A Generalized Framework for Quality of Experience (QoE)-based Provisioning in a Vehicular Cloud

Moayad Aloqaily, Burak Kantarci[¥], and Hussein T. Mouftah

School of Electrical Engineering and Computer Science, University of Ottawa,
Ottawa, ON, Canada

[¥]Department of Electrical and Computer Engineering, Clarkson University
Potsdam, NY, USA

maloqaily@uottawa.ca, bkantarc@clarkson.edu, mouftah@uottawa.ca

***Abstract* — Recently, Vehicular Cloud Computing (VCC) are promising to convey relatively more communication, on-demand and based on pay-as-you-go fashion. Such environment concept's is being widely adopted, which is resulting in several research issues and challenges. Privacy, service cost and provisioning delay are identified as the most crucial challenges to be addressed. This paper extends our previous work [10] and builds a generalized of quality-of-experience (QoE) design. QoE requirements are collected via numerous vehicular nodes in the vehicular cloud and re-formulated by a weighted combination of these factors, i.e., delay, price and information revealed to the Trusted Third Party (TTP). Extensive simulations are run in order to evaluate the performance of our proposed framework. Through simulations, we show that QoE-based service provisioning in a vehicular cloud fulfils the service requirements by making a compromise between delay, service cost and information revealed to the TTP.**

***Keywords* — Cloud computing, mobile cloud computing, quality of experience, privacy, vehicular cloud computing.**

I. INTRODUCTION

The numbers of vehicles in the modern transportation systems are in rapid growth, causing severe problems and challenges. Such growth has made driving sometimes unsafe and harmful. To this end, researchers start investigating new systems to avoid such problems and safe lives. The use of the modern technology found upon the only solution for such problems. Intelligent Transportation Systems (ITS) have been widely adopted to enable set of traffic management, such traffic monitoring, diverse traffic applications, and control of traffic flow [1].

Vehicular networks have been an expanding research and development area as several standards have been set to enable inter-vehicle communications [2, 3]. Recently, vehicular cloud computing has been proposed as a promising solution to consolidate the benefits of mobile cloud computing and vehicular networking [3]. Users subscribed to the cloud can use the infrastructure (IaaS), platform (PaaS) and software services (SaaS) in a flexible and an efficient manner.

VCC inherits the benefits of cloud computing and vehicular communications. Vehicle drivers can join mobile cloud and buy services via mobile devices or in-vehicle computers from anywhere to process any type of request on demand at any time [4].

VCC is an ongoing and promising solution; however, still several challenges need to be addressed. One of the most crucial issues when we handle vehicular cloud is the lack of control over the data which is stored and/or processed on virtual resources [5]. These concerns lead to security and privacy challenges in cloud systems. In a vehicular cloud system, establishing secure relationships between drivers/SPs is a vital part of trustworthy communication [6]. Providing security and privacy in a vehicular cloud is having several difficulties than it is in other networks; first, mobility issue, which leads to frequent topology changes in the computing network; second, the dynamicity of the environment; and last, the variety of computing capabilities of the vehicles [7].

Service delay and service provisioning cost are further of serious concerns for the drivers. The aforementioned service parameters can be affected of each other when provisioning, in most cases, users are more concerned with one or more of these factors [8].

In this paper, we are extending and generalizing our QoE-based framework [10] to provide provisioning services at fair cost, using more privacy, and with less delay. To this end, we collect the information of the newly joining users, as well as the experience of the users who have already been served by the vehicular cloud. Through these values, we define QoE value for each Service Provider/Trusted Third Party (SP/TTP) tuple. A negotiation server matches the user request with the SP/TTP tuple that would offer the best service based on the user requirements and the QoE values assigned to each tuple.

The paper is organized as follows. The related work is presented in Section II. Section III covers the proposed system architecture along with the software architecture. Numerical results are presented and discussed in Section IV. Finally, we conclude the paper and give future directions in Section V.

II. RELATED WORK

As we declared earlier, VCC system has many open issues that need to be carefully study. Most importantly, privacy, pricing, and service delay.

The authors in [9] and [10] present the existing challenges for security and privacy in the cloud in a comprehensive manner. However, these studies can be improved by taking the special requirements of vehicular clouds into consideration.

There are a well number of studies in the literature handle the VANET security and privacy. For example, Yan et al. [11] and [12] proposed active/passive location security algorithms. Its algorithm found to detect the location of vehicles.

