Rajeev Koodli
Nokia Research Center
R. Ravikanth
Axiowave

One-way Loss Pattern Sample Metrics
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Abstract

The Internet exhibits certain specific types of behavior (e.g., bursty packet loss) that can affect the performance seen by the users as well as the operators. Currently, the focus has been on specifying base metrics such as delay, loss and connectivity under the framework described in [frame-work]. It is useful to capture specific Internet behaviors under the umbrella of IPPM framework, specifying new concepts while reusing existing guidelines as much as possible. This draft proposes the use of "derived metrics" to accomplish this, specifically providing means for capturing the loss pattern on the Internet.

1. Introduction

In certain real-time applications (such as packet voice and video),

the loss pattern or loss distribution is a key parameter
that determines the performance observed by the users. For the same
loss rate, two different loss distributions could potentially produce
widely different perceptions of performance. The impact of loss pattern
is also extremely important for non-real-time applications that use
an adaptive protocol such as TCP. There is ample evidence in the
literature indicating the importance and existence of loss burstiness
and its effect on packet voice and video applications
[Bolot], [Borella], [Handley], [Yajnik].

In this document, we propose two derived metrics, called "loss distance"
and "loss period", with associated statistics, to capture packet loss
patterns. The loss period metric captures the frequency and length
(burstiness) of loss once it starts, and the loss distance metric
captures the spacing between the loss periods. It is important to note
that these metrics are derived based on the base metric
Type-P-One-Way-packet-Loss.

2. The Approach

This document closely follows the guidelines specified in [frame-work].
Specifically, the concepts of "singleton, sample, statistic",
measurement principles, Type-P packets, as well as standard-formed
packets all apply. However, since the draft proposes to capture
specific Internet behaviors, modifications to the sampling process
may be needed. Indeed, this is mentioned in [AKZ], where it is noted
that alternate sampling procedures may be useful depending on specific
circumstances. This draft proposes that the specific behaviors be
captured as "derived" metrics from the base metrics the behaviors
are related to. The reasons for adopting this position are the
following

- it provides consistent usage of singleton metric definition for
  different behaviors (e.g., a single definition of packet loss
  is needed for capturing burst of losses, 'm out of n' losses
  etc. Otherwise, the metrics would have to be fundamentally
  different)
- it allows re-use of the methodologies specified for the singleton
  metric with modifications whenever necessary
- it clearly separates few base metrics from many Internet behaviors

Following the guidelines in [frame-work], this
translates to deriving *sample* metrics from the respective
singletons. The process of deriving sample metrics from the singletons
is specified in [frame-work], [AKZ], and others.

In the following sections, we apply this approach to a particular
Internet behavior, namely the packet loss process.

3. Basic Definitions:

3.1. Bursty loss:

The loss involving consecutive packets of a stream.

3.2. Loss Distance:

The difference in sequence numbers of two successively lost packets which may or may not be separated by successfully received packets.

Example. Let packet with sequence number 50 be considered lost immediately after packet with sequence number 20 was considered lost. The loss distance is 30.

Note that this definition does not specify exactly how to associate sequence numbers with test packets. In other words, from a timeseries sample of test packets, one may derive the sequence numbers. However, these sequence numbers must to be consecutive integers.

Typo in last sentence.

3.3. Loss period:

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 Let P_i be the i'th packet.
 Define f(P_i) = 1 if P_i is lost, 0 otherwise.
 Then, a loss period begins if f(P_i) = 1 and  f(P_(i-1)) = 0

   Example. Consider the following sequence of lost (denoted by x)
            and received (denoted by r) packets.

            r r r x r r x x x r x r r x x x

   Then, with i assigned as follows
                                1 1 1 1 1 1
      i:    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5

  f(P_i) is,

  f(P_i):   0 0 0 1 0 0 1 1 1 0 1 0 0 1 1 1

            and there are four loss periods in the above sequence
            beginning at P_3, P_6, P_10, and P_13.
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4. Definitions for Samples of One-way Loss Distance, and One-way Loss Period.

4.1 Metric Name:

4.1.1 **Type-P-One-Way-Loss-Distance-Stream**
4.1.2 **Type-P-One-Way-Loss-Period-Stream**

4.2 Metric Parameters

+ Src, the IP address of a host
+ Dst, the IP address of a host
+ T0, a time
+ Tf, a time
+ lambda, a rate in reciprocal of seconds
+ Path, the path from Src to Dst (See [AKZ] for comments)

4.3 Metric Units

4.3.1 Type-P-One-Way-Loss-Distance-Stream:

A sequence of pairs of the form <loss distance, loss>, where loss is derived from the sequence of <time, loss> in [AKZ], and loss distance is either zero or a positive integer.

4.3.2 Type-P-One-Way-Loss-Period-Stream

A sequence of pairs of the form <loss period, loss>, where loss is derived from the sequence of <time, loss> in [AKZ], and loss period an integer.

