Performance analysis of RSU relaying for LOS and NLOS in vehicular network

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Abstract

In this paper, we analyze the vehicle to infrastructure(V2I) communication link performance of the autonomous vehicles at intersection in urban area. Unlike highway, the propagation of communication is affected by an increase of vehicles and buildings in urban area. Therefore, RSU relaying is necessary to avoid none line of sight (NLOS) situation. The road side unit (RSU) is located at the intersection and all broadcast safety messages (BSM) are relayed through the RSU so that all vehicles can be in line of sight (LOS) status. In urban area, there is no performance analysis for RSU relaying to avoid NLOS status. Therefore, we analyze performance of RSU relaying for LOS and NLOS in vehicular network. For performance analysis, mean system time and mean queue size are derived and analyzed the impact of service time from these two perspectives.

Ⅰ. Introduction

Studies on autonomous vehicles have been actively carried out. Most of studies are analyzed and evaluated in highway, not in urban area[2]. Unlike highway, communication propagation is affected increasing vehicular density and buildings in urban area. Therefore, performance of communication link can be severely degraded in urban area[1]. It can lead to accidents and dangerous conditions. Vehicular assisted relaying was proposed to improve the performance of communication propagation[1]. But vehicular resources are not sufficient to process all broadcast safety message (BSM). Vehicle to infrastructure(V2I) communication by RSU has the ability to improve this situation.

The intersection with a traffic signal controller is selected as a suitable location for RSU. Thus, all BSM are relayed by the traffic signal controller equipped with RSU at the intersection. In other words, not only the line of sight (LOS) between V1 and V2 but also the none line of sight (NLOS) between V1 and V3 are covered by the RSU. As a result, it helps to avoid being affected by communication propagation degradation.

We analyze the performance of RSU when processing BSM for all vehicles in NLOS and LOS situations. Then, based on the numerical results, we propose a proper service time and queue size.

Ⅱ. Related work

There are many studies on the performance analysis of V2I and V2V communication links. However, most of these studies are evaluated on highway[2]. There are many difficulties in V2V and V2I communication due to the complex environment in urban area[1]. When the positions of the vehicles are on the perpendicular street (NLOS state), performance of communication link is degraded. The vehicle assisted relaying was proposed by Md. Noor A Rahim et al. to overcome this situation. But vehicle resources are not sufficient[1]. So, we select the RSU relaying to put all vehicles into the LOS state at the intersection.

Ⅲ. System model

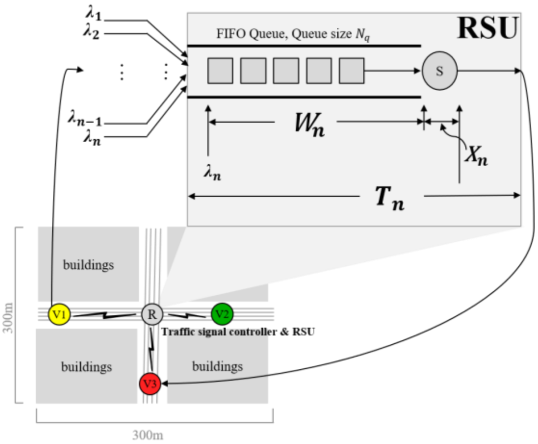

Figure 1. communication scenario

The system time of the RSU is estimated using M/G/1 Queueing model. The key notations adopted for this system model are shown in Table 1. As show in Figure 1, we set up environment with a four way, four lane urban intersection that limited the region of interest (ROI) to the 300m X 300m area around the intersection.

