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Comparative Game Theoretic Approach for Message Forwarding in VANET

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***Abstract*—In this paper, we present a game theoretic framework for different type of VANET system problem like broadcast storm problem, routing algorithm, robust to imperfect measurement. This type of problem give different result depends on environment of VANET systems. We analyze different game theory approaches and applying them with the mathematical model structure. Finally, the performance of each scheme is compared with that of other existing schemes. The main goal of our paper is to make literature survey study on existing game theoretic approaches so as to find the improvement points to consider it as an implementation issue in VANET message forwarding.**

***Index Terms*— Broadcast Communication, Game Theory, Message forwarding, VANET.**

I. Introduction

VANET (Vehicle Ad hoc Network) is an open mobile Ad hoc network consists of vehicle and roadside equipment which help in proper communication between them. In VANET technology for proper communication every moving cars act as nodes or wireless router. Each vehicle can connect other vehicles within its range of 100 to 300 meters to form wide range of mobile network. If due to some reason car fall out of vehicles range then we can say that vehicle is drop out of network. If vehicle want to join the VANET then only thing they require is OBU(On Board Unit). OBU contain sensor technology which helps node to notify other nodes location and their movement nature which can be used for effective communication purpose.

In VANET again there are two types of communication exist out of which first is vehicle to vehicle (V2V) and another is vehicle to road side unit (V2R). Road side unit (RSU) is act like wireless transceiver and receiver at same time. It also acts as memory store unit or router. Whenever vehicle pass through RSU for service requirement, RSU provide proper service to vehicle based on its capacity. VANET application scope area vary like file sharing [1]-[4], dynamic route planning and traffic alert notification. The main feature of VANET is it's dynamic topology over regularity of vehicle movement.In [5], authors subjected VANET difference between VANET and conventional ad hoc wireless network. A VANET not only consist of dynamic path calculation on other hand it also varies according to vehicle density. For urban area, density of vehicle is much more as compared to rural. In VANETs, effective and efficient message delivery among vehicles must be guaranteed. Under different circumstances which includes different environment (urban or rural area) or time of day(night time with low vehicular density or day time) intermittent connectivity, vehicle become main problem for it. store-carry and forward message switching becomes an important idea for routing in VANETs.

II. Feature of VANET

VANET is an emerging technology which is responsible smarter inter-vehicle communications with mostly smooth internet connectivity to achieve essential notification alert with proper road safety alert without losing balance of entertainment and comfort. Some of the main characteristics of VANET are as follow:

- Roadside Infrastructure
  Availability of fixed roadside communication infrastructure (e.g., fixed access points) is unique to VANET. Zhao te al. in [6] have shown that the fixed nodes with storage can increase the capacity of the network. Also there are several routing schemes which utilize the fixed roadside access points in order to improve the message delivery ratio. For example, the GVGrid [7] routing protocol uses these fixed infrastructures to create routes on demand to the vehicles in the destination area. These fixed nodes are also responsible for rebuilding links that are broken due to mobility.
- Predictable Mobility
  VANET has its own unique mobility pattern. The motion of a vehicle is quite predictable as it is constrained by the roads, traffic lights, road intersections, etc. Also, mobility is predictable because humans are creatures of habit. We drive along the same routes at approximately the same time of day (for example, to and from work). Further, public transport buses follow fixed routes and schedules. The studies of Wu et al. in [8] suggest that multilane roads ensure

greater connectivity and experience less delay than those of single lane roads.

