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Generation and dissemination of traffic information in Vehicular Ad-hoc Networks

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Abstract: *In this paper, we propose CIGDP (Counter-flow Initiated Generation and Dissemination Protocol), a protocol for dissemination of traffic information in urban traffic networks using a distributed computers architecture approach. Vehicles detect, generate and propagate information without relaying on any existing infrastructure. We focus on the following type of traffic events: jams, slippery section, rainy and dark areas. Because the vehicles, participant in the event are moving away from the intended receivers for such kind of information, we suggest a new approach in which information will be generated and propagated by cars in the opposite direction. We evaluate the performance of suggested protocol using realistic simulation of the vehicle traffic in Nottingham city, UK.*

Keywords: *ad hoc networks, opportunistic forwarding, localized algorithm, traffic information*

1. INTRODUCTION

Popularity of mobile ad-hoc networks (MANETs) is due to their ability to enable distributed application among mobile nodes. Many protocols have been proposed for routing and data delivery in MANET networks [3,7,8]. However, most of them are inefficient when used in vehicular ad-hoc networks (VANETs). VANET networks have characteristics of high node's mobility, dynamically changing topology and constrained movement that makes topology-based routing algorithms less appropriate. Furthermore, as indicated by [9,11,12] an opportunistic forwarding and the use of localized algorithms are better suited for such networks. There are many possible applications for VANET networks. In this paper, we focus on the generation and dissemination of information about various traffic events such as traffic jams, slippery section, rainy and dark areas etc.

Deployment of applications on VANET networks requires the support of data dissemination services. Some recent research works [9,11,12] propose dissemination algorithms that address the unique characteristic of VANET networks. The authors of [11] have proposed MDDV (Mobility-centric Data Dissemination algorithm) that uses the conception of message head for dissemination purposes. The message head is dynamically changing as the message is propagated. However, MDDV does not consider how the information is generated, neither who generate it.

In a closely related work, Saito et al. [10] propose RMDP (Received Message Dependent Protocol). The RMDP protocol uses vehicles in the opposite direction to disseminate traffic information. However, they do not consider an aggregation of the disseminated information. In RMDP, every vehicle broadcast its own information along with that learned from other vehicles. In this way, vehicles that receive the information should decide whether it is true or false.

In this paper, we further develop the approach of disseminating the traffic information by vehicles in the opposite direction. The basic idea behind CIGDP protocol is that vehicles in the opposite direction act as master nodes; they make inquiries about new traffic information, make decisions about the accuracy of such information based on the number of received responds and then generate and propagate the messages. We assume that all vehicles are equipped with at least GPS device, IEEE 802.11 wireless transceiver and some mobile computing device. The evaluation of the protocol is done with SWANS (Scalable Wireless Ad hoc Network Simulator) [2] built atop the JiST (Java in Simulation Time) platform [1], a general-purpose discrete event simulation engine. The SWANS is organized as independent software components that can be composed to form complete wireless network simulation. One such component used in our simulations is STRAW [4] (Street Random Waypoint), a very realistic integrated mobility and traffic model for VANETs.

The remainder of this paper is organized as follows: In Section 2 we describe CIGDP protocol, in Section 3 the evaluation of the performance is presented, Section 4 contains conclusions and some ideas regarding future work in this direction.

2. PROTOCOL FOR TRAFFIC INFORMATION PROPAGATION IN VANETS

2.1. VANET Networks Background

In VANET networks, vehicles exchange information with their neighbours (vehicles within their short radio range) and ad hoc networks' routing protocols are used to propagate information to other vehicles. Some important characteristics [11] that distinguish VANET networks from other types of ad hoc networks include:

- High mobility that leads to extremely dynamic topology
- Regular movement, restricted by both road topologies and traffic rules
- Vehicles have sufficient power, computing and storage capacity
- Communication locality, limited to vehicles geographically close to each other
- Partitioned; as indicated by [5] probability for connectivity decrease with distance
- Vehicles are usually aware of their position and spatial environment. We assume that vehicles are able to track their exact location using a GPS device and pre-stored digital maps.

Because of these properties a special considerations should be taken in the design of a protocol for VANET networks. As discussed in [12], due to the partitioned, highly dynamic nature of these networks localized algorithms based on vehicles interacting with neighbours are better suited.

2.2. Traffic event detection

Detection of traffic events is done locally on every vehicle, independently from one other, by estimation of data from system sensors and devices. Detected events are stored in local buffers and reported only when request is received. Here we discuss detection phase of different types of events.

