AN APPLICATION OF LOW-COST RFID SYSTEM TO TAXI-CALL SERVICE

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ABSTRACT: The development and implementation of low-cost and high-efficiency system based on RFID(Radio Frequency IDentification) technology for taxi-call service are presented in the paper. It includes hardware implementation of the system and operations of taxi-call service system where approximately 500 probe-equipped vehicles 100 communication beacons and 464 position beacons are deployed in 267.29㎢ area to provide taxi-call service. A position beacon broadcasts an inherent identification number referring to its location to probe-equipped vehicles. An in-vehicle unit stores identification numbers from position beacons for vehicle's driving history with its passage times. A communication beacon provides two-way communications between traffic management center and probe-equipped vehicles for collecting and disseminating traffic information. Probe data via RF from probe vehicles are obtained for a five-minute period and accumulated in traffic information center through the communication beacons. For taxi-call service, traffic management center locates the positions of taxi in real time and dispatches taxi the nearest to a customer.

Key Words: taxi-call service, RFID detection system, travel time estimation

1.INTRODUCTION

Advanced Vehicle detection systems utilizing AVI technologies such as RFID(Radio Frequency IDdentification), Image Processing GPS(Global Positioning System) on the traffic networks is useful for a variety of traffic engineering applications from traffic flow managements to transportation planning. Traditional detection methods have relied on mechanical or electrical devices on the top of, or embedded in the pavements. These systems are relatively expensive to install and hard to maintain, and are limited in their capabilities, especially for Wide Area Detections Systems(WADS).

Among those AVI technologies, RFID-based Wide Area Detection Systems(WADS) have received considerable attention since the RFID-based systems can be implemented at the lowest-cost compared with other AVI technologies. Table 1 illustrates a comparison of the proposed RFID systems and GPS systems for infrastructure built and maintenance cost.

Table 1. A comparison of GPS and the proposed RFID system (unit : $)

	GPS+Wireless data networks	GPS+Beacon	This Proposal
Infrastructure-built cost	-	83,333	11,416
In-vehicle unit cost	597,500	341,416	86,333
communication fee (for three years)	5,310,250	150,000	15,000
Total	5,907,750	574,750	111,750

< Assumption >

- # of nodes in korea (1 node/Km) : 50,000 probe vehicles (1%) : 1,024,363
- ID Beacon : $62.5 ID Beacon installation cost : $20.83 In-vehicle unit : $50
- IDs collector beacon : $ 833.3 its installation cost : $833.3,
  # of IDs collector beacon : 10% of ID-beacons
- wireless communication fee : 0.6cent/packet × 86,400packet/month = $144;
  wired communication fee = $83.3

For high efficiency and lowest cost of the proposal system, it uses two different types of beacons mounted on an overpass, an utility pole or traffic signal lights to communicate with the probe-equipped vehicles driving on the roads. The first type of beacons called a ID beacon broadcasts an inherent identification number referring to its location to the probe-equipped vehicles, and the identification numbers are recorded in-vehicle units with passage times. And the other type of beacons called a IDs collector beacon collects the identification numbers and passage times from the in-vehicle units. The probe data via RF from the probe vehicles are obtained for a five-minute period and accumulated in the traffic information center through the IDs collector beacons. Figure 1 shows the system configuration.

