Power Saving Mechanisms for NR Sidelink Communication

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***Abstract*—The evolution of wireless communication technology provides users with higher performance, especially the generation of 5G NR allows greater bandwidth and higher data rate to meet higher service requirements. However, in the context of a high rate, there is greater energy consumption, especially the user equipment at the receiving end is more seriously affected. In addition, NR technology still provides sidelink communication to support V2X services, in which power saving is particularly important. For example, pedestrian-side devices in V2P communication links often have low battery capacity. How to save energy 3GPP has proposed some measures to deal with this problem, and corresponding technologies have also been added to NR sidelink to reduce power consumption. Therefore, based on this, this paper introduces in detail the power saving technologies that can be applied in NR sidelink, include discontinuous reception (DRX), partial sensing and bandwidth part (BWP) and gives the problems that need to be considered in the application of these technologies. To the best of the authors' knowledge, this is the first research paper focusing on power saving under NR sidelink. In this work, in addition to providing a basic description, it also provides a basic result graph in the DRX part.**

Keywords*—*V2X, sidelink, power saving, DRX, partial sensing, BWP

I. INTRODUCTION

Cellular-vehicle-to-everything (C-V2X) allows short-distance communication between users. And thanks to the evolution of wireless network technology, C-V2X supports LTE-V2X and NR-V2X. LTE-V2X was proposed by 3GPP in Release 14 to meet the basic communication requirements, successively supporting more advanced use cases in Release 15, and then formally proposing NR-V2X in Release 16. Both technologies support V2X with two resource allocation modes. One is the centralized allocation mode (Mode3 in LTE-V2X, and Mode1 in NR-V2X) that depends on the base station's network coverage, the other is distributed mode (Mode4 in LTE-V2X, and Mode2 in NR-V2X). In the former mode, the resource allocation management reservation is managed by the base station through uplink (UL) and downlink (DL). While the latter resource allocation is automatically selected by each user, and with the assistance of the SB-SPS algorithm mechanism on the sidelink (SL), the same resource can be selected with sensing procedure and used for several consecutive periods. Moreover, NR technology can provide enhanced capabilities, including support for carrier frequencies up to 100 GHz, carrier bandwidth up to 400 MHz, a maximum data transfer rate of 20 Gbps, ultra-low latency of as low as 1 ms, and enhanced receiver functionality. As a result, the issue of energy consumption for end-user equipment is of increasing concern. Consequently, 3GPP has devoted significant efforts to define 5G with the objective of facilitating high-performance applications with optimized battery consumption.

Based on this the power saving is a crucial issue in both wireless technology and V2X. In addition, in previous work [1-3], most of the power saving research was based on LTE, and only a small part focused on NR, and almost no work focused on NR sidelink power saving. This article will comprehensively introduce measures used to reduce the power consumption of NR sidelink. It also provides potential future application of power-saving technologies in the V2X field and basic results. The remaining is arranged as follows, Section II presents the main power saving technologies for sidelink, Section III provides the basic results and future trends for power saving utilized in V2X communication, and final section is conclusion.

II. POWER SAVING TECHNOLOGIER FOR SIDELINK

A. Discontinuous reception

Discontinuous reception (DRX) was first proposed in the context of LTE [4], in order to solve the problem of a large amount of power consumption caused by the user's continuous detection of PDCCH downlink control information in each subframe. However, when DRX is configured, users can periodically wake up from sleep state. This not only ensures periodic message reception but also conserves power, as the sleep state uses less energy than the active state. In addition, 3GPP has also added DRX functionality to NR as well as sidelink to prolong the battery life of devices [5,6]. The difference is that under LTE technology, DRX utilization only considers the broadcast model assisted by the base station, and focuses on saving the power of the receiving user in the downlink. DRX under NR technology not only takes into account broadcast mode, but also includes multicast and unicast. The sidelink mode was designed for V2X, especially V2P communication included, where P refers to pedestrians or vulnerable road users (VRUs), and the main purpose is to save the battery capacity of human devices such as phones, laptops or other portable equipment. The main parameters of DRX include: $onDurationTimer$, $drx-InactivityTimer$, $shortDRX-Cycle$, $drxShortCycleTimer$ and $longDRX-Cycle$, the meaning and allowed value as shown in Table 1, and the detailed process for DRX is shown in Fig.1 and described as follows.

TABLE I. DRX PARAMETERS

Parameter	Meaning	Allowed value
$onDurationTimer$	the duration at the beginning of a DRX cycle	1, 2, 3, 4, 5, 6, 8, 10, 20, 30, 40, 50, 60, 80, 100, 200, 300, 400, 500, 600, 800, 1000, 1200, 1600. [ms]
$drx-InactivityTimer$	the duration for new transmission	0, 1, 2, 3, 4, 5, 6, 8, 10, 20, 30, 40, 50, 60, 80, 100, 200, 300, 500, 750, 1280, 1920, 2560. [ms]
$shortDRX-Cycle$	Short DRX cycle	2, 3, 4, 5, 6, 7, 8, 10, 14, 16, 20, 30, 32, 35, 40, 64, 80, 128, 160, 256, 320, 512, 640. [ms]
$drxShortCycleTimer$	the duration the UE shall follow the Short DRX cycle	1:1:16
$longDRX-Cycle$	Long DRX cycle	Must be a multiple of $shortDRX-Cycle$.

