# HST evaluations

Based on the company’s inputs, it is a common understanding that only LLS should be used for HST evaluations. Therefore, it is proposed to limit discussion scope to LLS assumptions only

**Proposal #1:**

* LLS to be used for Rel-17 HST evaluations

|  |  |
| --- | --- |
| Company | Comment |
| InterDigital | Agreed that only LLS to be used for HST. |
| Ericsson | We support the proposal #1. |
| Intel | Support the proposal #1. |
| ZTE | Support the proposal #1 |
| MotM/Lenovo | We support the rapporteur’s proposal |
| OPPO | Support the proposal. |
| LG | Support the proposal |
| Apple | Support |
| vivo | We agree with the proposal that LLS is used for Rel-17 HST evaluations |
| CATT | Support |
| NEC | Support the proposal |
| Samsung | Support |
| Huawei, HiSilicon | Fine with the proposal |
| CMCC | Support |
| Nokia/NSB | Support the proposal |
| MediaTek | Support the proposal |
| Futurewei | Support |
| QC | We support the proposal of LLS as evaluation methodology |

It is a common view that only LLS should be used for Rel-17 HST evaluations. Therefore, the following conclusion is made:

**Offline conclusion #1:**

* LLS to be used for Rel-17 HST evaluations

# Frequency range

Companies have provided views on the FR that should be used for HST evaluations. Some companies prefer to prioritize FR1 for HST evaluations (ZTE, CATT, IDC, Lenovo/MotM, CMCC, Nokia), while other companies prefer to treat FR1 and FR2 with equal priority (SS, Intel, E///, vivo), i.e.,

* Alt .1: FR1 + FR2, but FR1 is prioritized
* Alt. 2: FR1 + FR2

From simulation perspective, it is better to define assumptions for both FR1 and FR2 and decide possible FR prioritization later.

**Proposal #2:**

* Define HST simulation assumptions for both FR1 and FR2

|  |  |
| --- | --- |
| Company | Comment |
| InterDigital | Alt. 1 is preferred, FR2 for HST should not be a priority. |
| Ericsson | Support proposal #2 and prefer Alt.2. The evaluation for HST on FR2 is needed to ensure the performance for a potential commercial FR2 deployment. The deployment scenario for FR1 and FR2 can be quite different, the solution works for FR1 may not work for FR2.  |
| Intel | Support proposal #2 and Alt. 2. |
| ZTE | Alt. 1 is preferred. Simulation can be done mainly for FR1 for simplicity, unified solutions can be designed for both FR1 and FR2. |
| MotM/Lenovo | Alt 1 is preferred |
| OPPO | Alt.1 is preferred. M-TRP based HST is more beneficial in FR1. |
| LG | Support the proposal |
| Apple | It seems for both Alt1 and Alt2, we need to define simulation assumption for both FR1 and FR2.  |
| Vivo | We agree to define HST simulation assumptions for both FR1 and FR2 |
| CATT | Alt-1 is preferred.  |
| NEC | Alt-1 is preferred. FR1 is more suitable for HST, we can focus on this. And the solutions for FR2 may be quite different, which can be enhanced later. |
| Samsung | Agree with Apple and support proposal#2.It is unclear whether preferring Alt.1 means supporting proposal#2 or not. |
| Huawei, HiSilicon | FR1 should be prioritized which is more practical deployment for HST. For FR2, more discussion is needed since the simulation setup can be quite different, such as the terminal types, directional antenna assumptions, blockage modeling for HST cases.  |
| CMCC | FR1 should be prioritized for the HST-SFN scenario since there is strong commercial deployment demand, and until now RAN4 has only defined the requirements for up to 3.6GHz and 500kmh in R16 for HST-SFN scenario, and there were even no such kind of discussion for FR2 in RAN4. We should not be too advanced in RAN1. Unless there are strong commercial demands from operators on HST-SFN scenario for FR2, we think we would better to focus on FR1 to resolve the real commercial deployment issue. The current Alt.1 should also be clarified. We think the solutions for FR1 can also be applied for FR2, but we should not put effort on optimization for FR2.  |
| Nokia/NSB | Support the proposal.  |
| MediaTek | Support Proposal #2. FR1 is prioritized |
| Futurewei | Alt 1 |
| QC | We support proposal 2. For FR1 and FR2 prioritization, we have the same view as Ericsson and support Alt. 2. |

Companies have expressed their preference regarding prioritization of the FR for HST evaluations, i.e., Alt 1 vs Alt 2, as well definition of the simulation assumptions for HST in FR2. Given that 3GPP work is contribution driven and due to lack of concerns on the proposal#2, the following conclusion is proposed:

**Possible offline conclusion #2:**

* Define HST simulation assumptions for both FR1 and FR2
* Discuss possible FR prioritization during WI phase, if needed.

|  |  |
| --- | --- |
| Company | Comment |
| DOCOMO | Agree with Ericsson, and support the proposal#2 (FR1 + FR2).  |
| Intel | OK with conclusion #2 |
| Samsung | Support conclusion #2 |
| LG | Support conclusion #2 |
| Ericsson | Support conclusion #2 |
| QC | Support conclusion #2 |

**Offline conclusion #2:**

* Define HST simulation assumptions for both FR1 and FR2
* Discuss possible FR prioritization during WI phase, if needed.

# HST layout

Two HST layout options were proposed by companies based on TR 38.913 supporting FR1 + FR2 (Samsung, Lenovo/Motorola Mobility, Nokia) and TS 36.101 Annex B.3A with Ds=700m, Dmin=150m supporting FR1 (CMCC, Intel, IDC, CATT, Ericsson, LG, FUTUREWAY, Sony), i.e.,

* Alt 1: TR 38.913 (FR1 + FR2)
* Alt 2: TS 36.101 Annex B.3A (FR1: Ds=700m, Dmin=150m, FR2: TBD)

**Proposal #3:**

* Companies to provide their views on the preferred TRP layout for HST evaluation for both FR1 and FR2
	+ Alt 1: TR 38.913 (FR1 + FR2)
	+ Alt 2: TS 36.101 Annex B.3A (FR1: Ds=700m, Dmin=150m, FR2: TBD)

|  |  |
| --- | --- |
| Company | Comment |
| InterDigital | Alt 2 that is in line with RAN4 discussions is preferred. |
| Ericsson | Support Alt 2. Suggest the TBD value for FR2: Ds=400-500m Dmin=20-50m. Note the approximate Dmin derived from 38.913 for FR2 (Figure 6.1.5.2) is very small.  |
| Intel | Alt 2. TBD for FR2 may use the same deployment assumptions as for FR1, i.e. Ds=700m, Dmin=150m |
| ZTE | Support Alt 2 for saving effort. Simulation can be done mainly for FR1 for simplicity, unified solutions can be designed for both FR1 and FR2 |
| MotM/Lenovo | Alt 1 is preferred. Better to use a unified simulation framework for FR1 and FR2 |
| OPPO | Alt 2 from RAN4 is preferred. |
| LG | Alt 2 from RAN4 is preferred. |
| Apple | Alt 2 is preferred |
| Vivo | Similar to TS 36.101 Annex B.3A (FR1: Ds=720m, Dmin=120m, 2 RRHs in UE’s vision); For FR2, using the same deployment assumptions as FR1 is better. |
| CATT | Alt 2 is preferred. |
| NEC | Alt 2 is preferred. |
| Samsung | For FR1, okay for Alt 2.For FR2, existing layout in Alt 1 can be a starting point. |
| Huawei, HiSilicon | Alt.2 is preferred. |
| CMCC | Alt 2 from RAN4 is preferred. We’d better keep consistency among RAN1 and RAN4 as much as possible, especially considering that Alt 2 was used in Rel-16 WI NR\_HST in RAN4. |
| Nokia/NSB | Support the proposal.  |
| MediaTek | Support Proposal #3. Alt 2 is preferred |
| Futurewei | Alt 2 |
| QC | Support Alt 2 to align with the previous RAN4 study. For FR2, we propose Ds = 200-300m and Dmin = 30-50m. |

Based on the company’s inputs, there is clear majority supporting Alt 2. For FR2 it was proposed to use the same deployment parameters as for FR1 as a starting point.

