

Source: Johns Hopkins University APL

Title: Discussion on evaluation methodology for commercial deployment scenario

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 and specify enhanced sidelink operation on FR2 licensed spectrum [RAN1, RAN2, RAN4] (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]*
- *Work 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.*
 - o *Beam management in FR2 licensed spectrum considers sidelink unicast communication only.*

The current focus for Objective 3 in 4Q 2022, as stated in the updated WID, is on updating the evaluation methodology for commercial deployment scenarios. Some commercial use cases for FR2 sidelink discussed previously at the RAN plenary [2] include those focused on 1) network coverage and capacity expansion and 2) device-to-device communications.

The first set of use cases assume that there are nodes in the network that are connected to a base station and thus network control is available. This is referred to as mode 1 operations. Use cases include examples such as communicating via sidelink to extend coverage to FR2 devices outside of network coverage. In addition, based on network topology, some use cases that are possible are sidelink for FR2 relaying purposes as well as facilitating increased capacity for disadvantaged devices, which [2] defines to be those devices that are in areas with poor coverage i.e., and likely suffering from low link quality and lower data rates.

The second set of use cases includes examples involving direct device-to-device communications among devices that could be both within and outside of network coverage, referred to as mode 1 or mode 2 operations respectively. Use cases here include devices communicating directly using the FR2 band, gaming use cases where consoles communicate directly with each other, extended reality (XR) device-to-device communications, personal area networking (PAN), devices in vehicles, and near-field communications [2].

2. Discussion

In 3GPP FR2 represents frequencies in the range 24.25 – 52.6 GHz. These frequencies offer large bandwidths but significantly higher attenuation compared to frequencies below 7 GHz. Therefore, in addressing Objective 3's current focus on updating the evaluation methodology for commercial deployment scenario, several modifications need to be considered for FR2 sidelink operations.

2.1 Sidelink FR2 Scenarios

A number of deployment scenarios are detailed in existing 3GPP documents. In many of these scenarios FR2 sidelink could be used to improve the network coverage and throughput. To evaluate the use of FR2 sidelink it is typically necessary to adjust the height of some of the nodes.

Section 6.2 of [3] features a number of deployment scenarios. Several FR2 sidelink cases can be derived by modifying some of these scenarios.

The Urban Micro (UMi) and Urban Macro (UMa) aim to capture real-life open area and street canyon scenarios such as city or station squares. They may include both Outdoor-to-Outdoor (O2O) and Outdoor-to-Indoor (O2I) elements. The dimensions of a typical open area are around 50 to 100 m. Whereas in the Urban Micro and Urban Macro scenarios BSs are mounted on surrounding buildings (typically 10 to 25 m above the ground respectively), in the case where sidelink is being used both the transmitters and receivers are 1 to 2 m above the ground.

The Indoor scenario aims to capture typical indoor environments such as offices, shopping malls, and factory floors. Office deployments may feature cubicles, walled offices, meeting rooms, open areas, and corridors. Shopping malls may have one to five floors, each with a number of stores. They may include an atrium open to all the floors. Factory deployments typically feature an open hall with varying amount of clutter such as machinery, assembly lines, storage shelves, and work benches. In these scenarios employees may want to interact with office equipment or the company IT system, customers may want to interact with store displays, and workers may want to communicate directly with machinery. As in the Urban case, the main difference between these scenarios and the scenarios described in [3] is that all nodes are typically 1 – 2 m above the floor instead of BSs being mounted high on the walls/ceilings.

A Personal Area Network (PAN) is a short-range network of devices centered around a specific person or workspace. On a person it may connect a phone, headset or headphones, Virtual Reality (VR) goggles or Augmented Reality/eXtended Reality (AR/XR) glasses, a portable gaming console, and any other ‘smart’ items in that person’s possession. At a workspace it may also connect to devices such as a mouse, a printer, a display, or a gaming controller. In a vehicle a user’s devices might interact with the vehicle’s systems. Most of the communications is directly from one device to another over a very short range.

Another deployment scenario is Device-to-Device Relay to improve network capacity and coverage. This is similar to the vehicle-to-vehicle relay described in [4] except any type of device may be used to relay data. Events such as major sporting events and festivals may bring a large number of people to an area for a limited time which overwhelms the installed infrastructure. Device-to-device relay could be used to create an ad-hoc backhaul in order to increase the ability of attendees to access the network. This scenario has many aspects that are similar to the Urban scenario described above.

