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A Cooperative Heterogeneous Vehicular Clustering Mechanism for Road Traffic Management

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Abstract

The vehicular ad-hoc networks integrates with long-term evolution (LTE) forming a heterogeneous network, capable of providing seamless connectivity, which meets the communication requirements of intelligent transportation systems. However, heterogeneous network-based applications involve LTE resource (data and spectrum) usage cost and must be taken care while developing such a solution. One of the scenarios is the access of the information to/from remote server over the internet via LTE for road traffic management applications. Although clustering of the vehicle is significant to minimize the data and LTE network usage, however, the problem of non-cooperation of the vehicles in clustering process and within a cluster are major issues in sharing costly data acquired from the internet. Because, who and why one (vehicle) should pay the cost is the big question, proliferating the non-cooperative behavior among the cluster members. To solve these issues, strategic game-theoretic based clustering mechanism named as cooperative interest-aware clustering (CIAC) is developed. The proposed CIAC not only balance the cost of usage by controlling non-cooperative behavior among the vehicles within the cluster but at the same time motivate vehicles to participate in the clustering process to share the data and cost as well. It consists of a cluster head selection process based on the strategic game-theoretic approach and a fair-use policy. The implementation results show superiority in performance of our protocol over the existing approaches.

Keywords VANET · Road traffic management · LTE · Vehicular clustering · Cooperation · Game theory

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1 Introduction

Traffic congestion on roads in urban areas place pressure on transportation infrastructures and cause damage to the economy, human health, and the environment. Countries spend large amounts of money to enable transportation systems to handle increasing traffic on roads. The U.S. Department of Transportation invested and focused on vehicle-to-vehicle (V2V) communication that is based on dedicated short-range communication (DSRC). Researchers also focus on telecom networks as a part of the solution. The integration of VANET with telecom technologies provides promising solutions for road traffic management.

Traffic efficiency applications require a heterogeneous network that demonstrates low latency, reliability, and speedy communication to send periodic traffic updates to remote servers. These applications optimize vehicle flow to reduce congestion and travel time and involve the collection, monitoring, and processing of data as well as sending of instructions back to vehicles for smooth driving. In such applications, the information delivery is location and time sensitive which necessitates reliable and efficient communication infrastructure development that can meet the requirements. The usual working of such application consumes much more LTE spectrum which ultimately increases the cost and should be reduced. Although, clustering of vehicles is a good choice in this regard but general clustering techniques cannot work well with all types of use cases and network scenario. The clustering solutions developed for safety and infotainment applications have their data rate and frequency requirements [1,2]and cannot work for road traffic efficiency class of applications. Also, a stable cluster is required that is developed on some specific clustering criteria, and cost factor should also be taken into consideration while developing such a solution. Although some of the solutions [3–5] exists, none of them considered above-mentioned factors and are related to road safety and in-car infotainment.

Few studies based on clustering of vehicles are conducted to minimize the LTE resource usage but when it comes to road traffic management applications such as driving assistance and route planning special consideration are there to be a focus on. The first consideration is road traffic efficiency applications have their loco-temporal requirements (data rate and delay sensitivity). The second consideration is the cost of use because data is to be accessed from a remote server over the Internet via LTE network that involves cost. A third consideration is who and why one should pay the cost, for this cooperation is required among the participating vehicles in the cluster. Last but not the least is instability due to inherent characteristics of VANET (i.e., rapid topological changes due to the high speed of vehicles).

To address the issues mentioned above, a Cooperative Interest-Aware Clustering (CIAC) is presented. The CIAC consists of a clustering mechanism formed by parameters such as speed, location, direction and LTE link quality by the group of vehicles. A strategic game theoretic based approach is adapted to tackle the non-cooperative behavior of vehicles reluctant to participate in the clustering process. A salient feature included in our solution is the fairness in the free access to information from neighbors. This feature ensures that distinct vehicle is selected as a cluster head (CH) every time to pay the cost of the Internet. Vehicles are reluctant to be CH and want to be free rider within the cluster. Our mechanism is to motivate vehicles to participate and share not only the information but also the cost of Internet usage. To validate, the performance of the CIAC, simulation experiments are conducted using popular tools such as SUMO [6], Veins [7] and simuLTE [8] over OMNet++ network simulator [9]. The results of CIAC are compared with modified distributed and mobility-adaptive clustering (MDMAC)[10] and vehicular multi-hop algorithm for stable clustering (VMaSC) [11]. The implementation results demonstrate the effectiveness and efficiency of the proposed mechanism. The rest of the paper is organized into five sections. In Sect. 2 (background), the cooperative and heterogeneous vehicular clustering based existing solutions are discussed. Section 3 discusses the mechanism of cooperative heterogeneous clustering, the main algorithm and a system model of the proposed mechanism. The simulation study is presented in Sect. 4, and this section also provides a results analysis after the implementation of the proposed mechanism. The conclusion of the work is provided in Sect. 5.

2 Background

The data communication schemes commonly used for traffic data collection, processing, and distribution in VANET improve over time [12]. Recent improvements in information and communication technology (ICT) empower the design and implementation of VANET. These improvements enable some applications to be developed in VANET [13]. VANET-based applications incorporate various vehicle resources to assist drivers on the road [2]. By capturing, evaluating, and disseminating road traffic-related information, a traffic management system improves traffic flow and reduces traffic congestion. DSRC is the primary technology for such traffic management systems. The bandwidth restriction of DSRC limits the information frequency and size of the data to be communicated to vehicles [1]. QoS-based data aggregation techniques are suitable for DSRC [14]. Vehicles exchange information on route choices, congestions, and traffic and decide by selecting the best option [15]. Most of the traffic efficiency applications are using DSRC for local message exchange, but a vehicle to infrastructure (V2I) in the absence of roadside units (RSUs) other radio access network are also being utilized which form heterogeneous VANET. The traffic management application most often requires access to content providers such as Internet cloud, remote servers of traffic management centers (TMC) and traffic information systems (TIS) for smooth functioning. To access these servers the networks other than DSRC such as Wi-Fi, WiMAX, 3G/LTE, and LTE-Advance (LTE-A) are used as depicted in Fig. 1. The accessed information from these servers is disseminated among vehicles via DSRC. At the same time, data is collected from vehicles and send to these servers for processing.