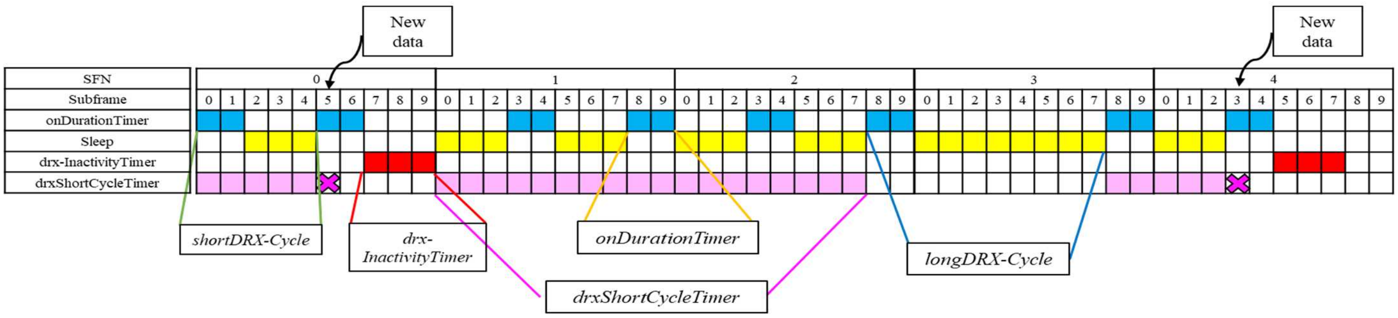

Fig. 1. The procedure of DRX mechanism.

During $onDurationTimer$, if control information indicates a new transmission, the $drx-InactivityTimer$ needs to be started or restarted to ensure sufficient time to receive, like there is a new transmission on SFN0 subframe5 as shown in Fig.1 and the $drx-InactivityTimer$ will work from SFN0 subframe6 to subframe8. Otherwise, the user will go to sleep, like there is no new transmission during active state on SFN0 subframe 0 to 1 as shown in Fig.1, then the user goes to sleep state from SFN0 subframe2 to subframe4. And, if $shortDRX-Cycle$ is configured, the user will first enter a short cycle sleep with the number of short cycles equal to $drxShortCycleTimer$ (SFN0 subframe9 to SFN2 subframe6). If there is still no new data to receive during these periods, then the user will enter a long sleep cycle, and the duration is $longDRX-Cycle$ (SFN2 subframe7 to SFN3 subframe6). While, if only $longDRX-Cycle$ is defined, the user can only go to long cycle sleep and then wake up and repeat. At the same time, there are several control elements that require attention. If a DRX command MAC control element or a long DRX command MAC control element is received, $onDurationTimer$ and $drx-InactivityTimer$ should stop and user move to sleep immediately. And if a long DRX command MAC control element is received, the user needs to move the long cycle sleep state directly.

One of the indicators used to measure the efficiency of DRX is power saving factor (PSF), which is a parameter used to measure the time that the user is in dormant state, also known as the sleep ratio. PSF follows Equation 1, where T_{active}, T_{on} and T_{sleep} are the total time for receiving data, monitoring data and in sleep state, respectively. The PSF of basic DRX procedure as shown in Fig.2. And all allowed parameters of DRX cycle and $onDurationTimer$ are tested, and only $longDRX-Cycle$ is set here, and $drx-InactivityTimer$ is fixed. The figure shows that, for the same $onDurationTimer$, a larger DRX cycle will result in a greater PSF because a larger DRX cycle will enable the user to remain in the sleep state for a longer time. In the same DRX cycle, the larger the $onDurationTimer$, the shorter the PSF will be since the user must remain in the detection state for a longer time.

$$PSF = \frac{T_{sleep}}{T_{active}+T_{on}+T_{sleep}} \quad (1)$$

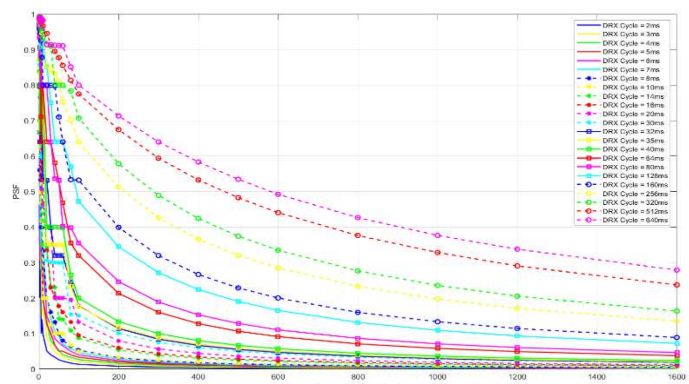

Fig. 2. Power saving factor of the basic DRX procedure.