**Offline conclusion #3:**

* TRP layout for HST evaluation for both FR1 and FR2
	+ Alt 2: TS 36.101 Annex B.3A
		- FR1: Ds=700m, Dmin=150m
		- FR2
			* Alt 2-1: Ds=700m, Dmin=150m
			* Alt 2-2: Ds=400-500m, Dmin=20-50m
			* Alt 2-3: Ds=200-300m, Dmin=30-50m
			* Alt 2-4: Ds=580m, Dmin=5m

Companies are encouraged to provide preference on the proposed values for FR2:

|  |  |
| --- | --- |
| Company | Comment |
| DOCOMO | Agree with Alt.2 (TS 36.101 Annex B.3A) # we added Alt “2-“x in FR2, to avoid confusion. |
| Intel | OK with conclusion #3. Prefer Alt 2-1 as mandatory and all other cases as optional to be reported by each company if used. |
| Huawei, HiSilicon | For FR2, not clear the real deployment, which need some more discussion/study. Especially, not clear the use case of Dmin=5m, what’s the use case for real scenario?We further check the mentioned Section 6.1.2 in 38.913 and Section 6.2.2 in 36.878 (where 38.913 referred the scenarios in 36.878). **The Dmin=5m was introduced in the scenario for tunnel environment**: **Scenario 2d**● RRHs or RAUs are deployed through **fiber in tunnel environment**● RRHs or RAUs share the same cell id● Repeaters are not installed on the carriageTable 6.2.2-2: Parameters for Scenario 2d

|  |  |
| --- | --- |
| Parameter | Value |
| RRH Railway track distance | 5m |

 |
| Samsung | Suggest to consider the existing deployment for FR2, Alt 2-4 from TR38.913, as well. Besides, we are unclear on the concern on Alt 2-4, which was agreed in NR evaluation assumption agenda. |
| Ericsson | Dmin=5min is suggested in TR38.913, which is a reasonable assumption for FR2 HST deployment. We support conclusion #3, alt 2-4 is fine.  |
| QC | We support Alt 2-3 as the primary option. Although Alt 2-4 is suggested in a TR, the Dmin=5m value is too small, which will make the beam planning (e.g., SSB beams) in FR2 a bit tricky. Also, due to the same reason, the ratio of Ds/2 to Dmin should not be too large. In this regard, we think Alt 2-3 is a balanced configuration. |

**Offline conclusion #3:**

* TRP layout for HST evaluation for both FR1 and FR2
	+ Alt 2: TS 36.101 Annex B.3A
		- FR1: Ds=700m, Dmin=150m
		- FR2: discuss the following alternatives in RAN#102-e meeting
			* Alt 2-1: Ds=700m, Dmin=150m
			* Alt 2-2: Ds=400-500m, Dmin=20-50m
			* Alt 2-3: Ds=200-300m, Dmin=30-50m
			* Alt 2-4: Ds=580m, Dmin=5m
			* Note: if no consensus is reached, each company to provide used value for Ds and Dmin

# gNB antenna orientation

Two companies provided views on the gNB antenna orientation in HST deployment.

* Alt 1: Bi-directional only
* Alt 2: Unidirectional + Bidirectional

Considering operator’s input on realistic deployment scenario and given RAN4 requirements are only defined for bi-directional model, it seems natural to use bi-direction antenna orientation should mandatory antenna orientation and unidirectional as optional

**Proposal #4:**

* Use bi-directional as mandatory and uni-directional as optional gNB antenna orientation

|  |  |
| --- | --- |
| Company | Comment |
| InterDigital | Agree with the proposal. |
| Ericsson | Bi-directional as mandatory for FR1, unidirectional, where doppler offset always have the same sign, should also be considered in the evaluation for FR2. |
| Intel | Support proposal #4 |
| ZTE | Support proposal #4 |
| MotM/Lenovo | We support the rapporteur’s proposal |
| OPPO | Support the proposal. |
| LG | Support the proposal. |
| Apple | Support the proposal |
| Vivo | We agree with the proposal |
| CATT | Support the proposal. |
| NEC | Support the proposal. |
| Samsung | Support the proposal |
| Huawei, HiSilicon | Fine for the proposal |
| CMCC | Fine with the proposal |
| Nokia/NSB | Support the proposal |
| MediaTek | Support the proposal |
| Futurewei | Support |
| QC | Support the proposal |

Based on the inputs, all companies support the proposal #4.

**Offline conclusion #4:**

* Use bi-directional as mandatory and uni-directional as optional gNB antenna orientation

# Channel model

Some companies proposed to reuse RAN4 channel models (TS 36.101 / TR 36.878) as much as possible (Samsung, Intel, IDC, CATT, Ericsson, LG, FUTUREWEI, CMCC, Sony, OPPO, Nokia), while other companies proposed by extend RAN4 models by including multi-path components using CDL framework (ZTE, CMCC, Huawei/HiSilicon, Lenovo/Motorola Mobility, vivo),i.e.,

* Alt 1: 4 taps – TS 36.101 (Annex B.3A) / TR 36.878 (RAN4)
* Alt 2: Multi-path extension of TS 36.101 (Annex B.3A) / TR 36.878 (RAN4) + CDL TR 38.901

Considering maturity of the model it is recommended to include RAN4 model as part of simulation assumption and continue discussion to finalize multipath extension of RAN4 model using CDL framework

**Proposal #5:**

* Adopt RAN4 4-taps model based on TS 36.101 (Annex B.3A) / TR 36.878
* Further discuss CDL based multipath extension from RAN4 model, e.g., using the following proposal (CMCC) as a starting point

|  |
| --- |
| CDL based channel model proposal for HST: Therefore, we think that some combination of the CDL channel model in TR38.901 and the 4-tap channel model in TS36.101 Annex B.3A could be considered. One simple way could be similar to the suggestion of ZTE, as illustrated in figure 3 below, 2-tap channel model for simplicity could be assumed which is similar to RAN4’s 4-tap assumption in order to reflect the characteristic of SFN-based transmission, and for each tap, CDL channel model in TR38.901 could be used to model the effect of the directional antenna of gNB.* + The delay for k’th TRP is modified as

where  is the delay of k’th TRP, which can be derived aswhere is the delay of the n’th channel cluster as in Table 7.7.1-1~7.7.1-5 in 38.901, and assume the location of the k’th TRP is xk, and the UE’s location is y(t).The delay spread for different TRPs could be modeled as different as suggested by Huawei.* + The normalized power for k’th TRP is modified as
	+ To generate the modified angle parameters, the scaling method mentioned in subclause 7.7.5.1 in TS 38.901 is used

where could be assumed, and of the k’th TRP is the AOD, AOA, ZOD and ZOA of LOS direction derived based on the locations and antenna heights of UE and TRPs.Fig. 3. Simplified and updated HST-SFN channel model for evaluation |

|  |  |
| --- | --- |
| Company | Comment |
| InterDigital  | Agree with the proposal to adopt RAN4 4-taps channel model. |
| Ericsson | 4-tap model is for SFN. DPS model (e.g. single tap, CDL/TDL) should also be supported. |
| Intel | Support proposal #5. For CDL based channel model extension:* The simulation assumptions should also include gNB antenna boresight direction (vertical and horizontal tilt) to the middle point on the railway between TRPs.
* Consider LOS channel model for CDL, i.e. CDL-D or CDL-E
 |
| ZTE | CDL-D or CDL-E channel model should be used since it is aligned with Rel-16 MTRP simulation assumptions. Agree with Intel that gNB antenna boresight direction to the middle point on the railway between two TRPs. Only two TRPs are involved in the simulation.  |
| MotM/Lenovo | Adopt RAN4 4-tap channel model |
| OPPO | Support the proposal. |
| LG | Support the proposal. |
| Apple | Support the first bullet of the proposal |
| Vivo | CDL-D channel combined with RAN4 model, similar to CMCC’s proposal |
| CATT | Adopt RAN4 4-taps model. |
| NEC | Support the proposal. |
| Samsung | Support to have RAN4 model |
| Huawei, HiSilicon | Fine with the example proposed by CMCC, where 2-tap CDL-D/E channels are modeled. |
| CMCC | It would be more practical to model the directional antenna pattern of gNB in the simulation, and 2-tap CDL-D/E channel could be a balance between complexity and practicality. The gNB antenna boresight could direct to the middle point on the railway between two TRPs |
| Nokia/NSB | Agree with Ericsson.  |
| MediaTek | Adopt RAN 4 4-taps model |
| Futurewei | Support the proposal |
| QC | Support the proposal and should start the evaluation with the simplified two TRPs channel model and the multipath extension of RAN4 model. Also, we should consider time synchronization mismatch between the TRPs. For the CDL extension, CMCC’s proposal can be considered as the starting point, with LoS CDL channel models. Also, for the specific deployment for HST-SFN, the K-factor for the CDL channel models may need further study. Another point that needs to clarified is how this model can be extended for in-tunnel deployment and how the corresponding deployment of antennas would look like. |

