Effect of Estimation Error in Node-Clustering with V2X Communications for Crash Warning Applications

Takeshi Hirai[1], Tutomu Murase[2]
[1,2]*Nagoya University*

***Abstract*-- In crash warning application (CWA) using V2X (Vehicle-to-Everything), we have already proposed the Node-Clustering communication method to accommodate more communication nodes. In this method, a cluster-head node estimates other nodes' status information, and transmits all cluster-members information; then, if a node (cluster-member) knows that the estimated information is not correct, the node transmits an updated message. As the estimation is less accurate, the correction messages are more transmitted. This may cause severer congestion in a wireless channel, therefore, we evaluate the impact of the estimation error for the maximum numbers of accommodated nodes which have to meet the requirements of CWA such as 10 information frames per second.**

I. INTRODUCTION

In recent year, CWA (crash warning application) [1] is expected to prevent traffic accidents as one of ITS (Intelligent Transport System) applications. In CWA, nodes, such as vehicles and pedestrians with the V2X (Vehicle-to-Everything) communication equipment, broadcast own current status information (ID, location velocity etc.). DSRC (Dedicated Short Range Communications) [2] have been developed as a V2X communication protocol. It uses IEEE802.11p [3] in a MAC layer protocol and can be operated without any infrastructure at a low cost.

CWA must satisfy the QoS requirement for V2X communications [4] [5]. Specifically, nodes must receive 10 or more frames at least from another node that are likely to collide with the node. This paper calls such two nodes *crash nodes*. The frame conveying status information of the sending node may not be received by radio interference. It is more difficult to satisfy the requirement as nodes increases because the interference amplifies. We define *accommodation capacity* as the maximum numbers of nodes which can satisfy the requirement. Accommodation capacity should be increased so as to accommodate more nodes for practical uses of CWA.

To increase accommodation capacity, Node-Clustering communication method [6] which could mitigate interference power has been proposed. In the method, a cluster is formed by multiple nodes. Then, a representative node of each cluster (a cluster head) only broadcasts estimated status information of all the nodes of the cluster except the cluster head and real (measured) status information of the cluster head. If an error of the estimation of a node is unacceptable, the node transmits an updated message (called correction message) which includes estimated status information of all other nodes of the cluster except the node and real (measured) status information of the node.

This method has advantages that it can suppress the interference power by decreasing nodes that are transmitting simultaneously with maintaining the same amount of information. However, when the correction messages are frequently sent, the advantages might weaken. This is likely to cause to reduce the accommodation capacity. This paper evaluates the accommodation capacity of this method in the more accurate model that considers the estimation accuracy.

II. RELATED WORKS AND ISSUES

Our Node-Clustering communication method mainly consists of two phases. (1) The first phase is that the cluster heads (they can be changed to another member in round-robin manner time by time) collect the status information on the cluster members. In this phase, cluster heads estimate member's information. The method does not use conventional cluster-based communication methods [7] [8], in which a cluster head collects the member's information by "Intra-Cluster communication". The conventional method causes severer congestion since it yields communication traffic. In the method, instead, each cluster head obtains by estimating the current status of own cluster members. The estimation values are calculated from the received past status information of the members. This calculation requires no extra radio resources nor produces any Intra-Cluster traffic. (2) The second phase is Inter-Cluster Communication. In this phase, the cluster heads broadcast status information that consists of own and estimated member's information generated by the first phase. However, the proposed method includes some error in the estimation. In order to keep accuracy of the information, correction messages are sent. When each member receives and detects that the error exceeds the acceptable ranges, the member transmits a correction message (i.e. an information frame which includes measured and correct information).

The following example describes the proposed method in a case for five nodes (A~E) to transmit 10 frames per second. *Info(A,t)* and *Info(A', t)* denote the exact and estimated information of Node A at the time t, respectively. First, A says *Info(A, t)*, *Info(B', t)*, ... , *Info(E', t)* at time *t*. Then after 100msec, B says *Info(A', t + 100)*, *Info(B, t + 100)*, ... , *Info(E', t + 100)*. C and D follow B in this order after another 100msec and 100msec, respectively. Finally, E says *Info(A', t + 400)*, *Info(B', t + 400)*, ... , *Info(E, t + 400)*. If E hears the frame by A in which

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E's information was estimated by A and E finds error out of an acceptable range, then E transmits a correction message. The followings show the case. A says *Info(A, t)*, *Info(B', t)* , ... , *Info(E', t)* at time t, then immediate after A, E says *Info(A, t)*, *Info(B', t)*, ... , *Info(E, t)*, then after 100msec, B says *Info(A', t + 100)*, *Info(B, t + 100)*, ... , *Info(E', t + 100)*.

