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Path Situation Assessment of Multi-hop Information Dissemination-in Vehicular Wireless Networks

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Abstract: Path situation assessment can help to avoid the path congestion through controlling the transmitted information period. A path load assessment scheme is proposed for traffic information dissemination in vehicular wireless networks, in which the basic probability assignment function of the local cluster load and the stale path load can be achieved using fuzzy set. The local cluster and stale path load become the evidences of the fresh path load assessment. Then, the fresh path situation set could be built from the fused evidences by evidence theory. The sample with the maximal confidence will be regarded as the fresh path load. Simulations show that the average end-to-end delay of information with path load assessment is less than half of the scheme without path load assessment under heavy load. For the wireless resource utilization, the proposed scheme is less than two times as the scheme without path load assessment.

Key words: Path situation assessment, information dissemination, evidence theory, fuzzy theory, vehicular networks

INTRODUCTION

Traffic information is disseminated through seven channels at 5.9G Hz that is allocated to public and private vehicular communication applications. Information dissemination protocols can be divided into two categories: single-hop broadcasting and multi-hop broadcasting. And there are two metrics of information dissemination, the information loss rate and the end-to-end delay, in vehicular wireless networks (Dimitrakopoulos, 2011).

The quality of metrics depends on the selected relay node and the transmitted path load (Panichpapiboon and Pattara-Atikom, 2012). For the relay node, a cluster head can be elected to route the traffic information between the clusters that be set up in an area. Cluster based information dissemination scheme can avoid to transmit the broadcast information repeatedly by fusing the correlated information at the cluster head (Singh and Gupta, 2011). For the path load, some special multi-hop broadcast protocols has been proposed based on the road topology or pre-routing information (Wu *et al*., 2010; Chen *et al*., 2010). However, the stale path load information leads to the routing failure and disconnection. The end-to-end delay and the information loss rate are also increased along with the path load information invalidation.

The fresh path situation set can be predicted using D-S (Dempster-Shafer) fusion algorithm to fusing the cluster load and the stale path load information based on the evidence mass function. The cluster head can control transmission time on the flexible period according to the path load for the multi-hop traffic information dissemination. Then, the quality of traffic information metrics and channel resource efficiency can be enhanced through avoiding the congestion in vehicular wireless networks.

PATH SITUATION ASSESSMENT MATHEMATIC MODEL

With enhancing the car PC performance, pre-computing can be performed to assess the multi-hop path load for end-to-end information dissemination rapidly. The path situation assessment is a deduced process on the decision level (Stampouli *et al*., 2009).

Multi-hop path situation assessment method can be divided into three parts: problem detection, hypothesis generation and situation assessment. Let the stale path situation set as $S = (S_1, S_2, \ldots, S_m)$ and the detected local cluster head queue set as $L = (L_1, L_2, \ldots, L_n)$. Then, the confidence set $P(E|S, L)$ of the path situation $E = (E_1, E_2, \ldots, E_l)$ based on S and L represents the different path situation probability under the known metric parameters. Let $\Theta = \{\theta_1, \theta_2, \ldots, \theta_k\}$ as the sample space of path situation. And the situation characteristic set $D = \{D_1, D_2, \ldots, D_J\}$ as the path state metric set. Thus, the path situation assessment method is a mapping process

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from the situation characteristic set D to the situation space frame Θ: f: D→Θ. From above discussions, the path situation assessment is a dynamical and chronological process and the results accuracy will be enhanced with increasing time.

PATH SITUATION ASSESSMENT IN CLUSTER HEAD

In fact, the packets queue at the cluster head can represents the information load in single-hop cluster and be measured by the scheduler implicitly. The path information in fore period contributes to estimate the quasi-fresh path load in multi-hop dissemination as a reference parameter. Based on the cluster queue and stale path information, the path situation assessment can help to enhance the stability of path and the efficiency of wireless resource.

Basic probability assignment function of cluster load parameter: Let the queue length at the local cluster head as {O, H, L}, represent three load in the cluster as {overload, heavy load, light load}, respectively.

Let the queue length of cluster as Q, the light load threshold as Q_{LT}, the heavy load threshold as Q_{HT}, the maximal buffer as B and $Q = x$, $Q_{LT} = x_L$, $Q_{HT} = x_U$, here $x \le B$, then the basic probability assignment function of the queue $m_Q = \{q_1, q_2, q_3\}$ will be quantified using the triangle and trapezoidal functions as Fig. 1 (Qiu *et al*., 2007).

