지능형 교통 시스템을 위한 긴급 상황에서의 도로 예약 방식

정회원 유 재 봉*, 종신회원 박 찬 영*°

The Road Reservation Scheme in Emergency Situation for Intelligent Transportation Systems

Jae-Bong Yoo* *Regular Member,* Chan Young Park*° *Lifelong Member*

요 약

운송은 우리 사회에서 사람들과 화물, 정보의 이동을 제공함으로서 중요한 역할을 해왔다. 하지만 교통사고와 교통 체증, 대기 오염 등을 유발하는 부정적인 면도 가지고 있다. 이러한 문제의 주 원인은 차량 수의 급격한 증가에 있다. 이러한 문제들을 완화시키는 가장 쉬운 방법은 새로운 도로 기반 시설을 건설하는 것이지만, 시간과 비용, 공간 등과 같은 자원의 제약이 있다. 따라서 기존 도로 기반 시설을 효율적이고 안전하게 관리할 필요가 있다. 본 논문에서는 유비쿼터스 센서 네트워크를 사용한 도로에서 긴급 차량 출동을 위한 빠르고 안전한 도로 예약 방식을 제안한다. 또한 앰뷸런스나 소방차, 경찰차와 같은 긴급차량들이 목적지에 빠르고 안전하게 도착할 수 있도록 세 가지 예약 방법에 대한 비교분석을 하고 다양한 도로 상태에서 예약되지 않은 경우에 비해 예약을 한 경우 약 1.09 ~ 1.2 배 빠른 속도를 낼 수 있음을 시뮬레이션을 통해 보여준다. 도로 예약을 사용하는 경우 긴급차량의 속도를 줄이지 않으면서 안전하게 운행할 수 있으며, 교통 체증을 완화시키는 데도 도움을 줄 수 있음을 보인다.

Key Words : road reservation, incident management, emergency response, USN, ITS

ABSTRACT

Transportation has been playing important role in our society by providing for people, freight, and information. However, it cuts its own throat by causing car accidents, traffic congestion, and air pollution. The main cause of these problems is a noticeable growth in the number of vehicles. The easiest way to mitigate these problems is to build new road infrastructures unless resources such as time, money, and space are limited. Therefore, there is a need to manage the existing road infrastructures effectively and safely. In this paper, we propose a road reservation scheme that provides fast and safe response for emergency vehicles using ubiquitous sensor network. Our idea is to allow emergency vehicle to reserve a road on a freeway for arriving to the scene of the accident quickly and safely. We evaluate the performance by three reservation method (No, Hop, and Full) to show that emergency vehicles such as ambulances, fire trucks, or police cars can rapidly and safely reach their destination. Simulation results show that the average speed of road reservation is about 1.09 ~ 1.20 times faster than that of non-reservation at various flow rates. However, road reservation should consider the speed of the emergency vehicle and the road density of the emergency vehicle processing direction, as a result of Hop Reservation and Full Reservation performance comparison analysis. We confirm that road reservation can guarantee safe driving of emergency vehicles without reducing their speed and help to mitigate traffic congestion.

※ 이 논문은 2011년도 한림대학교 교비연구비(HRF-201109-056)에 의하여 연구되었음.
* 한림대학교 유비쿼터스컴퓨팅학과 고속통신 연구실(cypark@hallym.ac.kr), (° : 교신저자)
논문번호 : KICS2010-06-272, 접수일자 : 2010년 6월 17일, 최종논문접수일자 : 2011년 9월 25일

Ⅰ. Introduction

Since the twentieth century, transportation has been one of the great industries. As the indispensable element of the economy, it has been playing an important role in our society by providing mobility for people, freight, and information. While the transportation has such positive effects on our economy, it cuts its own throat by creating car accidents, traffic congestion and air pollution. The main cause of these problems is a noticeable growth in the number of vehicles. With the dramatic increase in demand for vehicles, wider road infrastructures have been built to expand the capacity of the existing road networks, but such a temporary expedient will not contribute to a functional solution for extreme traffic congestion[20]. To solve these problems, road management and road infrastructure should be improved considering the various constraints such as time, money, and space. At this stage, ITS (Intelligent Transportation System) could be considered one of the most suitable solutions.

ITS is a composite traffic information management system that grafts information communication technology onto the components of a traffic system in order to improve the efficiency, productivity and safety of public transportation. As critical issues related to car accidents and traffic congestion are being magnified in modern societies, the ITS is gradually spotlighted as a method to deal successfully with these problems. To manage road networks effectively and safely, recent research has been investigating challenges such as safety driving and traffic congestion mitigation with various angles.

In this paper, we focus on emergency vehicle response for incident management in ITS fields so as to guarantee safe and fast driving and relieve traffic congestion. An Emergency vehicle is the general term for ambulances, fire trucks, and police cars in this paper. In the current freeway management system, although emergency vehicles heading to an accident scene have higher priorities than general vehicles in the legal aspect, they might move to the accident scene by using a shoulder on the freeway, or by making a terrible rush ignoring the traffic signals in urban areas. Consequently, they earn demerits through taking risks of colliding with other vehicles, and taking a long time to arrive at their destinations. In order to reduce additional cost and time for rescue and guarantee the safety of emergency vehicles, our idea is to allow emergency vehicles to reserve a road on a freeway for arriving to the scene of the accident quickly and safely using ubiquitous sensor networks.

