                  Advanced Stream and Sampling Framework for IPPM
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Abstract

   To obtain repeatable results in modern networks, test descriptions
   need an expanded stream parameter framework that also augments
   aspects specified as Type-P for test packets. This memo proposes to
   update the IP Performance Metrics (IPPM) Framework with advanced
   considerations for measurement methodology and testing. The existing
   framework mostly assumes deterministic connectivity, and that a
   single test stream will represent the characteristics of the path
   when it is aggregated with other flows. Networks have evolved and
   test stream descriptions must evolve with them, otherwise unexpected
   network features may dominate the measured performance. This memo
   describes new stream parameters for both network characterization and
   support of application design using IPPM metrics.

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].

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Table of Contents

1. Introduction

   The IETF IP Performance Metrics (IPPM) working group first created a
   framework for metric development in [RFC2330]. This framework has
   stood the test of time and enabled development of many fundamental
   metrics, while only being updated once in a specific area [RFC5835].

   The IPPM framework [RFC2330] generally relies on several assumptions,
   one of which is not explicitly stated but assumed: the network
   behaves (halfway) deterministic and without state/history-less (with
   some exceptions, firewalls are mentioned). However, this does not
   hold true for many modern network technologies, such as reactive
   networks (those with demand-driven resource allocation) and links
   with time-slotted operation. Per-flow state can be observed on test
   packet streams, and such treatment will influence network
   characterization if it is not taken into account. Flow history will
   also affect the performance of applications and be perceived by their
   users.

   Moreover, Sections 4 and 6.2 of [RFC2330] explicitly recommend
   repeatable measurement metrics and methodologies. Measurements in
   today's access networks illustrate that methodological guidelines of
   [RFC2330] must be extended to capture the reactive nature of these
   networks. Although the proposed extensions can support methodologies
   to fulfill the continuity requirement stated in section 6.2 of
   [RFC2330], there is no guarantee. Practical measurements confirm
   that some link types exhibit distinct responses to repeated
   measurements with identical stimulus, i.e., identical traffic
   patterns. If feasible, appropriate fine-tuning of measurement
   traffic patterns can improve measurement continuity and repeatability
   for these link types as shown in [IBD].

1.1. Definition: Reactive Network Behavior

   A network or network path is defined to be reactive when at least one
   of the links or hosts in it exhibits reactive behavior. Reactive
   behavior is present when link-or host-internal sensing (measurement)
   of packet arrival for the flow of interest indicates that traffic is
   absent or present, or that traffic during a measurement interval is
   above or below a threshold, and the results of one or more successive
   measurements cause one or more network components to process future
   packets using a different mode of operation than for other
   measurement outcomes.

   Reactive network behavior must be observable by the test packet
   stream as a repeatable phenomenon where packet transfer performance
   characteristics *change* according to prior node- or link-internal
   observations of the packet flow of interest. Therefore, reactive

network behavior is deterministic with respect to the flow of
interest. Other flows or traffic load conditions may result in
additional performance-affecting reactions, but these are external to
the characteristics of the flow of interest.

Other than the size of the payload at the layer of interest and the
header itself, packet content does not influence the measurement.
Reactive behavior at the IP layer is not influenced by the TCP ports
in use, for example. Therefore, the indication of reactive behavior
must include the layer at which measurements are instituted.

Examples include links with Active/In-active state detectors, and
network devices or links that revise their traffic serving and
forwarding rates (up or down) based on packet arrival history.

2. Scope

The scope of his memo is to describe useful stream parameters in
addition to the information in Section 11.1 of [RFC2330] and
described in [RFC3432] for periodic streams. The purpose is to
foster repeatable measurement results in modern networks by
highlighting the key aspects of test streams and packets and make
them part of the IPPM performance metric framework.

3. New Stream Parameters

There are several areas where measurement methodology definition and
test result interpretation will benefit from an increased
understanding of the stream characteristics and the (possibly
unknown) network condition that influence the measured metrics.

1. Network treatment depends on the fullest extent on the "packet of
    Type-P" definition in [RFC2330], and has for some time.

