Stability Evaluation of Terminal Group for Inter-Vehicle Communication Network with an Autonomous Relay Access Scheme

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Abstract: This paper evaluates the stability of the terminal group for the inter-vehicle communication (IVC) network with an autonomous relay access scheme. Some stability criterions such as updating rate, terminal group convergence probability and total path average holding time have been conducted by computer simulation. As the results, dynamic moving of the terminal is the serious problem that can degrade the stability of the terminal group and directly affect to overall performance of the IVC network.

1. Introduction

Intelligent Transport System (ITS) has been interested as a new infrastructure for communication systems. It is designed to solve the transportation problems such as traffic accidents and congestion by connecting people, roads, and vehicles in a network through the use of modern communication technologies [1]. Road-to-Vehicle Communication (RVC) and Inter-Vehicle Communication (IVC) are considered to be the essential keys for establishing ITS [2].

As an IVC network that consists of several mobile terminals, it is difficult to design the centralized control scheme for such a system. Because of the dynamic moving of the terminal, path loss and fluctuation of propagation. Moreover, other terminals can become obstacles that cut into the transmission link between mobile terminals, thus degrading the transmission performance between the terminals. It is well known as the shadowing effect. To overcome these problems, a packet routing based on relay transmission [3] is one of the most attractive capabilities. The further study on the dynamic packet routing for the IVC system has been presented in [4], [5] where one of dynamic packet routing using a concept of terminal group is proposed. However, the performance of the packet routing in [4], [5] is also seriously affected by the stability of the terminal groups.

Thus, in this paper, the stability of such the terminal group for the IVC network with the autonomous relay access scheme is evaluated. Some stability criterions such as updating rate, terminal group convergence probability and total path average holding time have been conducted by computer simulation. As the results, dynamic moving of the terminal is the serious problem that can degrade the stability of the terminal group and directly affect to overall performance of the IVC system.

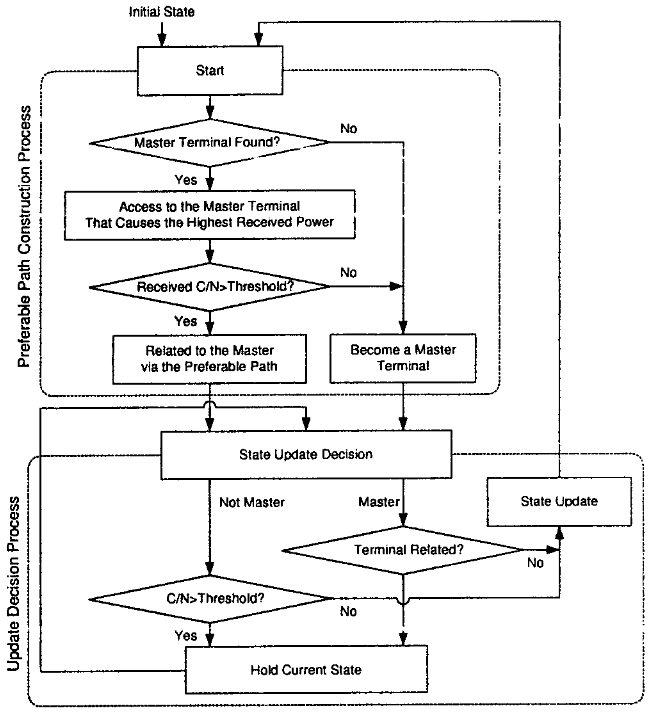


Figure 1. Terminal group construction and updating algorithm.

2. Autonomous Relay Access Scheme for IVC Network

In this section, we introduce the basic concept of the terminal group and packet routing scheme for relay transmission access scheme.

2.1 Basic Concept of Terminal Group

Concept of the terminal group has been proposed for obtaining relay transmission in the IVC network [3]-[5]. In such the transmission scheme, all mobile terminals are classified as either master terminal or slave terminal.