The remainder of this paper is organized as follows: The next section describes the related works. After an incident management process in the Section Ⅲ, then Section Ⅵ presents an overview of our incident management along with road reservation schemes. Next, simulation results are discussed in Section Ⅴ. Finally, the conclusion is given in Section Ⅵ.

Ⅱ. Related Works

Generally, ITS have been recognized as an integrated tool to reduce traffic congestion and improve safety. Although ITS has fallen short of our expectations, many countries have implemented and deployed incident management systems such as STREAMS[28] in Australia, COMPASS[21] in Germany, CHART[4], TranStar[2] and TransGuide[19] in North America, EMAS[12] in Singapore, Hanshin Expressway[33] in Japan, NingLian Expressway[26] in China and so on. To accomplish incident management, they rely on different technologies such as CCTV, loop detector, radar sensors, speed sensors, ramp meters, short message service, variable message sign, travelers' advisory radio transmitters and Internet.

Moreover, there has been considerable work in vehicular sensor networks which enable vehicles to communicate with each other via Vehicle-to-Vehicle Communication (V2V) as well as with roadside base stations via Infrastructure-to-Vehicle Communication (I2V). VICS[29] and AHS[5] system provide road traffic information for driving safety via I2V while FleetNet[11] and TrafficView[23] improve the driver's safety and comfort via V2V.

Finally, our work is laying on the similar way with Lane Reservation[24] and Active Highways[16] for the travel time guarantee by booking travel routes based on congestion pricing concept. However, they eschew dealing with traffic accidents on the high-priority lane. It is somehow similar to the vehicle routing problem with time windows (VRPTW) in the sense that both selects the optimal route from a depart node to a destination node within a given time window[8,17].

However, there are also differences between them. 1) While the VRPTW is to minimize the total distance traveled or the number of vehicles used, or a combination of these, our proposed road reservation is to minimize total travel time resulting from reserved lanes considering the traffic impact to unreserved lanes. 2) The VRPTW considers all vehicles to be identical, whereas our model consider them to be heterogeneous. In our model, we consider four types of vehicles: buses, cars, trucks, and emergency vehicles. 3) The biggest difference is the effect of the violation on the time constraint; the VRPTW can apply a penalty cost if the travel time limit is violated. However, the violation on the limit in case of emergency such as car accidents will cause an immeasurable loss of life. To the best of our knowledge, there has not been any published work on the performance evaluation and analysis of road reservation scheme specifically in incident management.

Ⅲ. Incident Management Process

Incident management is defined as activities to reduce the duration and impact of incidents and improve the safety of motorists, crash victims and incident responders[31]. It has already become an integral part of freeway traffic operation. In this section, we illustrate a brief overview of incident management process to understand the relationship between incidents and congestion.

3.1 Incident Management Process

Fig. 1 shows incident duration time defined as the elapsed time when a sudden incident occurs and it

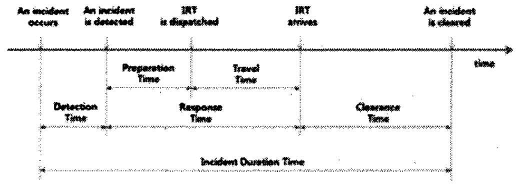


Fig. 1. Incident Management Process on a Highway

terminates[10] at the highway for incident management process. In the Fig.1, IRT means Incident Rescue Team.

The traffic congestion due to a traffic incident will be relieved after the incident is cleared[27]. The incident duration time is the total of detection time, response time, and clearance time. If any of the three factors can reduce the required time, the incident duration time will be shortened, resulting in reducing traffic congestion time. Considering this proposition, we propose a road reservation system using RFID-centric sensor networks to move emergency vehicles to the scene of the accident quickly and safely as well as to relieve traffic congestion by reducing response time.

3.2 Traffic Congestion

Traffic congestion is technically defined as a condition of traffic delayed because the number of vehicles trying to use the road exceeds the traffic network capacity to handle them[14]. Traffic congestion is divided into recurring and non-recurring. The recurring congestion (non-incident-related congestion) stems from the travel demand exceeding roadway capacity, which is most common during the peak morning and evening commuting periods. This phenomenon is often called a bottleneck. The non-recurring (incident related congestion) congestion is due to incidents such as accidents, vehicle breakdowns, construction zones, bad weather and special events[1,3]. Traffic incidents cause approximately between 50~60 percent of such traffic congestion in the roadways. Investments in traffic incident management experience a much greater benefit comparing with investments in new roadway construction. The traffic congestion may decrease road capacity, and increase the travel time[25]. Therefore, it is reasonable that we concentrate on reducing emergency vehicle response time as part of effort to relieve the traffic congestion caused by car accidents in this paper.