**Offline conclusion #5:**

* Adopt RAN4 4-taps model based on TS 36.101 (Annex B.3A) / TR 36.878 as baseline / mandatory model
* Adopt CDL-based multipath extension from RAN4 model with 2 RRHs as additional / optional model
	+ FFS: Modifications to K factor, extension for in-tunel deployment, possible modification of RRHs layout, etc.

|  |
| --- |
| CDL based channel model proposal for HST: ~~Therefore, we think that some c~~Combination of the CDL channel model in TR38.901 and the 4-tap channel model in TS36.101 Annex B.3A could be considered. ~~One simple way could be similar to the suggestion of ZTE, as~~ As illustrated in figure ~~3~~ below, 2-tap channel model for simplicity could be assumed which is similar to RAN4’s 4-tap assumption in order to reflect the characteristic of SFN-based transmission, and for each tap, CDL channel model in TR38.901 could be used to model the effect of the directional antenna of gNB.* + The delay for k’th TRP is modified as`

where  is the delay of k’th TRP, which can be derived aswhere is the delay of the n’th channel cluster as in Table 7.7.1-1~7.7.1-5 in 38.901, and assume the location of the k’th TRP is xk, and the UE’s location is y(t).The delay spread for different TRPs could be modeled as different ~~as suggested by Huawei~~.* + The normalized power for k’th TRP is modified as
	+ To generate the modified angle parameters, the scaling method mentioned in subclause 7.7.5.1 in TS 38.901 is used

where could be assumed, and of the k’th TRP is the AOD, AOA, ZOD and ZOA of LOS direction derived based on the locations and antenna heights of UE and TRPs.Fig. 1. Simplified and updated HST-SFN channel model for evaluationThe gNB antenna boresight could direct to the middle point on the railway between two TRPs. CDL-D and CDL-E channels models are recommended for evaluations. |

Companies are encouraged to provide additional comments, if any.

|  |  |
| --- | --- |
| Company | Comment |
| Intel | OK with the conclusion #5. For CDL model need to clarify antenna parameters used at the UE and gNB. |
| Huawei, HiSilicon | At first the discussion on in-tunel deployment is very different with above discussed HST layout and gNB antenna structures, and also the channel modeling. So, it seems not proper to be discussed together here. Then, RRHs should be instead with taps to align with the first bullet. Then, the K factor, it is already included in CDL-D and E, we do not see the necessity to modify it. The proposal need to be updated:**Offline conclusion #5:** * Adopt RAN4 4-taps model based on TS 36.101 (Annex B.3A) / TR 36.878 as baseline / mandatory model
* Adopt CDL-based multipath extension from RAN4 model with 2 taps as additional / optional model
	+ FFS: Modifications to K factor, possible modification of RRHs layout, etc.
 |
| QC | We are fine with the original conclusion. Some further comments:* The antenna parameters of UE and gNB for both FR1 and FR2 are part of the detailed simulation assumptions.
* Regarding in-tunnel deployment, there could be scenarios very similar to the HST layout discussed above where RRHs or RAUs are deployed through fiber in tunnel environment.
* Regarding the K factor, although the realistic channel for HST scenario would likely be a LoS channel, the characteristics of the LoS component (e.g., LoS probability, K factor, etc.) may depend on the specific environment. In TR 38.901, several recommended K factors are provided, i.e., for UMi, UMa, RMA, and InH. We think a further study is needed whether the HST-SFN channel can be represented by one of these cases or not.
 |
|  |  |
|  |  |

**Revised offline conclusion #5:**

* Adopt RAN4 4-taps model based on TS 36.101 (Annex B.3A) / TR 36.878 as baseline / mandatory model
* Adopt CDL-based multipath extension from RAN4 model with 2 taps as additional / optional model
	+ FFS: Modifications to K factor, possible modification of RRHs layout, etc.

|  |
| --- |
| CDL based channel model proposal for HST: Combination of the CDL channel model in TR38.901 and the 4-tap channel model in TS36.101 Annex B.3A could be considered. As illustrated in figure below, 2-tap channel model for simplicity could be assumed which is similar to RAN4’s 4-tap assumption in order to reflect the characteristic of SFN-based transmission, and for each tap, CDL channel model in TR38.901 could be used to model the effect of the directional antenna of gNB.* + The delay for k’th TRP is modified as`

where  is the delay of k’th TRP, which can be derived aswhere is the delay of the n’th channel cluster as in Table 7.7.1-1~7.7.1-5 in 38.901, and assume the location of the k’th TRP is xk, and the UE’s location is y(t).The delay spread for different TRPs could be modeled as different.* + The normalized power for k’th TRP is modified as

FFS: Use of 3D distance for calculation of Pk* + To generate the modified angle parameters, the scaling method mentioned in subclause 7.7.5.1 in TS 38.901 is used

where could be assumed, and of the k’th TRP is the AOD, AOA, ZOD and ZOA of LOS direction derived based on the locations and antenna heights of UE and TRPs.FFS: Further clarifications to and Fig. 1. Simplified and updated HST-SFN channel model for evaluationThe gNB antenna boresight could direct to the middle point on the railway between two TRPs. CDL-D and CDL-E channels models are recommended for evaluations. |

# Baseline scheme for comparison

Some companies provided their views on the baseline schemes that should be used for performance comparison, i.e.,

* Alt. 1 Rel-15 SFN
* Alt. 2 Rel-16 URLLC

To avoid lengthy discussion on the baseline scheme, it is recommended that each company to provide details on the baseline scheme used for comparison

**Proposal #6:**

* Each company to provide baseline scheme used for comparison as part of simulation assumptions

|  |  |
| --- | --- |
| Company | Comment |
| InterDigital | To have a meaningful comparison, we prefer to have Alt. 1. |
| Ericsson | Support Alt.2. DPS has been identified in RAN4 as an enhancement for HST-SFN, so DPS + Rel-16 URLLC should also be used as baseline. |
| Intel | Agree with the proposal. Each company should provide the baseline scheme as part of simulation assumption.  |
| ZTE | Alt.1 is preferred since the WID bullet is for SFN scenario. But proposal #6 is acceptable for us.  |
| MotM/Lenovo | We prefer Alt 1 |
| OPPO | Agree with the proposal. If URLLC scheme 1c (multiple TCI states for the same DMRS port(s)) is agreed in item 2d-1, it can also be considered as baseline. |
| LG | Support Alt 1.  |
| Apple | Alt1 should be baseline |
| vivo | Both Rel-15 SFN with single TRS and Rel-16 single DCI based MTRP schemes, such as scheme 1a for comparison. However, the simulation assumption for comparison with Rel-16 schemes needs to be aligned. Especially, whether switching between MTRP and STRP is needed, or only simulate the situation where UE is located near the center of two TRPs. |
| CATT | Support Alt 1. |
| NEC | Alt 1. |
| Samsung | Support Alt1. We prefer to align the baseline scheme for easy comparison of performance across different proposals (e.g., to compare gains vs. common baseline.) |
| Huawei, HiSilicon | Support Alt 1, since R16 URLLC is not designed for high speed cases. |
| CMCC | Support Alt.1. On the one hand, it is easy for comparison, on the other hand, the typical downlink transmission scheme in the first phase 5G commercial HST network is the SFN based transmission, so the performance gain of the Rel-17 HST-SFN enhancement compared to the traditional SFN-based transmission is important. Additionally, it is uncertain that whether the Rel-16 URLLC transmission schemes will be introduced in the 5G commercial macro network or not. If Rel-17 can provide a simple and dedicated enhancement for HST scenario compared to the commercialized the SFN-based transmission, it would still be promising for application in the commercial HST network.  |
| Nokia/NSB | Support the FL proposal. Each company may provide the baseline scheme as part of simulation assumption.  |
| MediaTek | Support the proposal |
| Futurewei | Alt 1. since the WID clearly states “HST-SFN” |
| QC | Support Alt 1 Rel-15 SFN as the preferred baseline. However, we support the proposal since Alt 2 should not be precluded. |