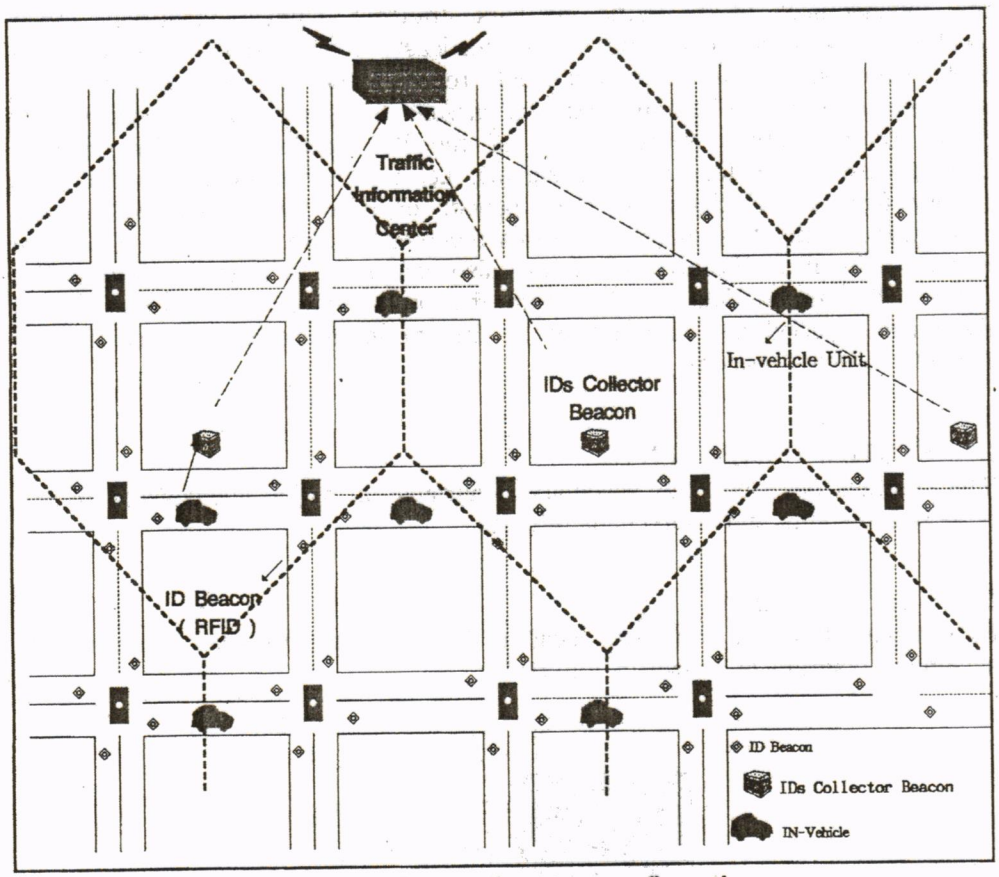


Figure 1. Proposed system configuration

For the taxi-call service, the traffic management center locates the positions of the taxi in real time, and dispatches a taxi the nearest to a customer. It also provides the shortest distance from the customer's origin to his(her) destination based on the estimated travel time.

In the following section, the basic operations of the proposed detection systems are described in details. Subsequent sections present hardware implementation of the system. The following chapter includes the travel time estimation procedure and the operations of taxi-call service system. Finally, the remarks and conclusions are included in the last chapter.

2.DETECTION MODEL

The proposed systems are composed of four major components: ID beacons, In-vehicle units, IDs collector beacons, Analyzer. The ID beacons installed in

the intersections of a traffic network transmit signals identifying their locations only to In-vehicle units, i.e. broadcasts a location ID number to the probe vehicles. The in-vehicle units only receives and accumulates location ID numbers from the ID beacons with the passage times when a equipped vehicle drives through about 40-50 meters of the ID beacons. The IDs collector beacons are designated to catch signals, i.e. collects information on driving history from In-vehicle units, short periods of time when equipped vehicles drive through the IDs collector beacons mounted on the roadside in 1 to 2km interval. The IDs collector beacons are also connected to a Traffic information Center. The probe data via RF from the probe vehicles is obtained for a five-minute period and accumulated in the traffic information center through the IDs collector beacons.

2.1 SYSTEM COMPONENTS

This section describes the schematic diagrams of major components of the proposed systems and their characteristics.

2.1.1 ID beacon

ID beacons broadcast their own location IDs to locate vehicles' positions. Its schematic diagram is shown in Figure 2.

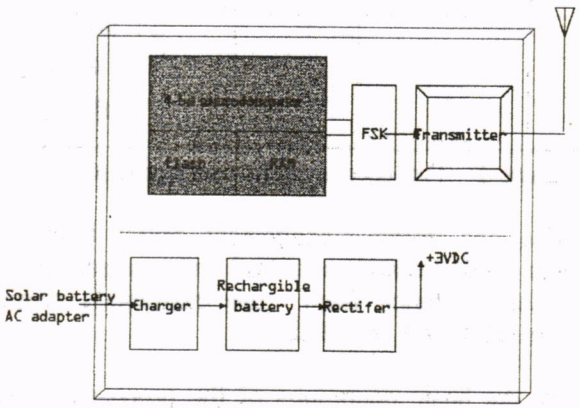


Figure 2 schematic diagram for ID beacon

The reading area must be considered when the ID beacons are installed, especially in the signalized intersections since a link travel time is calculated by connecting two reading areas. One alternative is to position them in the stop line of each links, and the other is on back of the links of the intersections. Since the former alternative is less affected by traffic lights, the former alternative is recommended.

2.1.2 In-vehicle units

In-vehicle units receive IDs from the ID beacons and accumulate them with the passage times in their internal memory. Its schematic diagram is shown in Figure 3.

