A study on network performance metrics and their composition

Andreas Hanemann
German Research Network, Munich, Germany
Athanassios Liakopoulos
Greek Research & Technology Network S.A., Athens, Greece
Maurizio Molina
DANTE, Cambridge, UK, and
D. Martin Swany
Department of Computer and Information Sciences, University of Delaware, Newark, Delaware, USA

Abstract

Purpose – Research backbone networks like GÉANT2 and the national research and education networks are used by a variety of scientists and research projects. These users and the network engineers operating the networks would like to get access to network performance metrics to optimise their use of the network and to troubleshoot performance degradations when they happen. A variety of tools for performing network measurements already exist, and the perfSONAR architecture developed in the Joint Research Activity 1 (JRA1) of GÉANT2 aims at integrating them into a coherent framework. However, a harmonised definition of the most interesting metrics and how measurements must be carried out is still lacking.

Design/methodology/approach – This paper suggests some of the elementary metrics which are relevant for assessing network performance, along with an indication about how to post-process (or "transform", or "compose") them in order to obtain derived summary values that can quickly and intuitively give an indication of network performance. Methods to perform the composition are presented, together with constraints which have to be taken into account to get accurate results. In particular, delay measurements are the most delicate ones to compose.

Findings – The authors carried out a series of experiments for proofing the validity of the composition of delay metrics, and briefly present some preliminary results, that confirm the applicability of the proposed methodology.

Research limitations/implications – Future work needs to confirm the paper's findings on other data sets, possibly collected in different network locations.

Practical implications – The practical implication of the findings is that it is possible for a network operator to accurately predict high percentiles of delays on an end-to-end path starting from independent delay measurements on subsequent path sections.

Originality/value – The main original contribution of this paper is the application to a real data set of a post-processing procedure that is derived from simple statistics theory.

Keywords Computer networks, Performance management

Paper type Research paper

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1. Introduction

Many modern networking applications can benefit from improved Quality of Service (QoS) supported across multiple administrative domains. GÉANT2, the Gigabit core pan-European research network, for example, supports Premium IP service to the European National Research and Education Networks (NRENs). Provisioning of end-to-end advanced transport services requires methods for verifying the established service level agreements (SLAs) between the service provider and its customers. Even in a well-engineered network, however, occasional equipment failure or misconfiguration can cause severe degradation of service performance.

Therefore, GÉANT2 is committed to constantly assessing the QoS in the network and to verify that the performance guarantees agreed upon with the NRENs are met. Moreover, end-users should be able to access the measurement infrastructure or the archived measurement data, even with lower privileges than the GÉANT2/NRENs Network Engineers. This requires the deployment of an appropriate monitoring infrastructure in the GÉANT2/NRENs networks, and coordination in the collection and exchange of performance metrics.

The Joint Research Activity 1 (JRA1) (GÉANT2 Joint Research Activity 1 (GN2-JRA1): performance measurements and monitoring, www.geant2.net/server/show/nav.754) in the GÉANT2 project, in cooperation with the Internet2's end-to-end piPEs (E2E piPEs: end-to-end performance improvement performance environment system http://e2epi.internet2.edu/e2epipes/) initiative and the US Department of Energy's ESnet (www.es.net/), defined a general framework for a multi-domain network measurement infrastructure. Currently, a prototype implementation, called "Performance focused Service Oriented Network monitoring Architecture" (perfSONAR), is under development and testing. In this context, harmonisation of the type of collected measurements is fundamental, so that they are also useful in a multi-domain context, as is the definition of common procedures to post-process them.

Because there is a large number of performance metrics defined in standards, proposed in the literature or used in practice, JRA1 does not aim to define new metrics or to mandate the list of those that should be monitored in the NRENs interconnected via GÉANT2. On the contrary, each administrative domain can potentially perform diverse sets of tests and use different sets of metrics to monitor network conditions. JRA1 addresses the problem of how to publish data sets collected via different testing methodologies in a unified way, making it possible to compare raw and aggregated metric values and their accuracy. For the time being, JRA1 focuses on data sets from widely-used metrics, but the outcome of the analysis could potentially be applied to other metrics.

This paper presents the work in progress in GN2-JRA1 related to the composition of network performance metrics. In Section 2, a brief description of the JRA1 monitoring architecture (perfSONAR) is provided. Section 3 presents our selection of the most significant metrics and their classification into categories. Section 4 explains the main reasons for post processing monitoring data. This operation is called "metric composition". Section 5 presents, as an example, experimental results of a composition of one way delay (OWD) data. Finally, Section 6 references related work on metric composition, and our conclusions, as well as future plans, are discussed in the last section.