Based on the inputs, majority of the companies prefer to use Rel-15 SFN (i.e., Alt. 1) for the comparison. Several other companies prefer to use other schemes, e.g., Rel-16 URLLC (i.e., Alt. 2). Based on the inputs the following conclusion is proposed:

**Offline conclusion #6:**

* Rel-15 SFN is used as the baseline for comparison
* Performance comparison with other schemes (e.g., Rel-16 URLLC, DPS, etc.) can be also provided

|  |  |
| --- | --- |
| Company | Comment |
| DOCOMO | Support Alt. 1 (Rel-15 SFN), because we assume the basic 5G-HST deployment is SFN, same as LTE-HST. We think it is better to align the baseline across companies to compare the performance gain fairly. The WID clearly says “HST-SFN”, and this should be the baseline.  |
| Intel | OK with the conclusion#6. |
| Samsung | Support conclusion #6 |
| LG | Same view with DOCOMO |
| Ericsson | Support conclusion #6. |
| QC | Support conclusion #6. |

**Offline conclusion #6:**

* Rel-15 SFN is used as the baseline for comparison
* Performance comparison with other schemes (e.g., Rel-16 URLLC, DPS, etc.) can be also provided

# Detailed simulation assumptions:

Companies are also encouraged to provide additional inputs regarding HST simulation assumptions using the following table below.

|  |  |  |
| --- | --- | --- |
| **Parameter** | **FR1** | **FR2** |
| Duplexing  | FDD | TDD | TDD |
| TRP layout (Ds, Dmin, etc) |  |  |  |
| gNB antenna configuration including number of antennas, pattern, ports, orientation, etc |  |  |  |
| UE antenna configuration including number of antennas, pattern, ports, orientation, etc |  |  |  |
| DMRS type |  |  |  |
| Number of DMRS symbols |  |  |  |
| TDD pattern | N/A |  |  |
| MCS |  |  |  |
| Number of scheduled RBs |  |  |  |
| Propagation condition |  |  |  |
| TRS configuration, TRS periodicity |  |  |  |
| PDSCH / PUSCH mapping |  |  |  |
| Rank |  |  |  |
| BW |  |  |  |
| Carrier frequency or maximum Doppler shift |  |  |  |
| Performance metric |  |  |  |
| Other assumptions or simulation parameters, e.g., correlation am |  |  |  |

## Intel:

|  |  |  |
| --- | --- | --- |
| **Parameter** | **FR1** | **FR2** |
| Duplexing  | FDD | TDD | TDD |
| TRP layout (Ds, Dmin, etc) | Ds=700m, Dmin=150m |  Ds=700m, Dmin=150m |  Ds=700m, Dmin=150m |
| gNB antenna configuration including number of antennas, pattern, ports, orientation, etc | 2  | 2 | 8x4 |
| UE antenna configuration including number of antennas, pattern, ports, orientation, etc | 4 | 4 | 2x4 |
| DMRS type | Up to each company | Up to each company | Up to each company |
| Number of DMRS symbols | 3  | 3  | 2  |
| TDD pattern | N/A | 7D, 2UL, 1S | 7D, 2UL, 1S |
| MCS | QPSK R = 1/2, 16QAM = 2/3, 64QAM R = 3/4 | QPSK R = 1/2, 16QAM = 2/3, 64QAM R = 3/4 | QPSK R = 1/2, 16QAM = 2/3, 64QAM R = 3/4 |
| Number of scheduled RBs | 10  | 10 | 10 |
| Propagation condition | 4 taps; Optional: CDL | 4 taps; Optional: CDL | CDL extension (CDL-E or CDL-D) |
| TRS configuration, TRS periodicity | 10ms, 2-slot pattern | 10ms, 2-slot pattern | 10ms, 2-slot pattern |
| PDSCH / PUSCH mapping | Start = 2, duration = 12 symbols | Start = 2, duration = 12 symbols | Start = 2, duration = 12 symbols |
| Rank | 1 or 2 |  1 or 2 | 1 or 2 |
| BW | 10 | 20 |  |
| Carrier frequency or maximum Doppler shift | 2GHz, 500kmph | 3.5GHz, 500kmph | 28GHz, 200kmph |
| Performance metric | BLER for the MCS | BLER for the MCS | BLER for the MCS |
| Other assumptions or simulation parameters, e.g., correlation am |  |  |  |

## ZTE:

|  |  |  |
| --- | --- | --- |
| **Parameter** | **FR1** | **FR2** |
| Duplexing  | FDD | TDD | TDD |
| TRP layout (Ds, Dmin, etc) | Ds=700m, Dmin=150m |  Ds=700m, Dmin=150m |  |
| gNB antenna configuration including number of antennas, pattern, ports, orientation, etc | Two TRPs;2 Tx per each TRP;Antenna boresight direction to the middle point on the railway between two TRPs | Two TRPs;2 Tx per each TRP;Antenna boresight direction to the middle point on the railway between two TRPs |  |
| UE antenna configuration including number of antennas, pattern, ports, orientation, etc | 2 antennas;Omnidirectional; | 2 antennas;Omnidirectional; |  |
| DMRS type | DMRS type 1, 1 front loaded DMRS symbol | DMRS type 1, 1 front loaded DMRS symbol |  |
| Number of DMRS symbols | 4 | 4 |  |
| TDD pattern | N/A | DDSU |  |
| MCS | MCS adaption | MCS adaption |  |
| Number of scheduled RBs | 4, 8, 20 | 4, 8, 20 |  |
| Propagation condition | CDL | CDL |  |
| TRS configuration, TRS periodicity | 10ms, 2-slot pattern | 10ms, 2-slot pattern |  |
| PDSCH / PUSCH mapping | Start = 2, duration = 12 symbols | Start = 2, duration = 12 symbols |  |
| Rank | Rank 1 |  Rank 1 |  |
| BW | 10 | 10 |  |
| Carrier frequency or maximum Doppler shift | 2GHz, 350kmph or 500kmph | 3.5GHz, 350kmph or 500kmph |  |
| Performance metric | Throughput | Throughput |  |
| Other assumptions or simulation parameters, e.g., correlation am | Subcarrier spacing: 30KHz | Subcarrier spacing: 30KHz |  |

## Apple:

|  |  |  |
| --- | --- | --- |
| **Parameter** | **FR1** | **FR2** |
| Duplexing  | FDD | TDD | TDD |
| TRP layout (Ds, Dmin, etc) | Ds=700m, Dmin=150m | Ds=700m, Dmin=150m | Ds=700m, Dmin=150m |
| gNB antenna configuration including number of antennas, pattern, ports, orientation, etc | 2Tx | 2Tx | (M, N, P) = (4, 8, 2) |
| UE antenna configuration including number of antennas, pattern, ports, orientation, etc | 2Rx | 2Rx | (M, N, P) = (2, 4, 2) |
| DMRS type | Type 1 | Type 1 | Type 1 |
| Number of DMRS symbols | 4 | 4 | 4 |
| TDD pattern | N/A | Companies provide input | Companies provide input |
| MCS | MCS 6, 14, 20 from MCS Table 1 | MCS 6, 14, 20 from MCS Table 1 | MCS 6, 14, 20 from MCS Table 1 |
| Number of scheduled RBs | 20 | 20 | 20 |
| Propagation condition | Alt1 in channel model section | Alt1 in channel model section | Alt1 in channel model section |
| TRS configuration, TRS periodicity | 20ms | 20ms | 20ms |
| PDSCH / PUSCH mapping | Companies provide input | Companies provide input | Companies provide input |
| Rank | 1 | 1 | 1 |
| BW | 20MHz | 20MHz | 20MHz |
| Carrier frequency or maximum Doppler shift | 2GHz, 350kmph | 3.5GHz, 350kmph | 30GHz, 350kmph |
| Performance metric | Throughput/BLER for PDSCH, BLER for PDCCH | Throughput/BLER for PDSCH, BLER for PDCCH | Throughput/BLER for PDSCH, BLER for PDCCH |
| Other assumptions or simulation parameters, e.g., correlation am | PDCCH related assumption needs to be discussed | PDCCH related assumption needs to be discussed | PDCCH related assumption needs to be discussed |

