Chapter 2
Clustering and 5G-Enabled Smart Cities:
A Survey of Clustering Schemes in VANETs

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ABSTRACT

This chapter highlights the importance of vehicular ad-hoc networks (VANETs) in the context of the 5G-enabled smarter cities and roads, a topic that attracts significant interest. In order for VANETs and its associated applications to become a reality, a very promising avenue is to bring together multiple wireless technologies in the architectural design. 5G is envisioned to have a heterogeneous network architecture. Clustering is employed in designing optimal VANET architectures that successfully use different technologies. Therefore, clustering has the potential to play an important role in the 5G-VANET-enabled solutions. This chapter presents a survey of clustering approaches in the VANET research area. The survey provides a general classification of the clustering algorithms, presents some of the most advanced and latest algorithms in VANETs, and it is among the fewest works in the literature that 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. Related to the transport, the declared aim of smart cities 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

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avoidance) and green applications (e.g. intelligent routing aiming to reduce fuel consumption, gas emissions or energy consumption). Moreover, self-driving cars play an important role in the context of smart cities, due to their potential of improving citizen's life by improving their comfortability. Various statistics demonstrate that people are spending a lot of their time in the vehicles, in traffic (INRIX, n.d.). Self-driving cars would allow people to use this extra time in a more efficient way.

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 as they are spending much of their daily time in their vehicles. Moreover, VANET has a crucial role in the context of self-driving vehicles (Ydenberg, Heir & Gill, 2018). 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 dedicated 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). Due to the importance of VANET, cellular technologies that have a high market penetration have considered to accommodate this type of communications starting from 4G. More improvements and developments are planned in 5G. LTE for instance was mainly considered for the communication between vehicle and infrastructure because according to the studies performed, it seemed to be unable to support the huge amount of messages exchanged by vehicles during rush hours. The general consensus is that VANETs and their diversity of applications 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 a thorough survey of clustering algorithms in VANETs.

There are some reviews in the literature dedicated to clustering in VANET (Vodopivec, Bester & Kos, 2012; Cooper, Franklin, Ros, Safaei & Abolhasan, 2017), but these do not provide any classification of the performance assessment of these algorithms. This review is an extension of the one presented in (Tal&Muntean, 2014) and similar to this is trying to address a gap that there is in the literature, namely the lack of a well-structured analysis of the performance assessment of clustering algorithms in VANET, while considering new and significant stages in this research field.

The structure of the chapter is as follows. In the first sections, an overview of vehicular networks, their enabling technologies, applications and challenges is presented. The following sections are dedicated to clustering: general concepts of clustering, survey of clustering in VANETs – application, classification, performance assessment and representative algorithms. The chapter ends with future directions and conclusions.