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To Go or Not To Go: N-hop Congestion Notice with Experience Support for Dynamic Detouring

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Abstract

A dynamic detour scheme for intelligent transportation systems (ITSs) to avoid traffic congestion is proposed in this paper. When running into traffic congestion, vehicles usually can do nothing but waiting. The proposed scheme can prevent driver suffer from traffic congestion by balancing traffic flows with n-hop notices method and experience-support method. Congestive information can be received from road side units. The notification range of congestion event is determined by the server. In this study, the range of congestion notification is defined as n-hop from congestion road. Only the vehicles located in the n-hop range will receive the notification. Also, the information about the average time for vehicles to get through each road can be recorded to help reselecting a new path to avoid congestion. According to simulation results, both n-hop notices and experience-support method are proved to improve traffic congestion effectively.

Keywords: *Intelligent Transportation System, Congestion Avoidance, detour*

1. Introduction

Recently, vehicular ad hoc network (VANET) becomes more and more attractive to wireless communication systems for telematics-automotives industry [1]. With the combination of network and information, intelligent transportation systems (ITSs) can provide traffic information services to drivers [2]. Traffic congestion is a main problem while too many vehicles on the road. It is important for ITS to solve the traffic congestion and to increase the utilization of each road by balancing traffic flows.

To achieve the purpose, a dynamic detour scheme with/without experience-support for ITS is presented in this paper. In order to avoid vehicles from congestive roads, the centralized server will collect traffic information from road side units (RSUs). Moreover, on board units (OBUs) of vehicles can receive congestive notices from RSUs to see if the following path suffers from congestion. When an OBU receives congestive notices, it will remove the congestion road from its map and reselect a new path to destination. However, the notification range of congestion event is determined by the server.

The proposed scheme can solve traffic congestion by balancing traffic flows with both n-hop notices method and users-experience method. The range of congestion notification is defined as n-hop from congestion road. Only the vehicles located in the n-hop congestion notification range will receive the notices. Therefore, the parameter n will affect the effectiveness of congestion evacuation. One of the issues in this study is to determine the size of n. Moreover, for some vehicles traveling with a similar path every day, OBU can record the average time of spending on each road. The information helps to reselecting a new path to avoid traffic congestion.

The remainder of this paper is organized as following sections. Section II describes the related research of ITSs. In section III, a dynamic detour scheme is proposed to solve the traffic congestion problem. In section IV, simulation and numerical analysis are described for the performance evaluation. Concluding remarks are made in section V

2. RELATED WORK

Intelligent Transportation Systems are a wide range, fully efficient, real-time and accurate information manage system for drivers and vehicles. The implementation of ITSs includes sensor network and control technologies, communications, and computer informatics [3]. There are three communication model in ITSs such as vehicle to vehicle (V2V) communication, vehicle to infrastructure (V2I) communication, and vehicle to vehicle to infrastructure (V2V2I) communication [4]-[6]. The communication models are chosen depending on applications.

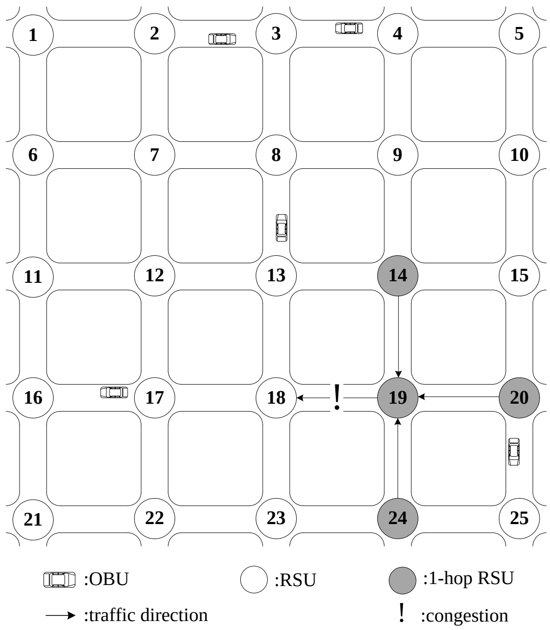

Fig.1. Chessboard-pattern streets

There are numerous research challenges that need to be addressed if a wide deployment of vehicular ad hoc networks (VANETs) becomes possible. One of the critical issues consists of the design of scalable routing algorithms that are robust to frequent path disruptions caused by vehicles' mobility. A stable routing protocol was proposed to support ITS services in VANET network, and the key idea behind the proposed scheme is to group vehicles according to their moving directions. Vehicles are grouped according to their velocity vectors. This kind of grouping mechanism ensures that vehicles, belonging to the same group, are more likely to establish stable single and multihop paths as they are moving together [7]. Furthermore, a stable clustering scheme was published that are applicable in pseudolinear highly mobile ad hoc networks. The scheme presented two algorithms that are suited for various scenarios, depending on the amount of reliable mobility information available in the targeted system [8].

