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Review Article

Solving V2X Blocking Algorithm

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Abstract

LTE-V2X is becoming the most technology for automatic pilot. But the interference affects the capacity of V2X when the traffic is busy. This article presents the soling V2X blocking algorithm to void the problem happening. It is time division method. Node B acts as a master to assign the slot and symbol to all of OBUs under the area. If out of range of LTE network, the OBUs votes one OBU as Node B to allocate the slot and symbol to them, all OBUs Synchronization with the OBU, then time division can work.

Keywords: V2X; OBU; Node B; Time division; LTE; interference; blocking; PBCH; broadcast; synchronization; Mode 3. Mode 4

Background

The vehicle to vehicle communication in LTE-V2X is broadcasting, so that there is interference to each other. According to my article <Theoretical maximum blocking capacity of LTE-V2X intelligent Vehicle Network, 2022>, it is difficult for vehicles to communicate to each other if OBUs transmit the maximum power randomly. We have to solve this problem.

Objective

Void the interference, vehicle to vehicle V2X communicate smoothly.

Method

Time division transmitting.

Theoretical Knowledge

V2X

At present, people are no longer satisfied with the fact that the driver drives the car according to the actual sight range. People expect that in the future, the car can be controlled more intelligently to realize driving or completely driven by the car control system. Therefore, They need to anticipate possible events in advance, they need to negotiate with each other, they need to exchange messages with pedestrians, and they need to exchange messages with traffic management systems. These requirements require the establishment of V (Vehicle) -V (Vehicle), V (Vehicle) -P (Pedestrian), V (Vehicle) -I (Infrastructure), V (Vehicle) -N (Network) communication. These communication networks are collectively called V2X networks (Chen Shanzhi et al., 2018).

V2X PC5 and Uu interface

We define the interface of V (Vehicle) -V (Vehicle), V (Vehicle) -P (Pedestrian), V (Vehicle) -I (Infrastructure) as PC5, define the interface of V (Vehicle) -N (Network) as Uu.

V2X interference

1. All of the OBUs transmit maximum power so as to communicate with each other. In LTEV2X, the frequency range is from 5855MHz-5925NHz, only 3 channels with 20MHz band wide. There will be interference when traffic is busy, as OBUs closed are using same frequency.
2. R=1m, number of vehicles can communicate: 2
3. R=3m, number of vehicles can communicate: 12
4. R=5m, number of vehicles can communicate: 0 (Yongdong Li, 2022)

V2X frame structure (3GPP, 2022 Release16)

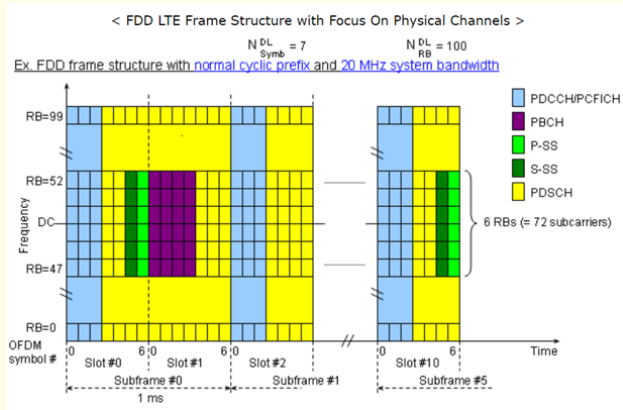

Diagram 1: PBCH broadcasts the V2X information every 4ms.

V2X mode (Shen Yafei, 2022)

1. *Mode 3:* The mode for Uu interface communication between vehicle with Node B,V2N, all controlled by Node B, Node is master and OBU is slaver, the communication same with LTE Node B and UE;
2. *Mode 4:* The mode for PC5 interface communication, V2V, V2P, V2I, there is not master and slaver, communicate to each other by broadcasting method.