Ⅳ. Our Incident Management System

Before proceeding to our approach which provides fast and safe response for emergency vehicles by reducing response time under a road reservation scheme, it will be helpful to glance at our prior works. We designed and developed an incident management system: (i) INTRACS (Intelligent Traffic Control System) for incident detection[32], (ii) Intelligent Bridges System based on RFID middleware for processing massive data in real time by conforming with ALE (Application Level Event) specification[31], and (iii) IMAGES (Intelligent Multi-Agent System) which is a microscopic simulator using multi-agent concept[30]. In this section, we will describe the road reservation scheme for fast and safe emergency response for incident management in detail after presenting a sketch of our system architecture.

4.1 System Overview

We designed a freeway incident management system using ubiquitous sensor networks. It is logically divided into low-level, mid-level, and high-level as illustrated in Fig. 2. In low-level, traffic data is basically read by RFID readers when vehicles with RFID tags move along the road. The traffic data is generated from a simulator and a test-bed, and real roads. We developed a simulator called IMAGES based on a microscopic approach using longitudinal and lateral model. The objective of IMAGES is to reflect the way real human makes decisions and performs actions in the real world on the simulator[30]. It also has an interface to process real-time traffic data from real roads. Moreover, we implemented a small test-bed to detect accidents on the bridges[31]. We used the IMAGES to generate traffic data in this paper.

In mid-level, traffic data generated at the low-level is collected and filtered by RFID middleware which can generate ECReports in the

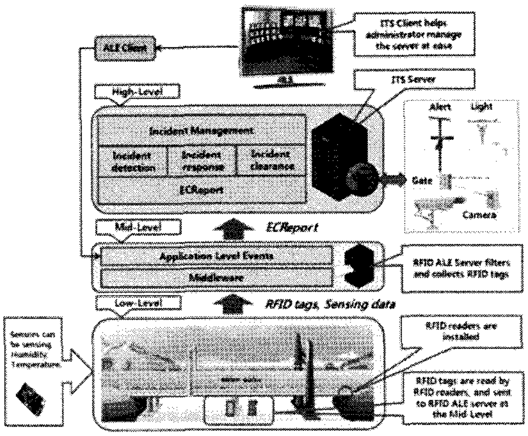


Fig. 2. System Architecture

XML format by ALE specification for the communication of the heterogeneous systems. The results (ECReports) are reported to the high-level. ALE is RFID middleware where RFID tags recognizing a reader play the role of delivering data to an application class such as EPCIS in the RFID system[15,31].

In high-level, the ITS server processes RFID tag information and atmospheric information such as temperature, humidity and illumination and so on. The main responsibility of the server is incident management such as incident detection, incident response and incident clearance.

4.2 Road Reservation Scheme

Safer and faster evacuation related to the survival rate of the accident victims, the safety of emergency vehicles, traffic mitigation. In other words, safer and faster emergency vehicle response can dramatically improve a crash survivor's prognosis and reduce the collateral costs to society. For example, victims' chances of survival are reduced by 7-10% with every minute of delay until defibrillation with CPR (Cardiopulmonary Resuscitation)[7]. In contrast to any other freeway crash, emergency vehicle crash has a number of unique consequences such as taking that emergency vehicle out of service, requiring other emergency vehicle response, and prolonging emergency response times[22]. To reduce such additional costs and guarantee the maneuver of emergency vehicle against traffic congestion and car accidents, we adopted the road reservation scheme to our incident management system.

In this part, we explore how emergency vehicles can arrive at the scene of the accident rapidly and safely using the road reservation scheme. As shown in Fig. 3, our incident management for road reservation mainly consists of four components such as roadside sensors, RFID readers, vehicle sensors, and the central server. First, roadside sensors are laid out at a regular interval around the freeway. They can communicate with passing vehicles (single hop) and with other roadside sensors (multi-hop) to gather traffic flow information and disseminate messages related to road reservation. Second, RFID readers read RFID tags of vehicles, and then send them to the roadside sensors for identifying vehicles. That is, these kinds of sensors are deployed as a communication medium for information transfer or exchange between vehicle sensors and the central server for incident management. As mentioned above, the ALE middleware provides a flexible way for management and implementation with a logical to physical mapping. It is assumed that a RFID reader represents a logical reader referring to one or more physical RFID readers which may be deployed at many places along the road considering range, transmission speed, susceptibility to environmental interferences and so on. Third, each vehicle has a tag and the sensor which can communicate with roadside sensors and other vehicle sensors. Finally, the central center (ITS server) collects traffic information from road sensors and maintains traffic statistic information such as traffic flow and density.

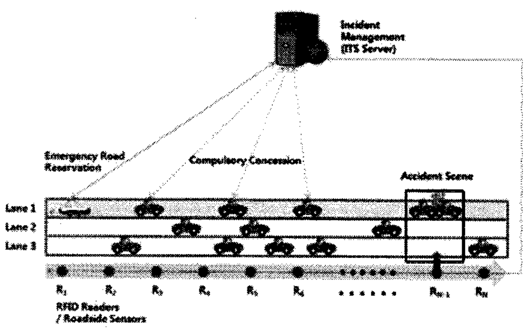


Fig. 3. Incident Management for Road Reservation

It can also track the position of a certain vehicle by identifying the vehicle.

