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Spatial-based Grouping of VANETs Using Particle Swarm Optimization Algorithm

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***Abstract*– Nowadays, VANETs are one of the most important networks in the mobile network research domain; these networks have highly mobile nodes that are constantly exchanging information. High mobility, large number of vehicles, and lack of concentrated infrastructures has caused many problems regarding routing, communications security, Packet lost, repeated communications, inappropriate information transfer, etc. Moreover, due to the high mobility, the topology of these networks is constantly changing and optimal information propagation is one of the most important challenges in these networks. In this paper, the VANET`s nodes, i.e., vehicles, are grouped with an algorithm and information is exchanged in the form of small groups. This grouping reduces the constant topology changes. Moreover, it is predicted that grouping mitigates lost data and information transmission in different routes. This paper investigates the formation, selection, and identification of each group. Moreover, the grouping algorithm is optimized using particle swarm optimization to optimize the formation and head selection of each group.**

***Index Terms*– VANETs, Grouping and Particle Swarm Optimization**

I. INTRODUCTION

VANETs are a type of ad hoc networks that allows communication between adjacent vehicles and between vehicles and fixed equipment usually installed at the side of the roads. The main goal of VANETs is creating more comfort and security for the passengers [2].Accordingly, an electronic device is installed in each vehicle that allows connecting to other vehicles (OBU-On board unit) [14]. Therefore, each vehicle equipped with VANET**.** Operates as a node in the ad hoc network and is able to send or receive others messages through the network. These messages are mostly used for security and traffic control purposes [6], for instance, accident alert, entertainment, traffic observation, road sign announcement, paying parking expenses, etc. These messages are useful tools for the driver to select an appropriate route. In addition, multimedia and internet facilities are embedded for the passengers. Paying tolls and parking expenses are other services of these networks. Today, large vehicle manufacturing factories have initiated different projects regarding these types of networks and equipping their vehicles with VANET capabilities. Vehicular ad hoc networks (VANETs) are a leading challenging group of mobile ad hoc networks (MANETs) [8], which have currently attracted considerable research interest regarding wireless networking and vehicle industries. Due to their relatively high flexibility, communication in VANETs poses stronger challenges in public communication. Environments without an underlying structure and a highly dynamic network topology constantly change these networks [10], [11]. VANET can be considered as a component of intelligent transportation systems (ITSs) [4]. As mentioned, highly dynamic nodes and servers without a central station cause collisions in wireless VANET communications and packages are mostly lost or delayed. In these scenarios, simultaneous communication easily fails. VANETs employ different wireless technologies, including DSRC, which is a type of Wi-Fi, as well as WIMAX and cellular technology. Other short band wireless protocols, e.g., IEEE802.11, Bluetooth, and CALM are also usable in these networks [12]. This paper proposes VANET grouping that allows using particle swarm optimization to optimize communications in concentrated traffic conditions and the formation these groups.

The remainder of the paper is organized as follows: section II presents the related works; section III, particle swarm optimization; section IV, a brief summary of grouping; in section IV-A, group identification; in section IV-B, weight calculation of each node using PSO; in section IV-C, inviting to group formation using PSO; in section IV-D, forming optimal groups using PSO; in section IV-E, group selection; and in section V, conclusions are presented.

II. RELATED WORKS

There are many studies regarding grouping in VANETs. GAP protocol based grouping and authentication is proposed in [9] to reduce the delay and lost messages. The node clustering methods are introduced in [14], in which the node at the center of the group is considered as the leader node. These two methods do not specify the parctical processes that nodes perform to manage the group and the collected information is not sufficiently reliable. A grouping algorithm is used in [3] to reduce the number of communications and lost packages and prevent information propagation in different routes. Moreover, information exchange security is provided using a hybrid method of symmetric and asymmetric encryption algorithms and the grouping prevents repetitive communications. This paper aims to form and select groups and group leaders using particle swarm optimization.

