Internet Engineering Task Force (IETF)
Request for Comments: 6390
BCP: 170
Category: Best Current Practice
ISSN: 2070-1721
October 2011

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Guidelines for Considering New Performance Metric Development

Abstract

This document describes a framework and a process for developing Performance Metrics of protocols and applications transported over IETF-specified protocols. These metrics can be used to characterize traffic on live networks and services.

Status of This Memo

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1. Introduction

Many networking technologies, applications, or services are distributed in nature, and their performance may be impacted by IP impairments, server capacity, congestion, and other factors. It is important to measure the performance of applications and services to ensure that quality objectives are being met and to support problem diagnosis. Standardized metrics help ensure that performance measurement is implemented consistently, and they facilitate interpretation and comparison.

There are at least three phases in the development of performance standards. They are as follows:

1. Definition of a Performance Metric and its units of measure

2. Specification of a method of measurement

3. Specification of the reporting format

During the development of metrics, it is often useful to define performance objectives and expected value ranges. This additional information is typically not part of the formal specification of the metric but does provide useful background for implementers and users of the metric.

The intended audience for this document includes, but is not limited to, IETF participants who write Performance Metrics documents in the IETF, reviewers of such documents, and members of the Performance Metrics Directorate.

1.1. Background and Motivation

Previous IETF work related to the reporting of application Performance Metrics includes "Real-time Application Quality-of-Service Monitoring (RAQMON) Framework" [RFC4710]. This framework extends the remote network monitoring (RMON) family of specifications to allow real-time quality-of-service (QoS) monitoring of various applications that run on devices such as IP phones, pagers, Instant Messaging clients, mobile phones, and various other handheld computing devices. Furthermore, "RTP Control Protocol Extended Reports (RTCP XR)" [RFC3611] and "Session Initiation Protocol Event Package for Voice Quality Reporting" [RFC6035] define protocols that support real-time Quality of Experience (QoE) reporting for Voice over IP (VoIP) and other applications running on devices such as IP phones and mobile handsets.

The IETF is also actively involved in the development of reliable transport protocols, such as TCP [RFC0793] or the Stream Control Transmission Protocol (SCTP) [RFC4960], which would affect the relationship between IP performance and application performance.

Thus, there is a gap in the currently chartered coverage of IETF Working Groups (WGs): development of Performance Metrics for protocols above and below the IP layer that can be used to characterize performance on live networks.

Similar to "Guidelines for Considering Operations and Management of New Protocols and Protocol Extensions" [RFC5706], which is the reference document for the IETF Operations Directorate, this document should be consulted as part of the new Performance Metric review by the members of the Performance Metrics Directorate.

1.2. Organization of This Document

This document is divided into two major sections beyond the "Purpose and Scope" section. The first is a definition and description of a Performance Metric and its key aspects. The second defines a process to develop these metrics that is applicable to the IETF environment.

2. Terminology

2.1. 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 RFC 2119 [RFC2119].

2.2. Performance Metrics Directorate

The Performance Metrics Directorate is a directorate that provides guidance for Performance Metrics development in the IETF.

The Performance Metrics Directorate should be composed of experts in the performance community, potentially selected from the IP Performance Metrics (IPPM), Benchmarking Methodology (BMWG), and Performance Metrics for Other Layers (PMOL) WGs.

2.3. Quality of Service

Quality of Service (QoS) is defined in a way similar to the ITU "Quality of Service (QoS)" section of [E.800], i.e., "Totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service".

2.4. Quality of Experience

Quality of Experience (QoE) is defined in a way similar to the ITU "QoS experienced/perceived by customer/user (QoSE)" section of [E.800], i.e., "a statement expressing the level of quality that customers/users believe they have experienced".

NOTE 1 - The level of QoS experienced and/or perceived by the customer/user may be expressed by an opinion rating.

NOTE 2 - QoE has two main components: quantitative and qualitative. The quantitative component can be influenced by the complete end-to-end system effects (including user devices and network infrastructure).

NOTE 3 - The qualitative component can be influenced by user expectations, ambient conditions, psychological factors, application context, etc.

NOTE 4 - QoE may also be considered as QoS delivered, received, and interpreted by a user with the pertinent qualitative factors influencing his/her perception of the service.