2. GN2-JRA1 monitoring architecture (perfSONAR)

The perfSONAR system is a framework that enables information about network performance to be gathered and exchanged in a multi-domain, federated manner. The goal of perfSONAR is to enable the ubiquitous gathering and sharing of this performance information in order to ease the management of advanced networks, to facilitate cross-domain troubleshooting and to allow next-generation applications to tailor their execution to the state of the network. This system has been designed to accommodate easy extensibility for new network metrics and to facilitate the automatic processing of these metrics as much as possible.

The perfSONAR architecture is composed of three different layers, as shown in Figure 1. The measurement point layer is responsible for performing active or passive measurement tests via multiple measurement points (MPs), i.e. existing network monitoring tools. The MP is wrapped into a higher-level abstraction called measurement point service, belonging to the service layer, which hides the implementation details of the MP. The service layer is composed of multiple services that control the monitoring infrastructure to receive, store and exchange measurement and network topology data. Services interact with each other without human intervention (e.g. measurement data retrieved by a measurement point service is fed into a measurement archive service and manipulated by a transformation service) and with the upper user interface layer. The end-users interact via the visualisation tools at the user interface layer only.

The whole architecture is based on web services (WS) technology, which allows the definition of the interaction between services through well-defined, language-independent interfaces. Web services are closely tied to the eXtensible Markup Language (XML). The perfSONAR system uses and extends a schema defined by the Global Grid Forum's Network Measurement Working Group (https://forge.gridforum.org/projects/nm-wg). This schema defines an extensible message and storage format for network measurements. The perfSONAR approach removes any dependencies from the lower networking technologies and permits new services to be added easily. The following services have been defined in the perfSONAR framework:

- measurement point (MP) service: performs the measurements and forwards data to other services;
- measurement Archive (MA) service: stores the measurement data;

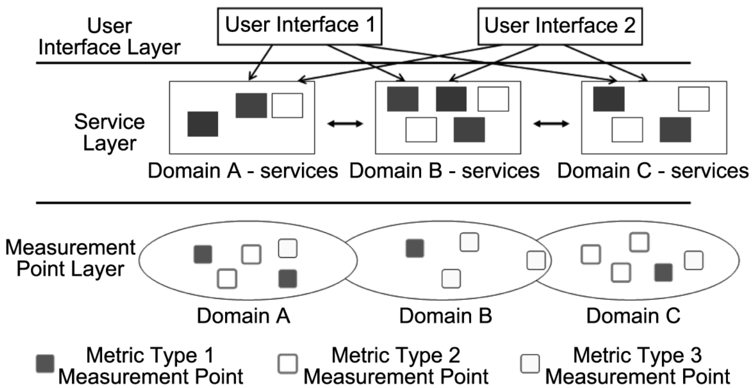


Figure 1.
The PerfSONAR service oriented architecture for multi-domain network monitoring

- lookup service (LS): registers information regarding active services and their capabilities;
- topology service (TS): stores network topology information;
- authentication service (AS): provides the authentication and authorisation services required in user-services interactions;
- transformation service (TrS): performs manipulation (aggregation, statistics) on available data sets; and
- resource protector (RP) service: arbitrates the use of limited measurement resources.

Currently, perfSONAR is focusing on IP-level metrics, as this is the main service provided by the NRENs. The framework has been built flexibly enough to cater for new metrics and to different types of technology.

For the described architecture to be truly useful in a multi-domain environment; there is a need to harmonise the type of collected measurements and the procedures for their composition in the TrS. This is the main focus of the study described in this paper. A more extended description is available in (DJ1.2.3, 2006).

3. Network metric selection and classification

We surveyed several network metrics, both the ones defined in standards (RFCs of the IETF IPPM Working Group, available at: www.ietf.org/html.charters/ippm-charter.html, (ITU-T rec. Y.1540, 2002)) and non-standard ones which are commonly collected by network operation centres. Furthermore, we analysed the replies to a questionnaire circulated by the NRENs among potential users of perfSONAR in the first phase of the JRA1 project. As a result, we selected the metrics of greatest relevance for network performance, i.e. useful for assessing the service level offered to IP traffic forwarded though a network. They can be divided into four main groups:

(1) availability;

(2) loss and error;

(3) delay; and

(4) bandwidth.

Availability metrics assess how robust the network is, i.e. the percentage of time the network runs without any problem, impacting the availability of services. It can also refer to specific network elements (e.g. a link or a node), and in that case, it will measure the percentage of time they run without failure. Loss and error metrics are indicative of the network congestion conditions and/or transmission errors and/or equipment malfunctioning. They usually measure the fraction of packets lost in a network due to buffer overflows or other reasons, or the fraction of packets containing bit errors. Delay metrics also assess the network congestion conditions or effect of routing changes. They measure the delay (one way delay-OWD and round trip time-RTT) and delay variation (IPDV or "jitter") of the packets transferred by a network. Finally, bandwidth metrics assess the amount of data that a user can transfer through the network in a time unit, both dependent on and independent of the existing network traffic.

