3GPP TSG RAN WG1 Meeting #113 **R1-2305169**
Incheon, Korea, May 22nd – May 26th, 2023

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Title: Discussion on Enhanced Sidelink Operation on FR2 Licensed Spectrum

Agenda item: 9.4.3

Document for: Discussion and Decision

1. Background

The Objective 3 of the Work Item Description (WID) on NR sidelink evolution [1] is:

> *Study enhanced sidelink operation on FR2 licensed spectrum [RAN1, RAN2] (Determine in RAN#98-e whether to continue the study or study + specification work for FR2 until the end of R18)*
>
> - *Focus only on updating the evaluation methodology for commercial deployment scenario in 4Q 2022. [RAN1]*
> - *Study is limited to the support of sidelink beam management (including initial beam-pairing, beam maintenance, and beam failure recovery, etc) by reusing existing sidelink CSI framework and reusing Uu beam management concepts wherever possible. [RAN1, RAN2]*
> - *Beam management in FR2 licensed spectrum considers sidelink unicast communication only.*

The focus for Objective 3 in 4Q 2022, as stated in the current WID, was on updating the evaluation methodology for commercial deployment scenarios. The next phase of study for this objective should also include updating the evaluation methodology for vehicle-to-everything (V2X) scenarios. Sidelink FR2 operations for V2X scenarios will present several opportunities for enhanced scenario performance, and also challenges for the implementation of beam management concepts when the nodes (vehicles) are mobile and the environment can be highly dynamic. This contribution outlines several study topics in these areas based on discussions from the RAN1#112bis-e meeting [2].

2. Discussion

In 3GPP, FR2 represents frequencies in the range of 24.25 – 71 GHz. These frequencies offer large bandwidths but significantly higher path loss compared to frequencies below 7 GHz. While Objective 3's 4Q 2022 focus was on updating the evaluation methodology for commercial deployment scenarios, the evaluation methodology for sidelink FR2 operations for V2X scenarios should also be considered.

Future sidelink FR2 scenarios will demand extremely high data rates for next-generation UEs and for vehicular nodes. In order to implement sidelink FR2 operations in V2X scenarios and to update the evaluation methodology, study will be required understand the challenges with beam management including beam acquisition and pairing, beam maintenance, and beam failure recovery.

2.1 V2X Scenarios

The current focus for this objective is on commercial deployment scenarios, where sidelink FR2 could be used to meet high data rate demands. In addition to benefitting commercial deployment scenarios, sidelink FR2 operations can enhance performance for several V2X scenarios identified by 3GPP documents. 3GPP-interested scenarios include those related to safety e.g., automated driving and vehicle platooning, and those not related to safety e.g., mobile high data rate entertainment and mobile hotspot/office/home [3]. In addition, sidelink FR2 is valuable in several scenarios

discussed in Section 5 of [4]. High data rates, high reliability, and the ability to support dense sets of users achievable by sidelink FR2 links will expand the possibilities of information and data exchange in such scenarios.

Some of the V2X scenarios that will benefit from enhanced sidelink operation on FR2 licensed spectrum include:

- Sensor and state map sharing (SSMS), a concept where the sharing of raw or processed sensor data among vehicles builds a collective situational awareness [4].
- Remote driving, which refers to when a vehicle is controlled remotely by a human or through cloud computing mechanisms [4].
- Cooperative driving, where a group of vehicles can automatically communicate for a wide variety of purposes that improve safety and fuel economy [4].
- Information sharing for high/full automated driving, where it is assumed that high resolution data is exchanged among vehicles in the same area [4].
- Video data sharing for assisted and improved automated driving (VaD), which enhances the visual range of drivers that may be experiencing obstructed views e.g., from trucks driving in front of them [4].
- Multi-hop access to sparsely-deployed backhaul nodes among interconnected UEs inside vehicles in situations, where direct access to network infrastructure is limited or unavailable.
- Scenarios with high-speed motion and turning of both UEs, where specific beam management techniques not encountered in commercial scenarios would need to be developed.