ITS application can be divided into five application fields [9]. In advanced traffic management system (ATMS), it attempts to use available traffic information to develop optimal traffic control strategies at a single intersection, along an arterial or freeway, along a given corridor, or throughout a given area. The goal of ATMS is to increase the utilization of infrastructure [10]. Advanced traveler information system (ATIS) lets driver or pedestrian get important information at anytime and anywhere. A traveler can know related information about his/her location. It can help user to save time on the road [11]. Moreover, drivers are prevented to get involved into traffic accidents by advanced vehicle control and safety system (AVCSS) [12]. Advanced public transportation system (APTS) can provide more flexible route services according to the different needs of each person [13]. The use of commercial vehicle operation (CVO) is to increase transport efficiency, increase service quality, and reduce labor cost [14]. In this study, a dynamic detour scheme is proposed to improve traffic congestion by using ATMS and ATIS.

3. Detour Scheme with N-hop Notification

The investigation proposes a detour scheme called N-hop Notification scheme to avoid running into traffic congestion. The investigation designs the detour scheme based on traffic jam alert via ITS. In addition, drivers' experience for finding good reroute path is also considered in the study. Details on the key design and distinct features that are incorporated in each element of the proposed scheme are described below.

3.1 System model

The environment of the study is supposed to be as chessboard-pattern streets as shown in Fig.1. Moreover, to perform efficient information collection and relay, it is supposed that vehicles equip with on-board unit (OBU) and road side units (RSU) can collect the traffic condition on each intersection. OBU can communicate with RSU through the wireless technology. When vehicle travels to the communication coverage of RSU, OBU will receive the beacon packet form RSU. By the way, OBU could send packet to server via the RSU if necessary. In our system model, server is a data collection center. The features of the three components are introduced as follows:

a) *On-board unit (OBU)*: The device is set up in the vehicle. It is able to communicate with RSU and make simple computation. OBU can know its location by receiving beacon packet from RSU. When OBU gets notification about the traffic congestion occurred at the vehicle's future path, it will change planning path according to received information. Hence, driver can take advice from OBU to choose the better path in advance.

b) *Road side unit (RSU)*: RSU exists at intersection as a communication bridge between OBU and server. It includes an extension of sensor equipment which can sense moving speed of vehicles. Each RSU is in charge of four adjacent road sections. Therefore, when congestion event occurs or disappears, the RSU must take responsibility for informing server.

c) *Server*: Server is a data collection center. It can transform received sensing data into practical information and analyze the data record in database. At some time, server can send information to some OBU which needs it. When server receives congestion event or congestion termination report, it will select n-hop RSUs to inform. To

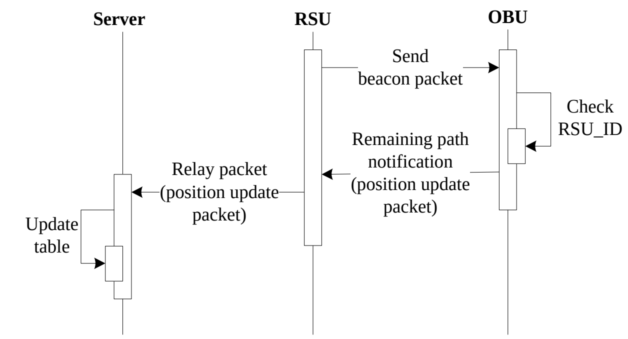

Fig.2. Normal data exchange procedure

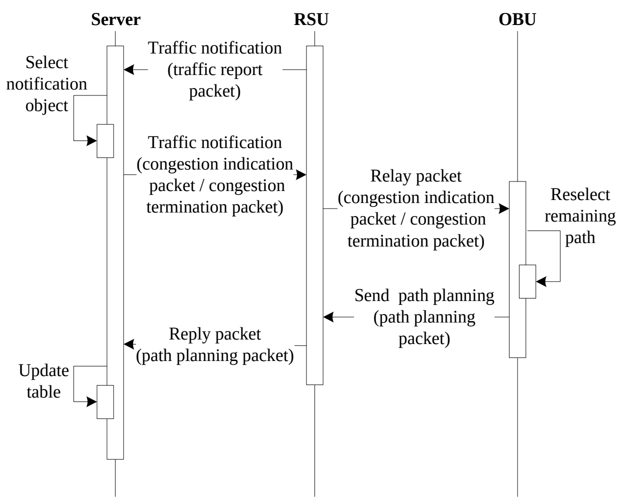

Fig.3. Congestion trigger procedure

prevent broadcasting storm, only the vehicles which locate in the n-hop notification range will receive the message.

3.2 System design

In the proposed dynamic detour scheme, each RSU monitors the traffic status by sensing the speed of vehicles, and it will report this traffic information to the server. According to traffic status report from RSU, the server recognizes the congestion occurring or relieving and informs RSUs which are n-hop away from the congestion point. The informed RSU broadcasts the newest notification. Hence, the OBU can get the traffic congestion status if it is within n-hop away from the congestion point.

Fig.1. also shows an example of congestion informing situation. In this scenario, a road can be defined as two RSU ID. The traffic direction from intersection 19 to 18 is in congestion. RSU 18 will report the instant congestion information to server with wired network. When receiving the congestion information from the RSU 18, the server will select related RSUs and OBUs. The server selects all RSUs which locate in the n-hop away from the congestion point. Also, it selects OBUs which will involve into congestion road in its future path according to the planning path registered in database.