2.5. Performance Metric

A Performance Metric is a quantitative measure of performance, specific to an IETF-specified protocol or specific to an application transported over an IETF-specified protocol. Examples of Performance Metrics are the FTP response time for a complete file download, the DNS response time to resolve the IP address, a database logging time, etc.

3. Purpose and Scope

The purpose of this document is to define a framework and a process for developing Performance Metrics for protocols above and below the IP layer (such as IP-based applications that operate over reliable or datagram transport protocols). These metrics can be used to characterize traffic on live networks and services. As such, this document does not define any Performance Metrics.

The scope of this document covers guidelines for the Performance Metrics Directorate members for considering new Performance Metrics and suggests how the Performance Metrics Directorate will interact with the rest of the IETF. However, this document is not intended to supersede existing working methods within WGs that have existing chartered work in this area.

This process is not intended to govern Performance Metric development in existing IETF WGs that are focused on metrics development, such as the IPPM and BMWG WGs. However, this guidelines document may be useful in these activities and MAY be applied where appropriate. A typical example is the development of Performance Metrics to be exported with the IP Flow Information eXport (IPFIX) protocol [RFC5101], with specific IPFIX information elements [RFC5102], which would benefit from the framework in this document.

The framework in this document applies to Performance Metrics derived from both active and passive measurements.

4. Relationship between QoS, QoE, and Application-Specific Performance Metrics

Network QoS deals with network and network protocol performance, while QoE deals with the assessment of a user’s experience in the context of a task or a service. The topic of application-specific Performance Metrics includes the measurement of performance at layers between IP and the user. For example, network QoS metrics (packet loss, delay, and delay variation [RFC5481]) can be used to estimate application-specific Performance Metrics (de-jitter buffer size and RTP-layer packet loss), and then combined with other known aspects of a VoIP application (such as codec type) using an algorithm compliant with ITU-T P.564 [P.564] to estimate a Mean Opinion Score (MOS) [P.800]. However, the QoE for a particular VoIP user depends on the specific context, such as a casual conversation, a business conference call, or an emergency call. Finally, QoS and application-specific Performance Metrics are quantitative, while QoE is qualitative. Also, network QoS and application-specific Performance Metrics can be directly or indirectly evident to the user, while the QoE is directly evident.

5. Performance Metrics Development

This section provides key definitions and qualifications of Performance Metrics.

5.1. Identifying and Categorizing the Audience

Many of the aspects of metric definition and reporting, even the selection or determination of the essential metrics, depend on who will use the results, and for what purpose. For example, the metric description SHOULD include use cases and example reports that illustrate service quality monitoring and maintenance or identification and quantification of problems.

All documents defining Performance Metrics SHOULD identify the primary audience and its associated requirements. The audience can influence both the definition of metrics and the methods of measurement.

The key areas of variation between different metric users include:

- o Suitability of passive measurements of live traffic or active measurements using dedicated traffic
- o Measurement in laboratory environment or on a network of deployed devices
- o Accuracy of the results
- o Access to measurement points and configuration information
- o Measurement topology (point-to-point, point-to-multipoint)
- o Scale of the measurement system
- o Measurements conducted on-demand or continuously
- o Required reporting formats and periods
- o Sampling criteria [RFC5474], such as systematic or probabilistic
- o Period (and duration) of measurement, as the live traffic can have patterns

5.2. Definitions of a Performance Metric

A Performance Metric is a measure of an observable behavior of a networking technology, an application, or a service. Most of the time, the Performance Metric can be directly measured; however, sometimes, the Performance Metric value is computed. The process for determining the value of a metric may assume an implicit or explicit underlying statistical process; in this case, the Performance Metric is an estimate of a parameter of this process, assuming that the statistical process closely models the behavior of the system.

