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Meeting Always-Best-Connected paradigm in heterogeneous vehicular networks: A graph theory and a signaling game analysis

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ABSTRACT

Due to the high mobility of vehicles and the dynamic topology changes of vehicular networks, it is difficult to satisfy drivers needs through a single wireless network. Consequently, by integrating different wireless access networks such as LTE and IEEE 802.11p, the vehicular network is expected to be a good platform called Heterogeneous Vehicular Network that can meet various vehicular user requirements. In such networks, vehicles need to have mechanisms in place to decide which access network is the most suitable for every application that the vehicular user requires. Always-Best-Connected is considered as a special concept to allow users getting connected to Internet using the access network that best suits their needs or profile at any point in time. Clearly, this concept provides multiple access networks simultaneous for mobile users moving in heterogeneous access network environment. In this paper, we propose two approaches called graph theory-based approach, and signaling game-based approach. The first approach is based on graph theory while the second one based on signaling game theory to compute the suitable path which provides Always-Best-Connected service for a smart vehicle moving in vehicular networks.

1. Introduction

Currently, most mobile devices come with various network interfaces. Smart vehicles become equipped with multi-radio interfaces such as the Universal Mobile Telecommunications System (UMTS) and IEEE 802.11 (WLAN). Thanks to these technologies, the number of heterogeneous vehicular networks that are available at a specific area grew dramatically. All of these wireless networks show different communication characteristics in terms of throughput, delay, availability and costs. The combination of these characteristics offer a high communication performance.

Moreover, with the emergence of heterogeneous vehicular networks, vehicle to roadside communication has received considerable attention [1–6], whereby the vehicles can exchange (download/upload) data with the multiple access technologies installed in fixed locations along the road in order to enjoy a large number of applications including local electronic advertisement, intelligent transportation system (ITS) and environment data collection. Furthermore, the diversity of wireless networks in heterogeneous vehicular networks provides multiple Internet access for vehicular users. Such users expect to select best access network to enjoy their multimedia applications with their subscribed Quality of Service (QoS) [7,8]. In heterogeneous vehicular networks, the goal is not only to be always connected, but also to be connected to the best, anywhere, anytime and with any access network [9]. This concept, called Always-Best-Connected (ABC), allows a mobile user in an environment of multiple access networks to connect to the Internet services using the networks that best suit to his needs at any point in time. In order to achieve this concept, several network interfaces must be addressed so that the best technology can be selected depending on the user's profile, the type of application and the service needed. Fig. 1 illustrates an example of heterogeneous vehicular networks.

In this paper, we study the problem of providing Always-Best-Connected service for moving vehicles in a geographical area (urban zone) equipped with heterogeneous networks as IEEE 802.11p, HiperLan, Bluetooth, etc. The goal is to satisfy the needs (achieving Always-Best-Connected service) of each vehicle crossing the coverage region while minimizing the connectivity cost (maximizing

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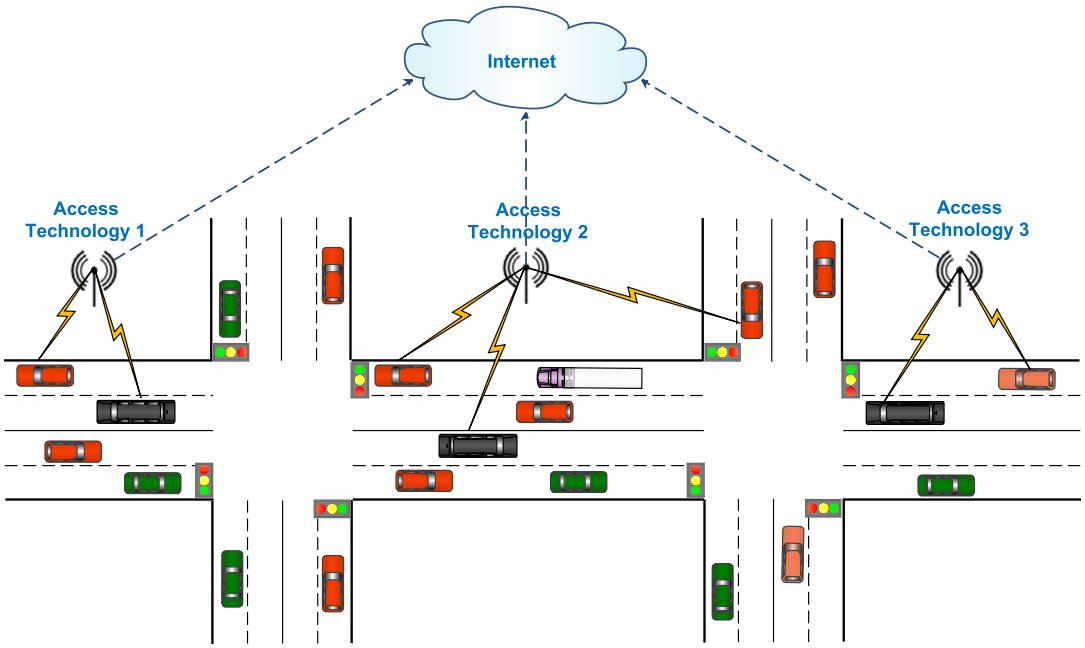

