Interests-Sensitive Data Dissemination Protocol for Vehicular Ad-hoc Networks

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Abstract. Vehicular ad-hoc network (VANET) is a potential player in an intelligent transportation system that would increase road safety as well as road confort. In VANETs, vehicles excahnge road-related information either through an established infrastructure, which is costly, or through their collaboration when in common transmission range which we adopt in this paper. Information dissemination is realized through broadcasting, thus an intelligent selection technique should be deployed to decrease the traffic load caused by unnecessary rebroadcasting. In this paper, we propose an interest-aware data dissemination protocol that periodically exploits the current neighbors ínterests to select the proper set of data to be broadcasted. The proposed approach is structure-less and imposes minimum overhead on the communication bandwidth. The protocol is evaluated through simulation experiments and rResults obtained demonstrate that this approach maximizes the number of relevant data reports received by the vehicles, especially if a certain data type is more popular than the others.

1 Introduction

Vehicular ad-hoc networks (VANETs) have emerged as a result of the increased number of vehicles capable of wirelessly interconnecting through their onboard radio communication devices, thus forming an ad hoc network on the fly. Moreover, DSRC standard (Dedicated Short Range Communication), developed by IEEE, provides vehicular ad hoc networks with large bandwidth. Seven non-overlapping channels, each of 27 Mbps bandwidth, can be used for data dissemination. Only one channel is dedicated for safety messages while the rest can be used for other road-related services.

Data dissemination is performed either through vehicle to infrastructure communication or vehicle to vehicle communication. While the former requires the existing of an infrastructure in form of road side units which imposes additional cost and delay, the latter is purely based on the ability of vehicles within common transmission range to communicate. Multi-hop transmission is needed in order for the data to reach farther vehicles.

The easiness and self configuring nature of VANETs enabled a broad range of information applications ranging from road safety to journey comfort to appear. Vehicles collect and exchange information, in form of data reports, for traffic intensity, services along the road, weather conditions, free parking places and others. Thus, each vehicle can be a report producer, a report receiver, or both at the same time. It has been shown

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that VANETs have a highly dynamic topology due to its highly mobile nodes. Consequently, vehicular ad hoc networks tend to be often sparsely connected. Thus, data reports received by a vehicle are most likely to be stored for a while before being retransmitted when encountering a new neighbor. Limiting the number of stored reports and selecting the most important ones for transmission is a challenge that attracted research lately. Intelligent dissemination protocols should be adopted to decide which reports to store and rebroadcast later so as to efficiently share the wireless bandwidth as well as decrease the amount of unwanted messages received by the drivers.

Data dissemination has long been studied for mobile users with short range wireless communication forming a mobile ad-hoc network (MANET). Various protocols have been suggested in the literature, the simplest of all is one that relies on flooding. Each moving node broadcasts data to all its neighbors until either covering the whole network or reaching the maximum number of hops. This uncontrolled simple flooding approach leads to increasing the number of unnecessary data retransmission, causing what is known by the broadcast storm that results in inefficient bandwidth utilization and severe congestion, as observed in [4]. Consequently, a constrained flooding approach should be implemented. Different improvements over the basic flooding approach have been proposed in the literature that either control the time when to rebroadcast, or apply rules to decide whether to rebroadcast or not. A comprehensive survey can be found in [1,2,3]. Relying on the observation that travelers tend to have individual preferences in the type of content of data reports they would prefer to receive, we propose in this paper incorporating drivers ’ interests in the selection of data reports to be broadcasted. Reports are assumed to belong to one of predefined service categories. Neighbors ínterest in each category is locally computed at each vehicle. Most certainly, exploring the continuously changing neighbors ínterests without imposing extra overhead is not trivial. However, our protocol uses the periodic transmission of the beacon messages generated by the medium access control protocol for interests advertisement. The proposed protocol is evaluated through simulation experiments and proved to maximize the number of relevant information received by the vehicles.

The rest of the paper is organized as follows. Section 2 presents the different dissemination approaches suggested before. Section 3 presents an overview of the proposed interests-sensitive dissemination algorithm. In section 4, the simulation experiments and the analysis of the obtained results are discussed. Finally, section 5 concludes the paper with proposals for future work.