A Performance Metric should serve some defined purposes. This may include the measurement of capacity, quantifying how bad some problems are, measurement of service level, problem diagnosis or location, and other such uses. A Performance Metric may also be an input to some other processes, for example, the computation of a composite Performance Metric or a model or simulation of a system. Tests of the "usefulness" of a Performance Metric include:

(i) the degree to which its absence would cause significant loss of information on the behavior or performance of the application or system being measured

(ii) the correlation between the Performance Metric, the QoS, and the QoE delivered to the user (person or other application)

(iii) the degree to which the Performance Metric is able to support the identification and location of problems affecting service quality

(iv) the requirement to develop policies (Service Level Agreement, and potentially Service Level Contract) based on the Performance Metric

For example, consider a distributed application operating over a network connection that is subject to packet loss. A Packet Loss Rate (PLR) Performance Metric is defined as the mean packet loss ratio over some time period. If the application performs poorly over network connections with a high packet loss ratio and always performs well when the packet loss ratio is zero, then the PLR Performance Metric is useful to some degree. Some applications are sensitive to short periods of high loss (bursty loss) and are relatively insensitive to isolated packet loss events; for this type of application, there would be very weak correlation between PLR and application performance. A "better" Performance Metric would consider both the packet loss ratio and the distribution of loss events. If application performance is degraded when the PLR exceeds some rate, then a useful Performance Metric may be a measure of the duration and frequency of periods during which the PLR exceeds that rate (as, for example, in RFC 3611).

5.3. Computed Performance Metrics

5.3.1. Composed Performance Metrics

Some Performance Metrics may not be measured directly, but can be composed from base metrics that have been measured. A composed Performance Metric is derived from other metrics by applying a deterministic process or function (e.g., a composition function). The process may use metrics that are identical to the metric being composed, or metrics that are dissimilar, or some combination of both types. Usually, the base metrics have a limited scope in time or space, and they can be combined to estimate the performance of some larger entities.

Some examples of composed Performance Metrics and composed Performance Metric definitions are as follows:

Spatial composition is defined as the composition of metrics of the same type with differing spatial domains [RFC5835] [RFC6049]. Ideally, for spatially composed metrics to be meaningful, the spatial domains should be non-overlapping and contiguous, and the composition operation should be mathematically appropriate for the type of metric.

Temporal composition is defined as the composition of sets of metrics of the same type with differing time spans [RFC5835]. For temporally composed metrics to be meaningful, the time spans should be non-overlapping and contiguous, and the composition operation should be mathematically appropriate for the type of metric.

Temporal aggregation is a summarization of metrics into a smaller number of metrics that relate to the total time span covered by the original metrics. An example would be to compute the minimum, maximum, and average values of a series of time-sampled values of a metric.

In the context of flow records in IP Flow Information eXport (IPFIX), the IPFIX Mediation Framework [RFC6183], based on "IP Flow Information Export (IPFIX) Mediation: Problem Statement" [RFC5982], also discusses some aspects of the temporal and spatial composition.

5.3.2. Index

An index is a metric for which the output value range has been selected for convenience or clarity, and the behavior of which is selected to support ease of understanding, for example, the R Factor [G.107]. The deterministic function for an index is often developed after the index range and behavior have been determined.

5.4. Performance Metric Specification

5.4.1. Outline

A Performance Metric definition MUST have a normative part that defines what the metric is and how it is measured or computed, and it SHOULD have an informative part that describes the Performance Metric and its application.

5.4.2. Normative Parts of Performance Metric Definition

The normative part of a Performance Metric definition MUST define at least the following:

(i) Metric Name

Performance Metric names are RECOMMENDED to be unique within the set of metrics being defined for the protocol layer and context. While strict uniqueness may not be attainable (see the IPPM registry [RFC6248] for an example of an IANA metric registry failing to provide sufficient specificity), broad review must be sought to avoid naming overlap. Note that the Performance Metrics Directorate can help with suggestions for IANA metric registration for unique naming. The Performance Metric name MAY be descriptive.

(ii) Metric Description

The Performance Metric description MUST explain what the metric is, what is being measured, and how this relates to the performance of the system being measured.

(iii) Method of Measurement or Calculation

The method of measurement or calculation MUST define what is being measured or computed and the specific algorithm to be used. Does the measurement involve active or only passive measurements? Terms such as "average" should be qualified (e.g., running average or average over some interval). Exception cases SHOULD also be defined with the appropriate handling method. For example, there are a number of commonly used metrics related to packet loss; these often don't define the criteria by which a packet is determined to be lost (versus very delayed) or how duplicate packets are handled. For example, if the average PLR during a time interval is reported, and a packet's arrival is delayed from one interval to the next, then was it "lost" during the interval during which it should have arrived or should it be counted as received?

