International Journal of Smart Home
Vol.8, No.1 (2014), pp.157-164
http://dx.doi.org/10.14257/ijsh.2014.8.1.17

Vehicle Trajectory Discovery for Vehicular Wireless Networks

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Abstract

This paper introduces vehicle trajectory discovery for vehicular wireless networks. Nowadays, GPS-based navigation systems are popular used for providing efficient driving paths for drivers, as well as it's still a major challenge to process such information in order to explain moving object interactions, which could help in deriving trajectory patterns. To that end, we consider a vehicular wireless networks-based representation of trajectory data. This paper shows the inefficient elements during the route discovery in well-known reactive protocols such as ERS (Expanding Ring Search) Method.

Keywords: *ERS, CRS, Vehicular Wireless Network, Trajectory Discovery*

1. Introduction

Mobility is a vital good in any modern society which is based on division of labor. However, daily increasing levels congestion underscores the importance of new technological development, *e.g.*, intelligent transportation system [9]. The idea of such systems is to ensure the efficient utilization of the available road capacity by controlling traffic operations and influencing driver's behavior by providing information. An example is dynamic route guidance systems, which help the road user to navigate through the road network easier and more efficient. Currently, the traffic problem is often based on lack of information. Of course when making travel choices, road users constantly combine various hardly obtain data about the global situation. Thus, they have only a partial and inaccurate knowledge about the traffic conditions in the network and it is not possible for them coordinate their behavior with the other, *e.g.*, changes their departure time to relax the situation. Additionally, the most useful information to a driver is predictive information [28].

Broadcasting is an open operation to resolve many issues in networks. In multi-hop networks, when intermediate nodes receive different set of streams, they cooperatively forward streams toward the final destination. In addition, they executed more frequently such as finding a route to a particular host, and sending an alarm signal particularly [1-3]. Especially, as the demands for mobile network/communication, so called considerable mobility of vehicle, increase explosively, the importance of careful use of radio resources increases. Their astonishing incremental environment is extremely next generation wireless network in vehicle inner space after all. However, widely network broadcasting in vehicle traffic environment incurs considerable overhead in terms of wireless bandwidth, node processing, and energy consumption [4]. In order words, Techniques to reduce the extent of such broadcasting, therefore, are a key requirement in resource-constraint multi-hop wireless

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ISSN: 1975-4094 IJSH

networks. Expanding Ring Search (ERS) is a widely used technique that aims to avoid network-wide broadcasting by searching successively larger areas in the network centered on the source broadcast [5]. ERS can be used not only in multi-hop wireless networks, but also in other multi-hop networks, *e.g.*, in Mesh Networks and peer-to-peer networks. Network-wide broadcast is initiated only if the information cannot be located in the local area, and one key parameter from the ERS is the threshold of local search before initiating a possible network-wide broadcast [6-8].

In this research paper, we propose if there exists an optimal search threshold that would minimize the broadcast cost of ERS for the Vehicle Trajectory discovery. Our mainly approach is a theoretical model to gain an insight of the performance dynamics of ERS as a function of the search threshold, and then we're probably able to show that there exists an optimal threshold for any random network topology. This research paper is organized as follows. Section II provides Basic Definition for VWN, Section III present VWN and Trajectory, Section IV have Trajectory strategies for VWN. Finally Section V shows VWN Model. Section VI present Experiments, and Section VII is conclusion in this paper.

2. Basic Definitions for VWN

A trajectory can be defined as the spatio-temporal evolution of a moving object. This evolution is typically represented as a sequence of sample points, representing the spatio-temporal positions detected by a tracking device, such as GPS tools or WI-FI sensors. More formally, a trajectory T of an object ♂ is represented as: T♂ = < x_1; y_1; t_1….. x_n, y_n, t_n > where n is the number of sample points recorded during the movement of the object ♂, x_i, y_i represent the spatial coordinates of the sample point and t_i the timestamp [10, 11]. A complex network is a network with thousands or millions of nodes whose structure is irregular, with non-trivial topology features. The following features typically characterize vehicular wireless networks:

a) Clustering coefficient: represents the density of triangles in the network. Sparse random graphs have smaller clustering coefficients, while real-world networks typically have larger coefficients;
b) Average shortest path length: is the average node-to-node distance. Random graphs exhibit a small average shortest path length as well as real-world networks;
c) Power law distribution: is a distribution that follows a power law function, $p(x) = a * x^{-\alpha}$, such that p(x) is the probability of occurrence of x, a is a constant of proportionality and α is the power law exponent.

