Connectivity
<draft-ietf-bmwg-ippm-connect-00.txt>

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2. Introduction

Connectivity is the basic stuff from which the Internet is made. Therefore, metrics determining whether pairs of hosts (IP addresses) can reach each other must form the base of a measurement suite. We define several such metrics, some of which serve mainly as building blocks for the others.

This memo defines a series of metrics for connectivity between a pair of Internet hosts. It builds on notions introduced and discussed in the revised IPPM Framework document (currently <draft-ietf-bmwg-ippm-framework-00.txt>); the reader is assumed to be familiar with that document.

The structure of the memo is as follows:

+ An analytic metric, called Type-P-Instantaneous-Unidirectional-Connectivity, will be introduced to define one-way connectivity at one moment in time.
+ Using this metric, another analytic metric, called Type-P-Instantaneous-Bidirectional-Connectivity, will be introduced to define two-way connectivity at one moment in time.
+ Using these metrics, corresponding one- and two-way analytic metrics are defined for connectivity over an interval of time.
+ Using these metrics, an analytic metric, called Type-P1-P2-Interval-Causal-Connectivity, will be introduced to define a useful notion of two-way connectivity between two hosts over an interval of time.
+ Methodologies are then presented and discussed for estimating Type-P1-P2-Interval-Causal-Connectivity in a variety of settings.

Careful definition of Type-P1-P2-Interval-Causal-Connectivity and the discussion of the metric and the methodologies for estimating it are the two chief contributions of the memo.

3. Instantaneous One-way Connectivity

3.1. Metric Name:

Type-P-Instantaneous-Unidirectional-Connectivity

3.2. Metric Parameters:

+ Src, the IP address of a host
+ Dst, the IP address of a host
+ T, a time

3.3. Metric Units:

Boolean.

3.4. Definition:

Src has *Type-P-Instantaneous-Unidirectional-Connectivity* to Dst at time T if a type-P packet transmitted from Src to Dst at time T will arrive at Dst.

3.5. Discussion:

This metric is probably not directly useful, because it is instantaneous and unidirectional. For most applications, bidirectional connectivity is considerably more germane (e.g., any TCP connection). Most applications also require connectivity over an interval. Finally, one might not have instantaneous connectivity due to a transient event such as a full queue at a router, even if at nearby instants in time one does have connectivity. These points are addressed below, with this metric serving as a building block.

Note also that we have not explicitly defined *when* the packet arrives at Dst. The TTL field in IP packets is meant to limit IP packet lifetimes to 255 seconds (RFC 791). In practice the TTL field can be strictly a hop count (RFC 1812), with most Internet hops being much shorter than one second. This means that most packets will have nowhere near the 255 second lifetime. In principle, however, it is also possible that packets might survive longer than 255 seconds. Consideration of packet lifetimes must be taken into account in attempts to measure the value of this metric.

Finally, one might assume that unidirectional connectivity is difficult to measure in the absence of connectivity in the reverse direction. Consider, however, the possibility that a process on Dst's host notes when it receives packets from Src and reports this fact either using an external channel, or later in time when Dst does have connectivity to Src. Such a methodology could reliably measure the unidirectional connectivity defined in this metric.

4. Instantaneous Two-way Connectivity

4.1. Metric Name:

Type-P-Instantaneous-Bidirectional-Connectivity

4.2. Metric Parameters:

+ A1, the IP address of a host
+ A2, the IP address of a host
+ T, a time

4.3. Metric Units:

Boolean.

4.4. Definition:

Addresses A1 and A2 have *Type-P-Instantaneous-Bidirectional-Connectivity* at time T if address A1 has Type-P-Instantaneous-Unidirectional-Connectivity to address A2 and address A2 has Type-P-Instantaneous-Unidirectional-Connectivity to address A1.

4.5. Discussion:

An alternative definition would be that at A1 and A2 are fully connected if at time T address A1 has instantaneous connectivity to address A2, and at time T+dT address A2 has instantaneous connectivity to A1, where T+dT is when the packet sent from A1 arrives at A2. This definition is more useful for measurement, because the measurement can use a reply from A2 to A1 in order to assess full connectivity. It is a more complex definition, however, because it breaks the symmetry between A1 and A2, and requires a notion of quantifying how long a particular packet from A1 takes to reach A2. We postpone discussion of this distinction until the development of interval-connectivity metrics below.

5. One-way Connectivity

5.1. Metric Name:

Type-P-Interval-Unidirectional-Connectivity

5.2. Metric Parameters:

+ Src, the IP address of a host
+ Dst, the IP address of a host
+ T, a time
+ dT, a duration

{Comment: Thus, the closed interval [T, T+dT] denotes a time interval.}

5.3. Metric Units:

Boolean.

5.4. Definition:

Address Src has *Type-P-Interval-Unidirectional-Connectivity* to address Dst during the interval [T, T+dT] if for some T' within [T, T+dT] it has Type-P-instantaneous-connectivity to Dst.

6. Two-way Connectivity

6.1. Metric Name:

Type-P-Interval-Bidirectional-Connectivity

6.2. Metric Parameters:

+ A1, the IP address of a host
+ A2, the IP address of a host
+ T, a time
+ dT, a duration

{Comment: Thus, the closed interval [T, T+dT] denotes a time interval.}

6.3. Metric Units:

Boolean.