The correction frames may impact on wireless channel congestion, thus the accommodation capacity may change depending on the estimation error. This paper evaluates it in the more accurate model considers the error of the estimation. Through this evaluation, we show that the proposed method can sufficiently improve the accommodation capacity, even if there are some errors in the estimation value.

III. Estimation Error

Estimation error occurs if a node may suddenly change its moves such as turning right/left, acceleration and deceleration. However, using maps may prevent it.

Next, we describe how the accommodation capacity changes with or without the estimation error. First, in the case of no error, the accommodation capacity increases at first as the number of cluster members increases, then decreases. This occurs because of a tradeoff between interference reduction and parallel transmission reduction [6]. Second, in the case of estimation error, the accommodation capacity decreases depending on the amount of error. When a cluster size is increasing, error probabilities or amount of error is also increasing. In the previous example, at t + 400, A's estimated information sent from E is estimated based on A's real (and correct) information at time t, that is, 400msec ago. Thus, the accommodation capacity increased faster than that in no error case.

IV. Vehicle, Channel and Communications Model

The accommodation capacity is evaluated for various values of the estimation errors and the number of the cluster members. *Estimation inaccuracy* is defined as the probability to generate the correction messages. It is assumed in the vehicle mobility model that; crash nodes which are two nodes we focus on approach at 60km/h, become close then crash in head-on; nodes surrounding the focused nodes are uniformly distributed; they sense others' carriers before communications or act according to CSMA/CA. The surrounding nodes affect opportunities of transmitting frames in CSMA/CA and interference powers to the receiving frames for the crash nodes. In a cluster, cluster members are not assumed to change. Regarding wireless communications, IEEE802.11p is used, the channel capacity sets to 3Mbps. A frame header size and a payload size are set to 32byte and 250byte, respectively. Information frames are tried to be periodically sent in 15 frames per second. This is slightly more than 10 frames per seconds that are required in CWA because of transmission error.

V. Accommodation Capacity to Estimation Inaccuracy

Figure 1 shows the accommodation capacity to the number of cluster members. The vertical axis shows the accommodation capacity and the horizontal axis shows the number of the cluster members. Estimation errors vary from 0 to 14%. As shown in Fig.1, even if the estimation inaccuracy is 2%, the Node-Clustering communication method (9 members) can increase the accommodation capacity by 19% than the conventional method (i.e. 1 member).

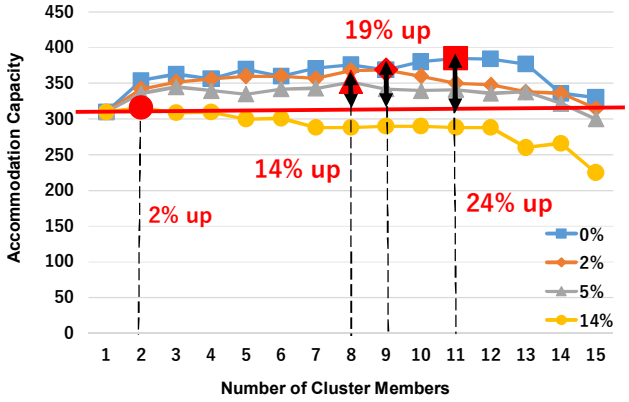

Fig. 1. Accommodation capacity for the number of cluster members with estimation inaccuracy

VI. Conclusion

In CWA using V2X communication, we evaluated the accommodation capacity in Node-Clustering communication method, considering estimation error in information frames. In this method, only a cluster head estimates other cluster member's information from past information and transmits all information frames on behalf of other members. Correction frames are transmitted if the information is inaccurate. It may accelerate congestion. We evaluated the accommodation capacity in the more accurate model (considering estimation error) and showed that the method still has sufficient improvement even if there is some estimation error. The evaluation showed the accommodation capacity of the proposed method increases 19% more than that of the conventional method even in the estimation error 2%.

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