Reducing Probe Data in Telematics Services Using Space and Time Models

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Abstract - In-vehicle information devices such as car navigation systems and smartphones are now widely used and they provide drivers with a lot of information, such as traffic jam information, weather forecast, etc., by a communication function such as cellular networks. These services gather a lot of information from cars or traffic sensors on the road, which results in many small pieces of data being transmitted over cellular networks. We propose a method that, by predicting car behavior, reduces the amount of such data. We observe the amount of traffic data, simulate vehicle behavior, and evaluate our models. Our conclusions show good results.

Keywords: Telematics service, ITS, Smartphone, Probe data, Car navigation System

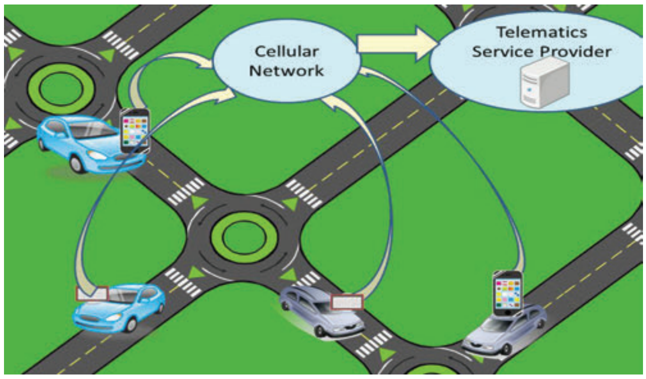

Figure 1: Telematics service

1 INTRODUCTION

Recent years have witnessed the emergence of many telematics services. For example, vehicle information devices can assess traffic conditions and display the fastest route to a destination. Such services provide information obtained from traffic sensors, historical traffic data, and in-vehicle information devices or smartphones, which are in widespread use [1]-[4].

Nevertheless, vehicle information devices for these services have to connect the cellular networks, and drivers have to pay additional costs for telematics services. If drivers use smartphones, then they do not have to pay these additional costs; however, the display sizes on these devices are too small. A new device called gDisplay Audioh [5] can display the same image with a smartphone connected by wireless or wired communication functions.

Therefore, smartphones can become popular telematics terminals that have several sensors and wireless communication functions [6]. Each smartphone frequently transmits a small amount of probe data. Therefore, a large amount of probe data can be transferred from vehicles to telematics service providers (TSPs). However, such increasing volumes of data traffic need to be regulated because of the high communication costs for both users and TSPs.

In a previous study [7], we proposed data compression methods for probe data by considering only the data itself, but we were unable to reduce the amount of communication of control information that is a task that requires peak cutting methods. Therefore, in this paper, we propose a new method for reducing probe data on the basis of vehicle behavior prediction.

2 TELEMATICS SERVICE

2.1 What are Telematics Services

Telematics services are services that provide useful information to the driver. These services have to gather a lot of information from each in-vehicle device (See Fig. 1). There are four types of telematics services:

1. A TSP gathers a large amount of information from in-vehicle information devices through the cellular network for each service; such information includes traffic jam information, weather information, route guidance, etc. The TSP then analyzes the data and delivers useful information to each in-vehicle information device.

2. If an accident takes place, the in-vehicle information device calls an emergency center, providing, automatically or manually, location information synchronized with the airbag information.

3. Entertainment services such as SNS, messaging, Internet, etc.

4. Vehicle relationship management (VRM), which gather a large amount of different types of information from the controller area network (CAN) for monitoring the vehicle status, etc.

Current in-vehicle information devices communicate with the TSP's server through a cellular network. Therefore, most of those services are able to run on the smartphones. Many drivers have smartphones and can use the cellular network at fixed costs and without having to pay additional money.

However, smartphones' displays are too small to show drivers a map or other information, which they cannot use when they are driving. In the near future, it is expected that display-audio devices, which show the smartphones display image on the in-vehicle devices, will be used widely.

2.2 What are Probe Data

Probe data are gathered from many vehicles to the TSP's servers, as shown in Fig. 2. There are three types of probe data:

1. Probe data that are gathered from various vehicles at short fixed intervals (e.g., 1 min and 5 min). This data includes average speed, travelling time, location information, and wiper information. The data are analyzed for traffic information, weather forecast, etc.

2. Probe data that are transported to the TSP or other services as soon as possible; these include airbag information and broken information for making emergency calls.

3. Probe data that should be stored and gathered to the manufactures for VRM; these include error logs in various Electronic Control units (ECUs), etc.

In this paper, we focus on the first type probe data. The size of each data is very small, but the number of communications is very large. Therefore, we have to solve the following three problems for minimizing the total packet count of them:

- Minimizing the probe data
- Minimizing the control information for each communication
- Minimizing the number of communications

In our previous research, we proposed a compression method for minimizing the probe data. In this paper, we propose a new method for reducing the number of communications in telematics services.

