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u-City에서 RFID를 이용 교통신호제어에 관한 연구

(An approach for Traffic Signal Control using RFID in the u-City)

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요 약

현재 우리나라에는 최첨단의 정보통신 서비스를 제공을 목적으로 ubiquitous city(u-City)가 건설 중에 있다. 이들 도시에서 ITS(Intelligent Transportation Systems)는 도시거주민들에게 적절한 교통정보를 제공하는 동시에 최적으로 도시교통을 제어하는 방안이다. ITS의 한 부분으로서 교통흐름에 적합한 교통신호제어가 필요하며 이를 위해 많은 교통정보를 실시간으로 수집하여야 한다. 이러한 교통정보의 수집은 도시운영을 위하여 최첨단 정보통신 서비스가 제공되는 u-City에서는 어렵지 않을 것이다. 이러한 미래지향적인u-City의 ITS 교통제어에 적합한 새로운 시스템에 대하여 이 논문에서는 연구하였다

Abstract

This study proposed a traffic responsive urban traffic control system using RFID(Radio Frequency Identification) technology to get traffic information. The proposed system is a decentralized control using model predictive control. The objective of proposed system is to get traffic data using advanced technology for controlling the junctions' traffic rights. A simulation example is provided to demonstrate the applicability of the proposed model.

Keywords : RFID, Traffic signal control, u-City, ITS

I . Introduction

The Korean government plans to build futuristic cities, ubiquitous City(u-City),with the latest information technology (IT) infrastructure and "ubiquitous" environment (Songdo City, 2007)[11]. This plan will be achieved by integrating IT infrastructure and ubiquitous information services into urban space. In the "u-City", Intelligent Transportation System (ITS) will be one of the important services like Hong Kong (W. LAM, 2001)[27]. ITS refers to transportation related guidance, control and information systems. These system uses computer and information technology to address transportation functions at the level of individual vehicles roadways and large transportation networks.

ITS needs to get the real time traffic information. Especially the problem of how to measure traffic through urban area as a real time is one of important research topic. There is reviewed several systems that are capable of estimating traffic situation using different detectors (S. M. Turner, 1995); DMI (The integration of an electronic Distance-Measuring Instrument with the floating car technique), Cellular phone (used by motorists to report their position at designated checkpoints), AVI(Automatic vehicle identification), AVL(Automatic vehicle location), GPS (Global Positioning System)receivers (S.H.Lee, 2006)[23].

Now days, the RFID technology gained rapidly development[12]. There could be a system using RFID tag to control traffic signal. There is a vehicle security system using RFID (e-Plate)[10]. In this case,

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all vehicles have an electronically tagged self-powered number plate for identifying whether stationary or on the move. In another works, it is introduced the RFID-based logistic system and information services in ITS(F. LIU, 2006)[7]. They capture and transfer logistics information on the basis of the RFID technology and the associated ITS computer network. Yang developed RF controller for ITS application(Yang G., 2007)[28]. They did not focus on traffic signal controller. The operation of a passive RFID system in fast identification application is researched and analyzed (K. Penttila, 2004)[15]. They found the achievable identification velocities of a passive RFID system. Reliable identification accuracy was achieved up to 40 km/h moving velocities.

The quality of a traffic signal control system is generally defined in terms of safety and efficiency. Many methods have been developed to solve the intersection signal control problems[1~4, 9, 18~20]. A commonly used signal timing model is provided by Webster(1958)[25], who developed a detailed procedure to calculate cycle length and green times. M. Papageorgiou reviewed most of the currently implemented traffic control systems may be into two principal classes; Fixed-time, Traffic responsive (M. Papageorgiou, 2003)[17]. Fixed-time strategies for a given time of day are derived off-line by use of appropriate optimization codes. Traffic-responsive strategies (TRS) make use of real-time measurements to calculate in real time the suitable signal settings. Due to dynamic nature of the problem and technological development, traffic responsive strategies are expected to have better performance in the ubiquitous cities.

In the literature, advanced traffic-responsive programs for networks include OPAC (Garter, 1983) PRODYN(Farges et al, 1983) CRONOS(Noillot et al, 1992) and COP(SEN and Head, 1997)(M. Papageorgiou,2003)[8, 17, 26]. These strategies calculate in real time the optimal values of the next few switching times over a future time horizon H, starting from the current time and the currently applied stage. To obtain the optimal switching times, these methods solve in real time a dynamic optimization problem employing realistic dynamic traffic models with a sampling time, fed with traffic measurements. In another work, a Fuzzy Traffic Controller was presented with traffic responsive strategies[6, 13, 24]. It is composed a set of two inductive loops, spaced by a distance (one set per lane), to detect vehicle as well as its speed.