One sure indication of traffic jam is relatively short traversed distance for defined time period. Vehicles calculate the traversed distance in Δt_1 intervals (Δt_1=10s). Decision for traffic jam is taken on the traversed distance for the last 3min. Conclusion for traffic jam is taken, if the distance is less than d_1, where d_1 is 15% of the distance that a vehicle would traverse if it were moving with the average speed for that segment.

The 3-minute period is chosen appropriately to the cycles of traffic lights. The traversed distance is calculated using the data from GPS.

Slippery sections are detected by slide conditions of tires (e.g. ABS system of the car is "on"). Rainy and dark conditions are detected by working windscreen wipers and headlights. Accidents are detected directly by the systems in vehicles (airbags deployed).

Different types of events are stored for different time. For example, jam event is removed immediately after no longer valid, while other events are stored for some time, before erased.

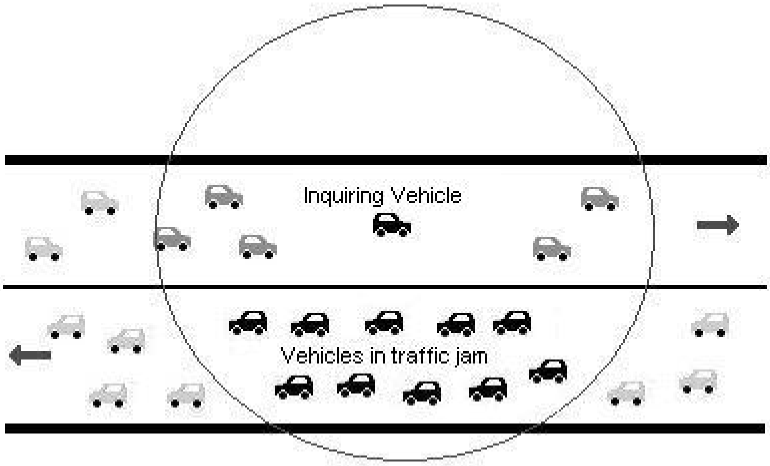

Fig. 1: Inquiring scheme

2.3. Algorithm for Inquiring and Messages Generation

For simplicity, we focus on traffic jam event only. As mentioned previously, message generation is done by vehicles in opposite direction. It seems to be better since information is propagated backward from the point of view of participant vehicles.

Let assume that a traffic jam occurs and participant vehicles detect it. Along the opposite lane and heading away from the jam situation, vehicles are moving and the first of them to decide new information is needed (for example after an arbitrary timeout), starts the querying process. It sends a broadcast message in which it includes its location and movement direction (Fig. 1). Vehicles in the same direction that receive the message skip one query cycle. Vehicles in the opposite direction that have detected some traffic event start uni-cast their responses. In the example, they respond with a jam event. Inquiring vehicle then decides whether traffic jam has really occurred accounting for the number of responses and the number of lanes in the road. Depending on that, the collected information is discarded (false information is filtered here) or a message for that event is generated containing the following set of information:

- Current location of the vehicle
- Time of registration
- Location of event (road segment)
- Direction
- Status (ACTIVE or PASSIVE)
- Code of event
- Time-to-Live
- Some other information

Most of the fields are self-explanatory. Status and Time-to-Live fields are explained in the next section. Code of event contains the type of traffic event detected (jam, etc.).

The vehicle that generates the message marks itself Active in the status field and broadcast the message, so that vehicles in the same directions within its transmission range also make a copy of the message and mark themselves Passive. Vehicles query the network at Δt_2 intervals. Δt_2 is a system parameter and its determination is trade-off between unnecessary communication overhead and early message generation.

2.4. CIGDP

The dissemination of generated information is process that concerns the transport of messages to intended receivers. In the case of traffic jam, intended receivers are these vehicles that plan to pass by the location of the jam and have an alternative route. Every message for a jam is associated with a number called Time-to-Live (TTL). Every crossroad, that the message passes, causes decrement of this number. The value deducted depends on the type of the crossroad – it is more if the crossroad is with streets with equal traffic outputs (CETO) and less for crossroad with trunk and secondary roads (CTSR). When the TTL field equals zero the dissemination process ends and the message is discarded. The initial value of TTL is dependent on how extensive the jam is (number of vehicles, average traversed distance etc.)

The Status field reflects the state of the vehicle for this particular message. The assigned values can be Active and Passive. A vehicle can be marked Active for one message and Passive for another. Active vehicles are those that actually do the dissemination of the message. The reason to have Passive vehicles is to increase reliability for message delivery, expansion of covered area and reduce the communication overload at the same time. When Passive vehicle does not "hear" the Active one for some time then it marks itself Active and becomes source of dissemination for this message. In this way, after a crossroad, where vehicles usually take different directions, Passive vehicles may eventually become Active expanding the covered area.