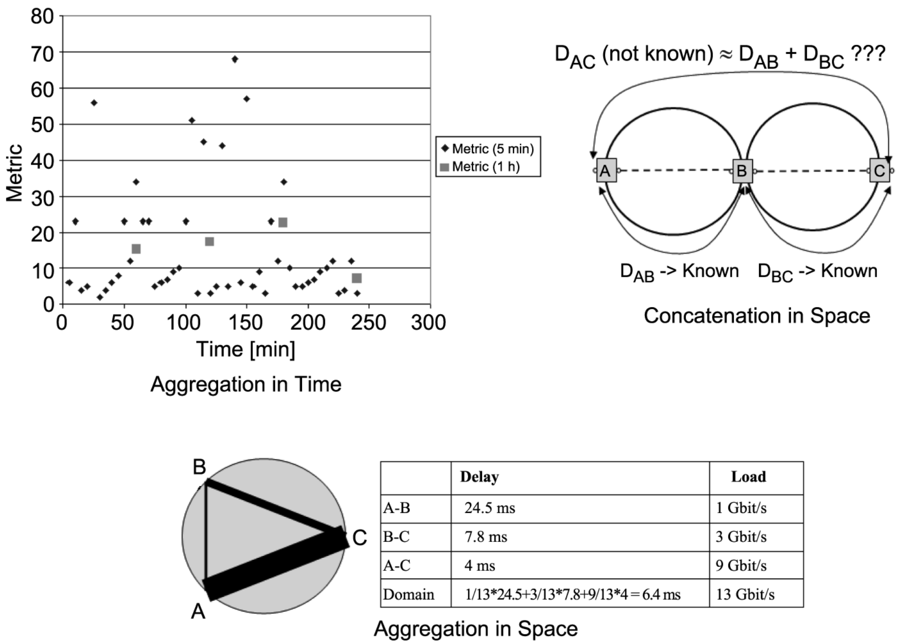
Aside from the performance-related metrics, several additional metrics are often useful to explain the causes of performance degradations. Examples are the CPU load, memory consumption or even chassis temperature of network devices. The monitoring infrastructure may observe these additional metrics to ease troubleshooting when their values indicate degradation in service levels, or to prevent degradation by upgrading equipment before it reaches critical conditions. These metrics are further divided into device-specific, flow monitoring and routing metric groups.

For each metric relevant in the context of perfSONAR, a definition was given in (DJ1.2.3, 2006) (with reference to standards when possible), and a procedure for its measurement was described, along with considerations of accuracy. This effort tried to reconcile the variety of metric definitions and measurement methods that are often possible.

4. Network metric composition (transformation service)

Unfortunately, establishing a common understanding of network metric definitions, their measurement methodologies and their accuracy is not enough. In general, network measurements need to be post-processed (composed) to be useful for the various tasks of network engineering, management and planning. This becomes fundamental in a multi-domain environment such as the one targeted by perfSONAR.

There are several reasons for composing network metrics: the first one is data reduction. Consider, for example, a network domain in which delay measurements are performed on all links. A network manager might ask whether there is a general problem with the network delay. Therefore, it would be desirable to obtain a single summary value calculated from the delay measurements on a single domain's links. We call this composition "aggregation in space". In the example in Figure 2, a weight,



	Delay	Load
A-B	24.5 ms	1 Gbit/s
B-C	7.8 ms	3 Gbit/s
A-C	4 ms	9 Gbit/s
Domain	1/13*24.5+3/13*7.8+9/13*4 = 6.4 ms	13 Gbit/s

Figure 2.
The three possible types of metric composition

proportional to the traffic carried on the links is applied, to produce a summary OWD value for this single domain. Other rules to produce a summary value may be used; for example, a service provider that offers service level agreements (SLAs) to his/her customers might prefer to estimate the maximum value of the average OWD between any edge points in its network. As shown in Table I, aggregation in space can potentially be performed with a large group of performance metrics. However, the specific operation on the collected data sets depends on the usage of the results.

