High Availability of Charging and Billing in Vehicular Ad Hoc Network

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Abstract. VANET (Vehicular Ad Hoc Network) is actually an important field for the development of a variety of services. In VANET charging and billing of services could not be enabled in the same way as in 3GPP networks and MANET (Mobile Ad Hoc Network) because of the characteristics of such network namely the high speed of nodes, frequent disconnection between nodes, rapidly changing topology and the large size of the network. The purpose of this work is to propose a flexible high level charging and billing scheme to allow a high availability of the charging and billing process in VANET.

Keywords: VANET · Charging · Billing · Prepaid · Online/Offline charging

1 Introduction

In recent years, the field of vehicular ad hoc network (VANET) has attracted a growing amount of interest. VANET [1] is a term associated with technologies (architecture, data, and protocols) developed and standardized under the umbrella work of intelligent transport systems (ITS) [2]. Standardization of ITS is done in various governmental and nongovernmental standard development organizations namely IEEE, ISO, ITU. VANET comprise vehicle-to-vehicle and vehicle-to-infrastructure communications based on wireless local area network technologies. Vehicular networking offers a wide variety of applications [3], including safety, non safety and infotainment applications. The abundance of VANET applications is a benefit for a wide range of parties: governments, vehicle manufacturers, operators and consumers. For the operators promoting their services in VANET a robust charging and billing architecture is needed. Although many works have been done in charging and billing in ad hoc environment, most of them does not addressed the high availability of charging and billing process when nodes move from VANET infrastructure to a pure infrastructureless VANET environment. Charging and billing process relies on an existing infrastructure which constitutes a severe limitation and raises a highly complex problem for which no satisfying solution exists.

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To address this problem, we propose a scheme making the charging and billing control available even out of VANET infrastructure. We address this problem from two perspectives: First, when a vehicle under online charging and billing in VANET environment moves to an infrastructure-less environment; Second, when a vehicle under online charging in VANET moves to a different autonomous VANET domain or network.

This paper is structured as follows: Sect. 2 provides background information on vehicular networks and charging/billing systems in traditional mobile networks. Section 3, proposes requirements for billing and charging in VANETs and provides a critical overview of existing solutions. Section 4 proposes a hybrid charging and billing mechanism to take into consideration VANETs characteristics. We conclude our work in Sect. 5.

2 Background on VANET and Charging/Billing

2.1 Vehicular Ad Hoc Network

Ad hoc networks are communication networks that are formed in a more or less spontaneous way and comprise an arbitrary number of participating nodes. They typically comprise wireless communication terminals forming a wireless stand-alone network. Examples of such networks are mobile ad hoc network (MANET) [4] and vehicular ad hoc network (VANET). The current trend in ad hoc networks is vehicular ad hoc network. VANET is an emergent technology that receives, recently, the attention of the industry and research groups. It allows different deployment architectures in highways, urban and rural environments [5]. In VANET architecture, the communication can be either among nearby vehicles or/and between vehicles and roadside units leading to three possibilities: Vehicle-to-Vehicle (V2V) communication, Vehicle-to-Infrastructure (V2I) communication and Hybrid architecture (as shown in Fig. 1):

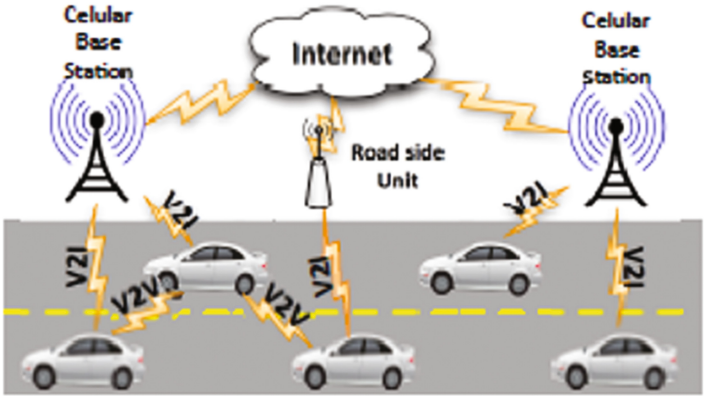

Fig. 1. VANET communication architecture

Vehicular ad hoc networks present some particular characteristics despite being a special case of classical mobile ad hoc networks namely the high speed of nodes, the rapidly changing topology, frequent disconnections between nodes [1] and in several cases the large size of the network. The particularities of VANET make it a very interspersing domain which deserves in the last years several studies addressing different aspects, such as: applications [6,7], communication [8], security [9,10], routing protocols [11–13], access [14] and cloud computing in VANETs [15–17].