There are two types of messages from the incident management server: *(i) a reservation message* for emergency vehicles to preempt the lowest density lane, and *(ii) a compulsory concession message* which lets other vehicles move another lane for making space for oncoming emergency vehicles. Consider the following scenario: An emergency condition does occur at the section of roadside sensor R_{N-1} in Fig.3. The incident detection module in the incident management server is executed to detect a traffic incident by analyzing the information received from roadside sensors[31,32]. After that, the incident management server finds out the lowest density lane for emergency vehicles based on traffic statistic information, and sends other vehicles compulsory concession messages which command all other vehicles on the lowest density lane to yield to emergency vehicles with the road reservation algorithm. Consequently, emergency vehicles are allowed to reserve the dedicated path to the accident scene by receiving a reservation message from the incident management server. They can reach the accident scene (R_{N-1}) rapidly and safely by keeping the lowest density lane without experiencing speed reduction. The proposed algorithm for road reservation is based on road density and the velocity of an emergency vehicle. It enables our incident management system to book only the relevant route path for an emergency vehicle, so that the system can manage road networks efficiently and safely.

4.3 Road Reservation Algorithms

The road reservation algorithm is defined by a set of *m* vehicles, $V=\{V_1, V_2, \cdots, V_m\}$ and a set of *n* road sensors, $R=\{R_1, R_2, \cdots, R_n\}$. Let $I_{i,j}$ be an incident which happened at the location from R_i to R_j, where $i \le j \le n$. Note that a list of emergency vehicles (*ER*) should be registered at the central server (*CS*) that monitors traffic information sent from R_n. Once $I_{i,j}$ is detected and verified by the *CS*, the IRT will be dispatched. The road reservation algorithms follow the procedures, cf. Algorithm 1, 2, 3, and Fig. 4.

1) Request Permission ($V_m \rightarrow CS$): V_m request permission to the central server via road sensors.

2) Grant Permission ($CS \rightarrow V_m$): If V_m in *ER* is assigned to the IRT, the *CS* gives permission to V_m via road sensors.

3) Road Reservation: This procedure consists of two parts: One is to find the reservation range and calculate the lowest density lanes. The other is to reserve a lane for V_m. Each algorithm uses a different method to find the reservation range (RR) as follows:

A. *Default-Siren-Range(siren)*: The study[6] reported that the siren is a severely limited warning device, effective only at very short ranges and very low speeds because of road noise, air conditioner, radio noise, or the soundproofing in modern vehicles. For example, no siren sound was audible in the vehicle (60*km/h*, no-air condition or radio) until the ambulance is within 100*m*. However, the effective distance could decease to 15*m* in the vehicle (60*km/h*, air condition and radio). For simplicity, *RR* is set to 50*m* for No Reservation.

B. *Velocity-based-Range(velocity)*: The braking distance of V_m should be considered to avoid a collision. Let V_m be vehicle α and the leading vehicle of V_m be vehicle β. The total braking distance is defined as:

$$D_s = D_p + D_d,\ \ D_p = v_\alpha t_p,\ \ D_d = (v_\alpha^2 - v_\beta^2)/2\mu g$$

where D_s is the total braking distance of vehicle α, D_p is the distance travelled during perception-reaction time, D_d is the braking deceleration distance, t_p is the time for the driver in the vehicle α to perceive and react to the warning, μ is the coefficient of friction between tires and the road, and g is the acceleration of gravity. The perception-reaction time t_p is $0.5 \sim 2.5s$[9,13]. If vehicle α is travelling at 140*km/h* and vehicle β is at 0*km/h* (breakdown or incident), D_s requires about 235*m*. *RR* is equal to D_s for Hop Reservation.

C. *Destination-based-Range(start, destination)*: Simply, *RR* is the distance between start and destination

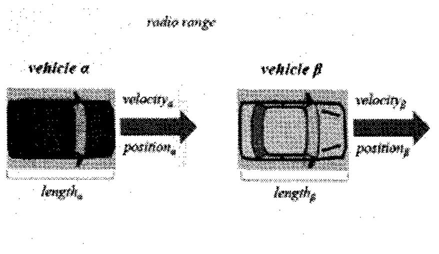


Fig. 4. An Illustration for the Road Reservation Algorithm

Algorithm 1. No Reservation for Emergency Vehicles

```
1.  Request a permission
    Skip this procedure
2.  Grant a permission
    Skip this procedure
3   Road Reservation (V_m ∈ ER)
    update = true
    DO
      1) Find the Reservation Range and the Lowest Density Lane (LDL)
        Let V_m be vehicle α
        IF update THEN
          A  Determine the Reservation Range (RR)
             RR = Default-Siren-Range (α_siren), update = true
          B. The CS calculates LDL for V_m
             No need to calculate LDL
        ENDIF
      2) Reserve a lane
        IF (V_m has a permission) THEN
        ELSE
          Let the vehicles in front of vehicle α on the same lane in RR be vehicle β.
          s_α = p_β − p_α − (l_α + l_β)/2
          IF s_α >= the_desired_minimum_gap THEN
            IF ||p_α − p_β|| < RR THEN // RR means the range of siren
                Vehicle β yields to vehicle α and changes into another lane
                Vehicle α accelerates
            ENDIF
          ELSE
            Vehicle α decelerates or tries to change the lane
          ENDIF
        ENDIF
    UNTIL(V_m arrives at l_{i,j})
```

