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An Intelligent Radio Access Technology Selection For Vehicular Communications

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Abstract

The access technology selection, where a user can associate with any radio access technology (RAT) with the availability of multiple RATs has been intensively investigated by vehicular Ad hoc Network (VANET). In particular it carries and distributes information, inter-communicates and is capable of communicating with other stationary units deployed along roadways. The current study proposed hybrid optimal radio access selection algorithm (ORAS) for LTE/VANETs network. The periodically broadcasted network information supports mobile users to make their selection decisions; mobiles consider their own individual preferences, cost and partial QoS information signaled by the network while making their decision. The switches algorithm between VANET and LTE based on the load value of network and quality of service requirements were proposed. The simulation results have shown that the proposed algorithm has better performance compared to LTE and VANETs separately in terms of packet delivery ratio, latency and application-level throughput.

Keywords: Vehicular Ad hoc Network, QoS, LTE, Optimal Radio Access Selection

INTRODUCTION

Vehicular Ad-hoc Network (VANET) are emerging as the preferred network design for intelligent transportation systems providing communications among nearby vehicles in the support of internet access, as well as a variety of safety applications. Intelligent VANET defines a novel way of using vehicular networking by integrating heterogeneous emerging wireless technologies, such as 3G cellular systems, long-term evolution (LTE), IEEE 802.11 and IEEE 802.16e, for effective vehicle-to-infrastructure (V2I) communications. Investments of the world's leading vehicle manufacturers and public transport authorities have set to be the key drivers of the remarkably increasing popularity of this newly emerging field. A close collaboration with numerous other parties has led to the development of a strategic plan through which novel Intelligent Transportation System (ITS) services could be defined and offered (e.g., navigation safety, traffic management, infotainment, etc.).