The membership function of the queue fuzzy set can be expressed as the Eq. 1~3, here q_i, i = 1, 2, 3 represent the basic probability assignment of three situations {O, H, L}, here:

$$x_M = \frac{1}{2}(x_U - x_L)$$

$$\mu_L(x) = \begin{cases} 1, & x \le x_L \\ (x_M - x)/(x_M - x_L), & x \in (x_L, x_M] \\ 0, & x > x_M \end{cases} \quad (1)$$

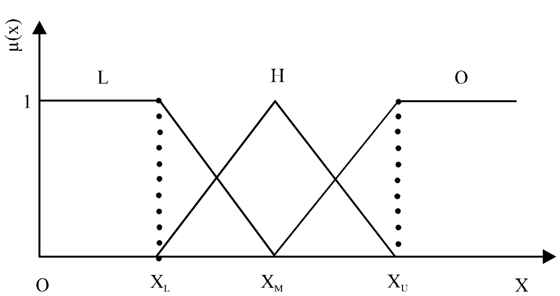

Fig. 1: Mermbership funcion of local cluster parameter

$$\mu_H(x) = \begin{cases} (x - x_L)/(x_M - x_L), & x \in (x_L, x_M] \\ (x_U - x)/(x_U - x_M), & x \in (x_M, x_U] \\ 0, & \text{others} \end{cases} \quad (2)$$

$$\mu_O(x) = \begin{cases} 0, & x \le x_M \\ (x - x_M)/(x_U - x_M), & x \in (x_M, x_U] \\ 1, & x > x_U \end{cases} \quad (3)$$

Basic probability assignment function of path load parameter: The available bandwidth of selected path represents the path load. Here the available bandwidth of path is defined as the minimum available rate of the links along on the path which equal to the available bandwidth of bottleneck link on the path. Let the bottleneck link capacity as C, the number of traffic applications in progress as N_S. Then, the available bandwidth R of path is equal to the average rate as follow:

$$R = \frac{C}{N_s + 1} \quad (4)$$

The utility function represents the path congestion level and is defined as follow:

$$U(P) = \ln R \quad (5)$$

Let R_T is the path congestion threshold and R_{CT} is the path congestion alarming threshold. Then, $U_T = \ln R_T$ can be defined as the utility function congestion threshold. $U_{CT} = \ln R_{CT}$ is the congestion alarm threshold. The path can ensure the quality of metrics under $R > R_{CT}$. Let the path situation set as {O, H, L}, represent three situations as {over load, heavy load, light load}, respectively. Then the fuzzy set of the path load parameter can be quantified using the triangle and trapezoidal functions as Fig. 2. Here:

$$U_M = \frac{1}{2}(U_{CT} - U_T)$$

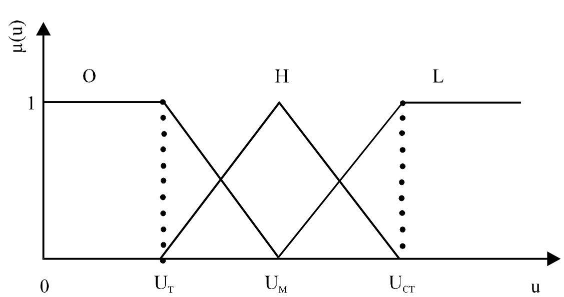

Fig. 2: Membership function of path load parameter

Let the basic probability assignment function of path situation set as $m_p = \{A_1, A_2, A_3\}$, A_i, i = 1, 2, 3 represent the basic probability assignment $\{\mu_0(u), \mu_H(u), \mu_L(u)\}$ of three situations {O, H, L}, respectively. And the basic probability assignment can be expressed by the Eq. 6~8:

$$\mu_o(u) = \begin{cases} 1, & u \le U_T \\ (U_M - u)/(U_M - U_T), & u \in (U_T, U_M] \\ 0, & u \ge U_M \end{cases} \quad (6)$$

$$\mu_H(u) = \begin{cases} (u - U_T)/(U_M - U_T), & u \in (U_T, U_M] \\ (U_{CT} - u)/(U_{CT} - U_M), & u \in (U_M, U_{CT}] \\ 0, & \text{others} \end{cases} \quad (7)$$

$$\mu_L(u) = \begin{cases} 0, & u \le U_M \\ (u - U_M)/(U_{CT} - U_M), & u \in (U_M, U_{CT}] \\ 1, & u > U_{CT} \end{cases} \quad (8)$$

PATH SITUATION ASSESSMENT

The objects of multi-hop path situation assessment are different path loads. Let the path load as {over load, heavy load, light load}. The evidences are the decisions to the path situation according to the different metrics. The nature of path situation assessment is discerned the concrete situation from the known situation set according to the fusion evidence based on the cluster and path parameters. Thus, the path situation assessment process can be shown in Fig. 3.

The different situation decisions can be deduced by the measured parameters and their basic probability assignment in cluster head. The new situation can be deduced once again and the basic probability assignment can be renewed with the changes of parameters. The basic probability assignment of the estimated path situation represents the path situation decision. Finally, the decision logic makes a sentence that the alternative proposition is the maximal confidence one in situation set.