Another important reason for composing network metrics is to perform trend analysis. For doing so, a single value for an hour, a day or a month is computed from the basic measurements which are scheduled with finer granularity, e.g. every five minutes (Figure 2). In this way, trends can be more easily observed, like an increasing usage of a backbone link which might require the installation of alternative links or the rerouting of some network flows. This type of composition is called "aggregation in time". This method reduces the amount of data at the expense of data time resolution. Aggregation in time is widely used by visualisation tools, such as MRTG (Multi Router Traffic Grapher (MRTG), available at: http://mrtg.hdl.com/mrtg.html), that present various parameters of network performance in different time-scales. Aggregation in time is fundamental in estimating packet loss in a link using active measurements; since packet losses are usually quite rare, only the time aggregation of several different experiments may be meaningful.

Finally, composition may be performed for scalability. Owing to the number of network elements in large networks like GÉANT2 and the connected NRENs, it is impossible to perform a full mesh of measurements between all the equipment, either regularly or on demand. However, if regular measurements are scheduled between selected MP pairs, say, A to B and B to C, we can try to infer the value of a network performance metric (e.g. the OWD) on a path, say, A to C, even in the absence of a direct measurement between the end points of that path. This type of composition is called "concatenation in space" (Figure 2).

For each selected network metric, we examined which composition operation can reasonably be applied and for what purpose, which statistical operations are more useful (e.g. average, max, min, X-percentiles, median) and when it is useful to perform, in sequence, two or more compositions. A summary of the results is shown in Table I, and some details are explained in the following (symbols in the text are used to refer to locations in the table). The full work is contained in (DJ1.2.3, 2006).

The lower part of the Table shows which composition operations are useful with respect to metrics, and the specific statistical operation done during the composition.

For example, it is reasonable to aggregate OWD measurements in time by computing a value for a longer time–interval, taking the average of measured values (*). For some applications, however, the average value may not be significant, as it might be sensitive to high, sporadic delay values. In that case, a 97.5-2.5 per cent percentile aggregation is beneficial to avoid extreme values resulting from measurement inaccuracies, instead of simply calculating a maximum/minimum value (**).

The remark "ToS effect" for aggregation in space of packet loss measurements (#) means that it can be interesting to track whether the prioritisation of packets in router waiting queues leads to different packet loss for different ToS values.

Table I.
Summary of the composition study

	Aggregation in time	Aggregation in space	Concatenation in space
Definition	Aggregate measurements of the same scope and type performed in different time windows or time instants	Aggregate measurements of the same type but of different (physical or logical) scope	Concatenate measurements of the same type performed on consecutive paths
Usability	Reduce the amount of collected data, observe trends	Provide a summary metric value for a group of network elements or links in a domain	Combine the results from multiple measurements in order to estimate the e2e performances for a longer path
Requirements	NA	NA	Measurements should be taken in consecutive links
	NA	Measurements should be performed in the same timeframe	
	Measurements should be performed with the same type-packets, e.g. size, ToS, etc. (For space aggregation, this applies to physical space aggregation only. Logical space aggregation is by definition over packet properties!)		
	Measurements should to be collected during the entire time widow. Otherwise, measurements have to be weighted	Measurements should be weighted according to the link characteristics (e.g. capacity, utilisation) and their significance	
	NA	Measurements should have comparable accuracy	

(*continued*)

	Aggregation in time	Aggregation in space	Concatenation in space
	Operations should be performed over an adequate data set		
Most relevant operations			
OWD, RTT	Average (*), percentiles (**)	Average, maximum, percentiles	Average (+) percentile (but difficult to compute exactly) (++)
IPDV	Average, percentiles	Average, maximum, percentiles	Average Percentile (but difficult to compute exactly)
Packet loss	Average, median, percentiles	Average, minimum,maximum (ToS effect) (#)	Average
Available bandwidth	Average, minimum, maximum	Average, minimum, maximum, percentiles	Minimum (^)
Utilisation	Average, median	Average, minimum, maximum, percentiles	NA
Capacity	NA (capacity is a slowly varying "metric")	Average, minimum, maximum	Minimum (^)
Achievable bandwidth	NA (not likely that tests are performed regularly) (&)	NA	NA (&&)
Availability	Average	Average	Average

Table I.

The achievable bandwidth on a path requires the sending of a lot of test packets which will likely disturb other traffic. Therefore, these measurements will only be carried out in specific situations, so no data for their time aggregation (&) will be available. Moreover, since the end-to-end RTT plays a role in these kinds of tests, concatenating results on consecutive path portions makes little sense (&&).

The concatenation in space for available bandwidth and capacity (^) is simple, because the minimum bandwidth of a link is the bottleneck when transferring data through a concatenation of links.

Concatenating in space OWD is easy for the average (+), but presents statistical difficulties (++) when it comes to percentiles. The following sections discuss how OWD distributions from different links can be concatenated together to estimate the OWD-distribution for the end-to-end path, and thus its percentiles.

