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Performance evaluation of wide-spread assignment schemes in a vehicular cloud

Ebrahim Al-Rashed *, Mohammed Al-Rousan, Naser Al-Ibrahim

Department of Computer Engineering, Kuwait University, Kuwait

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ABSTRACT

A parking lot based vehicular cloud is a cloud system where the resources are parked vehicles with onboard computing units. The dynamic and random process of vehicles joining and leaving a vehicular cloud results in a randomly changing number of available resources. This dynamic nature results in tasks assigned to departing resources to fail which reduces system efficiency. In this paper, we introduce a *vehicular cloud model* that considers multiple task request types and multiple resource capability types. We studied the performance of each type of user task request in tour model when using classical assignment policies, i.e. First Fit, Best Fit, and Last Fit. We also propose and investigate two techniques, task handoff and queueing, to increase the efficiency of the system and reduce the failure rate in the cloud. System simulation results show that the Last-Fit technique having the lowest task completion failure, while Best-Fit having the lowest task assignment failure. Simulations also show that hand off and queueing are very effective in increasing efficiency and reducing failure rates.

1. Introduction

In recent years, the research community has focused on techniques to efficiently manage energy, radio frequency and computing capabilities in networking environments and components [1], of which vehicular networks have received great research attention [2,3]. Today's vehicles are equipped with On Board Units, OBUs, that provide significant computing and storage capabilities to operate and control the different attached components and sensors in the vehicle. Newer vehicles models are manufactured with more sophisticated components and complex control applications driving manufacturers to equip vehicles with even more powerful OBUs. However, these OBUs are not utilized while vehicles are parked leading to wasted computing and storage resources. Therefore, it is desirable to utilize the vast amount of under-utilized computational resource units swarming the roads in the form of a vehicular computing cloud [4–7].

Cloud Computing refers to the usage of central remote servers connected to the Internet to maintain data and applications. Follow Me Cloud [8] is an example of a recent cloud computing application where their framework aims to smooth migrate of some/all portions of an ongoing IP service between a data center and user equipment of a 3GPP mobile network to another optimal DC with no service disruption. Another application that utilize cloud services is [9] where the data of offline questionnaires were sent to the for the purpose of analysis and visualization in order to develop a predictive model for health-shock.

Vehicles On-board computers are typically comprised of random access memory, processor, and data storage just like any other computer albeit with limited resources and capabilities. However, according to [10] and [11], new vehicles are currently available with some on-board unit capabilities that is almost as powerful as personal computers with a dual core processor up to 2.8 GHz and storage capabilities in Gigabytes. Moreover, due to the advances in technology these days, it is anticipated that in-vehicle storage capacity, memory speed and computational power will multiply in the future, enabling the vehicle to perform even more complex computational tasks. This anticipated increase in computing capabilities of future vehicles, the under-utilized computing resources available in vehicles, and the low attention given to such systems by researchers have motivated us to investigate the development of a stable vehicular cloud model by managing resource availability.

Vehicular clouds refer to a group of vehicles whose computing power, sensing, communication and physical resources can be coordinated and dynamically allocated to authorized users [7]. Therefore, building a cloud out of vehicles equipped with OBUs that have sufficient computing capabilities for executing applications and storing information locally can save cost and space by employing an otherwise wasted resources. Several models were proposed

* Corresponding author.
E-mail addresses: ibrahim.esmael@ku.edu.kw (E. Al-Rashed), malrousan@gmail.com (M. Al-Rousan), 01naser14@gmail.com (N. Al-Ibrahim).

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in a vehicular cloud due to the generality of resources in the cloud. Cooperation as a Service (CaaS) is a model where nodes in the cloud aim to collaborate together towards a common objective [4]. For instance, dynamically rescheduling traffic lights and planning an evacuation are examples of cooperation as a service. Another model is the Network as a Service (NaaS) model, where resources are shared in the cloud [10]. Our focus will be towards the Infrastructure as a Service (IaaS) model where resources in the cloud are used to form data centers.

One type of a vehicular cloud is the one based on a parking lot is a data center in which vehicles with on-board units are considered resources which dynamically enter and exit the cloud. Such a cloud system could employ a park-and-plug architecture similar to the one proposed by [12], where parked vehicles are provided with cables connected to a resource manager. Vehicular cloud of this nature is interesting since there are an abundant of idle computing resources on board parked vehicles for extended length of time. It is interesting to harness and collect these unused computing resources and structure them into a service cloud that can yield financial benefit to the owners of the vehicles and the cloud operator. This can be achieved by assuming a park and plug scenario where the cars that participate in the cloud are plugged into a standard power outlet and are provided with an ethernet connection to a central controller at the parking structure. Vehicle owners will get rewarded depending on the duration their vehicles stay connected to the cloud controller. However, such a vehicular cloud structure is more challenging than traditional cloud structures in that vehicles enter and leave the parking structure randomly with rates dependent on the time of day and day of week. Due to this dynamic nature, a lot of security issues rises. One such issue is data privacy between the cloud controller and the resource or between the user task request and the resource its running on. Although this is an important issue that needs to be addressed and overcome, this is out of the scope of this paper. Another issue is the quality of experience of such a vehicular cloud. ITU defines quality of experience as '*The overall acceptability of an application or service, as perceived subjectively by the end-user*'. Quality of experience has become a new measurement for the overall performance of a network or service as seen subjectively by the end user. Many research work has been conducted in this field including [13–18]. In the context of the a vehicular cloud based on a parking lot as described by this paper, QoE would be of interest in terms of delay, cost, and privacy as seen by the task submitting user of the cloud. This is out of the scope of this paper and would be investigated in a future extension.