The integration of DSRC with LTE makes a heterogeneous network that works well for traffic efficiency applications such networks are called as V2-LTE (which is V2I). A typical V2-LTE-based vehicular network is presented in Fig. 2. The network consists of VANET (V2V), Internet connection, 3G/LTE network, TMC (it consists of remote server and traffic management authorities), and global poisoning system (GPS). Vehicles generate an immense amount of data to be collected, processed, and disseminated by the remote server over the Internet. For these operations, the vehicles need to communicate over the Internet via roadside units (RSUs) or 3G/LTE networks.

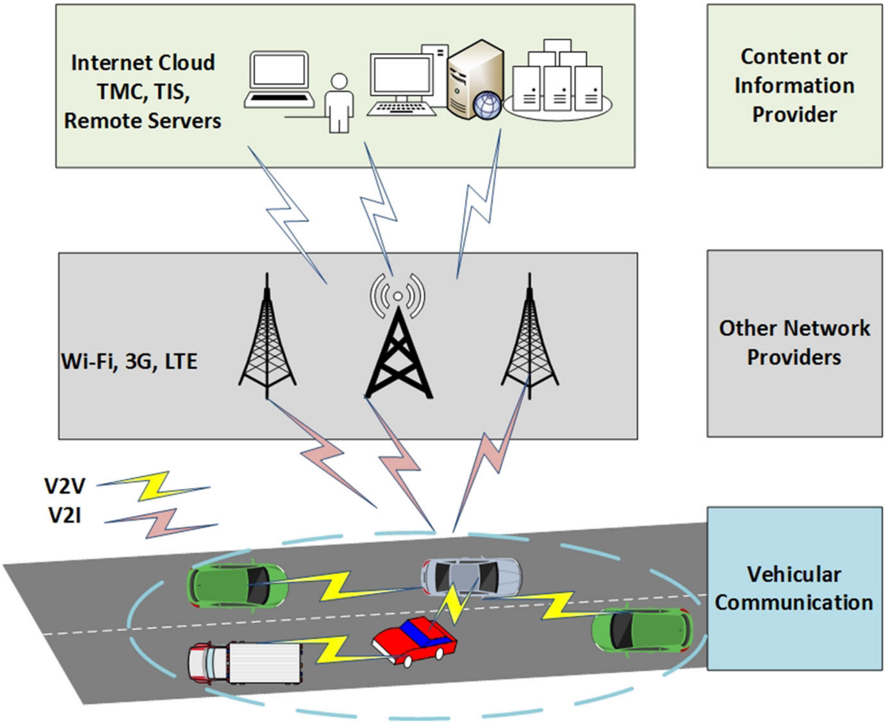

Fig. 1 Heterogeneous vehicular network

Frequent and seamless connections are necessary for the dissemination of such data to and from Internet-based servers.

Most V2-LTE-based applications play with the choices of LTE technology to be used. The first choice is the use of an LTE-based communication mechanism for the collection of data directly from vehicles. The second choice is the use of an LTE network for data dissemination back to the interested vehicles over a particular road segment. The third choice is indirect data collection and dissemination from vehicles to form vehicle clusters. Majority of the solutions are based on vehicle clustering such as the LTE4V 2X system presented in a [16]. Clustering is implemented in two forms. The first is to initiate and manage the clusters via an LTE network paradigm [17], and the second is to manage via the VANET paradigm. The clustering process performed with LTE-based eNodeB has a wider regional view [18,19] than V2V-based clustering. Some of previous surveys and studies have focused on the overview of LTE networking [3–5] for the vehicular environment. None of these focused on road traffic management, and existing work focuses on one of the following: safety, architectural, and performance aspects. Considering that traffic efficiency applications have their own spatial and temporal requirements, the significance of using emerging technologies, such as LTE, should be measured separately. These applications optimize vehicle flow to reduce congestion and travel time and involve the collection, monitoring, and processing of data as well as sending instructions back to vehicles to manage road

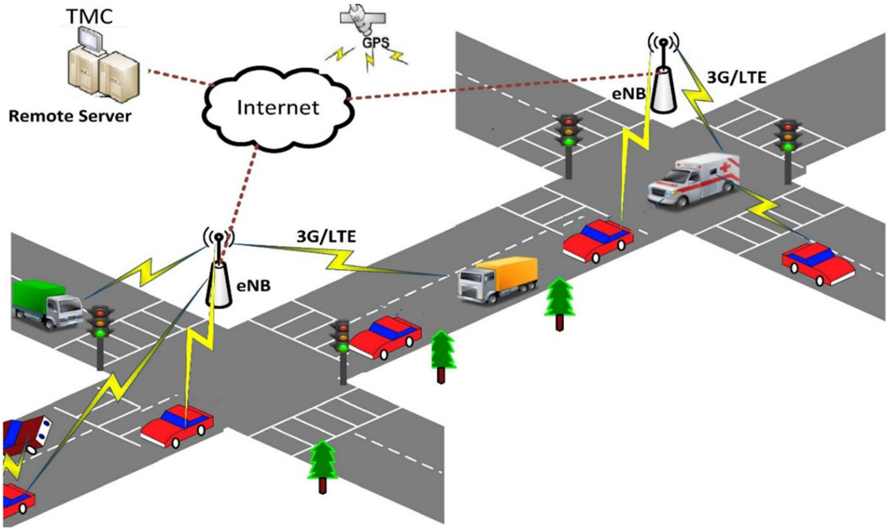

Fig. 2 Typical example of LTE-based vehicular network

traffic. The selection of technology (Wi-Fi, WiMAX, and LTE) [20–23] for data transfer is based on application requirements and the feasibility of the selected technology for applications [11]. The primary option of communication for these applications is DSRC, which is insufficient to meet the current development demands of applications. Cloud computing [24] and IoVs [25] already combine multiple communication technologies. So, the combination of technologies can be a good choice for better connectivity that is a basic requirement for ITS.