Fig. 1. Illustration of an example of heterogeneous vehicular networks.

the user's utility). We take advantage of graph theory to model the mobility pattern in a geographical area. Dijkstra's algorithm [10] is proposed to compute the suitable path which provides the always best connected service, whilst the signaling game theory is applied to model the system.

The remainder of the paper is structured as follows. Section 2 presents related work. In Section 3 we introduce the system model that we consider in this paper. Numerical results for the two both approaches are presented and discussed in Section 4. Finally we conclude the paper in Section 5.

2. Related work

In heterogeneous network environment, the technologies act as multi-access points to Internet for mobile users. Several researches are developed so that these users can be always best connected. For example, in [11–13] the concept and the architecture of an always best connected scenario are described. Sharma et al. [14] proposed a vertical hand off system between WLAN and GPRS links by using an extension of the Mobile IP protocol. While [15] intends to achieve ABC over WLAN and WiMAX by using a new mechanism to detect QoS support of the underlie networks. In [16], a cost function is defined over some networks characteristics such as RSS (Received Signal Strength), preferred access network type, QoS requirements of applications, monetary cost of services, and power consumption in order to choose a suitable network. In addition to the factors cited above, [17,18] also consider user preferences to select the access network that more flexible. In our previous work, we have introduced the ABC concept in vehicular networks. In [19, 20], we proposed two fully-decentralized algorithms to select an access network for Group Vertical HandOver (GVHO) in Heterogeneous Networks. Whilst in [21,22], we proposed two algorithms to compute the path which provides an ABC service for a smart vehicle moving in a road network installed with multiple access technologies. Furthermore, signaling game theory have been also applied to study several problems in wireless networks. For example in [23], the authors proposed an intrusion detection game based on the signaling game theory. In [24], the signaling game theory was applied to study two competition problems between service providers with asymmetric information. In [25], the authors used signaling game approach to study the problem of power control in wireless networks. In [26], a recent work based on signaling game is proposed to study the problem of wireless access network selection in vehicular networks.

In this paper, two mechanisms are proposed to achieve always best connected service in heterogeneous vehicular network. On one hand, we propose a mathematical model based on graph theory to model the mobility pattern and compute the path which provides the ABC service. On the other hand, we use signaling game theory for modeling the system and analyze the users' utility. According to the best of our knowledge, this work has not been done before. Specifically, we consider a situation where players (vehicles) compete to maximize the expectation of their own utility in order to find the suitable path which provides them always best connected service. We assume that the quality of technologies installed in the road network area takes two values: high or low. To avoid the computational complexity, we will focus our study on the case of two players namely, player 1 and player 2. We further assume that player 1 is the only one who is informed about different technologies installed in the road network area. Based on this information, player 1 sends a signal to the uninformed player, i.e. player 2. Since player 2 receives the signal, he takes its own decision and computes the optimal path which provides him the ABC service.

3. System model

Considering a limited geographical area composed of nodes and edges (urban area), a vehicle can travel from a starting point to a destination point via multiple paths which are themselves constituted of several edges installed with various wireless access technologies. When the vehicle moves into the radio range of any technology, it may use the opportunity to establish connectivity with the technology and then send or receive data from it. This paper focuses on how to choose these technologies, then the suitable path, to provide Always-Best-Connected service to a mobile user while minimizing his connectivity cost. This concept depends on the characteristics of access networks in terms of throughput, communication range and network coverage. Then, the edge will be chosen by the vehicle that provides efficient access networks.