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Document for: Discussion and Decision

# Introduction

In SA1 #71 meeting, 3GPP TR 22.885 [1] is updated to V0.3.0, there are a number of use cases of V2X. Base on the use cases, some of common requirements (mainly for V2V) are as follows:

* *The RV V2V Service layer periodically broadcasts a message, indicating its current position, speed, acceleration and optional estimated trajectory.*
* *The E-UTRA(N) shall be able to support a maximum frequency of 10 V2V messages per second.*
* *The E-UTRA(N) shall be able to support high mobility performance(e.g. a maximum absolute velocity of 160 km/h).*
* *The E-UTRA(N) shall be able to support high mobility performance (e.g. support a maximum relative velocity of 280 km/h.*
* *The E-UTRA(N) shall be able to support a maximum latency of 100ms.*

That is to say, comparing to R12 D2D scenario, V2V safety services require higher capacity. In V2V communication scenarios, every vehicle has to receive information from all the nearby vehicles continuously, which brings great challenges to system capacity.

There are some conclusions related to resource allocation from the last meeting [2] as follows:

Agreements:

* The resource allocation principles listed below should be studied for PC5-based V2V (note that other schemes are not precluded):
  + Scheduling assignment
    - Each data transmission is scheduled by an SA.
      * FFS whether SA and Data are not transmitted on separate physical channels:
      * FFS whether SA and data from a single transmitter can be transmitted in the same subframe
    - Study the number of transmissions of a given TB
  + Enhancement to resource selection/structure
    - Study which of the following principle(s) is(are) beneficial:
    - Collision avoidance
      * A UE identifies the resources that will be occupied and/or collided by the other UEs and avoids a colliding resource allocation for its transmission.
      * FFS
        + Details of the identification of the occupied and/or collided resources, e.g., by reading other UEs’ SA and/or sensing the energy level
        + How to select the resources and MCS for transmission
        + Whether a UE performs the resource selection procedure for every transmission, and if not, what triggers reselection

FFS if the initial selection and reselection procedures are the same or not

* + - * + Whether signaling from eNB (e.g., information on the resource load) or another UE is beneficial.
        + Whether resource in this context is in the physical domain or the logical domain
    - Resource selection based on transmitter-specific information

In this contribution, some further considerations on technique schemes for resource allocation are provided.

# Discussion

# Semi-Persistent Resource allocation in PC5 V2V

In this paper, we try to find a better scheduling model to optimize the use of DATA resources for V2V safety service which is related to the safety of life and property. The choice of scheduling model depends on the characteristics of the service and topology change. For service feature, it is considered as a periodical service according to SA1 #71 meeting [1]. For topology change, it is considered as a gradual process since we drive on the planned road. These above conditions allow the vehicle to occupy a resource at least for a period time. In theory, semi-persistent scheduling has some prior knowledge, the conflict probability of its resource is lower than the model which will randomly selects DATA resource for every packet, especially in the case of limited resource. The corresponding simulation results also demonstrate the same conclusion. The following Figure 1 illustrates the semi-persistent occupy, where T is the semi-persistent occupied period. That is to say, a resource is occupied by a vehicle means that the resource will be occupied by the vehicle in a period of T. There is one or multiple service periods in T, i.e., T is a multiple of service period of a vehicle.

 

1(a) 1(b)

**Figure 1 Vehicles persistently occupy DATA resources**

In semi-persistent resource allocation scheme, the vehicle uses SA to indicate its own DATA resource. The channel design of SA and DATA can be divided into two types (refer to R1-156607):

Type1: SA is located in the same subframe of data;

Type2: SA and service data are FDM in different subframe.

In the following, the resource is DATA resource if there is no further clear indication.

***Proposal 1: Semi-persistent resource occupy should be considered for PC5 V2V safety services no matter there is network coverage or not.***

# Resource Selection of Semi-Persistent Resource allocation scheme

**2.2.1 Trigger Condition of Primary Resource Selection and Resource Reselection**

Once start, the vehicle begins to select primary resource for the packet before its timeout point if it has sufficient understanding of the occupancy of the resource, such as a full frame, otherwise discards the packet.