2.1 Cooperative Clustering

In cooperative clustering vehicles are encouraged to participate in clustering process and become part of it, for that some incentives are given to the vehicles for their right act, and penalties are put against those who behave negatively [26]. A solution in [27] is presented but not stable enough to realize the benefits of cooperation in data sharing fully. An important scheduling algorithm is presented in [28], the purpose is to select one vehicle for one specific transmission of data. Cooperation in communication link failure by choosing a helper node in maintaining link is presented in [29], but there is no consideration of cost factor at all. In [30] an affinity propagation mechanism is developed to provide stability to cluster over VANET network infrastructure, but there is considerable clustering overhead involved in it. There is a need for a solution that considers LTE resource utilization and cost factor as well.

2.2 Heterogeneous Clustering

Vehicular clustering that entirely based and depends on LTE network is very costly and based entirely on VANET faces shorter coverage and overloaded network infrastructure [31,32]. The integrated solution those are heterogeneous such as [11,18,33] are more effective in managing vehicles on the roads. There are some solutions those are effective at VANET level such as MDMAC [10] cannot work with heterogeneous networks. A heterogeneous network-based solution named as VMaSC is described in [[11] which is highly scalable and not focusing on cost factor and cooperation for sharing costly data. Another heterogeneous VANET-UMTS based solution named as clustering-based multi-metric adaptive mobile gateway management mechanism (CMGM) [34] aimed to reduce cost and 3G network resource usage.

Content downloading and floating car data applications [27,35–38] exploit emerging technologies such as IoVs and Big data but are related to road safety and infotainment-related activities. The road traffic management application such as [5,21] needs special performance requirements. The chosen clustering criteria are very important during the clustering process such as [39] consider the destination of vehicles but the problem is it is entirely LTE based as all data, and network control is within LTE network infrastructure. There is no cooperativeness among the cluster members which is essential in sharing costly data among the vehicles.

The emerging 5G based and device-to-device solutions [40] are entirely cellular networks depended and are not end-user oriented such as [41] Anyhow, 5G is not going to replicate/replace 4G instead it is going to augment and complement 4G technologies. Also, the 4G will proceed in parallel with 5G until its full deployment which may take several years from now [42]. The use of LTE is viable for vehicular applications except for the cost factor which is crucial as LTE is not free to use. However, the cost of use could be controlled and to take benefits from the use of LTE in future applications. A heterogeneous vehicular clustering mechanism with the aim to minimize the cost of use of the Internet by providing cooperative access to the remote server is proposed in Sect. 3.

3 Cooperative Interest-aware Clustering Mechanism

The non-cooperative behavior of the vehicles is critical when it comes to paying the cost of the use of the Internet for accessed information and of course with the stability of cluster it is not possible to come up with a useful solution. First, for the stable clustering, member vehicles (Mv) are selected among the vehicles on the road based on clustering criteria such as location, speed, direction, and link quality (LQ), then a game theoretic approach is incorporated in it to enforce them to be selected as a CH. The location, speed, and direction information are exchanged periodically among the vehicles, and LQ is measured through LTE device (i.e., its default behavior to opt for stronger signal strength level (SSL)).

A vehicle Sv (vehicle who initiate the process) start clustering process by sending a message inquiring about who is there, those have matching clustering criteria and also want to be part of the cluster and consequently willing to be CH. The interested vehicles imply strategic game theoretic algorithm (SGTA) to decide whether to participate with the will of being elected as CH or not. The Sv also starts SGTA over the responses gathered from neighbors to select a CH among them and that CH is going to bear the cost of connecting to the Internet via LTE network. The vehicles will opt for strategic

Table 1 Strategies and payoffs

	Member vehicle	
	Reject	Accept
Source vehicle		
Reject	−1, −1	−2, 3
Accept	3, −2	1, 1

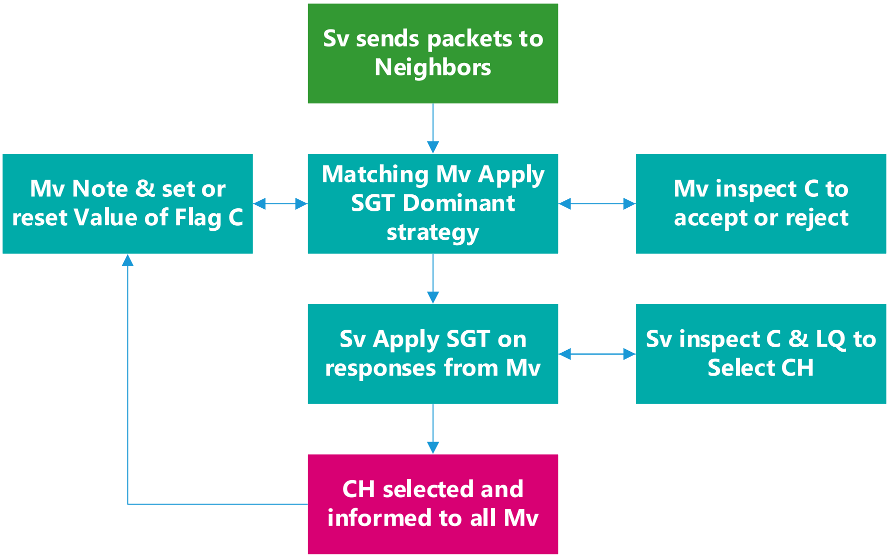

Fig. 3 Block diagram of SGT based clustering mechanism CIAC

choice against each other that is maximum benefit/payoff, and this is the motive to participate in the cluster. The values of different flags are used in our mechanism to control bias over the selection of the same vehicle again and again in repeated clustering. A detail description of the SGTA is presented in Sect. 3.1.