Proposal 1: The study topic for Objective 3 of the WID for NR sidelink evolution should include updating the evaluation methodology of V2X scenarios, in addition to the current focus on commercial deployment scenarios.

Proposal 2: Beam management concepts should be considered for V2X scenarios.

These proposals were introduced in a previous document [5] and were identified as topics for RAN plenary discussion by the FL during RAN1#112 [6].

2.2 Sidelink Initial Beam Pairing

The relevant agreement from the RAN1#112bis-e meeting is listed below.

Agreement

To study the feasibility of adapting S-SSB for initial beam pairing between UE1 and UE2, at least the following can be considered.

- Whether/how to enable UE2 to identify UE1 (e.g., source ID) from UE1's S-SSB transmission, to enable UE1 to identify the corresponding beam measurement/reporting from UE2
- Mapping between S-SSB transmission/resource and beam related information
- Allocation of beam reporting resources respectively associated with different S-SSB transmit beams
- Structure and contents of S-SSB
- Triggering and/or activation of S-SSB transmission, if needed
- Mechanism for S-SSB monitoring and reporting/responding
- Mechanism to mitigate/avoid the interference between overlapped S-SSB transmissions from different UEs, including S-SSB transmission resources
- Potential impact to/from other UEs, and whether/how to avoid or mitigate this impact

2.2.1 S-SSB Synchronization Using SyncRef UE

In sidelink, S-SSBs are sent from a SyncRef UE with the S-PSS and S-SSS, which are the Sidelink Synchronization Signals (SLSS) used for UE clock and frame synchronization purposes. Because the SyncRef UE performs a critical function, it is necessary to maintain the R16/17 SLSS IDs and synchronization priorities at FR2 frequencies. When

adapting S-SSB for initial beam pairing, it is necessary to distinguish the S-SSB transmissions sent from SyncRef UEs from the S-SSB transmissions used for beam pairing. Directional beams are used by SyncRef UEs for their S-SSB transmissions. The transmission procedure for the SyncRef UEs in the presence of these directional beams has to be investigated.

Proposal 3: Study how to identify/differentiate S-SSBs sent from SyncRef UEs and from UEs seeking beam pairing when adapting S-SSB for initial beam pairing.

Proposal 4: Investigate approaches for supporting directional beams for S-SSB transmissions from SyncRef UE.

2.2.2 Adapting S-SSB for Initial Beam Pairing

The S-SSBs are identified by the SLSS IDs which do not represent a particular UE. Because it is necessary to identify the UEs for beam pairing purposes, the adapted S-SSB should contain the specific UE's identifying information. The SLSS ID is constructed using 2 candidate sequences for S-PSS (N_{S-PSS}) and 336 candidate sequences for S-SSS (N_{S-SSS}). Specifically, $\text{SLSS ID} = 336 \times N_{S-P} + N_{S-S}$, $N_{S-PSS} = \{0,1\}$, $N_{S-SSS} = \{0,1,\ldots,335\}$. Note that N_{S-PSS}, which is the GNSS/network coverage indicator, and N_{S-SSS}, which is based on the gNB Cell ID or an out-of-coverage SyncRef UE ID, do not identify a specific UE.

The large number of candidate sequences available in N_{S-SSS} could be used to identify the UE when S-SSBs are adapted for initial beam pairing purposes. In such a case, it is necessary to differentiate the S-SSB sent by the SyncRef UE. A possible approach is to increase the candidate S-PSS sequences to 3, that is $N_{S-PSS} = \{0,1,2\}$, with $N_{S-PSS} = 2$ indicating the SLSS IDs that do not correspond to the SyncRef UE. Note that in the NR Uu, $N_{S-PSS} = \{0,1,2\}$. So, this expanded sequence set is similar to the SSB in NR Uu. When $N_{S-PSS} = 2$, there are 336 IDs available for UEs that could be used for S-SSB transmissions for beam pairing purposes.