Once selected, the vehicle will keep the resource as its own occupied resource and will persistently occupy it for transmission, and it will not reselect new resource unless the resource will not satisfy the requirements of the new arrival packet. In particular, the reasons why the resource will not meet the requirements of the new arrival packet may include the following cases:

1. The change of the existing service period, such as from 500ms to 200ms, the resource may not satisfy the delay requirement of the service；
2. The change of the packet size of the existing service, such as adding some path history information, the new packet size exceeds the capacity of the resource;
3. The vehicle has new service, such as DENM message, the resource may not satisfy delay requirement of the DENM message, or the DENM message can use the resource while the existing CAM message have no resource for transmitting;
4. The resource is conflict, for example, two vehicles can no longer reuse the same resource due to topology change
5. The change of the channel environment of the resource, such as influenced by strong interference

Therefore, in the above cases, the vehicle needs to reselect resource for a service packet when all of its occupied resources are not available for the packet.

***Proposal 2: The vehicle needs to reselect resource for a service packet when all of its occupied resources are not available for the packet, including the case when the current resource cannot carry the coming larger packet and the case when collision happens.***

**2.2.2 Resource Selection Principle**

We do not distinguish primary resource selection process and reselection process because there is no difference between them. The vehicle considers to select a resource from its resource reuse range, once selected, the vehicle will keep the resource as its own occupied resource and will persistently occupy it for transmission unless the above triggering conditions come true. The resource reuse range should be considered as more than two hops in order to reduce the probability of hidden nodes.

In order to select a resource from its resource reuse range, the vehicle has to know the states of all resources in its resource reuse range persistently. Resource state maintenance can be achieved by decoding SA and/or monitoring.

The principle of maintenance resource state by decoding SA is as follows: The state of a resource is regarded as occupied if the SA decoding is successful. Whether SA decoding is successful depends on the decode range of SA which generally corresponds to a distance between on hop and two hops. The hidden nodes problem may still exist even if the SA decoding is successful.

The principle of maintenance resource state by monitoring is as follows: The state of the resource is represented by the measurement value of the resource, and the resource reuse range is represented by the measurement value of the SA resource. In particular, monitoring involves the following three measurement values: the received total power of DATA, the interference power of DATA and the received signal power of SA. The lower the received total power of DATA, the more likely the resource is non-occupied. The greater the interference power of DATA, the worse the channel environment of the resource. The greater the received signal power of SA, the shorter the distance between the vehicle transmitting SA and the vehicle receiving SA. Monitoring is related to the reliability of measurement. After analysis, we think that the measurement errors of monitoring have little influence on resource selection (refer to section 2.4).

***Proposal 3: Both monitoring and SA decode mechanisms should be applied to resource selection.***

We propose the following two schemes according to the above mentioned two types of channel design:

Scheme 1: Semi-persistent resource allocation scheme with type 1 channel

Scheme 2: Semi-persistent resource allocation scheme with type 2 channel

Scheme 1 has higher resource utilization because SA and DATA reuse the same subframe, but its scalability is relatively poor. Scheme 2 allows for more sub channels with better scalability, but has lower resource utilization because SA and DATA are separated. In the following we describe scheme 1 and scheme 2 from the perspective of resource maintenance and selection.

**Scheme 1:**

The vehicle needs to continuously monitor all subframes except its own one. Specifically, the vehicle needs to measure received total power of all subframes except its own one, and characterizes the state of the resource as the measurement value of the received total power. Vehicle assumes that the frame length is 1s (coming from the lowest Tx frequency of 1Hz), it is the basis of determining the state of the resource in the following subframe and the own occupied resource will be considered as released if it is not continuously occupied after 1s. For V2V 10Hz transmission rate, UE persistently occupies 10 resources (each one is selected from a 100ms window). While for V2V 2Hz transmission rate, UE persistently occupies 2 resources. In case of new service arrival, the vehicle will select a resource block(set) for it. For example, the vehicle may choose a resource with the lowest received total power as its own resource, and also may randomly choose a resource from some resources whose received total power are less than a threshold.

The vehicle also needs to continuously decode SA for all subframes except its own one. Specifically, the vehicle regards the state of a resource as occupied if the SA decoding is successful, and tries to avoid the resource while select its own resource.

Scheme 1 mainly use high frequency isolation to reduce the interference between vehicles in order to improve the system capacity, therefore there is only one target transmitting vehicle in a subframe, and the received total power of the other interference vehicles are as low as possible, then the subframe with lower received total power should be selected in priority.