6.4. Definition:

Addresses A1 and A2 have *Type-P-Interval-Bidirectional-Connectivity* between them during the interval [T, T+dT] if address A1 has Type-P-Interval-Unidirectional-Connectivity to address A2 during the interval and address A2 has Type-P-Interval-Unidirectional-Connectivity to address A1 during the interval.

6.5. Discussion:

This metric is not quite what's needed for defining "useful" connectivity - that requires the notion that a packet sent from A1 to A2 can elicit a response from A2 that will reach A1. With this definition, it could be that A1 and A2 have full-connectivity but only, for example, at at time T1 early enough in the interval [T, T+dT] that A1 and A2 cannot reply to packets sent by the other. This deficiency motivates the next metric.

7. Two-way Causal Connectivity

7.1. Metric Name:

Type-P1-P2-Interval-Causal-Connectivity

7.2. Metric Parameters:

+ Src, the IP address of a host
+ Dst, the IP address of a host
+ T, a time
+ dT, a duration

{Comment: Thus, the closed interval [T, T+dT] denotes a time interval.}

7.3. Metric Units:

Boolean.

7.4. Definition:

Address Src has *Type-P1-P2-Interval-Causal-Connectivity* to address Dst during the interval [T, T+dT] if there exist times T1 and T2, and time intervals dT1 and dT2, such that:

+ T1, T1+dT1, T2, T2+dT2 are all in [T, T+dT].
+ T1+dT1 <= T2.
+ At time T1, Src has Type-P1 instantanous connectivity to Dst.
+ At time T2, Dst has Type-P2 instantanous connectivity to Src.
+ dT1 is the time taken for a packet sent by Src at time T1 to arrive at Dst.

+ dT2 is the time taken for a packet sent by Dst at time T2 to arrive at Src.

7.5. Discussion:

This metric defines "useful" connectivity -- Src can send a packet to Dst that elicits a response. Because many applications utilize different types of packets for forward and reverse traffic, it is possible (and likely) that the desired responses to a Type-P1 packet will be of a different type Type-P2. Therefore, in this metric we allow for different types of packets in the forward and reverse directions.

7.6. Methodologies:

Here we sketch a class of methodologies for estimating Type-P1-P2-Interval-Causal-Connectivity. It is a class rather than a single methodology because the particulars will depend on the types P1 and P2.

7.6.1. Inputs:

+ Types P1 and P2, addresses A1 and A2, interval [T, T+dT], and
+ N, the number of packets to send as probes for determining connectivity.
+ W, the "waiting time", which bounds for how long it is useful to wait for a reply to a packet.

Required: W <= 255, dT > W.

7.6.2. Recommended values:

dT = 60 seconds.
W = 10 seconds.
N = 20 packets.

7.6.3. Algorithm:

+ Compute N *sending-times* that are randomly, uniformly distributed over [T, T+dT-W].
+ At each sending time, transmit from A1 a well-formed packet of type P1 to A2.

+ Inspect incoming network traffic to A1 to determine if a successful reply is received. The particulars of doing so are dependent on types P1 & P2, discussed below. If a successful reply is received, the value of the measurement is "true".
+ If no successful replies are received by time T+dT, the value of the measurement is "false".

7.6.4. Discussion:

The algorithm is inexact because it does not (and cannot) probe causal connectivity at every instant in time between [T, T+dT]. The value of N trades off measurement precision against network measurement load. The state-of-the-art in Internet research does not yet offer solid guidance for picking N. The values given above are just guidelines.

7.6.5. Specific methodology for TCP:

A TCP-port-N1-port-N2 methodology sends TCP SYN packets with source port N1 and dest port N2 at address A2. Incoming network traffic is interpreted as follows:

+ A SYN-ack packet from A2 to A1 with the proper acknowledgement fields and ports on A1 indicates causal connectivity. The measurement terminates immediately with a value of "true". {Comment: the connection now established between A1 and A2 should be properly torn down using the usual FIN handshake (not by using a RST packet, as these are not transmitted reliably).}
+ A RST packet from A2 to A1 with the proper ports on A1 indicates causal connectivity between the addresses (and a *lack* of service connectivity for TCP-port-N1-port-N2 - something that probably should be addressed with another metric).
+ An ICMP port-unreachable from A2 to A1 indicates causal connectivity between the addresses (and again a *lack* of service connectivity for TCP-port-N1-port-N2). {Comment: Are there TCP implementations that generate ICMP's instead of RST's? Do the RFC's allow this? Certainly they do for UDP, so the notion makes sense.}
+ An ICMP host-unreachable or network-unreachable to A1 (not necessarily from A2) with an enclosed IP header matching that sent from A1 to A2 *suggests* a lack of causal connectivity. If by time T+dT no evidence of causal connectivity has been gathered, then the receipt of the ICMP can be used as additional information to the measurement value of "false".

{Comment: Similar methodologies are needed for ICMP Echo, UDP, etc.}

8. Security Considerations

This memo raises no security issues.

9. References

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10. Authors' Addresses

Jamshid Mahdavi <mahdavi@psc.edu>
Pittsburgh Supercomputing Center
4400 5th Avenue
Pittsburgh, PA 15213
USA

Vern Paxson <vern@ee.lbl.gov>
MS 50B/2239
Lawrence Berkeley National Laboratory
University of California
Berkeley, CA 94720
USA
Phone: +1 510/486-7504