5. Experimental assessment of concatenation in space for OWD

It is simple to apply the concatenation in space to mean OWD values. The mean OWD value along the path from host[1] A to host C via host B($<OWD_{AC}>$), knowing the corresponding mean OWD values along the path from host A to host B($<OWD_{AB}>$) and B to C($<OWD_{BC},>$), is:

$$<OWD_{AC}>=<OWD_{AB}> + <OWD_{BC}>$$

This is a simple consequence of the fact that if a random variable x is the sum of two other random variables y and z, its mean is equal to the sum of the means of y and z. This is always true, no matter whether y and z are independent or not.

However, the mean OWD value is not a sufficient metric to assess the performance along a path, especially when delay-sensitive applications are deployed over the network. In such cases, it is highly recommended to estimate a high quantile[2] for the OWD along a path, as this represents the "upper bound" on the OWD while eliding a few of the worst offending measurements. This introduces challenges from a statistical point of view, because the quantile of OWD along the path AC can be computed only knowing the corresponding OWD distribution along the path AC. If the latter is unknown, the only possibility is to compute it from the distributions of OWD_{AB} and OWD_{BC} by performing the convolution of these two distributions. The convolution (Convolution operation, http://mathworld.wolfram.com/Convolution.html.) of two distributions y and z is a mathematical operation involving an integration and is denoted as "$y*z$" or "$y \otimes z$", or "y(x)z".

Contrary to the composition of means, however, the composition of distributions through the convolution formula holds, in principle, only if y and z are independent.

To prove the applicability of the convolution approach to infer the high quantiles of OWD_{AC} given two OWD_{AB} OWD_{BC} datasets, we collected OWD measurement data among three different IPPM measurement boxes (IPPM Measurement tool, available at: www-win.rrze.uni-erlangen.de/ippm/messprogramm.html) in Erlangen (Germany), Frankfurt (Germany) and Rome (Italy) (Figure 3). We collected measurements on both A to B, B to C and A to C, to be able to compare the distribution obtained by the convolution operation ($OWD_{AB} \otimes OWD_{BC}$) with the distribution of the direct A to C measurement (OWD_{AC}).

In our experiments, we were sure that the routing of packets from A to C was through B, which is of course a requirement for such an analysis to make sense.

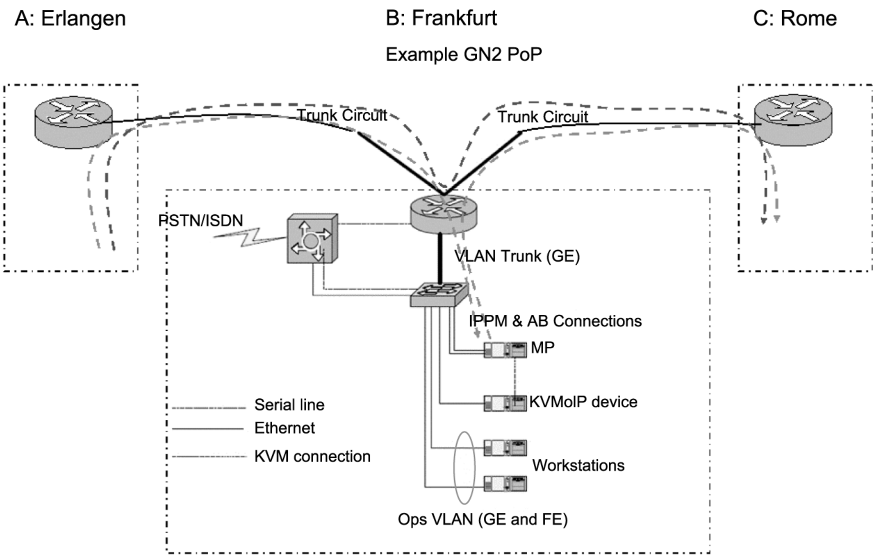


Figure 3.
OWD measurement setup

While there are clearly cases where the OWD from A to B and from B to C might exhibit dependence, we assert that these cases do not reduce the usefulness of our approach, and this is what we tested.

Each IPPM measurement box transmitted 15 packets per second. We observed that the OWD distributions (of both AB, and BC and AC) are very concentrated around a typical value for each path. As shown in Figure 4, most of the singleton delays are around a typical value (5.6 ms for AB, 9.3 ms for BC, 14.9 ms for AC), as "represented" by the thick line at the bottom of the graphs. However, higher values occurred quite regularly, throughout the 24 h measuring period. These high values represent a small fraction of the total collected values, but they are exactly what needs to be kept under control to ensure the proper functioning of the network.