**Scheme 2:**

The vehicle needs to continuously decode SA for all subframes except its own one. Specifically, the vehicle regards the state of a resource as occupied if the SA decoding is successful, and regards other resources as non-occupied, and the vehicle will select a resource from the non-occupied resources as its own resource. In the case of incomplete FDM of SA, the vehicle will give up its own resource and reselect resource if it found a conflict on its own resource. The conflict can be found through decoding different SAs and comparing the resources indicated by different SAs.

The vehicle needs to continuously monitor all subframes except its own one. Specifically, the vehicle needs to measure the received signal power of SA of all subframes except its own one. In case of new service arrival, the vehicle will select a non-occupied resource block(set) for it. For example, the vehicle may choose a non-occupied resource of a subframe with the highest received signal power of SA, and also may randomly choose a non-occupied resource from some non-occupied resources in the subframes whose received signal power of SA are higher than a threshold.

In scheme 2, the vehicle chooses a non-occupied resource of a subframe with higher received signal power of SA which means that it is FDMed with nearby vehicles. When the vehicle and its nearby vehicles transmit simultaneously with the same power, the ratio of the inband emission between their resources and the received signal power is relatively small which is helpful for decoding of the receiving vehicle.

**2.2.3 Retransmission Number**

Whether fixed retransmission number will be adopted is also should be determined in resource allocation scheme. Considering the difference between urban and freeway scenarios, the designing of retransmission number can only take into account the scenario with poorer primary transmission BLER if fixed retransmission number is adopted, which results in a waste of system resources. In addition, higher complexity will be introduced to the resource allocation scheme since the differences of service priority and packet size. Different retransmission number is favorable to guarantee the coverage of large packet. Therefore, different retransmission number should be considered for PC5-based V2V while the same minimum resource unit is adopted by different TB sizes.

***Proposal 4: Retransmission numbers should be adaptively configurable.***

# Collision Issues of Semi-Persistent Resource allocation scheme

Collision issue is an important problem in semi-persistent resource allocation scheme. From the above analysis, the only chance the vehicle may find conflict of its own resource by itself is incomplete FDM of SA and success SA decoding. The conflict indication in SA from the third vehicle(s) can inform involved vehicles to adjust resources and then avoid continuous conflict. This kind of conflict indication is preventively and can get the opportunity to adjust conflict resource before the packet loss at the expense of a small feedback overhead.

The third vehicle(s) has a chance to find resource conflict. Specifically, in scheme 1, the third vehicle considers a resource as a conflict resource if the interference power of the resource is higher than a threshold, and it will indicate the confliction in its own SA(also DATA) resource which is nearest by the conflict resource. In scheme 2, the third vehicle considers a resource as a conflict resource if the resource was indicated by several SAs decoded successfully from different vehicles, and also if the DATA of the resource cannot be decoded for many times consecutively while the SA indicating the resource can be decoded successfully, and it will indicate the confliction in its own next SA.

***Proposal 5: Confliction information of Tx UEs noticed by another UE should be broadcasted by collision indication.***

# Measurement Accuracy

According to the analysis of the above chapters, monitoring involves the following three measurement values: the received total power of DATA, the interference power of DATA and the received signal power of SA. The accuracy of each measurement is analyzed as follows:

(1) The received total power is a measurement of the total power instantaneously received in a certain frequency bands, the error is about +/-2.5dB, mainly caused by radio frequency[3];

(2) The interference power is a measurement of the total interference power of system in a certain frequency bands. The receiving vehicle can measure zero power RS if available Similar as aspect 1, the error is about +/-2.5dB [3].

(3) The received signal power of SA is a measurement of SA signaling, the error is about +/-6dB if the SA can be decoded successfully by referencing RSRP measurement accuracy[4].

# Simulation Results for Freeway scenario

The detail simulation assumptions are provided in Table 1.

**Table 1: simulation assumptions**

|  |  |
| --- | --- |
| **Simulation Parameters** | **Value** |
| Deployment scenario | Freeway as defined in [1] |
| Carrier frequency | 5.9GHz |
| System bandwidth | 10MHz |
| Tx Power | 23dBm |
| Antenna gain | 3dBi |
| Traffic Model | Data transmission：   * 100ms period, and periodic traffic as defined in [1] |
| Synchronization | Ideal |
| Carrier Frequency Offset | Ideal |
| Vehicle velocity | 70km/h, 140km/h |
| Pathloss model | As defined in [1] |
| Shadowing fading | As defined in [1] |
| Vehicle density | 21 vehicles/lane/km as defined in [1] for 70km/h  10 vehicles/lane/km as defined in [1] for 140km/h |
| Resource selection method | Semi-persistent scheme 1 given in section 2:   * Small packet(190B) with 16PRB * Big packet(300B) with 32PRB   R12 D2D mode 2:   * SA period 20ms, SA resource pool size is 4ms, and data resource pool size is 16ms |
| Modulation and coding scheme | Data transmission :   * QPSK, Turbo coding, coding rate is 0.50/0.39(respectively for 190Byte and 300Byte, assuming 4 DMRS symbols) |
| Measurement accuracy | Modeled as defined in section 2.4 |