A historical breakthrough took place when the Federal Communications Commission (FCC) allotted a 75 MHz additional bandwidth over the 5.85–5.925 GHz spectrum range for the purpose of sustaining Dedicated Short-Range Communication (DSRC) based ITS services, [1]. Furthermore, the FCC Notice of Proposed Rule Making (NPRM) 13–22 was proposed to allow tools like Wi-Fi to share the 5.9 GHz DSRC band for the purpose of supporting commercial applications [2]. Afterwards, the FCC was subject to remarkably active solicitation on issues regarding DSRC technologies, service regulations, spectrum licensing and so forth. The American Society for Testing and Materials (ASTM) developed a single Physical (PHY) and Medium Access Control (MAC) standard. ASTM's standard was based on the IEEE 802.11, [2]. The IEEE Task Group p (TGp) was then established. It took over ASTM, and initiated the development of an amendment to the 802.11 standard, namely the IEEE 802.11p [3], that specifically addresses the communication challenges associated to vehicular environments. However, LTE standard was released years ago; yet, the demand of high speed data is increasing. 5G network technologies were studied by engineers although 4G network is not been yet universally on the international scale [2] [3]. The proposed Hybrid Networks became a part of 4G-LTE standard several years ago. It was positioned by some wireless operators in the market though it is not deployed widely. During the next wireless communication generation system, it is predictable that the Hybrid Networks technique will be more popular. Contrarily, multiple Radio Access Technologies (RATs), such as mobile WiMAX, IEEE 802.11 WLANs, HSPA+ and LTE are being combined to form a Hybrid wireless network. This cost-effective solution provides worldwide service coverage and high capacity. However, radio resources need to be jointly managed. Typically, a decision should be made, when a new or a handover session attains, as to the technology that must be connected with. Robust decisions inevitably help to enhance resource utilization and user satisfaction. The modeling of system and technical awareness will be highly complex if Base Stations (BS) are well-prepared with a big amount of transmission and reception antennas. If users locate in a small cell, within cellular Hybrid Networks, it will include a variety of access methods, assuming that the macro-cell is equipped with various pico-cells in this area. Users can either interact with pico-cell BS or macro-cell BS. Finding a widespread strategy in such situation is difficult since it is subject to the users' number in this small cell, also the system must include all users' QoS. Yet, the infrastructure architecture of LTE imposes longer delays and overheads on traffic, as transmissions inevitably have to pass through base stations and network controllers. This issue may be overcome by offloading some of the traffic to V2V links. To this end the hybrid scheme of combining LTE with 802.11p is considered, where the former provides V2I connectivity and the latter enables V2V networking. Very few studies are available on analysis of hybrid LTE/802.11p VANETs. As per [4], the researcher emphasized the gap in the literature on this proposal and provided a framework for realistic simulations of hybrid LTE/802.11p networks based on NS-3. [5] presents a multi-hop routing algorithm in hybrid LTE-802.11p VANETs and validates this proposal through simulations. The problem of Radio Access Technology (RAT) selection in hybrid VANETs is investigated in [6], which proposes multi-objective criteria for selection between 802.11p and LTE, whose effectiveness is validated through simulations. [6] [7] for V2X applications were evaluated and showed that the major consensus among the results reported in the aforementioned studies is the proposal for a hybrid scheme in which the 802.11p technology is complimented by a cellular standard. Such schemes include data delivery via 3G networks and 3G assisted clustering techniques [8] [9] [10]. Recent proposals tend to focus on the application of the Long Term Evolution (LTE) cellular networks in combination with 802.11p. The standard, IEEE 802.11p Dedicated Short-Range Communications (DSRC), is considered one of the most V2X proposals [11]. Altering the signal bandwidth to 10 MHz and the operating frequency to the licensed Intelligent Transport Systems (ITS) band at 5.9 GHz help to modify the Wi-Fi-based standard adopts the PHY layer of IEEE 802.11a. IEEE 802.11p supports two modes of network topologies: the traditional infrastructure Basic Service Set (BSS) in which transmissions are relayed through Access Points and the Independent BSS (IBSS) where subscribing nodes communicate directly with each other by forming an Ad hoc network. Both modes necessitate synchronization of nodes by transmission of beacon signals. Contrary to the classic variants of 802.11, the MAC layer in 802.11p does not implement association, authentication and security to reduce the time termed Enhanced DCF. While IEEE 802.11p enjoys a wide popularity in both the VANET community and the automotive industry [12], it also brings along a number of considerable drawbacks. Studies like [13] and [14] report that the radio channel and propagation conditions of this standard are highly time-variant and frequency-selective. [15] analyzed the scalability issues inherent in the MAC protocol utilized in 802.11p. While some have proposed potential modifications as potential resolutions to such problems other communication technologies have also been investigated as alternative and perhaps more efficient solutions. Motivated by the endorsement of the Car-2-Car Communication Consortium (C2C-CC) [16] and ETSI [17], the feasibility and performance of cellular communications such as HSUPA [18], UMTS [19], WiMAX [20, 21], and LTE [22] [23] [24]. This paper proposed an ancient hybrid optimal radio access selection algorithm (ORAS) which combines LTE and VANET Networks with accomplishing high data packet delivery ratio and low delay while maintaining the minimum level of cellular infrastructure usage by means of increasing link transmission stability and reducing the number hope per route. The proposed a multi-hop routing protocol based IEEE 802.11p/LTE hybrid architecture. The multi-hop algorithm features, which are utilized in this hybrid architecture, include route variety using the comparative mobility metric as the average comparative signal in relation with the neighboring vehicles in order to achieve the broadcast redundancy reduction and the routing overhead minimization along with increasing transmission stability link.

Vehicular Connectivity**:** Vehicular connectivity may take the form of infrastructure-based networks, known as Vehicle-to-Infrastructure (V2I), where vehicles communicate with each other and other nodes in the network via intermediate Access Points (APs) and central controllers that route and relay messages from their origins to destinations. Alternatively, the vehicular link may enable direct communications between vehicles without recourse to intermediate structures. This mode is known as Vehicle-to-Vehicle (V2V), and the Vehicular Ad Hoc Network (VANET) is the emergent system. This architecture is determined by multi- hopping, in which messages transmitted by a source are relayed by several intermediate nodes to reach their intended destination.