Some methods of calculation might require discarding some data collected (due to outliers) so as to make the measurement parameters meaningful. One example is burstable billing that sorts the 5-min samples and discards the top 5 percentile.

Some parameters linked to the method MAY also be reported, in order to fully interpret the Performance Metric, for example, the time interval, the load, the minimum packet loss, the potential measurement errors and their sources, the attainable accuracy of the metric (e.g., +/- 0.1), the method of calculation, etc.

(iv) Units of Measurement

The units of measurement MUST be clearly stated.

(v) Measurement Point(s) with Potential Measurement Domain

If the measurement is specific to a measurement point, this SHOULD be defined. The measurement domain MAY also be defined. Specifically, if measurement points are spread across domains, the measurement domain (intra-, inter-) is another factor to consider.

The Performance Metric definition should discuss how the Performance Metric value might vary, depending on which measurement point is chosen. For example, the time between a SIP request [RFC3261] and the final response can be significantly different at the User Agent Client (UAC) or User Agent Server (UAS).

In some cases, the measurement requires multiple measurement points: all measurement points SHOULD be defined, including the measurement domain(s).

(vi) Measurement Timing

The acceptable range of timing intervals or sampling intervals for a measurement, and the timing accuracy required for such intervals, MUST be specified. Short sampling intervals or frequent samples provide a rich source of information that can help assess application performance but may lead to excessive measurement data. Long measurement or sampling intervals reduce the amount of reported and collected data such that it may be insufficient to understand application performance or service quality, insofar as the measured quantity may vary significantly with time.

In the case of multiple measurement points, the potential requirement for synchronized clocks must be clearly specified. In the specific example of the IP delay variation application metric, the different aspects of synchronized clocks are discussed in [RFC5481].

5.4.3. Informative Parts of Performance Metric Definition

The informative part of a Performance Metric specification is intended to support the implementation and use of the metric. This part SHOULD provide the following data:

(i) Implementation

The implementation description MAY be in the form of text, an algorithm, or example software. The objective of this part of the metric definition is to help implementers achieve consistent results.

(ii) Verification

The Performance Metric definition SHOULD provide guidance on verification testing. This may be in the form of test vectors, a formal verification test method, or informal advice.

(iii) Use and Applications

The use and applications description is intended to help the "user" understand how, when, and where the metric can be applied, and what significance the value range for the metric may have. This MAY include a definition of the "typical" and "abnormal" range of the Performance Metric, if this was not apparent from the nature of the metric. The description MAY include information about the influence of extreme measurement values, i.e., if the Performance Metric is sensitive to outliers. The Use and Application section SHOULD also include the security implications in the description.

For example:

(a) it is fairly intuitive that a lower packet loss ratio would equate to better performance. However, the user may not know the significance of some given packet loss ratio.

(b) the speech level of a telephone signal is commonly expressed in dBm0. If the user is presented with:

Speech level = -7 dBm0

this is not intuitively understandable, unless the user is a telephony expert. If the metric definition explains that the typical range is -18 to -28 dBm0, a value higher than -18 means the signal may be too high (loud), and less than -28 means that the signal may be too low (quiet), it is much easier to interpret the metric.

(iv) Reporting Model

The reporting model definition is intended to make any relationship between the metric and the reporting model clear. There are often implied relationships between the method of reporting metrics and the metric itself; however, these are often not made apparent to the implementor. For example, if the metric is a short-term running average packet delay variation (e.g., the inter-arrival jitter in [RFC3550]) and this value is reported at intervals of 6-10 seconds, the resulting measurement may have limited accuracy when packet delay variation is non-stationary.

5.4.4. Performance Metric Definition Template

Normative

- o Metric Name
- o Metric Description
- o Method of Measurement or Calculation
- o Units of Measurement
- o Measurement Point(s) with Potential Measurement Domain
- o Measurement Timing

Informative

- o Implementation
- o Verification
- o Use and Applications
- o Reporting Model

5.4.5. Example: Loss Rate

The example used is the loss rate metric as specified in RFC 3611 [RFC3611].

Metric Name: LossRate

Metric Description: The fraction of RTP data packets from the source lost since the beginning of reception.