4.4. Definitions:

4.4.1 Type-P-One-Way-Loss-Distance-Stream

When a packet is considered lost (using the definition in [AKZ]), we look at its sequence number and compare it with that of the previously lost packet. The difference is the loss distance between the lost packet and the previously lost packet. The sample would consist of <loss distance, loss> pairs. This definition assumes that sequence numbers of successive test packets increase monotonically by one. The loss distance associated with the very first packet loss is considered to be zero.

The sequence number of a test packet can be derived from the timeseries sample collected by performing the loss measurement according to the methodology in [AKZ]. For example, if a loss sample consists of {<T0,0>, <T1,0>, <T2,1>, <T3,0>, <T4,0>}, the sequence numbers of the five test packets sent at T0, T1, T2, T3, and T4 can be 0, 1, 2, 3 and 4 **respectively, or 100, 101, 102, 103 and 104 respectively, etc.**

4.4.2 Type-P-One-Way-Loss-Period-Stream

We start a counter 'n' at an initial value of zero. This counter is incremented by one each time a lost packet satisfies the Definition 3.3. The metric is defined as <loss period, loss> where "loss" is derived from the sequence of <time, loss> in Type-P-One-Way-Loss-Stream [AKZ], and loss period is set to zero when "loss" is zero in Type-P-One-Way-Loss-Stream, and loss period is set to 'n' (above) when "loss" is one in Type-P-One-Way-Loss-Stream.

Essentially, when a packet is lost, the current value of "n" indicates the loss period to which this packet belongs. For a packet that is received successfully, the loss period is defined to be zero.

4.4.3 Example:

Let the following set of pairs represent a Type-P-One-Way-Loss-Stream.

{<T1,0>,<T2,1>,<T3,0>,<T4,0>,<T5,1>,<T6,0>,<T7,1>,<T8,0>,<T9,1>,
<T10,1>}

where T1, T2,..,T10 are in increasing order.

Packets sent at T2, T5, T7, T9, T10 are lost. The two derived metrics can be obtained from this sample as follows.

(i) Type-P-One-Way-Loss-Distance-Stream:

Since packet 2 is the first lost packet, the associated loss distance is zero. For the next lost packet (packet 5), loss distance is 5-2 or 3. Similarly, for the remaining lost packets (packets 7, 9, and 10) their loss distances are 2, 2, and 1 respectively. Therefore, the Type-P-One-Way-Loss-Distance-Stream is:

{<0,0>,<0,1>,<0,0>,<0,0>,<3,1>,<0,0>,<2,1>,<0,0>,<2,1>,<1,1>}

(ii) The Type-P-One-Way-Loss-Period-Stream:

The packet 2 sets the counter 'n' to 1, which is incremented by one for packets 5, 7 and 9 according to Definition 3.3. However, for packet 10, the counter remains at 4 satisfying Definition 3.3 again. Thus, the Type-P-One-Way-Loss-Period-Stream is:

{<0,0>,<1,1>,<0,0>,<0,0>,<2,1>,<0,0>,<3,1>,<0,0>,<4,1>,<4,1>}

4.5. Methodologies:

The same methodology outlined in [AKZ] can be used to conduct the sample experiments.

4.6 Discussion:

The Loss-Distance-Stream metric allows one to study the separation between packet losses. This could be useful in determining a "spread factor" associated with the packet loss rate. For example, for a given packet loss rate, this metric indicates how the losses are spread. On the other hand, the Loss-Period-Stream metric allows the study of loss burstiness for each occurrence of loss. Note that a single loss period of length 'n' can account for a significant portion of the overall loss rate. Note also that it is possible to measure distance between loss bursts seprated by one or more successfully received packets: See Section 5.4, and 5.5

4.7 Sampling Considerations:

The proposed metrics can be used independent of the particular sampling method used. We note that Poisson sampling may not yield appropriate values for these metrics for certain real-time applications such as voice over IP, as well as to TCP-based applications. For real-time applications, it may be more appropriate to use the ON-OFF [Sriram] model, in which an ON period starts with certain probability 'p', during which certain number of packets are transmitted with mean 'lambda-on' according to geometric distribution and an OFF period starts with probability '1-p' and lasts for a period of time based on exponential distribution with rate 'lambda-off'.

For TCP-based applications, one may use the model proposed in [Padhye1]. See [Padhye2] for an application of the model.

5. Statistics:

5.1 Type-P-One-Way-Loss-Noticeable-Rate

Define loss of a packet to be "noticeable" [RK97] if the distance between the lost packet and the previously lost packet is no greater than delta, a positive integer, where delta is the "loss constraint".

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   Example. Let delta = 99. Let us assume that packet 50 is lost
            followed by a bursty loss of length 3 starting from
            packet 125.
            All the *four* losses are noticeable.
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Given a Type-P-One-Way-Loss-Distance-Stream, this statistic can be computed simply as the number of losses that violate some constraint delta, divided by the number of losses. (Alternately, it can also be defined as the number of "noticeable losses" to the number of successfully received packets).

