Chapter 73
Towards Smarter Cities and Roads:
A Survey of Clustering Algorithms in VANETs

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ABSTRACT

This chapter highlights the importance of Vehicular Ad-Hoc Networks (VANETs) in the context of smarter cities and roads, a topic that currently attracts significant academic, industrial, and governmental planning, research, and development efforts. In order for VANETs to become reality, a very promising avenue is to bring together multiple wireless technologies in the architectural design. Clustering can be employed in designing such a VANET architecture that successfully uses different technologies. Moreover, as clustering addresses some of VANETs' major challenges, such as scalability and stability, it seems clustering will have an important role in the desired vehicular connectivity in the cities and roads of the future. This chapter presents a comprehensive survey of clustering schemes in the VANET research area, covering aspects that have never been addressed before in a structured manner. The survey presented in this chapter provides a general classification of the clustering algorithms, presents some of the most advanced and latest algorithms in VANETs, and in addition, constitutes the only work in the literature to the best of authors' knowledge that also reviews the performance assessment of clustering algorithms.

INTRODUCTION

Nowadays, smart cities represent a very important research direction for academia, industry and governments that are eager to embrace various technologies, which will make cities "smarter". The main purpose of smart cities is to improve all the facilities provided in a city (e.g. buildings, infrastructure, transportation, energy distribution, etc.) in order to improve the citizens' quality of life, while creating a sustainable environment by reducing gas emissions and energy consump-

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tion. IBM has launched in 2010 IBM Smarter Cities[1] challenge, aiming to support 100 cities in addressing some of their critical challenges, and Dublin Ireland is one of them. In the same year, the European Commission has launched the European Initiative on Smart Cities[2] that addresses four dimensions of the city: buildings, heating and cooling systems, electricity and transport. Related to the transport, the declared aim is to promote sustainable forms of transportation, to build intelligent public transportation systems based on real-time information, traffic management systems for congestion avoidance, safety applications (e.g. collision avoidance) and green applications (e.g. intelligent routing aiming to reduce fuel consumption, gas emissions or energy consumption).

In this context, Vehicular Ad-hoc Networks (VANETs) or simply vehicular networks represent a hot research topic both for academia and industry due to their high potential to create not only smarter cities, but also smarter roads. This potential relies in the *on the wheels connectivity* provided by VANETs that can also meet the *always connected* need of drivers and passengers. Statistics shows that vehicles occupy the third position, after homes and offices, in the top of the places where people spend their time on a daily basis (Araniti, Campolo, Condoluci, Iera, & Molinaro, 2013). VANETs are based on "smart" vehicles that are able to communicate to each other and to the infrastructure via vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, known under the generic term of V2X communications, but also via other wireless communications technologies (e.g. cellular, WLAN).

V2X communications are considered the main enabling technology of VANETs. They have exclusively dedicated spectrum that is of high importance particularly for safety applications. As this technology has a low penetration rate and also some limitations (i.e. short-lived and intermittent connectivity), in some architectures, other access technologies are employed as well, in order to support the diversity of VANET applications (i.e. safety, traffic management and infotainment applications). Best candidates among the other access technologies are cellular technologies due to their theoretically ubiquitous coverage. First considered was Universal Mobile Telecommunication System (UMTS), but its limited capacity and data rates impose significant challenges in the case of infotainment applications for example. Long Term Evolution (LTE) appears to be the most promising enabling technology for vehicular applications due to the high data rates provided, support for high mobility (up to 350km/h) and high market penetration – LTE was confirmed as the fastest developing mobile system technology ever[3]. However, cellular technologies do not provide built-in support for direct communication between vehicles. Therefore they are appropriate mainly for the communication between vehicle and infrastructure. In addition, according to the studies performed so far, it is more likely that not even LTE can support the huge amount of messages exchanged by vehicles during rush hours. Moreover, the latest statistics show a huge growth in mobile data (without considering the vehicular space) that appears to be impossible to be accommodated by the cellular technologies only. Consequently, VANETs cannot rely on a single type of access technologies, thus there is a need of bringing together multiple technologies, V2X communications, cellular technologies and WLAN, in order to enable support for a wide range of VANET applications.

In this context, clustering can play a very important role in the design of VANET architectures: on one hand clustering addresses some of the V2X communications limitations such as sparse deployment of the infrastructure, and intermittent connections and on the other hand it optimizes the communication via cellular access technology. In addition, clustering algorithms in VANET address some of the main VANET challenges: scalability and stability, and have been integrated in a various range of applications. This chapter presents

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