3.1 Strategic Game Theoretic Algorithm

In strategic game theory, each player in our case vehicles has a set of choices (in our case accept or reject to be a CH), each choice comes up with some benefits or loss, and therefore actions are named as a strategy as shown in Table 1. Vehicle seeks for maximum benefit, and the strategy that has maximum benefit is called as dominant, and the strategy where benefits are equal is called as an equilibrium state. A flow diagram of SGTA based clustering mechanism is presented in Fig. 3, and algorithm 1,2 describes its step by step process details.

The Table 1 shows that if both Sv and Mv rejects then, they will get the payoff of −1. If Sv rejects and Mv accepts then Sv will get the payoff of −2 and Mv will get the payoff of 3. If Sv accepts and Mv rejects then Sv get the payoff of 3 and Mv will get the lowest payoff of −2. If both accept then, they will get the payoff of 1, which is not bad. The game-theoretic properties motivate each player to have a dominant strategy which is in our case the accept strategy. As we can see in Table 1, the payoff for accept strategy is higher corresponding to the possible strategy of the opponent player.

The dominant strategy in our mechanism is to accept the request to be selected as CH. As joining the cluster means to get free access to data acquired by a chosen CH otherwise have to pay the cost for internet connection via LTE. It is better to be part of a cluster to enjoy the free data for route planning and driving assistance. If selected as CH then there is no problem also because the next possibility will not be your turn to serve as CH, someone else from the rest of the participants will serve you. This is the motive for the participation in the cluster, and at the same time, a fair-use policy is incorporated within STGA using control flags to control overuse of the same vehicle as CH.

Algorithm 1 *SGTA Part at Mv*

```
Game theory applied by Neighbor after receives HELLO packet
Set strategies and related payoffs S= { St1, St2, St3, St4}
Find maximum (Vipo) {
            St1: IF Mv \& Sv accept set Vipo = 1
            St2: IF Mv accept \& Sv rejects set Vipo = 3
            St3: IF Mv = reject \& Sv= accept set Vipo = –2
            St4: IF Mv = reject \& Sv = accept set Vipo = –18.  }
Dominant strategy(DS) =St  WHERE
Vipo = Max (Vipo)
 IF C != 0 AND C>5 then reject
 {
       set C=C –1, ststate= 0 (ststate is opt strategy)
Otherwise, apply DS
          C=C+1, ststate= 116.     }
Send ACK back to Sv
Sv select CH and inform all Mv
At Mv IF CHID=MvID  (MvID is any vehicle ID)
              {
                     C=C+2, VID=CH
              ELSE IF ststate=1
                             C=C–0
                ELSE C=C–1
                }
Note CHID and start communication
```

The Mv is maintaining a queue to store the value of C flag and during the clustering process, every time the vehicle looks its value whether to accept or reject offer being selected as CH or not. This is to enforce fair use policy if its value is greater than equal to 5 vehicles will reject otherwise will opt to accept. Upon the acceptance, 3 will be added to flag C otherwise 2 will be minus from the value of C. The values of flag C will be decreased by 1 if all vehicle rejected the offer and increased by 1 if all accept the offer as according to game theory vehicles payoffs are interrelated to

Algorithm 2 *SGTA Part at Sv*

```
REPLY received by Sv
IF ststate =1
{
    NOTE  LQs vehicles
    Find Maximum (LQ) among received replies having ststate=16. }
IF LQSv = Maximum AND C>= 5 (Do reject)8.    {
    C=C−2
    Find Maximum (LQ) of only vehicles with ststate=1
    Set vehicles with maximum LQ = CH12.     }
IF LQSv = Maximum LQ AND C< 5 ( Do accept) 14.  {
     C=C+3
     Set Sv = CH17. }
 IF LQSv != Maximum(LQ) AND C< 5 (Do accept)19. {
    C = C +1
     Find maximum LQ of only vehicles with ststate=1
     Chose Mv of Maximum(LQ) = CH23.      }
 IF LQSv != Maximum(LQ) AND C>= 5 (reject)
{
      C = C −1
      Find Maximum (LQ) of only vehicles with ststate=1
      SELECT Mv of Max(LQ) = CH29.   }
 INFORM all
 Otherwise, Resend HELLO packet
```

each other decisions of acceptance and rejection. The value of flag C will be set as per Table 1 with the condition that Sv dominates in decision making and choose a vehicle with the highest LQ value among the multiple accepted offers. When clustering is repeated assuming same vehicles are participating in the clustering process, there will be a greater possibility that some else vehicle will choose as CH. The primary players are Sv and Mv having strongest LQ value. One more thing is that to enforce fair use policy; algorithm behavior is controlled in a way that the dominant strategy opted by SGT is overruled through flags to not to select the same vehicle as CH again in a new turn of the clustering process.

To check the correctness of our chosen strategies, we used GAMBIT [43] software, which is an open source software use bt the researcher for Game theory analysis. The snapshot of the GAMBIT software when we analyzed our strategic game to find dominant strategies are shown in Fig. 4.

