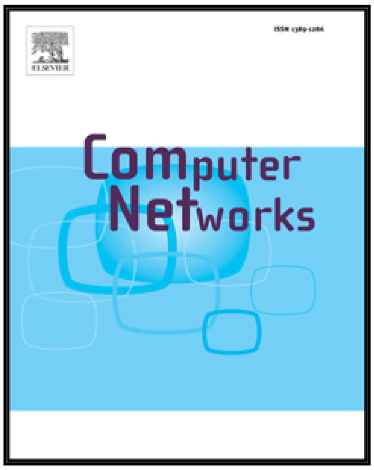

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ABSTRACT

Connected Vehicle is a new intelligent transportation paradigm that uses wireless communications to improve traffic safety and efficiency. It has received a great deal of attention in recent years, across many communities. While the DSRC is widely recognized as the de facto standard for V2V, other wireless technologies are required for large-scale deployment of V2I communications. Thanks to its high data rates and large-scale deployment, the LTE-A enhanced by small cells (SCs) densification, is positioned as one of the major candidate technologies for V2I communications. However, using LTE-A small cells for V2I communications is challenging due to their small coverage which leads to frequent handoffs and more signaling overhead. In this paper, a novel architecture that integrates VANET and 4G LTE-A Heterogeneous Network for enhanced mobility in LTE-A small cells is introduced. First, we propose a new network-based mobile gateway selection scheme with one-hop clustering to efficiently relay traffic from neighboring vehicles toward the serving SC. The problem is formulated as a multi-objective binary programming problem. Then, for seamless mobility of connected vehicles, we propose a local k-hops anchor-based mobility scheme with three procedures, namely intra-domain, k-hops inter-domain and inter-domain procedures. Numerical results show the effectiveness of the proposed mobility schemes for reducing the generated signaling load towards the core network.

1. Introduction

Over the last decade, Connected Vehicles communications (V2X) have attracted tremendous interest and extensive research and development activities from academic, industrials and standards organizations. V2X communications consist of wireless communication between vehicles and infrastructure, between vehicles, and between vehicles and wireless devices. They are also known respectively as Vehicle-to-Infrastructure (V2I), Vehicle-to-Vehicle (V2V) or Vehicular Ad Hoc Networks (VANETs), and Vehicle-to-Device (V2D).

The main motivation behind the development of V2X is safety applications. In fact, providing information and assistance to road users have great potential to prevent road accidents. According to [5], 80% of collisions would be avoided if 50% of intersections are equipped with V2I Road Side Unit (RSU). While 50% of collisions would be avoided if only 20% of intersections are equipped.

Connected vehicles also support many non-safety applications such as Traffic Management and Telematics including Road congestion control, Smart road pricing, and Direction and route optimization. DSRC/WAVE is one of the leading wireless technologies for connected vehicles. Its effectiveness for V2V and V2I communications, regarding its reliability and low latency, has been proved in many real-world testbeds. While the deployment of connected vehicles infrastructure (RSU and backhaul) with seamless service continuity is critical for V2I safety and non-safety ITS applications, still there is no plan for V2I infrastructure large-scale deployment due to the need for considerable public investments. Thanks to recent advances in LTE-A Releases-10/11/12, The 4G LTE-Advanced (LTE-A) mobile network appears as one of the major candidate technologies for V2I communications [19]. In fact, the LTE-A promises to deliver reduced connection setup time and higher data rates by using new physical layer technologies and new network elements and functions such as, network densification using Small Cells (SCs), Dual Connectivity (DC), Relaying functionality, Carrier Aggregation (CA), Device to Device (D2D) communication, etc.

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Although the macrocell will remain the major Radio Access Network (RAN) element for wide-area coverage and high-mobility users, it is no longer sufficient to meet user's demand in many high-density areas. Indeed, due to the proliferation of mobile devices and applications, mobile data demand continues to grow exponentially [26]. Small cells, which include microcells, picocells, and femtocells, are widely recognized as a key solution for enhancing RAN capacity and coverage. They are increasingly used by mobile operators, in the so-called Heterogeneous Network (HetNet), to offload traffic from their macrocells. A HetNet is typically composed of several layers (macrocells, small cells), and in some cases different access technologies (e.g., LTE-A, UMTS, WiFi). SCs densification involves deploying more small coverage base stations in high demand areas to bring higher spectral efficiency per coverage area. According to [26], even with low SCs indoor penetration, we can achieve good performance for traffic offloading and good outdoor coverage.

Nevertheless, the SCs deployment faces many challenges, such as mobility management, backhaul deployment, and interference management.

As an extended version of our previous work in [2], in this paper, we focus on challenges relevant to mobility for VANETs using LTE-A network. Specifically, we introduce a new integrated VANETs and 4G LTE-A architecture that reduce the mobility signaling overhead based on the following contributions: First, we propose a new network-based mobile gateway selection scheme with one-hop clustering to efficiently relay traffic from neighboring vehicles toward the serving SC. Then, we propose k-hops anchor-based local traffic forwarding schemes that reduce the mobility signaling overhead toward the core network, we develop analytical models to study the handover signaling overhead, and we present numerical results highlighting the effectiveness of the proposed mobility schemes. The motivation behind the proposed architecture is elaborated in the forthcoming subsections.

1.1 LTE-A network access for VANET