, actual latency experienced), but whether the service is provided in accordance with the contracted service levels. For instance, whether the latency that is experienced falls within the acceptable range that has been contracted for the service. The specific quality depends on the SLO that is in effect. Different groups of applications set forth requirements for varying sets of service levels with different target values. Such applications range from Augmented Reality/Virtual Reality to mission-critical controlling industrial processes. A non-conformance to an SLO might result in degradation of the quality of experience for gamers up to jeopardizing the safety of a large area. However, as those applications represent significant business opportunities, they demand dependable technical solutions.

The same service level may be deemed perfectly acceptable for one application, while unacceptable for another, depending on the needs of the application. Hence it is not sufficient to simply measure service levels per se over time, but to assess the quality of the service being provided with the applicable SLO in mind. However, at this point, there are no metrics in place that are able to account for the quality with which services are delivered relative to their SLOs, and whether their SLOs are being delivered on at all times. Such metrics and the instrumentation to support them are essential for a number of purposes, including monitoring (to ensure that networking services are performing according to their objectives) as well as accounting (to maintain a record of service levels delivered, important for monetization of such services as well as for triaging of problems).

The current state-of-the-art of metrics available today includes (for example) interface metrics, useful to obtain data on traffic volume and behavior that can be observed at an interface [[RFC2863](#)] and

[RFC8343] but agnostic of actual end-to-end service levels and not specific to distinct flows. Flow records [RFC7011] and [RFC7012] maintain statistics about flows, including flow volume and flow duration, but again, contain very little information about end-to-end service levels, let alone whether the service levels delivered to meet their targets, i.e., their associated SLOs.

This specification introduces a new set of metrics, Precision Availability Metrics (PAM), aimed at capturing end-to-end service levels for a flow, specifically the degree to which flows comply with the SLOs that are in effect. The term "availability" reflects the fact that a service which is characterized by its SLOs is considered

unavailable whenever those SLOs are violated, even if basic connectivity is still working. "Precision" refers to the fact that services whose end-to-end service levels are governed by SLOs, and which must therefore be precisely delivered according to the associated quality and performance requirements. It should be noted that "precision" refers to what is being assessed, not to the mechanism used to measure it; in other words, it does not refer to the precision of the mechanism with which actual service levels are measured. The specification and implementation of methods that provide for accurate measurements is a separate topic independent of the definition of the metrics in which the results of such measurements would be expressed.

[Ed.note: It should be noted that at this point, the set of metrics proposed here is intended as a "starter set" that is intended to spark further discussion. Other metrics are certainly conceivable; we expect that the list of metrics will evolve as part of the Working Group discussions.]

## [2.](#) Conventions used in this document

### [2.1.](#) Terminology and Acronyms

[Ed.Note: needs updating.]

PAM Precision Availability Metric

OAM Operations, Administration, and Maintenance

EI Errored Interval

EIR Errored Interval Ratio

SEI Severely Errored Interval

SEIR Severely Errored Interval Ratio

EFI Error-Free Interval

### [3.](#) Performance Availability Metrics

#### [3.1.](#) Preliminaries

When analyzing the availability metrics of a service flow between two nodes, we need to select a time interval as the unit of PAM. In [\[ITU.G.826\]](#), a time interval of one second is used. That is reasonable, but some services may require different granularity. For that reason, the time interval in PAM is viewed as a variable parameter though constant for a particular measurement session. Further, for the purpose of PAM, each time interval, e.g., second or decamillisecond, is classified either as Errored Interval (EI), Severely Errored Interval (SEI), or Error-Free Interval (EFI). These are defined as follows:

- \* An EI is a time interval during which at least one of the performance parameters degraded below its pre-defined optimal level threshold or a defect was detected.
- \* An SEI is a time interval during which at least one the performance parameters degraded below its pre-defined critical threshold or a defect was detected.
- \* Consequently, an EFI is a time interval during which all

performance objectives are at or above their respective pre-defined optimal levels, and no defect has been detected.

The definition of a state of a defect in the network is also necessary for understanding the PAM. In this document, the defect is interpreted as the state of inability to communicate between a particular set of nodes. It is important to note that it is being defined as a state, and thus, it has conditions that define entry into it and exit out of it. Also, the state of defect exists only in connection to the particular group of nodes in the network, not the network as a domain.

From these definitions, a set of basic metrics can be defined that count the numbers of time intervals that fall into each category:

- \* EI count.
- \* SEI count.
- \* EFI count.

### [3.2.](#) Derived Performance Availability Metrics

A set of metrics can be created based on PAM introduced in [Section 3](#). In this document, these metrics are referred to as derived PAM. Some of these metrics are modeled after Mean Time Between Failure (MTBF) metrics – a "failure" in this context referring to a failure to deliver a packet according to its SLO.

- \* Time since the last errored interval (e.g., since last errored ms, since last errored second). (This parameter is suitable for the monitoring of the current health.) [Ed. note: Need a definition of "current health". Is there an alternative to "current"? Past health?]
- \* Packets since the last errored packet. (This parameter is

suitable for the monitoring of the current health.)