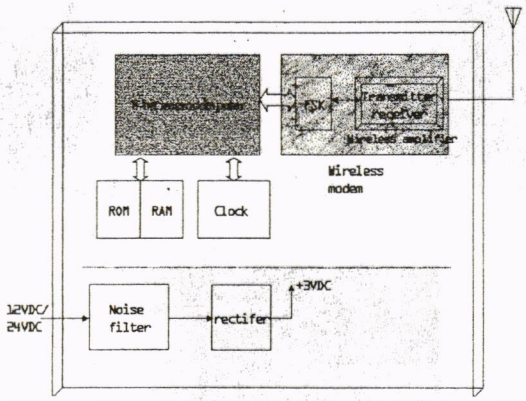


Figure 3 schematic diagram for in-vehicle unit

2.1.3 IDs collector beacons

As the probe-equipped vehicle approaches the IDs collector beacon, the beacon generates a signal and the internal antenna module broadcasts the signal into reading area. The reading area is tuned such that only one tag at a time is read. The beacon can collect real time data on driving histories with passage times and stores the data in an internal storage buffer and transmits the information to traffic information center.

Its schematic diagram is shown in Figure 4.

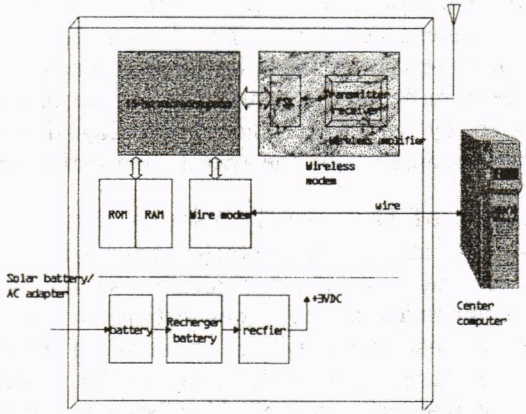
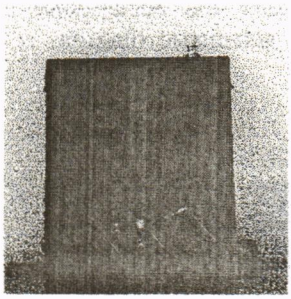
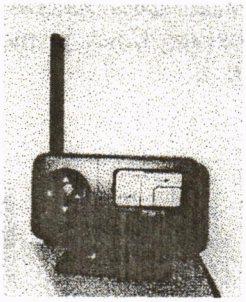


Figure 4 schematic diagram for IDs collector beacon

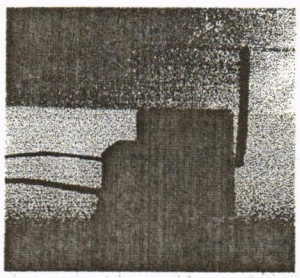
Figure 5 shows the products for the proposed RFID system components



a. IDs collector beacon



b. In-vehicle unit



c. ID beacon

Figure 5 Major component of the proposed system

3.Taxi-call system

3.1 Travel time estimation

For the travel time estimation, an approximate value for the travel time estimation is initially determined by weighted average method and then the level of the significance test is applied. If the number of the sample is less than the required the number of the sample, or the required data are missing, the value is estimated by voting technique and Bayesian Pooling, otherwise the arithmetic average is applied for the travel time estimation.

3.2 The operations of taxi-call System

Using an ID beacon, a location of the vehicles can be found and an in-vehicle unit installed inside of the vehicle communicates with a IDs collector beacon for two-way data communications. By connecting an in-vehicle unit to the taximeter, a status of customer's riding, duration of his(her) riding and a driving history can be found. And traffic data can be collected and monitored to the traffic center in real time as well. The beacon infrastructures are used not only for collecting traffic information but also for taxi-call system. Figure

3.2 shows the picture of the taxi-call monitoring program.

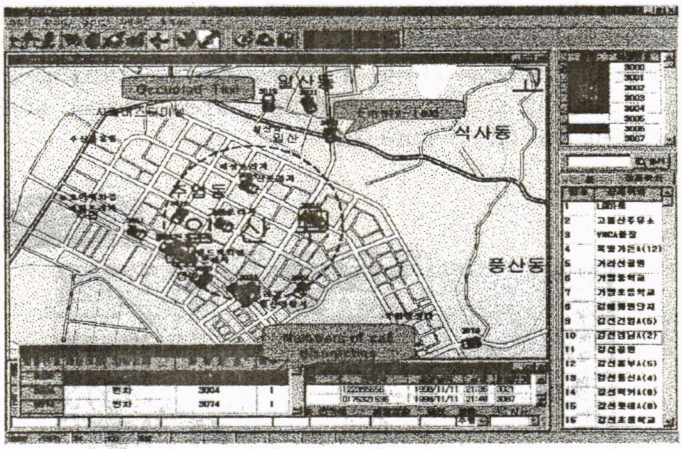


Figure 6 Taxi-call monitoring program

The taxi-call system displays a location of taxi and a status of customer's riding on the electronic map in real time. The operator of the system dispatches the closest taxi to a customer location within 2Km. Preventing disputes among the taxi drivers for fairness of dispatching taxies, the taxi-call system displays the current dispatched report for each vehicle so that the operator can consider fairness of dispatching the vehicles.
By monitoring and analyzing a status of the customer's riding, his (her) origin, riding time, driving distance, non business distance(time), and the number of using taxi-call(Figure 3.3) , the taxi call system also provides important information for managing a taxi company.