Proposal 5: Study expanding the SLSS sequences to accommodate the transmissions from beam pairing UEs in addition to the transmissions from SyncRef UEs.

In NR Uu, the time required for initial beam pairing depends on the number of SSBs in an SSB burst and the length of an SSB burst which are specified in 3GPP TS 38.213 [7]. Unlike the Uu case where the gNB is stationary, in sidelink V2X applications, both transmit and receive nodes are in motion so the variations in the beam dynamics are more than in gNB-based scenarios. Because of such variations in the beam dynamics, the sidelink may require more frequent transmission of the adapted S-SSB signals to avoid increasing the time required for beam pairing. The periodicity of an S-SSB burst in the R16/17 sidelink is significantly smaller than that in NR Uu so the frequency of the S-SSB transmissions has to be increased.

Proposal 6: Increase the number and frequency of S-SSB transmissions similar to those used in SSB transmissions in NR Uu.

Although the beam pairing transmissions from UEs may use different SLSS IDs and correspondingly different sequences, inter-UE interference may cause degradation in the detection performance when multiple such UEs share common time-frequency resources for their S-SSB transmissions. This interference can be especially high at a UE receiver that is located close to a transmit UE that is seeking to pair with a different UE that is farther away. In such scenarios it might be spectrally efficient to support multiple sets of time-frequency resources such that not all UEs transmit on the same set of resources. The selection of the set of time-frequency resources can be determined by the UE by estimating the interference on each such set or by some assignment that reduces the interference.

Proposal 7: Study the inter-UE interference resulting when a single set of time-frequency resources are assigned to the S-SSB transmissions for beam pairing purposes.

In NR Uu, each SSB occupies 4 symbols, but in sidelink the S-SSB occupies the entire slot. Increasing the number of S-SSBs in a S-SSB burst duration to match the corresponding number in the NR Uu will require significantly more time resources dedicated to the S-SSBs. The S-PSS and S-SSS signals in the S-SSB are contained in the first five symbols of the S-SSB slot. Because of this, unlike in the NR Uu SSB case, the S-PSS and S-SSS can be sent effectively in only a single direction, using a single beam, in a slot. The beam pairing process can be significantly expedited with

an S-SSB design that occupies 4 symbols as in NR Uu. In such a case, the beam with S-SSBs can sweep in two directions within a single slot.

Proposal 8: For initial beam pairing purposes, consider a 4-symbol S-SSB similar to that used in NR Uu.

2.3 Initial FR2 Beam Pairing for Existing Unicast Connections

At the RAN1#112bis-e meeting, the following agreement was reached [2].

Agreement
RAN1 can study the following candidate procedure where initial beam pairing starts after sidelink unicast link establishment between UE1 and UE2, including studying whether and in which cases initial beam pairing after sidelink unicast link establishment is feasible.

- UE1 and UE2 set up sidelink unicast link, following existing link establishment procedure
  - FFS the beams used for unicast link establishment.
- UE1 and/or UE2 configure the resources for beam sweeping and/or beam reporting
  - FFS details of resources configuration
- UE1 and/or UE2 use the configured resources to transmit reference signals and determine a pair of transmit beam and receive beam based on beam sweeping.
  - FFS applicable reference signal(s)
  - FFS whether/how to indicate the determined beams between UE1 and UE2
- FFS difference between initial beam pairing (after sidelink unicast link establishment) and beam maintenance

The first 'For Further Study' bullet, "FFS the beams used for unicast link establishment," implies that the unicast link establishment must occur in the FR2 frequency band. It is possible that the unicast link could be first established using some other method and the connection only later transitioned to the FR2 band. In particular, there are a number of useful scenarios where a unicast link is first established in the FR1 frequency band and eventually switched when operating in FR2 becomes advantageous.