## vivo:

|  |  |  |
| --- | --- | --- |
| **Parameter** | **FR1** | **FR2** |
| Duplexing  | FDD | TDD | TDD |
| TRP layout (Ds, Dmin, etc) | Ds: 720m, Dmin: 120m, RRH height: 35m, UE height: 1.5m | Ds: 720m, Dmin: 120m, RRH height: 35m, UE height: 1.5m | Ds: 720m, Dmin: 120m, RRH height: 35m, UE height: 1.5m |
| gNB antenna configuration including number of antennas, pattern, ports, orientation, etc | 2 ports: [Mg, Ng, M, N, P]=[1, 1, 1, 1, 2],8 ports: [Mg, Ng, M, N, P]=[1, 1, 1, 4, 2],one-to-one mapping between antenna elements and TXRUs, bi-directional antenna | 2 ports: [Mg, Ng, M, N, P]=[1, 1, 1, 1, 2],8 ports: [Mg, Ng, M, N, P]=[1, 1, 1, 4, 2],one-to-one mapping between antenna elements and TXRUs, bi-directional antenna | 2 ports: [Mg, Ng, M, N, P]=[1, 1, 4, 8, 2] (R16 assumption for beam management),directional antenna |
| UE antenna configuration including number of antennas, pattern, ports, orientation, etc | 2 ports: [Mg, Ng, M, N, P]=[ 1, 1, 1, 1, 2] , 4 ports: [Mg, Ng, M, N, P]=[1, 1, 1, 2, 2], one-to-one mapping between antenna elements and TXRUs | 2 ports: [Mg, Ng, M, N, P]=[ 1, 1, 1, 1, 2] , 4 ports: [Mg, Ng, M, N, P]=[1, 1, 1, 2, 2], one-to-one mapping between antenna elements and TXRUs | 2 ports: [Mg, Ng, M, N, P]=[1, 1, 2, 4, 2] (R16 assumption for beam management),directional antenna |
| DMRS type | Type 1, single symbol | Type 1, single symbol | Type 1, single symbol |
| Number of DMRS symbols | 3 symbols, pos=[2 7 11] | 3 symbols, pos=[2 7 11] | 3 symbols, pos=[2 7 11] |
| TDD pattern | N/A | DDDSUUDDDD, S: 6D 4G 4U | DDDSUUDDDD, S: 6D 4G 4U |
| MCS | MCS 4/MCS 13/MCS 17 based on 64QAM table; MCS adaption | MCS 4/MCS 13/MCS 17 based on 64QAM table; MCS adaption | MCS 4/MCS 13/MCS 17 based on 64QAM table; MCS adaption |
| Number of scheduled RBs | 48 | 48 | 48 |
| Propagation condition | CDL-D, DS desired=100ns | CDL-D, DS desired=100ns | CDL-D, DS desired=10ns |
| TRS configuration, TRS periodicity | 10ms, 2slot pattern | 10ms, 2slot pattern | 10ms, 2slot pattern |
| PDSCH / PUSCH mapping | Type A, Start symbol 2, Duration 12 | Type A, Start symbol 2, Duration 12 | Type A, Start symbol 2, Duration 12 |
| Rank | Rank up to 2; RI adaptive | Rank up to 2; RI adaptive | Rank up to 2; RI adaptive |
| BW | 20MHz | 20MHz | 80MHz |
| Carrier frequency or maximum Doppler shift | 2.6GHz, 500km/h | 2.6 GHz, 500km/h | 30GHz, 240km/h |
| Performance metric | Throughput; BLER | Throughput; BLER | Throughput; BLER |
| Other assumptions or simulation parameters, e.g., correlation am | 1) SCS: 30kHz2) Precoding method: precoding cycling for ports=2; PMI feedback for ports>2 | 1) SCS: 30kHz2) Precoding method: precoding cycling for ports=2; PMI feedback for ports>2 | 1) SCS: 120kHz2) Precoding method: precoding cycling |

## CATT:

|  |  |  |
| --- | --- | --- |
| **Parameter** | **FR1** | **FR2** |
| Duplexing  | FDD | TDD | TDD |
| TRP layout (Ds, Dmin, etc) | Ds=700m, Dmin=150m | Ds=700m, Dmin=150m |  |
| gNB antenna configuration including number of antennas, pattern, ports, orientation, etc | 2Tx per TRP | 2Tx per TRP |  |
| UE antenna configuration including number of antennas, pattern, ports, orientation, etc | 2Rx | 2Rx |  |
| DMRS type | Type 1 | Type 1 |  |
| Number of DMRS symbols | 3 | 3 |  |
| TDD pattern | N/A | 7D, 2U, 1S |  |
| MCS | MCS 4; MCS 13; MCS 17 based on 64QAM table | MCS 4; MCS 13; MCS 17 based on 64QAM table |  |
| Number of scheduled RBs | 20 | 20 |  |
| Propagation condition | HST-SFN 2/4 taps | HST-SFN 2/4 taps |  |
| TRS configuration, TRS periodicity | 10ms, 2-slot pattern | 10ms, 2-slot pattern |  |
| PDSCH / PUSCH mapping | Start = 2, duration = 12 symbols | Start = 2, duration = 12 symbols |  |
| Rank | 1 | 1 |  |
| BW | 10MHz | 20MHz |  |
| Carrier frequency or maximum Doppler shift | 2GHz, 350km/h or 500 km/h | 3.5GHz, 350km/h or 500 km/h |  |
| Performance metric | Throughput | Throughput |  |
| Other assumptions or simulation parameters, e.g., correlation am |  |  |  |

## Samsung:

|  |  |  |
| --- | --- | --- |
| **Parameter** | **FR1** | **FR2** |
| Duplexing  | FDD | TDD | TDD |
| TRP layout (Ds, Dmin, etc) | Ds=700m, Dmin=150m |  Ds=700m, Dmin=150m | Ds=580m, Dmin=5m |
| gNB antenna configuration including number of antennas, pattern, ports, orientation, etc | 2 ports: (M,N,P,Mp,Np)=(1,1,2,1,1),8 ports: (M,N,P,Mp,Np)=(2,2,2,2,2) | 2 ports: (M,N,P,Mp,Np)=(1,1,2,1,1),8 ports: (M,N,P,Mp,Np)=(2,2,2,2,2) | 2 ports: (M,N,P)=(4,8,2) |
| UE antenna configuration including number of antennas, pattern, ports, orientation, etc | 4 ports: (M,N,P,Mp,Np)=(1,2,2,1,2) | 4 ports: (M,N,P,Mp,Np)=(1,2,2,1,2) | 2 ports: (M,N,P)=(2,4,2) |
| DMRS type | Type 1 | Type 1 | Type 1 |
| Number of DMRS symbols | 3 symbols | 3 symbols | 3 symbols |
| TDD pattern | N/A | 7D 1S 2U, S: 6D 4G 4U | 7D 1S 2U, S: 6D 4G 4U |
| MCS | MCS 4; MCS 13; MCS 17 from MCS table 1 | MCS 4; MCS 13; MCS 17 from MCS table 1 | MCS 4; MCS 13; MCS 17 from MCS table 1 |
| Number of scheduled RBs | 25, 50 | 25, 50 | 25, 50 |
| Propagation condition | Alt1 in channel model section | Alt1 in channel model section | Alt1 in channel model section |
| TRS configuration, TRS periodicity | 10ms, 2slot pattern | 10ms, 2slot pattern | 10ms, 2slot pattern |
| PDSCH / PUSCH mapping | Type A, start symbol 2, duration 12 | Type A, start symbol 2, duration 12 | Type A, start symbol 2, duration 12 |
| Rank | 1 or 2 | 1 or 2 | 1 or 2 |
| BW | 10MHz | 40MHz | 50MHz |
| Carrier frequency or maximum Doppler shift | 2GHz, 350km/h or 500km/h | 3.5 GHz, 350km/h or 500km/h | 30 GHz, 350km/h or 500km/h |
| Performance metric | Throughput | Throughput | Throughput |
| Other assumptions or simulation parameters, e.g., correlation am |  |  |  |