On the other hand, isolated strategies are applicable to single intersections while coordinated strategies consider an urban zone or even a whole network comprising many intersections. In the ITS, it would be considered the traffic responsive, coordinated intersection control. TRS can be considered a centered and decentralized. A combination of decentralized multi-destination dynamic routing and real-time intersection signal control for congested traffic network is proposed by J. Lei and Ümit Özügner(J. Lei, 1999)[14]. They considered the effects of applying routing and signal controlling in a traffic network to handle saturated an under saturated traffic conditions.

In this paper, RFID based traffic data collection system is described in section Ⅱ. We focused on measuring traffic information in the road. In Section Ⅲ, a model predictive control is proposed in order to minimize the number of vehicles in queue in a arterial road. We simulated the proposed model in different situations.

Ⅱ. RFID sensors and their usage in Urban Traffic

1. Traffic control system using RFID

We assume that every vehicle has its own RFID tag in the futuristic city. A unique electronic identification code is established for each vehicle tag and each unique code is linked to TIS and a databasein the centralized vehicle-database.We proposed a traffic control system using semi-active RFID tag to get traffic information. The structure of this system in the two intersections is outlined in Fig.1. Consider each intersection with 4 ways and the way with 3 lanes.

The proposed system consists of two parts: (1) Traffic Information Server (called TIS), (2) Traffic

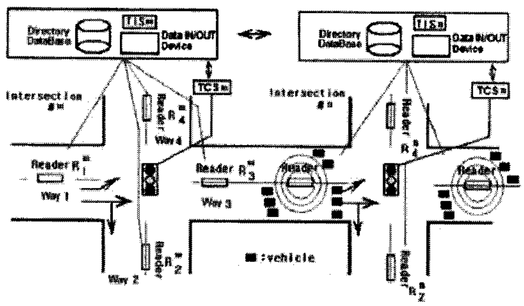

그림 1. 두개의 교차로에서 RFID를 이용한 교통신호 제어구성도

Fig. 1. The architecture traffic signal control using RFID in two intersections

control system (called TCS). Each TIS manages more than one RFID reader, which detects the presence of small RF transmitters (often called tags), and provides the traffic information to the traffic control system. The system allows controlling the omni directional range of each of the RF readers to read tags within a range of 1 to 20 meters.

The distance between RFID reader and the stop line of intersection is about 80m~100 meters, which is decided and could be changed by estimating the waiting queue length in the red time. One reader on the way will detect bidirectional vehicle movements. TIS #m and #n communicate each other to share their data.

TCS control traffic signal and calculate green time for each lane with traffic information (queue, incoming flow rate, outgoing flow rate, turning rate, link velocity, and delay time)

2.Link velocity and travel time

Link velocity and travel time are important for applications ranging from congestion measurement to real-time travel information (S. M. Turner, 1995). The link velocity (m/s) can be calculated by dividing distance with travel time. In the system, the distance between two RFID readers is fixed and known on road. RFID reader detects the compatible tag(s) within its range, then "asks" the detected tag to transmit its identity. The information received by the reader is then passed to TIS database to store arriving time. The travel time of a vehicle is the difference of arriving time between two readers. The link velocity V_{link} of one vehicle $V(i)$ between reader R_m^p and R_n^r is given by;

$$V_{link}(V(i),R_m^p,R_n^r) = D(R_m^p,R_n^r) \Big/ (T_a(V(i),R_m^p)-T_a(V(i),R_n^r)) \qquad (1)$$

where Ta represents an arrival time of vehicle at the reader R_m^p R_m^p and R_n^r represents RFID readers in the m, n way and intersection #p, # r; $D(R_m^p, R_n^r)$ is a distance between the reader R_m^p and R_n^r.

The average of link velocity is more reasonable to inform the traffic situation. The average link velocity V_{link_aver} between the reader R_m^p and R_n^r is set;

$$V_{link\_aver}(R_m^p, R_n^r) = \sum_{i=1}^{N} V_{link}(V(i), R_m^p, R_n^r)/N \qquad (2)$$

where N is the number of vehicle during time interval.