In Figure 5, we use a *Quantile-Quantile* (QQ) plot to assess the difference among the convolution of distributions AB and BC with the "real" distribution of AC. If the convolution AB⊗BC was exactly like the distribution of AC, all the points would appear on the diagonal.We used the following range of quantile values: 0.1, 0.2, ..., 0.9, 0.91, 0.92, ..., 0.99, 0.991, 0.992, ...0,999.

The left graph in Figure 5 is the QQ plot we obtained. We see the points are well aligned with unitary slope, but with an offset from the diagonal. This is not surprising, considering the measurement setup of Figure 3. OWD tests from A to B must reach the intermediate point in B to get timestamped. That is, they must exit the router on an (unloaded) Gbit Ethernet interface, cross an (unloaded) switch and get timestamped by the MP's CPU. This takes time. Analogously, packets from B to C undergo a similar process in the opposite direction, before reaching the router in B.

In this case, since we have also the direct A to C measurement, it is easy to estimate this offset value: the formula $<OWD_{AC}> = <OWD_{AB}> + <OWD_{BC}>$ must always hold true if $OWD_{AC} = OWD_{AB} + OWD_{BC}$. If it does not, it is due to the fact that in reality $OWD_{AC} = OWD_{AB} + OWD_{BC} - \delta$, where δ accounts for the fact that OWD_{AB}

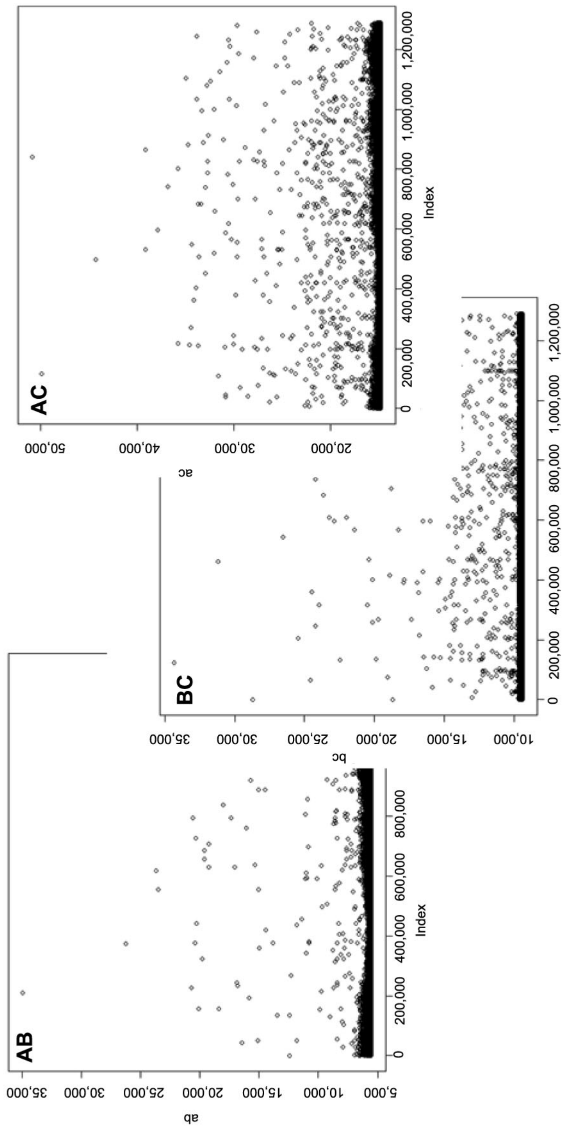


Figure 4.
Snapshot OWD measurement along the paths "Erlangen (A) to Rome (B) via Frankfurt (C)" – 1,296,000 tests packets of 41 bytes each sent at 15 pkt/s rate, for 24 hours – delay values are in μs

and OWD_{BC} measurements are not obtained by timestamping in the router B the packets travelling from A to C, but with separate measurements packets that must reach (or originate from) a MP connected to router B. We calculated a $\delta = 0.109$ ms. We expect this value to depend only from the MP hardware and from the way it is connected to the router. We then proved that applying this correction[3] to the raw data the QQ plot well aligns onto the diagonal (right graph of Figure 5), also for high quantiles. This proves the usefulness of the convolution approach to estimate high quantiles of an OWD distribution without direct measurements.