- Vehicle Density
  Partitions and congestion are common in VANET because vehicles are often distributed unevenly. Rapid topology change and frequent fragmentation are also common phenomena in VANET. Usually as the density of the vehicle increases, connectivity also increases. But after reaching a critical value, an increase in vehicle density results in a decrease in connectivity (analogous to a traffic jam). Chen et al in [9] suggested that increase in density may also increase delay if there are not a large enough number of lanes to avoid slow moving vehicles.
- Transmission Range
  In general, connectivity drops sharply beyond the transmission range and at least 500 meters of transmission range (simulation scenario) are required to stay well connected. Burns in [10] suggested that at a range of 500 ft., a node can only reach 37\% of the other nodes.
- Connection Lifetime
  Probability distribution of connection lifetime (i.e. contact duration) and interconnection lifetime (i.e. time between two meetings of nodes) resemble that of a power law. Driving direction and transmission range directly affect connection lifetime. Zhang et al. in [11] simulation shows that 90\% of all paths have less than 50 seconds of lifetime.
- Path Length
  Connectivity decreases with an increase in path length (i.e. number of hops). Even a small message, sent over 3 to 4 hops away, is likely to suffer route errors using traditional MANET protocols.
- Latency
  Opportunistic routing and bi-directional vehicular traffic increases message delivery ratio while decreasing delivery latency.
- Unbounded Network
  Unlike MANET, large-scale network and large-scale movement are the major implications of the unbounded nature of VANET as proposed by L. Nassar et al. in [12]. Since it is almost impossible to trace the identity of the destination vehicles in an unbounded network prior to data transmission, the traditional identity based addressing models hardly achieve 100% application delivery ratio with low overhead.
- Node Availability
  Unlike other types of wireless networks, nodes in VANET can frequently join or leave the network. The reliability of a vehicular node as a message forwarder diminishes even further due to security and privacy issues. Maciel et al. in [13] implies that the network should not depend on a single vehicle to forward messages.
- Predicable Mobility
  The velocity, location, and trajectory information of a vehicle can be used to estimate its projected movement in a point in time. For example, Gao in [14] introduce a mobility pattern aware routing scheme for VANET and it which leveraged the position information and speed of vehicle. However, the high mobility generates short-life contacts that make routing challenging.
- Environmental Factors
  Vehicles can move into many different environments (e.g. city environments, disaster situation, extreme weather conditions etc.) which can interfere with wireless communications. In urban environments, many tall buildings may obstruct and interfere with the wireless signals. Multi-path fading is a common phenomenon in such built-up environments. Vehicles usually remain closer together than in highway scenario; hence can create interference if transmission range is increased by increasing the power of radio communication equipment.

III. Motivation

Game theory is a formal analytical framework with a set of mathematical tools to study the complex interactions among independent players who are responsible for taking rational decision. During the past years, game theory has made a revolutionary impact on a wide number of disciplines ranging from economics, politics, and philosophy. The need of large-scale distributed wireless networks, as well as the recent interest in mobile flexible network has given opportunity to arise many game theoretic problems where the nodes are autonomous decision makers [24]. Further, the need for self-organizing, self-configuring, and self-optimizing networks eventually led to the use of many game theoretic concepts in wireless communication networks. In a game theoretic framework, one can distinguish between two main categories: Non-cooperative [4] and cooperative game theory [5]. While non-cooperative game theory mainly deals with modeling competitive behavior, cooperative game theory is dedicated to the study of cooperative behavior among a number of players and its impact on their decision making process .

IV. Related Work

VANET has got main attention on the solving efficient routing mechanism problem. Many researchers have given the solution of epidemic routing over intermittent connectivity problem. Since epidemic routing is like flooding based message forwarding.in which message get forwarded by replicating message on the node and transmitting it to the node comes in contact. Another solution is given in [15] where two hop routing scheme has been proposed in which message get forwarded iff intermediate node within it's range contain destination node. A number of DTN routing protocols have been proposed, out of which most of can roughly be classified into two categories depend on their strategies and those are flooding based protocol and forwarding based protocol.

Flooding-based protocols give guarantee of message to reach destination by making replica of message and thus increase the probability for any copy of the message to reach the destination. For example, in [16] Vahdat et al. proposed epidemic routing, where if a node has a message to send, then it transmits the copies to all the nodes it meets in the random movement. In contrast, many works focus on forwarding strategies using knowledge about the network without flooding.

The forwarding-strategy based protocols rely on knowledge about the network to select the best path to the destination. Recently, in [17] Balasubramanian et al. proposed a routing protocol that intentionally optimizes one chosen performance metric. However, all these works have not considered the incentives of nodes to cooperate, which may lead to performance degradation in the face of selfish nodes.

Again many routing strategies based on nature of node to forward the message. In some strategies of VANET vehicles are show willingness to forward the message [18], [19] while in other scenario there exist some node which we can say are selfish nodes. Selfish nodes are node which due save their resources (like computation energy, power or buffer memory) do not forward message [20], [21].