There are some assumption regarding the generalization of our proposed solution. One is that the same vehicles are traveling along the same part of the road. Second is most of the vehicles are traveling towards the same destination over a particular road segment? This assumption increases the chances of the meeting of the same vehicle again on the same road strengthening our idea. Despite all this, our idea is, do serve others you will be served in response sooner or later up to certain extent. As if you have been served by others three times you must have to serve other for at least three times that we are doing in our approach. After the selection of CH, data, as well as status updates, are being exchanged between CH and Mvs.

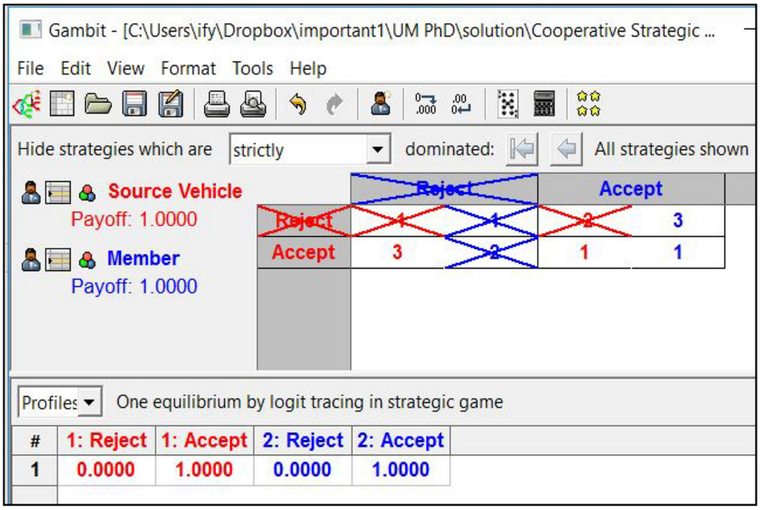

Fig. 4 Dominant strategy analyzed by Gambit software

3.2 Model (System) of Proposed Mechanism

A system model of the CIAC mechanism is developed which explains the overall operation, workflow, and status at various stages of the system. Our system has five defined states as presented in Fig. 5, before booting, the state of the system is not started, not selected and no error. After booting system gets into the new state having properties; started, not selected and no error. After the start, Hello message is broadcasted consists of information regarding the average speed of the vehicle, direction, location, and destination coordinates. CH selection process starts at this stage, and the Sv selected CH among the vehicles with the strongest LQ value and shown willingness to be CH. This state has properties started, selected and with no error. From this state, if LTE connection lost then the system will be in a state with properties, started, selected and error. Here, the system will wait for the timer (in our case 2 s) and change properties to start, not selected and error. If within specified time LTE connection re-established then system again go the selected state with no error otherwise system will prompt to the second stage. At this stage, the system will re-initiate the clustering process.

The model is developed to check the system at macro-level for operational correctness and clarity. The micro-level evaluation is done through simulation study by using simulation framework of OMNet++ for network simulations.

4 Results and Discussion

In this section, the first simulation setup is presented. Next, there is a table of performance metrics explaining each metric, and then a comparative analysis of the results of proposed solutions with existing approaches is presented in details.

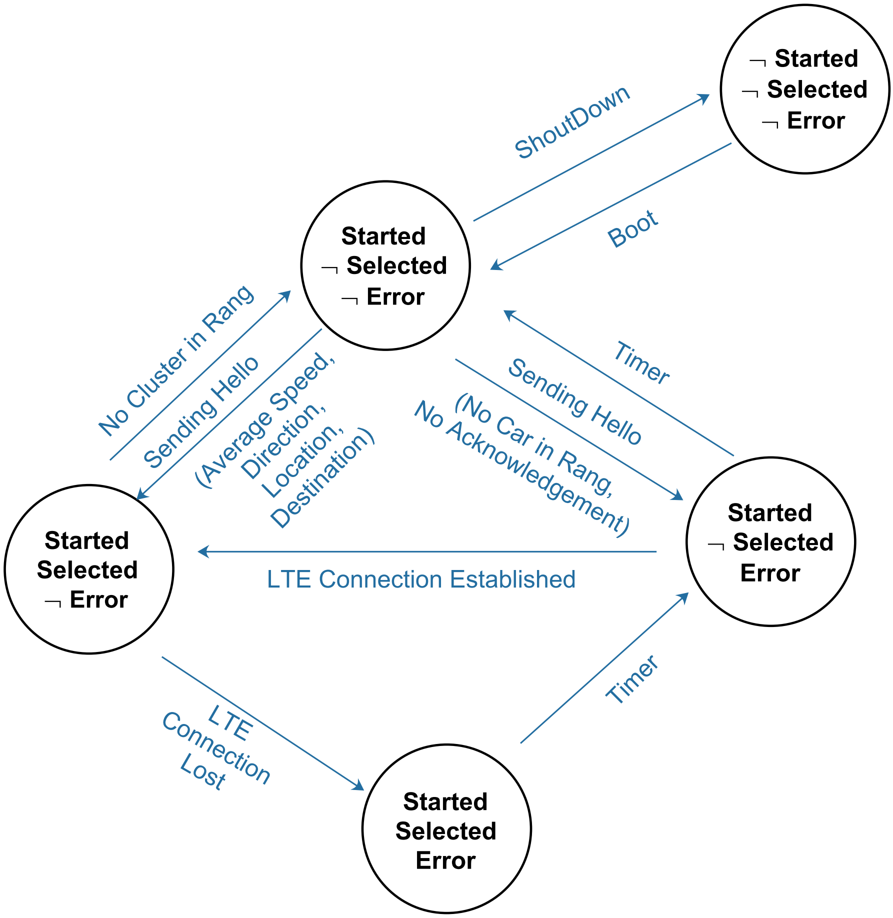

Fig. 5 Abstract model (system)

Table 2 Tools used for simulation

Tool	Description	References
OMNet++	4.6 Version for the simulation network of VANET	[9]
SUMO	Version sumo-0.19.0 to simulate mobility of vehicles	[6]
Veins	To incorporate the behavior of cars on the roads	[7]
simuLTE	To integrate LTE with VANET	[8]

4.1 Simulation Setup

The list of tools used for the implementation of our work presented in Table 2. The map of Kuala Lumpur is used for building road networks within the simulation by using OpenStreetMaps [44] for realistic outcomes of the results.