- \* Mean time between EIs (e.g., between errored milliseconds, errored seconds) is the arithmetic mean of time between consecutive EIs.
- \* Mean packets between EIs is the arithmetic mean of the number of SLO-compliant packets between consecutive EIs. (Another variation of "MTBF" in a service setting.)

An analogous set of metrics can be produced for SEI:

- \* Time since the last SEI (e.g., since last errored ms, since last errored second). (This parameter is suitable for the monitoring of the current health.)
- \* Mean time between SEIs (e.g., between severely errored milliseconds, severely errored seconds) is the arithmetic mean of time between consecutive SEIs.
- \* Mean packets between SEIs is the arithmetic mean of the number of SLO-compliant packets between consecutive SEIs. (Another variation of "MTBF" in a service setting.)

Determining the period in which the path is currently PAM-wise is helpful. But because switching between periods requires ten consecutive intervals, shorter conditions may not be adequately reflected. Two additional PAMs can be used, and they are defined as follows:

- \* errored interval ratio (EIR) is the ratio of EI to the total number of time unit intervals in a time of the availability periods during a fixed measurement interval.

- \* severely errored interval ratio (SESR) - is the ratio of SEIs to the total number of time unit intervals in a time of the availability periods during a fixed measurement interval.

### [3.3.](#) Network Availability in Performance Availability Metrics

The definitions of EI, SEI, and EFI allow for characterization of the communication between two nodes relative to the level of required and

acceptable performance and when performance degrades below the acceptable level. The former condition in this document referred to as network availability. The latter – network unavailability. Based on the definitions, SEI is the one time interval of network unavailability while EI and EFI present an interval of network availability. But since the conditions of the network are everchanging periods of network availability and unavailability need to be defined with duration larger than one time interval to reduce the number of state changes while correctly reflecting the network condition. The method to determine the state of the network in terms of PAM is described below:

- \* If ten consecutive SEIs been detected, then the PAM state of the network is determined as unavailability, and the beginning of that period of unavailability state is at the start of the first SEI in the sequence of the consecutive SEIs.
- \* Similarly, ten consecutive non-SEIs, i.e., either EIs or EFIs, indicate that the network is in the availability period, i.e., available. The start of that period is at the beginning of the first non-SEI.
- \* Resulting from these two definitions, a sequence of less than ten consecutive SEIs or non-SEIs does not change the PAM state of the network. For example, if the PAM state is determined as unavailability, a sequence of seven EFIs is not viewed as an availability period.

#### [4.](#) Statistical SLO

It should be noted that certain Service Level Agreements (SLA) may be statistical, requiring the service levels of packets in a flow to adhere to specific distributions. For example, an SLA might state that any given SLO applies only to a certain percentage of packets, allowing for a certain level of, for example, packet loss and/or exceeding packet delay threshold take place. Each such event, in that case, does not necessarily constitute an SLO violation. However, it is still useful to maintain those statistics, as the number of out-of-SLO packets still matters when looked at in proportion to the total number of packets.

Along that vein, an SLA might establish an SLO of, say, end-to-end



latency to not exceed 20ms for 99% of packets, to not exceed 25ms for 99.999% of packets, and to never exceed 30ms for anything beyond. In that case, any individual packet missing the 20 ms latency target cannot be considered an SLO violation in itself, but compliance with the SLO may need to be assessed after the fact.

To support statistical SLAs more directly, it is feasible to support additional metrics, such as metrics that represent histograms for service level parameters with buckets corresponding to individual service level objectives. For the example just given, a histogram for a given flow could be maintained with three buckets: one containing the count of packets within 20ms, a second with a count of packets between 20 and 25ms (or simply all within 25ms), a third with a count of packets between 25 and 30ms (or merely all packets within 30ms, and a fourth with a count of anything beyond (or simply a total count). Of course, the number of buckets and the boundaries between those buckets should correspond to the needs of the application respectively SLA, i.e., to the specific guarantees and SLOs that were provided. The definition of histogram metrics is for further study.

## [5.](#) Availability of Anything-as-a-Service

Anything as a service (XaaS) describes a general category of services related to cloud computing and remote access. These services include the vast number of products, tools, and technologies that are delivered to users as a service over the Internet. In this document, the availability of XaaS is viewed as the ability to access the service over a period of time with pre-defined performance objectives. Among the advantages of the XaaS model are:

- \* Improving the expense model by purchasing services from providers on a subscription basis rather than buying individual products, e.g., software, hardware, servers, security, infrastructure, and install them on-site, and then link everything together to create networks.
- \* Speeding new apps and business processes by quickly adapting to changing market conditions with new applications or solutions.
- \* Shifting IT resources to specialized higher-value projects that use the core expertise of the company.

But XaaS model also has potential challenges:

- \* Possible downtime resulting from issues of internet reliability, resilience, provisioning, and managing the infrastructure resources.