2 Data Dissemination Approaches

In general, data dissemination approaches proposed for ad-hoc networks considered one or more of the three main resource constraints in MANETs, namely communication bandwidth, energy consumption and storage [5]. Controlled flooding were suggested to decrease the number of repetitive retransmissions, thus efficiently use the bandwidth as well as decrease the energy consumption on the mobile devices. Control is performed either by the sender or the receiver. Receiver-based approaches proved to perform well in MANETs. In [6], data is forwarded to all nodes within a specific area defined by the sender. Each receiving node decides whether to rebroadcast the data or not based on its physical location with respect to the specified area. An improvement over this geographic-based approach were proposed in [7] where a content-based forwarding approach (CBF) is defined. In this approach, the next node for forwarding the message is selected by all neighboring nodes based on their actual position when receiving the message using a contention process. The farthest node that most likely would reach the destination is the best one considered for forwarding the data. Other variants exist in the literature. A comprehensive survey can be found in [1, 3].

Although the above techniques succeeded in reducing traffic load, they did not take into consideration the node ' s content requirements. A more selective approach should be used to intelligently select the set of data reports to be forwarded to prevent users from receiving unwanted messages. In [8], Wolfson et al. proposed a spatio-temporal selection approach that is based on the data novelty probability. The novelty probability of a data report reflects how new, and hence useful, this report is for the recipients based on its generation time and distance to generation location. As time or distance or both increases, report ages and eventually disappears. Although this approach proved to be efficient in terms of throughput and response time, it did not consider the individual users interests in the novelty probability. An autonomous gossiping approach for ad hoc networks were proposed in [9] where information is sent only to neighbors interested in receiving it. Each node advertises its profile that defines its interest. In addition, each data item maintains its own profile. Based on nodes and data item profiles, data items decide whether to replicate to a better node, migrate or do nothing.

However, it is worthy to note that VANETs have unique and challenging features that do not exist in MANETs. Examples of such features are the highly dynamic topology, highly mobile nodes, time critical responses, and insensitivity to energy consumption and computation power that are considered unlimited As a result, data dissemination protocols specifically designed for VANETs have been proposed. In [10], Tonguz et al. propose using the traffic density as well as the covered distance to decide whether to retransmit or not. In a dense area, only a subset of cars needs to rebroadcast. Moreover, as distance increase between the source of information and the node, the frequency of broadcasting is decreased. A similar approach, but taking time into consideration, was proposed in [11] where nodes receive data and store it for later retransmission. Only fresh data is rebroadcasted. Combining both distance and time in a relevance function, which extend the idea of Wolfson previously proposed for MANETs to VANETs, is introduced in [12, 13]. AutoCast in [14] uses a probabilistic flooding, that depends on neighborhood size. Individual interests in data disseminated were taken into consideration in some recent work. In [15], messages selected are based on their benefit to expected recipients. The benefit depends on the message context, vehicle context and information context. A different approach in [16] is based on a pull model where a node uses an utility-based approach to determine which data to pull upon meeting another node.

3 Interests-Sensitive Data Dissemination Algorithm

The interests-sensitive dissemination algorithm we propose is a structure-less algorithm that does not rely on any existing infrastructure. It is based on the same model as in [12, 13] to send and receive data reports, but augmented with an interest level component that collects neighbors ínterests using the MAC layer single hop beacon messages. We assume that data reports belong to one of predefined service categories based on their content. Categories may represent traffic data, parking service, weather information, and many others. Each vehicle has its own interest in each of those categories based on their content. Each vehicle has its own interest in each of those categories. The vehicle model and protocol description are presented below.

3.1 Vehicle Model

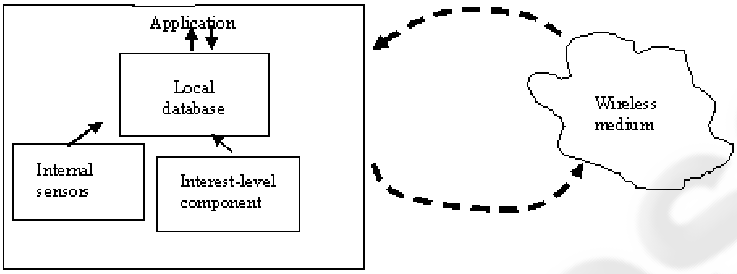

Fig. 1. Vehicle Model.