When the congestion from road 19 to 18 becomes relieving, RSU 18 will report instantly the congestion relieving to the server. However, when the server receives congestion termination notice, only the RSU between n-hop from RSU 18 will be informed to broadcast the congestion termination notice. When the notified RSU receives the notice, it will broadcast this information to OBU which is located in the coverage range of RSU.

As an OBU receives the packet about instant traffic status, it will check if it has to reselect a new path. If the OBU has to reselect a new path, it must send reselected path information to the server through RSU. Hence, server has capable to update the latest path information of OBUs.

3.2.1 *Dynamic detour scheme*

a) *Initial path procedure*: An RSU broadcasts beacon packet periodically. Beacon packet includes RSU ID. An OBU can receive the beacon packet while it is in the coverage range of a RSU, so the OBU is able to know its location. At beginning, the OBU plans a future path for driver. When an OBU receives the beacon packet from an RSU, it will send the path planning packet to the RSU. The RSU always relays the planning packet from OBU to server, so the server is able to update remainder path table.

b) *Normal data exchange procedure*: Due to the remaining path of vehicle will change over time, the remainder path table in server might be out-of-date. If the congestion notification occurs under such condition, server can not notify the correct OBU. Normal data exchange procedure is shown in Fig. 2. When the OBU receive the beacon packet, it will check if the RSU ID stores in its past position table which stores the two latest RSU IDs that is the OBU has passed. Hence, the OBU can know whether it comes to a new area by checking received RSU ID and its past position table. When the OBU enters a new area, it has to update remaining path table in the server by sending position update packet to RSU. The position update packet includes previous RSU ID which is the vehicle has passed.

c) *Congestion trigger procedure*: Congestion trigger procedure is shown in Fig. 3. An RSU includes four extension devices to sense four direction speeds on the road. According to average speed of each road, the RSU is able to know the traffic status of four roads. If average speed is less or greater than a threshold, we can declare the road involved into or relieved from traffic congestion. At the meanwhile, the RSU will send a traffic report packet to the server. When the server receives the traffic information from RSU, it will send congestion indication packet or congestion termination packet depending on received information. The RSU plays a relay role to forward packet from server to OBU. Once the OBU receives packet about

```
//road_start:start RSU ID in congestion indication packet
//road_end:end RSU ID in congestion indication packet
//CT_start:start RSU ID in congestion termination packet
//CT_end:end RSU ID in congestion termination packet
//CP:current position of OBU
//Dest:destination of OBU

procedure OBU {
    while(rev_packet=packet heard from RSU){
        switch(rev_packet){
            case 'beacon_packet':
                if RSU_ID is new
                    Update(past_position_table);
                    Send position_update_packet to RSU;
            break;
            case 'congestion_indication_packet':
                if OBU_ID is selected
                    Delete(road_start, road_end);
                    Reselect_Remainder_Path(CP,Dest);
                    Send path_planning_packet to RSU;
            break;
            case 'congestion_termination_packet':
                if Road was Deleted
                    Road_Recover(CT_start, CT_end);
                    Reselect_Remainder_Path(CP,Dest);
                    Send path_planning_packet to RSU;
            break;
        }
    }
}
```

Fig.4. Procedure for OBU

traffic of its future path, it will reselect a new path and inform server to update remainder path table.

3.2.2 *System design for different devices*

a) *Design for on-board unit (OBU)*:

Procedure for OBU receiving packet is shown in Fig.4. There are two kind of events will trigger OBU to do something. The first is the initial path selection at beginning. The other is that OBU receive packet from RSU. In the initial path selection, OBU selects a path for driver and sends the path planning packet through the RSU to the server. The path planning packet is composed of OBU ID and the future path. Dijkstra's algorithm is used to select a shortest path for driver in the research [15]. In addition, the future path can be expressed by the RSUs' ID on the road.

When drivers are on the way to destination, OBU may receive some packets and take different procedure depending on packet type. If the packet type that OBU received is beacon packet, it will record RSU ID in its past position table and send position update packet through RSU to server. Therefore, server can update remaining path table to correct path information of OBU.

If OBU receives the congestion indication packet, it means that the driver may be involved into traffic congestion in his future path. At the moment, OBU will remove the congestion road from its map and reselect a new path for driver. To update the new path from the remaining path table in server, OBU must send path planning packet about the update to server via RSU.

```
procedure RSU {
    loop{
        average_speed=sense speed of traffic;
        if(average_speed<=min_speed){
            Set_Road(road_start,road_end,1);
            Send traffic_report_packet to server;
        }
        else{
            if(Check_Road(road_start,road_end)){
                Set_Road (road_start,road_end,0);
                Send traffic_report_packet to server;
            }
        }
        if(RSU receives packet){  //Packet relay method
            if(receive packet from OBU for server){
                Relay packet to server;
            }
            else if(receive packet from server for OBU){
                Relay packet to OBU;
            }
        }
    }
}
```

Fig.5. Procedure for RSU

Another type of packet OBU may receive is congestion termination packet which indicates that some road congestion was relieved. As receiving it, OBU will check whether the indicated road in this packet is removed from map. If so, the OBU will recover the road in its map, and reselect a new path. Then, it will send path planning packet to server via RSU as well.

b) *Design for road side unit (RSU)*:

An RSU broadcasts beacon packet periodically, which can help the OBU to locate its position. Procedure for RSU is shown in Fig.5. Each RSU monitors the four adjacent roads, which traffic direction is toward to RSU itself. As described above, the RSU has capability to sense the traffic speed. When the RSU checks average speed is less than the minimum speed, it will set value of road state is 1 with Set_Road function in procedure. That means the road is in congestion status. Additionally, the RSU sends traffic report packet to server. On the contrary, when congestion is relieved, RSU will change the status of road by using Set_Road function and report congestion termination information to server as well.

c) *Design for server*:

Server is a decision center in the investigation, which maintains remainder path table ordinarily. When server receives packet from RSU, it will transform the data into information. The process of server receiving packet is shown in Fig. 6.

```
//Remahinder_Path:the remainder path in
                    path_planning_packet
//Table:a table for storing remainder path of vehicle
//n:n-hop from event road
//s_road:start RSU ID of the road
//d_road:end RSU ID of the road

procedure Server{
    while(rev_packet=packet heard from RSU){
        switch(rev_packet){
            case 'path_planning_packet':
                for each i as RSU ID of Remainder_Path
                    Table[OBU_ID][Remainder_Path[i]]=i;
            break;
            case 'position_update_packet':
                Table[OBU_ID][RSU_ID]=0;
            break;
            case 'traffic_report_packet':
                if the road is jammed
                    Select_RSU(s_road, d_road,n);
                    Select_OBU(s_road, d_road);
                    Send(congestion indication packet);
                if congestion has terminated
                    Select_RSU(s_road, d_road,n);
                    Send(congestion termination packet);
            break;
        }
    }
}
```

Fig.6. Procedure for server

Because the remainder path of vehicles will change, the vehicles need to send position update packet to update the remaining path. While the server receives the position update packet, the server will set the relationship between the vehicle and the RSU to 0. As a result, the server can know the current position of the vehicle.

When the server receives the traffic report packet, it will select the RSUs which are n-hop from the congestion road. Furthermore, the server also selects the OBUs under these selected RSUs which will pass through the congestion road. However, if the congestion status is terminated, the server only selects the RSUs which locate n-hop from the congestion terminated road. The selected RSUs will transmit the congestion termination packet to all the vehicles in their coverage areas.

3.2.3 *User experience- supported method*

As introduced above, the dynamic detour scheme can support vehicles to avoid traffic congestion as the congestion event happens. However, the OBU can only select the shortest path to avoid traffic congestion. It is observed that the commuter usually knows the fast routing path according to their experience, which is not always the shortest path. They almost “remember” and can predict which road is more time-saving at different time period. According to the observation, the user experience can enhance OBU to select the faster path while congestion event happens, if the experience about time-saving road is recorded by OBU.

The important fields for such experience record include the traffic direction of the road section, the passing time for different time slot, and the number of passing. A road section and its two opposite traffic directions can be represented by two RSU, the start RSU ID and the end RSU ID. If the OBU want to record the drive’s experience, it also needs to record the time and the frequency to pass this road section. According to the database which accumulating the records, the vehicles can analyze the average time to pass each road section. Therefore, if the congestion event happens, the vehicle can select the better routing path to avoid the congestion, not only based on the shortest path but also the shortest time in experience.

There are two types user experience-supported method. One is user experience-aided method, and the other is experience-leading method. The most different between these methods is how to select the path to the destination at beginning.

a) *User experience-aided method*

User experience-aided method selects the shortest path to the destination in the beginning. When the notification about the traffic congestion is received, the vehicles will analyze and reselect the remaining path which may spend less time via user experience database instead of the shortest path.

b) *User experience-leading method*

According to the user experience database, user experience-leading method selects the path spending the shortest time to the destination in the beginning. Even the notification about the traffic congestion is received, the vehicle still reselect the new most time-saving path by the user experience database. Only when no experience records about the path to destination can be referenced, the path with shortest distance is arranged for the remaining routing to the destination.

4. Simulation Results

The proposed scheme is simulated by using Network simulator NS2 [16]. The simulation parameters are listed in Table 1. The impact of the number of vehicles and road congestion ratio in two scenarios were observed from simulation results. In Scenario 1, the congestion point may occur randomly on road. Paths of drivers including origin and destination are randomly determined. In addition, Scenario 2 is initialized to investigate the crowd condition in hot spots. Destinations of most vehicles are set to be the same in Scenario 2. As a result, the congestion will occur on the surrounding roads of the crowded destination.

Table 1. Simulation parameters

Size of scenario	800 x 800 m^2
Length of each road	200 m
Communication range	100 m
Speed limit	50km/h (=13.88m/s)
Acceleration	2.8~6.9 m/s^2
Condition of congestion	Average speed is 0m/s (continue 2s)
Congestion trigger time	1~64s
Congestion time	200~1000s
Number of vehicle	100
Road congestion ratio	20%
Notification range	2-hop