## Huawei, Hisilicon:

|  |  |  |
| --- | --- | --- |
| **Parameter** | **FR1** | **FR2** |
| Duplexing  | FDD | TDD | TDD |
| TRP layout (Ds, Dmin, etc) | Ds=700m, Dmin=150m |  Ds=700m, Dmin=150m |  |
| gNB antenna configuration including number of antennas, pattern, ports, orientation, etc | 4TX /8TX per each TRP; | 4TX /8TX per each TRP; |  |
| UE antenna configuration including number of antennas, pattern, ports, orientation, etc | 2 RX/4RX;Omnidirectional; | 2 RX/4RX;Omnidirectional; |  |
| DMRS type | DMRS type 1& type 2 | DMRS type 1& type 2 |  |
| Number of DMRS symbols | 1+1+1 | 1+1+1 |  |
| TDD pattern | N/A | DDDDDDDSUU |  |
| MCS | MCS adaption | MCS adaption |  |
| Number of scheduled RBs | 48 | 48 |  |
| Propagation condition | CDL-D/E | CDL-D/E |  |
| TRS configuration, TRS periodicity | 10ms, 2 slot pattern | 10ms, 2 slot pattern |  |
| PDSCH / PUSCH mapping | Start symbol 2, duration 12 | Start symbol 2, duration 12 |  |
| Rank | Rank adaption | Rank adaption |  |
| BW | N/A | N/A |  |
| Carrier frequency or maximum Doppler shift | 2GHz, 350kmph or 500kmph | 3.5GHz, 350kmph or 500kmph |  |
| Performance metric | Throughput; BLER | Throughput; BLER |  |
| Other assumptions or simulation parameters, e.g., correlation am | Subcarrier spacing: 15KHZ/30KHz | Subcarrier spacing: 30KHz |  |

## CMCC:

|  |  |  |
| --- | --- | --- |
| **Parameter** | **FR1** | **FR2** |
| Duplexing  | FDD | TDD | TDD |
| TRP layout (Ds, Dmin, etc) | Ds=700m, Dmin=150m | Ds=700m, Dmin=150m |  |
| gNB antenna configuration including number of antennas, pattern, ports, orientation, etc | 2 ports: [Mg, Ng, M, N, P]=[1, 1, 1, 1, 2],one-to-one mapping between antenna elements and TXRUs,  | 2 ports: [Mg, Ng, M, N, P]=[1, 1, 1, 1, 2],one-to-one mapping between antenna elements and TXRUs,  |  |
| UE antenna configuration including number of antennas, pattern, ports, orientation, etc | 4 ports: [Mg, Ng, M, N, P]=[1, 1, 1, 2, 2], one-to-one mapping between antenna elements and TXRUsOmnidirectional; | 4 ports: [Mg, Ng, M, N, P]=[1, 1, 1, 2, 2], one-to-one mapping between antenna elements and TXRUsOmnidirectional; |  |
| DMRS type | DMRS type 1 | DMRS type 1 |  |
| Number of DMRS symbols | 1+1+1 | 1+1+1 |  |
| TDD pattern | N/A | DDDDDDDSUU, S: 6D 4G 4U |  |
| MCS | MCS 4/MCS 13/MCS 17 based on 64QAM table | MCS 4/MCS 13/MCS 17 based on 64QAM table |  |
| Number of scheduled RBs | 20 | 20 |  |
| Propagation condition | CDL-D/E | CDL-D/E |  |
| TRS configuration, TRS periodicity | 10ms, 2 slot pattern | 10ms, 2 slot pattern |  |
| PDSCH / PUSCH mapping | Start symbol 2, duration 12 | Start symbol 2, duration 12 |  |
| Rank | Rank 1 | Rank 1 |  |
| BW | N/A | N/A |  |
| Carrier frequency or maximum Doppler shift | 2.6GHz, 500kmph | 2.6GHz, 500kmph |  |
| Performance metric | Throughput; BLER | Throughput; BLER |  |
| Other assumptions or simulation parameters, e.g., correlation am | Subcarrier spacing: 30KHz | Subcarrier spacing: 30KHz |  |

## Nokia/NSB:

|  |  |  |
| --- | --- | --- |
| **Parameter** | **FR1** | **FR2** |
| Duplexing  | FDD | TDD | TDD |
| TRP layout (Ds, Dmin, etc) | Ds=700m, Dmin=150m |  Ds=700m, Dmin=150m | Ds=700m, Dmin=150m |
| gNB antenna configuration including number of antennas, pattern, ports, orientation, etc | 2  | 2 | (M, N, P) = (4, 8, 2) |
| UE antenna configuration including number of antennas, pattern, ports, orientation, etc | 2 | 2, 4 | (M, N, P) = (2, 4, 2) |
| DMRS type | Type 1 | Type 1 | Type 1 |
| Number of DMRS symbols | 3  | 3  | 3 |
| TDD pattern | N/A | 7D 1S 2U, S: 6D 4G 4U | 7D 1S 2U, S: 6D 4G 4U |
| MCS | MCS 4; MCS 13; MCS 17  | MCS 4; MCS 13; MCS 17  | MCS 4; MCS 13; MCS 17  |
| Number of scheduled RBs | 20 | 20 | 20 |
| Propagation condition |  |  |  |
| TRS configuration, TRS periodicity | 10ms, 2-slot pattern | 10ms, 2-slot pattern | 10ms, 1 slot-pattern |
| PDSCH / PUSCH mapping | PDSCH : Type A, Start = 2, duration = 12 symbolsPUSCH: Type A, duration= 14 | PDSCH : Type A, Start = 2, duration = 12 symbolsPUSCH: Type A, duration= 14 | PDSCH : Type A, Start = 2, duration = 12 symbolsPUSCH: Type A, duration= 14 |
| Rank | 2 | 2 | 2 |
| BW | 20 MHz | 20 MHz | 80MHz |
| Carrier frequency or maximum Doppler shift | 2GHz, 500kmph | 4GHz, 500kmph | 30GHz, 350kmph |
| Performance metric | SNR @70% of maximum throughput  | SNR @70% of maximum throughput  | SNR @70% of maximum throughput  |
| Other assumptions or simulation parameters, e.g., correlation am | SCS: 30kHz | SCS: 30kHz | SCS: 120kHz |

## QC:

|  |  |  |
| --- | --- | --- |
| **Parameter** | **FR1** | **FR2** |
| Duplexing  | FDD | TDD | TDD |
| TRP layout (Ds, Dmin, etc) | Ds=700m, Dmin=150m | Ds=700m, Dmin=150m | Ds=200m, Dmin=50m |
| gNB antenna configuration including number of antennas, pattern, ports, orientation, etc | 2 or 4 ports  | A MIMO with 2-4 ports and optional massive MIMO configuration | BS: (M, N, P, Mg, Ng) = (8, 16, 2, 1, 1) with (dH,dV) = (0.5, 0.5)λ,UE: (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1) with (dH,dV) = (0.5, 0.5)λ |
| UE antenna configuration including number of antennas, pattern, ports, orientation, etc | 4 antennas – omni directional | 4 antennas – omni directional | 2 ports |
| DMRS type | Configuration type 1 | Configuration type 1  | Configuration type 1 |
| Number of DMRS symbols | 3 or 4 | 3 or 4 | 3 or 4 |
| TDD pattern | N/A | DDSU or DDDSU | DDSU or DDDSU (S: 10D:2G:2U) |
| MCS | Adaptive | Adaptive | Adaptive |
| Number of scheduled RBs | 10-50 RBs | 10-50 RBs | 10-50 RBs |
| Propagation condition | CDL-D/E, 100 ns | CDL-D/E, 100 ns  | CDL-D/E, 20ns/30ns |
| TRS configuration, TRS periodicity | 2 slots, 20 ms | 2 slots, 20 ms | 2 slots, 10ms |
| PDSCH / PUSCH mapping | PDSCH: S=2, L=12 | PDSCH: S=2, L=12  | PDSCH: (S=2, L=12) |
| Rank | Rank 1 (baseline) and rank 2 optional | Rank 1 (baseline) and rank 2 optional | Rank 1 |
| BW | 100 MHz | 100 MHz | 400 MHz |
| Carrier frequency or maximum Doppler shift | 4GHz max. speed of 500 km/h | 4GHz max. speed of 500 km/h | 30GHz, speed of 500 km/h |
| Performance metric | DL Throughput, BLER | DL Throughput, BLER | DL Throughput, BLER |
| Other assumptions or simulation parameters, e.g., correlation am | DL precoder: precoder cycling30KHz SCS. | DL precoder: precoder cycling30KHz SCS. Clarify how TRS beamforming is done | DL precoder: precoder cycling120kHz SCS |