We consider a network formed by a number of moving vehicles modeled as in Figure 1. Each vehicle is equipped with a GPS receiver for localization, integrated sensors to collect road-related data, such as road surface condition, speed, light intensity or others, as well as a wireless radio communication interface to communicate with other vehicles. Each moving vehicle is modeled to have unlimited processing power but limited storage capacities. A local database is maintained at each vehicle that is limited in size to M reports, where M is a configurable parameter. The interest level component calculates and stores the interest level of current neighbors for each category. In the example shown in Table 1, 65 percent of the current neighbors are interested in receiving traffic related reports, 25 percent are interested in weather conditions, while 10 percent are interested in information about availability of parking places. This information is collected from the beacon messages periodically generated by each vehicle and saved in the node ś neighbor table.

Table 1. Interests Levels for 3 categories.

Category	Interest level
Traffic conditions	0.65
Weather conditions	0.25
Parking places	0.1

3.2 Interests-Sensitive Algorithm

As mentioned before, a vehicle can generate, send or receive data reports. A data report is composed of the following tuples:
carid, report-id (ID), generation time (t), generation location in x (x), generation location in y (y), category-id (CAT)

where category-id represents the service category the record belongs to. Report generation occurs upon detection of variations in the vehicle sensed data, like change in speed, road surface, or others. In this case, a report is generated and added to the vehicle local database either for immediate or later transmission. Sending data reports occurs upon either detecting a new vehicle in the neighborhood, or having a new data report generated that needs to be sent immediately. In this case, the vehicle checks its local database and selects the most relevant reports to be broadcasted. The relevance of the reports is based on the current neighbors ś interest level that is calculated for each category (i) by dividing the number of nodes interested in i, $(nodes_i)$, by the total number of neighboring nodes, as follows.

$$intLevel(i) = \frac{\sum nodes_i}{\sum neighbouringNodes} \tag{1}$$

The number of nodes interested in each category is calculated from the information saved in the neighbors table updated with the recipient of each beacon message, while the interest level is calculated upon transmitting a data report.

Lastly receiving data reports occurs when in range with any of the neighboring vehicles transmitting. The received set of reports is checked against the stored one and new reports are then added to the database. Figure 2 illustrates a simplified pseudo code for the proposed algorithm.

4 Simulation Methodology and Experimental Results

To further prove our concept, we simulated the behavior of the proposed protocol using Vsim, a VANET simulator created in the University of Ulm, Germany [17]. The simulator used combines both a road traffic simulation with a communication simulation as discussed below. In the following subsections, we present the simulation methodology, then the analysis of the results obtained.

4.1 Traffic Model

Traffic simulation is based on the traffic model of Nagel and Schreckenberg [18] where vehicles are generated randomly from the roads endpoints, heading to randomly chosen destinations. Their velocity and position are updated every 100 msec taking into consideration the rules for changing lanes and the behavior at intersections. In our experiment, a single bidirectional road model was used for testing. Vehicles are generated from both ends and move in opposite directions.

```
begin
    while (true) {
    If (change in sensed data > threshold) {
        compose report;
        add to localDB;
        }
    TransmitData();
    ReceiveData();
    }
end.
TransmitData() {
    if (new neighbor || timer expires) {
       for each category (i)
           calculate interest level;
       sort database descendingly;
       transmit top R records;
    }
ReceiveData()  {
    if (receive report from neighbor){
       for each report i in localDB {
          if (receivedreport == report.i)
              discard;
       }
       insert in localDB
    }
```

Fig. 2. Pseudo-code of the algorithm.

4.2 Communication Model

In this model, vehicles are communicating using 802.11 standard, where every 100 ms each vehicle broadcasts a beacon message to exchange its state with the surrounding neighborhood. A beacon message (HELLO message) is used by each node to build its own neighbor table. Each HELLO message is of length 105 bytes: 25 bytes for the header and 80 bytes for the data. The message header contains the car-ID, generation time, (x,y) coordinates of the vehicle and a list of its categories of interests. We limited our model to only 4 categories, as discussed below. The transmission range is set to 500m.