One scenario where switching a unicast connection from the FR1 band to the FR2 band would be useful involves vehicle-to-vehicle (V2V) communications. In V2V operation a vehicle often becomes aware of another vehicle when they are separated by a fairly large distance. At some distance, vehicles may want to connect and exchange information. When vehicles are still separated by a large distance the information exchanged may be somewhat sparse, perhaps only occasional updates of location and direction and speed of travel. Longer separation distances coupled with small amounts of data are conveniently handled over FR1 frequencies. In some cases, two vehicles may eventually pass closely. When their separation becomes small enough, the vehicles may want to increase both the amount and frequency that they exchange information. Links over short distances carrying large amounts of data are well suited for the FR2 frequency band, so at some point the vehicles will want to transition their connection from the FR1 band to the FR2 band.

Preserving the unicast connection while transitioning from the FR1 band to the FR2 band offers several advantages over establishing a new connection. Information can be exchanged between the vehicles that facilitates the initial FR2 beam pairing. The time and frequency resources used for beam sweeping can be coordinated before beginning the process, ensuring that both nodes are prepared for the necessary procedures. Additionally, location information could be used to reduce the number of candidate beams that need to be tested.

Other scenarios when a unicast link is established before transitioning to the FR2 band include cases where unicast link establishment can be provided by the higher layers. One example is vehicle platooning as described in Section 5.2 of [3]. In this case, the V2V communications are conducted within a fixed group of vehicles. Therefore, the unicast links can be configured by other means before the network starts to operate. Another example is advanced driving as described in Section 5.3 of [3]. One use case for advanced driving is information sharing between UE and Road Side

Unit (RSU) through V2X. When a vehicular UE leaves the coverage of an RSU, the RSU can predict the next RSU serving the UE and pass the information about the new unicast link to the departing UE.

Another case is when the connection between two UEs is disrupted e.g., by blockage, and beam failure recovery is unsuccessful. In this case, the two UEs would start the connection attempt through initial beam paring. However, the unicast link information from the previous session is still valid and can be leveraged to speed up the connecting procedure.

These use cases lead us to the following observation.

Observation 1: It is possible, and in many cases desirable, to establish a unicast connection in another frequency band or by some other means before transitioning the connection to the FR2 band.

This work item focuses on the FR2 band so there is no reason to dwell on the details of how a connection was established prior to switching to FR2 other than to acknowledge that it is possible that a unicast connection has already been established between two UEs and they may want to transition this connection to the FR2 band. It is also not necessary that all of the procedures developed under this work item be totally self-contained within the FR2 band and require the unicast connection to be established in FR2. In particular, it is not necessary to specify which, or even if, beams are used for establishing the unicast connection. Most UEs will have capabilities in other bands and there are scenarios where switching bands to FR2 makes sense. A reasonable compromise is to acknowledge that a unicast connection may exist before an FR2 link is established but not delve into the details of how or why the unicast connection was established. With this in mind we submit the following proposal.

Proposal 9: A unicast connection that exists between two UEs may be transitioned to the FR2 band. Information may be exchanged over the existing connection to assist in the initial FR2 beam pairing.

2.4 Beam Maintenance

2.4.1 Background

At the RAN1#112bis-e meeting, the following agreement was reached [2]:

Agreement

Consider using sidelink CSI-RS as a starting point for beam maintenance.

- FFS: whether/how to enhance existing aperiodic and non-standalone SL CSI-RS
- FFS: periodic and/or semi-persistent SL CSI-RS transmissions
- FFS: standalone SL CSI-RS transmissions
  - ✓ Note: standalone SL CSI-RS transmission means at least no accompanying sidelink data (SL MAC SDU) transmissions in the same slot. FFS: accompanying SCI(s) or SL MAC CE transmissions or PSFCH.
- FFS: one or multiple SL CSI-RS transmissions within one slot
- FFS: SL CSI-RS transmissions with or without repetition on transmit beams

The use of CSI-RS as the beam management reference signal aligns with Uu operations as described in Section 8.2.1.6.1 of [8]. CSI-RSs are sent across all candidate downlink beams during Uu operations. The gNB directs beam selection and switches, informed by beam measurement reports from the UE. Higher-layer parameters define the CSI-RS resource allocation (Section 7.4.1.5.3 of [9]). CSI-RS can be selectively transmitted across a beam subset based on prior beam link data, thus minimizing overhead [10].

