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QualityScan scheme for load balancing efficiency in vehicular ad hoc networks (VANETs)

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ABSTRACT

The main terminal devices in vehicular ad-hoc networks (VANETs) are highly mobile moving cars that handoff much more frequently than handheld devices. Nevertheless, frequent handoff or high handoff latency can influence the quality of service (QoS) of real-time network services. Since conventional handoff mechanisms cannot fulfill the requirements of VANET, many fast handoff schemes have been proposed. However, the schemes based on the signal strength of APs (access points) ignore the loading states of different APs and thus cannot utilize the bandwidth effectively. Whenever some APs are very busy, the QoS will be degraded. In order to solve this problem, we can pre-establish the APs and regulate their number according to different traffic types. In this paper, we present a fast handoff scheme for VANET, QualityScan, which decreases the handoff latency and considers loading states of the regional APs simultaneously. By the pre-established AP controller (APC), our scheme gathers the loading states of the APs regularly and predicts network traffic of the next moment. Based on the parameters obtained by passive scanning, the mobile nodes (MNs) can choose the optimal AP for the optimal QoS. According to our simulation analysis, QualityScan not only achieves load balance of the APs, but also improves QoS and handoff efficiency in VANET.

1. Introduction

The rapid advancement of wireless networks in the past few years has allowed users to access the Internet at any time and from anywhere. Owing to the low cost, easy deployment and increase of the available bandwidth, the development of wireless networks never stops. To improve driving safety and transportation efficiency and to decrease automobile pollution, great efforts by the automobile manufacturers and the academia have made VANETs more appealing. The latter integrate wireless communications with intelligent transportation system (ITS) (Hartenstein and Laberteaux, 2008; Suriyapaibonwattana and Pomavalai, 2008; Toh, 2007).

In vehicular ad hoc networks (VANETs), because of high mobile speed of moving cars, the handoff occurs constantly (Kwak et al., 2009; Choi et al., 2007). However, handoff latency degrades the quality of service (QoS) of some real-time network services, like multimedia streaming and voice over Internet protocol (VoIP) (Powar and Apte, 2009). Because conventional mobility management strategies no more meet the requirements of VANETs, novel schemes have been designed specifically for VANETs (Zhu et al., 2009; Kuo et al. 2014; Wu et al. 2012b).

In VANETs, the network traffic on busy roads is comparatively high and the network congestion might occur. The QoS might be degraded when there is only one AP. The simplest solution is to increase the number of APs in this area for network traffic distribution. However, due to the specific features of VANET, traditional fast handoff schemes based on signal strength cannot meet the needs of VANET. In this paper, we present a QualityScan scheme to enhance the handoff latency and achieve the load balance of the access points (APs).

This paper presents a QualityScan scheme that puts emphasis on APs' loading states, which comprises not only signal strength but also usage or workload rate of APs. In order to distribute the network traffic efficiently, even during peak times, to provide high-quality network service, we propose that regional APs should cluster together to form a group. In our proposed scheme, we establish an AP controller (APC) to regularly gather the information of the APs in the subnetwork. Together with the vehicle speed and the traffic flow of the road section retrieved from transportation information system (TIS), we can perform calculations and predict the upcoming network traffic. The APC then provides the calculation results to the APs to send the adjacent APs' information embedded in beacon frames to the MNs for

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determining the next handoff AP. Our proposed scheme obtains the information of the neighboring APs via in-advance passive scanning, selects the optimal handoff AP beforehand and simultaneously balances the system load. In this way, the omission of active scanning during the handoff can promote a significant reduction of handoff delay. Moreover, efficient traffic distribution and QoS improvement can be achieved by virtue of an appropriate handoff AP (Meneguette et al. 2013).

The rest of this paper is organized as follows. Section 2 introduces the background and related work. The proposed load balancing scheme is described in Section 3. Section 4 provides our simulation model and experimental results. Finally, Section 5 concludes the paper and discusses our future work.

2. Related work and background

In addition to several works of the present fast handoff mechanisms, including SyncScan, DeuceScan and Neighbor Graph, this section introduces the load balance for 802.11 wireless networks, and gives an overview of IEEE 802.11e. IEEE 802.11p and its physical (PHY) and medium access control (MAC) layers are specified in the final part.

2.1. The present fast handoff mechanisms

The measurements of the handoff latency of the APs and mobile nodes (MNs) from different vendors have revealed that the probe delay occupies the biggest part of the handoff latency, accounting for more than 90% of the latency (Pack et al., 2007; Mishra et al., 2004). The QoS of the MNs might be degraded and the transmission might be ended owing to too high handoff latency. Take VoIP service for example; according to the definition of acceptable delays for voice applications in G.114, the delay below 150 ms is transparent to clients and the delay from 150 to 400 ms also is tolerable. Nevertheless, the delay beyond 400 ms will result in unacceptable service and connection (ITU-T Recommendation G.114, 2005).

