Research on Incentive Method of Resource Sharing in VANET Based on Game Theory

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Abstract. The article studies the methods of using game theory in the VANET (Vehicle Ad-hoc Network) to encourage vehicle nodes to contribute their resources to other nodes to share. Vehicles are divided into resource contributors and resource consumers. A resource sharing incentive method based on revenue value is proposed. A revenue value is added to vehicles according to a game model who contributes their resources for sharing. The vehicle nodes are divided into different levels according to the revenue values they have. The higher the level is, the more discounts are obtained when a node wants to pay for other resources. Simulation experiments show that the incentive mechanism designed in the paper can effectively encourage more vehicle nodes to participate in resource sharing.

1. Introduction
At present, many vehicles are equipped with short-range wireless broadcast communication devices and computing processing hardware. With the increase of throughput of the network and the application of short-range wireless broadcast technology, vehicles already have the ability to communicate with each other to form a VANET[1]. In a VANET, each vehicle as a node on the network can share its resources with other vehicles. What this article is going to study is to design an incentive method to increase the willingness of vehicle nodes to share their resources.

In the existing research, resource sharing incentive mechanisms are mainly divided into three categories, namely pricing-based incentive mechanisms, reputation-based incentive mechanisms, and game theory-based incentive mechanisms. Pricing-based incentive mechanisms often introduce the concepts of virtual currency and credit exchange. It is used to pay for the forwarding behavior of the resource provided node and relay nodes[2]. However, the pricing-based incentive mechanism cannot take care of all nodes in the entire network, and some edge nodes may permanently fail to provide their services. In addition, the problem of node collusion cannot be effectively avoided in this kind mechanism. The reputation-based incentive mechanism solves the problem by observing and isolating selfish nodes in the network[3]. The basic idea is to use the reputation value of the nodes to stimulate the cooperation among nodes. The reputation value of a node is determined based on its previous performance and the packet forwarding rate in the network[4]. When the reputation value is below a certain threshold value, the node will be isolated as a selfish node. But reputation based method is not applicable to the dynamically changing topology environment, which cannot maintain high stability, and excessive penalties may cause some vehicle nodes to exit the system. The incentive mechanism based on game theory considers each participant's strategy set[5]. A vehicle node selects the optimal strategy in the set to get the max benefit. The strategy objectively urges nodes to share their resources. Game theory is widely used in then incentive mechanism.
The above incentive mechanism is mainly aimed at the selection of relay vehicle nodes in the process of information forwarding, while research on resources sharing is rare. This paper combines game theory and the punishment idea of reputation incentive mechanism to propose a revenue-based resource sharing incentive method.

2. Architecture
Figure 1 shows the architecture of the VANET in this article. There are three different roles in the network: vehicle nodes, roadside units (RSU), and cloud management centers. Vehicle nodes undertake functions such as information collection, resource storage and handling. The cloud center is responsible for resource scheduling and vehicle information management. RSU plays as a connecting role to connect the vehicle with the vehicle and the vehicle with the cloud center. Generally, RSU can be used to temporarily store the information uploaded by the vehicle to the cloud and also support communication within vehicles in its radiation range.

3. Game Model Based on Revenue Value
In order to encourage vehicle nodes to contribute their own resources for sharing, the model uses the basic idea of pricing game to design a mechanism based on revenues.
For each vehicle node in the network, sharing its resources will get a certain revenue, while using the resources provided by other vehicle nodes will consume its revenue. In each round of the game, the vehicle nodes are divided into two types, one is a consumer, and the other is a resource contributor. Participants in the game model are resource consumers and contributors. The roles of resource contributors and consumers are not absolute. A vehicle is a resource contributor in one round of the game, and it can become a resource consumer in another round.
Each participant has its own strategy set, and each strategy in the set will enable the game participants to obtain certain revenues. The payoff function is used to describe the revenues of the participants. Payoff function, strategy set and corresponding revenue is shown in Figure 2.

The parentheses in figure 2 are composed of two parameters, the former one represents the revenue of the resource contributor, and the latter one represents the revenue of the resource consumer. For example, (20, -10) represents the revenue of the resource contributor under the strategy of choosing to contribute resources is 20, and the revenue of the resource consumer under the choice of using the resource strategy is -10. (0,0) in the middle of the table means that when the resource contributor and the resource user have negotiated and exited together. The revenue of both parties is 0.
After one round resource sharing is completed, the resource contributor and resource consumer vehicle nodes will automatically generate a set of information about this sharing, called a ticket. Basic items of the ticket include: whether the sharing is successful, the size of the resource used, the use of start time and completion time, resource consumer id, resource contributor id and some other information. After the ticket is generated, it will be automatically transmitted by the vehicle node to the RSU, and then uploaded to the cloud service center. The cloud center will send the bill between the consumer and the contributor. The corresponding revenue value is assigned to the relevant vehicle.
In the above game model, the dominant strategy of resource contributors is to contribute resources, and there is no dominant strategy for resource consumers. However, in actual applications, if resource consumers do not contribute resources after using resources, they cannot obtain revenue values. That means they cannot continue to use resources for a long time. This restriction will encourage resource consumers to choose to become resource contributors in a new round of games.

In the game model, there is lack of motivation to encourage vehicle nodes to contribute their resources continuously. They only do a contribution when they feel necessary. For this reason, some extensions to the incentive model are needed.