Additionally, the higher-layer parameter can configure CSI-RS to be aperiodic, periodic, or semi-persistent [9]. For periodic CSI-RS, the UE sends measurements on a schedule. For periodic and semi-persistent CSI-RS, the gNB

triggers the UE to send semi-persistent reports. For all CSI-RS types, the UE can be triggered to send aperiodic reports (Section 5.2.1.4 of [11]).

The sidelink CSI-RS is a simplified version, transmitted periodically. Previous contributions have identified two key enhancements necessary for sidelink CSI-RS to support effective beam management:

1. CSI-RS should carry additional information to denote the beams that transport them.
2. CSI-RS should transmit more frequently and independently from data traffic, implying a standalone operation.

This contribution focuses on the second aspect of sidelink CSI-RS enhancement.

The RAN1#112bis-e meeting reached another agreement [2]:

Agreement

The container(s) of sidelink beam reporting for beam maintenance is at least selected from the following options:

- Option 1: SL PHY layer signal (e.g., PSFCH, SCI)
- Option 2: SL MAC CE
- FFS: PC5-RRC, Signaling over Uu link (e.g., UCI)

A primary consideration in choosing between the aforementioned options is latency. While Uu employs PHY layer signals for beam reporting, the sidelink currently utilizes MAC CE for this purpose, resulting in higher latency.

Moreover, the topic of beam correspondence was discussed in in RAN1 Meeting 112 [6]. Although no conclusions were drawn to narrow the scope of the sidelink study, beam correspondence has been frequently referenced in discussions during the RAN1#112 and RAN#112bis-e meetings as a probable scenario.

2.4.2 Beam Measurement Coordination for Semi-Persistent and Aperiodic Types

With Uu Downlink (DL) channels, the gNB initiates the beam measurement and reporting process for semi-persistent and aperiodic beam reporting, with the UE conducting the beam measurement and sending reports upon receiving commands from the gNB [11].

For sidelink, emulating the Uu DL procedures would naturally assign the beam measurement initiation to the transmitting UE, which effectively taking on the role of the gNB. However, sidelink channels exhibit high dynamics when both UEs are mobile, with the receiving UE having first-hand knowledge of the current channel condition. Therefore, it's advantageous to let the receiving UE initiate the beam measurement, allowing for a quicker response to changes in channel conditions.

Observation 2: In the case of sidelink, the receiving UE is capable of discerning the need for beam measurement more promptly than the transmitting UE.

Proposal 10: Sidelink should incorporate an option that allows the receiving UE to initiate semi-persistent and aperiodic beam measurement procedures.

2.4.3 Beam Measurement Reporting to MAC

The current sidelink physical layer models dictate that various PHY parameters, including "multi-antenna processing," are controlled by the higher layers [12]. The architecture in [12] should be extended to include allocation of beam management functionalities, such as initiating beam measurements, processing reports, and selecting and changing beams, between PHY and MAC.

The architecture for local beamforming should be independent from the choice of beam reporting container. For example, if we opt to transmit beam reporting via a PHY channel, we can still relay beam measurement results to the local MAC layer. Doing so would enable beam management at the MAC level, should that be our preference.

Observation 3: As we consider the container for beam reporting, it makes sense to maintain the existing local architecture.

Proposal 11: RAN1 should clarify the functional split and interface between MAC and PHY regarding beam management functionalities, independent of container choice for beam reporting.

