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Research on Resource Scheduling Method Based on LTE-V2X Direct Connect Communication

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***Abstract*—V2X direct communication technology based on LTE network LTE-V2X as the main solution of C-V2X at this stage has aroused widespread attention and general support from domestic and foreign governments and related industries. At present, domestic mobile communication networks cannot fully meet LTE-V2X's various scenarios support capabilities, so not only the existing LTE network and hardware needs to be upgraded, but also the LTE-V2X direct communication algorithm needs to be further optimized to reduce the network and hardware operating load. The resource scheduling method is an important component Therefore, this paper considers the rational use of spectrum resources and the smoothness of communication pipelines, and studies and analyzes appropriate resource scheduling methods based on different infrastructure and operating scenarios to make LTE-V2X direct communication performance optimal.**

Keywords—LTE-V2X, direct communication, resource scheduling

I. INTRODUCTION

LTE-V2X(Long Term Evolution-vehicle to everything) refers to the V2X Internet of Vehicles wireless communication technology formed based on the evolution of LTE mobile communication technology, and has a greater advantage than DSRC(Dedicated Short Range Communications)in my country's LTE-V2X technology research and development and industrial development. LTE-V2X includes two operating modes: cellular communication and direct communication. Among them, the direct communication mode can work both within and outside the network coverage, using ITS(Intelligent Traffic System)dedicated near 5.9GHz The frequency spectrum carries out direct communication between terminal devices, and realizes low-latency and highly reliable communication between vehicles and surrounding vehicles, roadside infrastructure, pedestrians and other nodes.

Since LTE-V2X direct communication usually uses self-organizing or base station-scheduled resource utilization methods, when different resource scheduling methods are used, LTE-V2X signal collision probability and system performance are not the same, which will significantly increase the network and hardware operating load. Therefore, this paper considers the rational use of spectrum resources and the smoothness of communication pipelines, and selects appropriate resource scheduling methods based on different infrastructure and operating scenarios to optimize the performance of LTE-V2X direct communication.

According to different scheduling subjects, resource scheduling can be divided into base station scheduling and vehicle self-organizing scheduling; according to different resource dimensions, it can be divided into time-domain segmentation scheduling and frequency-domain segmentation scheduling; according to the threshold excitation judgment information source, it can be divided into Scheduling based on the degree of interference, scheduling based on energy perception, scheduling based on driving directions, and scheduling based on geographic location.

II. RESOURCE POOLS

Resources are usually composed of frequency domain resources and time domain resources. Communication resources are formed by combining the two. If the time domain is regarded as the X axis and the frequency domain is regarded as the Y axis, the matrix formed by the arrangement is the resource pools, such as As shown in Fig. 1, One of the squares represents an RB(Resource Block), the time domain is 1ms, and the frequency domain is 180kHz. According to the algorithm assumption in Table 1, 300bytes data packets need to consume 4 frames, each frame needs 10RB. Fig. 1 shows the situation in which different vehicles occupy different time and frequency domain resources in the resource pool. A total of 4 vehicles are transmitting data , Each sending a data packet occupies 18 or 24 RB, the time domain span is 3 or 4ms.

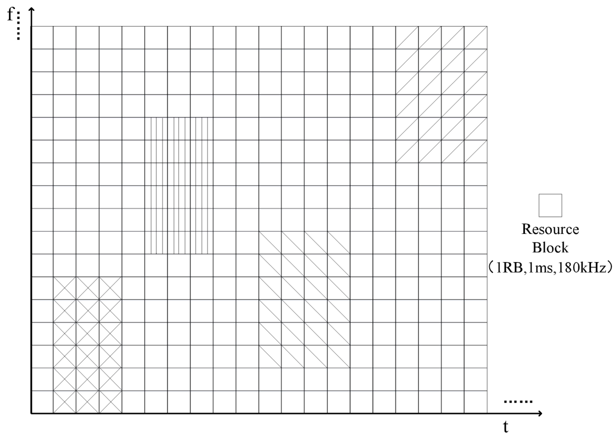

Fig. 1. Schematic diagram of resource pools

TABLE I. LTE-V2X SYSTEM DIRECT LINK COMMUNICATION LINK LAYER SIMULATION HYPOTHESIS PARAMETERS

No.	description		parameter
1	Carrier frequency		6GHz
2	Carrier number (bandwidth)		1(10MHz)
3	Number of frames used per data packet	190Bytes	3
4		300Bytes	4
5	Number of RBs used to transmit data packets per frame	190Bytes	10RB
6		300Bytes	10RB
7	Modulation	190Bytes	QPSK
8		300Bytes	QPSK
9	Transmit power		23dBm
Remarks	This parameter is to simulate the collision avoidance scheduling method based on geographic location and perception method. This parameter is suitable for highway scenarios (support vehicle speed of 70/140km/h, transmission cycle is 100ms); urban scenarios (support vehicle speed of 15/60km/h, transmission cycle is 100/500ms)		