A second Device-to-Device Relay scenario can occur in structures when it is not possible to connect to an external network. Detailed in section 5.15.1 of [4], this use case involves a large underground parking structure with no network coverage. In addition to communications between vehicles, it would be useful to include pedestrians walking in the structure in the ad-hoc network. Other possible locations where a similar network would be useful include mines, waste disposal sites, abandoned properties, caves or other remote and challenging terrain where search and rescue operations may be necessary, underground infrastructure (e.g. sewers, water supply, transit tunnels), and building complexes without coverage extensions.

The channel dynamics introduced by the device mobility or by the variations in the surrounding environment may require dynamic adaptation of beams. The FR2 beam management techniques should perform robustly under such channel dynamics.

Proposal 1: Consider the FR2 sidelink in the Urban scenario. Use representative values for the number of devices, device density and device mobility in this scenario.

Proposal 2: Consider the FR2 sidelink in the Indoor scenario. Use representative values for the number of devices, device density and device mobility in this scenario.

Proposal 3: Consider the FR2 sidelink in the PAN scenario. Use representative values for the number of devices, device density and device mobility in this scenario.

Proposal 4: Consider the FR2 sidelink in the Device-to-Device Backhaul scenario. Use representative values for the device mobility, device heights, and device mobility, where applicable.

Proposal 5: Consider the FR2 sidelink in the Device-to-Device Disconnected Network scenario. Use representative values for the number of devices and device mobility in this scenario.

2.2 Channel Model

An essential component of the evaluation methodology for FR2 sidelink operations is ensuring an appropriate and accurate channel model. Section 7.2 of [3] provides details on scenarios that can be used to calibrate channel models. These scenarios include:

- Urban micro (Umi)-street canyon and Urban Macro (UMa)
- Indoor-office – example depiction in Figure 1 from [3]
- Rural macro – focuses on “continuous wide area coverages supporting high speed vehicles”
- Indoor Factory (InF): “focuses on factory halls of varying sizes and with varying levels of density of ‘clutter’, e.g. machinery, assembly lines, storage shelves, etc.”

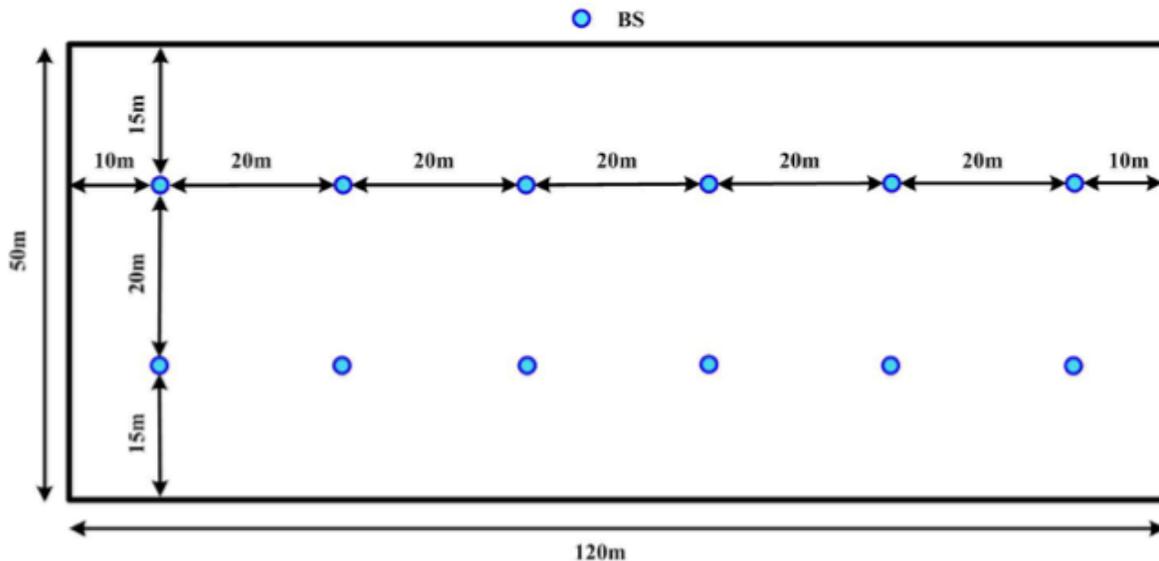


Figure 1. Layout of indoor office scenarios [3]

Some relevant evaluation parameters within these scenarios include:

- Base station antenna height values
- User terminal (UT) height and mobility (speed) values
- Minimum BS-UT distance values

Observation 1: The evaluation parameters for channel model calibration scenarios in [3] assume BS deployments i.e., NR-Uu links.