In [19], Dressler et al. utilize parked vehicles to provide vehicular cloud services in place of Roadside Units (RSUs) using the Virtual Cord Protocol (VCP) protocol to enable dynamic cloud services. In [20], Gu et al. proposed leveraging the excessive storage resources in parking lots as an auxiliary vehicular data center (VDC) to a two-tier data center. Three VDC management policies (i.e., non-replication, simple replication and network coding based replication) were proposed to minimize the data retrieval cost for which a closed form is derived. In [21], Arif et al. modeled parking lot occupancy and derived closed forms for the probability distribution as a function of time. In all these previous work, the resources are assumed to be of same computing capability even though vehicles differ in that aspect due to different models and makes of vehicles on the road at any time. These previous works also did not recognize that computing tasks arriving to the cloud system might be of differing requirements which might be the case if different resource capabilities are prices differently.

Our contribution in this paper is that, as far as we know, we re the first work to present a vehicular cloud model of different resource computing capability types arriving according to a distributions to reflect the different resource type representation relative to the set of all resources. We also investigated the performance of the proposed cloud model under the classical assignment policies, i.e. Best Fit, Last Fit, and First Fit and the effect each has on the different task type. We also investigated the different type proportionality to the overall vehicle population by employing different distributions, i.e uniform, exponential, and normal distributions. Additionally, we proposed two failure reduction schemes, handoff and queueing to improve the efficiency of the system.

The paper is organized as follows. Section 2 contains the related work done in this field. The network model is discussed in Section 3. Section 4 discusses our experimental results and finally we conclude in Section 5.

2. Related work

Recently, more attention has been paid to vehicle cloud computing environments which can be categorized into two groups, general cloud computing and Parking-lot based cloud computing. However, a few research projects have been reported that study the utilization of parked vehicles within the cloud computing environments. An interesting research project is introduced by [12] where they investigated job scheduling and resource allocation problems in vehicular cloud in parking lots. Two different environments for scheduling strategy were considered: deterministic and scholastic. Deterministic fashion is suitable for cars arrive and depart at known time, thus, the authors assign jobs to a car such no interruption is accepted. Whereas for dynamic environment the author assigned jobs in semi-fixed policy by assigning multiple cars for each job request and by using multiple check points on job migration when a car is about to leave the parking lot. One related project is proposed by [19], in which investigation of the potentials of a vehicular cloud based on parked vehicles as a spatio-temporal network and storage infrastructure is reported. This study relied on establishing connected clouds of parked vehicles; these clouds maintained network connectivity internally to provide dynamic storage capabilities. Therefore, moving cars passing by are able to download and upload information with high success rate. The simulation experiments showed that the proposed system succeeded in handling the dynamic transaction demands with vehicles parking and leaving even at rush hour times. The concept of vehicular cloud for cars in the long-term parking lot is proposed by [21] in which predicting the parking occupancy at an airport parking lot given time-varying arrival and departure rates is made. Therefore, the study provided analytical solutions for determining the probability distribution of the parking lot occupancy as a function of time, given the expected number of cars in the parking lot and its variance. However, the study neither investigated task assignment policy when new jobs are admitted, nor task migration procedure when vehicles departs the parking lot, as we do in our work. [20] utilized storage resources on parked vehicles to form vehicle data center. The work proposed a two-tier data center architecture where the first-tier is considered to be a regular cloud and the second-tier is considered to be vehicular cloud. Three different policies (non-replication, simple replication and network coding based replication) to manage the vehicular data center were proposed and analyzed. For each management policy, the total communication cost in closed form is provided and verified by simulation results. [22] proposed an intelligent RFID-enabled authentication scheme for healthcare applications in VCC environment. Their proposed solution uses Petri Nets-based authentication model which uses this authentication for tags, and readers. Both server, and tag authentications are protected by strong elliptical curve cryptography (ECC)-based key generation mechanism.

Many other research projects addressed several services and issues in VANET systems [23–31]. A new cloud-computing model for VANET called VANET-Cloud was proposed by [23]. Their model is