Algorithm 2. Hop Reservation for Emergency Vehicles

```
1.  Request a permission
    Request_Permission(V_m → CS)
2   Grant a permission
    IF V_m ∈ ER THEN
      Grant_Permission(CS → V_m)
    ENDIF
3.  Road Reservation (V_m ∈ ER)
    update = true
    DO (V_m arrives at l_{i,j})
      1) Find the Reservation Range and the Lowest Density Lane (LDL)
        Let V_m be vehicle α and the coverage range of R_n be d_n.
        IF update THEN
          A.  Determine the Reservation Range (RR)
              RR = Velocity-based-Range (α_velocity), update = true
          B.  The CS calculates the LDL for V_m
              lower = argmax_n p_α ≥ R_n, upper = argmin_n (p_α + RR) ≤ R_n
              LDL = argmin_l Σ_{n=lower}^{upper} Σ_{l=1}^{L} Σ_m^M v_min/(d_n ar)
        ENDIF
      2) Reserve a lane
        IF (V_m has a permission) THEN
          Let the vehicles in front of vehicle α on the LDL in RR be vehicle β.
          Vehicle α moves to the LDL
          s_α = p_β − p_α − (l_α + l_β)/2
          IF s_α >= the_desired_minimum_gap THEN
            IF ||p_α − p_β|| > radio_range THEN
                Send_Concession_Message(CS → β)
            ELSE
                Send_Concession_Message(α → β)
            ENDIF
            Vehicle β changes into another lane except the LDL
            Vehicle α enforces and accelerates on the road up to its desired speed
          ELSE
            Vehicle α decelerates
          ENDIF
    UNTIL(V_m arrives at l_{i,j})
```

Algorithm 3. Full Reservation for Emergency Vehicles

```
1.  Request a permission
    Request_Permission(V_m → CS)
2.  Grant a permission
    IF V_m ∈ ER THEN
        Grant_Permission(CS → V_m)
    ENDIF
3.  Road Reservation (V_m ∈ ER)
    update := true
    DO
      1) Find the Reservation Range and the Lowest Density Lane (LDL)
         Let V_m be vehicle α the coverage range of R_n be d_n
         IF update THEN
           A.  Determine the Reservation Range (RR)
               RR = Destination-based-Range (α_start, α_destination). update = false
           B.  The CS calculates the LDL for V_m
               LDL = argmin_l Σ_{n=start}^{destination} Σ_{i=1}^{L} Σ_{m}^{M} v_min/(d_n Δt)
         ENDIF
      2) Reserve a road
         IF (V_m has a permission) THEN
            Let the vehicles in front of vehicle α on the LDL in RR be vehicle β.
            Vehicle α moves to the LDL
            s_α = p_β − p_α − (l_α + l_β)/2
            IF s_α >= the_desired_minimum_gap THEN
               IF ||p_α − p_β|| > radio_range THEN
                   Send_Concession_Message(CS → β)
               ELSE
                   Send_Concession_Message(α → β)
               ENDIF
               Vehicle β changes into another lane except the LDL
               Vehicle α enforces and accelerates on the road up to its desired speed
            ELSE
               Vehicle α decelerates
            ENDIF
    UNTIL(V_m arrives at I_{i,j})
```

(the scene of accident) for Full Reservation.

After finding the Lowest Density Lane (*LDL*) as shown in Algorithm 2 and 3, The *CS* sends a *compulsory concession message* to other vehicles within the reservation range. Once they receives it, they move another lane for making space for oncoming emergency vehicles. In the proposed algorithms, *the_desired_minimum_gap* means the minimum gap between vehicle a and β, and radio_range means signal strength range of a sensor node.

V. Simulation

5.1 Simulation Tool

IMAGES used in this paper is a freeway traffic flow simulator. We designed and developed this simulator for freeway incident management in ubiquitous sensor networks using multi agent concepts as mentioned in Section IV. The IMAGES is composed of three modules: Road Management Module, Driver-Vehicle Agent module, and GUI & Statistics module. The Road Management Module generates road, land, shoulder, and on/off ramps. This module also includes a longitudinal and lateral model for acceleration, deceleration, and lane changing[18]. In the Driver-Vehicle Agent module, complex human driving behavior involves an agent that consists of vehicle properties (position, speed, length, and kinds of vehicles) and driver properties (acceleration, deceleration, desired time gap, and visibility). The GUI & Statistics module displays vehicle movements as well as networks statistics representing average speed, density, and flow rates as graphs[30].

5.2 Simulation Model

A simulation model is simply set up so as to evaluate traffic flow characteristic such as speed, time, and density by every 1,000 vehicle/hour. The simulation model has a three-lane highway section 10*km* long for simulating an emergency vehicle travel to an accident scene. Each experiment is conducted 10 trials per flow rate for each reservation method. The scenario is as follow: We observed the average speed and average arrival time for the emergency vehicle to arrive at the accident scene by each reservation method during 1,400 seconds as shown in Table 1. At 940 seconds, a sudden incident occurs one of three lanes, and the desired speed of an emergency vehicle is set to 140*km/h*. We assumed that the detection time is 160 seconds, so the emergency vehicle starts at 1,000 seconds.