Method of Measurement or Calculation: This value is calculated by dividing the total number of packets lost (after the effects of applying any error protection, such as Forward Error Correction (FEC)) by the total number of packets expected, multiplying the result of the division by 256, limiting the maximum value to 255 (to avoid overflow), and taking the integer part.

Units of Measurement: This metric is expressed as a fixed-point number with the binary point at the left edge of the field. For example, a metric value of 12 means a loss rate of approximately 5%.

Measurement Point(s) with Potential Measurement Domain: This metric is made at the receiving end of the RTP stream sent during a Voice over IP call.

Measurement Timing: This metric can be used over a wide range of time intervals. Using time intervals of longer than one hour may prevent the detection of variations in the value of this metric due to time-of-day changes in network load. Timing intervals should not vary in duration by more than +/- 2%.

Implementation: The numbers of duplicated packets and discarded packets do not enter into this calculation. Since receivers cannot be required to maintain unlimited buffers, a receiver MAY categorize late-arriving packets as lost. The degree of lateness that triggers a loss SHOULD be significantly greater than that which triggers a discard.

Verification: The metric value ranges between 0 and 255.

Use and Applications: This metric is useful for monitoring VoIP calls, more precisely, to detect the VoIP loss rate in the network. This loss rate, along with the rate of packets discarded due to jitter, has some effect on the quality of the voice stream.

Reporting Model: This metric needs to be associated with a defined time interval, which could be defined by fixed intervals or by a sliding window. In the context of RFC 3611, the metric is measured continuously from the start of the RTP stream, and the value of the metric is sampled and reported in RTCP XR VoIP Metrics reports.

5.5. Dependencies

This section introduces several Performance Metrics dependencies, which the Performance Metric designer should keep in mind during Performance Metric development. These dependencies, and any others not listed here, SHOULD be documented in the Performance Metric specifications.

5.5.1. Timing Accuracy

The accuracy of the timing of a measurement may affect the accuracy of the Performance Metric. This may not materially affect a sampled-value metric; however, it would affect an interval-based metric. Some metrics -- for example, the number of events per time interval -- would be directly affected; for example, a 10% variation in time interval would lead directly to a 10% variation in the measured value. Other metrics, such as the average packet loss ratio during some time interval, would be affected to a lesser extent.

If it is necessary to correlate sampled values or intervals, then it is essential that the accuracy of sampling time and interval start/ stop times is sufficient for the application (for example, +/- 2%).

5.5.2. Dependencies of Performance Metric Definitions on Related Events or Metrics

Performance Metric definitions may explicitly or implicitly rely on factors that may not be obvious. For example, the recognition of a packet as being "lost" relies on having some method of knowing the packet was actually lost (e.g., RTP sequence number), and some time threshold after which a non-received packet is declared lost. It is important that any such dependencies are recognized and incorporated into the metric definition.

5.5.3. Relationship between Performance Metric and Lower-Layer Performance Metrics

Lower-layer Performance Metrics may be used to compute or infer the performance of higher-layer applications, potentially using an application performance model. The accuracy of this will depend on many factors, including:

(i) The completeness of the set of metrics (i.e., are there metrics for all the input values to the application performance model?)

(ii) Correlation between input variables (being measured) and application performance

(iii) Variability in the measured metrics and how this variability affects application performance

5.5.4. Middlebox Presence

Presence of a middlebox [RFC3303], e.g., proxy, network address translation (NAT), redirect server, session border controller (SBC) [RFC5853], and application layer gateway (ALG), may add variability to or restrict the scope of measurements of a metric. For example, an SBC that does not process RTP loopback packets may block or locally terminate this traffic rather than pass it through to its target.

5.6. Organization of Results

The IPPM Framework [RFC2330] organizes the results of metrics into three related notions:

- singleton: an elementary instance, or "atomic" value.
- sample: a set of singletons with some common properties and some varying properties.
- statistic: a value derived from a sample through deterministic calculation, such as the mean.

Performance Metrics MAY use this organization for the results, with or without the term names used by the IPPM WG. Section 11 of RFC 2330 [RFC2330] should be consulted for further details.

