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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Quality of service and performance – Generic and user-related aspects

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Network contribution to transaction time

ITU-T Recommendation G.1040

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ITU-T Recommendation G.1040

Network contribution to transaction time

Summary

This Recommendation defines a new performance metric for networks that transport short data transactions, such as those associated with credit cards and other point-of-sale transactions. The main factors contributing to transaction time are packet network performance and host processing time.

The new metric is called network contribution to transaction time (NCTT), and it uses packet transfer performance levels (such as round-trip time and packet loss ratio) as inputs in order to estimate the portion of transaction time attributable to the network alone. Since this is the portion under the control of the network operator, knowledge of this value is useful for operators and users alike. The scope of this Recommendation is limited to the performance of the path between user-network interfaces (UNI-UNI) and uses limited configuration information from transaction client and host systems.

Source

ITU-T Recommendation G.1040 was approved on 22 February 2006 by ITU-T Study Group 12 (2005-2008) under the ITU-T Recommendation A.8 procedure.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

Introduction

Users would like to reduce the complexities of network performance to a "**single number**", one that captures all service aspects, quantifies their individual experience with the service over time, and simplifies reporting and rebate reconciliation. This Recommendation defines such an overall metric for data transactions.

Users purchase IP networking capabilities to conduct transactions using either voice or data communications. Voice transactions are largely free-form, while data transactions are structured according to well-specified, and often standardized protocols. When the protocol behaviour of the client and server are known, it is possible to estimate the packet transport network's contribution to the overall transaction time experienced by users. The bases for the estimates are real measurements of packet loss and delay.

Users may measure transaction time using any of the available means, including integrated instruments in the application programs, test transactions launched by measurement equipment, and passive monitoring at strategic locations. Most of these techniques measure a time interval that is attributable to both network performance, client performance in terms of processing time, and host/server performance.

This Recommendation defines a metric that uses the network's packet delay and packet loss performance to isolate an estimate of the network's contribution to transaction time. The metric can be customized for each specific user and/or transaction type. When a user measures their typical transaction time, this metric can account for the portion attributable to the network. When the user measures longer transaction times and inquires about cause, it is possible to say **if the network contributed to the increase**, and **how much**.

The new metric is called "network contribution to transaction time" (NCTT). It differs from the handshake time defined elsewhere in that NCTT does not include host processing times.

There is no perceptual interpretation proposed as part of this metric. User organizations will often have individual objective criteria for transaction time performance, and the criteria may vary depending on various circumstances. ITU-T Rec. G.1010 gives guidance regarding response times for various applications, and ITU-T Rec. Y.1541 provides performance objectives for IP-based networks.

ITU-T Recommendation G.1040

Network contribution to transaction time

1 Scope

The scope of this Recommendation is limited to the definition, description, and examples of the network contribution to transaction time (NCTT) performance metric for short data transactions with relevance to network providers and users. This is a metric derived primarily from the performance characteristics of the user-network interface to user-network interface (UNI-UNI) path, although it also uses limited configuration information from clients and hosts.

This performance metric is intended to be applied in situations where packet network communications are used to complete repetitive data transactions, such as credit card authorization for purchase, and where measurements of the supporting network's performance are available.

The NCTT metric is derived from packet transfer delays and packet loss ratios from client to host and host to client, effectively a round-trip across the network. Measurements will usually supply the needed network characterization, and measurement considerations are given below.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[1] ITU-T Recommendation G.1000 (2001), *Communications Quality of Service: A framework and definitions*.

[2] ITU-T Recommendation G.1010 (2001), *End-user multimedia QoS categories*.

[3] ITU-T Recommendation Y.1540 (2002), *Internet protocol data communication service – IP packet transfer and availability performance parameters*.

[4] ITU-T Recommendation Y.1541 (2006), *Network performance objectives for IP-based services*.

3 Abbreviations

This Recommendation uses the following abbreviations:

ICMP Internet Control Message Protocol

NCTT Network Contribution to Transaction Time

RT Round-Trip

RTO Retransmission Time-Out

RTT Round-Trip Time

TCP Transmission Control Protocol

UDP User Datagram Protocol

UNI User-Network Interface

4 Network contribution to transaction time

This clause defines the metric called network contribution to transaction time (NCTT). The metric uses UNI-UNI packet transfer performance levels (such as round-trip time and packet loss ratio) as inputs in order to estimate the portion of transaction time attributable to the network alone. Since this is the portion under the control of the network operator, and knowledge of this value is useful for operators and customers alike.