Vehicular Wireless Networks (VWN) can be characterized by the so called "small world" property when the average number of edges between any two vertices is very small and the clustering coefficient is large. Intuitively, this represents a short path between two edges [12-14]. This is also known as the "six degrees of separation". Scale free networks are characterized by a degree distribution that follows a power law function. Intuitively, few nodes have many edges, many nodes have few edges.

3. VWN and Trajectory

This section presents one approach about how to create a complex network from trajectory data. This approach constructs a simple graph where each node represents a trajectory and each edge represents a relationship among the nodes [15]. A relationship between two nodes is established when there is an encounter between two trajectories in space and time with a minimum frequency of meetings. In this approach, a set S of trajectories is represented as a network *(N,E)* with the help of a similarity function f between trajectories in S and a threshold constant c. This network is called trajectory network. The trajectory network *(N,E)* is constructed as follows: (1) each node in N represents a trajectory in S; (2) there is an edge between two nodes *n* and *m*, $f(m; n) \geq c$, that is, m and n represent trajectories whose similarity is above the given threshold. In what follows, we will not distinguish between trajectories in *S* and nodes in *N*. Let f be the similarity function for trajectories used to construct the trajectory network, and let *s*, *t* and *k* respectively be the spatial, temporal and frequency parameters of f. Given a trajectory *T*, the spatial and temporal parameters induce a buffer $B[s, t](T)$ around *T*. Given two trajectories *T* and *U*, we define the function of VWN [16].

Step 1. Build Trajectory Network: Intuitively, we define that two trajectories are similar our conditions they are within a certain distance of each other (spatial threshold) within a given time interval (temporal threshold) for a certain number of times (frequency parameter). The values of these parameters obviously depend on the application domain under study. For example, in the traffic management domain, we can establish that two vehicles meet with a minimum frequency of meetings. This representation describes the interactions between vehicles regardless of the direction of their trajectories.

Step 2. Analyze Trajectory Network Features: In our approach we are interested in identifying the existence of two very important network features: the power-law distribution and the small-world effect. The analysis of the distribution degree of network vertices allows identifying whether such distribution is highly skewed, meaning that it has a power-law distribution profile. In this case, we conclude that few trajectories have many encounters, while most of the trajectories have very few encounters. The discovery of such property can be useful, for example, to identify trajectories having a high degree of encounters, which means that this trajectory has passed through paths with a high number of moving objects. Besides, small-world property may help to identify a set of trajectories that represent hubs in the trajectory network [17]. The small-world effect feature determines the mean shortest path length between pairs of trajectories as well as if the network has a high clustering coefficient. Through this measure we can quantify how well connected the trajectories in the network are. Besides, a high clustering coefficient indicates the presence of a transitivity property among high connected nodes.

Step 3. Identify relevant trajectories within trajectory network: our approach aims at analyzing trajectories that have greater relevance within the network. The relevant trajectories are those that possess a high degree of connectivity. These trajectories are plotted on a map for visual analysis, allowing the user to give an interpretation of the relevance of these trajectories. This type of analysis will help reducing the number of trajectories to be analyzed. Furthermore, we can restore back the spatial information, which was lost during the creation of the network [18]. Visualizing trajectories that are very connected, which we hereinafter call hub trajectories, is useful for understanding entities moving in the high dense paths with respect to the amount of moving objects.

4. Trajectory Strategies for VWN

As we mentioned Sections 2 and 3, we consider two trajectory strategies basically; Lucas' algorithm, a traffic-efficient single-path strategy, and expanding ring search, a time-efficient flooding algorithm. A comparison shows the basic problems of both approaches [19].

4.1. Lucas' Algorithm

Lucas' algorithm is a simple single-path strategy that follows the straight line connecting source and target and traverses all barriers that intersect this guideline. It was proposed as a modification of an online path-planning algorithm of Lumelsky and Stepanov [20].

Algorithm 1. Lucas' algorithm

```
1: repeat
2.        Follow the straight line connecting source and target.
3.        if a traffic is heavy then
4.           Start a complete right-hand traversal around the heavy
             and remember all points where the straight line is crossed.
5.          Go to the crossing point that is nearest to the target.
6.        endif
7. until target is reached.
```

This algorithm needs at most $d + 3/2\,p$ steps, where d is the length of the shortest path and p the sum of the perimeter lengths of all traffic. This algorithm matches the asymptotic lower bound for single-path online algorithms and also the asymptotical lower bound for traffic.

