**3GPP TSG RAN WG1 #104-e R1-2101412**

**e-Meeting, January 25 – February 05, 2021**

**Source: Moderator (OPPO)**

**Title: FL summary for AI 8.11.1.1 – resource allocation for power saving**

**Agenda item: 8.11.1.1**

**Document for:** **Discussion and Decision**

Introduction

In the latest revised Rel-17 WID for NR sidelink enhancement [1], the objective for enhancing RA to reduce UE power consumption in mode 2 has been updated as followed.

|  |
| --- |
| 2. Resource allocation enhancement:   * Specify resource allocation to reduce power consumption of the UEs [RAN1, RAN2]   + Baseline is to introduce the principle of Rel-14 LTE sidelink random resource selection and partial sensing to Rel-16 NR sidelink resource allocation mode 2.   + Note: Taking Rel-14 as the baseline does not preclude introducing a new solution to reduce power consumption for the cases where the baseline cannot work properly.   + This work should consider the impact of sidelink DRX, if any. |

This contribution provides a summary of the submitted contributions, email discussion topics and outcomes during RAN1#104-e meeting.

Collection of agreements / conclusion in RAN1#104-e

Agreements**:**

* Random resource selection is applicable to both periodic and aperiodic transmissions
  + FFS conditions for random resource selection

Topics for email discussion

[104-e-NR-R17-SL-01] Email discussion on resource allocation for power saving– Kevin (OPPO)

* 1st check point: Jan 28
* 2nd check point: Feb 2
* 3rd check point: Feb 4

## Topic #1: PSFCH and S-SSB reception for Type A UE

**Background**: In the last meeting RAN1#103-e, there was an FFS item on whether a Type A UE should be capable of performing PSFCH and S-SSB reception as an exception.

|  |
| --- |
| * + Type A: UE is not capable of performing reception of any SL signals and channels, FFS with exception of performing PSFCH and S-SSB reception (aim to conclude in RAN1#104-e) |

From reviewing contributions submitted to this meeting,

* Main reasons for not to support PSFCH reception for Type A UEs:
  + Minimum reception capability, same as PUE in LTE-V
  + Likely only perform broadcast transmissions as it cannot receive any data, and receiving HARQ feedback is not required in SL broadcast
* Main reason to support PSFCH reception was mainly to improve communication reliability
* The main reason not to support S-SSB reception was that the UE can always sync to network or GNSS timing, same as in LTE-V
* The main reason to support S-SSB reception was that S-SSB transmitted from UE synchronized to eNB/gNB is prioritized over GNSS

### Proposals before 1st check point (Jan 28)

**Proposal 1 (for conclusion):**

* PSFCH reception is not supported for Type A UE
* S-SSB reception is not supported for Type A UE
* SL reception Type B is additionally added
  + Type B: Same as Type A with an exception of performing PSFCH and S-SSB reception

|  |  |
| --- | --- |
| **Company** | **Comments** |
| OPPO | Agree |
| Fraunhofer | Agree |
| Apple | Agree |
| Ericsson | First of all, we would like to remark that the UE Type definition, i.e., A, D (or B), are not related to UE capabilities but just as a reference for evaluation and designing the power saving features.  We do not think that having S-SSB reception support but not having PSFCH reception support is justified from a product perspective. If companies think that there should be a UE that is not capable of receiving any signal, we can be fine with an additional UE Type where neither S-SSB nor PSFCH can be received.  Therefore, we are OK to define two types of UE, i.e., Type A and Type B as in proposal 1, to be used as a baseline to define and design power saving features. |
| CATT | Since these types are used as the reference for evaluation and designing of SL power saving features in R17, it’s better to add another type( B1 )which supports S-SSB reception but not PSFCH reception. |
| Qualcomm | We agree with the proposal and would like to reiterate that these types are only for evaluation and to facilitate discussion but do not define UE capabilities. |
| Lenovo&MM | Agree |

### Proposals before 2nd check point (Feb 2)

FL observations and comments based on inputs received in Sec. 3.1.1:

* TBD

### Proposals before 3rd check point (Feb 4)

FL observations and comments based on inputs received in Sec. 3.1.2:

* TBD

## Topic #2: Periodic-based partial sensing (determination of Y candidate slots for periodic transmission)

**Background**:



Figure 1

In R14 LTE sidelink, the partial sensing scheme is optimized for periodic traffic type only, where

* UE performs monitoring of subframes in sensing occasions according to for a set of Y candidate subframes determined within the resource selection window
* The smallest denominator was set to 100ms for Pstep and 20/50ms reservation periodicities were not taken into consideration.
* Period sensing occasions within the sensing window are determined by the kth bit of the higher layer parameter *gapCandidateSensing*.

From reviewing contributions submitted in this meeting, the above Rel-14 LTE sidelink partial sensing scheme can be taken as the baseline, but some enhancements are needed for a power constrained UE configured with partial sensing to perform periodic transmission in NR sidelink mode 2. First of all, it is aimed to confirm the same principle as in LTE-V that a UE first determines a set of Y candidate slots within the resource selection window when resource selection is triggered in slot n.