Although researchers have achieved much great progress on VANETs study, there are still some challenges that need to be overcome and some issues that need to be further investigated (e.g., security, services.). Especially, one aspect that has not been tackled by research namely the charging and billing issue.

2.2 Charging and Billing

Charging is the process of collecting, evaluating and accounting a network resource usage [18]. This resource usage is related to an event that can be either a voice communication or an internet session or a value added service. Billing is the step that follows the charging operation, it consists of two mains steps: mediation step that collect, validate, filter correlate, aggregate and convert data to create data record called data Detailed Record (CDR) and rating step which is a process that puts a cost on a call or a service (monetary values). After the rating step bills are generated.

There exist two modes of charging: postpaid and prepaid. In postpaid mode a bill is generated in arrears periodically stating what was owed to the service provider by the customer. The subscriber is then expected to settle the bill (payment). In Prepaid mode of charging and billing, the customer pays a sum in advance. The paid amount is depreciated as telecoms services are consumed.

In mobile networks (GSM/UMTS/LTE) online and offline charging are two mechanisms used to charge subscribers for rendered services [18]. Offline charging is a mechanism that consists of a chain of logical functions, this chain end by generating charging information (CDR) related to a resource usage in the network which is then transferred to the billing system to generate the subscriber bill. In this scenario the charging process does not affect, in real time, the service rendered. Offline mode is used to charge a postpaid user. In the same fashion, the online charging information passes through a chain of logical functions. However, authorization for the network resource usage must be obtained by the network prior to resource usage to occur. The online mode is used to charge prepaid users.

3 Requirements and Critical Overview of Existing Solutions

3.1 Requirements

The charging and billing system in VANET must be different from the charging and billing process in other mobile networks. We identified main charging and

billing requirements to be fulfilled by a charging and billing system in order to carry out its basic tasks in vehicular ad hoc network:

(a) The VANET charging/billing system should take into consideration the high speed of vehicles in terms of controlling the charging process and insuring its high availability.
(b) The VANET charging/billing system should be flexible. In fact, due to frequent disconnections, the charging solution needs to be aware of the underlying environment updates and adapt to the network topology changes.
(c) The VANET charging/billing system should allow the roaming of the charging function between different VANET providers. In fact, when a vehicle travels long distance it is not unusual to traverse different VANET infrastructures belonging to different domains. A service should be charged continuously and accurately in this context.

3.2 Related Work

To the best of our knowledge there is no solution dedicated to VANET environments for billing and charging issues. However, some research works have addressed this problem in peer-to-peer and MANET networks. Authors in [19] propose the MMAPPS (Market-Managed Peer-to-Peer Services) charging solution for peer-to-peer networks. The MMAPPS accounting and charging system addresses, mainly, the issue of accountability in peer-to-peer environments and associated problems.

The work [20] proposes a Secure Charging Protocol (SCP). SCP aims at answering the complex authentication, authorization, accounting and charging (AAAC) problem in MANET. It provides a view based on a different business model. This later has been adjusted to cope with technological changes. The work also addresses the improvements made to the SCP protocol in terms of Quality of Service (QoS) and User Interfaces.

The work in [21] proposes a solution for charging in MANET. The solution enables charging without any access to external networks. For example, when a communication is initiated by a mobile communication device within an ad hoc network, a small initiation fee is stored securely on the device, typically on a smart card. Transfer of the charging information may then occur more or less automatically and/or when the device reaches a coverage area of the operator network. When the network operators system receives the charging information from a communication device (i.e. when it comes into contact with the infrastructure) the corresponding account is updated and charged with the activities that have occurred since the last update.

3.3 Analysis and Discussion

Generally, the works discussed above provide a suitable charging and billing solution for peer-to-peer networks and ad hoc environment but did not meet the requirements highlighted previously. Specifically, the peer-to-peer architecture

proposed in [18] does not consider mobility and then does not meet the requirement (a) and (b) in term of flexibility and high availability. The SCP protocol proposed in the work [19] has only addressed the security issue in charging process assuming an existing solution. As far as the work in [20] is concerned, it does not take into consideration the requirement (b) and (c). In fact, this work focus on updating the operator charging system with data collected during offline charging. The cooperation between the offline and online charging systems is not considered. Therefore, when a node roams from an environment with VANET infrastructure to an environment where the infrastructure of VANET is absent (i.e. no RSUs and no possible connection with external networks) the charging process is interrupted. Similarly, when the vehicle traverses different autonomous VANET systems the charging is interrupted or may not be possible to update the operator charging system. Therefore the high availability of charging and billing is not considered at all.