To increase the confidence level, we repeated simulation thrice at each velocity of the vehicles and average is taken to represent on graphs for comparative analysis. Other parameters are shown in Table 3 those are set for our simulation setting.

4.2 Performance Metrics

The results of the CIAC protocol is compared with MDMAC, VMaSC, and NCIAC (a version of CIAC with no cooperation). The performance metrics for comparison is displayed in Table 4. First, we check the utility of Mv and CH in the cluster and vehicle participation in clustering as we aimed to increase node (vehicle) participation and balancing the use of every node within the cluster as CH.

4.3 Analysis of Results

The result analysis of the CIAC with other existing approaches is displayed in graphs by taking the velocity of vehicles and maximum interested vehicles at different clustering iteration(s) along X-axis. Taking a percentage of vehicles act as CH, the utility of vehicles as CH or Mv and participation rate of vehicles in clustering on Y-axis.

Our goal is to check how many numbers of vehicles out of total interested vehicles those act as CH after various iterations. Increasing number of percentage after each iteration means not only a few vehicles always act as CH every time. This is to check the working of the fair-use policy within our proposed mechanism. The new vehicle is chosen in new iteration shows balance in use of CH and cost-incurring. This is to confirm that the CH selection is not just confined to a few same vehicles. If there is an increase from the first iteration to the next iteration which shows the CH responsibilities are shared by new vehicles on each iteration which is necessary for data and cost sharing. We repeated simulation five times at a various number of interesting vehicles (vehicles those willing to be CH out of total vehicles introduced within simulation area), and performance of CIAC is compared with existing approaches such as MDMAC, VMaSC, and NCIAC. The results comparison after iteration 1, 2, 5 are presented in Figs. 6, 7, 8 respectively.

Figure 6 represents a comparison of the percentage of vehicles act as CH against different maximum interested vehicles for NCIAC, CIAC, MDMAC, and VMaSC. The graph represents how many vehicles out of total interested vehicles are acting as CH after the first iteration of clustering. It is clear that when there is less number of vehicles the participation of vehicle as CH is same and with the increase in a number of vehicles it is decreasing. The number of CH means a number of clusters formed out of total vehicles and when there are 25 vehicles only 8 percent of the vehicle are acting as CH for VMaSC which is lowest. The reason is that VMaSC allows vehicles to connect to CH through intermediate vehicles, cluster size and scale are higher. The performance of CIAC and non-cooperative version of our CIAC that is NCIAC is same against a various number of vehicles.

Figure 7 represents a comparison of the percentage of vehicles act as CH against different maximum interested vehicles for NCIAC, CIAC, MDMAC, and VMaSC after the second iteration. Now it is clear from Fig. 7 that the percentage of vehicles act as

Table 3 Simulation parameters

Parameters	Values	Parameters	Values	Parameters	Values
Simulation area	3 km * 3 km	RSU antenna type	Sector directional (16 dBi)	ENodeB TxPower	45 dBm
IEEE 802.11p (frequency/BW)	5.89 GHz/10 MHz	OBU vehicle antenna type	Omni-directional (8 dBi)	Number of vehicles	100
Data rate	6 Mbps	OBU height	1.5 m	Resource blocks	100
TxPower	26 dBm	RSU height	10 m	Guard subcarriers	423
Header packet size	256 B	LTE (frequency/BW)	2.1 GHz/20 MHz	Control subcarriers	500
Beacon interval	25 ms	UE TxPower	20 dBm	No. of subcarriers per RB	12
Maximum velocity	10–35 m/s	LTE BS antenna type	3-sector directional (16 dBi)	LTE vehicles antenna type	Omni-directional
Base station height	18 m	Vehicle height	1.5 m	Simulation Time	300 s

Table 4 Performance metrics

Parameter	Definition
Participation as CH	It is the percentage of vehicles out of total interested vehicles those act as CH after various iterations
	Increasing number of percentage after each iteration means not only few vehicle always act as CH every time
	The new vehicle is chosen in new iteration shows balance in use of CH and cost-incurring
Participation rate	It is the percentage of the vehicles participating in the cluster out of total interesting vehicles
	More participation means cooperation algorithms performance is good
Utility	It is the probability of use of vehicle both as CH and Mv against various number of interesting vehicles after iterating clustering several times