Architectures that support both V2I and V2X modes in parallel are classified under the term Vehicle- to-X (V2X) as shown in figure 1.

Multi-Channel: The major benefits behind multi-channel access are two-fold: (1) Support reliable and delay-minimal emergency communications, (2) Maximize the throughput of non-safety applications in a distributed manner [25]. Allowing for multi-channel operations in vehicular environments is a remarkably challenging task. This is true since the proper functionality of these operations comes as a result of efficient coordination and synchronization. Nowadays, modern vehicles are being equipped with either single-radio 2 or dual-radio 3 transceivers. While the formers were perceived as short-term means for promoting vehicle intelligence, the latter were envisioned for long-term deployments.

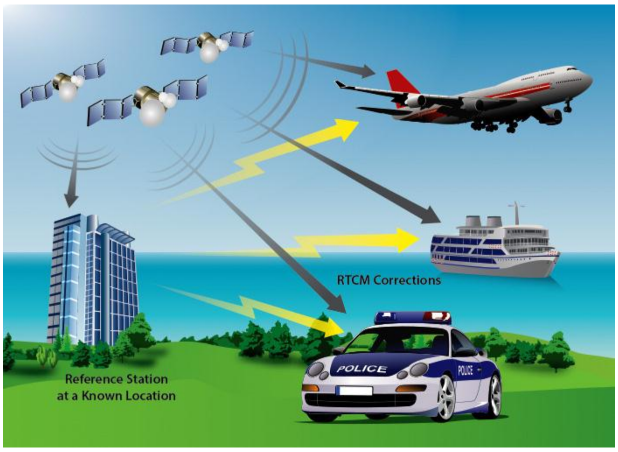

Figure 1: Infrastructure Vehicular Connectivity

Both radio technologies present some drawbacks when it comes to operating as part of a multi-channel architecture, for example, single-radio devices suffer notable losses in terms of channel capacity when switching channels. This results in data starvation, let alone and packet expiry. Highly precise synchronization is stringently required to overcome these shortcomings, yet it is very difficult to realize in the context of vehicular environments given their severity.

Dedicated Short-Range Communications: DSRC is also known as Wireless Access in Vehicle Environment (WAVE). The U.S. FCC has allocated 75MHz of spectrum in the 5.9 GHz band for DSRC use while European and Japan have allocated their own spectrum band and system design. In the U.S., DSRC includes seven licensed channels that are shared between public safety and private applications. Unlike standard 802.11 where each channel is 20 MHz wide, the channels in 802.11p are 10 MHz to make the signal more robust against fading (with an option to use 20 MHz by combing two 10 MHz channels) [26]. At the physical layer, IEEE 802.11p is similar to 802.11a/g based on OFDM (Orthogonal Frequency Division Multiplexing) modulation. 802.11p differentiates itself from normal 802.11 with a unique ad hoc mode, random MAC addresses for privacy preservation, and IPv6 for routing in the network layer.

The unique ad hoc mode enables 802.11p nodes to communicate outside the context of a basic service set in a highly mobile environment where authentication and association are not defined in 802.11p PHY/MAC, but rather handled by the uppers layer or the station management entity. This reduces the delay (typically a few seconds) incurred in an initial first frame exchange in which the communication timing between two vehicles may be short, especially if the vehicles are traveling in opposing directions.