In LTE-V2X direct communication, the form of vehicle resource pool is shown in Fig. 2. When the vehicle is driving, if there is no relevant threshold for judging incentives, the vehicle will use part of the resources in the resource pool for a fixed time. For example, the horizontally-striped background squares in Fig. 2 represent a combination of time domain and frequency domain resources. The vehicle will reuse the same resources at a fixed period of 100 ms.

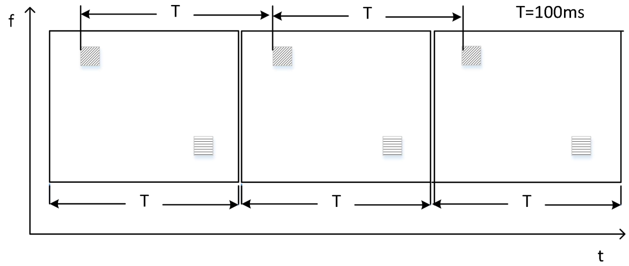

Fig. 2. Schematic diagram of using resource pool based on LTE-V2X direct connection communication

III. Research on Scheduling Methods Based on Scheduling Subjects

A. *Based on base station scheduling/vehicle self-organizing scheduling method*

Based on the scheduling of the base station, the method is that the base station obtains the information uploaded by the OBU (On Board Unit) or RSU (Road Side Unit) on the 2GHz uplink, according to the global information requirements, and according to the proposed allocation criteria, arranges all the coverage Resource usage of vehicles using the 5.9GHz band. This scheduling is suitable for scenarios where base stations can be connected to communicate. The advantage is that it can avoid collisions caused by two vehicles operating independently and using the same resource blocks at the same time in a small range. The scheduling method based on the base station is shown in Fig. 3.

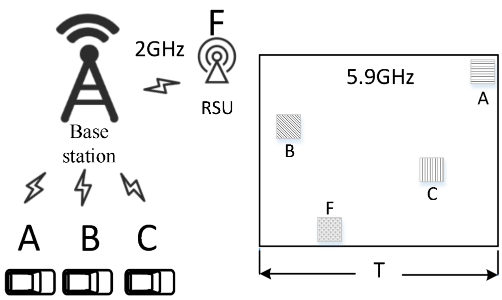

Fig. 3. Schematic diagram of scheduling method based on base station

Vehicle-based self-organizing scheduling is suitable for scenarios where there is a lack of base station communication in the surroundings. The method is that OBU or RSU uses relevant known information to determine which of the 5.9GHz frequency resources are used to achieve self-organized scheduling by vehicles. However, in this case, because there is no "command center" for global scheduling throughout the entire process, occasional collisions occur when different scheduling subjects use the same spectrum resources. The vehicle-based self-organizing scheduling method is shown in Fig.4. In Fig.4, car C and car E select the same resource block to transmit data, and a collision occurs.

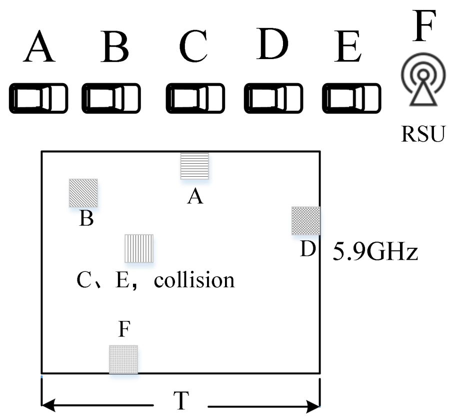

Fig. 4. Vehicle self-organizing scheduling method

B. *Random scheduling method*

The random scheduling method is an extreme case of the self-organizing scheduling mode. OBU and RSU do not refer to any relevant information, and randomly select resource blocks to implement information transmission. As shown in Fig.5, except for the resource block 1.1 in use and the resource block 3.2 that is not available, all other resource blocks are candidate resource blocks.

