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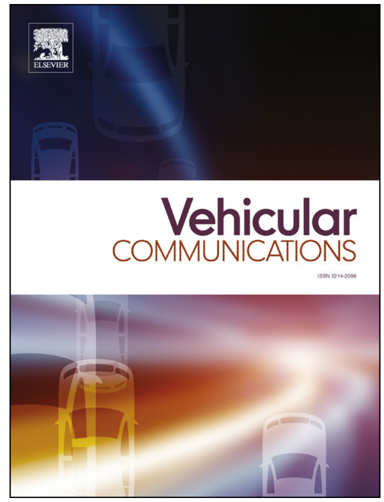


Vehicular cloud networks: Challenges, architectures, and future directions

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# Vehicular Cloud Networks: Challenges, Architectures, and Future Directions

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**Abstract**

Vehicular Cloud Computing is a promising solution to exploit the underutilized vehicular resources and to meet the requirements of VANET applications and services. Although modern vehicles have important capacities of computation and storage, there is an increasing need for resources, in particular, for safety applications which require the cooperation between vehicles. The vehicular cloud offers to users the opportunity to rent resources on-demand or to share them freely to run their applications or to carry out some tasks. Even though this paradigm is feasible, its implementation still faces problems. Many researchers have focused on the architectural design in order to overcome different challenges and consequently meet user requirements to provide him/ her with reliable services. In this work, we survey the vehicular cloud paradigm. We focus on its features and architectures. We first present a brief overview of the motivation of vehicular cloud. Then, we explore challenges related to its design. Furthermore, we highlight the features of existing vehicular cloud architectures: we provide a taxonomy of vehicular cloud followed by our classification criteria. Finally, we discuss issues that can be considered as open research directions.

*Keywords:*
Vehicular cloud architectures, cloud computing, VANET, classification

## 1. Introduction

In the last two decades, vehicular ad hoc networks (VANETs) were the topic of many research studies. The emergence of multiple wireless access technologies and the wide number of applications provided by VANET [1] explain the significant interest in this field. Enabling communication between vehicles and infrastructure equipment (e.g. roadside units, cameras) provides drivers and traffic authorities with information related to traffic conditions and incidents. The collected data help drivers to avoid congested roads and hazards. Traffic authorities are also able to manage traffic dynamically according to the situation (e.g. a dynamic scheduling of traffic lights). The integration of a myriad of devices such as GPS, sensors, and on-board units has made vehicles smart. It contributed to the extension of the deployment of VANETs. Indeed, vehicular capacities enable passengers to exploit various services (internet access, multimedia applications, vehicular social networking, etc.). In spite of these benefits, many challenges leverage the quality of service (QoS) of the delivered applications such as the mobility of nodes, obstacles, bandwidth limitations, and frequent interruptions of links [1], [2]. Furthermore, applications do not have the same requirements regarding resources (bandwidth, computing, storage) and QoS constraints (delay, jitter, packet loss rate, etc.). Some applications need high bandwidth such as multimedia applications to ensure a smooth play; other applications are demanding in terms of delay such as real-time applications. In most of the cases, a single vehicle cannot possess the needed resources.

Cloud Computing (CC), which is a solution that aims to provide users with their required resources, seems to be a way to overcome the shortcomings of VANETs. In this context, vehicular cloud (VC), which is an extension of mobile cloud computing (MCC) based on the vehicular network, has emerged [3]. It consists in exploiting the underutilized vehicular and infrastructure resources optimally. Vehicles can collaborate to share their resources or rent them to consumers which can bring significant benefits to the different agents implicated in the vehicular network (drivers, passengers, traffic authorities, and police, etc.). Many researchers focused on this new paradigm and tried to find solutions to different problems that can affect the deployment of this concept. In particular, the architectural side was the emphasis on many studies due to the characteristics of vehicular networks.

In the literature, some surveys have been conducted on the vehicular cloud such as the work presented in [4], [5]. In [4], the authors focused on the features and applications of the vehicular cloud. In [5], a vehicular cloud taxonomy was suggested. Besides, the authors proposed an extensive study of the features, applications, and security issues of the vehicular cloud. Unlike [4, 5], we present a detailed study of the vehicular cloud challenges. In particular, we suggest taxonomies of the resource management and security issues. Also, we propose a new taxonomy of vehicular cloud. Furthermore, our work focuses on the architectural side: we suggest new metrics to classify the

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