LTE TTI (3GPP, Release 9)

1. TTI meaning is Transmission Time Interval;
2. 1 TTI=1ms;
3. 1 TTI is minimum data scheduling unit.

Define radio condition

1. ***Condition 1:*** The area is covered by Node B signal. All OBUs can received the broadcast information from PBCH of V2X Node B, see diagram 2.

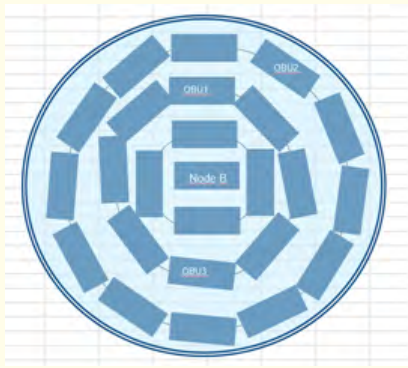

Diagram 2: Condition 1, all OBUs are covered by Node B.

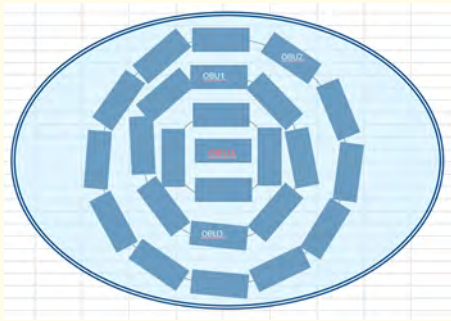

Diagram 3: Condition 2, OBUs are out of range covered by Node B.

2. ***Condition 2:*** The area is out of the range covered by Node B signal. OBUs cannot received the broadcast information from PBCH of V2X Node B, OBUs have to communicate to each other directly by PC5, all OBUs work under mode 4.

Problem

1. When traffic is busy, OBUs are close to each other, V1 and V3 communication is blocking by the interference from V2 and others. (See Diagram 4)
2. We must reduce or void the interference.

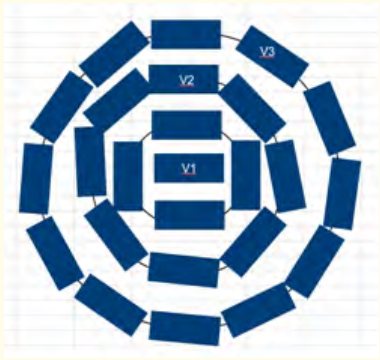

Diagram 4: Traffic busy, Interference to each other, V1-V3 cannot communicate.

Solution

1. Vehicles transmit power at different time
   For surviving from the interference, there are three ways:

1.1. Frequency division
1.1.1. There are over 3 vehicles for V2X communication;
1.1.2. V2X only 70MHz frequency range, only support 3 channels (3X20MHz<70MHz);
1.1.3. It is difficult to realize the frequency division by 3 channels in one area covering more than3 vehicles.
1.2. Code division
1.2.1. V2X OBUs communicate by the PBCH;
1.2.2. Under the same frequency for V2X, if broadcasting is the only way to communicate, different OBU's PBCH have to multiply by different orthogonal codes;
1.2.3. It will increase the complexity of channel coding;
1.2.4. It is not the best way.
1.3. Time division
1.3.1. If OBUs transmit at different slots and different symbols of one same subframe, the signal of OBUs' broadcasting will be split in the time domain, there will not be interference;
1.3.2. The key problem is the synchronization of all OBUs which are in the same area;
1.3.3. The synchronization should include the synchronization of frame, slot and symbol;
1.3.4. The synchronization also should be setup under the condition 1 which there is base station signal and the condition 2 which out of coverage of base station.
1.3.5. For condition 1:
1.3.5.1. Mode 4 change to mode 3
1.3.5.1.1. If Vehicle with OBU enters the area coved by the base station, it will get the broadcast message system message(SIB) that it is ordered to change to mode 3, meaning the OBU should becomes UE to communicate with Node B(Base station);
1.3.5.1.2. OBU changes the mode 4 to mode 3, it means that the OBU do not broadcasting itself information and only listen to the broadcasting from the Node B;
1.3.5.1.3. Mode 4 changes to mode 3, also it means that the OBU do not transmit power by broadcasting way anymore;
1.3.5.1.4. After 1.3.5.1.3, there is only downlink power from Node B and uplink from UE(OBU in this area), the downlink and

uplink in V2X V-N is time division, the interference will disappear;