Proposal 6: Study modification of scenario parameters to update FR2 sidelink evaluation methodology as it pertains to channel model calibration. The parameter updates include BS height modified to UT height,

minimum BS-UT distance values modified to minimum UT-UT distance values, and BS power values modified to UT power values.

2.3 Traffic Model

According to [5], XR and cloud gaming (CG) represent a very high-priority 5G media application, and therefore is an important application when considering FR2 sidelink evaluation methodology. Traffic models for XR applications are statistical in nature, where traffic characteristics such as packet size and packet arrival processes are modeled as random variables.

The deployment scenarios considered for XR include:

- Dense Urban: UEs implementing XR applications are located in an urban area with densely-deployed BSs
- Indoor Hotspot: Considers only indoor XR users for work and gaming XR applications
- Urban Macro: XR users deployed over larger area where lower data rate-intensive XR applications are relevant

Observation 2: XR deployment scenarios are for environments where network connections to BSs are assumed and traffic models are parameterized accordingly.

Proposal 7: Consider XR traffic models for the FR2 sidelink by modifying the models in [5] for FR2 sidelink parameters.

2.4 Antenna Types and Modeling

At FR2 frequencies the composite antenna consists of multiple panels where analog weights are used within the elements in the panel and digital weights are used at the outputs from the panels. The rectangular panel array antenna shown in Figure 2 is defined using the tuple (M, N, P, M_g, N_g) , where M and N are, respectively, the number of antenna elements in each column and row of a panel, P is the polarization, and M_g and N_g are, respectively, the number of panels in the column- and row-dimensions.

TR 37.885 [6] lists some values for the antenna parameter values for the UE in V2X applications. In particular, Table 6.1.4-7 of this report lists the parameter values for pedestrian UE and cellular UE as $(2,4,2,1,2)$, that is a single dual-polarized panel of size 2×4 antenna elements mounted back-to-back on the UE. The size of this panel is very small, about $0.6 \text{ cm} \times 1.2 \text{ cm}$ at 50 GHz, and even at 30 GHz this is small $1 \text{ cm} \times 2 \text{ cm}$. Because antenna technology has evolved since publication of this report and it is desirable to use antennas with higher gains for next generation UEs, it is reasonable to use multi-panel antennas that support digital beamforming. Figure 3 shows a 4-panel antenna array for each side of the UE with a total of $8 \times 4 \times 2$ elements on both sides of the UE, with corresponding tuple $(2,4,2,2,4)$.

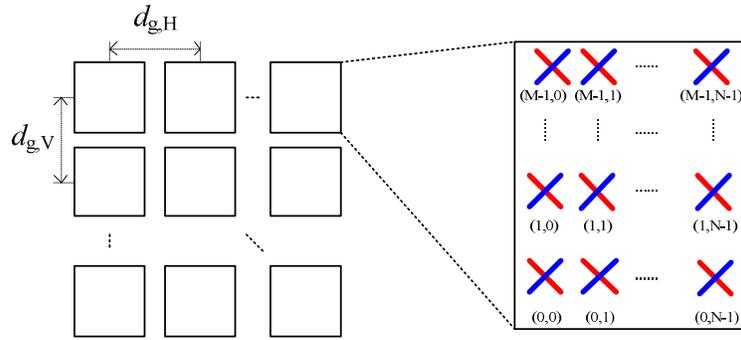


Figure 2. Antenna panel model (from TS 38.901 [3].)

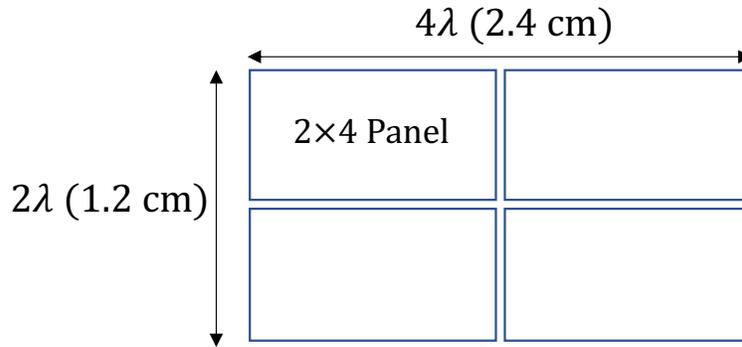


Figure 3. A 4-panel antenna array for each side of the UE. (Dimensions at 50 GHz.)