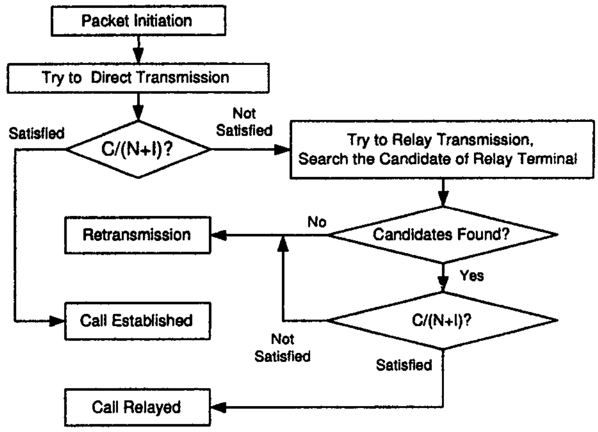
Each slave terminal is related to a certain master terminal via a preferable path, which is expected to achieve successful transmission between two terminals. Figure 1 shows a flow chart of the terminal group construction and updating algorithm [5]. First of all, a terminal classified and described as the terminal X, searches for other master terminals that are already classified. If there are no master terminals around, the terminal X is classified as a master terminal. If master terminals are found, the terminal X measures the received signal power from each terminal, and identifies the terminal providing the highest power which we denote as the master terminal Y. Then, the terminal X calculates the received C/N ratio from the terminal Y. If the received C/N ratio is higher than the preliminary threshold, we define such a C/N ratio as C/N_{master}, the terminal X is related to the master terminal Y via the connection of the preferable path. If the received C/N ratio is lower, the terminal X is classified as a master terminal. Moreover, we have introduced two different conditions of classification update for the master and not-master terminal respectively. The condition for master terminal is that no terminal is related to it. And the condition for the other terminals is that the received C/N ratio from its master terminal falls below the CN_{master}. At certain intervals, each terminal examines such a condition, and updates its own classification if the condition is satisfied.

Note that the classification is not fixed, but depended on the location of the terminal. By introducing such a star formed group shown in Figure 2, a packet that reaches a terminal in a group can be relayed to any terminal in the group via the master terminal.

2.2 Basic Concept of Packet Routing Scheme

Figure 2 shows the concept of the packet routing achieved by the algorithm in [3]. First of all, a terminal P that generates a packet toward another terminal Q tries a direct transmission. We evaluate the transmission quality between two terminals using the $C/(N+I)$ ratio. If the achieved $C/(N+I)$ for the transmission between P and Q satisfies the preliminary threshold, P successfully sends its packet to Q. If it is not satisfied, P accesses other terminals and tries to find a terminal R belonging to the same terminal group as the terminal Q that satisfies the $C/(N+I)$ condition between P and R. Terminal R then becomes a candidate for a relay terminal, and terminal P sends its packet to such a candidate. The behavior of the candidate that receive such a relayed packet is determined the simple rules for each terminal as follows:

1) A slave terminal should send the received packet that is addressed to another terminal to its master terminal.
2) A master terminal should send the received packet that is addressed to another terminal to such the addressed terminal.



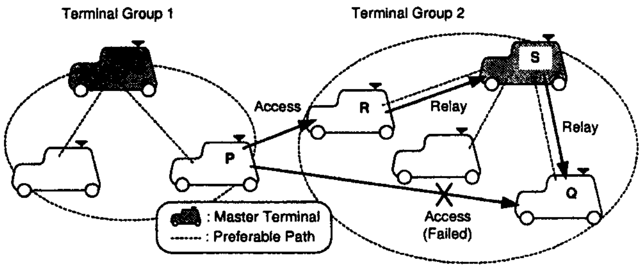


Figure 2. Concept of packet routing scheme in the IVC network.

Thus, we can achieve the autonomous and adaptive packet routing between terminals by exploiting the terminal groups. In this case, the candidate R sends the received packet from P to its master S, then sends the packet to the destination Q, as determined by above rules. As for each transmission such as R to S, or S to Q, the condition $C/(N+I)$ should also be satisfied. As the concept of relay transmission, the terminal group stability is one of the most important factors to guarantee the performance of the IVC network system such as throughput and delay performance.

