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Internet Protocol Packet Delay Variation measurements in communication networks: How to evaluate measurement uncertainty?

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A B S T R A C T

Measurement of Quality of Service (QoS) parameters is a relevant task in communication networks. Similarly to other contexts, the measurement result has to be completed with the related uncertainty in order to provide information about the significance and reliability of the overall measurement process. This aspect is particularly crucial in communication networks. In fact, the measured values of QoS parameters have often to be compared against suitable thresholds to check their compliance with required quality constraints (QoS levels delivered to the user are generally offered for a fee) or to reliably verify the effect of new services conveyed by the network on its performance.

Nevertheless, uncertainty estimation in QoS parameters measurement is still an open issue. Most literature concerning communication and computer networks test and measurement clearly evidences the lack of the advisable practice of uncertainty evaluation in QoS parameters measurement according to the guide for the expression of uncertainty in measurements (GUM).

In addition, it is worth emphasizing that uncertainty modeling and evaluation in QoS parameters measurement are not trivial tasks because several aspects are involved in a QoS measurement process. All these aspects can be thought of as sources of measurement uncertainty, capable of significantly influencing the reliability of measurement results.

The paper investigates these issues by promoting and assessing the applicability of GUM to the specific and critical context of communication and computer networks test and measurement. More specifically, a simple model for uncertainty evaluation in Internet Protocol Packet Delay Variation measurement is proposed: a fundamental QoS parameter in Voice over IP and real time video streaming applications. The model is based on two main contributions: the former accounting for the instrumental measurement uncertainty and the latter for the measurand variability.

A number of tests in a simulated scenario proves the effectiveness of the proposed model. To exemplify its practical application, some experiments in a real test-bed, i.e. the local area network of the University of Cassino and Southern Lazio, are finally conducted.

1. Introduction

During the last years, our lives and working activities have been increasingly influenced by communication and computer networks. Many scientific, manufacturing, social

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and financial applications are now implemented in modern networks. To warrant the expected quality of services to the end user, suitable management and monitoring policies have to be adopted to minimize the downtime and inefficiency costs, particularly when performance critical applications, such as real-time services, are involved [1]. In this framework the reliable measurement of Quality of Service (QoS) parameters becomes a fundamental issue to be effectiveness accomplished. Typically, this measurement activity requires the evaluation of several indexes as: throughput, available bandwidth, Internet Protocol Packet Delay Variation (also known as packet jitter), one way delay, round trip delay, and packet loss [2–4].

A reliable evaluation of such quantities is fundamental for network managers to fine–tune, to troubleshoot the network and to maintain its efficiency [5–7]. As an example, the analysis of these indexes allows: (i) optimizing the algorithm of flow control and routing, (ii) developing strategies and algorithms for the detection of unwanted traffic and intrusion, and undesired behaviors, (iii) evaluating the network capability in supporting new value added services, (iv) evaluating the quality delivered to the user for applying the corresponding proper rating [8,9].

On the other hand, the estimation of the above-mentioned QoS parameters is a complex task for several reasons as reported in [10,11]. Some of them depends on the interaction of a number of parameters related to the measurement network. Others come from the measurement chain and the method employed. A detailed description of these aspects is reported in Section 3.

Consequently, also the modeling and the estimation of the measurement uncertainty to be associated to QoS parameters measurements are not trivial tasks. Most literature concerning communication and computer networks test and measurement clearly evidences the lack of the advisable practice of uncertainty evaluation in QoS parameters measurement according to the guide for the expression of uncertainty in measurements (GUM) [12,13]. More specifically, measured values of QoS parameters are never associated with an interval having a stated coverage probability which is needed to assess the measurement uncertainty according to standards in force [12,14].

Among the QoS parameters, the Internet Protocol Packet Delay Variation (hereinafter *IPDV*) plays a very important role in multimedia applications. The performance of many real-time services is strictly influenced by this parameter, especially when a service runs on a complex multi-hop networks where, generally, the data path involves several apparatuses (switches, routers, and so on), protocols and communication medium. Usually these services run on networks that could convey other services. As a consequence the attention of the network manager is often paid to verify if new services can decay the overall QoS. As an example, with reference to the voice over IP or video streaming services, a constant packet rate should be assured to provide an adequate QoS. The presence of additional data traffic and/or technological limits of the involved active devices, could influence the packet arrival times at the receiver, with an unacceptable performance deterioration of QoS [15,16].

As for the *IPDV* estimation, even though the standard *RFC 3393* [17] reports the metric to be adopted, and the standard *RFC 5481* [18] suggests some important information about the measurement procedure, however, these suggestions allows some degrees of freedom to the test engineer such as the sampling time, statistics to be considered and so on. Consequently, the interpretation of the measurement results may be very critical, thus making even more ambiguous the evaluation of the QoS at the end user. These aspects have been clearly highlighted by the deep sensitivity analysis reported in [19].

In this scenario, stemming from previous experiences in the field [20–24], aims of this paper are to investigate the applicability of GUM to this context and to propose a method for uncertainty evaluation in Internet Protocol Packet Delay Variation measurements. In particular, according to the GUM approach [12], the overall uncertainty has been modeled as the sum of two main components: the first one, referred to as instrumental measurement uncertainty, generally evaluated through a "type B" approach. The second component is due to the measurement repeatability, generally evaluated through a "type A" approach. A number of experiments, conducted in simulation environment has proven the goodness of the proposed approach, its practical application has been shown by considering a real test bed i.e. the local area network of the University of Cassino and Southern Lazio.

2. Fundamentals of IPDV measurement

IPDV measurement are generally performed through instruments called "protocol analyzers".

Typically, a protocol analyzer involves a network traffic generator and one or more nodes displaced at the measurement points of interest [24]. The traffic generator provides a well-defined data stream on the network under test, which is collected and analyzed by the measurement nodes in order to evaluate the *IPDV* [10,23].

The reference traffic generator contains suitable hardware and software sections which, depending on the specific application, are generally capable of generating known data traffic with different protocols and settings. The test engineer can define some quantities such as packet size, number of packets, packet rate, inter–departure time distribution between transmitted packets, to cite a few.

Measurement nodes also include suitable hardware and software sections dedicated to acquisition and processing, respectively, which, in sequence, gather, analyze and process the incoming frames for QoS parameters evaluation. In particular, the acquisition hardware consists of a network interface card. The protocol decode stage identifies the component fields of the frames, while the protocol statistics stage gives statistical information about the captured data. In addition, the parameters of interest can be evaluated by selecting proper measurement settings, such as the length of the observation record. Finally, given the high amount of data, the sequence of values provided by the measurement node are often furtherly post processed to obtain more concise and manageable information. This