3. Queue length in the lane

The queue length on each way is considered for most traffic signal model. The turning movement rates is assumed known and fixed in the model (C. Diakaki, 2002). We showed the example to count the number of vehicle on each lane in the way in Fig. 2. In the case, TIS #p detects one tag at reader R_m^p and does not detect at any other points ($R^p_{m \neq s}$, s=1,2,3,4) within the intersection, the vehicle owned that tag is come from other intersection and waiting on the way m, TIS#p increases then the queue length at reader R_m^p.

The total queue length $q_m^p(k)$ and the each lane queue length of the way m, at the discrete time kT, in the intersection #p is given by:

$$q_m^p(k) = q_{m,left}^p(k) + q_{m,straight}^p(k) + q_{m,right}^p(k) \qquad (3)$$

where $q_{m,left}^p(k)$, $q_{m,right}^p(k)$ and $q_{m,straight}^p(k)$ represent the queue length of the left, right turn and

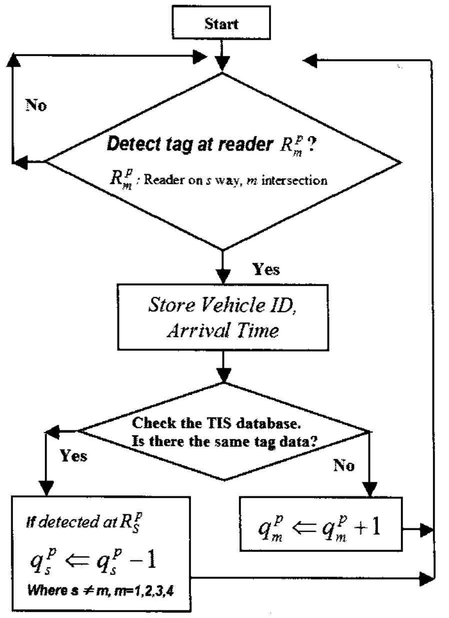

그림 2. TIS #p에서 대기 차량수를 계산 알고리듬
Fig. 2. An algorithm of calculating of queue length of the way m in the TIS #p.

straight going lane on the way m.

The traffic on each lane is expressed by numbers of vehicles conservation equation:

$$q^p_{m,left}(k+1) = q^p_{m,left}(k) + q^p_m(k)*T^p_{m,left} - q^p_{m,m\_L}(k)$$
$$q^p_{m,right}(k+1) = q^p_{m,right}(k) + q^p_m(k)*T^p_{m,right} - q^p_{m,m\_R}(k) \quad (4)$$
$$q^p_{m,straight}(k+1) = q^p_{m,straight}(k) + q^p_m(k)*T^p_{m,straight} - q^p_{m,m\_S}(k)$$

where $q^p_{m,left}(k)$, $q^p_{m,right}(k)$ and $q^p_{m,straight}(k)$ are the queue length on the left, right turn and straight going lane of the way m in the intersection #p. The incoming queue length to each lane is given by multiplying total queue length $q^p_m(k)$ with the turning rate form m way to left ($T^p_{m,left}$), right($T^p_{m,right}$)and straight way($T^p_{m,straight}$) ; The numbers of vehicle going out from the way m to left, right, and straight are $q^p_{m,m\_L}(k)$, $q^p_{m,m\_R}(k)$ and $q^p_{m,m\_s}(k)$. We measured the queue length of each lane using the TIS #p database.

4. Out-going Flow rate in the lane

In section 3, we proposed a traffic model. The out going flow rate (vehicles/sec) on "each lane" is needed for that traffic model. We should know the numbers of vehicle during cycle time to calculate the flow rate within the intersection. With one reader on the way in the intersection, it cannot be known where the tag is from, before searching the TIS database about the tag. The algorism is shown in Fig 3. If the detected tag at the reader R^p_m is come from one of reader in the same intersection #p, increase the number of vehicle $q^p_{s,m}(k)$ between reader R^p_s and R^p_m. If there is no data about the detected RFID tag in the TIS #p, increase the number of vehicle $q^p_m(k)$ of that lane like counting queue length. We set "5 sec" to decide whether there are arriving vehicles to reader R^p_m or not.