### Proposal before 1st check point (Jan 28)

**Proposal 2**: If UE is configured to perform partial sensing and provided with a resource reservation interval () from higher layer, it is up to UE implementation to determine Y candidate slots within a resource selection window, where

* The resource selection window is defined in the same way as in R16 NR-V2X according to step 1 [TS 38.214 Sec. 8.1.4].
* UE determination of Y candidate slots should exclude slots in which its own SL and UL transmissions occur in the resource selection window.
* Due to integer multiple of resource reservation periods, UE determination of Y candidate slots should exclude slots that would coincide with its own SL and UL transmissions within the corresponding periodic sensing occasions.
* Periodic sensing occasions that correspond to the set of Y candidate slots should align with the SL-DRX ON duration as much as possible (if configured) and/or as early as possible to maximize number of contiguous sensing slots before the resource selection trigger in slot n.
* FFS min and max Y candidate slots should be applied (e.g., a range of Y values per priority level)

|  |  |
| --- | --- |
| **Company** | **Comments** |
| OPPO | We are OK with the 1st sub-bullet. Not support for the other bullets   * For the 2nd and 3rd bullet: UE should not exclude the slot that is used for UL transmission. Whether to prioritize between UL and SL is up to UE hardware implementation. If there are two sets of RF, UE can transmit UL and SL (if they are in different carrier) at the same time, in that case, there is no necessary to exclude the slots for UL transmission. In legacy resource exclusion procedure of sensing, only the slots for SL transmission is considered, not for UL transmission. We suggest to follow legacy behaviour. * For the 4th bullet: the relationship between DRX and sensing is discussing in another email thread [104-e-NR-R17-SL-LS-01], it is not necessary to discuss that here again. * For the last bullet: in LTE-V2X, only min Y slots was applied. We are not convinced to apply max Y slots. No intension to introduce additional feature unless performance gain can be justified. |
| Fraunhofer | For the determination of the selection window for periodic transmissions, we prefer to stick to the same procedure as defined in Rel-16. Exclusions based on UL transmissions can be left out.  We agree that the candidate slots should align with the DRX ON duration as much as possible. |
| Apple | We are fine with the main bullet and the first sub-bullet.  For the second and third sub-bullets, we share the views from OPPO that only SL transmissions slots should be considered. The prioritization between SL and UL can be handled separately with the existing R-16 rule.  For the fourth sub-bullet, we are fine in general. But some clarification is needed, such as how to quantify “as much as possible”, “as early as possible”?  For the fifth sub-bullet, we think only the lower bound on Y can be applied, and we do not mention the example that range of Y is per priority level. |
| Ericsson | We do not see the need to introduce a new scheme for periodic transmissions. We propose to reuse the LTE mechanism (where the 2nd and 3rd sub-bullets do not need to be specified and can be left to UE implementation) and discuss the potential enhancements needed to address the periodicities introduced in NR (see Section 3.3.1) and any other potential issue.  We have two comments regarding the sub-bullet on DRX. First, it is probably a good idea to leave the discussion for later, when more about the DRX procedure is known. In general, a wider discussion on the connection between SL DRX and partial sensing has to take place. Besides that, we believe that aspects may be left to UE implementation, like for the other bullets. |
| InterDigital | When SL DRX is not configured, we agree that determination of Y can be UE’s implementation. But when SL DRX is configured, Y should be selected based on the DRX ON duration of the reception UE(s) which is the target of the transmission, instead of the UE itself.   * For the 2nd and 3rd, we prefer to reuse the R16 procedure, in which SL Tx slots can be considered but not UL slots. * We agree with the principle of the 4th bullet that periodic sensing should align with the SL DRX ON duration as much as possible (if configured). * For the 5th bullet, we do not see the motivation to consider Y max.   We assume that this proposal is applicable to the first TB of periodic traffic.   * should be greater than 0ms. |
| CATT | In principle we should reuse Rel-16 procedure as much as possible. For this particular proposal, we don’t agree with the sub-bullet regarding DRX alignment. In fact, it’s more efficient that sensing operation is allowed in SL DRX inaction duration without the restriction of its own SL DRX configuration. We should discuss the details related to DRX issue. |
| Qualcomm | We think that we need to discuss the different scenarios (Tx UE doing power savings, Rx UE doing power savings, or both UEs) and then discuss the general design(s) with evaluation results prior to discussing this level of detail.  For example, if the transmitter isn’t receiving data, e.g. P2V-only application, then it isn’t clear why some of the points would apply, e.g. the one about DRX.  Similarly, when both UEs are doing power savings, it is more efficient to fully align their DRX and partial sensing windows.  We should also consider whether some aspects need to specified or can be left up to UE implementation. |
| Lenovo&MM | Rel-14 LTE sidelink partial sensing scheme can be taken as the baseline and select the resource(s) for periodic transmission. FFS, the sensing scheme for aperiodic transmission  The relationship between partial sensing and SL DRX on duration should be further clarified such that the partial sensing slots are defined by the partial sensing configuration or SL DRX on duration. |

### Proposals before 2nd check point (Feb 2)

FL observations and comments based on inputs received in Sec. 3.2.1:

* TBD

### Proposals before 3rd check point (Feb 4)

FL observations and comments based on inputs received in Sec. 3.2.2:

* TBD

## Topic #3: Periodic-based partial sensing (determination of periodic sensing occasions for periodic transmission)

**Background**: Continuation from Topic #2, as it is mentioned that in R14 LTE-V the smallest denominator was set to 100ms for Pstep and 20/50ms reservation periodicities were not taken into consideration, the whole R14 partial sensing was based on an assumption that the reservation periodicity of PUE’s transmission will always be in an integer multiple of 100ms. And k (*gapCandidateSensing*) is (pre-)configured according to the set of possible resource reservation periods allowed in the resource pool. In R16 NR sidelink, the set of up to 16 (pre-)configured possible resource reservation periodicities can be much smaller ([1:99], 100, 200, …, 1000) to cater for wider range of traffic patterns especially ones with short latency requirement. As such, it would be very difficult and dangerous to continue assuming a common denominator can be used in periodic-based partial sensing for NR sidelink. As such, the k value will no longer need to be based on a bitmap which identifies a set of periodic sensing occasions that are integer multiple of 100ms to cover other allowed reservation periodicities in the resource pool.

### Proposals before 1st check point (Jan 28)



Figure 2

**Proposal 3**: If UE is configured to perform partial sensing and provided with a resource reservation interval () from higher layer, the UE monitors slots of a set of periodic sensing occasions, where a periodic sensing occasion is a set of slots according to if is included in the set of Y candidate slots.

* is a periodicity value from the configured set of possible resource reservation periods allowed in the resource pool (*sl-ResourceReservePeriodList*)
  + Option 1: corresponds to all values from *sl-ResourceReservePeriodList*
  + Option 2: corresponds to a subset of values from *sl-ResourceReservePeriodList*
    - FFS how to determine the subset
* k equals to
  + Option 1: Only the most recent sensing occasion for a reservation period (k=1)
  + Option 2: The two most recent sensing occasions for a reservation period (k = [1, 2])
  + Option 3: All possible sensing occasions before
  + Option 4: FFS others

|  |  |
| --- | --- |
| **Company** | **Comments and option selection for and k** |
| OPPO | We are OK with the proposal in principle. While it needs to clarify that down selection from these options should be considered later. |
| Fraunhofer | We agree with the proposal as such, with the option to decide on the and k values as FFS. |
| Apple | We are fine with the proposal with modification.  For Preserve, we support Option 2. If Option 1 is selected, then the sensing efforts will be large especially with small resource reservation periods. For example, if the resource reservation period is 1 ms, then no power saving gain can be achieved at all. Here, we may configure a resource reservation period threshold, and only apply the configured resource reservation periods which are larger than the threshold.  For k, we prefer to add an option that the k is by (resource pool) configuration. Any integer value between 1 and a configured value is used to determine the number of sensing occasions. This is restricted within the sensing window [n-T0, n-Tproc,0). |
| Ericsson | Regarding Preserve, we think that the easiest thing is to have full configurability (from the values in *sl-ResourceReservePeriodList*), avoid a fruitless discussion, and focus on more important issues.  Moreover, for the values of k only Option 1 should be considered. That is aligned with the procedure in 8.1.4. |
| InterDigital | We are OK with the proposal |
| CATT | We are OK to discuss the selection of and k values later. |
| Qualcomm | Similar to Proposal 2, we think we need to consider the general principle prior to discussing the details. |
| Lenovo&MM | For , option 1 is our preference.  For k, option 1 is our preference. |

### Proposals before 2nd check point (Feb 2)

FL observations and comments based on inputs received in Sec. 3.3.1:

* TBD

### Proposals before 3rd check point (Feb 4)

FL observations and comments based on inputs received in Sec. 3.3.2:

* TBD

## Topic #4: Contiguous-based partial sensing (when is provided by higher layer) – re-evaluation and pre-emption checking for periodic transmission

**Background**: Continuation from Topic #3, partial sensing for a periodic transmission in a resource pool that allows aperiodic transmissions (which is all SL Tx pools), should also take into consideration of resource reservation by aperiodic transmissions. In various submitted contributions to this meeting, it is proposed that an additional sensing (short-term sensing/extended partial sensing) should be performed by the UE for periodic transmissions to take into account of aperiodic resource reservations.

Furthermore, it was agreed in the last meeting (RAN1#103-e) that “re-evaluation and pre-emption checking are supported by UEs that perform sensing”, it is also proposed in contributions that the additional sensing can also be used for the purpose of re-evaluation and pre-emption checking.

### Proposals before 1st check point (Jan 28)



Figure 3

**Proposal 4:** If UE is configured to perform partial sensing and provided with a resource reservation interval () from higher layer, the UE additionally monitors slots