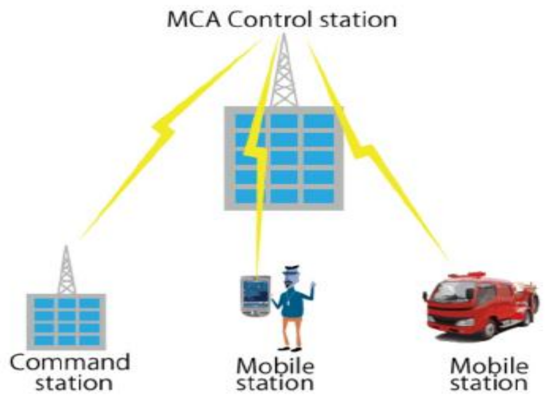

Figure 2: Multi-channel access

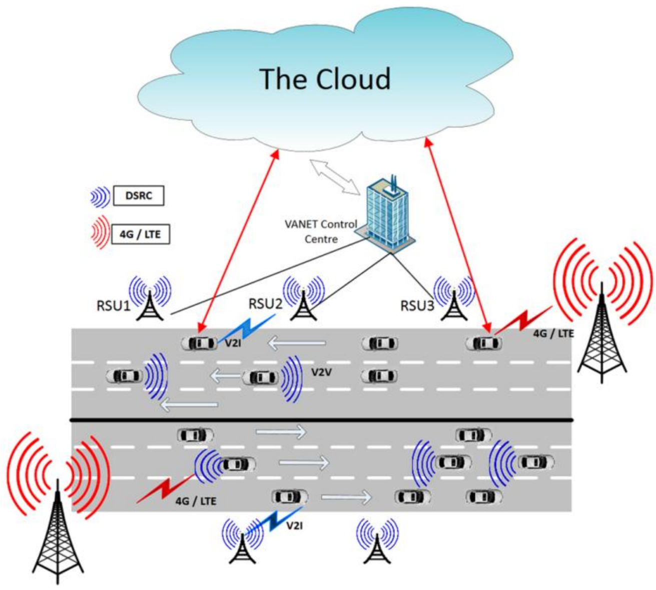

Figure 2: DSRC-based multi-channel

In addition, IEEE 802.11p includes the enhancement of priority classes based on 802.11e and power control based on 802.11h. Prioritization and Quality of Service for safety time-critical messages in VANET are addressed with enhanced distributed channel access (EDCA) with different contention window size. DSRC/WAVE provides a flexible architecture with multiple protocol stacks above the network layer (for example, TCP, UDP, and WAVE Short Message in the transport layer). The standard for DSRC/WAVE uses IEEE 802.11p in the lower layers (Physical and MAC) and IEEE 1609 in the upper layers (1609.1 for application services, 1609.2 for security services, 1609.3 for networking services, 1609.4 for multichannel and EDCA mechanisms).

An application message for V2V communication consists of information such as GPS coordinates, timestamp, vehicle speed, vehicle acceleration, and vehicle direction while I2V includes additional information such as traffic signal status and the number of vehicles detected. Typically, these application messages are 150 bytes or less with the remaining overhead attributed to other layers of the protocol stack. Further details on the application message structure for different safety and non-safety scenarios are described in [27], as shown in figure 2.

METHODOLOGY

The optimal radio access selection algorithm, based on IEEE 802.11p Radio Resource Management (RRM), examines the IEEE 802.11p network load through the monitor mechanism of network load. The monitor mechanism in turn observers the queue length to determine the current network loads. The ORAS/ RRM entity broadcasts beacons through its IEEE 802.11p interface once the queue length is inferior to a particular threshold limit. Nonetheless, the existing network load might cause a collisions case which leads to severe performance degradation on the condition that the queue length exceeds specific threshold limit. The parameter Network Load Monitor section, which can compare with Threshold value, defines the threshold limit. The Threshold value differs between 75% to 85% of the total queue capacity.

The messages insides the queue sometimes are duplicated, because it might come from same sender. These duplicated messages may take a huge space of the queue; a compression method should be applied in order to reduce the number of duplicated messages. Tackling these situations requires the ORAS/ RRM entity to apply a Beacon Frequency mechanism to solve network load issue which helps the vehicular networking applications adjust and function the IEEE 802.11p interface with a different application requests. Consequently, LTE radio access technology usage along with performing vertical handovers cost are reduced.