2.4.4 Beam Reporting the Presence of Beam Correspondence

Previous discussions have indicated that supporting beam maintenance requires more resources for both beam measurement reference signals and beam reporting. The demand for resources can be reduced by leveraging beam correspondence. For instance:

- To measure transmit beams, the transmitting UE can require the receiving UE to send reference signals (such as standalone CSI-RS) through a corresponding beam. This eliminates the need for transmitting and receiving measurement reports.
- When two-way links are present, the quality of a beam in one direction can be inferred from measurements conducted in the reverse direction, thereby saving the need for beam measurements in both directions.

Observation 4: Beam correspondence benefits beam maintenance operations by reducing resource requirements.

Proposal 12: RAN1 should include considerations on beam correspondence in the beam maintenance study.

2.5 Beam Failure Recovery

The topic of beam failure recovery in sidelink FR2 networks was also discussed at the RAN1#112bis-e meeting [2]. Since the FR2 objective from the WID states "*reusing Uu beam management concepts wherever possible,*" it is essential to understand how beam failure recovery is implemented in NR Uu.

Beam failure recovery in NR Uu comprises steps that include beam failure detection, identification of a new candidate beam, and a beam recovery request [13]. Beam failure detection takes place based on counts of beam failure instances indicated from the lower layers to the MAC entity [14]. A beam failure instance takes place when the measured L1-RSRP on an SSB/CSI-RS is below a certain threshold [13]. For each beam failure instance, the beam failure instance indication counter is incremented and the beam failure detection timer starts. If the number of beam failure instances reported from the lower layers exceeds the beam failure instance max count threshold before the beam failure detection timer expires, this triggers a beam failure recovery [14]. The identification of a new candidate beam comes next after beam failure detection. This process is somewhat similar to the stages of initial beam pairing where RSRP measurements help determine the strongest beam. The UE uses a random access approach to choose the next best beam [13]. Once a candidate beam pair has been identified, the UE informs the network about the beam failure and a recovery request is made that includes information about the candidate beam. The beam recovery is finalized once there is a network/gNB response on the downlink confirming the new candidate beam pair [13].

Beam failure recovery in NR Uu identifies specific roles for the network/gNB and the UE at various stages of the process. The peer-to-peer aspect of sidelink networks makes transition of such a process into this context a possibly challenging one since individual UEs on a sidelink connection do not necessarily have the clear and specific roles that the network/gNB and UE have in NR Uu links. Moreover, UEs in sidelink networks may not inherently connect to multiple UEs as gNBs in NR Uu do by definition, nor do UEs have the same antenna system capabilities as gNBs. As such, maintaining UE-to-UE connections in sidelink FR2 networks may not be straightforward. These various factors, especially in the context of highly dynamic V2X scenarios, imply that beam failure recovery mechanisms in sidelink networks should be studied.

At the RAN1#112bis-e meeting [2], a consensus was not reached regarding sidelink beam failure instance, specifically the last FFS point.

Proposal 3-1-h: RAN1 can study ~~consider~~ the following two options of schemes to trigger sidelink beam failure instance (BFI) that PHY layer provides to MAC layer.

- *Scheme 1: Sidelink BFI is triggered based on sidelink HARQ feedback*
  - *FFS whether/how to support candidate beam identification in case of BFD*
  - *Note: this scheme follows the principle of sidelink RLF.*
    - *FFS any other enhancements*
- *Scheme 2: Sidelink BFI is triggered based on the measurement of reference signal for BFD*
  - *FFS details on reference signal for BFD*
  - *Note: this scheme follows the principle of Uu BFR.*
    - *FFS any other enhancements*
- *Other options are not precluded.*
- *FFS: whether/how to down-select among options, or to prioritize the study of Scheme 2.*

Proposal 3-1-i: RAN1 can study the following two options of schemes to trigger sidelink beam failure instance (BFI) that PHY layer provides to MAC layer.