B. Partial sensing

Resource selection in sidelink is performed by the user with the assistance of sensing-based semi-persistent scheduling (SB-SPS) [6]. The general content is that the user needs to sense all resources before selecting resources, obtain available resources that meet the conditions according to SL-RSRP value, and then randomly select one for the transmission. Furthermore, the sensing time can be set 1000 ms and 100/1100 ms in LTE-V2X and NR-V2X, respectively. A longer sensing duration may exclude high interference resources, while a shorter duration may help reduce delay, but it cannot guarantee resource quality. Moreover, the longer the sensing time will inevitably increase the user's energy consumption. Therefore, the concept of partial sensing arises in response to contemporary needs. In partial sensing, only a subset of the subframes have to be monitored. And the conventional sidelink resource allocation scheme is mode 2 in NR-V2X, the resource pool can be (pre)configured to allow full sensing only. A UE having partial sensing capabilities may perform periodic-based partial sensing (PBPS) and/or contiguous partial sensing (CPS). PBPS can only be performed if the periodic resource reservation is configured in the resource pool. CPS is used to detect aperiodic traffic.

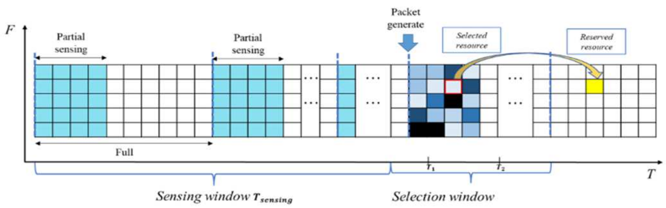

Fig. 3. The procedure of partial sensing.

C. Bandwidth part

The frequency bands that 5G can use are frequency range 1 (FR1) and frequency range 2 (FR2), the former is a low frequency band with a frequency range less than 6GHz, and the latter is a millimeter wave greater than 6GHz. The allowable bandwidth as small as 5 MHz and as large as 400 MHz, if all UEs are required to support larger bandwidths, there will undoubtedly be higher requirements for UE performance. And since high bandwidth means high sampling rate, and higher power consumption. Therefore, it is proposed in NR that different UEs can be configured with different bandwidths part (BWP). As shown in Fig.4, there are four BWP settings, and users can use the corresponding bandwidths at different time depending on service requirements. Each terminal can support up to 4 BWP settings, but only 1 can be active at a time. In this way, the on-demand use of spectrum resources is realized, which is flexible and helps save power. In addition, different SCSs can be used at different BWPs, but only one SCS in one BWP.

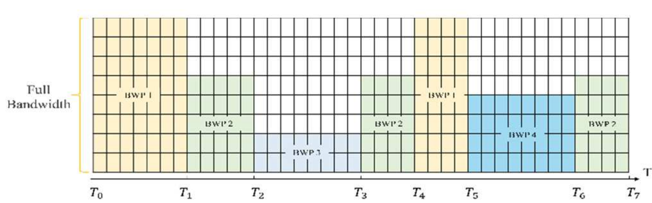

Fig. 4. The exmple of bandwidth part.

III. Utilization of Power Saving Techniques in NR Sidelink V2X Communication

The application of the above technologies in sidelink V2X can be used alone or in combination with each other. When DRX is combined with partial sensing, it is necessary to determine the consistency between the DRX cycle and the sensing duration, and because the sleep state may cause message delay, how to optimize the value of each parameter of DRX and resource reservation interval relationships are important. When DRX is combined with BWP, it is necessary to specify the number of available resources in each BWP setting, and the number of resources may change over time. In addition, because SB-SPS allows users to use the same resource for N consecutive periods, how to determine the impact of BWP settings at different time on the number of periods also needs to be considered. When combining partial sensing and BWP, need to consider changes in the number of resources and time synchronization in each setting. When the three are combined, attention needs to be paid to the above-mentioned issues, including consistency of time, determination of the number of resources, and determination of the periods of use of resources.

Power saving technology is bound to attract significant attention to future development. High-definition and fast applications will definitely cause a lot of power consumption, and how to save power reasonably on the device is urgently. In addition, with the development of V2X technology, the evolution of V2P will greatly improve pedestrian safety and reduce the occurrence of accidents. However, in order to receive and transmit messages in a timely and accurate manner, the power problem of pedestrian devices needs to be overcome. The combination of V2P and power saving technology will increase the momentum for V2X development.

IV. Conclusion

In this work, the power saving techniques that can be applied to NR sidelink communication, including DRX, partial sensing and BWP, are introduced in detail. Furthermore, it explains in particular the points to be paid attention to when applying the above technologies to sidelink communication. And more importantly, combine it with V2X communication supported under sidelink. In addition, we will explore algorithmic research on adaptive parameters and combination with other approaches such as reinforcement learning or deep learning.

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