V. Description of the Research Work

Here we will analyze main papers with their game theory approaches VANET related problems. The papers which we are going to consider for research work are as follow

A. Routing Algorithm Based on Multi-Community Evolutionary Game for VANET [8]

In VANETs, there are two main communication methods vehicle-to-vehicle and vehicle-to-infrastructure communications. VANETs have applications that are particularly important in sparsely populated and rural areas because of the lack of fixed communication infrastructure. Thus here vehicle to vehicle communication is considered. VANET is taken as a vehicular DTN, where each node is instantiated by vehicle driven by people running in a road with some velocity. In VANET system it is assumed that each vehicle is equipped with On Board Unit (OBU) for communication purpose between two vehicles. Every vehicle can communicate with each other when two vehicles come in contact range of each other. In general multiple community of vehicle is considered for system design. Community is made of same type of vehicle set like taxi community or bus community.

The message forwarding problem has been solved using Evolutionary Game theory has been developed which give credit to nodes based on their message forwarding rewards. Each vehicle act as player in this game which has OBU and which is interested in participate in game or forwarding the message. If node forward message then trusted third party give reward to node. If message get forwarded between same community nodes then node get higher number of credit and if message get forwarded between different community then node gets lower credits.

when there only exist Population 1 or Population 2, the probability that the node receives the rewards, if it plays strategy *p*

$$P'_{s,1}(x) = \frac{(1-(1-x\alpha)^m)}{mx} \tag{1}$$

$$P'_{s,2}(y) = \frac{(1-(1-y\alpha)^n)}{ny} \tag{2}$$

where X: = {(x, x-) | x+ x- = 1} and Y: = {(y, y-) | y+ y- = 1} respectively be the set of probability distributions of Population 1 and Population 2 over the S pure strategies sample space and α is

$$\alpha = 1\text{-}Q_\tau \tag{3}$$

In equation (3) Q_τ is the probability that the node relays the copy to the destination within time τ is given by 1-Q_τ where

$$Q_\tau = (1+\lambda\tau)e^{-\lambda\tau} \tag{4}$$

where λ is bandwidth between source and destination. In reality VANET consist of number of various communality but in this evolutionary approach as number of community increases overall success probability decreases.

B. *Using a symmetric game based in volunteer's dilemma to improve VANET's multihop broadcast communication* [13]

In this symmetric based game system broadcast storm problem has been solved using volunteer's dilemma game theory. In this game importance is given to interdependency concept and each vehicle is selected as agent for decision maker. Due to interdependency concept decision made by one agent affect decision behavior of other agents. Agents make their decision when best strategy to be selected for message forwarding. If one agent decide one strategy for message forwarding then other agent decide their strategy based on previous agent strategy to increase overall performance.

In Broadcast communications message get forwarded to the vehicle which will listen the message. The decision made by receiver to forward the message affect positively or negatively to other node for their decision to gain lowest cost of network. When that happens, even the vehicles which have not forwarded the message will benefit by a forwarding performed by another vehicle. This behavior, in which common good is produced by a player, was modeled by the volunteer's dilemma. Adapting it to the broadcast storm problem in MANETs, Naserian [22] called this the forwarding dilemma game; it is the decision between forwarding a message and generating a benefit; or not forwarding the message to enjoy the benefit to be generated. In this paper a new approach for VANETs based on the later ideas is proposed.

Broadcast message forwarding game G = {N; (S_{pi})(I ∊ N); (U_{pi})(i ∊ N)g where N is the number of participating vehicles, S_{pi} is the strategy set, and U_{pi} is a utility function for a pi player. If player play pi strategy then it represented by $S_{pi} = \{0, 1\}$If $S_{pi} = 1$ message will get forwarded and $S_{pi} = 0$ message will not get forwarded. The game started whenever a vehicle receives a broadcast message that must be forwarded.

Paper Name	Routing Algorithm Based on Multi-Community Evolutionary Game for VANET	Using a symmetric game based in volunteer's dilemma to improve VANET's multihop broadcast communication	DARWIN: Distributed and Adaptive Reputation mechanism for Wireless ad-hoc Networks
Problem Statement	Message forwarding	Broadcast storm problem.	Selective message Forwarding
Game Theory	Evolutionary Game	the volunteer's dilemma Game	reputation-based cooperative Game
Environment	VANET	VANET	VANET
Nature	Dynamic	Dynamic	Dynamic
Protocol	802.11p protocol	Static protocol	CSMA/CA protocol, Dynamic Source Routing (DSR) protocol
Topology	Hybrid	Hybrid	Hybrid
Routing Decision	Dynamic(based on previous strategies)	Dynamic (forwarding dilemma game)	Dynamic(Dynamic Source Routing protocol)
Mapping	End to end connection with help of intermediate node	One to many	One to many
Overall Increase In Performance	2.4%	8%	30%