* Option 1: from slot ty0 -32, where ty0 is the first slot in the set of Y candidate slots, until before the last transmission for the TB, except for slots in which its own SL and UL transmissions occur
* Option 2: from slot n-32 until before the last transmission for the TB, except for slots in which its own SL and UL transmissions occur

|  |  |  |
| --- | --- | --- |
| **Company** | **Option 1, 2 or others** | **Comments** |
| OPPO |  | Firstly, it needs to clarify in the main bullet that this proposal targets for period traffic. For aperiodic traffic, UE cannot predict the arriving time of the packet so that it cannot sense the slots before slot n (packet arrival time).  In our view, considering the aperiodic traffic in the RP, UE should do short term sensing (e.g., 32 slots) before slot n. furthermore, UE should do short term sensing (e.g., 32 slots) before each selected resource for re-evaluation/pre-emption check.  For option 1 and 2, as we commented in proposal 2, UL transmission should be removed. Furthermore, for option 1, whether the UE should monitor from ty0 -32 depends on whether the time position of the corresponding slot is before or after slot n. For option 2, if the time gap between slot n and the first selected resource is > 32 slots, UE does not need to sense the slots between [n+1, ty0 -32]. |
| Fraunhofer |  | We prefer to retain the procedure used in Rel-16 for re-evaluation/pre-emption. Based on the proposal, exclusions based on UL transmissions can be removed. |
| Apple |  | We have the following comments about the proposal:   1. We assume this is for resource re-evaluation and pre-emption checking. We may mention it in the proposal. 2. Why “resource reservation interval” is mentioned in the main bullet? Do you intend to mean the periodic resource reservation? Note that for aperiodic resource reservation, the resource reservation interval of 0 ms is also provided by higher layer. 3. In the figure, why a UE starts the contiguous-based sensing for resource re-evaluation before n (slot for resource selection) in the case of partial sensing? A UE is not supposed to perform sensing for resource re-evaluation until the resource is selected. Here, is the slot n the initial periodic data arrival time or the data arrival time after one period? 4. We should consider another option that the sensing for resource re-evaluation could start from m-32 until m-T3 to avoid collision with aperiodic reservation from another UE, where m is the slot of the selected resource. |
| Ericsson |  | We do not agree with this proposal. First, we should anchor the behaviour of the sensing mechanism for aperiodic transmissions (see 3.5) and once it has been agreed, we can revisit the issue defined in this proposal. |
| InterDigital |  | For resource (re)selection, the UE should perform short-term sensing before slot n.  For pre-emption and re-evaluation, the UE should perform short-term sensing from slot n+1 to m-T3. |
| CATT |  | The intended use case of the proposal should be further clarified. Also, we think It’s better to discuss this proposal after detail mechanism of sensing has been decided. |
| Qualcomm |  | We prefer to discuss this issue after Proposals 4 and 5 are settled. |
| Lenovo&MM | Option 1 | Option 1 is acceptable to us. |

### Proposals before 2nd check point (Feb 2)

FL observations and comments based on inputs received in Sec. 3.4.1:

* TBD

### Proposals before 3rd check point (Feb 4)

FL observations and comments based on inputs received in Sec. 3.4.2:

* TBD

## Topic #5: Contiguous-based partial sensing (when is NOT provided by higher layer) – re-evaluation and pre-emption checking for aperiodic transmission

**Background**: For UE with aperiodic traffic, data packets could arrive at any time for SL transmission without any prior knowledge. Therefore, it is not possible for a power constrained UE to predict and perform monitoring of slots before the resource selection trigger. From reviewing the contributions submitted to this meeting, in general, there are two partial sensing schemes, but both based on sensing in a contiguous manner.

### Proposals before 1st check point (Jan 28)

|  |  |
| --- | --- |
| Option 1 | Option 2 |

**Proposal 5:**

* When resource selection is triggered in slot n and resource reservation interval () is NOT provided from higher layer,
  + Option 1: In slot n, UE performs random resource selection
    - For a UE that performs sensing and for the purpose of re-evaluation and pre-emption checking, the UE monitors slots starting from n+1 until before the last transmission for the TB, except for slots in which its own SL and UL transmissions occur
  + Option 2: In slot , UE reports a set of candidate single-slot resources (*SA*) to the higher layer after performing resource exclusion based on sensing results obtained during for resource selection within the resource selection window .
    - Alt. 1: is fixed
    - Alt. 2: is dependent on the remaining PDB
    - Alt. 3: FFS
    - Alt. 4: is based on received HARQ feedback
    - For re-evaluation and pre-emption checking, the UE monitors slots starting from n+1 until before the last transmission for the TB, except for slots in which its own SL and UL transmissions occur
* Option 1 and Option 2 are both supported, or only one option is supported
  + FFS how UE selects Option 1 or 2 when both are supported

|  |  |  |
| --- | --- | --- |
| **Company** | **Option 1, 2 or both** | **Comments** |
| OPPO | Option 1 and option 2 | We are OK with these two options in principle. While we suggest to discuss the details later. |
| Fraunhofer | Both | We are fine with the proposal, since both option 1 and 2 are possible actions that can be done by type D UEs. |
| Apple | Both with modifications | In both options, the sensing for resource re-evaluation could be starting from m-32 to m-T3 just to avoid the collision with aperiodic resource reservation. Specifically,  In Option 1, the sensing does not start at n+1, rather start from m-32.  In Option 2, the sensing for resource selection is from n+1 to n+TA-Tproc,1 and the sensing for resource re-evaluation is from m-32 to m-T3. |
| Ericsson | Option 1 and Option 2 | We are OK to support both options and the conditions to trigger each of them when supported by the UE, but at this point further discussion on is necessary. Thus, our proposal is to include Alt. 4 in in the Proposal 5. (Alt. 4: T\_A is based on received HARQ feedback) |
| InterDigital | Both | We are ok with the proposal and support both options. |
| CATT | Both (but details needs to further modified) | Details needs to be further discussed. Particularly, for option 1 we think it should be FFS on whether to support re-evaluation and pre-emption for UEs perform sensing but operate random selection. This incurs more power consumption with no performance gain. |
| Qualcomm | Both options | We observed that both schemes provide significant performance for the power saving UE over random selection only. We also note that Option 1 could be viewed as a special case of Option 2 where TA = 0.  We share the view that details should be discussed later and suggest a more general proposal to agree on the principle without yet defining the precise timeline. That discussion would also include what can be left up to UE implementation. |
| Lenovo&MM | Both options | Both options should be considered at this stage. |