    * State is often maintained on the per-flow basis at various
       points in the network, where "flows" are determined by IP and
       other layers. Significant treatment differences occur with
       the simplest of Type-P parameters: packet length.

    * Payload content optimization (compression or format
       conversion) in intermediate segments. This breaks the
       convention of payload correspondence when correlating
       measurements made at different points in a path.

   2. Packet history (instantaneous or recent test rate or inactivity,
       also for non-test traffic) profoundly influences measured
       performance, in addition to all the Type-P parameters described
       in [RFC2330].

   3. Access technology may change during testing. A range of transfer
       capacities and access methods may be encountered during a test
       session. When different interfaces are used, the host seeking
       access will be aware of the technology change which
       differentiates this form of path change from other changes in
       network state. Section 14 of [RFC2330] treats the possibility
       that a host may have more than one attachment to the network, and
       also that assessment of the measurement path (route) is valid for
       some length of time (in Section 5 and Section 7 of [RFC2330]).
       Here we combine these two considerations under the assumption
       that changes may be more frequent and possibly have greater
       consequences on performance metrics.

   4. Paths including links or nodes with time-slotted service
       opportunities represent several challenges to measurement (when
       service time period is appreciable):

       * Random/unbiased sampling is not possible beyond one such link
          in the path.

       * The above encourages a segmented approach to end to end
          measurement, as described in [RFC6049] for Network
          Characterization (as defined in [RFC6703]) to understand the
          full range of delay and delay variation on the path.
          Alternatively, if application performance estimation is the
          goal (also defined in [RFC6703]), then a stream with un-biased
          or known-bias properties [RFC3432] may be sufficient.

       * Multi-modal delay variation makes central statistics
          unimportant, others must be used instead.

   Each of these topics is treated in detail below.

3.1. Test Packet Type-P

   We recommend two Type-P parameters to be added to the factors which
   have impact on network performance measurements, namely packet length
   and payload type. Carefully choosing these parameters can improve
   measurement methodologies in their continuity and repeatability when
   deployed in reactive networks.

3.1.1. Test Packet Length

   Many instances of network characterization using IPPM metrics have
   relied on a single test packet length. When testing to assess
   application performance or an aggregate of traffic, benchmarking
   methods have used a range of fixed lengths and frequently augmented
   fixed size tests with a mixture of sizes, or IMIX as described in
   [I-D.ietf-bmwg-imix-genome].

   Test packet length influences delay measurements, in that the IPPM
   one-way delay metric [RFC2679] includes serialization time in its
   first-bit to last bit time stamping requirements. However, different
   sizes can have a larger effect on link delay and link delay variation
   than serialization would explain alone. This effect can be non-
   linear and change instantaneous or future network performance.

   Repeatability is a main measurement methodology goal as stated in
   section 6.2 of [RFC2330]. To eliminate packet length as a potential
   measurement uncertainty factor, successive measurements must use
   identical traffic patterns. In practice a combination of random
   payload and random start time can yield representative results as
   illustrated in [IRR].

3.1.2. Test Packet Payload Content Optimization

   The aim for efficient network resource use has resulted in a series
   of "smart" networks to deploy server-only or client-server lossless
   or lossy payload compression techniques on some links or paths.
   These optimizers attempt to compress high-volume traffic in order to
   reduce network load. Files are analyzed by application-layer parsers
   and parts (like comments) might be dropped. Although typically
   acting on HTTP or JPEG files, compression might affect measurement
   packets, too. In particular measurement packets are qualified for
   efficient compression when they use standard plain-text payload.

   IPPM-conforming measurements should add packet payload content as a
   Type-P parameter which can help to improve measurement determinism.
   Some packet payloads are more susceptible to compression than others,
   but optimizers in the measurement path can be out ruled by using
   incompressible packet payload. This payload content could be either
   generated by a random device or by using part of a compressed file
   (e.g., a part of a ZIP compressed archive).

3.2. Packet History

   Recent packet history and instantaneous data rate influence
   measurement results for reactive links supporting on-demand capacity
   allocation. Measurement uncertainty may be reduced by knowledge of

   measurement packet history and total host load. Additionally, small
   changes in history, e.g., because of lost packets along the path, can
   be the cause of large performance variations.