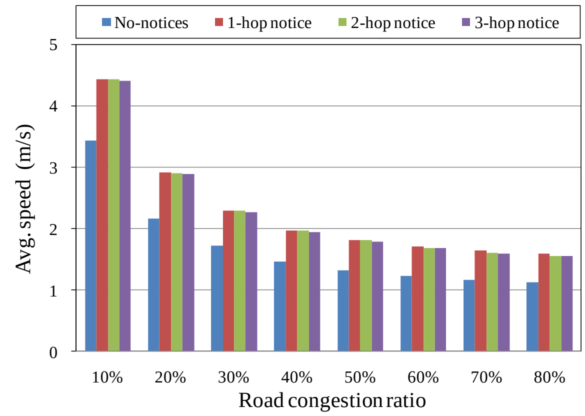

Fig.8. Scenario 1 – the effect of n-hop on average speed

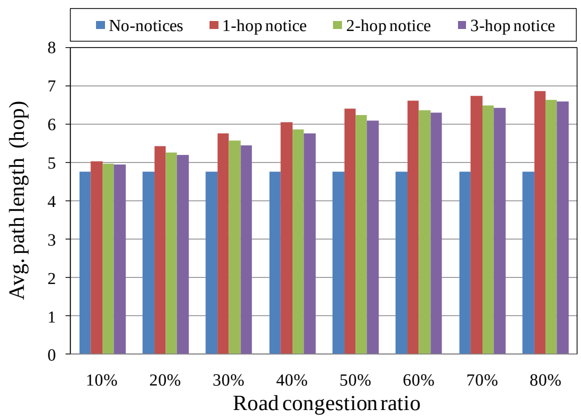

Fig.7. Scenario 1 – the effect of n-hop on path length

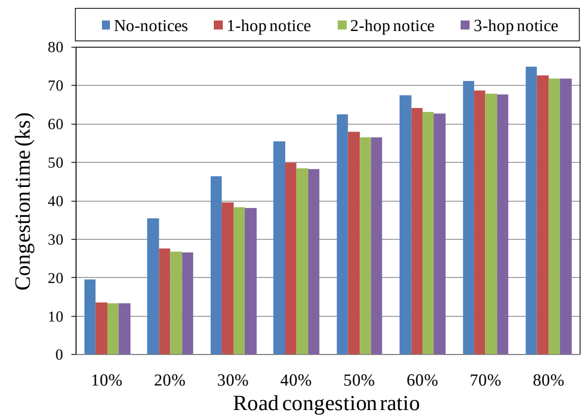

Fig.9. Scenario 1 – the effect of n-hop on congestion time

Some important performance factors such as the average path length, the average vehicle speed, the average arrival time, the congestion time, and the evacuation time are analyzed. The average path length denotes the length from origin to destination in hop counts. Furthermore, the congestion time denotes the total time of all vehicles in congestion road. The evacuation time is the time for all vehicles from congestion termination to that all the vehicles leave from the congestion roads and move in normal speed.

Fig.7. presents the effect of road congestion ratios on the average path in Scenario 1. Without notices, all vehicles select the shortest path. Hence, the average path length remains unchanged as the road congestion ratio increases. By contrast, the vehicles will receive congestion notification and react by reselect a proper road to destination, if the proposed scheme is utilized. Hence, the average path length increases as the road congestion ratio increases. Furthermore, if the vehicle can receive the congestion indication earlier, better path can be selected. That is why bigger n wins shorter average path length.

Although the path length is shorter with bigger notification range, the average speed decreases while the road congestion ratio increases in Scenario 1 as shown in Fig. 8. This is because the capacity of each road is limited and the vehicle needs to wait for previous vehicle. The average speed decreases as road congestion ratio increases. If the road congestion ratio becomes higher, there are fewer roads without congestion. At this time, OBU gets more difficult to select a new path without congestion. The vehicle has to select a new path continuously. The average speed will be decreased as well.

Fig.9 shows the effect of the road congestion ratios on the average arrival time in Scenario 1. The average arrival time increases as the road congestion ratio increases. The vehicle is able to avoid driving into congestion road by employing n-hop notice for dynamic detour scheme to select another proper path to its destination. Comparing to no-notices scheme, n-hop notice contributes well for light and middle degree of congestion. On the other hand, if the road congestion ratio is high, the number of road without congestion decreases. If the notification range is smaller, the vehicle might have no choice for proper path. As a result, the larger notification range is needed for high road congestion ratio. Therefore, using larger notification range to inform the selected OBU is suggested.