An Active vehicle may become passive in one of the following two cases: when the same message is received from the vehicle that is in front of it on the same road and direction or when a more recent message is received for the same event. Messages that are more recent are distinguished by having the same: code of event; location of event; and direction, but have more recent time of registration.

Dissemination interval was set to Δt_3, where Δt_3 is a system parameter. If a front vehicle, moving at the same road segment and direction receives the message it copies the message, marks itself Active and starts to propagate the message. The first vehicle moving in same direction will eventually become the only Active vehicle, while the others will have passed the initiative and have become Passive.

3. EVALUATION

3.1. Simulation Environment

All of the simulations of CIGDP were done using the SWANS network simulator [2]. The SWANS software is organized as independent software components that can be composed to form complete wireless network simulations. At the physical layer we have used STRAW [4], a realistic mobility and traffic model for VANET networks, with data that correspond to real Nottingham City maps. The MAC protocol used is IEEE 802.11b DCF. The radio range is set to 250m. At the network and transport layers we use IPv4/UDP protocols. We implement CIGDP as an application layer protocol for SWANS simulator.

The STRAW mobility model is divided into three components:

- Intra-segment component: Car-following Model
- Inter-segment component: Stop Signs, Stoplights and others
- Route management component: Random Waypoint and OD (Origin-Destination)

In our experiments, we have used the Origin-Destination model. This gives us more control over the simulation and opportunity to create conditions for occurring of traffic jam event.

3.2. Simulation Results

In first simulations, we have used only a portion of Nottingham city map. We have simulated the occurrence of one traffic jam. The system parameters used in simulations were Δt_1=10s, Δt_2=5,10s, Δt_3=5,10s and d_1=350m. Figure 2 shows the collision ratio and Figure 3 shows the acquisition ratio for traffic jam information in respect to time for four different combinations of Δt_2, Δt_3 parameters.

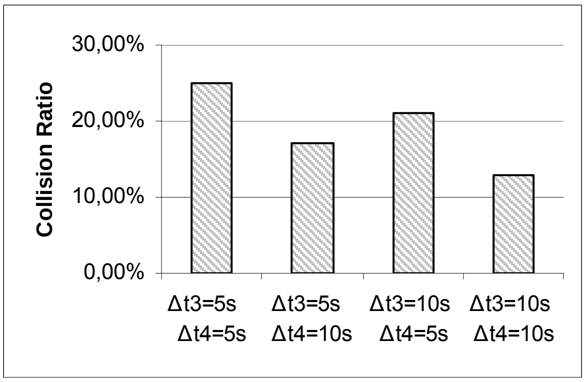

Fig. 2: Collision ration

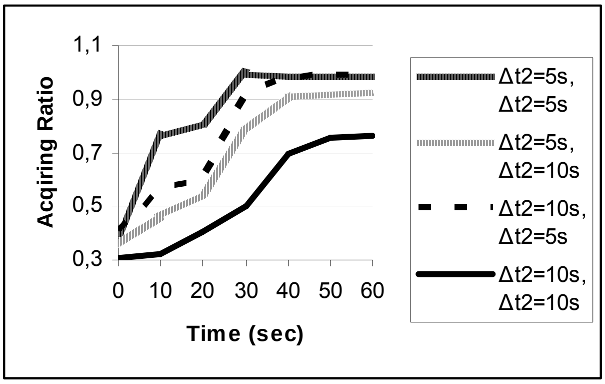

Fig. 3: Acquisition Ratio by Time

We have also estimated how re-routing affect the time for traversing the distance between origin and destination. Tab. 1 shows the times for five particular vehicles. They were chosen because all have an alternative route.

Tab. 1: Times for traversing the distance with and without re-routing.

Times for traversing OD distance (minutes)	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4	Vehicle 5
Without Re-routing	5,23	13,1	2,7	4,74	23,01
With Re-routing	4,07	7,3	3,1	4,05	18,04

4. CONCLUSIONS AND FUTURE WORK

In this paper, we have proposed CIGDP, a protocol for generation and dissemination of traffic information. Evaluation of the protocol shows that it performs well for traffic jam conditions in urban areas. The results show that only one of the vehicles takes longer time to arrive at its destination.

Some ideas for future work include adaptation of the algorithm for such situations like one-way streets or no vehicles in the opposite lane. Another direction for future work is evaluation of CIGDP accounting for the fact that not all vehicles are equipped with up to date communication and computer equipment. The performance of the algorithm should be analyzed for different percentages of equipped vehicles. Another direction may be to adapt the dissemination interval to speed of the vehicle.

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