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A knowledge and collaboration-based CBR process to improve network performance-related support activities

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ABSTRACT

In a context characterized by a growing demand for networked services, users of advanced applications sometimes face network performance troubles that may actually prevent them from completing their tasks. Therefore, providing assistance for user communities that have difficulties using the network has been identified as one of the major issues of performance-related support activities. Despite the advances network management has made over the last years, there is a lack of guidance services to provide users with information that goes beyond merely presenting network properties. In this light, the research community has been highlighting the importance of User-Perceived Quality (UPQ) scores during the evaluation of network services for network applications, such as Quality of Experience (QoE) and Mean Opinion Score (MOS). However, despite their potential to assist end-users to deal with network performance troubles, only few types of network applications have well established UPQ scores. Besides that, they are defined through experiments essentially conducted in laboratory, rather than actual usage. This paper thus presents a knowledge and Collaboration-based Network Users' Support (CNUS) Case-Based Reasoning (CBR) Process that predicts UPQ scores to assist users by focusing on the collaboration among them through the sharing of their experiences in using network applications. It builds (i) a knowledge base that includes not only information about network performance problems, but also applications' characteristics, (ii) a case base that contains users' opinions, and (iii) a user database that stores users' profiles. By processing them, CNUS benefits users through the indication of the degree of satisfaction they may achieve based on the general opinion from members of their communities in similar contexts. In order to evaluate the suitability of CNUS, a CBR system was built and validated through an experimental study conducted in laboratory with a multi-agent system that simulated scenarios where users request for assistance. The simulation was supported by an ontology of network services and applications and reputation scheme implemented through the PageRank algorithm. The results of the study pointed to the effectiveness of CNUS, and its resilience to users' collusive and incoherent behaviors. Besides that, they showed the influence of the knowledge about network characteristics, users' profiles and application features on computer-based support activities.

1. Introduction

A growing number of tools have been used by network support staff as a mean of providing assistance for user communities that have difficulties using network applications (Johnston et al., 2008). Despite the fact that such trend has been identified as one of the major issues of performance-related support activities, support systems still lack a sufficient set of features to fulfill the requirements of the current demand for assistance due to some reason.

Firstly, monitoring infrastructures have not been designed and developed considering the profiles of the general public interested in network performance data. Commonly, they present network information only suitable for network specialists. User's expertise level in dealing with performance data influences mostly the amount of effort network support staff should dedicate to them (Crovella & Krishnamurthy, 2006). By disregarding user-related technical and social factors, monitoring solutions frequently provide traffic performance information in a generic manner (Binczewski, Lawenda, Lapacz, & Trocha, 2009; Brauner et al., 2009; Hanemann et al., 2006; Jeliazkova, Iliev, & Jeliazkov, 2006;

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Sampaio et al., 2007). They rely on the assumption that users have enough knowledge to interpret the performance information provided by the visualization tools. Due to the fact that the interest on Internet applications has increased immensely over the years, where users have shifted from computer savvy people only to a more general audience who comes from diverse knowledge areas, this assumption is no longer true.

Secondly, the operation and management of wide area networks currently faces many scalability problems. Network support has become a very relevant activity and users have relied on their staff to get guidance about the best use of the available network resources. In general, the support staff consists of network experts that evaluate, almost manually, each problem situation, based on their expertise and previous knowledge about the applications' requirements. These approaches do not scale well since they mainly rely on human skills to act in environments that are continuously growing and changing their contexts. For these reasons, such scalability challenges led support staffs to include groups made up of specialists with strong network and application background knowledge to assist the users. Since the support activity is mostly carried out in complex environments, involving ever-emerging new (and more complex) applications, users' communities, and their respective network performance requirements, the development of computer-based guidance tools has become imperative. This explains why some of the current solutions rely on a knowledge base regarding network performance-related issues that is maintained by both application and network experts. However, the problem resides in the fact that systems capable of processing support-related knowledge to assist users in using their applications are still scarce.

Thirdly, the existing computer-based support solutions do not consider users' feedback. It is a consensus of the research community that the quality perceived by end users is not just a technical issue at network level (Hassan, Das, Hassan, Bisdikian, & Soldani, 2010). It also involves user's perception, expectations and experience, thereby requiring non-technical parameters almost never treated by quality of service (QoS) research. Therefore, discussions within the networking community have evolved to find new methods and approaches to measure the quality perceived by users.