**Figure 2 Performance comparison of 2 resource allocation schemes(freeway 70km/h)**



**Figure 3 Performance comparison of 2 resource allocation schemes(freeway 140km/h)**

With Figure 2 and Figure 3, we have following observations in freeway 70km/h and 140km/h scenario:

1. In general Semi-Persistent Resource allocation scheme shows significant performance gain over R12 mode2 random selection scheme in every distance bin. Since the same link level demodulation curves are used for these two schemes, it can be concluded that the gain comes from well managed resource collision in the former scheme.
2. For Semi-Persistent Resource allocation scheme, channel condition is LOS, so the gain of retransmission can only be shown in larger distance (e.g. 450m for 70Km/h case). In smaller distance, retransmissions consume multiple resource and lead to lower system capacity, which is reflected in PRR. However as vehicle density of freeway 140Km/h scenario is relative low, this impact is not quite obvious.
3. For R12 mode2 random selection scheme, in small distance, multiple transmission out-performs single transmission, because half-duplex issue caused by random selection was improved. In larger distance, interference will have more and more impaction; as multiple transmission cause more interference, it shows lower PRR performance comparing with single transmission.

# Simulation Results for Urban scenario

The detail simulation assumptions are provided in Table 2.

**Table 2: simulation assumptions**

|  |  |
| --- | --- |
| **Simulation Parameters** | **Value** |
| Deployment scenario | Urban as defined in [1] |
| Carrier frequency | 5.9GHz |
| System bandwidth | 10MHz |
| Tx Power | 23dBm |
| Antenna gain | 3dBi |
| Traffic Model | Data transmission：   * 100ms period, and periodic traffic as defined in [1] |
| Synchronization | Ideal |
| Carrier Frequency Offset | Ideal |
| Vehicle velocity | 60km/h |
| Pathloss model | As defined in [1] |
| Shadowing fading | As defined in [1] |
| Vehicle density | 24 vehicles/lane/km as defined in [1] |
| Resource selection method | Semi-persistent scheme 1 given in section 2:   * Small packet(190B) with 16PRB * Big packet(300B) with 32PRB   R12 D2D mode 2:   * SA period 20ms, SA resource pool size is 4ms, and data resource pool size is 16ms |
| Modulation and coding scheme | Data transmission :   * QPSK, Turbo coding, coding rate is 0.50/0.39(respectively for 190Byte and 300Byte, assuming 4 DMRS symbols) |
| Measurement accuracy | Modeled as defined in section 2.4 |



**Figure 4 Performance comparison of 2 resource allocation schemes(Urban 60km/h)**

As shown in Figure 4, in Urban scenario, Semi-Persistent Resource allocation scheme still show some performance gain over R12 mode2 random selection scheme within 200m disance.

# Conclusion

In this contribution, we have following proposals:

***Proposal 1: Semi-persistent resource occupy should be considered for PC5 V2V safety services no matter there is network coverage or not.***

***Proposal 2: The vehicle needs to reselect resource for a service packet when all of its occupied resources are not available for the packet, including the case when the current resource cannot carry the coming larger packet and the case when collision happens.***

***Proposal 3: Both monitoring and SA decode mechanisms should be applied to resource selection.***

***Proposal 4: Retransmission numbers should be adaptively configurable.***

***Proposal 5: Confliction information of Tx UEs noticed by another UE should be broadcasted by collision indication.***

# References

* 1. 3GPP TR 22.885 V0.3.0 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Study on LTE Support for V2X Services(Release 14)
  2. 3GPP TSG RAN WG1 Meeting #82bis, RAN1 Chairman’s Notes V0.3.0
  3. R4-146669, “Meeting minutes for tighten RSRP requirements,” CMCC, Singapore, 6th –10th Oct, 2014
  4. 3GPP TS 36.133 Evolved Universal Terrestrial Radio Access(E-UTRA); Requirements for support of radio resource management