3. Stability Evaluation Criterions

In order to evaluate the stability of the terminal group in the IVC network, we have proposed some stability criterions as follows:

Terminal Group Updating Rate: The proposed updating rate is to measure the changing rate of the terminal groups which are constructed by the algorithm in Figure 1. It is defined as the number of the updated terminal groups to the total number of the terminal groups. The updating rate should be increased according to the degree of dynamic moving of the terminals.

Terminal Group Convergence Probability: In our assumption, the mobile terminals are randomly located in the simulation area. And the terminal groups are classified according to the terminal group construction algorithm. The number of terminals in a group is commonly differed in the time intervals when the locations of the terminals are updated. Hence, the terminal group convergence probability is defined as the variation of the

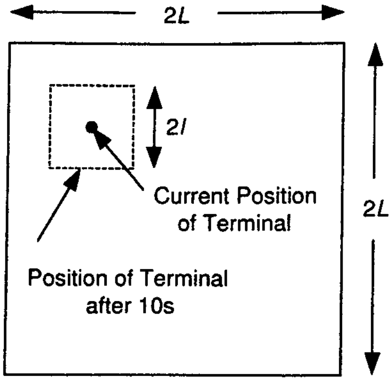


Figure 3. A model of terminal moving.

number of terminals in a group and is investigated from the initial state.

Total Path Average Holding Time: The packet routing based on the relay transmission scheme is the useful routing method in the IVC network. It is also provided the adaptively and autonomously packet routing. However, the performance of the packet routing based on such transmission scheme is closely related to the terminal group updating rate. Referring to the packet routing scheme in the previous section, the total path average holding time is defined as the average holding time of all relayed terminals in the routing path until one of the relayed terminals is failed. The dynamic moving of the terminal is the essential factor to determine the holding time.

4. Computer Simulation Results

In this section, we have conducted computer simulations for the stability evaluation of the terminal group in the IVC network.

4.1 Simulation Conditions

The model of the simulation area is $2L \times 2L$ square as shown in Figure 3, where 20 and 40 terminals are uniformly distributed. The length of l also reveals terminal velocity. Table 1 shows the simulation conditions for the stability evaluation of the terminal group. In our simulation, we assume that the received power of each signal is subject to path loss with a decay factor of 3.5 and log-normal shadowing with a standard deviation of 6.5 dB. Terminal classification is conducted every 10 sec. Transmission power of each terminal is determined by the C/N ratio at the distance of L apart from the terminal and assumed to be 40 dB.

4.2 Updating Rate

Figure 4 shows the terminal group updating rate according to l/L. The parameter l/L represented the dynamic moving of the terminal. For example, if we assume $l = L = 100$ m, and a terminal directly reaches at a region side in 10 s, the terminal velocity becomes equivalent to 36 km/h. Terminal group updating is expected to degrade the performance of packet routing that leads to packet misleading. We can observe that more frequent updating is conducted according to l/L increase.

Table 1. Simulation conditions for stability evaluation.

Simulation area	Square area ($2L \times 2L$)
Number of terminals	20 and 40
Terminal distribution	Uniformly
Path loss factor	3.5
Standard deviation of log-normal shadowing	6.5
Antenna	Omni-directional
Transmission power	40 dB-C/N at the distance of L
Classification	Every 10 sec.
CN threshold level	10 dB

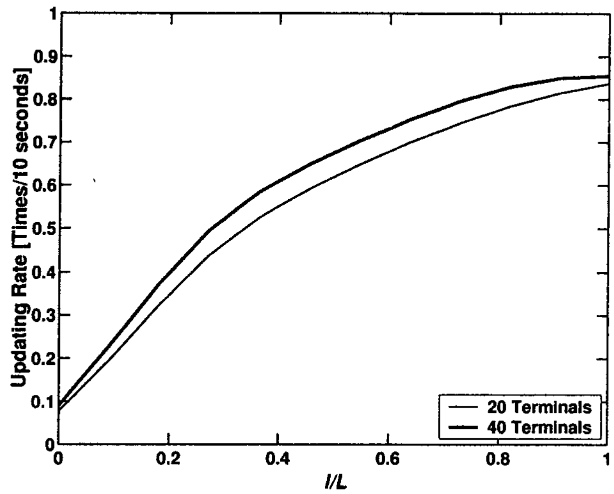


Figure 4. Terminal group updating rate.