MinChannelTime and MaxChannelTime are two probe timers of the active scanning and their definitions. If we define the probe timer as TA and the number of usable channels as N, the timer of TA can be given by (1).

$$N \times \text{MinChannelTime} \leq \text{TA} \leq N \times \text{MaxChannelTime} \tag{1}$$

Because the probe delay causes most of the handoff latency, many methods have been presented to decrease the probe delay and we will introduce several schemes next.

2.1.1. Introduction of SyncScan

SyncScan, presented by Ramani and Savage (2005), proposes the synchronization of beacon packets announcement for the APs to deliver the beacon packets in order in arranged intervals. By synchronizing short listening periods at the client with periodic transmissions from each base station, this low-cost mechanism keeps tracing the signal strength of the adjacent base stations. The SyncScan scheme decreases the handoff latency and the time in probing usable channels by executing a full channel prescan.

2.1.2. Introduction of DeuceScan

Proposed by Chen et al. (2008), in the DeuceScan scheme, the MNs continue to trace the signal strength from the nearby APs by beacon packets. According to the result of the first full channel prescan, the DeuceScan scheme keeps the partial prescan and utilizes the spatiotemporal graph to provide the received signal strength (ΔRSS) of every channel for the judgment of move direction. The AP with the best signal strength will be selected based on the spatiotemporal information and the signal strength variation. As a partial prescan approach, the DeuceScan scheme outperforms the SyncScan scheme in reducing the handoff latency.

2.1.3. Introduction of Neighbor Graph

Shin et al. (2004) proposed the Neighbor Graph algorithm that retrieves the topology provisionally through caching. The Neighbor Graph includes the relationship of the neighboring APs and the channel used by every AP. Furthermore, the APs in the neighbor list are the candidate available APs. With the Neighbor Graph, this algorithm decreases the number of channels probed and avoids probing nonexisting channels. Nevertheless, a great number of neighboring APs will lead to a great deal of data size which affects the efficiency of the Neighbor Graph.

2.2. Load balance for 802.11 wireless network

IEEE 802.11 scheme provides the access to wireless network by infrastructure and the MNs access to the network for data transmission through the APs, the bridges between wireless and wired networks. Nevertheless, since each MN selects the AP by itself, the unbalanced, overloaded or congested traffic load of the APs might occur. For example, in VANET, high traffic on busy roads or in rush hours leads to high network traffic, which increases the load of the regional APs and easily results in network congestion. By increasing the number of APs covering the same area, the network traffic can be distributed. But, without considering the loading states of the APs, most traditional fast handoff schemes select the handoff AP according to the signal strength.

As described in Yen et al. (2009), when every MN selects the AP to connect to independently, few APs might be connected by many MNs but others APs remain idle. Thus, two main issues to the approaches to load balancing include how to measure and define load metrics, and how to balance. In the following, we will briefly introduce several load metrics.

Fukuda and Oie (2004) stated that the most obvious load metric is the number of MNs that are currently accommodated by each AP. However, because the network utilization of each AP and the states of traffic differ all the time, this number just probably indicates the load of every AP. As given in Brickley et al. (2005), terminals connecting with the overloaded AP will encounter high rates of collision and large delays while fighting for medium access. Consequently, the frame drop rate is used to quantify performance of the system for regulating the coverage of each AP to attain the load balance. On the other hand, the load metric of potential bandwidth between a given AP and an end-host was proposed in Vasudevan et al. (2005), which calculates the transmission time and the potential bandwidth based on the beacon delays in contention-based environments.

Proposed in Ong and Khan (2009), the QoS-based integrated load balancing (iLB) scheme leverages on QoS-based fast handover to provide seamless handover and soft admission control to protect QoS of existing connections when resources are low. It selects the AP of the lower packet delay and gives a definition of a handoff threshold according to the packet loss rate. This mechanism collects the information of the adjacent APs by a pre-established AP controller (APC), and sends the information to each AP, which forward the information to the MNs by beacon frames. Moreover Tartarelli and Nunzi (2006) present a QoS and congestion management scheme, which establishes a policy server, designed for not only providing QoS guarantees based on both the type of traffic and the customers' contract, but also avoiding the congestion of the AP.

The APs are pre-established infrastructure in VANETs. The advance investigation helps us to solve the network congestion on busy roads or at toll stations by deploying more APs to distribute the network traffic. If we can consider each AP's loading state before the handoff, it would be good for the QoS enhancement after the handoff. The advantages include the improvement of the network congestion, the fully utilization of the bandwidth and the enhancement of the QoS.