Towards Quality of Service-Awareness of Mobile Healthcare Services[1]

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Abstract. Inevitably healthcare goes mobile – providing m-health applications to users anywhere-anytime, and relying their delivery on the best-effort Quality of Service (QoS) of the underlying wireless networks. We examine a technical and business viability of QoS-information system (QoSIS), which, based on Mobile Web 2.0 paradigm, predicts the QoS provided by networks available in a given m-health user location-time thus enabling this user an informed network choice.

1 Introduction

The effective use of any mobile healthcare i.e. m-health application like tele-monitoring or tele-treatment, strongly depends on the Quality of Service (QoS) provided by the wireless networks it uses. However, this QoS is often unknown. Public or private wireless network providers, for example Mobile Network Operators (MNOs), do not disclose any 'real-world' QoS information. For marketing purposes, they advertise only the best networks nominal data-rate values. Besides, according to the 4G vision, in a near future various networks provided by different MNOs over wireless technologies like 2.5/3/3.5G or WiFi/WiMAX, will be ubiquitously available for m-health users. Also, a seamless handover between these networks will support the users' mobility [1]. In the ideal scenario, these users have a priori knowledge on the QoS provided by different networks, based on which they can make an informed choice of which network they want to use for their applications [2].

Towards this end, we propose *QoS-Information System* (QoSIS), which, based on Mobile Web 2.0 paradigm, distributes to m-health users predictions about the QoS provided by different networks in a given location-time [3]. The predictions are used to choose the network provider and technology and to adapt application to the network's provided QoS, thus enabling an improvement of the user experience, and decreasing a probability of endangering of the m-health application user's life.

2 QoS-Information System Architecture

QoSIS (Fig. 1) is a system that collects from m-health users the (anonymized) QoS data about the QoS provided by networks. The collected historical data is stored and processed in databases, with the principal dimensions: location, time,

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wireless network provider and technology used. The QoSIS uses a QoS-prediction engine, which, based on data-mining techniques, builds a heuristic to derive QoS predictions from historical data.

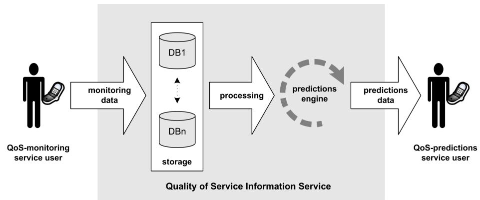

Figure 1**:** QoSIS high-level system architecture

QoSIS distributes the derived QoS predictions back to m-health users. These predictions are location-time specific predictions of the QoS achieved by a user of m-health application, when a given provider (e.g. Orange) and technology (e.g. 3G) is used. Along the Mobile Web 2.0 paradigm, the m-health users are data producers-consumers, i.e., “prosumers” [4].

3 QoS-predictions Service Case Study

We assess a technical feasibility of QoS predictions engine in a case study based on a mobile health telemonitoring application provided by the MobiHealth system [5, 6]. A QoS measure of importance is an application-level delay, i.e. a delay at which vital signs data being acquired from a mobile patient are available in his healthcare center. We collected historical data from a Chronic Obstructive Pulmonary Disease patient living in Geneva city, using his application acquiring his pulse rate, oxygen saturation, plethysmogram and alarm button activity continuously (freq. of 128 Hz), in different locations-times along consecutive days of his daily activities in December 2007. The overall application data rate sent was ~1.2-1.5 kbps. The patient used Sunrise-GPRS and UniGe-WiFi networks. The application-level delay has been categorized in five classes: <0, 750), <750, 1500), <1500, 2250), <2250, 3000), <3000,∞) The simplest delay prediction method is an ‘educated guess’; predicting delay’s median class, i.e. class 4, with an accuracy of 51.88%. We aim to predict delay for the eighth day of the m-health application usage based on seven days of historical data. Table I presents speed, accuracy and complexity of the predictions.

Technique/Algorithm [7]	speed (s)	Acc (%)	Model complexity
Hybrid: classification via regression, using M5P trees	414	55.95	5 trees, avg. 100 branches/tree, 3-46 functions/tree leafs
Trees: J48	1.26	55.47	485 branches, 319 leafs
Lazy: kStar	0.03	55.39	
Rules: PART	13.21	55.31	302 rules
Bayes: Bayesian Network	0.31	54.87	6 nodes, 5 relations
Funct.: Multilayer Perceptron	2445	54.28	1 hidden layer
Function: SMO	953	53.10	

Table 1. M-health application data delay predictions: speed, accuracy and model complexity

None of the techniques achieved accuracy significantly higher than the 'educated guess'. That may mean that our data is too random or that we lack some important predictive variable in our historical data.

For the given set of techniques, there is a trade-off between predictions speed and accuracy and model complexity. The most accurate is a hybrid model containing trees and linear functions in tree leafs; however it is slow and complex and therefore can have a tendency to over-fit future prediction cases. J48 tree is simpler, faster and having a less complex model.

Lazy algorithms do not build any model on the data, but search a space of historical data to find the cases similar to ones, the predictions is made for. Bayesian Network derives basic probability relationships between delay and all other variables (location, time, etc.). Non-linear functions (Multilayer Perceptron NN, SMO) take long time for building (complex) models, yet they do not exhibit an advantage in predictions accuracy.

4 QoSIS.net Business Viability

QoSIS.net is a company based on QoSIS. We assess its business feasibility along the MCM-business model framework [8]. The healthcare domain puts specific requirements on QoSIS.net related to the criticality of the m-health applications used by patients, yet we show that QoSIS.net can be also operational in other applications domains, e.g. entertainment [9].

The main QoSIS.net *product* is a QoS-prediction service - a *mobile service*, which delivery relies on wireless networks. QoSIS.net *customers* are m-health application providers (like MobiHealth BV [6] in a B2B segment) and their users. There are *costs* incurred for QoSIS.net: a) for services setup and maintenance and b) marketing costs for new customers' acquisition. Costs incurred for the QoSIS.net customers' relate to a) an ownership of mobile device with location-determination e.g. GPS module and b) the QoS-prediction service usage, i.e., data communication, storage and processing 'costs'. The *revenues* for QoSIS.net relate to the QoS-prediction service usage; customers pay monthly or per a prediction fee. A *competition* amongst QoSIS.net customers requires it to be a trustworthy enterprise. As privacy sensitive location-time information is acquired from m-health users by QoSIS.net, the users need to sign an informed consent.

5 Conclusive Remarks

In this paper we examine a technical and business viability of QoSIS, predicting the QoS provided by networks available in a given m-health user location-time thus enabling this user an informed choice of the network to be used. The predictions are possible to be derived; yet, there is a trade-off between models complexity and predictions speed and accuracy. At the moment we conduct analysis for other historical data (e.g. two, three weeks) and other predictions methods. The QoSIS business feasibility shows that using the QoS-predictions service is beneficial in terms of revenues increase for QoSIS.net and m-health application providers, and in terms of mobile users experience improvement. QoSIS.net critical success factor relates to an attraction of minimal number of customers, providing historical data as a base for deriving of accurate predictions. Our solution reaches beyond the current QoS-frameworks based on network-resources reservation and user's "locking-in" into network mechanisms. The novelty is that we employ Mobile Web 2.0 paradigm; m-health applications users are data producers-consumers. QoSIS.net empowers them to choose the network to use, yet, it does not require any change in the existing network infrastructures.

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