III. PARTICLE SWARM OPTIMIZATION (PSO)

Imagine you and a group of your friends are looking for a treasure. One of the group members has a metal detector and a radio that can inform its neighbors of its location and status. Therefore, you know whether your neighbors are closer to the treasure than you are. If a neighbor is closer to the treasure, you can move towards him. This increases your chance to find the treasure and the treasure is found faster than working alone. This is a simple example of swarm behavior in which individuals cooperate towards an end; this approach is more effective than those individuals working separately are. Swarm can be defined as an organized set of creatures that cooperate with each other. PSO is a social search algorithm that is modeled based on the social behaviors of bird groups. This algorithm was first used to recognize the patterns of simultaneous bird flights, their sudden path changes, and their optimal group formation. In PSO, particles flow in the search space and change their location under the influence of experience and knowledge of their own and their neighbors; therefore, the location of other swarm particles affects the search of one particle [7] connected that the result of modeling this social behaviors is a search process in which particles tend to move towards successful areas. Particles of swarm learn from each other and move towards their best neighbors based on the achieved knowledge. In this algorithm, there are np particles scattered randomly in the problem space and each particle possesses a location and cost [4]. As mentioned, a linear combination of its own and its neighbors` experience are used as equation (1) to move a particle:

$$x_{i_{new}} = v_{i_{new}} + x_{i_{old}} \qquad (1)$$

Where V is the movement speed of particles computed as follows:

$$v_i\_new = wv_i\_old + (x_i\ localBest\_\ x_i\ old)c_1r_1 + (x_i\ globalBest\ \_\ x_i\ old)c_2r_2 \qquad (2)$$

Where xi_localBest is its own experience and x_globalBest is the pattern experience. We must note that each particle has a xi_localBest and there is one xi_globalBest for all particles. Moreover, c1 and c2 are decision coefficients and are determined based on their importance, whether it is more important to move according to our own experience or that of others. These values are usually considered c1+c2=4, for instance c1=c2=2. Furthermore, r1 and r2 are two random variables [1,15] with a uniform distribution between 0 and 1 that is equivalent to the rand instruction of Matlab. WVi_old is known as the coefficient of inertia [1,15]. In PSO, the first two coefficients are important and the coefficient of inertia can be ignored.

The main process is applied to a number of particles as follows: first, n particles are randomly placed in the search space and the cost of each particle is computed based on its location. Subsequently, the equation above is used to move the particles. The important thing to note is what the xi_localBest and x_globalBest values are. The former is the values of the particles and the latter is the best value among all particles. Having these two parameters, the particles are updated. According to the equation above, the location and cost of each particle , as well as xi_localBest and x_globalBest are updated. For each particle, it should be determined whether the new location is better than xi_localBest and if so, xi_localBest is updated [15]. Finally, the best location is stored in x_globalBest and this process is repeated for a certain number of times [4], [7].

IV. GROUPING

A group in VANETs is defined as a set of vehicles that are geographically adjacent to one another. This geographical region is formed based on the vehicles` movements. A group requires at least one vehicle and a leader node is selected for each group to manage it. The leader node is responsible for forming the group and managing the communications .In VANETs, the number of connections is highly unsustainable and variable. Therefore, managing these nodes and their communications is very important. In these networks, all group members communicate with the leader and other nodes. In what follows, groups are formed, selected, and optimized.

A) Group Detection

In this stage, the node first continuously checks if there are any other adjacent nodes. If there is a node, it checks whether it is a leader node and in that case, moves to the group selection stage; otherwise, the node tries to form a group [3].

```
functionGroupDetection (...)
numberOfNeighbors = 0;
numberOfLeaders = 0;
while (neighbor(i) exists) do
if (isLeader(neighbor(i))) then
numberOfLeaders = 0;
end
numberOfNeighbors++;
i++;
end
if (numberOfLeaders == 0) then
GroupCreation();
else
GroupElection();
end
end function
```

B) Computing the Weight of Each Node Using PSO

In this algorithm, the best state is determined based on the following measures:

- The best location of the node in comparison to surrounding vehicles.
- The speed that is closer to the mean speed of the group.