We need to calculate the time spent in the RSU, that is, it is time to send the BSM from vehicle V1 to V2 or V3 via RSU. The total time spent in the RSU can be defined as (1).

$$E[T] = E[W] + E[S] \quad (1)$$

And mean waiting time is given by.

$$E[W] = E[N_q] \times E[X] + E[U] \quad (2)$$

Notation	Semantics
N_q	Queue size of waiting message

U	Unfinished work in the server
W	Waiting time to wait for the service
X	Service time
λ	Arrival rate
T	Time spent in the system
ρ	RSU utilization factor

Table 1. Key notations for the system model

The key observation is that the mean queue length $E[N_q]$ can be expressed in term of the waiting time by Little's result.

$$E[N_q] = \lambda E[W] \quad (3)$$

The utilization factor of RSU is given by

$$\rho = \lambda E[X] \quad (4)$$

Returning to (2) we apply (3), (4) to obtain.

$$E[W] = \frac{E[U]}{1-\rho} \quad (5)$$

Now, it remains to determine $E[U]$. According to the hitchhiker's paradox, the following equation is derived.

$$E[U] = \frac{1}{t}\int_0^t R(t')dt' = \frac{1}{t}\sum_{i=1}^{n}\frac{1}{2}X_i^2 = \lambda\frac{1}{2}E[X^2] \quad (6)$$

Returning to (5) we apply (6).

$$E[W] = \frac{\lambda E[X^2]}{2(1-\rho)} \quad (7)$$

Rewrite this result in terms of squared coefficient of variation for service time.

$$C_v^2 = V[X]/E[X]^2, \quad E[X^2] = V[X] + E[X]^2 \quad (8)$$

$$E[X^2] = (1 + C_v^2) \cdot E[X]^2 \quad (9)$$

Returning to (7) we apply (9).

$$= E[X] + \frac{1+C_v^2}{2}\cdot\frac{\rho}{1-\rho}\cdot E[X] \quad (10)$$

According to the definition of (1), (11) can be derived.

$$E[T] = E[X]\cdot(1 + \frac{1+C_v^2}{2}\cdot\frac{\rho}{1-\rho}) \quad (11)$$

In the case of constant service time, squared coefficient of variation has $C_v^2 = 0$.
Finally, the following (11) can be obtained.

$$E[W] = \frac{1}{2}\cdot\frac{\rho}{1-\rho}\cdot E[X] \quad (12)$$

$$E[T] = E[X]\cdot(1 + \frac{1}{2}\cdot\frac{\rho}{1-\rho}) \quad (13)$$

$$E[N_q] = \frac{\lambda^2 E[X^2]}{2(1-\rho)} = \frac{1}{2}\cdot\frac{\rho^2}{1-\rho} \quad (14)$$

Ⅳ. Numerical Result

In this section, we analyze the performance of the RSU from two main perspectives. First, we analyze the impact between the system time and the service time, and then analyze the effect between the service time and the limit queue size.

According to recommendation of IEEE 802.11p WAVE, we select the BSM interval as 100ms. And the system time of RSU is set within 3ms. Assuming that the maximum vehicles exist at roughly 5 meters interval, the numbers of maximum vehicles are 480. Therefore, we assume that ρ <1 only until the vehicle is 480, the mean service time should be within 0.208ms.

Figure 2 shows that the system time increases dramatically when the utilization factor is close to 1. In other words, system time recorded a sharp rise when the number of vehicles approaches the maximum.

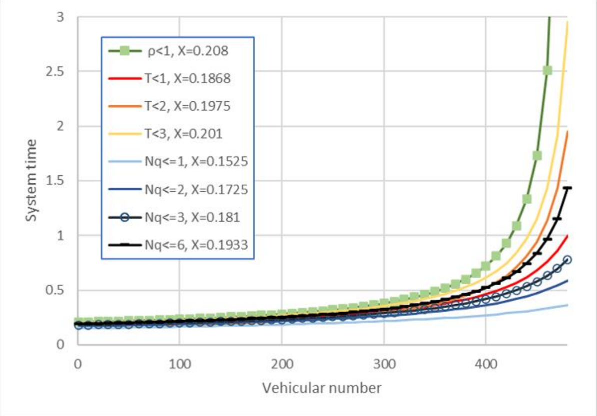

Figure 2. System time according to vehicle number

Ⅴ. Conclusion

In this paper, we have presented the queueing models for RSU relaying and derived the mean system time and mean queue size. If the number of vehicles is less than 400, we can see that the difference in system time per service time is not significant. If the number of vehicles is less than 360, only one queue is sufficient regardless of the service time.

In further study, we will study the effect between system time and service time for BSMs with various priorities in RSU.

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