4.2. Expanding Ring Search (ERS)

A straightforward multi-path strategy is Expanding Ring Search, which is nothing more than to start flooding with a restricted search depth and repeat flooding while doubling the search depth until the destination is reached. This strategy is asymptotically time-optimal, but it causes a traffic of $O(d^2)$, regardless of the presence of faulty nodes. The following comparison between expanding ring search with Lucas' algorithm shows the advantages and disadvantages of these strategies. Lucas' algorithm performs well if there are few barriers, but the sequential traversal of a maze takes too much time [21]. Expanding ring search works efficiently in a maze, but in open space it needs more messages than necessary. Thus, both strategies fail in optimizing time and traffic at the same time.

4.3. Continuous Ring Search (CRS)

We modify the expanding ring search as follows: the source starts flooding without a depth restriction, but with a delay of s time steps for each hop. If the target is reached, a notification message is sent back to the source. Then the source starts flooding a second time, and this second wave, which is not slowed down, is sent out to stop the first wave. This continuous ring search needs time $O(d)$ and causes a traffic of $O(d2)$, which is no improvement to expanding ring search [22, 23]. But an area is flooded at most two times, whereas expanding ring search visits some areas $O(\log d)$ times.

Algorithm 2. Trajectory for VWN ERS Algorithm

```
Input: Trajectory List traj, Temporal Distance Td, Spatial Distance Sd, Frequency f
Output : Trajectory VWN TN
n ← |traj|
create a undirected graph TN
for all trajectory T in traj  do
   create a node in TN
end for
for i = i to n do
   frequency ← 0
   for i = i + 1 to n do
         frequency   compare (traj[i],  traj[j], Td,  Sd)
         if frequency ≥ f then
            add edge (traj[i],  traj[j]) in TN
         end if
   end for
end for
return TN
```

5. VWN Model

In this section, we show our network of vehicular network model and notations. Then we have some preliminary research on hop-counts [24]. We make the following assumptions in our network of SV that we describe: i) We assume that the source node locates at the center of circular network distributed region randomly. ii) The query packet carries a TTL value and a sequence number. iii) We define the 'Search Cost (SC)' as the number of expected inter-broadcasts before the source node receives a SC-free acknowledgement from the intended destination of the inquiry packet iv) Eventually, we assume the broadcast are collision-free, that is all broadcasts are conscientiously scheduled so that all neighbors of the sender will be able to overhead the message successfully.

Algorithm 3. Source Node

```
broadcast 'RREQ, H = 1 and max j'
wait until a RREP is received
broadcast the 'stop_instruction' and H to everyone within the ring where it sent following
   conventional TTL scheme
use the 1st RREP for the data packet and save 2nd RREP as a backup
drop any later RREPs
```

We generalize a ring search schema with a search set of $\underline{R} = \{r_1, r_2, \ldots r_n\}$. In this schema, if the search does not locate the destination, a broadcast with TTL = r_1 is sent first. Otherwise, a new broadcast with TTL = r_2 is sent. A broadcast with TTL = r_n fails to locate the destination, a process is a continuous [25-27]. Besides, we also consider the following notations: ***M*** is number of network nodes; ***H*** is the maximum hop that M nodes may spread from the source node at the center of the network; ***r*** is radio transmission range; ***n(i)*** is number of nodes that are exactly ***i*** hops away from the source node; ***k*** is the size of the search set, where $1 \leq r_1 < r_2 \ldots < r_n \leq H$.

Algorithm 4. Intermediate node

```
listen to RREQ
check the max j after receiving the RREQ
if the H is bigger than the max j then
   drop the RREQ
else
   check the route cache after receiving the RREQ
   if there is route information in the cache (i.e. being the Route Node) then
         send a RREP and H to the source node
   else
         wait for a period of 'waiting time' (i.e., 2 × HopNumber)
         while waiting do
            if receive a 'stop instruction' then
            call the blocking procedure
            erase the source-destination pair in the route cache
         else if receives a 'RREP' then
            forward it to the source node
         end if
     end while
     if receives no 'stop instruction' then
         increase the hop serial number by 1 and rebroadcast RREQ
         end if
     end if
end if
```

We use the random distribute of nodes to estimate ***N(i)*** and ***n(i)***, the number of nodes within ***i*** hops from the source node and the number of node on the ***i-th*** hop *'ring'*, respectively, $0 \leq i \leq H$.