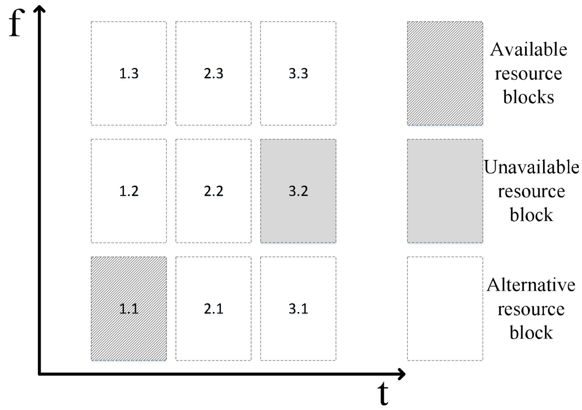

Fig. 5. Schematic diagram of random scheduling method

IV. Research on Scheduling Method Based on Resource Dimension

A. *Time domain split scheduling/frequency domain split scheduling method*

Time-domain split scheduling and frequency-domain split scheduling both belong to the base station scheduling category. The base station divides the UE (User Experience) into different groups by analyzing the relevant information data sent by the vehicles and RSUs in the coverage area. If two groups of UEs need to use resources at the same time, the base station uses frequency domain split scheduling. If the same type of resources need to be used in sequence, the base station uses time-domain split scheduling, and different groups of UEs use different blocks of resources according to the time-domain split or frequency-domain split criteria. The time-domain split scheduling is shown in Fig.6, and the frequency-domain split scheduling is shown in Fig.7.

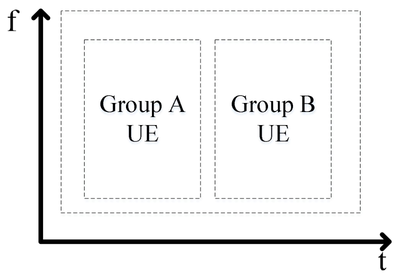

Fig. 6. Schematic diagram of time domain split scheduling method

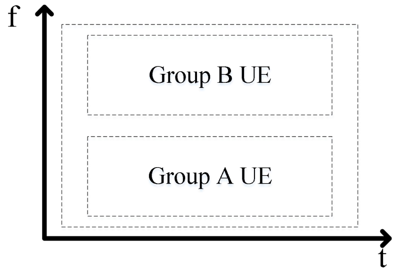

Fig. 7. Schematic diagram of frequency domain split scheduling method

V. Research on Scheduling Method Based on Threshold Incentive Judgment Information Source

A. Scheduling method based on energy perception/interference degree

Scheduling based on energy perception and interference level is both a base station-based scheduling mode and a vehicle self-organizing scheduling mode. The base station-based scheduling mode collects the sensing results reported by all vehicles in the coverage area to make resource scheduling decisions, while vehicle self-organizing scheduling The mode is to make resource scheduling decisions based on the vehicle's own perception results. The scheduling method based on the degree of interference is more sensitive to the energy value of the noise floor than the scheduling method based on energy perception, the scheduling algorithm is relatively complex, and the security of resource use is higher.

Scheduling method based on energy perception is that the OBU/RSU obtains the noise floor energy value Pr of each resource block through the energy perception method, and judges Pr≤Tuse, If the inequality is true, it means that the resource block is unused and can be used as an alternative. For resource blocks, if interference is encountered during transmission, you can select one of the candidate resource blocks for data transmission. The scheduling method based on perception is shown in Fig.8. In the Fig.8, OBU uses 1.1 resource blocks in this transmission cycle, and resource blocks 1.3, 2.1, 2.2, 2.3, 3.1, and 3.3 are unavailable through sensing. 1.2 and 3.2 resource blocks are used as alternative resource blocks.