Supposed the frame of discernment have three propositions. And L represents the decision that the local cluster load make to the different proposition at time t. P represents the decision that the stale path load make to the different proposition. $m_L(A_i)/m_p(A_i)$, i = 1, 2, 3 represents the basic probability assignment of proposition A_i. $m(A_i)$ is the new basic probability assignment by Dempster rule and can be computed as follow:

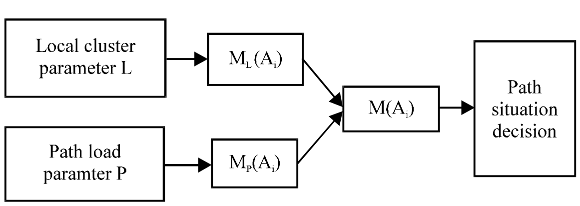

Fig. 3: Path situation assessment model

$$m(A_i) = m_L(A_i) \oplus m_P(A_i), i = 1, 2, 3 \quad (9)$$

The situation with the maximal confidence will be regarded as the quasi-fresh path load. The path situation is renewed by pre-computing with the measured load metrics periodically and keeps as a constant in the same period.

SIMULATION ANALYSIS

Path load information can help the cluster head to control the send period and avoid the network congestion. Simulations would only been examined for the safety information in the control channel of 10MHz bandwidth with or without path load assessment by ns-2 with version 2.34 (Miloslavov and Veeraraghavan, 2012).

The simulation topology was assumed that there were total four lanes and two lanes in each direction. The vehicles were randomly distributed in each lane on 2 km route which were divided to four clusters based on the direction-specific segment. The cluster heads broadcasted the periodic UDP packet with payload size of 100 bytes. The transmitted range of all nodes was 250 m. And the cluster head has the highest signal strength of the message transmitted. The broadcast period was the 4 sec under the 50% path load. For load between 50 and 100%, the broadcast period increase linearly between 4 and 20 sec. The tail drop algorithm would be performed in the cluster head queue manager. The fair scheduling algorithm was employed in the scheduler. The control channel model would use the Rayleigh fading model. In simulations, an independent module which used to fuzzy the local parameter and path parameter would be used as pre-computing components. Another pre-computing module would be used to fusing the basic probability assignment and assessing the fresh path load.

From Fig. 4, the scheme with path load assessment has less than the scheme without path load assessment for the average end-to-end delay. In particularly, the delay has severe worsen from 450 cars/1000 sec vehicular density for the scheme without path prediction and exceeded 200 m sec delay upper threshold.

Resource utilization was defined as the average rate between the received bytes correctly and the transmitted bytes of resource node. From Fig. 5, the maximum resource utilization of the scheme without path load assessment was about 26% and became inefficient

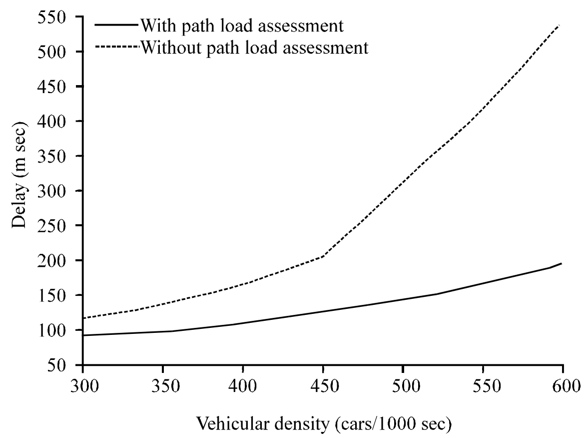

Fig. 4: Average end-to-end delay

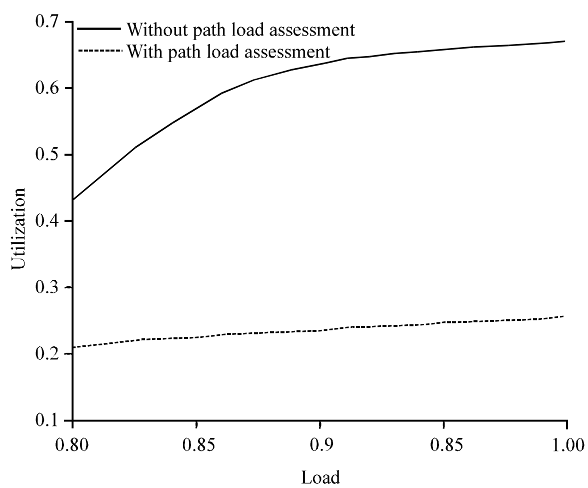

Fig. 5: Bandwidth utilization

operation in heavy load. But the maximum resource utilization of the scheme with path load assessment attained about 67% owing to avoid the path congestion. Certainly, the enhancing of the resource utilization was at the expense of the pre-computational complexity on the additional model.

CONCLUSTION

The multi-hop information will be dissemination repeatedly in vehicular wireless networks because of the bottle link congestion. The repeat packets transmission increases the end-to-end delay of traffic information and decreases the wireless resource efficiency.

The cluster head can control the transmitted period to avoid the path congestion according to the path situation. The fresh path situation that come from the cluster queue and the stale path load can help to enhance the performance of the end-to-end delay and bandwidth utilization. However, the rejected probability of traffic is increased because of the queue overflow in the cluster head. How to reduce the computing complexity is the next work for applying the path situation assessment scheme in the Intelligent Transportation System in future.

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