4.3 Experimental Results and Analysis

We consider a single road with vehicles generated from both ends in opposite directions. Data reports are generated by only 20 percent of the vehicles, which represent an injection rate of 0.2. Only four categories for data reports were defined in our simulation: traffic condition, road services, weather and no preferences. Each vehicle interest is selected randomly amongst those categories with different probabilities. We conducted two experiments, one with uniform distribution amongst different categories by setting the all probability values to 25 percent. In the second experiment, we simulated the scenario where 50 percent of vehicles were interested in traffic conditions, 20 percent in weather conditions, 20 percent in available gas stations and 10 percent in available parking places, as in table 2. Those values are tuning parameters that can be adjusted.

Table 2. Interests Levels for 4 categories.

Category	Interest level
Traffic conditions	0.5
Weather conditions	0.2
Gas stations	0.2
Parking places	0.1

Data report has a fixed size of 100 bytes and the local database size is fixed to 200 reports. The simulation experimented were conducted for a total simulation time of 30 minutes that is divided into steps, each of 100 msec length. The performance measure chosen for evaluation is the percentage of relevant reports received by the vehicles. It is calculated as the percentage of the number of relevant reports out of the total number of received reports. In Figures 3 and 4, the average percentage value for vehicles belonging to the same category obtained by applying our approach is plotted against the basic approach were relevance is not considered.

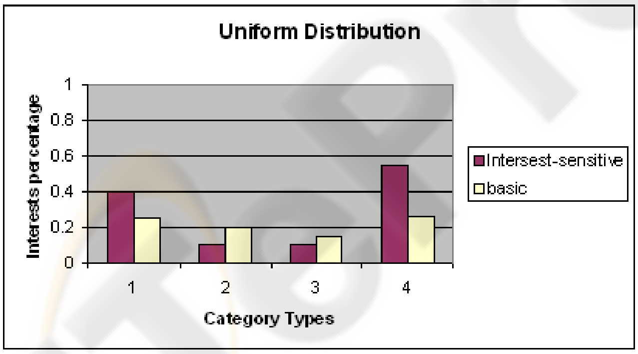

Fig. 3. Interest level per category, equiprobable interests.

Figure 3 represents the case where all categories have the same interest probability. It is clear that our approach has no benefits over the basic one as all categories are the same. As in Figure 4, when a certain category is of more interest to most of the vehicles, the improvement is clear for those vehicles. The percentage of relevant report received approaches 99 percent, while the rest of the vehicles experience decrease in their percentage. This is due to the selection process applied that selects only the top 10 relevant reports from the local database for transmission.

In order to enhance the performance of our approach, a better selection technique could be applied. The 10 reports selected for transmission should be selected from the 4

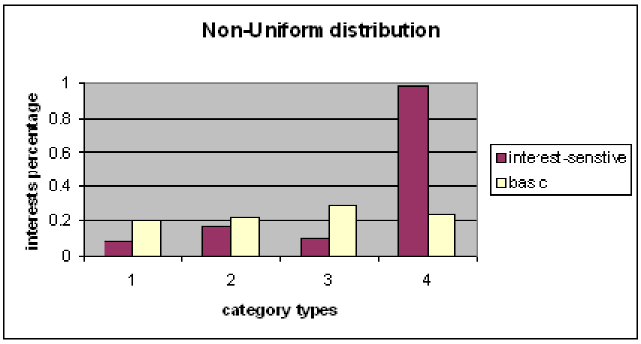

Fig. 4. Interest level per category, category 4 most popular.

different categories with respect to the percentage of their interest level at transmission time. In this case, and according the the values chosen in table 2, the ten selected data reports will consist of five reports belonging to category 1, two reports from category 2, two reports from category 3 and one report from category 4. Applying this technique is currently being investigated.

5 Conclusions

In this paper, we presented how we can substantially increase the percentage of relevant data reports received using a selective dissemination protocol that considers the vehicles índividual interests. With the application of our interest-sensitive protocol, up to 99 percent of the reports received were of interest to the users belonging to the most popular service category.Our experiments and results proved our concept. However more investigation needs to be conducted. Currently, we are testing the improved selection procedure to include non-popular categories as well. Furthermore, a city model is used for testing the effect of the city traffic on the overall performance.

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