4. Model Extensions in Applications
In order to encourage vehicle nodes to share their resources actively and continuously. The following is some extensions that can be made to the model in practical applications.

(1) The revenues in the above table are given when take a file as a count unit. In specific applications, the unit can be expanded to the storage resource space. That is, the larger the file, the more revenues are obtained when providing sharing.

(2) There are three ways for vehicle nodes to get revenues:
   ① share their own resources (recommended)
   ② use money for purchases, but there are certain restrictions on money purchases, a user can purchase up to 500 revenues in a year.
   ③ act as a resource backup node. Certain revenue will be given to backup nodes.

(3) Distinguish different levels of vehicle nodes according to revenues they own. Nodes at different levels can get certain discounts when using resources.

(4) Add a punishment mechanism. Some vehicle nodes have selfish behavior. We hope to appropriately punish those nodes who only use resources and never contribute. The game model will make penalty and deduct a certain revenue to those nodes who originally contribute resources but withdrew halfway. In addition, the model can count the number of times of resource contributing and consuming of nodes and then establish a reputation system for each vehicle node. When the number of time the resource consuming is far larger than the number of contributing, the reputation value of the vehicle node will be reduced to 0 and then the node will be forbidden to use any resource in the net.

(5) Add the ranking mechanism to the model. Set up a real-time ranking system according to the vehicle's revenue value in a certain road section. The ranking will be displayed in the vehicle, and the driver can observe the ranking of his revenue. The ranking results are regularly displayed and ranked. The top 10 drivers will receive 50 revenues, and the bottom 10 will receive reminders.

5. Simulation Experiments
In the game model, vehicle nodes are both resource consumers and resource contributors. One time resource sharing is called a round of games, and multiple vehicle nodes can take part in the game for one round. After n rounds of game, all vehicles in the net will reach a relatively stable state. Some of the original resource consumers will be converted into resource contributors, and there also may be resource contributors converted into resource consumers. The judgement whether a node is a resource contributor or not is based on its revenue value. The initial revenue value of a node is set to 100. At the end of the game, the node is classified as a resource contributor when the revenue value is greater than 200. Otherwise the node is classified as a resource consumer.

The simulation experiment uses OMNet and SUMO simulation software. There are three key parameters in the game. They are n (the number of game rounds), the number of vehicles in the network, and the number of initial resource contributors. At the end of a experiment, the number of resource contributors and consumers will be counted. The ideal experimental results are that as n increases, more nodes will act as contributors; when n approaches infinity, the ratio of resource contributors and consumers tends to a relatively stable status.
Figure 3. Nodes’ revenue after 20 rounds of game. Figure 4 Nodes’ revenue after 30 rounds of game.

Figure 3 and Figure 4 respectively show the revenue value of each vehicle node after 10 and 20 rounds of game when the number of vehicle nodes is 30 and the initial resource contributor is 4 nodes. The abscissa of the figure is the sequence of the node. The ordinate is the node revenue value. It can be seen from the figure, resource contributors in the network increased to 9 after 10 rounds of game, and increased to 11 after 20 rounds. This result shows that the game model achieves the goal of encouraging more nodes to share their resources. Continue increasing the number of game rounds, the ratio of contributors and tends to be stable at 3.5: 10.

Figure 5. Revenue of 60 nodes after 60 rounds of games.

Figure 6. Revenue of 100 nodes after 30 rounds of games.

Figure 7. Revenue of nodes after 20 rounds of games (the initial contributor is 1).
Figures 5 and 6 show the revenue value of each node in the network when there are 60 and 100 vehicle nodes in the network. The results show that with the increase of the number of vehicle nodes, the proportion of resource contributors will gradually decrease. This is because there are already enough nodes in the network to provide resource sharing, and the resources provided can already meet the need without requiring more nodes to contribute. There is no need to convert more nodes into resource contributors.

Figure 7 shows the revenue of nodes after 20 rounds of game where the number of nodes is set to 30 in network and the initial contributor is set to 1. It can be seen at the end of the experiment the number of contributors is 10. Comparing with figure 4 whose initial contributor is 4 and the final contributor after 20 round of games is 11, it can be seen that although the numbers of the initial resource contributors are different, the trend of the number of resource contributors does not change after multiple rounds of games. The ratio of contributors in the total number of vehicle nodes is basically the same. The experimental results show the stability of the model. The ratio will not change greatly with the change of the number of initial resource contributors. Because the initial resource contributors only play a guiding role. The vehicle node behavior tendency is affected by the game awards in the incentive mechanism. The balance of revenue and expenditure benefits of the game indirectly determines the stability of the model.

6. Conclusions

The incentive mechanism designed in this paper considers both short-term dynamic incentives and long-term incentives. In the game model, the revenue value is used as a revenue to encourage vehicle nodes to share their resources. In the level mechanism, higher-level vehicle nodes will get more concessions and revenues, while vehicles that do not contribute resources for a long time will be punished thereby encouraging vehicle nodes to share their resources for a long time. Simulation experiments show that the incentive mechanism is feasible and convergent, which can encourage vehicle nodes to contribute shared their resources.

The game model does not give a relatively perfect equilibrium solution, and there is still some randomness in the system. In addition, some security and privacy issues in the model need to be further improved and considered [5,6].

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