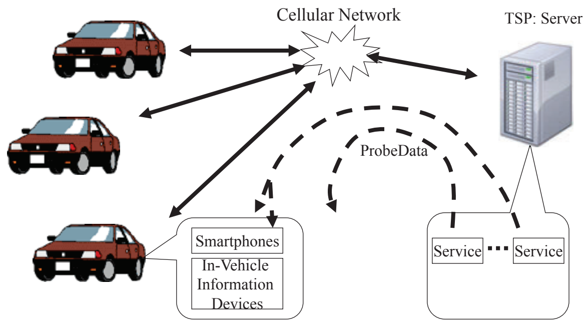

Figure 2: Probe data

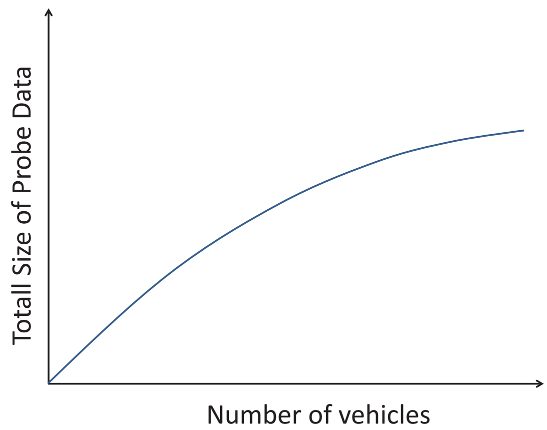

Figure 3: Number of vehicles and total size of probe data

2.3 Amount of Probe Data

Let x be the number of vehicles in a fixed area, which are able to communicate with the same base station through a cellular network. $0 \leq x \leq$ "miximum number of vehicles in the fixed area" Let s be the size of probe data transmitted in a single communication. Let t be a period of sending the probe data. Let t be a period of sending the probe data. In this case, the total size T of the probe data is given by the following equation:

$$T = st \sum x_i. \quad (1)$$

In our previous research [7], we proposed a data compression method. The data size depended on the number of vehicles. When the number of vehicles is small, the data are not compressed effectively; but when the number is large, the data can be compressed effectively. The relation between the number of vehicles and the total size of probe data is shown in Fig. 3. If all in-vehicle information devices transmit probe data, the total size of probe data increases monotonically.

3 RELATED WORKS

There are many studies on the reduction of probe data in a cellular network. These studies may be categorized into three types:

1. **Reducing the number of vehicle information devices that communicate to TSPs through a cellular network.**
   In [9], inter-vehicle communication technologies (V2V) were used, and good results were obtained. However, few vehicles have the equipment required for V2V communications, which accounts for a significant problem. In [10], roadside communication (V2R) technology was used, but the covered area was very small.

2. **Reducing the data size.**
   Our previous method [7] showed good results, but it could not be used for peak cutting.

3. **Controlling the number of vehicles driving in a fixed area.**
   In [9], the TSP sent a message to a vehicle and guided it along its route. In this case, control of the vehicle was limited.

We thus propose a new space and time model for reducing the size of probe data without requiring V2V or V2R technologies.

4 METHOD OF REDUCING PROBE DATA SIZE

4.1 Proposed Architecture

Figure 4 shows the architecture of a telematics service system based on a telematics agent model that we propose. In this model, there are two types of agents: one runs on smartphones, whereas the other runs on the servers in a TSP.

The TSP agent monitors vehicular traffic in certain areas divided into zones. If the number of vehicles in a zone exceeds a certain threshold, the TSP agent selects smartphones according to the space-and-time strategy and instructs the smartphone agents to cease probe data transfer.

The basis of this idea is that the amount of probe data that is needed to provide a large amount of information is not very large. Therefore, we can select some appropriate vehicles. The number of selected vehicles is defined by two threshold values as follows (Fig. 5).

1. If the number of smartphones is less than the threshold1, all vehicles are selected.

2. If the number of smartphones is less than the threshold2 and greater than the threshold1, a fixed number of vehicles are selected.

