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Exploring Software-Defined Network (SDN) for Seamless Handovers in Future Vehicular Networks:
Mobility Management Approach

Amina Gharsallah, NTS'Com Research Unit, ENET'COM, University of Sfax, Tunisia*
Faouzi Zarai, NTS'Com Research Unit, ENET'COM, University of Sfax, Tunisia
Mahmoud Neji, MIRACL, University of Sfax, Tunisia

ABSTRACT

With the rapid development of communication technology, vehicular communications systems are evolving to intelligent transportation system (ITS) by providing its wireless network services with increasing demand for high data rate. However, the highly mobile feature of vehicles and varying network densities in such communication systems pose challenges for the mobility management, including frequent handovers, increased delay, and failure of the handover process. In this work, the authors propose an optimized mobility management approach using software-defined network (SDN) in the future vehicular networks. In addition, the authors have proposed a new handover management mechanism. This new mechanism allows vehicles to select the most optimal network based on multi-criteria metrics. The simulation results show that the proposed approach performs well and achieves an improvement in terms of handover delay and handover failure rate, compared to existing approach.

KEYWORDS

Clustering, Handover, Internet of Things (IoT), Mobility Management, Software Defined Networking (SDN), Vehicle-to-Everything (V2X), Vehicular Networks

1 INTRODUCTION

Vehicle-to-Everything communications or V2X communications permit the exchange of information between vehicles and between a vehicle and network infrastructures. The goal of V2X communications is to enhance road safety, augment traffic efficiency, reduce environmental impacts and supply additional information services to travelers.

V2X communications, as presented in figure 1, include diverse types such as: Vehicle to Vehicle (V2V), Vehicle-to-Pedestrian (V2P), Vehicle to Infrastructure (V2I), and Vehicle-to-Network (V2N) , (2018). V2V communication is mainly done between nearby vehicles exchanging information on location, speed, and direction to avoid accidents. V2P transmission covers communication between a vehicle and a road user (a pedestrian or a cyclist). V2I communication takes place between a vehicle and the road infrastructure, called RSU (Road-Side Unit). V2N communication takes place between a vehicle and a V2X application server via a 4G/5G network.

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*Corresponding Author

V2X communication requires low latency, high-speed and ultra-reliable transmission. V2X applications include security applications and non-security-related applications. Security applications include driver assistance and road hazard warning applications. Non-security applications include road traffic management applications, remote vehicle diagnostics, air pollution monitoring, comfort and entertainment, (2018).

Security-related applications provide vehicle drivers with information about various hazards and situations that they usually cannot see. These applications require high reliability and low latency for high-speed message transfer. Examples of security-related applications are collision, loss of control, lane change warnings, and vulnerable road user safety applications.

Efficiency and traffic management applications aim to improve traffic management on the roads by providing road traffic assistance to the users. These applications require high reliability and longer latency requirements for high-speed message transfer. A vehicle or RSU collects information about traffic conditions. Then it transmits it to other vehicles allowing them to choose a different route, which optimizes travel time. Examples of traffic management applications are speed management (e.g., regulatory speed limit pop-up notification and green light speed notification) and cooperative navigation.

Entertainment and custom applications are ancillary applications and comfort use cases, which demand high data rates and flexible communication types. These applications can help extend internet access to the moving vehicle so that passengers can continue to work while on the move. Passengers can also access various applications, namely the web, Voice over IP (VoIP), video, online games, and navigation and location applications. Examples include infotainment and route planning.

In this work, our focus is on identifying a solution to the problem of mobility management for V2X communications in future vehicular networks. Indeed, the highly mobile feature of vehicles and varying network densities increase the number of handovers. This situation can lead to a significant accumulation of unnecessary handovers (Ping-Pong effects). In addition, it increases the risk of handover failure and handover delay.

We present a solution to optimize the handover procedure in next-generation vehicular networks. Our approach adopts a new technique of clustering vehicles according to their mobility profile. The vehicles in each cluster communicate with each other using LTE PC5 technology and are also connected to the cluster head via the multi-hop relay method. We have adapted the vehicle clustering and multi-hop relay methods to avoid frequent and unnecessary handovers between the base station and the vehicles. Also, the new approach introduces an SDN-based handover management mechanism. This novel mechanism allows vehicles to select the most optimal network for V2X communications based on various parameters.

The rest of the paper is organized as follows. Section 2 presents the main V2X communication standards. Section 3 presents the recent research works on vehicular networks, including existing mechanisms for vehicles clustering and handover management. Section 4 presents the proposed handover management approach using SDN. Section 5 presents the performance evaluation and the obtained results. Finally, the paper is concluded in Section 6 along with presenting promising new research directions.

2 V2X COMMUNICATION STANDARDS

Many standard protocols are used for V2X communication. IEEE 802.11p is the main norm for supporting vehicular networks. On the other hand, the LTE-V2X and 5G-V2X standards are rapidly becoming the preferred mode of V2X communications. The main V2X communication standards are described here.

2.1 IEEE 802.11p Standard

IEEE 802.11p standard derived from the IEEE 802.11 standard is an amendment by the IEEE Dedicated Short Range Communications (DSRC) working group for wireless access in the intelligent transport system. Indeed, the IEEE 802.11p Wireless Access for the Vehicular Environment (WAVE) standardization process - a kind of mobile Wi-Fi - stems from the allocation of the DSRC frequency band and the technological definition effort. This technology helps prevent collisions, in which cars are mutually attentive to changing conditions, and can significantly improve road safety. In addition, this technology supports more than 200km / h speed with a transmission range of up to 1000m. The DSRC spectrum is structured into seven