The Mean Opinion Score (MOS) (ITU-T, 2008a) is an example of such initiative. The MOS values are defined from subjective ratings by real users or predicted from objective measurements of applications' properties. Measurement tools are then employed to gather network measures that are used to infer the corresponding MOS. In another line of research, the Quality of Experience (QoE) (Hassan et al., 2010; Jain, 2004) concept has been introduced in computer networking research as a mean of measuring the quality from the users' perspective. As a result, this concept has gained attention from the scientific community as can be demonstrated by a network magazine special issue on the improvement of Quality of Experience for network services (Hassan et al., 2010). Finally, concerns related to users' satisfaction have also been demonstrated by the International Telecommunication Union (ITU) (ITU-T, 2008b). They have recommended, in a user-centric view, subjective evaluation methods (ITU-T, 1998, 2001, 2009) to assess the perceptual quality provided by Internet services.

User-Perceived Quality (UPQ) scores, such as MOS and QoE, are interesting resources for networking support activities. By classifying the network quality into few general types, they simplify the information regarding the network performance. Consequently, end-users and non-specialist network operators refrain from the burden of understanding technical network performance characteristics. As a matter of fact, such simplified information is more convenient for a non-specialist network user to take decisions related to the use of the network. It leads users to focus on performing their end-activities, instead of interpreting performance details of the network they intend to use. In support situations involving this kind of users, too much technical information can even harm their understanding of the support system's responses. Due to these reasons, MOS and QoE scores arise as key components for assisting end-users on the use of their applications. They consist in high-level information that indicate the appropriateness of the network performance in a given context. That is, User-Perceived Quality scores simplify users' guidance by pointing out what they can expect by using their application on the current network conditions.

Despite their potential to assist end-users to deal with network performance troubles, only few types of network applications have well established User-Perceived Quality scores. Perhaps, one reason for such absence resides in the fact that existing approaches define them through experiments essentially conducted in laboratory, rather than actual usage. Considering the rapid change of Internet applications' requirements and the dynamics of their contexts, such approaches are expensive and fairly limited. Indeed, they face practical problems.

In light of the above, this work looks for ways of furnishing network support infrastructures with User-Perceived Quality scores of network applications in timely fashion and based on the collaboration among users from a given community. Hence, it tries to address the following research question: *is it possible to conceive a process in which the domain knowledge and collaboration among users are explored to find User-Perceived Quality scores of network applications in order to improve the assistance of users in respect to their use of the network?* Accordingly, it has set out to find ways of better assisting network managers and operators in performing users' support activities, by considering users' opinions, applications' characteristics, and network performance conditions.

This paper then introduces a knowledge and Collaboration-based Network Users' Support (CNUS) CBR Process that, based on past experiences, predicts User-Perceived Quality (UPQ) by classifying them into five scores. The process is knowledge-based since it provides content-based recommendations according to the description of cases and also uses a domain ontology of network applications to better describe a case. Besides that, CNUS is collaboration-based because it considers the opinions of users weighted by their reputations. In respect to its users, the benefits of CNUS are twofold: to end-users that try to obtain more information about a network link due to an experienced performance trouble and to non-specialist network operators that look for a better understanding of users' characteristics. As discussed in further sections, end-users are benefitted by indications of the degree of satisfaction they may have based on the general opinion from members of their community in similar contexts. The non-specialist network operators in turn can have valuable information from the system's databases to define a more detailed profile of the users they support.

This research evaluates CNUS process through the combination of two approaches. First of all, we make a proof of concept through an empirical evaluation of Mentor Advisory tool (Carlomagno, Dourado, Sampaio, Monteiro, & Cunha, 2009). Mentor has been implemented according to the guidance approach for supporting network users introduced in Sampaio (2011). Besides that, it has CNUS's CBR modules, which are used to predict QoE. Since Mentor is a web application, which would require a great number of real users to be evaluated, CNUS's suitability is evaluated through a multi-agent system that simulates diverse users' assistance scenarios.

The remainder of this article is organized as follows: Section 2 presents the related works; Section 3 presents the CNUS process in detail; Section 4 presents a preliminary investigation that shows how the CBR process can be used; Section 5 presents the experimental studies carried out in laboratory to assess the feasibility