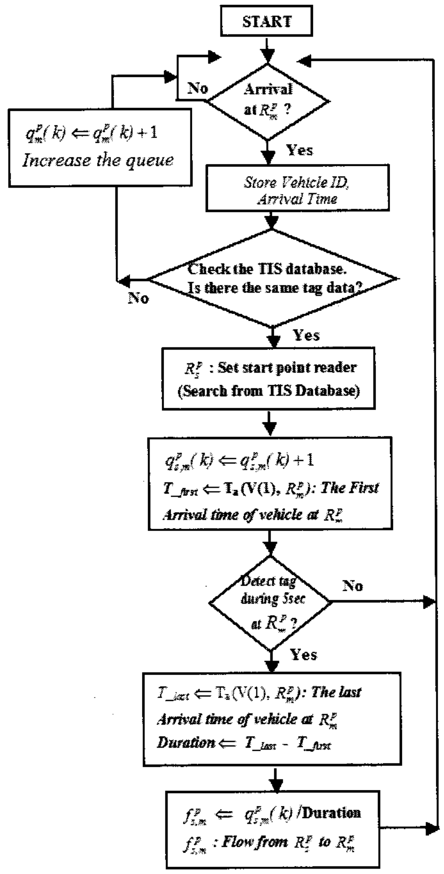

그림 3. 교차로 #p에서 출발하여 나가는 차량 속도를 계산 알고리듬
Fig. 3. The algorism calculating the out-going flow rate from the way s to m within the intersection # p.

The outgoing flow rate $f^p_{s,m}$ could be calculated by dividing the queue length $q^p_{s,m}$ with the duration of passing from starting to end vehicle.

5. Incoming Flow rate in the lane

We could calculate the incoming flow rate (vehicles/sec) on "each lane" by dividing the incoming numbers of vehicle with the time duration of arriving vehicles at RFID reader like calculating "out-going flow rate". The arrival time and the incoming numbers of vehicle could be calculated by checking TIS database and TCS green time sequence.

In this section, we briefly described about one way, but it could be extended about the other way and coordinated intersection. We focused on measuring traffic information in the proposed system; the link velocity, the queue length of each lane and flow rate. In the section 3, we optimized the traffic signal control to decrease vehicle queue length and delay time on the lane, using the traffic data; vehicle number, flow rate and capacity.

Ⅲ. CONTROL OF SINGLE INTERSECTION

In this section, we first introduce the queue model for a given single intersection which considers the red-green switching times explicitly. Subsequently, the model predictive control model to calculate the green signal times for N step horizon is developed. After analysis of the results in the single intersection it will be generalized to the multi intersection case.

1. Single intersection queue model

Consider a four way intersection with lanes L_j where $j = 1, 2, K, 8$ (Fig. 4). When green signal is ON at each lane, vehicles on odd indexed lanes should turn left and vehicles on even indexed lanes should go directly or turn right. No car is allowed to turn right without a green signal at any given direction.

The green signal times t_i, $i = 1,2,3,4$ with corresponding directions are given in Table 1. The summation of these green signal times is equal to the cycle time C which may vary between a lower and upper bound depending on the traffic density. A single intersection can be modeled by discrete time

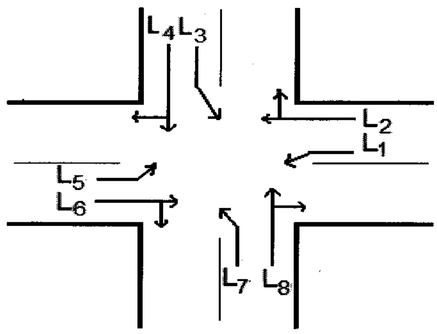

그림 4. 4개의 차로를 가진 단독 교차로
Fig. 4. Single intersection with 4 incoming lanes.

표 1. 초록신호등 할당 시간
Table 1. Green signal times for the lanes.

Signal times	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8
t_1	ON	-	-	-	ON	-	-	-
t_2	-	ON	-	-	-	ON	-	-
t_3	-	-	ON	-	-	-	ON	-
t_4	-	-	-	ON	-	-	-	ON

system in which the state variables $q_j(k)$ with $j = 1, 2, K, 8$ represent queue length at the beginning of the kth cycle (C). Individual queue lengths are mainly determined by incoming flows (f_j, $j = 1, 2, K, 8$), outgoing flows (c_j, $j = 1, 2, K, 8$) or lane capacities, and duration of the green signal time at each lane for that cycle.

Assuming the average flow f_{av}^{td} to be known during any time interval (td), a generic queue model for the jth lane can be written as

$$q_j(k+1) = \max\left[q_j(k) + t_{bg} f_j^{bg} + t_g f_j^g - t_j c_j, 0\right] + t_{ag} f_j^{ag}$$

where t_{bg}, t_g, t_{ag} denotes before green time duration, green time duration and after green time duration in a cycle respectively.