In [13], the authors have focused on identifying the risk around vehicular clouds, and a framework for vehicular cloud computing has been introduced.

The studies in [14] propose a pseudonym system using anonymous public keys and the public key infrastructure (PKI). The public key certification is frequently updated, which in turn may potentially lead to communications overhead.

To the best of our knowledge, the provisioning delay and pricing challenges in VCC are new and still unexplored issue. Connected vehicles will be freely shared to provide services. Real-time services, such as, ITS, smart grids, power electric will be available in the pay-as-you-go fashion. Internet access and storage will be available as well. To this end, drivers may have serious concerns about service pricing and service delay, the literature does not offer any genuine solution for available service-price matching. A pricing algorithm for resources allocation in cloud computing environment has been proposed by the authors in [15] where the main goal is to maximize the social welfare and characterize its optimal solution by maximizing the social utility through a simple pricing scheme. This study can be tailored to vehicular clouds and be improved by considering future changes in pricing and the presence of multiple providers.

III. PROPOSED ARCHITECTURE

This paper is adopting its solution based on the idea of having a Trusted Third Party (TTP) between the vehicle drivers and the service providers. Having said that our QoE-based service provisioning in a vehicular cloud improves naïve service provisioning approach; the framework can still be generalized to incorporate the presence of multiple Service Providers (SPs) and improve the negotiation server by addressing latency needs, as well.

A. QoE-based software architecture

The QoE-based software architecture (i.e. Figure 1) has three main entities as follows: 1) Vehicular drivers', 2) TTPs, and 3) SPs.

The left entity is basically related to *vehicle drivers* who are connected to the grid. A web browser with high-speed Internet connectivity is required to have more stable service provisioning. The driver may also have a mobile application on his/her smart phone which enables him/her to access the network and browse through all available TTPs and their available services.

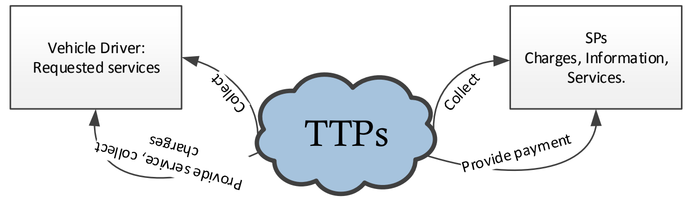

Figure 1: QoE-based software architecture

The main core of this software is the middle entity, *TTPs*, which resides between the *vehicular driver* and *SPs*. This entity plays the role of the mediator contractor for the *vehicle drivers.* Each *TTP* is mainly responsible for the communications with the *SPs* and providing the requested services to the *vehicular driver.* The computation process here is to compute the QoE weighted metrics for each driver and SP right after each delivered service. This entity is working as the brain of our architecture, the communications and the computation decoupled enables more generalized design. The SPs software entity part is not in the scope of this study.

B. QoE-based system procedure

QoE is expressed as a weighted function of three main parameters, delay, price and privacy as shown in Eq. 1. In the equation *D, P* and *I* stand for the delay, price and privacy to the provider, respectively. The sum of the coefficients in the equation is equal to one as shown in Eq. 2 [10].

$$QoE = \alpha.D + \beta.P + \gamma.I \quad (1), \quad \alpha + \beta + \gamma = 1 \quad (2)$$

The benefit of our QoE-based architecture is that the vehicle driver can prioritize his/her preferences on latency, price and privacy to the service provider. The coefficients of the QoE function can be adjusted so the driver have the advantage of receiving services with affordable price, more privacy and low delay.

Communication between TTPs and SPs is crucial since the TTP can negotiate with the SP on the QoE of the services. The output of the negotiation can be improved if the experience of previously provisioned drivers is used as an input. Further advantage of such negotiation is that the service provider does not have information about the identity of the vehicle drivers who requested similar services. TTPs guarantee to the drivers minimal personal information to the service provider without disclosure of the user identities. Indeed, it is more reliable for the user to deal with the TTPs rather than trusting the SP which is not known or trustworthy in most of the cases.

This development complies with our second objective. The personal information/data of our drivers are safe when dealing with TTPs, no need for the drivers to be concerned about their personal information/data when receiving service from a SP or switching to another SP. It is the TTPs responsibility to handle the driver's personal information and keep it safe, in case of leakage; TTPs will be able track and sue such behaviour. Thus, the user will be more convenient dealing with TTP, who will be more accountable about his actions.