### Proposals before 2nd check point (Feb 2)

FL observations and comments based on inputs received in Sec. 3.5.1:

* TBD

### Proposals before 3rd check point (Feb 4)

FL observations and comments based on inputs received in Sec. 3.5.2:

* TBD

Contribution summary

## Partial sensing for periodic transmissions

* Selection of Y candidate slots
  + LTE-V based selection of Y ≥ min candidate slots according to Tx priority, CBR level, HARQ enabling, subcarrier spacing or re-evaluation/pre-emption enabling: [2][5][8][9][14][17][20][21][22, multiple sets of Y][25][29]
  + Same as resource selection window, which size is left up to UE implementation, subject to T2min constrain on minimum size [13]
  + If HARQ feedback is enabled, HARQ RTT related timing restriction should be considered when determining the candidate slots [17]
* Determination of sensing slots
  + Slots that belong to (y – k\*reservation period), where y is included in Y candidate slots [2][3][4][8][11][12][13][14][28][22][25][29][34][35]
    - K=1, multiple, or by configuration
    - Reservation period according to the configured set of periodicity in the resource pool, or a subset
* X% of candidate resources is based on the total number candidate resources only within the Y candidate slots [2][25]
* X% for partial sensing UE is separately configured from that for full sensing UE [9]
* A short-term / extended sensing / continuous sensing (e.g., 32 slots) to account for aperiodic traffic [2][3][4][6][10][11][12][13][17][18][19][21][22][24][25][27][28][30][33][34][35][29]
  + Option 1: before 1st candidate slot
  + Option 2: before the resource selection in slot n
* Introduce reduced adaptive sensing windows with varying sensing intervals across time to enhance the UE's capability to save power as well as achieve adequate sensing results [16]

## Partial sensing for aperiodic transmissions

* Scheme 1: At packet arrival in slot n, UE performs random selection as well as sensing for re-evaluation and pre-emption checking until the last retransmission of a TB [2][9][10][13][14][22][32]
* Scheme 2: At packet arrival in slot n, UE performs sensing for a short period (e.g., 32 slots), then select resources based on sensing results. UE continue sensing for re-evaluation and pre-emption checking until the last retransmission of a TB [2][4][9][12][13, UE implement][14][29][32][35]
* Selection between scheme 1 and 2 (or adaptive sensing window) is based on HARQ feedback [14][30]

## Random resource selection

* When random selection is performed, re-evaluation and pre-emption checking is disabled [3][5]
* Higher priority is assigned to the resources which is randomly selected by a UE, to preserve these selected resources from being pre-empted by UEs performing sensing [6][12]
* When a resource is randomly selected, the same resource is reused periodically based on the SPS resource reservation procedure [9]
* Random resource selection should be applicable to both periodic and aperiodic transmissions [13]
  + random resource selection is applied for initial transmission and all retransmissions of a TB
* Conditions in which random resource selection can be applied
  + Random resource selection is enabled in a SL resource pool [13][22]
  + One of the following criteria is met [13]:
    - UE does not have sidelink RX chain to perform sensing (i.e. sidelink TX only UE)
    - Battery level is below preconfigured threshold [22]
  + Tx priority is within a preconfigured range of values [24]
  + Sensing accuracy [22]
  + Selection between random resource selection and partial sensing according to the system load [7]
  + Selection between random resource selection and partial sensing based on a pre-configured condition, such as SL congestion, packet reliability [12][22][27]
* UE performing random resource selection should respect PSSCH to PSFCH HARQ time gap, if UE monitors PSFCH and requests for sidelink HARQ feedback, otherwise the gap can be ignored [13]
  + UE ensures a minimum time gap Z between any two selected resources of a TB where a HARQ feedback for the first of these resources is expected
* Random resource selection preserves sidelink resource reservation signalling principle as defined for sidelink transmissions in Rel.16 [13]
  + Maximum distance in logical slots for the first and last sidelink transmissions in a SCI is less than 32
* For random resource selection, the resources are selected among the partial sensing slots [9]
* PSFCH resources associated with the randomly selected resources are separately configured from those for full/partial sensing based selected resources [9]
* Pseudo-random frequency hopping for periodic reservation based on CRC bits of the associated PSCCH [10]
* The frequency that a UE performs random resource selection should be restricted [27]
* For random resource selection, consider partitioning of candidate SL resources to reduce collision probability [28]
* Enhancements for random resource selection [35]:
  + Option 1: Restrict priority level for transmissions
  + Option 2: sensing UE excludes random selection UE’s reserved resources regardless of priority
  + Option 3: random selection based on a resource pattern