Table 1. Road Reservation Methods

Type	Existence	Reservation Range
No Reservation	No	Siren-based-Range
Hop Reservation	Yes	Velocity-based-Range
Full Reservation	Yes	Destination-based-Range

5.3 Simulation Results

Fig. 5 shows the result of average speed by road reservation method. For an emergency vehicle, the average speed of Hop and Full reservation is about 1.09 ~ 1.20 times faster than that of No Reservation. The reason why the average speed of two reservation cases is displayed as 138 km/h lower than its desired speed at the initial stage is that the space between the emergency vehicle and its front vehicle is not far enough, so the emergency vehicle reduces its speed. Its desired speed is reset to 138 km/h. Through the road reservation, the front vehicle

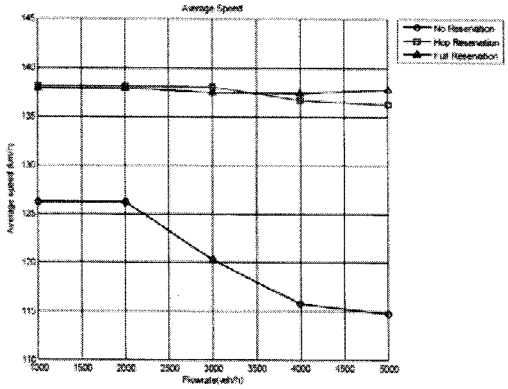


Fig. 5. Average Speed Vs. Flow rate

moves to another lane to create a sufficient space for the emergency vehicle, so it can keep its desired speed. In case of Full Reservation, it reserves the same lane as the emergency vehicle to an accident scene (destination-based), so it can maintain its speed if it is up to desired speed. However, in case of Hop Reservation, it takes into account the speed of the emergency vehicle and its front vehicle (velocity-based), so it could wait for a reservation message when the flow rate is high. In result, the emergency vehicle experiences a negligible decrease of the speed.

Fig. 6 shows the relationship between the average arrival time and flow rate. Speed is in inversely proportional to time. It is obvious that the average arrival time of non-reservation is longer than those of two reservations. Full Reservation has comparable performance to Hop Reservation with respect to the average speed and the average arrival time. It is necessary to look at the performance from the various angles. From the point of view of density by road reservation method, Hop Reservation has better performance than Full Reservation as shown in Fig. 7. In case of Full Reservation, an emergency vehicle reserves the lowest density lane even to an accident scene, and all other vehicles change their lanes to the other two lanes, resulting in high density. On the contrary, in case of Hop Reservation, an emergency vehicle reserves based on its speed, so the density is similar to No reservation.

Fig. 8 is the enlarged part of between 600 and 1,400 in Fig. 7. The Fig. 8 describes much information; when and where the accident happened and when the emergency vehicle leaved for the accident scene. According to the Fig. 8, the accident happened on Lane 1 at 940 seconds, and the emergency vehicle set off at 1,000 seconds. As mentioned before, an emergency vehicle reserves the lowest density lane even to an accident scene and terminates the reservation after the emergency vehicle passes in case of Full Reservation. Because Lane 1 has the lowest density, the accident happened here. The Fig. 8 shows that in case of No Reservation and Hop Reservation, each lane density is equally distributed, but not in case of Full Reservation. Although emergency vehicles requesting Full Reservation can move to the accident scene keeping their desired, the equilibrium of road

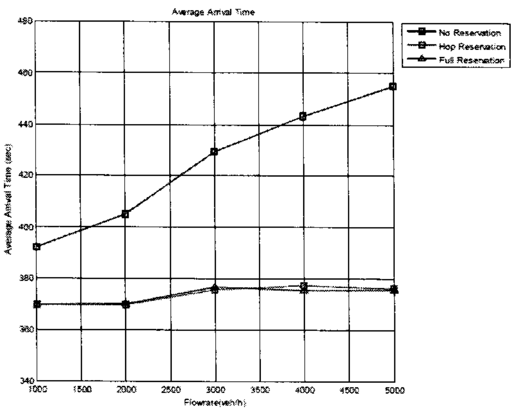


Fig. 6. Average Arrival Time Vs. Flow rate

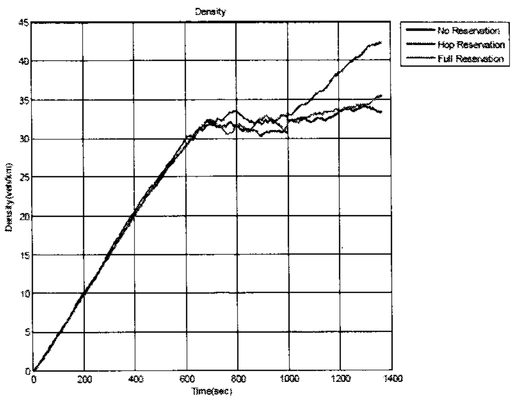


Fig. 7. Density Vs. Time (flow rate = 3,000 veh/h)