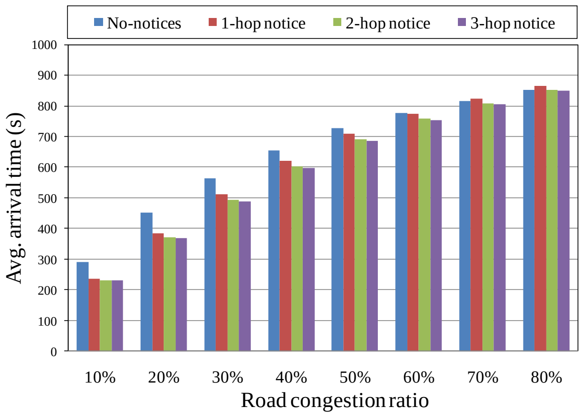

Fig.10. Scenario 1 – the effect of n-hop on arrival time

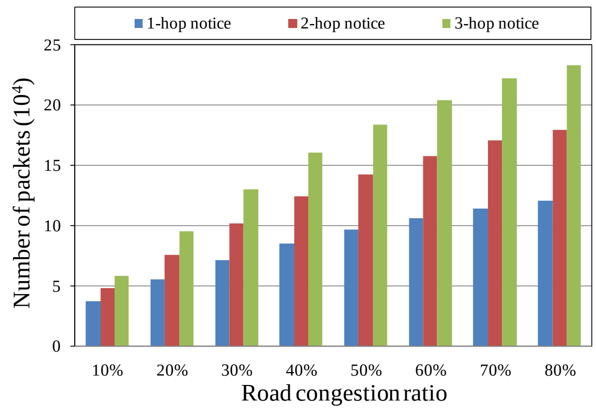

Fig.12. Effect of congestion degree on number of packets

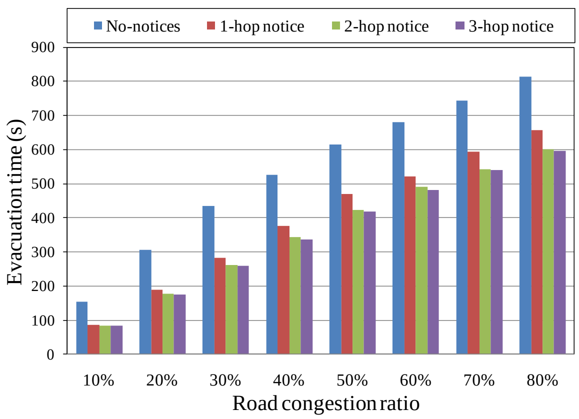

Fig.11. Scenario 1 – the effect of n-hop on evacuation time

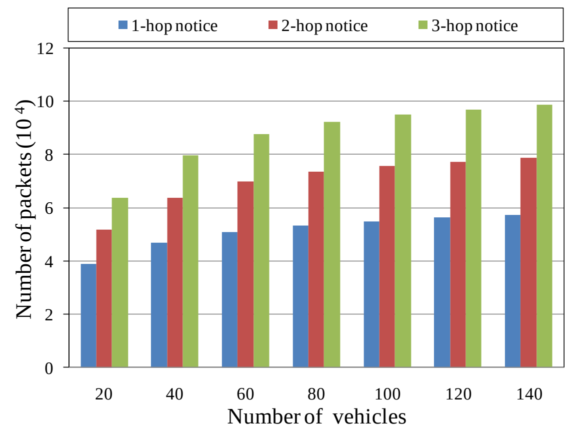

Fig.13. Effect of number of vehicles on number of packets

Fig.10 illustrates the effect of road congestion ratios on the congestion time. Congestion time denotes the total time of all vehicles in congestion road. The congestion time increases as the road congestion ratio increases by the no-notices scheme. Comparing to no-notices scheme, the congestion time of the proposed scheme can be reduced effectively. Higher road congestion ratio will result the fewer choice for proper road replacement. Consequently, the improvement ratio gets smaller as the congestion ratio grows.

Fig. 11 shows the effect of road congestion ratios on the evacuation time. The number of vehicles which are involved into congestion road increases as the road congestion ratio increases by no-notices scheme. As a result, the evacuation time increases as the road congestion ratio increases. The n-hop notice scheme can disperse the vehicles toward congestion roads to prevent serious jamming. While congestion terminated, vehicles can be evacuated more quickly. Furthermore, with larger notification range, the number of vehicles which are involved into congestion road becomes less as well as the evacuation time.

Fig. 12 and Fig. 13 denote the relationship between the number of notification packets on congestion ratio and the number of vehicles, respectively. As the number of vehicles or the road congestion ratio increases, the number of congestion events also increases. The RSUs will broadcast more congestion notification packet, and the OBUs also send back more future path packet. The number of transmitted packets increases as the number of vehicles or the congestion road ratio increase.

As the notification range increases, the number of notified vehicles increases as well as the number of transmitted packet. Although the average arrival time of the proposed scheme can be improved, more packets will be transmitted over the channel. Thus, the network may be full of control messages. Fewer bandwidths can be provided for data services. It is tradeoff between the number of transmitted packet and the average arrival time. In the study, 2-hop notification range is suggested to be the most suitable. With the 2-hop notification range, the average arrival time can be improved using acceptable network loading.

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Table 2. Scenario 2 – analysis of different n-hop notification range

observations \ n-hop notices		1-hop	2-hop	3-hop
Avg. path length	MAX	1.07	1.06	1.05
	MIN	1.15	1.11	1.09
	AVG	1.12	1.09	1.08
Avg. speed	MAX	1.39	1.39	1.38
	MIN	1.14	1.14	1.14
	AVG	1.30	1.30	1.30
Avg. arrival time	MAX	0.82	0.80	0.79
	MIN	0.93	0.92	0.92
	AVG	0.86	0.84	0.83
Congestion time	MAX	0.75	0.72	0.72
	MIN	0.90	0.89	0.88
	AVG	0.80	0.78	0.78
Evacuation time	MAX	0.58	0.54	0.53
	MIN	0.64	0.60	0.60
	AVG	0.62	0.58	0.58

Compare to no-notices scheme, Table 2 summarizes the maximum, minimum and average improvement ratio by n-hop notification range on the five concerned factors in Scenario 2. The average path length is almost the same because no-notices scheme always selects the shortest path. The vehicle may select longer path to avoid congestion road in the proposed scheme. Consequently, the average path length is larger than that of no-notices scheme. While the notification range is larger, the vehicle has more congestion information and choices. As a result, the vehicles can select a shorter path to avoid congestion road. In addition, the proposed scheme improves the average speed significantly, from 14% to 39%. In average arrival time, congestion time, and evacuation time, n-hop notices is better than no-notices scheme. Furthermore, with larger notification range, the number of vehicles involved into congestion road becomes less. However, 2-hop notices and 3-hop notices almost have similar improvement ratio. Hence, 2-hop notification range is suggested in the study.