3. If the number of smartphones is greater than the threshold2, a fixed numbers of vehicles are selected.

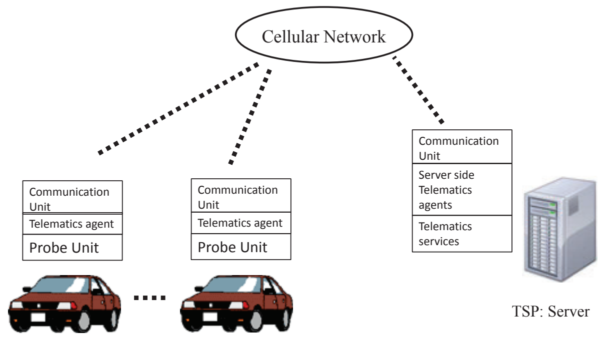

Figure 4: Proposed Architecture

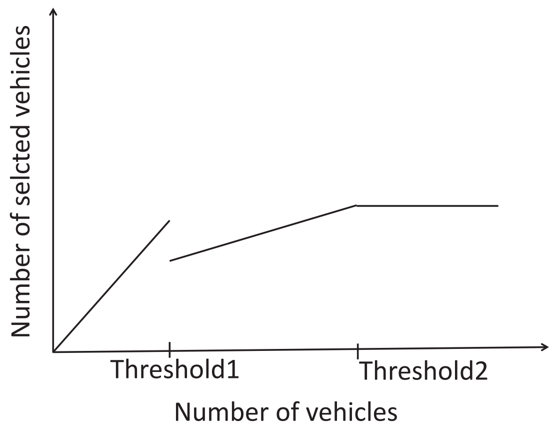

Figure 5: Number of vehicles and number of selected vehicles

The number of selected vehicles is limited and fixed. Therefore, communication traffic through the cellular network is limited.

4.2 Space and Time Strategy

The algorithm for selecting smartphones that should not transmit probe data is based on the following conditions.

1. In a particular area, a fixed number of smartphones are allowed to transmit probe data.

2. A smartphone transmits probe data only when its behavior cannot be predicted.

Thus, the volume of communication is limited. Actually, if there is less traffic in an area, then the number of smartphones will be relatively small. Hence, all the smartphones in the area

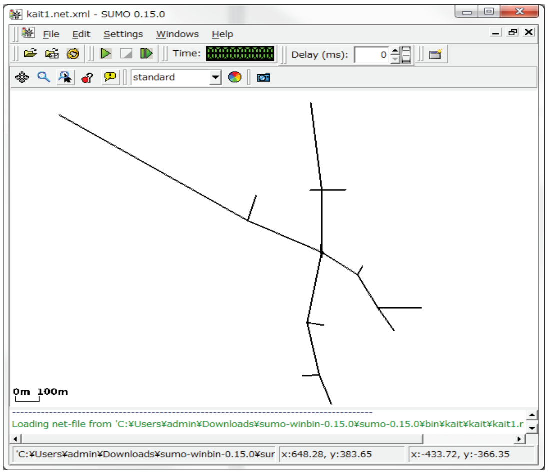

Figure 6: Atsugi City (near the Kanagawa Institute of Technology)

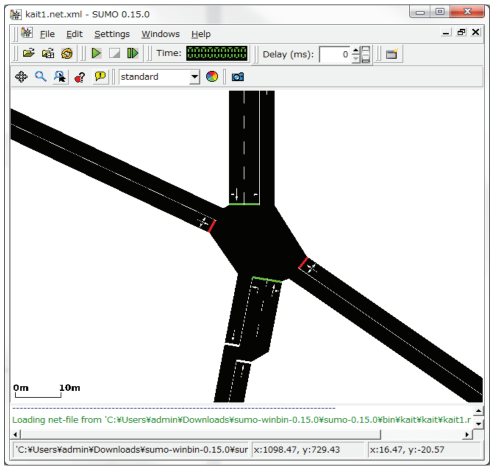

Figure 7: Atsugi City (near the Kanagawa Institute of Technology (zooming))

can connect to the TSP. Conversely, if an area has heavy traffic, it will have a large number of smartphones. Therefore, only a fixed number of smartphones will be allowed to transmit probe data.

4.3 How is the Behavior of a Vehicle Predicted

The prediction algorithm for the behavior of a vehicle is as follows:

- If a smartphone uses a route guidance application, the TSP can predict the route. Therefore, the smartphone can communicate with the TSP only illegally.
- If the smartphone does not use the route guidance application, it is difficult to predict the route. However, in many cases, the vehicle may be on a long street. Therefore, the smartphone can communicate with the TSP either illegally or drive on any route except the main route.
- In a fixed size area, the number of smartphones that communicate with the TSP is limited. Therefore, the TSP provides communication ratio as it decides.

5 EVALUATION

We evaluated our algorithm by carrying out a traffic simulation [11]. In a previous study [7], simulations were conducted using real traffic data and maps. We adopted the same approach in the present study to obtain accurate results.

5.1 Base Experiment

Table 1 and 2 show the avarage speed and the avarage travelling time, respsctively.

We observed the amount of traffic near the Kanagawa Institute of Technology. we shows them in the Figures 6 and 7.

Table 1: Average Speed in that area

Sparse case	8.3 m/s
Nomarl case	7.5 m/s
Crowded case	5.3 m/s

Table 2: Average travelling time

Sparse case	196s
Nomarl case	216s
Crowded case	328s

On a weekday morning, the number of vehicles in an hour is 1,729, which is normal in that area and is not considered as crowding. The number of signal turns is 52.

