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NETWORK FORMATION GAME AMONG COOPERATIVE NODES FOR DISSIMILAR SERVICE-MESSAGE SHARING IN VANETS

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ABSTRACT

Vehicles access required service messages from service-providers through road side units (RSUs). Vehicles access different types of service-messages but a RSU can provides only one service-messages at a time. In times, when one vehicle is accessing a type of service-messages from a RSU, that time if another vehicle requests for a different type of service-message, RSU can not provide that. Vehicles, those are outside the range of RSU, can access same type of service-messages from other vehicles through cooperative communication technique. The problem of cooperative dissimilar service-message sharing is addressed in this paper using network formation game.

Key Words: VANETs, Network Formation Game, Service-message, RSU, Load sharing, Cooperative Communication

INTRODUCTION

In cooperative VANETs, vehicles cooperate with other vehicles and share messages among themselves [1]-[9]. Vehicles access service-messages, from RSUs or from other vehicles. Services-messages are different types of services, such as traffic information, news, music, movies and Internet access. Vehicles are interested in accessing one type of service-message at a time.

Motivation

Intermittent connectivity problem and partitioned network issue make a difficult task for successful transmission in VANETs. Vehicle request RSU for a service-message and the RSU transmits the service-messages to the requesting vehicle. Vehicles may request for a different type of service-message while RSU is busy in serving another vehicle. A game theoretic model is proposed by Das et al. [10], which helps the vehicles which are accessing same type of service-message, to form coalition among them and access the service-message even though some of the vehicles are out of the transmission range of RSU. However, the authors have not discussed the scenario when vehicles need different types of service-messages. In this paper, the dissimilar service-message sharing problem in VANETs is discussed and the solution is addressed using network formation game solution.

RELATED WORKS

Nosratinia et al. 2004 [3] proposed a content distribution scheme with network coding to distribute content in VANET using broadcasting. A tree architecture is formed between the relay stations and the base station by a cross-layer utility function for the tree architecture formation problem, studied by Saad et al. 2011 [11]. The authors use network formation game framework and form a network graph before sending a packet from a node to the base station and keep this network graph for future transmission. This procedure does not produce good result in VANETs due to VANETs' dynamic nature. Das et al. [12] discussed a cross layer tree formation protocol, which uses cooperation at MAC-layer and reduce retransmission of packets. The studied protocol reduces retransmission delay and improved throughput.

With the use of coalition game theoretic technique Das et al. [10] also proposed cooperative service-based message sharing problem in VANETs. Vehicles share the same type of message they are accessing among vehicles those are interested in accessing the same type of message. The proposed protocol reduces the load of RSUs by cooperatively sharing same type of messages but does not address cases when vehicles request for different types of services. Hence, to solve the dissimilar service-message sharing (DSMS) problem, a novel protocol is studied in this paper using network formation game.

SYSTEM MODEL

Let us consider a network with RSUs, $r = \{r_1, r_2, \ldots, r_m\}$, vehicles $n = \{n_1, n_2, \ldots n_k\}$ and service-messages $s = \{s_1, s_2, \ldots, s_n\}$. Vehicles request RSU for a type of service-message and if the RSU is free then it transmits the service-message. A vehicle may requests for multiple types of service-messages but one message at a time. Vehicles can also works as relay and retransmit messages form RSU or other vehicles to the requesting vehicle. The delay in transmission of messages from RSU to vehicle and vehicle to vehicle is considered identical in the present study. The reception rate of a requesting vehicle from a direct cooperative vehicle is calculated as,

$$r_{n_j} = \frac{\eta_i \cdot \rho_j \cdot \delta_i}{\tau_i} \qquad \text{..... (1)}$$

Where, r_{n_j} is the reception rate of the requesting vehicle. Cooperative vehicle n_i transmits the ρ_j packet of service-message type δ_i with τ_i delay.

The reception rate of a requesting vehicle from a coopera-tive vehicle, which is not in the range of the requesting vehicle, is calculated as,

$$R_{n_j} = \frac{\eta_i \cdot \rho_j \cdot \delta_i}{\tau_i} \cdot \frac{\sum_{p \in k} \eta_p \rho_j \delta_i}{\tau_p} \qquad \text{..... (2)}$$

Where, R_{n_j} is the reception rate of the requesting vehicle when it has to access the ρ_j packet of service-message type δ_i from a cooperative node that is not within it's transmission range. Node n_i is a neighbouring node of the requesting vehicle n_j, and it collects the message from another cooperative node within its transmission range.

A. Incentive Function

The incentive [11] received by a cooperative node for serving a requesting node is calculated by the following equation.

$$\upsilon_j = \frac{\rho_j \cdot \delta_i}{\tau_i} \cdot \frac{\sum_{p \in k} \eta_p \rho_j \delta_i}{\tau_p} \qquad \text{..... (3)}$$

Where, ρ_j is the service-message type δ_i. Cooperative node n_j calculate its receive incentive by serving a requesting node n_i. τ_i is the delay required to transmit the message directly to n_i. If n_j, does not have

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the message it access the message from a cooperative node n_p with τ_p delay. The assumptions considered in this paper to formulate the network formation game are given below.