In case of exceeding a particular threshold limit by the network load, in ORAS selection algorithm, the ORAS/RRM entity triggers the Beaconing Frequency Adaptation mechanism that decreases the number of beacons transmitted in VANET. The Beaconing Frequency Adaptation mechanism modifies the QoS requirements of the applications by means of adapting the application's beaconing frequency. When the local frequency beaconing adjustment fails to achieve the network load minimization, the ORAS /RRM entities requests the near automobiles to adapt the Beaconing Frequency Adaptation mechanism; accordingly, the ORAS /RRM entities start adapting their beaconing frequencies in each neighbor.

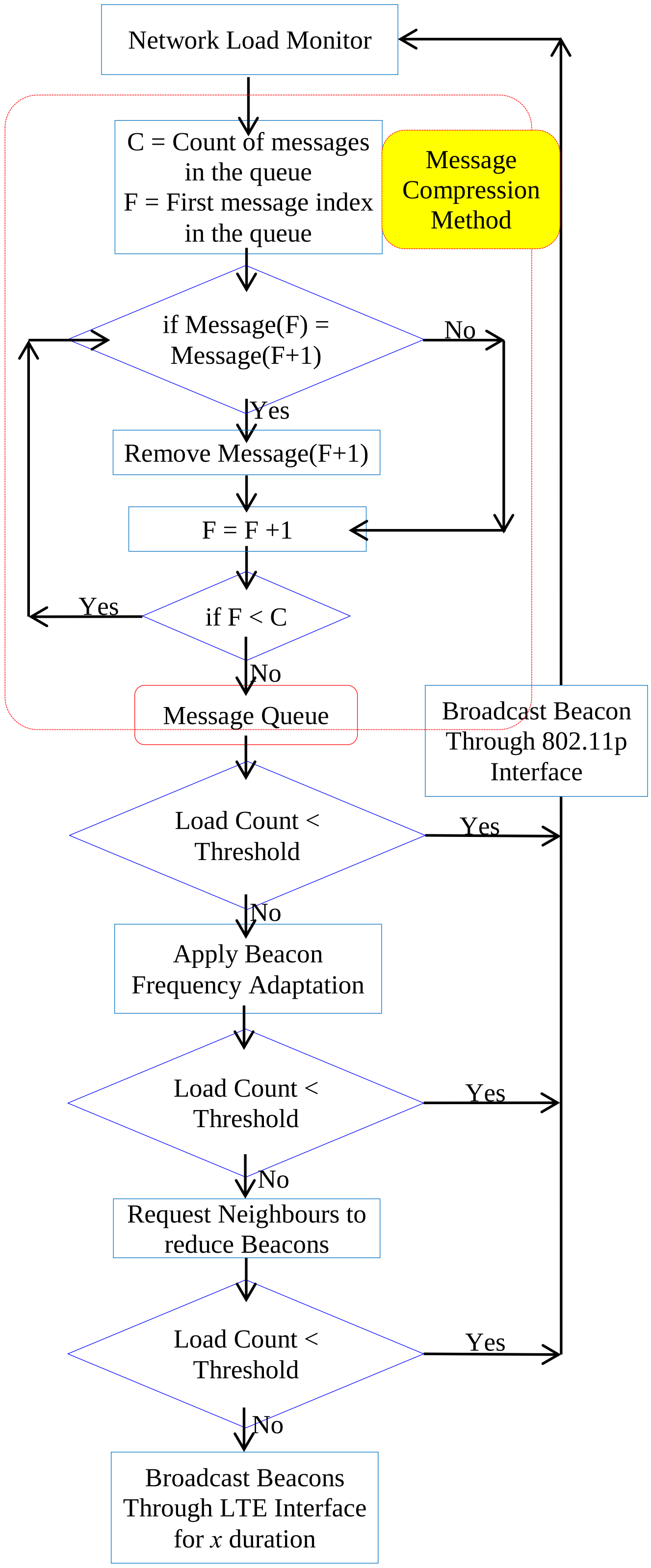

Figure 3: An ORAS Algorithm

Once the network load is lower than the Threshold value, the ORAS/ RRM entities spreads the beacons via its IEEE 802.11p interface along with the minimized beaconing frequencies. Nevertheless, when the network load refuses to decrease and the beaconing frequency fails to be decreased without sacrificing the QoS, the majority of the following beacons are sent for a specific period via the LTE interface. This period is frequently short because of vehicular mobility in which topology swiftly varies and forces the network load to disappear. Figure 3 clarifies the proposed ORAS selection algorithm.