In addition to these numbers, for the simulation, 2,593 (150%) vehicles constitute a crowded case, and 864 (50%) vehicles constitute a sparse case.

We then changed the number of vehicles and obtained the probe data from each vehicle. Figure 8 travelling time in that area, and Figure 9 shows the average speed of each vehicle in that area.

5.2 Reducing the Probe Data Based on the Space Model

We obtained the probe data from selected vehicles by space model. Selected ratio in that area is from 3% to 100%. Table 3,4, and 5 show the average speed and average travelling time from each simuralation.

This result means we have to select the smartphone at least

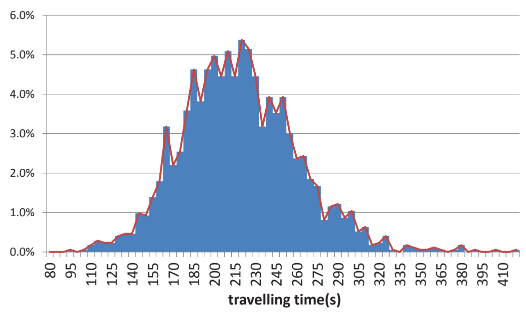

Figure 8: Travelling time in Atsugi City

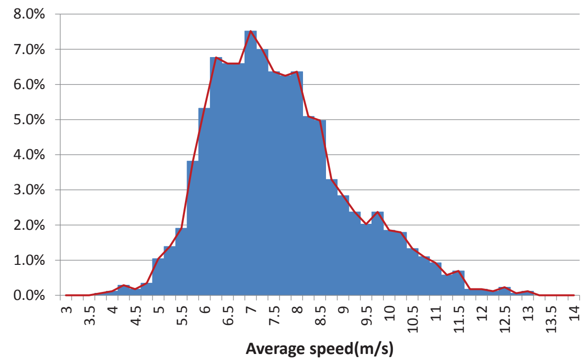

Figure 9: Average Speed in Atsugi City

20% in the crowded case.

5.3 Reducing the Probe Data Based on Time Model

We obtained probe data from the selected vehicles using the time model. The selection ratio for each vehicle varied from 20% to 100%. Tables 6, 7, and 8 show the average speed and average travelling time from each simulation.

The results indicate that we can reduce the number of selected smartphones in at least 80% of the normal cases in the time model. In other words, each smartphone should communicate with a TSP 20% of the time.

5.4 Discussion

From these results, we can reduce the traffic at most 80 by the space model. Because, we have to select the smartphones which communicate with the TSP is at least 20. Also, we can reduce the traffic by the Time model. Therefore, we should combine these two models. However, the result is obtained by the simulation. Therefore, we are planning the experiment by real vehicle and smartphones before the evaluation of combined model.

6 CONCLUSION

We proposed a new method for reducing the amount of probe data in telematics services. In addition, we confirmed the effectiveness of the proposed method by conducting simulations using real traffic data and maps.

In future work, the time and space models will be combined, and we will perform simulations on larger areas.

ACKNOWLEDGEMENT

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Table 3: Average speed and travelling time on space model (sparse)

Selecting ratio	Average speed	Average Travelling Time
100%	8.3m/s	195.8s
50%	8.3m/s	196.4s
20%	8.2m/s	197.4s
10%	8.4m/s	196.7s
5%	8.5m/s	194.1s
3%	8.7m/s	194.9s

Table 4: Average speed and travelling time on space model (normal)

Selecting ratio	Average speed	Average Travelling Time
100%	7.5m/s	216.5s
50%	7.5m/s	216.2s
20%	7.4m/s	220.3s
10%	7.5m/s	216.0s
5%	7.6m/s	216.8s
3%	7.1m/s	232.3s

Table 5: Average speed and travelling time on space model (crowded)

Selecting ratio	Average speed	Average Travelling Time
100%	5.3m/s	328.2s
50%	5.3m/s	326.2s
20%	5.4m/s	322.6s
10%	5.5m/s	318.1s
5%	5.6m/s	311.9s
3%	5.7m/s	315.1s

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Table 6: Average speed and travelling time for each selecting ratio on time model (space)

100%	8.3m/s	195.8s
50%	8.3m/s	194.8s
33%	8.3m/s	194.0s
20%	8.3m/s	192.0s

Table 7: Average speed and travelling time for each selecting ratio on time model (normal)

100%	7.5m/s	216.5s
50%	7.5m/s	215.5s
33%	7.5m/s	214.5s
20%	7.5m/s	212.4s

Table 8: Average speed and travelling time for each selecting ratio on time model (crowded)

100%	5.3m/s	328.2s
50%	5.3m/s	327.2s
33%	5.3m/s	326.2s
20%	5.3m/s	324.0s

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