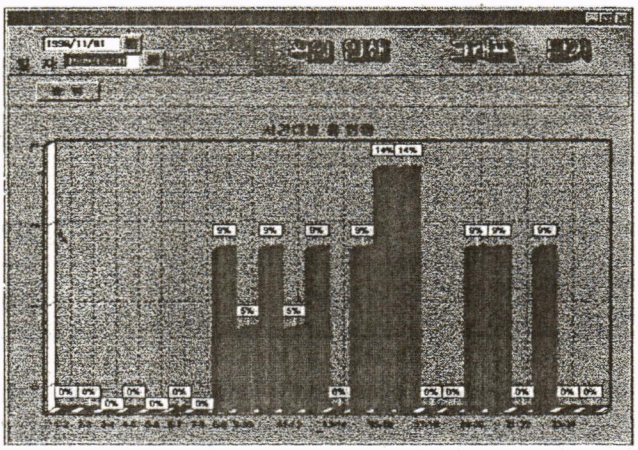


Figure 7 Distribution chart of taxi-call by service(hour)

Since the taxi drivers always carry cash, they can be in danger in any time. In the case of a dangerous situation, the taxi driver can push an emergency button on the in-vehicle unit, and a message can be sent to the traffic center. A monitor agent immediately contacts with the police for an emergency. Also, in the case of a stolen vehicle, a vehicle can be immediately found since a stolen vehicle trekking system can find the current location of the vehicle or trace the vehicle in real time(Figure 3.4)

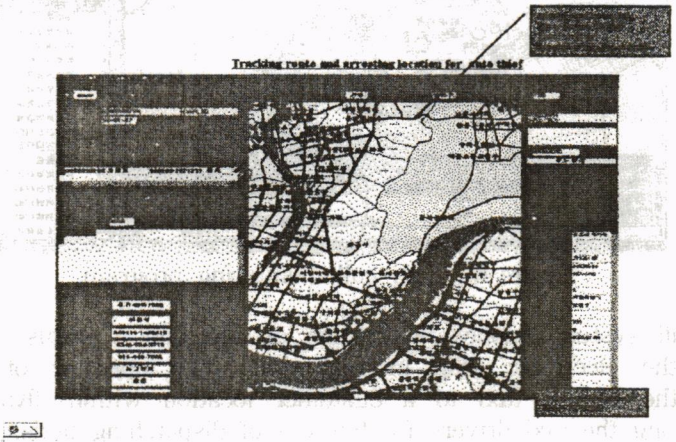


Figure 8 The stolen taxi tracking program

Since the taxi-call system can remarkably reduce the cost of the in-vehicle devices and communication costs compared with using a GPS and a wide wireless network (ex: GSM, Cellular) as shown in Table 3.1, most taxi call system operated by a beacon type are used in Seoul metropolitan and near cities.

Table 2. Comparison chart of an in-vehicle unit and communication cost for taxi-call

Type	In-vehicle device cost	Monthly communication fee
Beacon Type	$200	$10
GPS+Widearea wireless network	$460	$30

Another advantage of the taxi-call system using a beacon type is to reduce the initial investment and the operation costs. Since the taxies installed an in-vehicle module play a role of the probe vehicles for collecting traffic data, it is an easy way to expand the probe vehicles at the beginning.

4. Conclusions and Remarks

This paper described the low-cost and high-efficiency detection systems based on RFID technologies for the travel time estimation and the taxi-call service, and presented some results that demonstrate the efficiency of the proposed systems. The results offer the following benefits

- The same location referencing system using ID beacons without suffering from positioning errors.
- Quick installation and requires no routine maintenance for the detection system. And robustness even where dirt, vibration and harsh weather conditions would degrade the other systems.
- A full-duplex method instead of a half-duplex was utilized to increase the capacity of the beacon. Therefore the number of the probe vehicles can be increased by 2 times more than the previous model.
- The travel time estimation procedure was introduced, and the estimated value is found close to the measured average travel time.
- The taxi-call system provided important information for managing a taxi company. Information included a status of the customer's riding, his (her) origin, riding time, driving distance, non business distance(time), and the number of using taxi-calls.
- A stolen vehicle trekking system was implemented since the system could locate the current position of the vehicles or trace the vehicles in real time
- The proposed taxi-call system is used in Seoul metropolitan and near cities since it reduced the cost of the in-vehicle devices and communication costs, remarkably.

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