4.1 Data transaction time

A typical data transaction takes the form of a packet conversation, where the client identifies itself to a remote host and submits some request for processing on behalf of a user. The host, after assuring the identities and authorization of the client device and user, performs the request and communicates the result. In the case of "short" transactions considered here, the result is a simple confirmation of the request to exchange funds, or an account balance.

The reference path and reference transaction (illustrating a transaction with eight round-trip exchanges) are described in Figures 1 and 2 below.

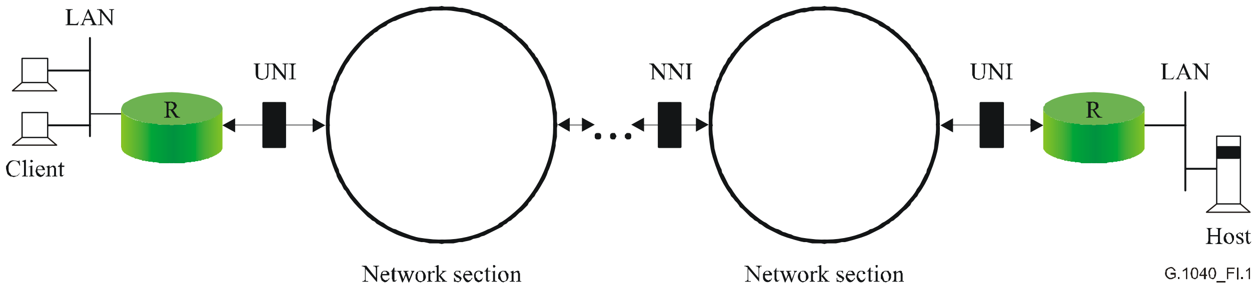

Figure 1/G.1040 – Reference path

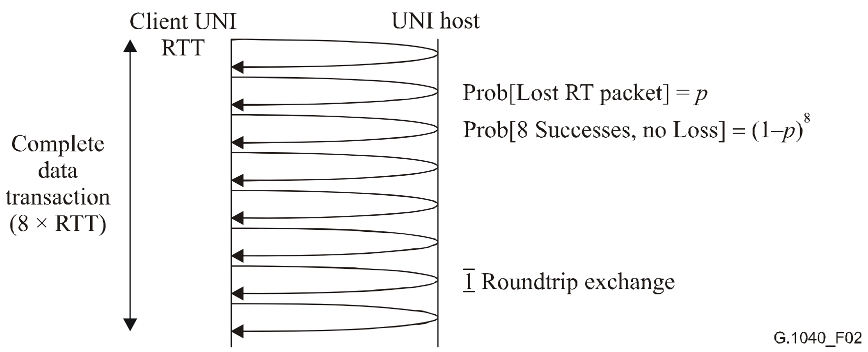

Figure 2/G.1040 – Reference transaction

The following time periods can be identified in each packet exchange:

4.1.1 Client to host transfer time

The time for a packet to traverse the UNI-UNI path between client and a host, identical to packet transfer delay defined in ITU-T Rec. Y.1540.

4.1.2 Host processing time

The time a host takes to prepare a response or acknowledgement packet, defined as the interval beginning when the last bit of the client's packet passes the host's UNI and ending when the first bit of the packet containing a valid response passes the host's UNI toward the client.

4.1.3 Client processing time

The time a client takes to prepare a response or acknowledgement packet, defined as the interval beginning when the last bit of the host's packet passes the client's UNI and ending when the first bit of the packet containing a valid response passes the client's UNI toward the host.

4.1.4 Host to client transfer time

The time for a packet to traverse the UNI-UNI path between host and a client, identical to packet transfer delay defined in ITU-T Rec. Y.1540.

4.1.5 Client retransmission time-out interval

The time a client will wait for acknowledgement or response to its packet transmission.

4.1.6 Host retransmission time-out interval

The time a host will wait for acknowledgement or response to its packet transmission.