To evaluate the effect of user experience-supported method, the congestion hit ratio is defined as the probability of the congestion point appears in the planning path. The average path lengths of no-notices scheme, n-hop notice scheme with n=2 in the comparison, experience-aided method, and user experience-leading method are compared for different congestion hit ratio in Fig. 14. Because all the vehicles select the shortest path in no-notices scheme, the path length remains unchanged even if the congestion hit ratio increases. When the congestion hit ratio increases, the vehicle may select longer path to avoid congestion road in the other proposed schemes. Therefore, their average path length increase as the congestion hit ratio increases. With user experience-aided method, the vehicle selects the shortest path to the destination at beginning. However, the user experience-leading method selects the best path through user experience database at beginning. The probability of

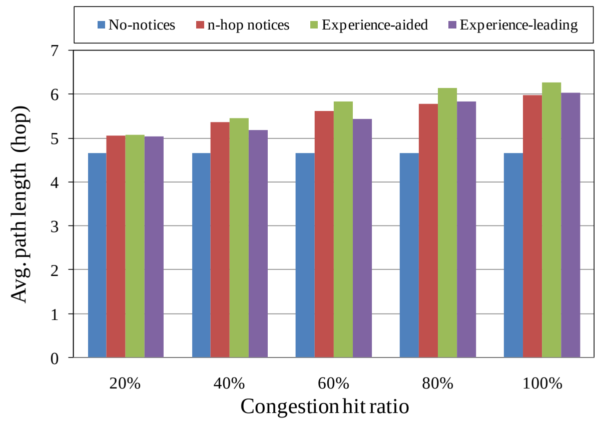

Fig. 14. Effect of user experience on path length

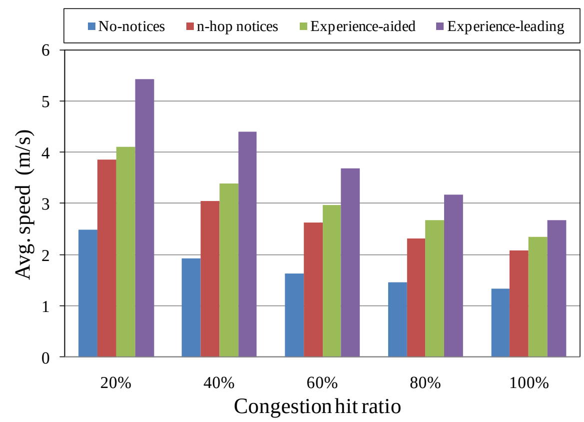

Fig.15. Effect of user experience on average speed

suffering from congestion for user experience-aided method is higher than that of user experience-leading method. That is, user experience-aided method has higher probability to change to longer path to avoid congestion road. Therefore, the average path length of user experience-leading method is slightly longer than that of user experience-leading method.

Fig.15 shows that user experience-leading method has highest speed, because it selects the best path through user experience database at beginning and has less chance to run into congestion. As compared with n-hop notices scheme, user experience-supported method gets better results in average speed. In average, user experience-aided method lifts vehicle speed to 12% than that of n-hop notices scheme under various congestion hit ratio. If experience-leading method is used instead, the improvement of average speed is up to 38%. Obviously, two types of user experience-supported methods including experience-aided method and experience-leading method lifts more average speed than the pure n-hop notices scheme. No-notices scheme is the worst choice if the driver preferred higher speed.