5.7. Parameters: the Variables of a Performance Metric

Metrics are completely defined when all options and input variables have been identified and considered. These variables are sometimes left unspecified in a metric definition, and their general name indicates that the user must set and report them with the results. Such variables are called "parameters" in the IPPM metric template. The scope of the metric, the time at which it was conducted, the length interval of the sliding-window measurement, the settings for timers, and the thresholds for counters are all examples of parameters.

All documents defining Performance Metrics SHOULD identify all key parameters for each Performance Metric.

6. Performance Metric Development Process

6.1. New Proposals for Performance Metrics

This process is intended to add more considerations to the processes for adopting new work as described in RFC 2026 [RFC2026] and RFC 2418 [RFC2418]. Note that new Performance Metrics work item proposals SHALL be approved using the existing IETF process. The following entry criteria will be considered for each proposal.

Proposals SHOULD be prepared as Internet-Drafts, describing the Performance Metric and conforming to the qualifications above as much as possible. Proposals SHOULD be deliverables of the corresponding protocol development WG charters. As such, the proposals SHOULD be vetted by that WG prior to discussion by the Performance Metrics Directorate. This aspect of the process includes an assessment of the need for the Performance Metric proposed and assessment of the support for its development in the IETF.

Proposals SHOULD include an assessment of interaction and/or overlap with work in other Standards Development Organizations (SDOs). Proposals SHOULD identify additional expertise that might be consulted.

Proposals SHOULD specify the intended audience and users of the Performance Metrics. The development process encourages participation by members of the intended audience.

Proposals SHOULD identify any security and IANA requirements. Security issues could potentially involve revealing data identifying a user, or the potential misuse of active test tools. IANA considerations may involve the need for a Performance Metrics registry.

6.2. Reviewing Metrics

Each Performance Metric SHOULD be assessed according to the following list of qualifications:

- Are the performance metrics unambiguously defined?
- Are the units of measure specified?
- Does the metric clearly define the measurement interval where applicable?
- Are significant sources of measurement errors identified and discussed?
- Does the method of measurement ensure that results are repeatable?
- Does the metric or method of measurement appear to be implementable (or offer evidence of a working implementation)?
- Are there any undocumented assumptions concerning the underlying process that would affect an implementation or interpretation of the metric?
- Can the metric results be related to application performance or user experience, when such a relationship is of value?
- Is there an existing relationship to metrics defined elsewhere within the IETF or within other SDOs?
- Do the security considerations adequately address denial-of-service attacks, unwanted interference with the metric/measurement, and user data confidentiality (when measuring live traffic)?

6.3. Performance Metrics Directorate Interaction with Other WGs

The Performance Metrics Directorate SHALL provide guidance to the related protocol development WG when considering an Internet-Draft that specifies Performance Metrics for a protocol. A sufficient number of individuals with expertise must be willing to consult on the draft. If the related WG has concluded, comments on the proposal should still be sought from key RFC authors and former chairs.

As with expert reviews performed by other directorates, a formal review is recommended by the time the document is reviewed by the Area Directors or an IETF Last Call is being conducted.

Existing mailing lists SHOULD be used; however, a dedicated mailing list MAY be initiated if necessary to facilitate work on a draft.

In some cases, it will be appropriate to have the IETF session discussion during the related protocol WG session, to maximize visibility of the effort to that WG and expand the review.

6.4. Standards Track Performance Metrics

The Performance Metrics Directorate will assist with the progression of RFCs along the Standards Track. See [IPPM-STANDARD-ADV-TESTING]. This may include the preparation of test plans to examine different implementations of the metrics to ensure that the metric definitions are clear and unambiguous (depending on the final form of the draft mentioned above).

7. Security Considerations

In general, the existence of a framework for Performance Metric development does not constitute a security issue for the Internet. Performance Metric definitions, however, may introduce security issues, and this framework recommends that persons defining Performance Metrics should identify any such risk factors.

The security considerations that apply to any active measurement of live networks are relevant here. See [RFC4656].

The security considerations that apply to any passive measurement of specific packets in live networks are relevant here as well. See the security considerations in [RFC5475].

8. Acknowledgements

The authors would like to thank Al Morton, Dan Romascanu, Daryl Malas, and Loki Jorgenson for their comments and contributions, and Aamer Akhter, Yaakov Stein, Carsten Schmoll, and Jan Novak for their reviews.

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