Observation 3: For faster beam acquisition and adaptation, it is desirable to support digital beamforming at the sidelink UE.

Observation 4: The size of an 2×4 element antenna panel is quite small at FR2 frequencies.

Proposal 8: Multi-panel antennas that can be used for digital beamforming should be considered in the evaluation model and the simulation results.

2.5 Use of Multibeam Antennas

Multibeam antennas are capable of providing significant advantages including faster beam acquisition and higher data rates at lower latencies. However, because the sidelink mode 2 scheme is based on Time Division Duplexing (TDD) and it is desirable to operate the multiple beams independently of each other, simultaneous use of the multiple beams in the sidelink may lead to significant technical challenges that have to be studied and evaluated in detail.

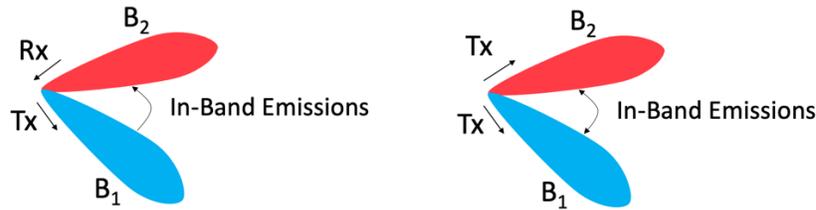


Figure 4. Simultaneous use of multiple beams: B₁ transmit, B₂ receive (left-side figure); B₁ transmit, B₂ transmit (right-side figure).

Figure 4 shows a UE with two beams used at the same time: beams B₁ and B₂ in transmit and receive directions (left-side figure); and both beams in the transmit direction (right-side figure). In the former case, since the beams are intended to operate independently, in-band emissions from beam B₁ will overwhelm the same time-slot receptions from beam B₂. In the latter case, the half-duplex exclusion time slots in each beam may have to include the time slots corresponding to both beams.

Observation 5: Using multiple beams in both transmit and receive directions in the same time slot leads to significant in-band emissions at the receive beam.

Observation 6: When using multiple transmit beams, to avoid inter-beam interference, half-duplex exclusions in one beam may have to include time slots corresponding to other beams.

Proposal 9: Number of simultaneous beams together with the respective beam isolations should be used in the evaluation methodology and simulation results.

3. Summary of Proposals

Proposal 1: Consider the FR2 sidelink in the Urban scenario. Use representative values for the number of devices, device density and device mobility in this scenario.

Proposal 2: Consider the FR2 sidelink in the Indoor scenario. Use representative values for the number of devices, device density and device mobility in this scenario.

Proposal 3: Consider the FR2 sidelink in the PAN scenario. Use representative values for the number of devices, device density and device mobility in this scenario.

Proposal 4: Consider the FR2 sidelink in the Device-to-Device Backhaul scenario. Use representative values for the device mobility, device heights, and device mobility, where applicable.

Proposal 5: Consider the FR2 sidelink in the Device-to-Device Disconnected Network scenario. Use representative values for the number of devices and device mobility in this scenario.

Proposal 6: Study modification of scenario parameters to update FR2 sidelink evaluation methodology as it pertains to channel model calibration. The parameter updates include BS height modified to UT height, minimum BS-UT distance values modified to minimum UT-UT distance values, and BS power values modified to UT power values.

Proposal 7: Consider XR traffic models for the FR2 sidelink by modifying the models in [5] for FR2 sidelink parameters.

Proposal 8: Multi-panel antennas that can be used for digital beamforming should be considered in the evaluation model and the simulation results.

Proposal 9: Number of simultaneous beams together with the respective beam isolations should be used in the evaluation methodology and simulation results.

4. References

[1] 3GPP RP-221938: "NR sidelink evolution".

[2] 3GPP RP-211646: "Moderator's summary for discussion [RAN93e-R18Prep-06] Sidelink enhancements (excluding positioning)".

[3] 3GPP TR 38.901: "Study on channel model for frequencies from 0.5 to 100 GHz".

[4] 3GPP TR 22.839: "Study on Vehicle-Mounted Relays".

[5] 3GPP TR 38.838: "Study on XR (Extended Reality) Evaluations for NR".

[6] 3GPP TR 37.885: "Study on evaluation methodology of new Vehicle-to-Everything (V2X) use cases for LTE and NR".