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A spectrum handoff scheme for optimal network selection in Cognitive Radio vehicular networks: A game theoretic auction theory approach

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ABSTRACT

The recent strides in vehicular networks have emerged as a convergence of multi radio access networks having different user preferences, multiple application requirements and multiple device types. In future Cognitive Radio (CR) vehicular networks deployment, multiple radio access networks may coexist in the overlapping areas having different characteristics in terms of multiple attributes. Hence, it becomes a challenge for CR vehicular node to select the optimal network for the spectrum handoff decision. A game theoretic auction theory approach is interdisciplinary effective approach to select the optimal network for spectrum handoff. The competition between different CR vehicular node and access networks can be formulated as multi-bidder bidding to provide its services to CR vehicular node. The game theory is the branch of applied mathematics which make intelligent decision to select the optimal alternative from predetermined alternatives. Hence, this paper investigates a spectrum handoff scheme for optimal network selection using game theoretic auction theory approach in CR vehicular networks. The paper has also proposed a new cost function based multiple attribute decision making method which outperforms other existing methods. Numerical results revel that the proposed scheme is effective for spectrum handoff for optimal network selection among multiple available networks.

1. Introduction

One of the major challenges for today's wireless communication is the exponential growth in wireless networking [1,2]. According to Cisco, the mobile data traffics are expected to have eightfold increase from 2015–20 [3]. There is a rapid progression in number of vehicles on the road with their communication applications. The exponential growth in vehicular communications may lead to the overcrowding of the allocated spectrum bands. It has raised the demand for the extra spectrum bands to improve the spectral efficiency for improving vehicular communications. It is difficult to find separate vacant spectrum to accommodate the growing demands. The only feasible way is to exploit the potential of existing spectrum by improving the spectrum efficiency of wireless system. Thanks to the new regulations [4] to open up licensed underutilized radio spectrum to use it opportunistically, and for which Cognitive Radio (CR) technology has been introduced. CR technology introduced by Mitola III in 1999 [5–7], is a key enabling technology to use underutilized spectrum by dynamic spectrum access. CR networks are receiving high attention from the research community to overcome the radio spectrum scarcity problem, as well as to improve the communication efficiency [8–12]. Hence, it is envisioned that the future vehicular communications will be CR enabled which can use underutilized spectrum opportunities to improve vehicular communication efficiency [13,14]. The dynamic usage of underutilized spectrum can be done by spectrum handoff decision [15,16,10]. Fig. 1 presents the system model showing different types of spectrum handoff in CR vehicular networks. It is shown that the intra-network spectrum handoff takes place within the same radio access technology whereas inter-network spectrum handoff takes place between the heterogeneous radio access technologies. It is shown that some CR vehicular nodes are connected with one radio access technology and some are connected with multiple radio access

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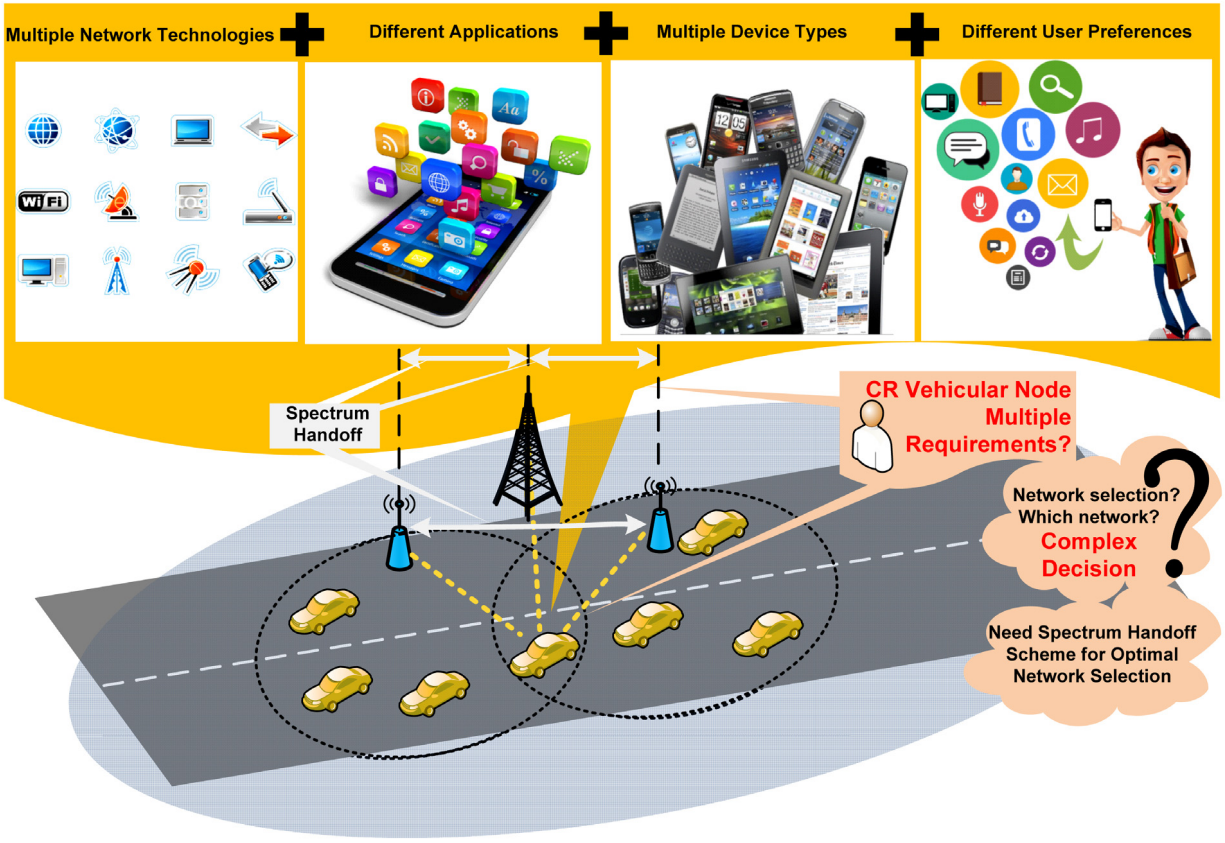