C. QoE-based sequence diagrams scenario

The communication procedure of our architecture is starting by the vehicular driver trying to connect to the first available TTP. The driver requests on-demand service from the TTP, the TTP will negotiate on this service on behalf of the driver and then deliver it to him. The charging of the used service will start upon providing the service to the drivers. Upon completion of the service, the user provides his/her rating about the three main concerns, i.e., delay, price, and information revealed. The rating stage is a must from every driver to build up the QoE database reputation. The rating takes an integer value in [1, 10] based on user satisfaction where ten denotes perfect service and one represents the poorest.

Ratings are used to analyze and decide which SP can offer the best price-delay-privacy combination based on the user's requirements. When the user decides to request another service, he/she will be able to adjust the coefficients of the QoE (i.e. $\alpha, \beta, and\ \gamma$) function or just simply goes with his/her interest, e.g., selecting the price only and omitting the delay and the information revealed. To demonstrate our architecture in details, two different scenarios have been developed.

Figure 2 illustrates the sequence diagram for a scenario where QoE-awareness is not enforced at all. Thus, the users do not take into consideration the experience of previous users on delay, price, nor information revealed to the SP, and they simply subscribe to the first available TTP within the driver range.

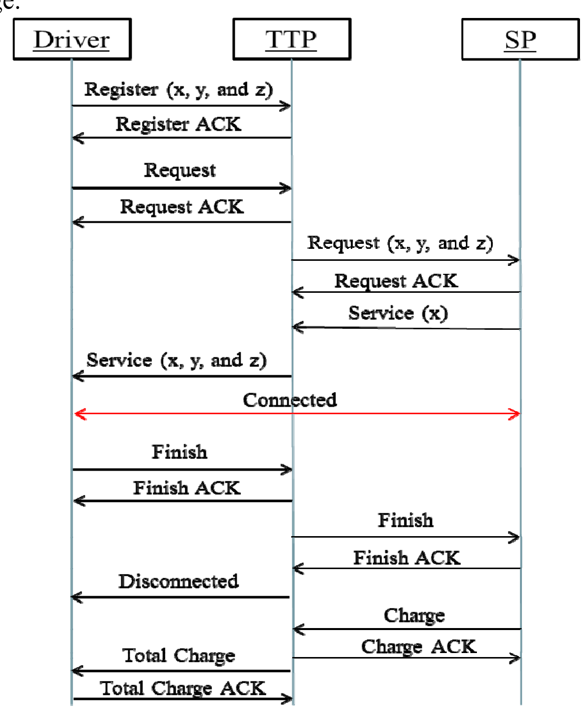

Figure 2: Sequence diagram without QoE interest

In a QoE-unaware deployment scenario, the driver registers to the first available TTP by providing his/her basic personal information such as name (x), credit card information (y) and so on. Upon providing the personal information to the TTP, the TTP decides to accept or reject the request of the corresponding driver. If accepted, the driver sends his/her service request to the TTP and wait for the response. The TTP contacts the proper SP and ask him for the requested service. At this level, the TTP has no concern about relaying the entire personal information of the driver to the SP (i.e. x, y, and z) since the user has no interest in privacy here. Once the service is ready, the TTP notifies the driver, and the driver is connected with the SP to receive the service. When the driver finishes receiving the service, he/she notifies the TTP back and the TTP also notifies the SP to stop the service. In the last step, the SP charges the TTP based on the type and duration of the service. Upon receiving the charges, the TTP sends the total charges to the driver.

In contrast to the QoE-unaware scenario in Figure 2, Figure 3 illustrates the sequence diagram for a QoE-aware scenario.

The rating is collected and analysed based on the QoE requirements of a newly arriving user as illustrated in Eq. 1. The rating database produces the best TTP selection that matches best with the user's QoE requirements. In Figure 3, D01 subscribes to the TTP that charges less by setting the QoE function at the price as shown in the figure. In addition, the driver could select the entire QoE factors by using the formulation in Eq. 1 which allows him/her to choose the best TTP that is to able handle all QoE concerns (delay, price, and information revealed) according to the user's requirements. Furthermore, the information received from the driver (e.g. x, y, a, and b) is not entirely relayed to the SP. The TTP chooses a subset of the driver's personal information to pass to the SP, if needed.