- *Scheme 1: Sidelink BFI is triggered based on sidelink HARQ feedback*
  - *FFS whether/how to support candidate beam identification in case of BFD*
  - *Note: this scheme follows the principle of sidelink RLF.*
    - *FFS any other enhancements*
- *Scheme 2: Sidelink BFI is triggered based on the measurement of reference signal for BFD*
  - *FFS details on reference signal for BFD*
  - *Note: this scheme follows the principle of Uu BFR.*
    - *FFS any other enhancements*
- *Other options are not precluded.*
- *FFS: whether~~/how to down-select among options, or~~ to prioritize the study of Scheme 2.*

The beam failure recovery agreement reached at the RAN1#112bis-e meeting [2] was:

Agreement

RAN1 is to study sidelink Beam Failure Recovery (BFR) mechanism at least for the scheme where SL BFI is triggered based on the measurement of reference signal for BFD (if supported), including

- candidate beam(s) identification
  - FFS details on reference signals for candidate beam identification, including structure, procedure, timing.
- sidelink BFR request (BFRQ), including resources, transmit and/or receive beams, container, timing, etc.
- sidelink BFR response (BFRR), including container, procedure, timing, etc.
- FFS applicability to the scheme where SL BFI is triggered based on SL HARQ feedback (if supported).

BFRQ and BFRR correspond to the final stages of beam failure recovery in NR Uu, where the UE informs the network of the new candidate beam selection and the network responds confirming the new candidate beam pair. There are a multitude of scenarios for V2X sidelink networks as discussed in Section 2.1. V2X scenarios can be highly dynamic especially as it pertains to UE mobility. In some scenarios, a TX UE may send messages to an RX UE that are never received by the RX UE. Consequently, if a TX UE fails to receive a certain number of acknowledgment messages from the RX UE, the TX UE may need to initiate the beam failure recovery process. Since the RX UE failed to receive

any messages, it may not be able to identify beam failure instances and initiate beam failure recovery in the manner that a UE in NR Uu does. Therefore, the specific roles the TX UE and RX UE can play in beam failure recovery in sidelink networks should be explored at this study phase.

Proposal 13: Comprehensively study possible configurations for beam failure recovery mechanisms in sidelink networks where either the TX UE or RX UE engages in candidate beam identification, BFR request, and BFR response.

Furthermore, while reference signal details for beam failure detection have been identified for further study, it is important to consider the dynamics of V2X scenarios for sidelink FR2 networks when it comes to these reference signals and thresholds. While these signals and thresholds are well-established in the specifications for NR Uu [13], sidelink FR2 network UE-to-UE interactions, especially for V2X scenarios, may be very different in nature from gNB-to-UE interactions. In the context of high mobility V2X scenarios, parameters such as L1-RSRP thresholds, beam failure instance indication counter thresholds, and beam failure detection timer values may need to be studied and adapted.

Proposal 14: Incorporate consideration of highly dynamic (high UE mobility) V2X scenarios when studying details for reference signals for BFD.

Candidate beam identification is another area for further study identified for beam failure recovery. It may be beneficial for UE pairs to develop a pre-identified candidate set of multiple beam pairs during the beam failure recovery process should beam failure take place very often in certain scenarios, such as highly dynamic sidelink scenarios. In scenarios where beam failure takes place very often, the NR Uu process of finding a new candidate set of beam pairs after every failure could cause recovery delays. Having a pre-identified set of multiple backup candidate beam pairs could potentially shorten recovery delays.

Proposal 15: UE pairs should establish multiple backup candidate beam pairs to mitigate beam failure recovery delays in scenarios where beam failure may take place often.

3. Summary of Proposals

Proposal 1: The study topic for Objective 3 of the WID for NR sidelink evolution should include updating the evaluation methodology of V2X scenarios, in addition to the current focus on commercial deployment scenarios.