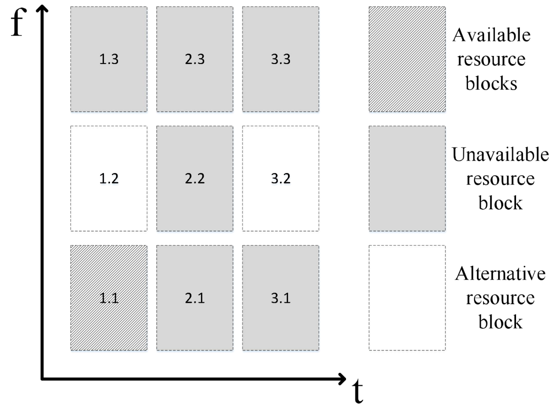

Fig. 8. Resource scheduling based on perception

The scheduling method based on the degree of interference is similar to the scheduling method based on energy perception. Both use energy sensing to obtain the noise floor energy value P_r of each resource block. The difference is that the former obtains P_{r1}, $P_{r2}\ldots P_{rn}$ After waiting for the noise floor energy of all resource blocks, they will be sorted according to their numerical value, and a certain number of small energy resource block groups that meet the percentage threshold will be selected as available resource blocks. The scheduling method based on the interference level is shown in Fig.9 , Assuming that the vehicle can perceive the energy of each resource block in this transmission cycle as P_{r1}, $P_{r2}\ldots P_{rn}$ is the same as in Fig.8, and set the order of energy to $P_{r3.3}$, $P_{r3.1}$, $P_{r2.2}$, $P_{r2.1}$, $P_{r3.2}$, $P_{r2.3}$, $P_{r1.3}$, $P_{r1.2}$ according to the largest energy In addition to the resource block 1.1 in use, Assuming that the vehicle will select the smallest 40% of the other resource blocks as candidate resource blocks, which is considered to be tolerable. Therefore, the vehicle will select resource blocks 1.3, 1.2, and 2.3 as the backup Select resource blocks.

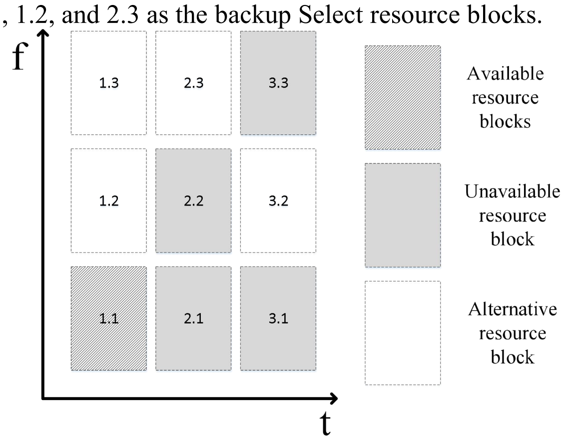

Fig. 9. Scheduling method based on interference degree

B. Dispatch based on geographic location/driving direction

The resource scheduling method based on geographic location and driving direction is similar to the principle of spectrum sharing, and all use spatial isolation to improve the spectrum reuse rate. In LTE-V2X direct communication, the geographical location and driving direction are used to realize spectrum multiplexing through the time domain division method or the frequency domain division method, which can effectively avoid in-band interference and near-far effects.

1) Time-domain segmentation scheduling based on geographic location and driving directions

a) In high-speed scenarios, there are two scheduling methods based on geographic location and driving direction. The first scheduling method is based on geographic location, as shown in Fig.10. Among them, vehicles that are far away can send signals in the same time zone to weaken the probability of a near-far effect.

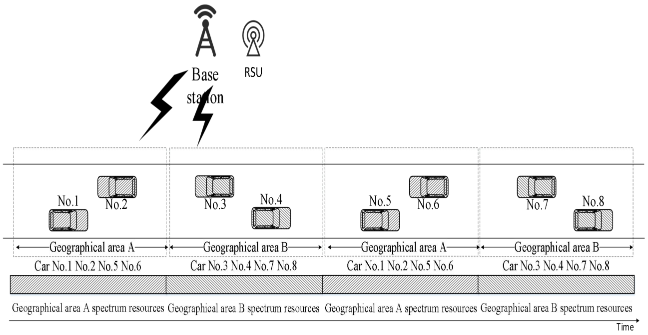

Fig. 10. Time-domain segmentation scheduling method based on geographic location

b) The second type of scheduling is a scheduling method based on driving directions, as shown in Fig.11. Vehicles in different driving directions use different time zones to send signals, which can not only improve the spectrum reuse rate, but also reduce the impact of Doppler frequency shift.

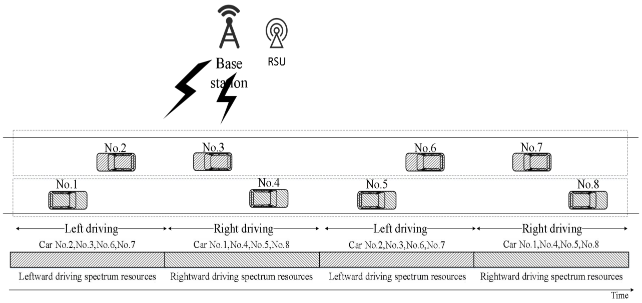

Fig. 11. Time-domain split scheduling method based on driving direction

At the same time, the base station performs time-domain segmentation scheduling based on geographic location and driving direction for vehicles and RSU, and can dynamically adjust the corresponding time-domain resource width according to the number of vehicles in different directions or different geographic areas.

c) In urban scenes, the NLOS(not line of sight) propagation environment in the intersection area will cause serious near-far effects and in-band interference. Therefore, time-domain segmentation of the resource pool according to the path or street of the vehicle can reduce the above-mentioned in-band interference. The time-domain spectrum segmentation scheduling method based on the geographic location of vehicles in urban scenes is shown in Fig.12.