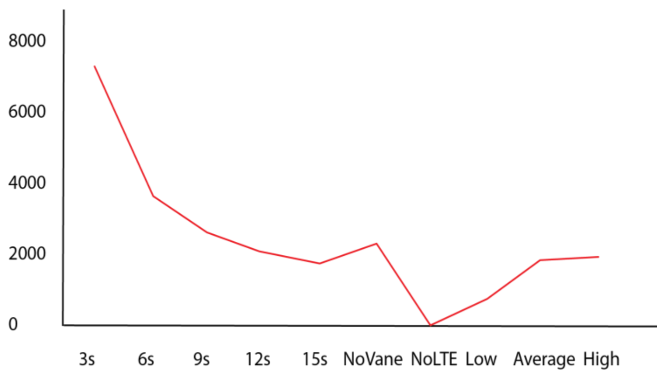

Figure 4: Handover in different ORAS Selection

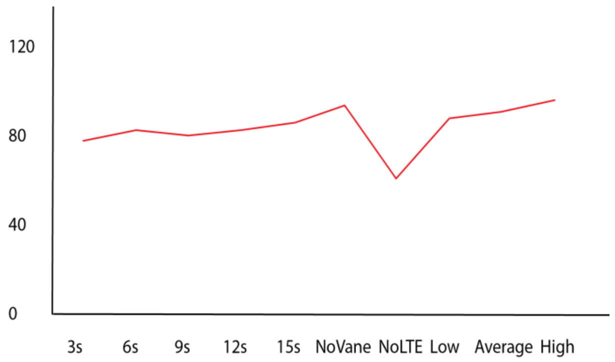

Figure 5: Packet Delivery Ratio in different ORAT Selection

RESULTS

This simulation study consists of a comparative study to evaluate the ORAS selection mechanism based on latency, throughput and packet delivery ratio (PDR). The road network denotes the highway of 2km long with two paths, each path is about 8m wide. There are 150 automobiles available in different speeds, ranging between a minimum of 60km/h to a maximum of 110 km/h). In order to model IEEE 802.11p simulation, the researchers conducted two Log propagation Distance models with 5.8GHz radio operating at 5 Mbps data rate. The communication range is set to 220m. For the LTE, the researchers modeled the radio access network to operate a single cell environment at 900 MHz with 10 Mhz bandwidth. The running program in each vehicle spreads 120 bytes beacons at various beaconing frequencies.

Each simulation frequently operates for 120sec, and the gained results show the average of over 10 different simulation experiments. We evaluated the proposed ORAS selection algorithm and the results show that the switching between two access technologies happens in discrete duration. We simulated with several epochs starting from 3s to 15s with 3s increments. In IEEE 802.11P, whenever the network load surpasses a specific Threshold value, the algorithm performs Handover. Figure 4 shows the Handover in different ORAS executed by every algorithm. The minimum amount of Handover is significantly minimizing, yet the high and average values become equivalent to periodic scheme between 12s and 15s. Figure 5 shows the statistics of packet delivery ratio for the periodic switching scheme contrasts between 75% and 85% success ratios.

CONCLUSION

The present work proposes an ORAT selection algorithm in IEEE 802.11p in which it is less infrastructure-based and LTE infrastructure-based in the cellular network context. It is built on the idea of using parameters including network load along with the desired QoS application requirements in order to switch between the two radio access technologies, which in turn reduces the vertical handovers' amount. Accordingly, the algorithm decreases the beaconing frequency as approved by the application's QoS requirements. Simulations show that resolving the network load problems causes' poorer Handover frequency. Likewise, the proposed work accomplishes significant performance progress in terms of latency, Throughput and packet deliver ratio.

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