4 Proposed Solutions for High Availability Charging in VANET

The main goal of this work is to insure the high availability of charging and billing control in vehicular environment. First, we propose a high level mechanism to address the problem of a vehicle leaving the VANET infrastructure while it is under online charging and billing process. Then, we propose a high level mechanism for seamless charging between VANET and 3GPP domains. Both cases involve a context-aware charging and billing system. Both mechanisms rely on a context-aware charging and billing solution. Through this solution, the operator will be able to continuously control its resource usage in VANET and out of VANET. Indeed, the roadside units will be responsible for detecting if a vehicle is under VANET control or not using some protocol (e.g. heartbeat protocol) or when the Signal Noise Ratio (SNR) reaches some predefined thresholds. Following is the presentation of our proposed schemes.

4.1 Online to Offline Charging and Billing Roaming

In this scenario, vehicles establish a V2V session (e.g. direct voice call service between vehicles). We propose to equip the vehicles with a prepaid system such as smart card or virtual storage in the operating system running on the vehicle.

However, the charging of the call is carried out by the VANET online Charging and billing infrastructure (OCS), the RSU collects the charging data (V2I communication) and send them to billing domain BD (Fig. 2). The data charging are information related to the call such as start time, duration of the call and end time of the call.

Since the communication between vehicle A and B is Vehicle-to-Vehicle communication, the media channel is not controlled by the RSU. Therefore, when the two vehicles leave the VANET charging area (i.e. the zone covered by VANET infrastructure namely RSUs) to a non VANET charging area (i.e. area where

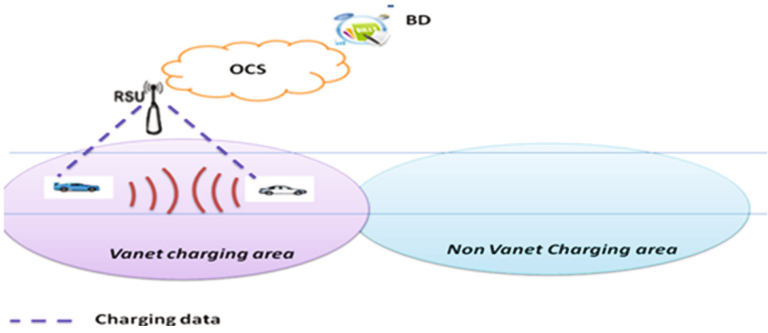

Fig. 2. Online charging based system

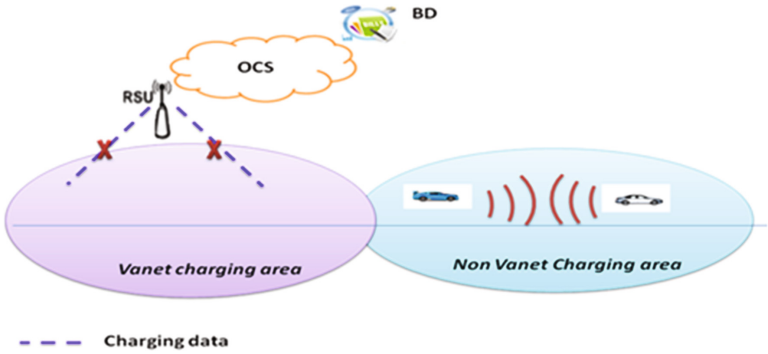

Fig. 3. Charging flow interruption

there is no VANET infrastructure and where VANET become a pure peer-to-peer mobile environment) the communication is not interrupted but the charging of the call is lost (Fig. 3).

From the VANET provider's business perspective, the scenario above present a crucial problem since the wireless resource (bandwidth) is used for free. To avoid this problem, we propose that the VANET provider implements an on-line context-aware charging and billing system (Context-aware OCS).