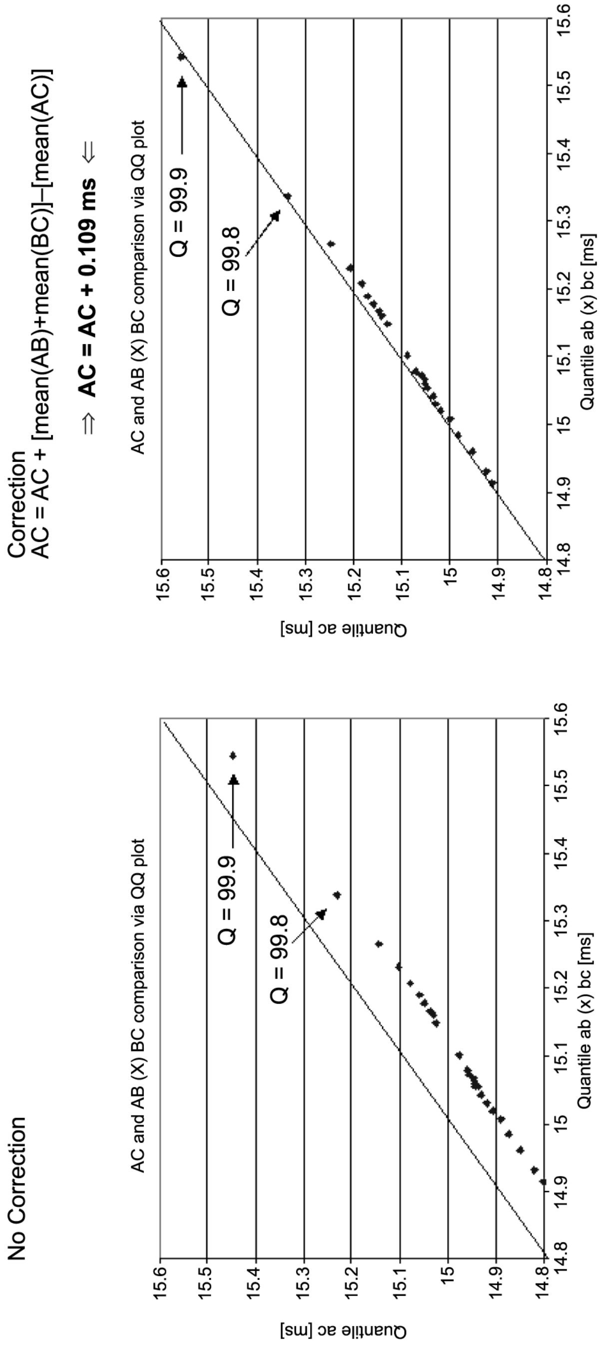


Figure 5.
Comparison of the OWD quantiles of a direct measure from A to C and of the quantiles of the convolution of AB(x)BC

The presented results are preliminary, but to our knowledge a no similar validation test for the convolution approach has been performed to date.

Further analysis is needed to confirm the obtained results. In particular, although we did not formally test the temporal independency of OWD_{AB} and OWD_{BC} data points, the fact that the convolution approach gives a QQ plot aligned on the diagonal is a strong indication that the delays on AB and BC are indeed independent. Actually, if in further tests in other networks or with other network loads we observed significant drifts from the diagonal, this would indicate that the independency hypothesis does not hold true in these other scenarios.

6. Related work

In the standardisation arena, both the ITU-T and the IETF produced several recommendations (respectively, RFCs) about performance metrics for IP networks. The more relevant ITU-T recommendations are Y.1540 (ITU-T rec. Y.1540, 2002), defining the performance metrics, and Y.1541 (ITU-T rec. Y.1541, 2002), defining six different classes of service, and specifying the performance bounds for network delays, losses and errors that define these classes. The IETF IPPM WG published several RFCs about performance metrics for IP networks as well (RFCs of the IETF IPPM Working Group, available at: www.ietf.org/html.charters/ippm-charter.html), but without defining any service classes on the basis of their values. The IETF also specifies in RFC 3763 (Shalunov and Teitelbaum, 2004) requirements for a One-Way Active Measurement Protocol (OWAMP), similar to the IPPM protocol (IPPM Measurement tool, available at: www-win.rrze.uni-erlangen.de/ippm/messprogramm.html) used in this work.

The issue of metric composition has been addressed by the ITU-T in an amendment to Y.1541 (Y.1541, 2002), limited to the case of concatenation in space of losses, errors and delays. In a forthcoming revision, (Morton *et al.*, 2006) some approximate formulas (not based on the full convolution) to compose OWD quantiles are proposed, but these formulas are based on a modelling approach, without the support of real data observations.

In the IETF, no significant work in the metric composition has been performed yet, but recently the group decided to undertake this activity, and draft documents for time and space composition are planned for the end of 2006 in the IPPM Working Group (RFCs of the IETF IPPM Working Group, available at: www.ietf.org/html.charters/ippm-charter.html). A Framework document (Morton and Van den Berghe, 2006) has already been published, containing some of the concepts developed by JRA1 in (DJ1.2.3, 2006).