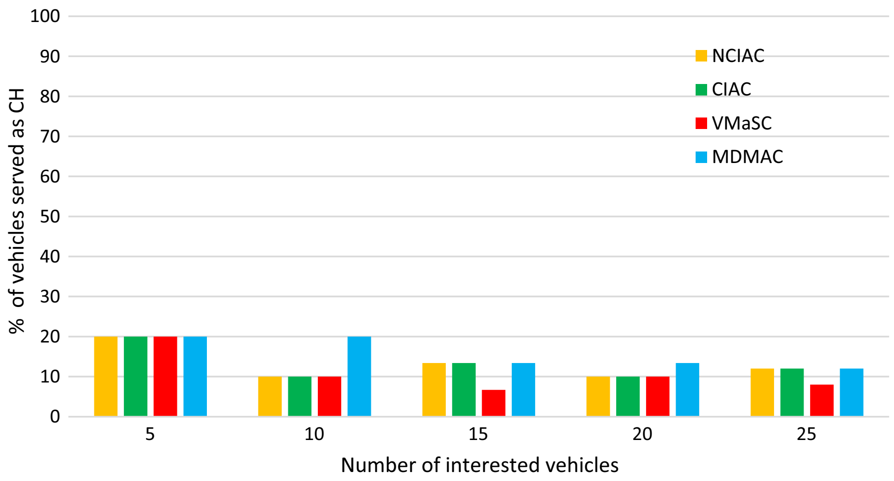

Fig. 6 CH against different maximum interested vehicles

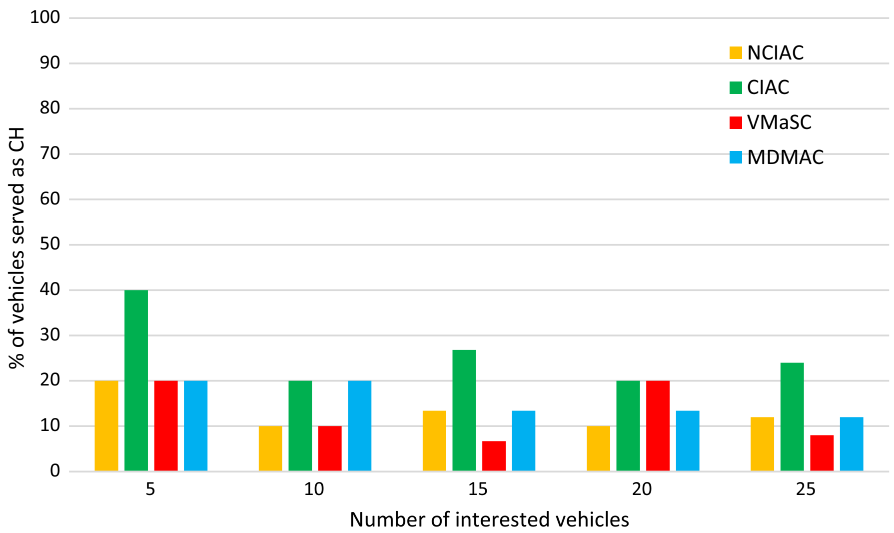

Fig. 7 Total of CHs versus interested vehicles after 2nd iteration

CH in case of CIAC is more than MDMAC, VMaSC, and NCIAC. The percentage for our CIAC is also decreasing with the increase in a number of vehicles but still higher than other approaches.

When we compared values after 5th iteration (as shown in Fig. 8), the CIAC values are much higher when there is less number of vehicles involved in clustering which is 80 percent even NCIAC is around 40 percent. The percentage of vehicles those acted as CH out a total of vehicles is decreasing with the increase in a number of vehicles. MDMAC is lowest among all, and when there are 25 vehicles, the percentage of the rest of three is same. After multiple repetitions of clustering process for CIAC, almost

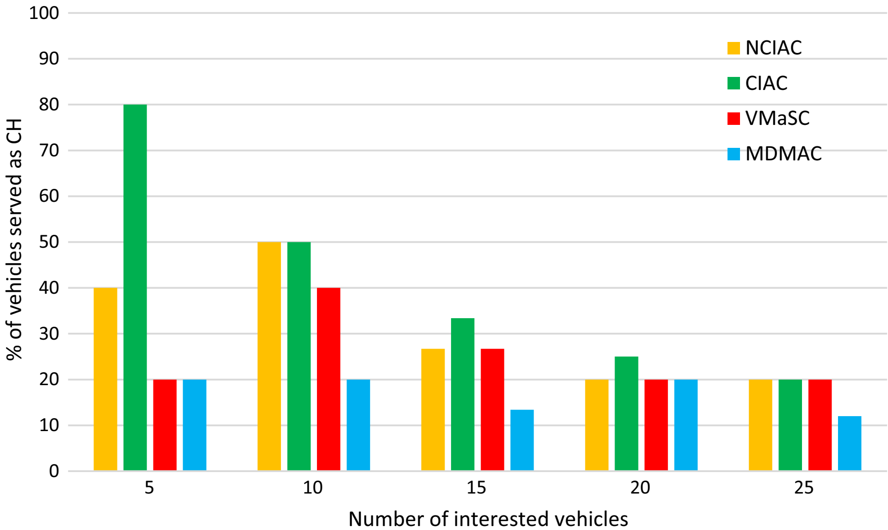

Fig. 8 Total of CHs versus interested vehicles after 5th iteration

every vehicle acted as CH which shows a balance in use as CH resulting in to balance in the cost of use as in our case CH is paying the cost for the access of information from the internet via LTE. This shows that for a typical road segment with the condition of the vehicle remain in proximity; there will be a fair balance in the cost of use which is due to the fair use policy of our protocol incorporated in CIAC Fig. 9 shows the utility of vehicles as CH and as Mv or free rider for CIAC and NCIAC against a various number of vehicles. We can see that the utility of vehicles as CH is increasing and utility of vehicles as Mv is decreasing. The utility of CIAC is greatest at a number of vehicles 5, and it is the same as NCIAC when the number of vehicles is 10 and 25. The probability that vehicles will remain a free rider is very less when there are less number of vehicles, and if increases the number of vehicles the utility of vehicle as the free rider is also increasing. The probability of vehicles those can remain as a free rider in case of CIAC is less than NCIAC and it same when a number of vehicles are high. This is because CIAC is avoiding to select the same vehicle again and again as CH due to the fair use policy of SGTA. Actually, after repeating clustering 5 times, we checked that how many vehicles served as CH and how many remain free rider.