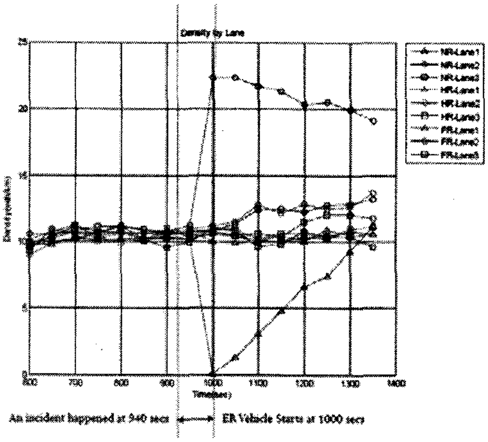


Fig. 8. Density by Lane (flow rate = 3,000 veh/h)

density can be lost.

Ⅵ. Conclusion

In this paper, we have proposed a road reservation scheme for safe and fast emergency vehicle response using ubiquitous sensor networks. In order to provide the safe maneuver for emergency vehicles and mitigate traffic congestion caused by car accidents, our incident management system allocated the dedicate path to them.

To compare No Reservation with our proposed reservations such as Hop Reservation and Full Reservation, we have evaluated the performance by three reservation method with various views; i) average speed by road reservation method with different flow rates, ii) average delay time by road reservation method with different flow rates, and iii) Density by road reservation method when the flow rate is 3,000 veh/h.

The results of our simulation demonstrated that the average speed of road reservation is about 1.09~1.20 times faster than that of non-reservation at various flow rates. However, road reservation should consider the speed of the emergency vehicle and the road density of the emergency vehicle processing direction, as a result of Hop Reservation and Full Reservation performance comparison analysis. Finally, we confirmed that road reservation can guarantee safety driving of emergency vehicles without reducing their speed and help to mitigate traffic congestion.

References

〔1〕 Bajwa, S. I., Chung, E. and Kuwahara, M., "Performance evaluation of an adaptive travel time prediction model," *Proc. IEEE Intelligent Transportation Systems, 2005.* pp.1000-1005., 2005

〔2〕 Bertini, R. L., Byrd, A. M. and Yin, T., "Implementing the ITS archived data user service in Portland, Oregon," *Proc. The 7th International IEEE Conference on Intelligent Transportation Systems,* pp.142-147., 2004

〔3〕 Bilchev, G., Marston, D., Hristov, N., Peytchev, E., and Wall, N., "Traffimatics—intelligent co-operative vehicle highway systems," *BT Technology Journal,* Vol.22, pp.73-83, 2004.

〔4〕 Chang, G., Shrestha, D., Pont-Du-Jour, J., Administration, M. S. H., and Maryland, U. o., *Performance Evaluation of CHART, an Incident Management Program, in 1997*: CHART Program, State Highway Administration of Maryland, 2000.

〔5〕 Daimon, T., Makino, H., Mizutani, H., and Munehiro, Y., "Study on Safety Assist Information of Advanced Cruise-Assist Highway Systems (AHS) using VICS in Blind Curve Section of Urban Expressway," *Journal of Mechanical Systems for Transportation and Logistics,* Vol.1, pp.192-202, 2008.

〔6〕 De Lorenzo, R. and Eilers, M., "Lights and siren: A review of emergency vehicle warning systems," *Annals of emergency medicine,* Vol.20, pp.1331-1335, 1991.

〔7〕 Dias, J., Brown, T., Saini, D., Shah, R., Cofield, S., Waterbor, J., Funkhouser, E., and Terndrup, T., "Simplified dispatch-assisted CPR instructions outperform standard protocol," *Resuscitation,* Vol.72, p. 108, 2007.

〔8〕 Eksioglu, B., Vural, A. and Reisman, A., "The vehicle routing problem: A taxonomic review," *Computers & Industrial Engineering,* Vol.57, pp.1472-1483, 2009.

〔9〕 Fambro, D., Fitzpatrick, K. and Koppa, R., "New Stopping Sight Distance Model for Use in Highway Geometric Design," *Transportation Research Record: Journal of the Transportation Research Board,* Vol.1701, pp.1-8, 2000.

〔10〕 Farradyne, P., "Traffic incident management handbook," *Prepared for Federal Highway Administration, Office of Travel Management,* 2000.

〔11〕 Festag, A., Fußler, H., Hartenstein, H., Sarma, A., and Schmitz, R., "Fleetnet: Bringing car-to-car communication into the real world," *Computer*, Vol.4, p.16, 2004.

〔12〕 Goh, M., "Congestion management and electronic road pricing in Singapore," *Journal of Transport Geography*, Vol.10, pp.29-38, 2002.

〔13〕 Green, M., "How Long Does It Take to Stop?" Methodological Analysis of Driver Perception-Brake Times," *Transportation Human Factors*, Vol.2, pp.195-216, 2000.

〔14〕 Hallenbeck, M., Ishimaru, J., Nee, J., Commission, W. S. T., Center, W. S. T., Office, W. D. o. T. R., and Administration, U. S. F. H., Measurement of Recurring versus Non-Recurring Congestion: Technical Report: Washington State Dept. of Transportation, 2003.