## Summary:

Several companies provided additional details of simulation assumptions. Based on the proposals above the following proposal is made:

|  |  |  |
| --- | --- | --- |
| **Parameter** | **FR1** | **FR2** |
| Duplexing  | FDD | TDD | TDD |
| TRP layout (Ds, Dmin, etc) | Ds=700m, Dmin=150m[For CDL based model – RRH height: 35m, UE height: 1.5m]  | Alt 1: Ds=700m, Dmin=150mAlt 2: Ds=400-500m, Dmin=20-50mAlt 3: Ds=200-300m, Dmin=30-50mAlt 4: Ds=580m, Dmin=5mRRH height: 35m, UE height: 1.5m |
| gNB antenna configuration including number of antennas, pattern, ports, orientation, etc | 2 ports: [Mg, Ng, M, N, P]=[1, 1, 1, 1, 2],one-to-one mapping between antenna elements and TXRUsomni-directional antennaNote: The results for other antenna configurations can be also provided  | 2 ports: [Mg, Ng, M, N, P]=[1, 1, 4, 8, 2],directional antennaFFS: on parameters of antenna elementNote: The results for other antenna configurations can be also provided |
| UE antenna configuration including number of antennas, pattern, ports, orientation, etc | 2 ports: [Mg, Ng, M, N, P]=[ 1, 1, 1, 1, 2] or4 ports: [Mg, Ng, M, N, P]=[1, 1, 1, 2, 2], one-to-one mapping between antenna elements and TXRUsomni-directional antenna | 2 ports: [Mg, Ng, M, N, P]=[1, 1, 2, 4, 2],directional antennaFFS: on parameters of antenna element |
| DMRS type | DM-RS type 1 |
| Number of DMRS symbols | 1+1+1 |
| TDD pattern | N/A | DDDDDDDSUU, S: 6D 4G 4U | DDDDDDDSUU, S: 6D 4G 4U |
| MCS | MCS 4/MCS 13/MCS 17 based on 64QAM tableCompanies can also provide results with MCS adaptation |
| Number of scheduled RBs | [4, 8, 10, 20, 25, 48, 50]TBD down-selection | [4, 8, 10, 20, 25, 48, 50]TBD down-selection | [4, 8, 10, 20, 25, 48, 50]TBD down-selection |
| Propagation condition | 4-tap channel model (TS 36.101 (Annex B.3A) / TR 36.878 (RAN4))Optional: CDL extension (CDL D/E, DS = 100ns) | CDL extension (CDL D/E, DS = 20ns/30ns) |
| TRS configuration, TRS periodicity | 10ms, 2-slot pattern |
| PDSCH / PUSCH mapping | Type A, Start symbol 2, Duration 12 |
| Rank | Rank 1Optional: rank 2 or rank adaptation | Rank 1 or 2 |
| BW | 10 MHz or 20 MHz | 10 MHz or 20MHz | 20MHz or 50MHz or 80MHz |
| Carrier frequency or maximum Doppler shift | 2GHz, 350kmph or 500kmph | 3.5GHz, 350kmph or 500kmph | 30 GHz200 km/h or 350km/h or 500km/h |
| Performance metric | Throughput; BLER |
| Other assumptions or simulation parameters, e.g., correlation  | 1) SCS: 30kHz[2) Precoding method: precoding cycling] | 1) SCS: 30kHz[2) Precoding method: precoding cycling] | 1) SCS: 120kHz[2) Precoding method: precoding cycling] |

Companies are encouraged to provide views regarding simulation assumptions above especially for the items highlighted in yellow:

|  |  |
| --- | --- |
| Company | Comment |
| Intel | 1. Prefer medium number of scheduled RBs (e.g. 10 or 20) for faster simulations2. OK with RRH and UE height proposed above in yellow.3. Precoding cycling per PRG for 4-tap channel model. For CDL based channel model prefer to have hybrid precoding based on reported PMI for given polarization and random precoding cycling across polarizations. 4. For CDL channel model, antenna element parameters for gNB and for UE should be defined to be the same as for SLS assumptions used in item 1. |
| Huawei, HiSilicon | 1. gNB antenna configurations for both FR1 and FR2: 4Tx and 8Tx are more realistic for the NR HST deployments. So, 2Tx should be updated to 4Tx and 8Tx: 4Tx: [Mg, Ng, M, N, P]=[1, 1, 1, 2, 2], and 8Tx [Mg, Ng, M, N, P]=[1, 1, 2, 2, 2].
2. For DMRS type: DMRS type-2 can be included as additional assumptions.
3. For Ranks, the restriction on rank-1 transmission is not necessary. In our understanding, at least rank-2 to rank-4 is more general in practical scenarios. So, it should be revised as Rank-1~Rank-4 adaptation, or leave companies to report.
4. For SCS in FDD system, 15kHz is also possible. We propose to include it in the evaluation assumptions.
 |
| ZTE | 1. We are fine with CDL based model – RRH height: 35m, UE height: 1.5m;
2. Number of scheduled RBs: 8, 24;
3. Precoding method: we think the discrepancy of companies results may be larger if we use precoding cycling rather than UE feedback PMI. That's because we have many precoders, company may have different selection of the subset precoders for cycling. Thus, we suggest to let companies decide what they use or we just use UE reported precoders.
 |
| vivo | 1. The RRH height and UE height highlighted in above table are fine2. Support the antenna parameters for FR2 in the table, which is more aligned with assumption for beam management in Rel-16 discussion 3. Fine with [10, 20, 25, 48, 50] RBs4. for port=2, precoding cycling is ok; for port>2, PMI feedback might be better |
| Samsung | Agree with ZTE on the precoding method. Suggest to consider UE reported PMI as well. |
| Apple | We are a little bit confused with the CDL extension model.* In equation , why not to count 3D distance?
* In equation , what is the meaning of and ?
* In addition, since this is considered as 1 tap per TRP, do we consider to model multiple sub-paths per cluster?

Regarding the TRS periodicity, as we mentioned that 20ms could be more typical since there is no restriction for >=20ms periodicity. We recommend at least to add 20ms as a second option.For Rank, we think rank2 for FR2 could be optional too, to keep consistent with FR1. |
| OPPO | 1. On the layout for FR2, we don’t think HST can work in FR2 with Dmin=5m. Even considering a beam reporting latency of 10ms, the DOA will change significantly within the latency. How can the gNB determine a narrow beam tracking a UE?2. Agree with Huawei that it is not reasonable to have fewer antennas in gNB than at UE. 3. The rank of FR2 should be 1 as mandatory and optional for 2. Higher rank in FR2 than that in FR1 is not a reasonable configuration. 4. What is the assumption on beam management mechanism in FR2? e.g. the number of analog beams and the latency of beam reporting?5. We don’t think 500km/h can work in FR2 especially considering small Dmin (e.g. Dmin=5m, or even 20-30m). However, if companies can provide reasonable performance in these configurations with current beam reporting mechanism, we can accept to list it as it is.  |
| Ericsson | For FR2 we are wondering if the RRH height of 35 meters is typical, a value choice from 5/10/15/20 meters seems more reasonable. 500 km/h is probably too high for FR2, we can focus on 200 km/h or 350 km/h.  |
| QC | It is not clear why PUSCH mapping is considered in the simulation assumption why the evaluation mainly for DL enhancement. Also, we want to clarify the common understanding of precoder cycling. In our understanding, it is per-RRH RBG-based precoder cycling. It is not PMI based with random cycling between the RRHs. Also, we agree with Huawei and OPPO that #Tx should more than 2 (4 or 8) and more than 2 ports. Also, the PMI precoder for 2 ports will be very limited.Also, as Ericsson pointed out, the RRH height of 35m doesn’t look typical in FR2. A height similar to or slightly higher than the train, in the range of 5-10m, would be more reasonable. |