More information about the measurement of basic metrics in perfSONAR and related projects can be found in (Hanemann *et al.*, 2005). For the composition of metrics, a related project is conducted at the University of Waterloo (http://bcr2.uwaterloo.ca/group/broadband_and_ip_metrics.htm). Here, the aim is not only to compare a variety of metrics including the network-related metrics we are dealing with, but also to link them with business-related metrics with respect to SLAs. However, no publications related to this project were found.

7. Conclusion and future work

The JRA1 (GÉANT2 Joint Research Activity 1 (GN2-JRA1): performance measurements and monitoring, www.geant2.net/server/show/nav.754) in the GÉANT2 project, in cooperation with Internet2 (E2E piPEs: end-to-end performance improvement performance environment system http://e2epi.internet2.edu/e2epipes/) and ESnet (www.es.net/), developed perfSONAR (performance focused service oriented network monitoring architecture, www.perfsonar.net), a service-oriented monitoring architecture for retrieving, storing, processing and presenting network performance metric measurement data in a multi-domain network environment. The first development phase for a perfSONAR prototype has been completed and a few demonstration services are already available for testing. In this paper, we presented some results of a study for harmonising the choice of network performance metrics in a multi-domain environment, and for defining common procedures for metric post-processing (or composition). In particular, we classified the possible compositions into three main categories: aggregation in time, aggregation in space and concatenation in space, and explained the utility and challenges associated with each of them. For concatenation in space, we also presented the analysis of some OWD data we collected, the analysis being finalised to validate a procedure for getting a picture of the performances on an end-to-end path given the availability of performance measurements only on disjointed sections of the path. This operation has an important practical utility, since in a large network it is impractical to set up dedicated measurements among all the possible end points of interest.

Future work will extend this experimental validation of concatenation in space using further data sets, possibly in different networks and with different network loads. JRA1 also plans to apply similar analysis methodology with different performance metrics, such as IPDV. Moreover, JRA1 wishes to perform a study of the error propagation when different metric composition strategies are applied and to verify results on GEANT2 and NRENs production networks.

Notes

1. Measurement points are typically located "close" to the host/router (e.g. connected through a high speed LAN switch) so that the time the measurement packet is received and timestamped by the host is a good approximation of the time it transits through a host's interface.
2. A q-quantile of a random variable X is any value x such that $Pr(X \leq x) = q$. While quantiles can take whatever value (e.g. 0.999) percentiles are specializations of quantiles constrained to take values with only two significant decimal digits, (e.g. 0.90, or 0.95). The terminology percentile exists for historical reasons.
3. This can be done by subtracting δ to each OWD_{AC} sample, or by adding $\delta/2$ to each OWD_{AB} and OWD_{BC} sample.

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About the authors

Andreas Hanemann received a diploma (MSc) in Computer Science from the University of Karlsruhe (TH), Germany. He has been involved in the JRA1 performance visualisation starting from the project launch in 2004. Since October 2002 he has been responsible for the Customer Network Management project at the Leibniz Supercomputing Centre, which provides a network performance visualisation tool for the German Research Network. E-mail: hanemann@dfn.de

Athanassios Liakopoulos received a Dipl.-Ing. degree in Electrical and Computer Engineering from the National Technical University of Athens (NTUA) in 1996, an MSc with Distinction in Telematics from the Electrical Engineering Department of the University of Surrey (UniS) in 1998 and a PhD in Electrical and Computer Engineering from the National Technical University of Athens (NTUA) in 2005. In 2000, he joined the GRNET S.A. and participated in national and European research projects, such as SEQUIN, 6NET, SEEREN, GN2. He was awarded for his performance during his academic studies and has published articles in recognised technical journals. E-mail: aliako@grnet.gr

Maurizio Molina graduated in Electronic Engineering (Italian Laurea) from the Polytechnic of Turin in 1993. Since then, he has worked in the telecommunications industry, including Telecom Italia Labs (Turin, Italy) and the NEC Network Laboratories (Heidelberg, Germany). He has published several papers about IP and ATM traffic modelling and network measurements. He has contributed to IETF, ITU-T and 3GPP standards. He joined DANTE's Systems group in November 2004, working on performance monitoring, security and authentication. Maurizio Molina is the corresponding author and he can be contacted at: Maurizio.molina@dante.org.uk

D. Martin Swany is an Assistant Professor in the Department of Computer and Information Sciences at the University of Delaware. He completed his PhD at the University of California, Santa Barbara in 2003. He is a 2004 recipient of the US Department of Energy Early Career Principal Investigator award and a 2005 Internet2 Faculty Fellow. His research interests include high-performance networking and distributed computing. E-mail: swany@cis.udel.edu