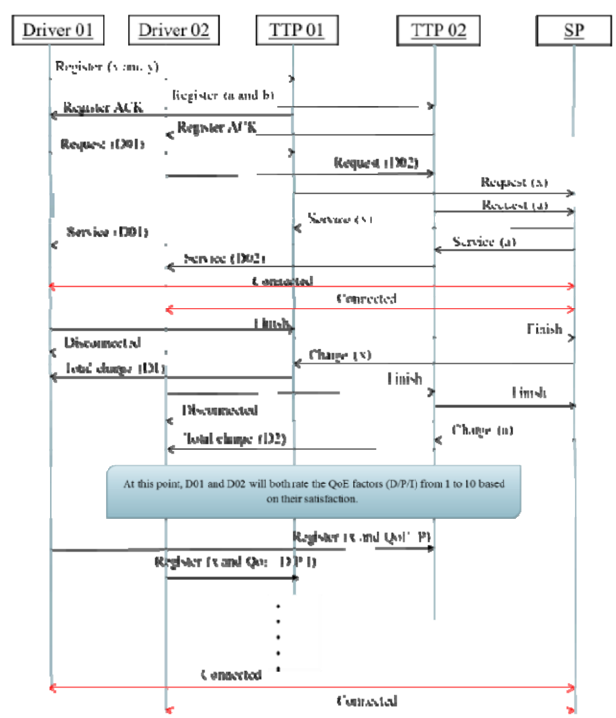

Figure 3: Sequence diagram for a QoE-aware scenario

IV. PERFORMANCE EVALUATION

A random waypoint movement mobility model has been used to handle the driver's mobility movement. It is worthwhile mentioning that there are other realistic mobility models however the aim of this study is to investigating the QoE-based provisioning framework in a vehicular cloud whereas the impact of vehicle trajectories are currently being investigated in the extended version of this paper. We use Network Simulator 2 (NS-2) to collect the numerical results of our QoE-based framework. The communication platform employs the Destination-Sequenced Distance-Vector Routing (DSDV) routing protocol, on IEEE 802.11.p communication stack with 512 byte packets. The data rate is set at 2Mb/s at 204 GHz bandwidth frequency.

For the sake of proofing and improving our framework concepts, we have selected three service providers (SP_{01}, SP_{02}, and SP_{03}), three TTPs (TTP_{01}, TTP_{02}, and TTP_{03}), and 25 drivers (D_1-D_{25}). We assume that initially the 25 drivers are randomly connected to the TTPs. Similarly, the three TTPs are connected randomly to the three SPs when simulations are initialized.

We evaluate our system using the QoE-based metrics: *delay, price, and information revealed*. The delay is the end-to-end latency needed for a driver to actually start receiving the requested service from the TTP who is engaged to. The price represents the usage price per time for the on-demand service. The privacy is the actual personal information amount that the user must provide to the SP in order to receive the service.

The delay factor in the QoE equation is the end-to-end delay calculated from the time of the requested service till the actual time when the services received (taking into consideration the value of α). As for the information revealed to the SP, three types of information is considered (x=name, y=address, z=credential such as credit card or bank account number). SPs randomly ask for x, y, or z. As for the pricing, we consider the service usage duration as the price unit. The drivers' feedback on the QoE is a challenging component in the simulations. When the driver selects one service parameter (i.e., either price, delay or information revealed only), the feedback is generated between 1-10 rating. In case of combined experience, a few combinations of the three factors are randomly generated and collected to form the QoE values obtained from a driver regarding a SP. These combinations look like as follows: Price=low=3; IR=medium of (x and y) =6; delay= high=9.

For the purpose of the testing and comparison, we have to re-test the three different modes of [10] which denote sensitivity to *delay, price, and information revealed. Neutral mode* stands for no interest in any of the QoE aspects. It simply connects to the first available TTP. *Delay sensitive* mode represents the situation where the user is interested in the provisioning delay only without any concerns about the price or the information revealed (i.e. $\alpha = 1,\ \beta = 0, and\ \gamma = 0$). The QoE-aware mode is tested using different coefficients on each set of experiments as shown in Table 1, and the coefficients are determined empirically.

Table 1: Coefficient factors used for *QoE-awareness* mode

	α	β	γ
Delay	0.4	0.3	0.3
Price	0.3	0.4	0.3
Information revealed	0.3	0.3	0.4

Figure 4 shows the delay performance under three different modes. The figure shows that the *Delay sensitive* mode and the *Neutral* mode introduce the least delay at its early stage of experience. However, when the number of vehicles increases (e.g. ~20), there will be more experience to improve QoE-aware decision, which will result in having very close delay compared to delay sensitive and the neutral modes. This is breakthrough improvement when we compare it the delay results in [10], where the results were the other way around.