The max term guarantees non-negative queue length in this model.

For an intersection in Fig. 4, the queue on each lane can be written as

$$q_1(k+1) = \max[q_1(k) + t_1 f_1^1 - t_1 c_1, 0] + t_2 f_1^2 + t_3 f_1^3 + t_4 f_1^4$$

$$q_2(k+1) = \max[q_2(k) + t_1 f_2^1 + t_2 f_2^2 - t_2 c_2, 0] + t_3 f_2^3 + t_4 f_2^4$$

$$q_3(k+1) = \max[q_3(k) + t_1 f_3^1 + t_2 f_3^2 + t_3 f_3^3 - t_3 c_3, 0] + t_4 f_3^4$$

$$q_4(k+1)=\max[q_4(k)+t_1f_4^1+t_2f_4^2+t_3f_4^3+t_4f_4^4-t_4c_4,0]$$

$$q_5(k+1)=\max[q_5(k)+t_1f_5^1-t_1c_5,0]+t_2f_5^2+t_3f_5^3+t_4f_5^4$$

$$q_6(k+1)=\max[q_6(k)+t_1f_6^1+t_2f_6^2-t_2c_6,0]+t_3f_6^3+t_4f_6^4$$

$$q_7(k+1)=\max[q_7(k)+t_1f_7^1+t_2f_7^2+t_3f_7^3-t_3c_7,0]+t_4f_7^4$$

$$q_8(k+1)=\max[q_8(k)+t_1f_8^1+t_2f_8^2+t_3f_8^3+t_4f_8^4-t_4c_8,0]$$

Although this queue model is designed to find queue lengths over the period $[kC,(k+1)C]$ it has inherently two sub-states. One is from the start of the kth cycle to the end of the green time in which non-negative queue lengths are guarantied by the max terms. The other sub-state is between the end of the green time and the end of the kth cycle. Additionally, this model not only considers the queue lengths but also the incoming flow rates that are helpful for unsaturated traffic conditions.

2. Model Predictive control for determining signal times

Assuming average flow during one cycle of store and forward model provide using well known controller design tools in control theory (Diakaki C, 2002). In this case, the resulting controller can do better for saturated traffic conditions. But if the network includes some unsaturated intersections, the designed controller may not behave well. Because the red-green signal passes are not considered for average flow assumption during one cycle. If the red-green signal passes are taken into consideration, then it will be almost impossible to represent the system for applying standard control theory tools with a sample time value of one cycle. On the other hand, some constraints related to traffic control system needed to be handled separately. Model predictive control presents the capability of handling the nonlinear model as well as some constraints of the system. It is an increasingly popular control approach because of its use of a possibly nonlinear control models and its ability to handle constraints on inputs, states and outputs (Rawlings, 2000).

In the following, the queue model and some constraints related to the traffic signal control problem are combined together in the model predictive control formulation.

$$\min_{\substack{t_i(k,N)\\ i=1,2,3,4}} \sum_{k=1}^{N}\sum_{j=1}^{8} w_j q_j(k) \tag{5}$$

s.t.

$$q_1(k+1)=\max[q_1(k)+t_1(k)f_1^{1-k}-t_1(k)c_1,0]+t_2(k)f_1^{2-k}+t_3(k)f_1^{3-k}+t_4(k)f_1^{4-k}$$

$$q_2(k+1)=\max[q_2(k)+t_1(k)f_2^{1-k}+t_2(k)f_2^{2-k}-t_2(k)c_2,0]+t_3(k)f_2^{3-k}+t_4(k)f_2^{4-k}$$

$$q_3(k+1)=\max[q_3(k)+t_1(k)f_3^{1-k}+t_2(k)f_3^{2-k}+t_3(k)f_3^{3-k}-t_3(k)c_3,0]+t_4(k)f_3^{4-k}$$

$$q_4(k+1)=\max[q_4(k)+t_1(k)f_4^{1-k}+t_2(k)f_4^{2-k}+t_3(k)f_4^{3-k}+t_4(k)f_4^{4-k}-t_4(k)c_4,0]$$

$$q_5(k+1)=\max[q_5(k)+t_1(k)f_5^{1-k}-t_1(k)c_5,0]+t_2(k)f_5^{2-k}+t_3(k)f_5^{3-k}+t_4(k)f_5^{4-k}$$