This system will collect several parameters in order to decide to switch automatically to the prepaid charging system implemented in the vehicle (e.g. smart card). We propose to use two parameters: the SNR (signal to Noise Ratio) between the RSUs and the vehicles, and/or GPS positions of RSU's zone edges. For the SNR, When the signal power reaches a predefined threshold the charging OCS system upload the charging profile to the prepaid system storage. As for the RSU edges GPS positions, the system (eventually the RSU) records the vehicles' GPS positions in each instant and compare them with a preconfigured table containing the GPS positions of RSU's zone edges. If the vehicle is near

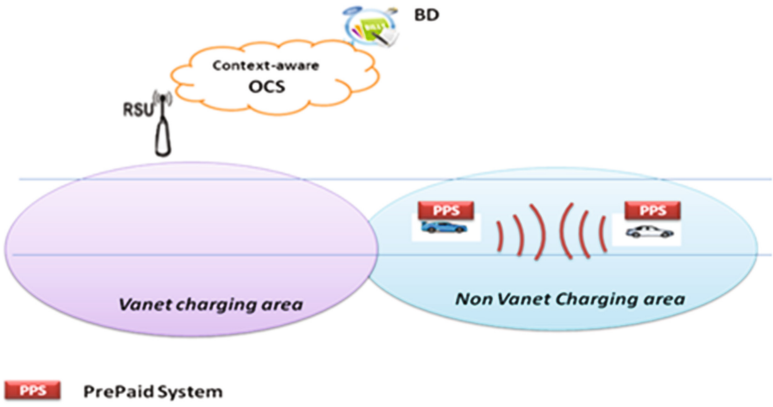

Fig. 4. Context-aware OCS and prepaid system

of these positions, the system switches the charging control to the prepaid by uploading the charging profile to the vehicles prepaid system.

The charging profile consist of subscription information namely, vehicle ID, owner of vehicle (subscriber), accounts, balances, services (voice, data, sms, video...), subscription time, expired time. The prepaid system is not necessarily a smart card it could be for example a virtual storage in an operating system implemented in the vehicle which stores the charging profile. Once the charging profile information is uploaded from the OCS to the vehicle's storage, the prepaid system will have a real-time control on the call. Therefore, a credit, or an appropriate amount of credits, is deducted from the currently available credits (Fig. 4). Consequently the user will be denied to make any VANET communication when it runs out of credits.

4.2 VANET-Online Charging to Non-VANET Online Charging Roaming

Similarly, in this scenario the service charging is carried out by the VANET online Charging and billing infrastructure (OCS). But the vehicles A and B move from a VANET infrastructure domain to a non charging VANET domain but covered by external network such as 2G/3G or 4G, (Fig. 5). When vehicle A and vehicle B leave the VANET charging environment to 3GPP domain, the operator loses the charging and billing control. To avoid this, the OCS system and the vehicle should include context-aware functions.

For the OCS system, we propose to measure the signal power parameter between the RSU and the vehicle, and collect GPS positions of RSU's edges. For vehicles, we propose to measure the signal power parameter received from both RSU and Radio Access Network (RAN) node. Thus, when the vehicle reaches the RSUs edges, it measures and compares the signal power of RSU and RAN node, when the signal power of the RAN node is higher, then the charging control

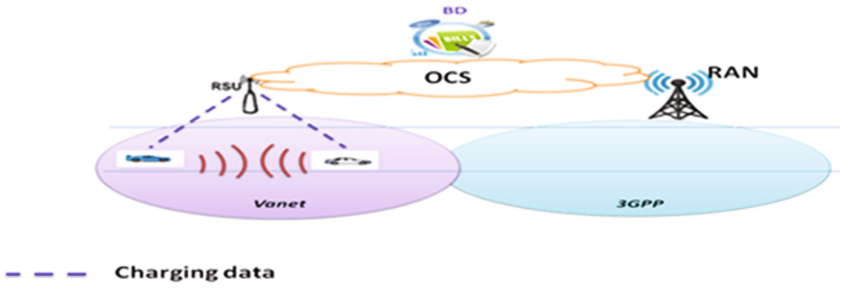

Fig. 5. VANET to 3GPP

Fig. 6. VANET-to-3GPP charging roaming

is switched to the 3GPP network (Fig. 6). The charging switching is preceded by an authentication procedure of the vehicle in the visited 3GPP network. This authentication is, generally, performed by an authentication server of the operator such as Authentication, Authorization and Accounting server (AAA). Therefore the high availability of charging and billing is granted.

5 Conclusion

Vehicular ad-hoc network are a challenging environment especially for charging and billing. Nowadays many VANET research are addressing several aspects (e.g. access, routing and services). However, no works have been found in charging and billing systems. In this paper we showed that existing solutions mainly for MANET and peer-to-peer do not meet our proposed requirements and therefore are not suitable for VANET. Hence, we described two high level proposals for insuring the high availability of charging and billing in vehicular ad hoc environment especially when a vehicle moves from a VANET charging environment to a non-VANET charging one. In the next steps of our work we will detail our solution in term of, business model, architecture, functional entities, protocols,

procedures and interfaces and in order to best enforce our solution a simulation of the work is also planned.

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