- From vehicles' point of view, RSU are the service-message providers.
- RSU can serve one type of service-message at a time.
- A cooperative vehicle can serve one requesting vehicle at a time.
- Cooperative vehicles can work as relay.
- The studied network formation game is among vehicles. Cooperative vehicle choose which requesting vehicles to serve
- Requesting vehicle can not choose a cooperative serving vehicle as it has no information about which cooperative vehicles has the service-message.
- A network graph is formed by the cooperative vehicles.

B. DSMS algorithm

Property 1: DSMS protocol forms a directed tree structure, rooted at requesting vehicle to the transmitter node through relay nodes (if present) in a network graph G.

Transmitter node can be a RSU or a cooperative vehicle which transmits the service-message to the requesting vehicles. If a RSU or a cooperative vehicle is not present within the requesting vehicle's transmission range then cooperative relay nodes helps to get the required service-message.

Definition 1: A node connects with another vehicle if and only if it increases its incentive.

Definition 2: In a point of time, when any vehicle can not improve their incentive by changing their current strategy, then the network is called Nash network.

Theorem 1: Proposed DSMS algorithm creates Nash network and vehicles always accept the best possible link to maximize its incentive.

Proof: DSMS algorithm accepts a link to serve a requesting vehicle which provides maximum incentive at that point of time. If a link was present that would provide it with a better incentive than that link would be selected. Hence, DSMS algorithm always selects the best link and maximizes its incentives and forms a Nash network [11].

Algorithm 1 Dissimilar service-message sharing algorithm

```
A node requests for a service-message
if RSU free then
    RSU transmits service-message
end if
if RSU busy then
    Neighboring vehicles receive the request for service-
message
    if Neighboring vehicle has service-message then
        It calculates its received incentive value
        One of the neighboring vehicles transmit service-
message
    end if
    if Neighboring vehicle does not have service-message
then
        Search for its neighboring nodes for a suitable co-
operative node
        If found transmit messages to the receiving node
    end if
end if
```

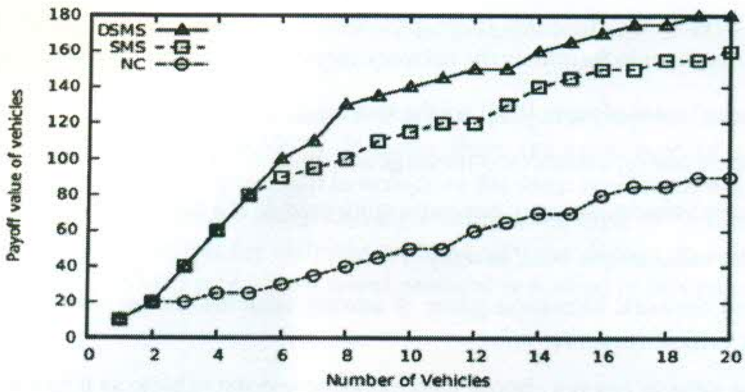

Figure. 1: Performance of DSMS protocol

NUMERICAL SIMULATION

The proposed DSMS protocol is evaluated in this section through numerical results and compared the outcome with a non-cooperative protocol. In this study, a single lane, 20 vehicles and 4 RSUs have been considered for simulation. Transmission range is kept to 300 meters for both vehicles and RSUs with a packet size of 1000 bytes. The considered simulation parameters are described in the Table I.

TABLE I : PARAMETERS FOR NUMERICAL SIMULATION

Parameters	Values
Number of lanes	1
Total number of nodes	20
Total number of RSUs	4
Transmission range of the vehicles	300m
Packet Size	1000 bytes
The width of the road	300m
Minimum node speed	10m/s
Maximum node speed	60m/s

In Fig. 1, we demonstrate the performance of the studied DSMS protocol and compare it with service-based message sharing (SMS) protocol and non-cooperative (NC) protocol. NC protocol do not share or relay messages with other vehicles, it only access service-messages from a RSU or a service-message generating vehicles. SMS protocol, on the other hand share and relay messages among other vehicles which are interested only in a specific service-message. Performance of SMS is better than NC as it shares same types of messages and also relay them to other vehicles. However, the proposed DSMS protocol outperforms them as it shares and relay all types of service-messages.

CONCLUSION

A novel DSMS protocol is proposed in this paper for dissimilar cooperative service-message sharing problem in VANETs. A vehicle can access service-message from other cooperative vehicles in times when RSU is busy in transmission of other type of service-message with DSMS protocol. The proposed protocol also helps vehicles to access service-messages while they are not in the range of RSU.

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