This statistic is useful when the actual distance between successive losses is important. For example, many multimedia codecs can sustain losses by "concealing" the effect of loss by making use of past history information. Their ability to do so degrades with poor history resulting from losses separated by close distances. By chosing delta based on this sensitivity, one can measure how "noticeable" a loss might be for quality purposes. The noticeable loss requires a certain "spread factor" for losses in the timeseries. In the above example where loss constraint is equal to 99, a loss rate of one percent with a spread of 100 between losses (e.g., 100, 200, 300, 400, 500 out of 500 packets) may be more desirable for some applications compared to the same loss rate with a spread that violates the loss constraint (e.g., 100, 175, 275, 290, 400: losses occuring at 175 and 290 violate delta = 99).

5.2 Type-P-One-Way-Loss-Period-Total

This represents the total number of loss periods, and can be derived from the loss period metric Type-P-One-Way-Loss-Period-Stream as follows:

Type-P-One-Way-Loss-Period-Total = maximum value of the first entry of the set of pairs, <loss period, loss>, representing the loss metric Type-P-One-Way-Loss-Period-Stream.

5.3 Type-P-One-Way-Loss-Period-Lengths

This statistic is a sequence of pairs <loss period, length>, with the "loss period" entry ranging from 1 - Type-P-One-Way-Loss-Period-Total. Thus the total number of pairs in this statistic equals Type-P-One-Way-Loss-Period-Total. In each pair, the "length" is obtained by counting the number of pairs, <loss period, loss>, in the metric Type-P-One-Way-Loss-Period-Stream which have first entry equal to "loss period."

Thus, this statistic represents the number of packets lost in each loss period.

5.4 Type-P-One-Way-Inter-Loss-Period-Lengths

This statistic measures distance between successive loss periods. It takes the form of a set of pairs <loss period, inter-loss-period-length>, with the "loss period" entry ranging from 1 - Type-P-One-Way-Loss-Period-Total, and "inter-loss-period-length" is the loss distance between the last packet considered lost in "loss period" 'i-1', and the first packet considered lost in "loss period" 'i', where 'i' ranges from 2 to Type-P-One-Way-Loss-Period-Total. The "inter-loss-period-length" associated with the first "loss period" is defined to be zero. This statistic allows one to consider, for example, two loss periods each of length greater than one (implying loss burst), but separated by a distance of 2 to belong to the same loss burst if such a consideration is deemed useful.

5.5 Example

We continue with the same example as in Section 4.4.3. The three statistics defined above will have the following values.

+ Let delta = 2.
  In Type-P-One-Way-Loss-Distance-Stream
  {<0,0>,<0,1>,<0,0>,<0,0>,<3,1>,<0,0>,<2,1>,<0,0>,<2,1>,<1,1>}, there
  are 3 loss distances that violate the delta of 2. Thus,

  Type-P-One-Way-Loss-Noticeable-Rate = 3/5
  ((number of noticeable losses)/(number of total losses))

+ In Type-P-One-Way-Loss-Period-Stream
  {<0,0>,<1,1>,<0,0>,<0,0>,<2,1>,<0,0>,<3,1>,<0,0>,<4,1>,<4,1>}, the
  largest of the first entry in the sequence of <loss period,loss>
  pairs is 4. Thus,

  Type-P-One-Way-Loss-Period-Total = 4

+ In Type-P-One-Way-Loss-Period-Stream
  {<0,0>,<1,1>,<0,0>,<0,0>,<2,1>,<0,0>,<3,1>,<0,0>,<4,1>,<4,1>}, the
  lengths of individual loss periods are 1, 1, 1 and 2 respectively.
  Thus,

  Type-P-One-Way-Loss-Period-Lengths = {<1,1>,<2,1>,<3,1>,<4,2>}

+ In Type-P-One-Way-Loss-Period-Stream
  {<0,0>,<1,1>,<0,0>,<0,0>,<2,1>,<0,0>,<3,1>,<0,0>,<4,1>,<4,1>}, the
  loss periods 1 and 2 are separated by 3 (5-2), loss periods 2 and 3
  are separated by 2 (7-5), and 3 and 4 are separated by 2 (9-7).
  Thus,
  Type-P-One-Way-Inter-Loss-Period-Lengths = {<1,0>,<2,3>,<3,2>,<4,2>}

6. Security Considerations

Since this draft proposes sample metrics based on the base loss metric defined in [AKZ], it inherits the security considerations mentioned in [AKZ].

7. Acknowledgements

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8. References

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Author's Addresses

Rajeev Koodli
Nokia Research Center
313, Fairchild Drive
Mountain View, CA 94043
Phone: +1 650-625-2359
Email: rajeev.koodli@nokia.com

Rayadurgam Ravikanth
Axiowave Networks Inc.
100 Nickerson Road
Marlborough, MA- 01752
Email: rravikanth@axiowave.com