Algorithm 5. Route or destination node

```
wait for the first arriving RREQ
if receive a RREQ then
   send the RREP and the H to the source route (contained in the RREQ packet)
end if
```

6. Experiments

In this section, we evaluate the performance of restrict ERS according to the calculated ideal value of searching threshold with traffic service. The effect of the searching threshold on the overhead of the ERS is analyzed for many networks with different sizes and node placement by the narrow environment. We investigate the RS({R}) schemes with R in a more general form. The cost of the $RS(\{r_1\})$ scheme is $C(\{r_1\}) = C(\Phi) + [N(r_1\text{-}1) - N(r_1)] \leq C(\Phi)$. Therefore, when $n(r_1) = N(r_1) - N(r_1 - 1) > 0$, *the* $RS(\{r_{1,}\})$ *scheme our-performances the* $RS(\Phi)$ *scheme.* This being so, we is equivalent to premise scheme in a place as following; (1) The cost of the $RS(\Phi)$ scheme is given by $C(\Phi) = M$. (2) The cost of the $RS(\{r_1, < r_2 \ldots. < r_n\})$ scheme decreases with the increase of $r_n \leq H$, *i.e.,* $C(\{r_1, < r_2 \ldots. < r_n\}) > C(\{r_1, < r_2 \ldots. < r'_n\})$, when $r_n < r'_n \leq H$. (3) For a large position integer H and a real-valued variable z, $0 < z \leq H\text{-}2/H$, the function $f(z)$, that is $f(z) = -1/1\text{-}z^2 + H^2z^2 - [(zH+1)(H\text{-}1) / H]^2$, achieves minimum when z takes a value close to $z^* = (H\text{-}1)^2 / (2H\text{-}1)H$. Accordingly, we have the $RS(\{1, [(H\text{-}1)^2 / 2H\text{-}1],$

H}) scheme is the optimum scheme that achieves lowest cost among all RS schemes as following in Figure 1.

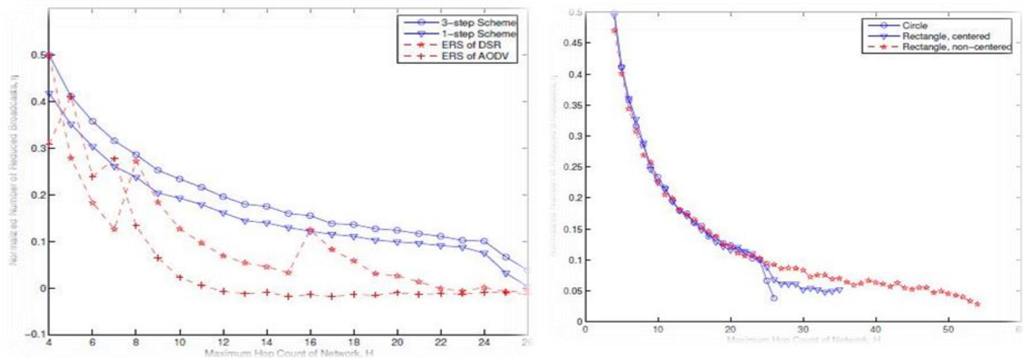

Figure 1. We show the Performance of a Class ERS Schemes, the *RS(R)* Scheme with *R = {1,2,3, ……L}* and a Limit of *L ≤ H* is Presented for Different Maximum Hop-count of the Network, *H*. From Left Figure, we could observe that the Benefit of using these ERS Scheme is Extremely Limited. In most of the Scenarios of ITS System/SV Traffic service that we have shown, the ERS Schemes have Higher Search Cost than pure Flooding *(n< 0)*. We also show the Performance of the *RS({r_1, r_2, r_3 = H})* Schemes with H = 60 by Right Figure

7. Conclusion

In this research, we focus on the problem of locating a randomly chosen destination in a large multi-hop wireless network with ERS into RS schemes, in which a search set *(R)* is used to set the TTL field of the inquiry packet sequentially before network-wide flooding in initiated. Our research is getting to more advantage, supporting the self-adaptive vehicle service of the aspect mechanism and Motor Company in Korea is going to sponsoring. Although, we have on-going project, we really a wishful thinking, smart vehicle and wireless network infrastructure (V2X) will hope to provide in next generation smart vehicle useful service, as well as improve many researcher to help.

Acknowledgements

This research was financially supported by Hansung University. Also, this research was financially supported by Gyeonggi College of Science and Technology.

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