## Re-evaluation and pre-emption checking

* For the UE performing sensing, support re-evaluation for random selection resources [24] [29]
* Conditions for performing re-evaluation and pre-emption checking
  + When multiple NACKs are received [3]
  + ACK/NACK ratio is below a threshold [9]
  + Re-evaluation or pre-emption checking is (pre-)configured [9]
  + Number of partial sensing slots before resource (re)selection triggering is below a threshold [9]
  + TX priority value is higher than the pre-emption priority value [9][24]
  + Interference/congestion level is above a threshold [9]
* Re-valuation/pre-emption is configurable for Type D UEs [8]
* The pre-emption priority used by power saving UE is separately (pre-)configured from that used by full-sensing UE [9]
* When performing resource re-evaluation or pre-emption, burst type of resources are prioritized in resource (re)selection [9]
* The transmission resources reserved by power saving UEs are not pre-empted. Transmission resources reserved for transmissions destined to power saving sidelink UEs are not pre-empted [11]
* Due to re-evaluation and pre-emption, UE can re-select resources in noncandidate slots if aperiodic resource sensing is performed [2]
* For semi-persistent reservation, the UE can skip pre-emption for certain reservation periods. The number of skip periods is (pre-)configured per priority [24]
* UE is only required to sense in the slots in which the SL transmission may reserve a resource overlapping with the resource to be pre-empted or re-evaluated [27]
* Re-evaluation and pre-emption is based on reduced sensing performed between the UE’s resource selection time and resource re-evaluation/pre-emption checking time [29]
* Supports re-evaluation and pre-emption at least on subsequent periods [30]

## Type A UE performing PSFCH and S-SSB reception

* PSFCH (no) / S-SSB (no): [3][6][15][21][26]
  + Reasons: maximum power saving, same as in LTE-V,
* PSFCH (no) / S-SSB (yes): [7][35]
  + Reasons: support only broadcast which does not require HARQ feedback, S-SSB from UE synchronized to eNB/gNB is prioritized over GNSS
* PSFCH (yes) / S-SSB (yes): [9][12][14][22, S-SSB not considered][31]
  + Reasons: reliable communication, power saving from less retransmissions, essential for communicating with others,

## Impact of SL-DRX on partial or full sensing

* SL-DRX parameters should be exchanged between Tx and Rx UEs for the purpose of aligning resource selection of Tx UE and the DRX ON period of Rx UE [2][5][6][9][11][18][27][29][30]
* If sensing is limited within DRX ON period, sensing accuracy and resource collision will be affected [2][3]
* PSCCH monitoring for sensing should be allowed during SL-DRX inactive period [2][3][5]
* DRX may increase latency for full sensing UEs [7]
* SL DRX and partial sensing are independent operation. SL DRX and partial sensing operation are specified separately from each other in Rel.17 [9][21][24]
* If the sensing is not restricted by DRX operation, then there will be no impacts on the resource selection [10]
* The full-time SL sync search should be avoided during SL DRX operation for power saving [12]
* The design of SL DRX cycle needs to ensure that UE partial sensing behavior is respected (i.e. UE wake up time intervals for the purpose of partial sensing need to be aligned with On duration intervals, as well as traffic characteristics) [13][17][21][22]
* No separate TX/RX alignment procedure is specified in RAN1 for partial sensing [14]
* The (partial) sensing operation and the resource selection performed by a UE takes into account the active time defined by SL DRX configuration, if (pre-)configured [14][16][17][20][21][29][30]
* The very initial transmission should be within the current “Active Time” of the Rx UE [17]
* It should be left to the UE’s implementation to decide whether sensing is limited to its DRX active time interval or it can also be performed outside of the active time [32]
* Consider PSCCH is used to align sidelink DRX wake-up time between TX UE and RX UE(s) [28]
* Sensing slots corresponding to selection target shall be included in DRX on-duration of the TX-UE [35]
  + If a sensing slot is not included in DRX on-duration, the corresponding selection target is excluded from identified resource set of the resource allocation
  + If a selection candidate is not included in DRX on-duration of RX-UE, the candidate is excluded from identified resource set of the resource allocation
  + If PSFCH occasion corresponding to a selection candidate is not included in DRX on-duration of PSCCH/PSSCH TX-UE, the candidate is excluded from identified resource set of the resource allocation

## Resource pool configuration with mixed RA

* A priority threshold is configured for a resource pool, at which reduced sensing UEs can select resources in a pool configured for mixed types of RA [3]
* Power constrained UEs occupy a sub-pool of the shared resource pool [7][11]
* Separation of resources is (pre-)configured where a specific portion of resource pool is allocated for each resource allocation mechanism (e.g., smaller bandwidth/frequency resource) [14][15][16][20][24]
* Different RSRP thresholds or increased RSRP threshold value is (pre-)configured for different resource selection scheme [25][29]
* UE reports whether one candidate resource overlaps with resources reserved by random resource selection UE to higher layer for further resource selection [25]
* A non-sensing UE sharing a resource pool with sensing UEs shall select/reserve resources for consecutive transmissions with a separation/gap large enough so that the sensing UE can react accordingly if a collision happens [14][24]
* Resource pool should not be shared among random selection UE and UEs configured with other RA schemes, unless random selection UE can reserve resources by sending reservation indication [21]