1.3.5.1.5. The UE search the signal and gets the frame and slot synchronization by PPSCH and PSSCH, same with LTE;

1.3.5.1.6. UE gets the system information by PBCH of Node B;

1.3.5.1.7. UE registers to V2X network;

1.3.5.1.8. The UEs send the information including the device ID by PRACH to Node B;

1.3.5.1.9. Node B records the Device ID and assigns some slot and some symbol to the UE, never conflicting with other UEs;

1.3.5.1.10. UE transmits the BSM (automotive control message in higher layer) message by this uplink using this slot and symbol to all OBUs in this area;

1.3.5.1.11. At the slot and symbol, all of OBUs in this area are listening to it, it is the time slot to get the message from the special OBU;

1.3.5.1.12. As the slot and symbol is unique in time domain, there is not any interference from others;

1.3.5.1.13. Node B records all device ID under the area and broadcasting the unique slot+symbol assigned to all OBUs, so that all OBUs can send themselves message to all in the special slot+symbol, at the same time other OBUs cab get the OBU message at the special time slot, also there is not any interference at any slot and symbol;

1.3.5.1.14. Example

1.3.5.1.14.1. V2X communication process under condition 1, see diagram 5

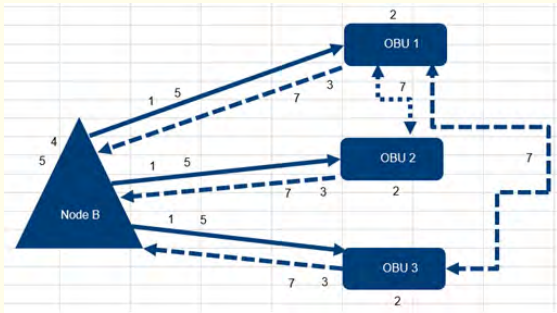

Diagram 5: V2X communication under condition 1.

1.3.5.1.14.2. Detail process under condition

1	Node B broadcasting SIB notice that all OBUs in this area Mode 4 ->Mode 3
2	OBUs change to Mode 3
3	OBUs all register to Node B
4	Node B records the Device ID of OBU1 OBU2 OBU3
5	Node B assigns the unique slot and symbol for every OBU
6	Node B broadcasting SIB including the slot and symbol information to all OBUs
7	All OBUs transmit power and send messages at the slot and symbol assigned by Node B.

Table 1: V2X communication process under condition 1.

1.1.6. For condition 2:

1.1.6.1. As area out of the range covered by Node B, there is not Node B;

1.1.6.2. OBUs transmit its' power randomly if there is not a master like Node B;

1.1.6.3. In the time domain, the signal will conflict to each other in high probability;

1.1.6.4. The interference will be happened, the capacity of the V2X system communication will be drop. If the SINR of the V2X signal at any area is under -7dB, all communication is broken;