4.1.7 Data transaction time

The total time to complete a transaction, as observed at the client UNI. This is the sum of all the component times for a given transaction type, where the number and direction of exchanges and device configurations are specified.

4.1.8 Round-trip exchange

A round-trip exchange, sometimes simply called an exchange, is a component of a data transaction where one packet traverses the network from UNI to UNI, and a response packet traverses the network in the opposite direction. An exchange may begin at a client and proceed from client to remote host to client, or begin at the remote host.

4.2 Definition of network contribution to transaction time

The main network factors contributing to transaction time are packet network performance, retransmission time for lost packets, and device processing time (which is often highly variable, and beyond the network provider's control). Removing the device processing times leaves the time attributable to network performance, in particular the round-trip packet transfer times and the time to recover from packet loss.

Network contribution to transaction time (NCTT) is defined as the sum of the round-trip times necessary to complete a given transaction type, plus the time for recovery from any lost packets during the transaction. A given transaction type will specify the number and direction of exchanges and the retransmission time-out interval.

4.3 Calculation of network contribution to transaction time

The network contribution to transaction time can be calculated as follows:

$$NCTT = (E \times RTT) + (L \times RTO)$$

where:

- E is the number of round-trip exchanges needed to complete a transaction
- RTT is the mean round-trip time for packet transfer
- L is the number of round-trip exchanges that experience a packet loss
- RTO is the retransmission time-out (assumed to be the same at client and host)
- L the number of losses experienced during a transaction, is dependent on the round-trip packet loss probability, p. If two one-way loss probabilities are given, then we have:

$$p = p_{RT} = 1 - \{(1 - p_{1-way}) \times (1 - p_{other-way})\}$$

- L is also dependent on the number of successful exchanges, E

If each round-trip exchange, i, takes A_i attempts to complete successfully, and the total attempts to complete a transaction, $A = \sum_{i=1}^{E} A_i$, then:

$$Prob(A_i = a) = p^{a-1}(1-p)$$

so the expected value of A is:

$$E\{A\} = E \times \sum_{a=1}^{\infty} a \times p^{a-1}(1-p) = \frac{E(1-p)}{p} \sum_{a=1}^{\infty} a \times p^{a}$$

which converges to:

$$E\{A\} = \frac{E}{1-p} \text{ for } 0 \le p < 1$$

Note that A is equal to the constant E plus a random number of losses, L, so $E\{A\} = E + E\{L\}$,

$$E\{L\} = \frac{E}{(1-p)} - E = E\frac{p}{(1-p)}$$

and the average NCTT is:

$$\text{Average}(NCTT) = (E \times RTT) + (E\{L\} \times RTO)$$

We note that the probability distribution of NCTT is a set of discrete values at:

$$(E \times RTT), (E \times RTT) + (1 \times RTO), (E \times RTT) + (2 \times RTO), \text{ etc.}$$

We can calculate the probabilities at L=0, 1, 2, etc., as follows:

$$pdf[NCTT] = C_{L}^{E+L-1}(1-p)^{E} p^{L} = \binom{E+L-1}{L}(1-p)^{E} p^{L}$$

$$pdf[(E \times RTT) + (L \times RTO)] = \binom{E+L-1}{L}(1-p)^{E} p^{L}$$

4.4 Example of network contribution to transaction time

As an example, consider a transaction that requires E = 8 successful packet exchanges between a client and a server. The network's contribution to a normal transaction is eight times the round-trip time (RTT), using the average RTT from measurements. If one packet is lost and retransmission is necessary, the transaction looks like Figure 3 below (from the network's perspective). This means that a total of nine packet transfers will be attempted.