Finally, we check the participation rate of vehicles in the cluster by putting a total number of vehicles in the simulation environment the same but changing the velocities of vehicles. Figure 10 represents the participation rate of vehicles in the cluster for CIAC and NCIAC at different velocities. The participation rate of vehicles in case of CIAC is much higher than NCIAC at all different maximum velocities of the vehicles. Although the rate is decreasing with the increase in the velocities of the vehicle's rate for CIAC remains much high throughout. The increases in vehicles participation in clustering reduce the direct links to LTE networks resulting significant decreases in data download from the internet based server which reduces cost. The incorporation of SGTA in CIAC increases the vehicles participation in clustering process and also

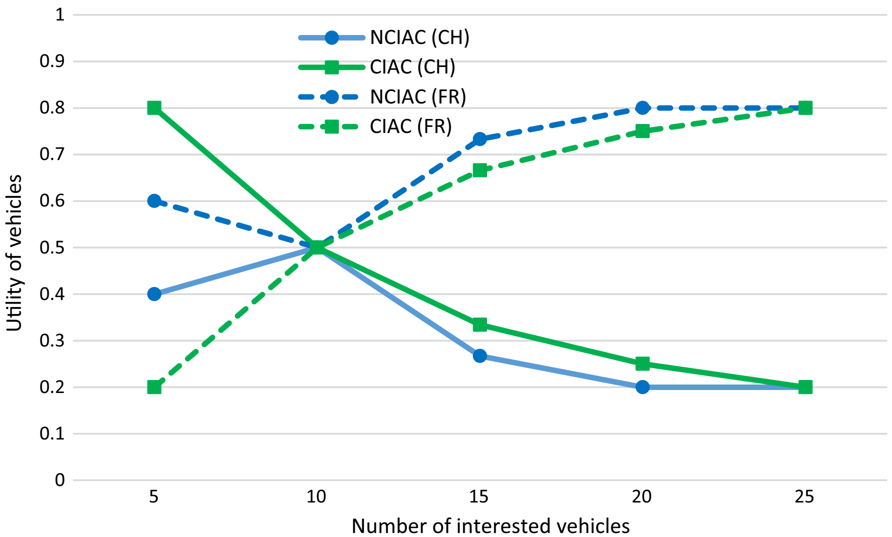

Fig. 9 Utility of vehicles as CHs and Mv versus interested vehicles

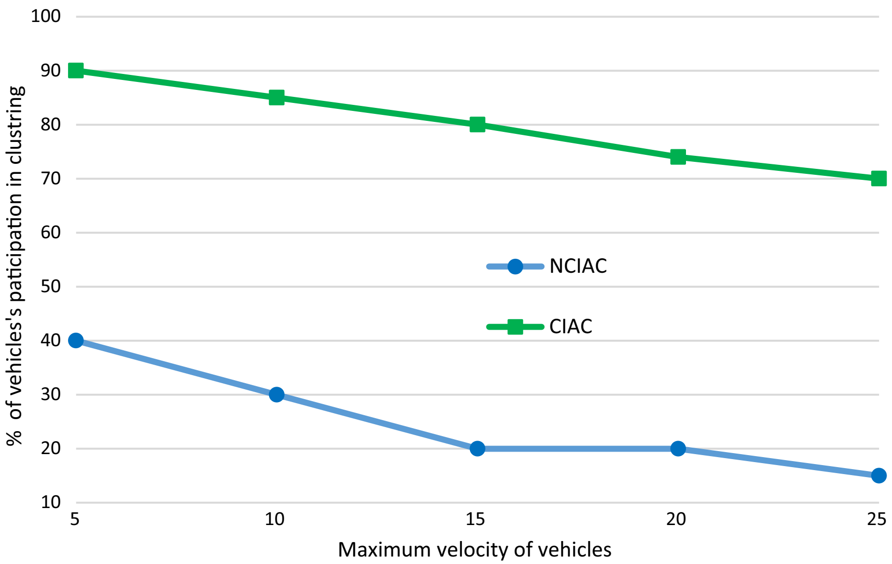

Fig. 10 Vehicles participation in clustering at various velocities

balancing the utility of the vehicle as CH over the participating vehicles. Which are the basic functional requirements for cooperative clustering. The CIAC shows better performance over the other approaches which not only reducing the cost of use but also the LTE resources.

CIAC rotates the role of CH among participating vehicles more fairly as compared to the well-known existing approaches which important factor of cooperative behavior.

CIAC increases the participation rate of vehicles in clustering process because of SGTA which motivates vehicles to participate and agree to be a CH to get the advantage of free shared data. The probability of vehicles those can remain as a free rider in case of CIAC is less which show that there is a decrease in the non-cooperative behavior of the vehicles. Hence, it is proved that CIAC is more cooperative clustering mechanism than existing approaches and it is a good choice for vehicular applications for road traffic management having heterogeneous network infrastructure.

5 Conclusion

The integration of LTE and V2V communication is useful for a variety of solutions. However, in the case of traffic efficiency applications, central control and making communications dependent on LTE network are ineffective. The cost of LTE subscription is one of the main factors to be considered when developing such solutions. When it comes to cost, cluster members proliferated to non-cooperation. A solution such as our CIAC is a good choice for clustering among the vehicles those are interested in accessing the TIS information from the remote servers over the Internet. A game theoretic approach is adopted, and also a fair-use policy is made. A system model of the system is also developed to check the correctness of the working of the mechanism and to explain how the system makes transitions at different stages of the clustering process. CIAC motivate vehicles to participate in the clustering process and also controls the CH selection procedure in a way that balance the use of vehicles as CH to share the accessed information and cost. CIAC is a good choice for vehicular applications for road traffic management having heterogeneous network infrastructure.

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