## Wake-up / go-to-sleep signals for SL-DRX

* Introduce wake up / go to sleep indication on sidelink (or keep sleep / keep awake indication) signals/triggers for UE power saving management [2][12][13][18][23]
  + Reuse the existing R16 WUS/GTS principle [2]

## Congestion control for partial sensing

* CBR could be measured with fewer OFDM symbols in a slot to save power [3]
* Calculation of CBR/CR should take the reception time (e.g., DRX ON duration) into account [6][22]
* For UE with no PSCCH/PSSCH reception capability or number of sensing slots is less than a threshold, a (pre-)configured CBR value is used for PHY parameter selection [9]
* CBR measurement calculation is based on number of sub-channels of the partial sensing slots within the measurement window [9]
* Restriction of transmission parameter based on the CBR measurement is performed per active period of a DRX cycle [18]
* The evaluation of CR and the definition of CR\_limit for power saving resource allocation schemes reuse the design for full sensing resource allocation schemes [29]

## Inter-UE coordination for power saving

* Inter-UE coordination should be used for power saving as well, where a UE selects resources based on coordination / assistance information from another UE [3][7][16][18][19][20][22][31]
* Inter-UE signaling to negotiate sidelink resources (e.g. PSCCH monitoring intervals) where UE(s) are expected to monitor PSCCH resources and perform sensing for sidelink communication [13]
* The resource allocation for power saving considers new aspects introduced in Rel-17 NR sidelink such as inter-UE coordination, sidelink DRX and so on [28]
* Support a UE informing other UEs of its reception and transmission availability [32]

## Indication of power-saving UE transmissions

* Using a reserved bit in SCI to indicate the type of UE or RA scheme [9][10][11][24]

## Other techniques for power saving

* Power control
  + SL pathloss based OLPC for PSFCH [6]
* UL/SL prioritization procedure
  + A (pre)configured offset value can be added to the priority value of P-UE’s SL TX to avoid the frequent dropping [9]
* SL processing and transmission capability
  + Support of PSSCH TX with 2 layers, high modulation order, and SL-SSB TX can be reduced [9]
* Power saving in SL data reception
  + A monitoring interval and a retransmission interval in a period are (pre-)configured. The first transmission of a TB is always limited in the monitoring interval. Only the retransmissions of a TB are allowed in the retransmission interval. Thus, a receiving UE only receives/decodes PSCCHs/PSSCHs in the monitoring interval and then determines whether to turn on in the retransmission interval [10]
* Longer PSFCH period for power limited UE [6][4]
* The CSI reporting procedure and HARQ-ACK based (re)transmission should be enhanced to ensure that the CSI report/retransmission can be received by the CSI requesting UE with discontinuous reception [6]
* Reserved bits of SCI format 1-A can be used to transmit some bits of the destination ID (shortened destination ID) [7][16]
* The second stage SCI contains a field to indicate when the UE is expected to receive the next transmission [7]
* NR supports adaptation(switching) of sidelink power saving resource allocation schemes in time (i.e. b/w random, partial or full sensing-based resource selection) [13][12][22][8]
* Introduce the notion of sidelink power saving states / modes and associate with these states / modes certain set of sidelink power saving features developed in Rel.17 [13]
* Sidelink bandwidth / slot adaptation for transmission / reception is supported as a power saving feature [13]
* To utilize the geographical location of group UEs and destination-L2 ID, as the reference parameters for partial sensing, in the application layer connection-less group. And to utilize the destination-L2 ID, as the reference parameter for partial sensing, in the application layer managed group [17]
* Cross-slot scheduling enhancement for power saving purpose [18]
* Dedicated BWP can be configured for power saving UEs and S-SSB BW should be (pre-)configured within the dedicated BWP [21]
* Reduced max number of retransmission per TB for power saving UEs [22]
* Support different initial RSRP thresholds for resources reserved by PUE [24]
* An upper limit of the number of RSRP threshold increments or the maximum value of increased RSRP threshold can be configured. When the upper limit or the maximum value is reached, UE increases the number of determined set of slots [25]
* Support an adaptive frequency search space based on the channel activity, VRU traffic conditions [30]
* Support sidelink cross-slot scheduling allowing only decoding 2nd and/or 3rd retransmission(s) after a minimum configured time gap [30]