$$q_6(k+1)=\max[q_6(k)+t_1(k)f_6^{1-k}+t_2(k)f_6^{2-k}-t_2(k)c_6,0]+t_3(k)f_6^{3-k}+t_4(k)f_6^{4-k}$$

$$q_7(k+1)=\max(q_7(k)+t_1(k)f_7^{1-k}+t_2(k)f_7^{2-k}+t_3(k)f_7^{3-k}-t_3(k)c_7,0)+t_4(k)f_7^{4-k}$$

$$q_8(k+1)=\max(q_8(k)+t_1(k)f_8^{1-k}+t_2(k)f_8^{2-k}+t_3(k)f_8^{3-k}+t_4(k)f_8^{4-k}-t_4(k)c_8,0)$$

$$\sum_{i=1}^{4} t_i(k)=C\ ,\quad k=0,1,\ldots,N-1$$

$$T_{\min}\le C\le T_{\max}\,.$$

$$t_{i\_\min}\le t_i(k,N)\le t_{i\_\max}\,,\ i=1,2,3,4$$

$$q_j(k)\le \alpha_j\,,\ i=1,2,3,4\,,\ k=1,2,\ldots,N$$

where C , $T_{\min}$ and , $T_{\max}$ represents cycle time, lower and upper bound for the cycle time respectively. The term $t_i(k,N)$ stands for the green signal time variable of each lane over N-step horizon. It can be written as

$$t_i(k,N):=[t_i(k)\ t_i(k+1)\ \mathrm{K}\ \ t_i(k+N)]^T,$$

$i=1,2,3,4$. For each step the horizon, summation of green times is equal to cycle time which may vary between a lower and upper value. Each green time values also has minimum ($t_{i\_\min}$) and maximum value ($t_{i\_\max}$) which is fixed over the horizon. The summation of the minimum green time values assumed to be equal or less than $T_{\max}$, also summation of the maximum green time values assumed to be equal or greater than $T_{\min}$ for feasibility concerns. The queue lengths are constrained by α_j $i = 1,2,3,4$ for each lane in the current intersection (spillback constraint for multi-intersection case).

The objective function includes weighting parameters w_j which assigned to the each lane. For each lane it has a default value of $w_j = 1$ for which the objective becomes minimizing the total queue length. The weighting parameter w_j may be set regarding different criteria's (maximum or average delay, priority of one lane, emergency vehicle passing etc.), then the optimization objective also change depend on assigned weighting parameter values.

3. Simulations for one intersection

In this sub section, we apply the above control method to control single intersection. The initial queue lengths and incoming flows between 100-200 seconds are given as for each lane.

$$q_1(0) = 5,\ q2(0) = 65,\ q3(0) = 34,\ q_4(0) = 80,$$
$$q_5(0) = 5,\ q_6(0) = 20,\ q_7(0) = 6,\ q_8(0) = 12,$$

$$f_j = 0.1\,veh/\sec \text{ for } j = 1,3,5,7$$
$$f_j = 0.2\,veh/\sec \quad j = 2,4,6,8$$

The capacity of lanes are assumed to be fixed and given

$c_1 = 0.25$ veh/sec, $c_2 = 0.5$ veh/sec, $c_3 = 0.25$ veh/sec, $c_4 = 0.5$ veh/sec, $c_5 = 0.25$ veh/sec, $c_6 = 0.5$ veh/sec, $c_7 = 0.25$ veh/sec, $c_8 = 0.5$ veh/sec,

The lower and upper bound for the cycle time is selected 90 secs (C fixed) and minimum green times are follows: $t_{i\_\min} = 10\sec$ i=1,3., $t_{i\_\min} = 15\sec$ i=2,4, maximum queue lengths $\alpha_j = 100$, and predicting the future step is selected as N=3.