1.1.6.5. Finding one source as the synchronization master of the area become the key point;

1.1.6.6. We can define one OBU under the best condition as the master, Node B.

1.1.6.7. How to find the OBU under best condition:

1.1.6.6.1. Trigger

1.1.6.6.1.1. When the OBU RSRP of receiver is under -7dB, it will not work(Yongdong Li,2022);

1.1.6.6.1.2. The OBU should switch mode 4 to mode 3;

1.1.6.6.1.3. At the same time, the transmit of the OBU should OFF, it will be helpful to reduce the interference;

1.1.6.6.1.4. The OBU listens to PBCH for capturing the broadcasting message from other OBUs, set Counts=0;

1.1.6.6.1.5. If the OBU receives one message from other OBU with device ID:

1.1.6.6.1.5.1. Counts+1;

1.1.6.6.1.5.2. Received_Device_counts = Counts;

1.1.6.6.1.5.3. Set up Device (Device ID, Received_Device_counts);

1.1.6.6.1.5.4. Transmit the message including Device (Device ID, Counts) to all OBUs by PBCH like Node B;

1.1.6.6.1.5.5. Wait for 3 TTI;

1.1.6.6.1.5.5.1. The reason that the OBU requiring to be Node B is that:

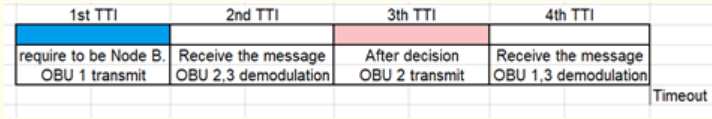

Diagram 6: The reason waiting for 3 TTI.

1.1.6.6.1.5.6. OBU 1 transmits the requirement including the counts of the requirement becoming Node B to all of OBUs;

1.1.6.6.1.5.7. After OBU 1 sends out the requirement becoming master, Other OBUs receive the signal and demodulate the message in 2nd TTI;

1.1.6.6.1.5.8. OBU 2 compares the counts received before with the counts sent by OBU1:

1.1.6.6.1.5.8.1. If OBU 2 counts received >=OBU 1 counts, OBU 2 counts+1 and sends out the next requirement being Node B;

1.1.6.6.1.5.8.2. If OBU 2 counts received <OBU 1 counts, OBU 2 keeps silent, do not transmit message anymore, as OBU1 gets more requirements than it, it can cover more OBUs, so OBU1's condition is better.

1.1.6.6.1.5.9. OBU 1 waits for 3 TTI, there is not any requirement sent by other OBUs;

1.1.6.6.1.5.10. OBU 1 becomes Node B;

1.1.6.6.1.5.11. OBU 1 send out SIB to all of OBUs, notice it becomes Node B;

1.1.6.6.1.5.12. At the same time, the SIB is included the device ID and the unique slot and symbol assigned to the device;

1.1.6.6.1.5.13. Node B setup;

1.1.6.6.1.5.14. All OBUs and OBU 1 work like condition 1;

1.1.6.6.1.5.15. The interference problem is solved.

1.1.7. Extension

1.1.7.1. Improvement:

1.1.7.1.1. Assign Node B PBCH more slots and more symbols work for broadcasting.

1.1.7.1.1.1. As V2X PBCH broadcast the message every 4 TTI, it will make the handshake of each other delay;

1.1.7.1.1.2. The reason why PBCH every 4TTI is power save (DU Sijian, 2018);

1.1.7.1.1.3. But the response is more important than power save;

1.1.7.1.1.4. So that we assign PBCH in every TTI;

1.1.7.1.1.5. The delay will reduce 2 times;

1.1.7.2. Border

1.1.7.2.1. If OBU is at the border of two areas, it can receive broadcast from two areas, it can select the one which ask it transmit

first;

1.1.7.2.2. Another area will still wait for its transmitting until the symbol in the slot timeout;

1.1.7.3. Movement

1.1.7.3.1. As the OBUs are always moving, the coverage will be change;

1.1.7.3.2. Under condition 1:

1.1.7.3.2.1. The OBU can receive the broadcast information including or dering it transmit at one symbol and slot from Node B;

1.1.7.3.2.2. The OBU transmits according to the master Node B assignment;

1.1.7.3.2.3. The SIB is transmitted every 4TTI by Node B, if it cannot receive any broadcast from PBCH in another 4TTI, it means that it is out of range, it should enter condition 2 mode;

1.1.7.3.2.4. If it receives another SIB from another Node Bin another 4TTI, it should work according to the newest order;