Fig. 1. System model showing spectrum handoffs in CR vehicular networks where vehicular node have multiple requirements.

technologies. When CR vehicular node is connected with multiple radio access technologies, then it is not easy for it to select the optimal network for the spectrum handoff decision. Fig. 1 also shows the convergence of multi radio access networks having different user preferences, multiple application requirements and multiple device types. Hence, it becomes a complex decision for CR vehicular node to select the optimal network for the spectrum handoff decision among multiple radio access networks. As Fig. 1 shows that the complexity features make the wireless system analogue to the real market which has various participants in the system transacting commodities (e.g. unutilized spectrum bands) under certain regulations (e.g. CR vehicular node communication applications). Therefore, economics and business management approaches [17,18] are found to be very effective to solve the radio resource management issues in wireless system. The components of wireless system can be categorized into four main groups such as buyers/tenderees, sellers/bidders, auctioneers and commodities for an application service. The buyers are the analogue to CR vehicular nodes that have to purchase commodities for an application service from the sellers (primary networks). The auctioneers can be any entity from the wireless system that controls and conducts the auction process. The auction process can be applied in centralized and/or distributed manner. A game theoretic auction theory approach, as a subfield of economics and business management provides useful tool to model, analyze, and optimized radio resource management in CR vehicular networks environment [19,18,20].

Therefore, this paper investigates a spectrum handoff scheme for optimal network selection using game theoretic auction theory approach in CR vehicular networks. The paper makes the following research contributions.

- Proposed a spectrum handoff scheme for optimal network selection based on game theoretic auction theory approach.
- Proposed a new cost function based multiple attribute decision making method which outperforms other existing methods.
- The scheme provides wider and optimum choice among available multiple networks considering CR vehicular node preferences.
- The proposed scheme provides joint resource auction that is flexible for its adaption for different types of CR vehicular nodes, and multiple networks availability scenarios.

The rest of the paper is organized as follows: Section 2 presents the related works. Section 3 presents mapping of game theoretic auction theory approach to CR vehicular networks. The mathematical modeling of the proposed work is done in Section 4. The proposed spectrum handoff scheme is presented in Section 5 and numerically evaluated in Section 6. Finally, the concluding remark and future works are given in Section 7.

2. Related works

Recently, we have provided a comprehensive survey work on spectrum handoff schemes in CR networks [10]. It shows that the spectrum handoff is one of the major challenging issue in CR networks that requires the attention of the research community. At present, there is no literature available for spectrum handoff schemes in CR vehicular networks using game theoretic auction theory approach. However, there are only limited studies partially addressing this issue.

Zhang et al. [18,20] advocate the use of auction theory for the resource allocation in CR networks. It has provided a detailed description of how auction theory can be used in design and optimization of CR networks. This survey presents an open issue that auction theory can be applied for multiple heterogeneous commodities to satisfy the Quality of Service (QoS) requirements.