   For instance delay in reactive 3G networks like High Speed Packet
   Access (HSPA) depends to a large extent on the test traffic data
   rate. The reactive resource allocation strategy in these networks
   affects the uplink direction in particular. Small changes in data
   rate can be the reason of more than 200% increase in delay, depending
   on the specific packet size.

3.3. Access Technology Change

   [RFC2330] discussed the scenario of multi-homed hosts. If hosts
   become aware of access technology changes (e.g., because of IP
   address changes or lower layer information) and make this information
   available, measurement methodologies can use this information to
   improve measurement representativeness and relevance.

   However, today's various access network technologies can present the
   same physical interface to the host. A host may or may not become
   aware when its access technology changes on such an interface.
   Measurements for networks which support on-demand capacity allocation
   are therefore challenging in that it is difficult to differentiate
   between access technology changes (e.g., because of mobility) and
   reactive network behavior (e.g., because of data rate change).

3.4. Time-Slotted Randomness Cancellation

   Time-Slotted operation of network entities - interfaces, routers or
   links - in a network path is a particular challenge for measurements,
   especially if the time slot period is substantial. The central
   observation as an extension to Poisson stream sampling in [RFC2330]
   is that the first such time-slotted component cancels unbiased
   measurement stream sampling. In the worst case, time-slotted
   operation converts an unbiased, random measurement packet stream into
   a periodic packet stream. Being heavily biased, these packets may
   interact with periodic network behavior of subsequent time-slotted
   network entities[TSRC].

   Time-slotted randomness cancellation (TSRC) sources can be found in
   virtually any system, network component or path, their impact on
   measurements being a matter of the order of magnitude when compared
   to the metric under observation. Examples of TSRC sources include
   but are not limited to system clock resolution, operating system
   ticks, time-slotted component or network operation, etc. The amount
   of measurement bias is determined by the particular measurement
   stream, relative offset between allocated time-slots in subsequent

network entities, delay variation in these networks, and other
sources of variation. Measurement results might change over time,
depending on how accurately the sending host, receiving host, and
time-slotted components in the measurement path are synchronized to
each other and to global time. If network segments maintain flow
state, flow parameter change or flow re-allocations can cause
substantial variation in measurement results.

Practical measurements confirm that such interference limits delay
measurement variation to a sub-set of theoretical value range.
Measurement samples for such cases can aggregate on artificial
limits, generating multi-modal distributions as demonstrated in
[IRR]. In this context, the desirable measurement sample statistics
differentiate between multi-modal delay distributions caused by
reactive network behavior and the ones due to time-slotted
interference.

Measurement methodology selection for time-slotted paths depends to a
large extent on the respective viewpoint. End-to-end metrics can
provide accurate measurement results for short-term sessions and low
likelihood of flow state modifications. Applications or services
which aim at approximating network performance for a short time
interval (in the order of minutes) and expect stable network
conditions should therefore prefer end-to-end metrics. Here stable
network conditions refer to any kind of global knowledge concerning
measurement path flow state and flow parameters.

However, if long-term forecast of time-slotted network performance is
the main measurement goal, a segmented approach relying on
measurement of sub-path metrics is preferred. Re-generating unbiased
measurement traffic at any hop can help to reveal the true range of
network performance for all network segments.

4. Conclusions

Safeguarding continuity and repeatability as key properties of
measurement methodologies is highly challenging and sometimes
impossible in reactive networks. Measurements in networks with
demand-driven allocation strategies must use a prototypical
application packet stream to infer a specific application's
performance. Measurement repetition with unbiased network and flow
states (e.g., by rebooting measurement hosts) can help to avoid
interference with periodic network behavior, randomness being a
mandatory feature for avoiding correlation with network timing.
Inferring the network performance between one measurement session or
packet stream and other streams with alternate characteristics is
generally discouraged with reactive networks because of the huge set

of global parameters which have influence instantaneous network
performance.

5. Security Considerations

   The security considerations that apply to any active measurement of
   live networks are relevant here as well. See [RFC4656] and
   [RFC5357].

6. IANA Considerations

   This memo makes no requests of IANA.

7. Acknowledgements

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