1.1.7.3.3. Under condition 2:

1.1.7.3.3.1. If the OBU is a slaver in the area, it cannot receive any SIB from PBCH, it should enter sending Node B requirement mode, then works according to 1.3.6;

1.1.7.3.3.2. If the OBU is a master as Node B in the area, it cannot receive any broadcast from other OBUs in 4TTI, it means it enter a new area there is not the OBU it ever assigned, it should enter sending Node B requirement mode, then works according to 1.3.6;

1.1.7.3.3.3. If the OBU can get any broadcast from other OBUs, it works according to 1.3.6.

1.1.7.4. High speed fading

1.1.7.4.3.1. Doppler frequency shift(JIANG XIAoming, 2021)

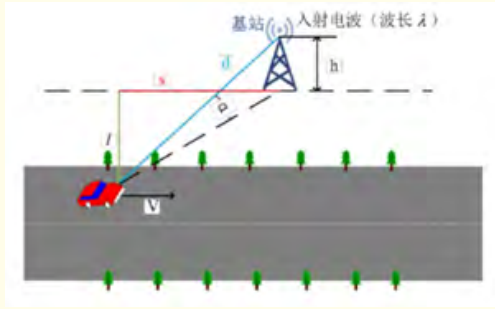

Diagram 7: Doppler frequency shift.

1.1.7.4.3.2. The frequency and loss will change, it will affect the V2X OBU searching and synchronization, the RSSP and SINR will be worse, see diagram 8 and 9;

$$\Delta f = (v/\lambda)\cdot\cos\alpha = \frac{v}{\lambda}\cdot\frac{\sqrt{(s-v\bullet\Delta t)^2+l^2}}{d}$$

Diagram 8: Doppler frequency shift.

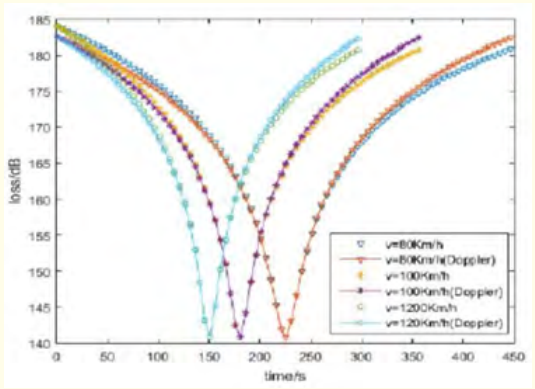

Diagram 9: Doppler frequency shift.

1.1.1.1.1.1. If the SINR under -7dB, the OBUs should be trigged to mode 3;

1.1.1.1.1.2. The OBU should work according to 1.3.6;

1.1.1.1.1.3. Because there may be some vehicles run the same direction with the OBU, they can setup V2X communication like condition 2.

Conclusion

1. Problem

1.1. LTE-V2X communication will be blocked under traffic busy status.;

1.2. The reason is interference from OBUs randomly transmitting.

2. Solution

2.1. Frequency division is difficult, as the channels is too lack;

2.2. Code division is complicated, as the channel coding have to multiply with orthogonal code;

2.3. Time division can void the interference;

2.3.1. Node B assigns different slot and symbol to different OBUs if there is a Node B covering the area;

2.3.2. Vote some OBU as Node B when there is not Node B covering in the area;

2.3.2.1. The OBU getting maximum reports is the best candidate acting Node B, as the one getting maximum reports means the one can broadcast to maximum OBUs;

2.3.2.2. Any OBU finds other OBU get more requirement than it, then keeps silent: do not transmit requirement anymore;

2.3.2.3. The last OBU transmitting requirement to be Node B becomes Node B;

2.3.3. Work like 2.1.1 after defining the OBU acting as Node B.

2.4. Optimization

2.4.1. More PBCH;

2.4.2. If SINR worse, change the work mode of condition 1 to condition 2 so as to resistance to interference of doppler frequency shift.

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