〔15〕 Harrison, M., "EPC information service (EPCIS)," *Auto-ID Labs Research Workshop*, 2004.

〔16〕 Iftode, L., Smaldone, S., Gerla, M., and Misener, J., "Active Highways (Position Paper)," *IEEE 19th International Symposium on Personal, Indoor and Mobile Radio Communications, 2008.* pp.1-5., 2008,

〔17〕 Kallehauge, B., Larsen, J., Madsen, O., and Solomon, M., "Vehicle routing problem with time windows," *Column Generation*, pp.67-98, 2005.

〔18〕 Kesting, A., *Microscopic modeling of human and automated driving: Towards traffic-adaptive cruise control,* 2008.

〔19〕 Kisgyorgy, L. and Rilett, L., "Travel time prediction by advanced neural network," *Periodica Polytechnica Ser Civil Engineering,* Vol.46, pp.15-32, 2002.

〔20〕 Lee, H., "A Study on ITS in Domestic and Advanced Countries," *ETRI Journal*, Vol.14, 1999.

〔21〕 Lerner, G., Huber, W. and Krause, G., "COMPANION development and field testing of a collective warning system," *Fourth ITS World Congress*, Berlin, 1997.

〔22〕 Levick and Nadine, "Emergency Medical Services: Unique Transportation Safety Challenge," *Transportation Research Board 87th Annual Meeting*, 2008.

〔23〕 Nadeem, T., Dashtinezhad, S., Liao, C., and Iftode, L., "Trafficview: Traffic data dissemination using car-to-car communication," *ACM SIGMOBILE Mobile Computing and Communications Review*, Vol.8, pp.6-19, 2004.

〔24〕 Ravi, N., Smaldone, S., Iftode, L., and Gerla, M., "Lane Reservation for Highways (Position Paper)," *IEEE Intelligent Transportation Systems Conference, 2007.*, pp.795-800., 2007

〔25〕 Schrank, D., Lomax, T. and Institute, T. T., *The 2005 urban mobility report: Texas Transportation Institute*, Texas A & M University, 2005.

〔26〕 Shunxin, Y., Wei, H. and Wei, W., "The development and application of an incident management system for the Northern section of Ninglian expressway," *26th Annual Southern African Transport Conference 2007,* pp.9-12., 2007

〔27〕 Skabardonis, A., Petty, K. and Varaiya, P., "Los Angeles I-10 Field Experiment: Incident Patterns," *Transportation Research Record: Journal of the Transportation Research Board,* Vol.1683, pp.22-30, 1999.

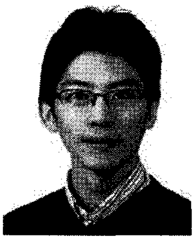
〔28〕 Transmax, *Transmax Annual Report 2008-09.*, Dec. 2009.

〔29〕 Yamada, S., "The strategy and deployment plan for VICS," *Communications Magazine, IEEE,* Vol.34, pp.94-97, 2002.

〔30〕 Yoo, J., Jeong, H., Yoo, B., Kim, S., and Park, C., "IMAGES: intelligent multi-agent system for freeway traffic flow simulation," *the 23rd*

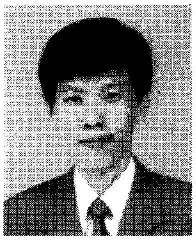
International Conference On Information Networking, pp.1-5., 2009
〔31〕 Yoo, J., Kim, B., Jung, H., Gu, T., Park, C., and Ko, Y., "Design and Implementation of Safe & Intelligent Bridges System Based on ALE-Compliant RFID Middleware in USN," *International Journal of Electronics, Circuits and Systems*, Vol.2, 2008.
〔32〕 Yoo, J., Kim, B., Jung, H., Park, C., Ko, Y., and Gu, T., "INTRACS: Intelligent Traffic Control System Based on Ubiquitous Technology," *The 6th International Conference on Informatics and Systems*, 2008.
〔33〕 Yoshino, T., Sasaki, T. and Hasegawa, T., "The Traffic-Control System on the Hanshin Expressway," *Interfaces*, Vol.25, pp.94-108, 1995.

유 재 봉 (Jae-Bong Yoo) 정회원



2003년 8월 한림대학교 컴퓨터 공학과 학사
2005년 8월 한림대학교 컴퓨터 공학과 석사
2009년 2월 한림대학교 컴퓨터 공학과 박사
2009년~현재 Post doctoral researcher at Information Sciences Institute of the University of Southern California.
<관심분야> intelligent transportation system, vehicular, sensor network, multi-agent system design, discrete event simulation modelling.

박 찬 영 (Chan Young Park) 종신회원



1987년 2월 서울대학교 공과대학 전자공학과 공학학사
1989년 2월 한국 과학 기술원 전기 및 전자 공학과 공학석사
1995년 8월 한국 과학 기술원 전기 및 전자 공학과 공학박사
1991년 3월~1999년 8월 삼성 전자 네트웍사업부 선임 연구원
1999년 9월~현재 한림대학교 유비쿼터스 컴퓨팅학과 교수
<관심분야> USN, ITS, Bio-IT