Table 1: Comparative analysis of message forwarding technique

The number of players is calculated based on how many vehicle received that message. A cost is expected by receiver node since cost is paid by sender node. If vehicle pi is forwarding the message then it's message payoff $U_{pi} = B - C$ where B is the benefit value and C is the benefit production cost. In system remaining vehicles which will use the good produced, will have payoff $U_{p\text{-}i} = B$. In matrix form game can be represented as below:

P_i /P_{-i}	All Quiet	At Least One Forward
Quiet	0	B
Forward	B - C	B – C

Table 2: The Game in Normal Form

In this system assumption is that B > C, so every node is going take part in game. Diekmann [23] system adopted based on Nash equilibrium with symmetric mixed strategy where in which each player may voluntarily forward the message and it get proper benefits it as follow:

$$p = 1 - \left(\frac{C}{B}\right)^{\frac{1}{N-1}}$$

$$p' = 1 - \left(\frac{C}{B}\right)^{\frac{N}{N-1}} \quad (5)$$

But in symmetric game as amount of Vehicle increases Percentage of stability performance decreases

C. DARWIN: Distributed and Adaptive Reputation mechanism for Wireless ad-hoc Networks [1]

In DARWIN system two player The Prisoners Dilemma game is used for message forwarding based on node reputation. Even message forwarding is occurring within source node, intermediate nodes and destination node; during game at time only two player are connected to message. Both players contain two possible choice of strategy either Cooperate (C) or Defect (D). Each player get payoff share based on its decision from strategy space S_i and payoff matrix table as follow:

		Player 2: Cooperate		Player 2: Defect	
Player 1	Cooperate	1	1	-1	2
	Defect	2	-1	0	0

Table 3: Payoff Matrix of the Prisoners' Dilemma Game

Nash equilibrium is a strategy where player does not get benefit by deviating from its strategy. Therefore to get benefit each player observe completed strategy K-1 and based on that decision take for K^{th} stage. That means total payoff indirectly based on each stage payoff $u_i^{(k)}$ is given by

$$U_i = \sum_{k=0}^{\infty} w^k u_i^{(k)} \quad (6)$$

where w ∈ (0, 1) is the discount factor. Assumption for infinitely repeated game is that it will end after will end after random number of repetition. Under this assumption can also be interpreted as a repeated game that ends after a random number of repetitions. Another assumption is that node could be selfish but not malicious. Total benefit for selfish node will become total benefit for that node minus cost of it's action. Every player in this system operate in promiscuous mode that means each node can listen packet send by its neighbor nodes. During every message forwarding to hop game gets created and both player will decide whether to drop packet or forward packet and repeat this game iteratively. Result of two hop game presented in time slot format. Time slot helps neighbor node to decide ratio of how many packet forwarded and dropped.

Without loss of generality we normalize the payoff matrix as in Table 3. Using standard game theory notation, we will denote by i ∈ {1, 2} a generic node and by −i its neighbor. Since the interaction among nodes is asynchronous in nature, we refine the game assuming that time is divided into slots and that slots last long enough to allow each node to send a sufficiently large number of packets. At the end of the slot each node finds the ratio of dropped packets by its neighbor; if the number of packets exchanged is sufficiently large, then this ratio is a good estimate of the probability of dropping a packet.

But in this system participation of player in game by force rather interest. Again it is observed that that if number of selfish node is more in network then network normalized

VI. Conclusion

By analyzing above paper we come with following conclusions

- We have studied corresponding network model and an evolutionary game model to formulate competition among multi-community bounded rational nodes in sparse VANET. In this system to overcome problem of community credit based system is used.
- In symmetric game therotic approach for broadcast storm problem for larger number of vehicle load balancing technique should be implementing.
- For reputation game approach instead of force choice participation should be done by interest of node, hence incentive mechanism should be selected for message forwarding.
- We studied various VANET related problem based on game theory for message forwarding hence we come to conclusion that for VANET system following things will required
  - Game theory
  - Incentive scheme
  - Credit based system
  - Load balancing in Credit based system

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