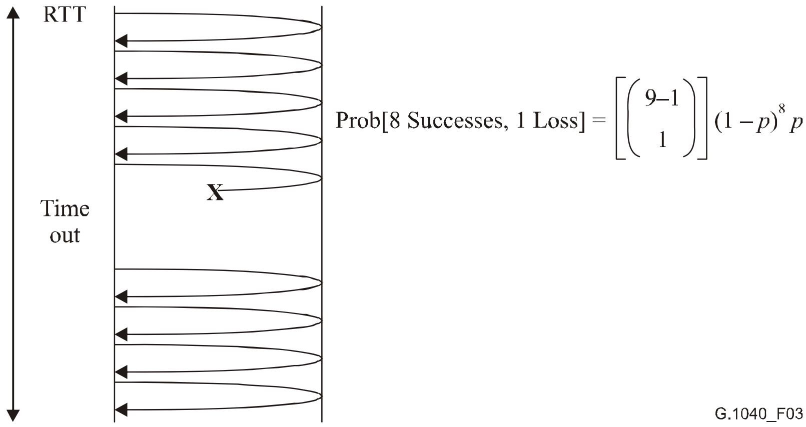

Figure 3/G.1040 – Transaction with nine round-trip exchanges needed because one packet was lost

Here the IP network contribution to transaction time is the timeout for retransmission plus the time for eight successful round-trip times. The probability of this case occurring is a function of the number of ways it can occur and the probabilities of each individual transfer outcome, whether successful (*1 – p*) or lost (*p*).

If we further assume that $p = 10^{-3}$, *RTT* = 0.080 seconds, retransmission time-out *RTO* = 1 second, and there are 350 thousand transaction attempts, we have the following probabilities for each of the cases of loss:

Table 1/G.1040 – NCTT for cases with 0 to 3 packets lost

Losses	NCTT [s]	Probability of occurrence	Transactions
0	0.64	0.99202794	347210
1	1.64	0.00793622	2778
2	2.64	3.5713E-05	12
3	3.64	1.1904E-07	0

Also, we can calculate the average NCTT as follows:

$$\text{Average}(NCTT) = (8\times 0.08) + (0.008\times 1) = 0.648$$

We conclude that this example IP network contributes less than a second to the average and 99th percentile of the total handshake time for this data transaction with eight RT exchanges.

Network contribution to transaction time can be estimated after every measurement interval. Site-pair specific measurements are certainly possible, so all the spokes could be monitored in a hub-spoke topology.

5 Measurement methodology considerations

If the input values are to be derived from network measurements, then this is a case where round-trip measurements are most relevant, such as those derived from ICMP echo-request/echo-reply (ping) measurements. However, UDP Echo and TCP-based methods are available, and it may be possible to use these as well.

In any case, the methodology must adhere to the following criteria:

1) The measurement packets must follow a representative path between client and host.
2) The packets must receive the same forwarding treatment as real transaction packets in each network element encountered (may not be true for ICMP).
3) The client and host must not contribute significantly to the measured round-trip-time, or at least permit the additional time to be removed as a measurement error on a per-packet basis.
4) Measurement intervals and measurement sample sizes must be sufficient to characterize the loss and delay of the client-host path with the desired accuracy.

Network contribution to transaction time can be estimated after every measurement interval. Site-pair specific measurements are certainly possible, so all the spokes could be monitored in a hub-spoke topology.

To customize this metric, the user supplies the number of round-trip exchanges for a normal (loss-free) transaction, and the time-out time for retransmission in the event of packet loss. In some cases, the customer may simply name a standardized protocol (e.g., POP3) and any configurable options.

6 Format for results

It appears useful to report the distribution of several NCTT values, since there are discrete calculations for every level of packet loss. Figure 4 plots the results for the example calculation in 4.4.

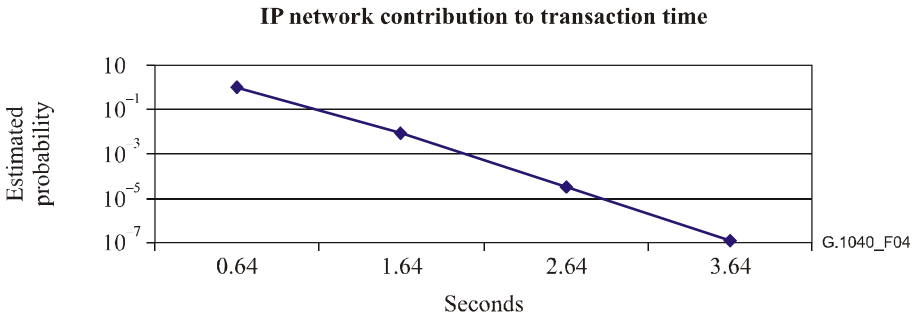

Figure 4/G.1040 – Distribution of NCTT

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