4.3 Convergence Probability

Figure 5 shows the convergence probabilities of the average number of terminals in a group for various values of l/L for 20 terminals. These results are temporary value within 2,000 seconds time interval and depend on its initial state. In this study, 100 initial states are conducted in the simulation. We can observe that the average number of terminals in a group converge rapidly when high l/L is employed. Although in stationary situation ($l/L = 0$), the convergence probability is determined by fluctuation of log-normal shadowing.

4.4 Total Path Average Holding Time

The computer simulation results of total path average holding time for the direct transmission and relay transmission access schemes are shown in Figure 6. As the results, the average holding time decreases according to l/L because the dynamic moving of the terminal. This parameter will effect to the packet transmission delay

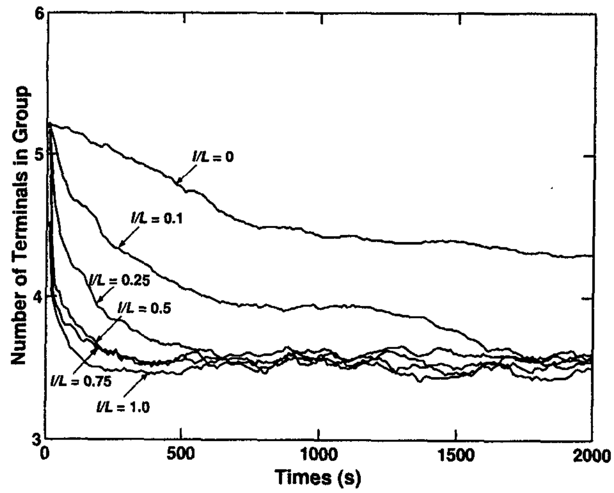


Figure 5. Convergence probability of average number of terminals in a group for various values of l/L (20 terminals).

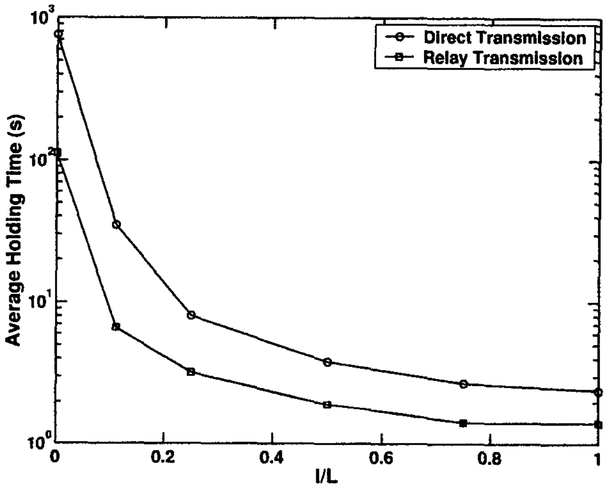


Figure 6. Total path average holding times for the direct transmission and relay transmission schemes (20 terminals).

performance of the IVC system. We can observe that the maximum average holding time of the direct transmission access scheme more than the relay transmission access scheme, because of the different number of the relayed terminals.

5. Conclusions

We evaluate the stability of the terminal group for the IVC network with the autonomous relay access scheme. The stability criterion such as terminal group updating rate, convergence probability of average number of terminals in a group, and total path average holding time for direct transmission access scheme and relay transmission access scheme are proposed. Our simulation results confirm that the stability of the terminal group can be effected by the dynamic moving of the terminal. Therefore, we can investigate the overall performance of the IVC network according to these stability criterions for our future study.

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