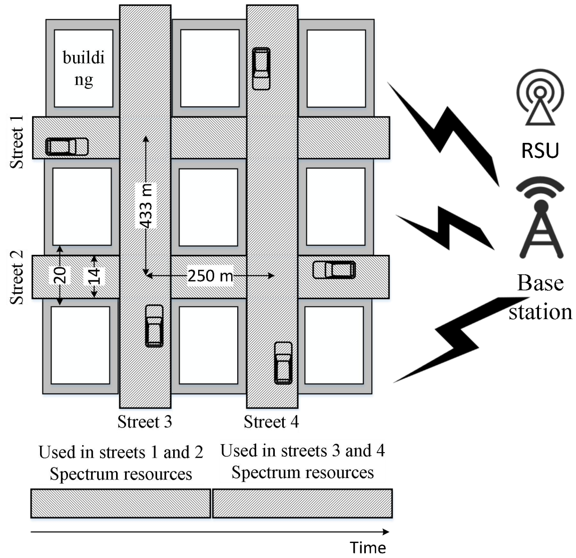

Fig. 12. Time-domain segmentation scheduling method based on geographical location in urban scene

d) The calculation assumptions of the V2V/V2I path loss model in the urban NLOS scenario are shown in Table 2.

TABLE II. ASSUMPTION OF V2V/V2I PATH LOSS MODEL IN URBAN NLOS SCENARIOS

parameter	Value and description
Path loss model	Winner+B1 Manhattan model NLOS situation, when the distance is less than 3m, it is calculated according to 3m
Shadow fading	Exponentially normal distribution
Standard Variance of Shadow Fading	4dB
Multipath loss	Not consider
Carrier frequency	5.9GHz
Vehicle antenna height	1.5m
RSU antenna height	6m

The calculation of Winner+B1 Manhattan path loss model in NLOS scenario is shown in Table 3.

TABLE III. CALCULATION METHOD OF WINNER+B1 MANHATTAN PATH LOSS MODEL IN NLOS SCENARIO

Calculation formula	condition
$PL = min(PL (d_1, d_2), PL(d_2, d_1))$ $PL(d_k, d_l) = PL_{LOS}(d_k)+ 17.9- 12.5n_j+ 10n_j log_{10}(d_l)+ 3log_{10}(f_c)$ $n_j = max(2.8 - 0.0024d_k, 1.84)$ PL_{LOS} calculation is shown in Table 2，$k,l \in \{1,2\}$。	$10\ m < d_1 + d_2 < 5000m$ $w/2 < \min(d_1, d_2)$ w=20m

In Table 3, d1 and d2 are the distance from the vehicle to the center of the intersection, as shown in Fig.13.

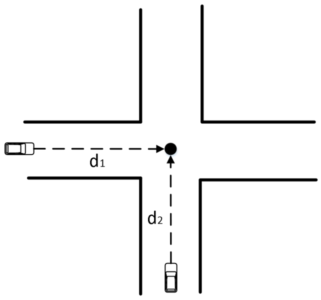

Fig. 13. NLOS scenario Winner+B1 path loss model d1 and d2 parameter example diagram

2) Frequency domain segmentation scheduling based on geographic location and driving direction

Similar to the time-domain segmentation scheduling method based on geographic location and driving direction, it is based on the geographic location or driving direction information of vehicles in high-speed scenes and urban scenes. The base station or RSU schedules and uses the vehicles in the resource pool according to the corresponding rules. Spectrum resources.

VI. Conclusion

This article first introduces the resource pool, and then researches and introduces the LTE-V2X direct communication resource scheduling method in typical scenarios, and selects the appropriate resource scheduling method for different infrastructure and operating scenarios, so that the performance of LTE-V2X direct communication is always maintained. Optimal state.

In addition, the Ministry of Industry and Information Technology has officially issued the "Management Regulations on the Use of the 5905-5925MHz Frequency Band for Internet of Vehicles (Intelligent Connected Vehicles) Direct Communication, which is used for the core radio direct communication in intelligent connected vehicles and supports LTE-V2X technology in intelligent network vehicles With the arrival of 5G, the LTE-V2X technology system will continue to evolve, including LTE-V2X enhancements and standardization of V2X wireless communication technology based on 5G New Air Interface (NR) to further support richer and more advanced Car networking application.

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