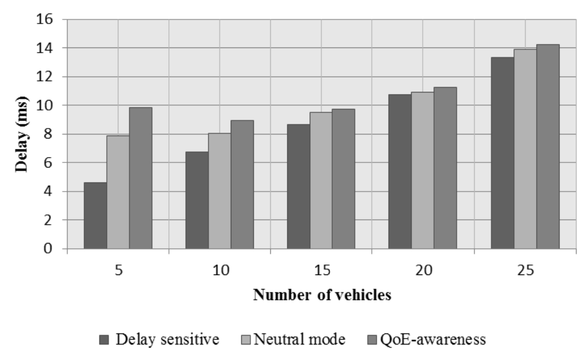

Figure 4: Measurements for the delay metrics modes

The service cost performance under the three different modes, *Neutral, Economy sensitive and QoE-aware* modes. In the *Economy sensitive* mode, the driver is only interested in minimizing the service cost using the following coefficient factors: $\alpha = 0,\ \beta = 1, and\ \gamma = 0$. Figure 5 shows an enhancement between the *Economy sensitive* and the *QoE-awareness.* We have notice also the effect of the experience when the number of the providers increase. Hence, it is more viable for the driver to adopt *QoE-awareness* with a bit of extra charges. Moreover, the new system shows a major gap between the *QoE-awareness* and the *Neutral mode.*

At last, we are re-evaluating the privacy concerns as shown in Figure 6. Here, the *Privacy sensitive* mode represents the case (i.e.$\alpha = 0,\ \beta = 0, and\ \gamma = 1$) where the drivers are only concerned about the information revealed to the SP. Figure 6 shows the enhancement on the amount of the information to be revealed to the SP. *Neutral mode* is not of our concern at this stage, since it is far from our two modes. On the other hand, a considerable amount of closeness (about 15%) to the *Privacy Sensitive* mode is achieved when *QoE-awareness* is adopted.

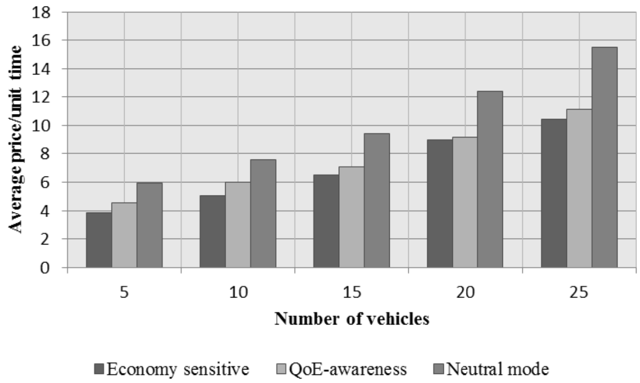

Figure 5: Measurements for the price metrics modes

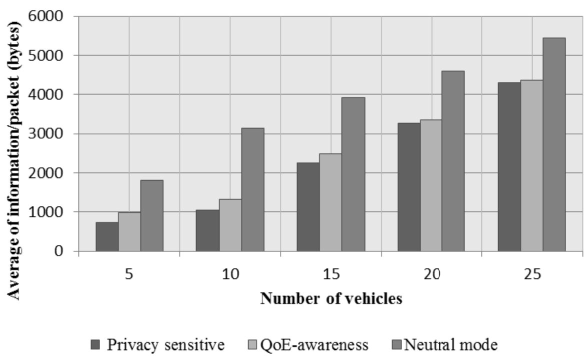

Figure 6: Measurements for the Information metrics modes

V. CONCLUSION

VCC still introduces several research challenges as it still investigated using different models. Privacy, service cost and delay are pointed as the most critical issues from the vehicular driver's point of view. The idea of using TTPs between the drivers and the SPs is a viable approach which is already adopted by several applications. In this paper, we have extended our previous proposal [10] and studied the performance of the proposed Quality of Experience (QoE)-based service provisioning in a vehicular cloud system. A major enhancement has been achieved on the delay performance whereas average service cost and average information revealed to the SP has been shown to be close to cost-sensitive and privacy-sensitive service provisioning modes.

This work is currently being extended to study the impact of using different optimization models on the vehicles. The impact of the presence of heterogeneous wireless networks under the vehicular cloud is also currently under study.

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