References

1. [RP-202846](http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_90e/Docs/RP-202846.zip) WID revision: NR sidelink enhancement LG Electronics
2. [R1-2100141](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100141.zip) Power saving mechanism in NR sidelink OPPO
3. [R1-2100205](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100205.zip) Sidelink resource allocation to reduce power consumption Huawei, HiSilicon
4. [R1-2100309](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100309.zip) Considerations on partial sensing in NR V2X CAICT
5. [R1-2100351](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100351.zip) Discussion on resource allocation for power saving CATT, GOHIGH
6. [R1-2100466](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100466.zip) Resource allocation for sidelink power saving vivo
7. [R1-2100486](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100486.zip) Power consumption reduction for sidelink resource allocation FUTUREWEI
8. [R1-2100492](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100492.zip) Discussion on resource allocation for power saving Zhejiang Lab
9. [R1-2100517](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100517.zip) Discussion on resource allocation for power saving LG Electronics
10. [R1-2100538](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100538.zip) Sidelink resource allocation for power saving Nokia, Nokia Shanghai Bell
11. [R1-2100546](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100546.zip) Resource allocation for power saving TCL Communication Ltd.
12. [R1-2100612](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100612.zip) Resource allocation for sidelink power saving MediaTek Inc.
13. [R1-2100672](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100672.zip) Design of sidelink power saving solutions Intel Corporation
14. [R1-2100687](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100687.zip) Resource allocation mechanisms for power saving Ericsson
15. [R1-2100696](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100696.zip) Discussion on Sidelink Resource Allocation for Power Saving Panasonic Corporation
16. [R1-2100701](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100701.zip) NR Sidelink Resource Allocation for UE Power Saving Fraunhofer HHI, Fraunhofer IIS
17. [R1-2101788](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2101788.zip) Considerations on partial sensing and DRX in NR V2X Fujitsu
18. [R1-2100766](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100766.zip) Sidelink resource allocation for Power saving Lenovo, Motorola Mobility
19. [R1-2100801](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100801.zip) Discussion on sidelink resource allocation for power saving Spreadtrum Communications
20. [R1-2100870](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100870.zip) Discussion on sidelink resource allocation for power saving Sony
21. [R1-2100924](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100924.zip) Discussion on sidelink power saving ZTE, Sanechips
22. [R1-2100946](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100946.zip) Discussion on resource allocation for power saving NEC
23. [R1-2100962](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100962.zip) Discussion on resource allocation for power saving Hyundai Motors
24. [R1-2100981](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100981.zip) Resource allocation for power saving InterDigital, Inc.
25. [R1-2101060](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2101060.zip) Discussion on resource allocation for power saving CMCC
26. [R1-2101086](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2101086.zip) Discussion on resource allocation for power saving ETRI
27. [R1-2101097](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2101097.zip) Discussion on sidelink resource allocation for power saving Xiaomi
28. [R1-2101231](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2101231.zip) On Resource Allocation for Power Saving Samsung
29. [R1-2101357](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2101357.zip) Sidelink Resource Allocation for Power Saving Apple
30. [R1-2101400](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2101400.zip) Discussion on Reduce Power Consumption for Sidelink ROBERT BOSCH GmbH
31. [R1-2101422](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2101422.zip) On NR Sidelink Resource Allocation for Power Saving Convida Wireless
32. [R1-2101485](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2101485.zip) Power Savings for Sidelink Qualcomm Incorporated
33. [R1-2101550](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2101550.zip) Discussion on resource allocation for power saving Sharp
34. [R1-2101572](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2101572.zip) Discussion on partial sensing and SL DRX impact ASUSTeK
35. [R1-2101630](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2101630.zip) Discussion on sidelink resource allocation for power saving NTT DOCOMO, INC.
36. [R1-2101663](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2101663.zip) Resource allocation for power saving with partial sensing in NR sidelink enhancement ITL
37. [R1-2100021](file:///C:\3GPP\RAN1_Meetings\Tdocs\2021\R1-2100021.zip) LS to RAN1 on SL DRX design RAN2

Appendix (past meeting outcomes)

## RAN1#103-e (26/Oct – 13/Nov 2020)

**Conclusion**

* SL reception Type A and Type D should be used as the reference for evaluation and designing of SL power saving features in R17.
  + Type A: UE is not capable of performing reception of any SL signals and channels, FFS with exception of performing PSFCH and S-SSB reception (aim to conclude in RAN1#104-e)
  + Type D: UE is capable of performing reception of all SL signals and channels defined in R16. It does not preclude UE to perform reception of a subset of SL signals/channels
  + If there are evaluations with assumptions other than the above reference, the detailed assumptions need to be reported
  + Note: the types and the associated capability defined here are not intended to be defined as Rel-17 UE features as is.

Agreements**:**

* Partial sensing based RA is supported as a power saving RA scheme
  + FFS details
* Random resource selection is supported as a power saving RA scheme
  + FFS any changes or enhancement
  + FFS on conditions to apply random resource selection

Agreements:

* In R17, a SL Mode 2 Tx resource pool can be (pre-)configured to enable full sensing only, partial sensing only, random resource selection only, or any combination(s) thereof
  + FFS details, including usage, potential restrictions, whether/how any enhancement or condition is needed for the coexistence of full sensing and power saving RA scheme(s) in a same resource pool, etc.

Agreements:

* Re-evaluation and pre-emption checking are not supported by UEs that do not perform any sensing (i.e. PSCCH reception)
* Re-evaluation and pre-emption checking are supported by UEs that perform sensing
  + FFS details and any conditions(s) in which re-evaluation and pre-emption can be performed
* FFS whether/how re-evaluation and pre-emption can be supported by UEs performing random resource selection that do perform sensing
* Note: details about sensing in this context, including when it is performed, are not decided yet.

Agreements:

* Further study congestion control based on CBR and CR for power saving RA schemes
  + Identify necessary changes from R16 CBR/CR (if any), including transmission resource selection and transmission parameters that can be adjusted and applicable to power savings RA schemes
  + Note: this is not intended to require all UEs to perform sensing for the purpose of CBR measurement