- \* Performance issues caused by depleted resources like bandwidth, computing power, inefficiencies of virtualized environments, ongoing management and security of multi-cloud services.
- \* Complexity impacts enterprise IT team that must remain in the process of the continued learning of the provided services.

The framework and metrics of the PAM defined in [Section 3](#) allow a provider of XaaS and their customers to quantify, measure, monitor for conformance what is often referred to as an ephemeral - availability of the service to be delivered. There are other definitions and methods of expressing availability. For example, [\[HighAvailability-WP\]](#) uses the following equation:

Availability Average =  $MTBF / (MTBF + MTRR)$ ,  
where:

MTBF (Mean Time Between Failures) - mean time between individual component failures. For example, a hard drive malfunction or hypervisor reboot.

MTTR (Mean Time To Repair) - refers to how long it takes to fix the broken component or the application to come back online,

While this approach estimates the expected availability of a XaaS, the PAM reflects near-real-time availability of a service as experienced by a user. It also provides valuable data for more accurate and realistic MTBF and MTTR in the particular environment, and simplifies comparison of different solutions that may use redundant servers (web and database), load balancers.

In another field of communication, mobile voice and data services, the definition of service availability is understood as "the probability of successful service reception: a given area is declared "in-coverage" if the service in that area is available with a pre-specified minimum rate of success. Service availability has the advantage of being more easily understandable for consumers and is expressed as a percentage of the number of attempts to access a given service." [\[BEREC-CP\]](#). The definition of the availability used in the PAM throughout this document is close to the quoted above. It might be considered as the extension that allows regulators, operators, and consumers to compare not only the rate of successfully establishing a connection but the quality of the connection during its lifetime.

## [6.](#) Other PAM Benefits

PAM provides a number of important benefits with other, more conventional performance metrics. Without PAM, it would be possible to conduct ongoing measurements of service levels and maintain a time-series of service level records, then assess compliance with specific SLOs after the fact. However, doing so would require the collection of vast amounts of data that would need to be generated, exported, transmitted, collected, and stored. In addition, extensive postprocessing would be required to compare that data against SLOs and analyze its compliance. Being able to perform these tasks at scale and in real-time would present significant additional challenges.

Adding PAM allows for a more compact expression of service level compliance. In that sense, PAM does not simply represent raw data but expresses actionable information. In conjunction with proper instrumentation, PAM can thus help avoid expensive postprocessing.

## [7.](#) Discussion Items

The following items require further discussion:

- \* Terminology - "Errored" vs. "Violated". The key metrics defined in this draft refer to intervals during which violations of objectives for service level parameters occur as "errored". The term "errored" was chosen in continuity with the concept of "errored seconds", often used in transmission systems. However, "violated" may be a more accurate term, as the metrics defined here are not "errors" in an absolute sense, but relative to a set of defined objectives.
- \* Metrics. The foundational metrics defined in this draft refer to errored/violated intervals. In addition, counts of errors/violations related to individual packets may also need to be maintained. Metrics referring to violated/errored packets, i.e. packets that on an individual basis miss a performance objective may be added in a later revision of this document.

The following is a list of items for which further discussion is needed as to whether they should be included in the scope of this specification:

- \* A YANG data model.
- \* A set of IPFIX Information Elements.
- \* Statistical metrics: e.g., histograms/buckets.

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- \* Policies regarding the definition of "errored" and "severely errored" time interval.
- \* Additional second-order metrics, such as "longest disruption of service time" (measuring consecutive time units with SEIs).

## [8.](#) IANA Considerations

TBA

## [9.](#) Security Considerations

Instrumentation for metrics that are used to assess compliance with SLOs constitute an attractive target for an attacker. By interfering with the maintaining of such metrics, services could be falsely identified as complying (when they are not) or vice-versa flagged as being non-compliant (when indeed they are). While this document does not specify how networks should be instrumented to maintain the identified metrics. Such instrumentation needs to be adequately secured to ensure accurate measurements and prohibit tampering with metrics being kept.

Where metrics are being defined relative to an SLO, the configuration of those SLOs needs to be adequately secured. Likewise, where SLOs can be adjusted, the correlation between any metrics instance and a particular SLO must be clear. The same service levels that constitute SLO violations for one flow that should be maintained as part of the "errored time units" and related metrics, may be perfectly compliant for another flow. In cases when it is impossible to tie together SLOs and PAM properly, it will be preferable to merely maintain statistics about service levels delivered (for example, overall histograms of end-to-end latency) without assessing

which constitutes violations.

By the same token, where the definition of what constitutes a "severe" or a "significant" error depends on policy or context. The configuration of such policy or context needs to be specially secured. Also, the configuration of this policy must be bound to the metrics being maintained. This way, it will be clear which policy was in effect when those metrics were being assessed. An attacker that can tamper with such policies will render the corresponding metrics useless (in the best case) or misleading (in the worst case).

## 10. Acknowledgments

TBA

## 11. References

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