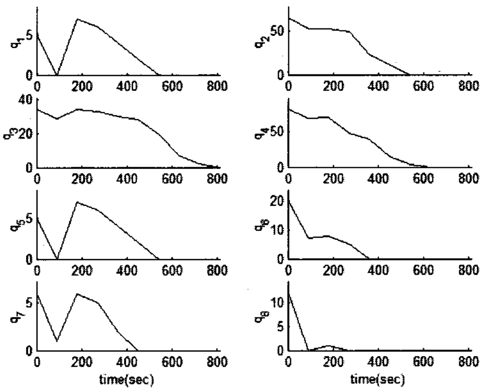

그림 5.a 각 차로별 시간대비 차량 수
Fig. 5.a Queue lengths versus time at each lane

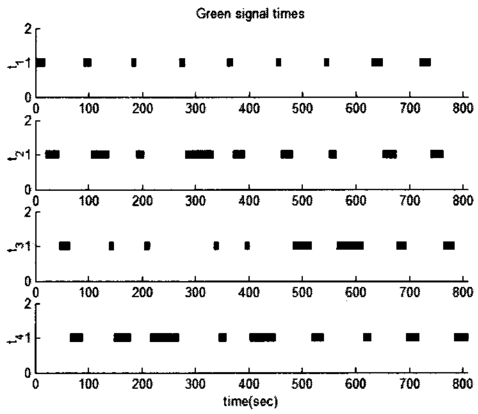

그림 5.b 초록 신호등 시간
Fig. 5.b The Green signal times.

The simulation results are given in Fig. 5.a-b. The queue lengths versus time results are shown in Fig. 5.a, and the duration of the green signal times at each cycle versus time are shown in Fig. 5.b.

In the second simulation, an emergency vehicle is assumed to pass from lane 4 for the same conditions in Fig. 5. So we increased only weighting factor of this lane to the $w_4 = 20$. Fig. 6.a-b shows the queue lengths and the green signal times respectively. Notice that the queue length in lane 4 gets zero in less time (compare Fig. 5.a and Fig 3.a) and more green time is assigned to that lane in the starting cycles (compare fourth column of Fig. 5.b and Fig. 6.b).

The responses of the proposed signal controller to the various test conditions are also tested with the simulations. Due to page restrictions they are not

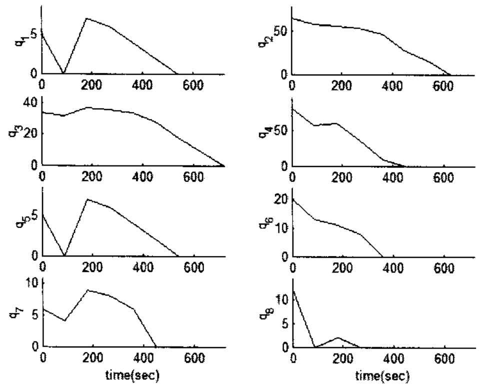

그림 6.a 각 차로별 시간대비 차량 수

Fig. 6.a Queue lengths versus time at each lane.

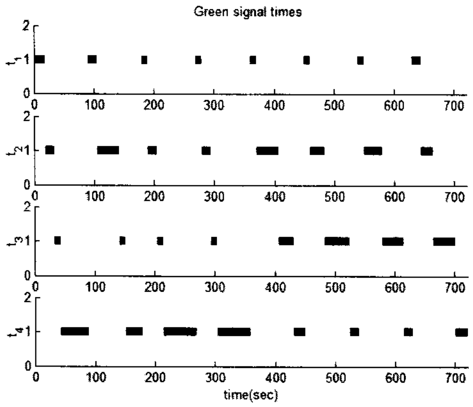

그림 6.b 초록 신호등 시간

Fig. 6.b Green signal times.

given here. In the following section, integration of the single intersection controller to multi-intersection is given

4. DECENTRALIZED MULTI-INTERSECTION TRAFFIC SIGNAL CONTROL

The single intersection traffic signal controller is extended to calculate the signal times of the intersection also considering the adjacent intersections. For simplicity in presentation considers the arterial (Fig. 7) Let us redefine the variables for the multi intersection case using an upper index p, which denote the intersection number. So, L_j^p and q_j^p represents the lane numbers and the queue length of pth intersection respectively. And the weighting parameters, incoming flows, the lane capacities, and the maximum queue length of lane j of pth intersection becomes w_j^p, f_j^p, c_j^p, and α_j^p respectively.

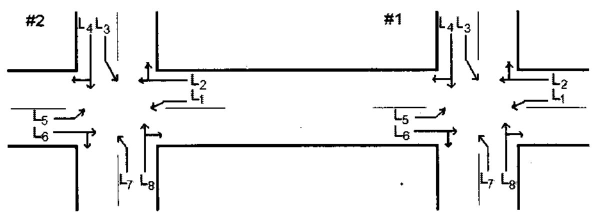

그림 7. 두개의 교차로를 가진 간선도로

Fig. 7. Arterial road with two intersections.