PBest: the best state of the node in comparison to previous states and *GBest:* the best public state of the node; the lower the absolute difference of these two values, the more the node has an appropriate weight. The best state is computed based on speed and frequency:

- The speed of this node is closer to the mean speed of the group.
- It has a better frequency.

```
01: functionCalcMyGroupWeight(…)
02: GBest = Best global position for nodes based on POS algorithm;
03: PBest = This node position based on POS algorithm;
04: return ABS (PBest - GBest);
05: end function
```

C) Group Formation Invitation Using PSO

In this stage, the leader node i invites other nodes to form a group. The group is formed based on the optimal weight computation function that was explained before.

```
01: function CallForCreateGroup(…)
02: return CalcMyGroupWeight();
03: end function
```

D) Optimal Group Formation Using PSO

At the group formation stage, the vehicle is not close to any leader node. This node checks if there are at least X neighbor nodes that belong to no other groups and the variable Y indicates that the vehicle is turned off or separate from the groups. If the number of neighbor nodes that belong to no group is less than group formation threshold, the vehicle waits one time interval (time1) to form a group and reruns the detection function. If then number of neighbor nodes is larger than X+Y threshold, the vehicle begins forming a new group; in other words, it sends a group formation request to its neighbors and nodes can reply to this request. If the number of neighbor nodes is larger than X, the vehicle invites them to form a group. If in comparison to other nodes, this node has a smaller weight, it is selected as the leader node. The leader of the group sends an encryption key to all nodes accepting the request and a public key to all nodes. Otherwise, the remaining Y nodes (not accepting the group formation request) are added to the group.

```
    01:functionGroupCreation (...)
    02: if (numberOfNeighbors>= X + Y) then
    03: AcceptedNeighbors = 0;
    04: n = 1;
    05: l = 0;
    06: MulticastNeighbors (NeighborsList[]);
    07: for (n=1; n _ numberOfNeighbors; n++) do
    08: ReceiveGroupElection(n);
    09: if (neighbor(n) accept) then
    10: acceptedNeighbors(l) = neighbor(n);
    11: l++;
    12: acceptedNeighbors++;
    13: end
    14: end
15: if (acceptedNeighbors>= X)then
16: ICaneBeLeader = true;
17: MyCreateGroupWeight=
CalcMyGroupWeight();
18: CallForCreateGroup(acceptedNeighbors[]);
19: for (n=1; n_acceptedNeighbors; n++) do
20:if(CallForCreateGroup(n)<MyCreateGroupWeight)then
21: ICanBeLeader = false;
22: end
23: end
24: if(ICanBeLeader)then
25: for (n=1; n_ acceptedNeighbors; n + +)do
26: SendGroupKey(acceptedNeighbors(n),
27: PuKacceptedNeighbors(n));
28: end
29: end
30: else
31: Y = Y + X - acceptedNeighbors;
32: Wait(time1);
33: GroupDetection();
34: end
35: else
36: Wait(time1);
38: GroupDetection();
39: end
40: end function
```

E) Optimal Group Selection Using PSO

This stage starts when the vehicle finds at least one leader node among its neighbors; if it has only neighbor that is a lead node, selection is performed automatically. Otherwise, the vehicle selects and joins one of the groups. groupValue represents the node quality and groupleader[j] represents the j-th neighbor of the node, which is a leader node. If there are several leaders among the neighbors, the vehicle selects the optimal group based on group value, which is computed based on PSO measures, e.g. speed, location, and frequency.

```
01: functionGroupElection (...)
02: if (numberOfLeaders>= 1) then
03: j = 1;
04: e = 0;
05: groupValue[e] = 0;
```

```
while (groupLeader[j] exists) do
groupValue[j] = CalcMyGroupWeight();
if (groupValue[j] _ groupValue[e])then
groupValue[e] = groupValue[j]
end
j++;
end
else
e = 1;
endif
sendRequest (groupLeader[e]);
receiveGroupKey(groupLeader[e]);
end function
```

V. CONCLUSION

As mentioned, one of the main challenges of VANETs is the optimal propagation of information. This paper proposes particle swarm optimization based grouping; grouping reduces the number of communications, particularly in heavy traffic conditions, thus increasing the communication quality. In this paper, grouping is optimized using particle swarm optimization and using the proposed automatic management, it is predicted that the number of communications is considerably reduced and the communication quality is improved.

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