Proposal 2: Beam management concepts should be considered for V2X scenarios.

Proposal 3: Study how to identify/differentiate S-SSBs sent from SyncRef UEs and from UEs seeking beam pairing when adapting S-SSB for initial beam pairing.

Proposal 4: Investigate approaches for supporting directional beams for S-SSB transmissions from SyncRef UE.

Proposal 5: Study expanding the SLSS sequences to accommodate the transmissions from beam pairing UEs in addition to the transmissions from SyncRef UEs.

Proposal 6: Increase the number and frequency of S-SSB transmissions similar to those used in SSB transmissions in NR Uu.

Proposal 7: Study the inter-UE interference resulting when a single set of time-frequency resources are assigned to the S-SSB transmissions for beam pairing purposes.

Proposal 8: For initial beam pairing purposes, consider a 4-symbol S-SSB similar to that used in NR Uu.

Proposal 9: A unicast connection that exists between two UEs may be transitioned to the FR2 band. Information may be exchanged over the existing connection to assist in the initial FR2 beam pairing.

Proposal 10: Sidelink should incorporate an option that allows the receiving UE to initiate semi-persistent and aperiodic beam measurement procedures.

Proposal 11: RAN1 should clarify the functional split and interface between MAC and PHY regarding beam management functionalities, independent of container choice for beam reporting.

Proposal 12: RAN1 should include considerations on beam correspondence in the beam maintenance study.

Proposal 13: Comprehensively study possible configurations for beam failure recovery mechanisms in sidelink networks where either the TX UE or RX UE engages in candidate beam identification, BFR request, and BFR response.

Proposal 14: Incorporate consideration of highly dynamic (high UE mobility) V2X scenarios when studying details for reference signals for BFD.

Proposal 15: UE pairs should establish multiple backup candidate beam pairs to mitigate beam failure recovery delays in scenarios where beam failure may take place often.

4. References

[1] 3GPP RP-230077: "WID revision: NR sidelink evolution". 3GPP TSG RAN Meeting #99, Rotterdam, Netherlands, March 20 – 23, 2023.

[2] Apple, “FL summary #3 for AI 9.4.3 Enhanced sidelink operation on FR2 licensed spectrum,” R1-2303905. 3GPP TSG-RAN WG1 Meeting #112bis-e. Apr. 17 – Apr. 26, 2023.

[3] 3GPP TS 22.186: “Service requirements for enhanced V2X scenarios”.

[4] 3GPP TR 22.886: "Study on enhancement of 3GPP Support for 5G V2X Services".

[5] Johns Hopkins University, APL, “Discussion on Enhanced Sidelink Operation on FR2 Licensed Spectrum,” R1-2300314. 3GPP TSG-RAN WG1 Meeting #112. Athens, Greece. Feb. 27 – Mar. 03, 2023.

[6] Apple, “FL summary #3 for AI 9.4.3 Enhanced sidelink operation on FR2 licensed spectrum,” R1-2301845. 3GPP TSG-RAN WG1 Meeting #112. Athens, Greece. Feb. 27 – Mar. 03, 2023.

[7] 3GPP TS 38.213: “Physical layer procedures for control”.

[8] 3GPP TR 38.912: “Study on New Radio (NR) access technology”.

[9] 3GPP TR 38.211: “Physical channels and modulation”.

[10] Giordani, et al., “A Tutorial on Beam Management for 3GPP NR at mmWave Frequencies”, IEEE Communications Surveys & Tutorials, vol. 31, No. 1, 2019, pp. 173 – 196.

[11] 3GPP TS 38.214: “Physical layer procedures for data”.

[12] 3GPP TS 38.202: “Services provided by the physical layer”.

[13] E. Dahlman, S. Parkvall, J. Skold. “5G NR: the Next Generation Wireless Access Technology,” Academic Press, August 9, 2018.

[14] 3GPP TS 38.321: “Medium Access Control (MAC) protocol specification”.