Each single intersection traffic controller considers the incoming flows from the upstream intersection and congestion status of downstream intersections. In the multi intersection case flow may be measured until a point near to adjacent intersection. Providing the signal time values, the queue lengths, and the lane capacities of the adjacent intersection for next coming cycle also help predicting the incoming flow for some additional time. So, the incoming flow information becomes a combination of measurement and prediction in the multi intersection case. On the other hand, the single intersection signal controller also looks at the queue length of the downstream intersections to calculate the signal times. For example assume that the queue lengths of lanes $L_{1,2}^2$ (in intersection 2) reach up to a threshold value but less than the critical value $\alpha_{1,2}^2$. Then, the single intersection signal controller in intersection 1 may take care of this situation by increasing weight factors (w_j^1) of other directions that do not towards to intersection 2. Or depending on downstream congestion status it is decreased the green signal time lower and upper bounds.

5. Simulations for Multi intersection case

The simulation conditions other than flows are kept as similar to the single intersection case. The only incoming flows are assumed 0.1 veh/sec and 0.5 veh/sec for lane 1 and lane 2 of intersection 1 respectively between 0-120 seconds. The solid lines in the Fig. 5 and Fig. 6 show the queue lengths versus time graph of intersection one and two respectively

There is an offset time of 60 seconds between

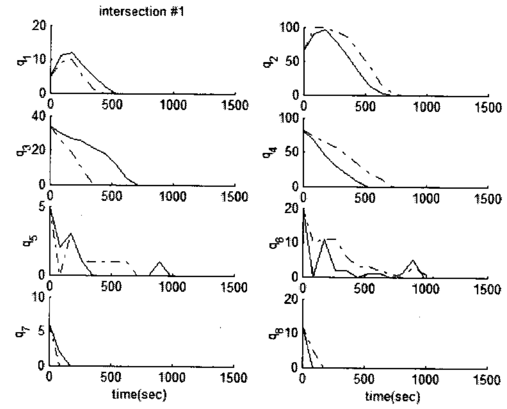

그림 8. 교차로 #1에 대한 각 차로별 시간대비 차량 수
Fig. 8. Queue lengths versus time for intersection 1.

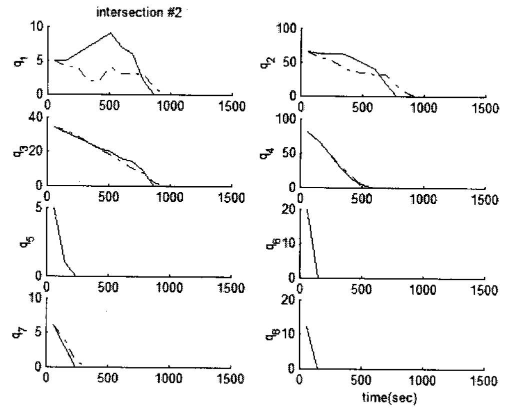

그림 9. 교차로 #2에 대한 각 차로별 시간대비 차량 수
Fig. 9. Queue lengths versus time for intersection 2.

intersections in two directions. Considering the green flow for unsaturated case, each intersection makes its own plan with a difference of 60 second. So, for simulations, the signal controller in intersection 1 makes plan at time t=0, and 60 second later the signal controller in intersection 2 makes its own plan. When the signal controller in intersection 2 makes a plan it use measurement of flow for $f_{1,2}^{2}$ for next 60 second and estimation for remaining 30 second since it is assumed to know the signal times of the intersection 1.

Assume the threshold values of intersection 2 are reached for the lane 1 and 2. Then set some of the weighting parameters of intersection 1 as $w_j^1 = 20$, $j = 1,3,5$. The dashed lines in Fig. 8 and Fig. 9 show the effect of these new weighting parameters. As seen from the figure (Fig. 9), the queue lengths for the lane 1 and lane 2 of intersection 2 do not increase so much but gets zero later. But in this case the queue length of lane 2 of intersection 1 reach up to its maximum value (Fig. 8). It is obvious that signalization and routing may be considered together (Khorrami and Ozguner, 1984)[16] to handle downstream congestion problem in a better way.

Ⅳ. Conclusion

We proposed a system using RFID for traffic data acquisition and suggested a decentralized traffic control for multi intersection case. In the future work, it is necessary more research for getting traffic actual data using RFID and storing the traffic data and searching the database.

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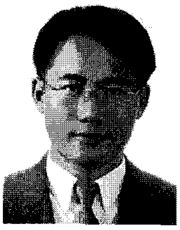

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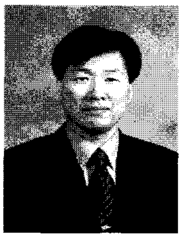

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