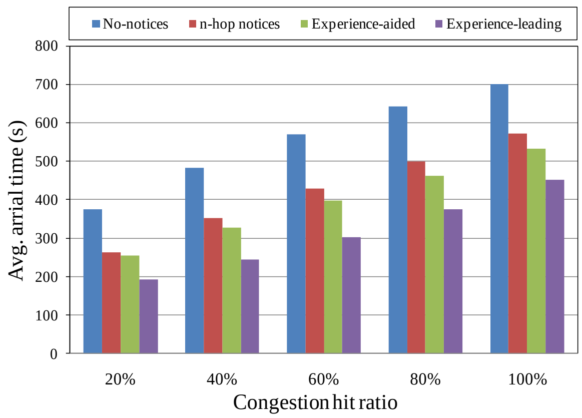

Fig.16. Effect of user experience on arrival time

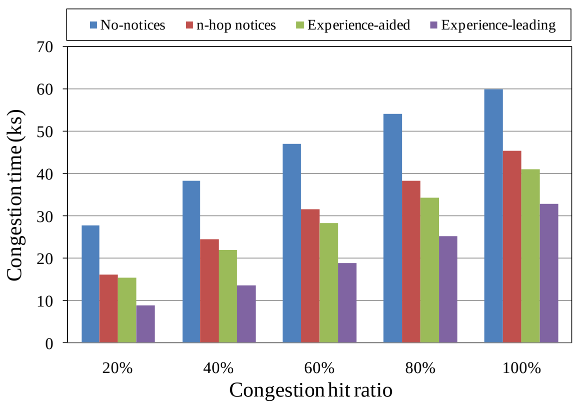

Fig.17. Effect of user experience on congestion time

The performance of the average arrival time for the four methods is shown in Fig.16. Comparing to n-hop notices scheme, user experience-aided method reduces the average arrival time by 6% in average under various congestion hit ratio. If the user experience-leading method is used, the average arrival time can be reduced up to 27%. As predicted, the user experience-leading method is still the best scheme. Despite of the predictable result, user experience-supported methods obtains better performance than that of n-hop notices scheme, because user experience is more reliable than the shortest path in distance.

The performance comparison of the four methods on the congestion time is shown in Fig.17. Obviously, the congestion time increases as the congestion hit ratio increases. Comparing to n-hop notices scheme, the congestion time can be shortened by 10% and 38% in average as using experience-aided method and user experience-leading method, respectively.

The effect on the evacuation time is shown in Fig. 18. The effect on evacuation time is consisted with that on average arrival time and congestion time. To compare with n-hop notices scheme in evacuation time, it can be reduced by 15% and 50% in average, as experience-aided method

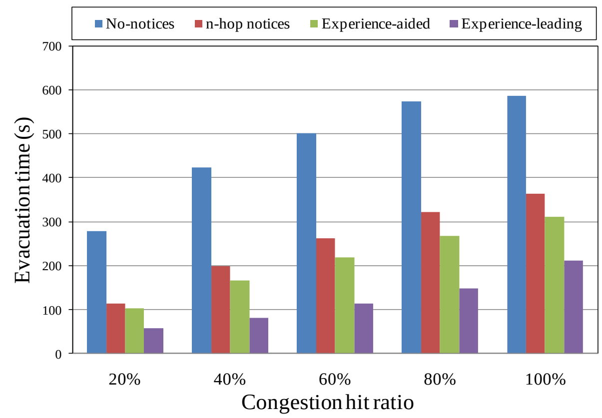

Fig.18. Effect of user experience on evacuation time

and user experience-leading method are utilized, respectively.

5. Conclusions

In this study, the speed of each road is sensed by RSU. When the traffic congestion is detected, RSU will report this information to server. Then, the server can select the specific area near the congestion point to broadcast information about the traffic jam. If OBU receives the information, driver can change his/her scheduled path which includes the congestion point or its nearby roads. Such dynamic detour scheme enables drivers to avoid involving into traffic congestion. In addition, a user experience-supported method is also proposed to enhance the performance of the dynamic detour scheme. User experience-supported method includes two variations: User experience-aided method and User experience-leading method. They determine the path to the destination by shortest distance and shortest time in the beginning, respectively. Cooperated with Dynamic detour scheme, both of them reselect a new path by referencing user experience records while they are notified about traffic jam. The following are features of the proposed dynamic detour scheme with user experience-supported method.

1) Enhancing traffic efficiency: Drivers can avoid congested road based on the help of the proposed scheme. It not only reduces the number of drivers suffering in the traffic jam, but also enhances the traffic efficiency totally.

2) Real-time and adaptive path selection: The dynamic detour scheme monitors the real-time traffic speed of roads and triggers a broadcast for any congestion condition. No matter initial path arrangement or path reselection on the way, OBU can be set to select the proper path based on both newest notification and driver’s experience. Besides, path selection is executed on the OBU; it makes server has surplus time to provide other real-time services.

3) Improving traffic congestion by the least resource: Notification packets about congestion is broadcast in limited n-hop area. The number of notification packets will lift significantly if broadcasting area is expanded by increasing the value of n. From the simulation result, the average arrival time can be improved with larger notification range, i.e. larger n. Hence, it is tradeoff between the number of transmitted packet

and average arrival time. Simulation results suggest that 2-hop notification range is the most suitable range. With 2-hop notification range, the average arrival time can be improved with acceptable network loading.

4) Taking advantage of drivers' experience: Sometimes, the driver's experience is more reliable than the shortest path. Therefore, the study makes an option to reference the user's experirnce based on historic records. Simulation results demonstrate that it can improve traffic time efficiently and effectively.

The goal of our research is to balance traffic flow on each road and improve driving efficiency. In fact, the driver usually runs into traffic jam, if without any notification about traffic congestion. On average, if the 2-hop notice scheme is compared with the no-notices scheme in congestion scenario 2, the average speed can be lifted up to 30%; the average arrival time can be reduced by about 16%; the congestion time is minimized by 22% e; the evacuation time is decreased by 42%. Moreover, if user experience is used to cooperated with the detour scheme, both experience-aided and experience-leading method always can significantly enhance the improvement of the average speed, the average arrival time, the congestion time, and the evacuation time according to simulation result. To summarize the study based on numerical analysis, both of the dynamic detour scheme and user experience-support method work well for preventing vehicles from involving the traffic congestion. We suggest using 2-hop notice range and user experience-lead method for future research.

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