**Offline conclusion #7:**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **FR1** | **FR2** |
| Duplexing  | FDD | TDD | TDD |
| TRP layout (Ds, Dmin, etc) | Ds=700m, Dmin=150mFor CDL based model – RRH height: 35m, UE height: 1.5m  | Alt 2-1: Ds=700m, Dmin=150mAlt 2-2: Ds=400-500m, Dmin=20-50mAlt 2-3: Ds=200-300m, Dmin=30-50mAlt 2-4: Ds=580m, Dmin=5mRRH height: [5/10/15/20/35]m, UE height: 1.5m |
| gNB antenna configuration including number of antennas, pattern, ports, orientation, etc | 2 ports: [Mg, Ng, M, N, P]=[1, 1, 1, 1, 2],4 ports: [Mg, Ng, M, N, P]=[1, 1, 1, 2, 2],one-to-one mapping between antenna elements and TXRUsomni-directional antennaNote: The results for other antenna configurations can be also provided  | 2 ports: [Mg, Ng, M, N, P]=[1, 1, 4, 8, 2],directional antennaFFS: on parameters of antenna elementNote: The results for other antenna configurations can be also provided |
| UE antenna configuration including number of antennas, pattern, ports, orientation, etc | 2 ports: [Mg, Ng, M, N, P]=[ 1, 1, 1, 1, 2] or4 ports: [Mg, Ng, M, N, P]=[1, 1, 1, 2, 2], one-to-one mapping between antenna elements and TXRUsomni-directional antenna | 2 ports: [Mg, Ng, M, N, P]=[1, 1, 2, 4, 2],directional antennaFFS: on parameters of antenna element |
| DMRS type | Mandatory: DM-RS type 1Optional: DM-RS type 2 |
| Number of DMRS symbols | 1+1+1 |
| TDD pattern | N/A | DDDDDDDSUU, S: 6D 4G 4U | DDDDDDDSUU, S: 6D 4G 4U |
| MCS | MCS 4/MCS 13/MCS 17 based on 64QAM tableNote: Companies can also provide results with MCS adaptation |
| Number of scheduled RBs | [4, 8, 10, 20, 25, 48, 50]TBD down-selection | [4, 8, 10, 20, 25, 48, 50]TBD down-selection | [4, 8, 10, 20, 25, 48, 50]TBD down-selection |
| Propagation condition | 4-tap channel model (TS 36.101 (Annex B.3A) / TR 36.878 (RAN4))Optional: CDL extension (CDL D/E, DS = 100ns) | CDL extension (CDL D/E, DS = 20ns/30ns) |
| TRS configuration, TRS periodicity | 10ms, 2-slot patternNote: results for 20ms periodicity can be also provided |
| PDSCH ~~/ PUSCH~~ mapping | Type A, Start symbol 2, Duration 12 |
| Rank | Rank 1Optional: other ranks or rank adaptation | Rank 1 ~~or 2~~Optional: other ranks or rank adaptation |
| BW | 10 MHz or 20 MHz | 10 MHz or 20MHz | 20MHz or 50MHz or 80MHz |
| Carrier frequency or maximum Doppler shift | 2GHz, 350kmph or 500kmph | 3.5GHz, 350kmph or 500kmph | 30 GHz200 km/h or 350km/h ~~or 500km/h~~ |
| Performance metric | Throughput; BLER |
| Other assumptions or simulation parameters, e.g., correlation  | 1) SCS: * 30kHz
* 15kHz as optional

2) Note: precoding method should be provided by each company | 1) SCS: 30kHz2) Note: precoding method should be provided by each company | 1) SCS: 120kHz2) Note: precoding method and analog beamforming details should be provided by each company |

# Other details

Some companies have provided comments regarding additional assumptions that should be provided for simulations, e.g., assumptions for PDCCH evaluations, directional antenna parameters, blockage modelling, clarification on TRS beamforming, etc. Companies are encouraged to provide views regarding remaining details that should be defined for HST scenario.

|  |  |
| --- | --- |
| Company | Comment |
| Apple | We propose to reuse some PDCCH evaluation assumptions in AI 2a as follows

|  |  |
| --- | --- |
| Parameters | Potential values |
| AL | 8 |
| # of RBs/symbols | 1 or 2 symbols. Companies to report # of RBs.  |
| DCI payload | 40+24(CRC)=64 |
| REG bundling size | 6  |
| Precoding assumptions | Precoding cycling, precoder granularity=REG bundle |

 |
| LG | In principle, we agree to reuse PDCCH evaluation assumptions in AI 2a. Detail assumption can be further discussed based on the conclusion of AI 2a. |
| OPPO | For FR2, the beam management mechanism should be considered, e.g. the number of analog beams and the latency of beam reporting should be provided by companies. |
| QC | PDDCH enhancement should be discussed under item 2a. In our views, item 2d of HSF-SFN enhancement is mainly for DL data. |

**Offline conclusion #8:**

* Discuss evaluation assumptions for PDCCH in RAN1#102-e meeting using the following values as starting point

|  |  |
| --- | --- |
| Parameters | Potential values |
| AL | [8] |
| # of RBs/symbols | [1 or 2 symbols. Companies to report # of RBs.] |
| DCI payload | [40+24(CRC)=64] |
| REG bundling size | [6] |
| Precoding assumptions | [Precoding cycling, precoder granularity=REG bundle] |

# EVM issues for RAN1#102-e

This section contains proposals on the remaining details of evaluation assumptions based on the tdocs submitted for RAN1#102-e meeting [1]-[20].

# Parameters of HST-SFN layout for FR2

Some companies expressed their preferences regarding HST layout based on the alternatives identified during email discussion before RAN1#102-e.

* Alt 2-1: Ds=700m, Dmin=150m (Nokia [20])
* Alt 2-2: Ds=400-500m, Dmin=20-50m
* Alt 2-3: Ds=200-300m, Dmin=30-50m (Qualcomm [19], Nokia [20])
* Alt 2-4: Ds=580m, Dmin=5m (Ericsson [15], Samsung? [11], Intel [8], Nokia [20]?)

One company [1] proposed to choose parameters of the HST deployment for FR2 by taking the CP length into account.

Based on the above inputs the following offline conclusion for HST layout in FR2 is made.

**Possible offline conclusion #9.1:**

* Adopt Alt 2-4 as baseline / mandatory HST layout for FR2. Other alternatives can be considered as additional / optional for evaluations.

|  |  |
| --- | --- |
| Company | Comment |
| InterDigital | We can support Alt 2-4, however Dmin=5 seems very small.  |
| Lenovo/MotM | We support Alt 2-3 as baseline. Alt 2-4 can be optional as it is applicable for a specific deployment (e.g., tunnel) scenario |
| Samsung | Support #9.1. Alt 2-4 targets for unified deployment scenario including both outdoor and tunnel. |
| Huawei, HiSilicon | As we point out before, Alt.2-4 with Dmin=5 is proposed for tunnel scenarios as defined in Section 6.2.2 in 36.878 (where 38.913 refers the scenarios in 36.878). So, other alternatives are more reasonable than Alt.2-4 in the evaluation.Then, we do not see HST is a typical scenarios for FR2 deployment. |
| Intel | OK with Alt 2-4 |

# Number scheduled RBs

Four companies expressed their preference regarding the number of scheduled RBs to be used for evaluations.

* Intel [8]: 10 RBs, other optional
* Ericsson [15]: 10 and 50 can be used, others are optional
* Qualcomm [19]: 8 and 48 RBs
* Nokia [20]: The number of scheduled PRBs is 20 and, optionally, 50

Based on the above inputs the following offline conclusion for the number of scheduled RBs is proposed.

**Possible offline conclusion #9.2:**

* The number of scheduled RBs are 10 or 50. Other values are optional.

|  |  |
| --- | --- |
| Company | Comment |
| InterDigital | Agree with Intel; 10 RBs mandatory, other optional. |
| Lenovo/MotM | Support |
| Samsung | Support |
| Huawei. HiSilicon | OK for the proposal. |
| Intel | Support |

# Modelling of practical RF impairments

One company [19] mentioned the need of using practical RF impairments in HST evaluations. However, concrete assumptions were not provided. Based on the input, the following proposal is made.

**Possible offline conclusion #9.3:**

* Real assumption on the time synchronization mismatch between the TRPs and UE carrier-frequency error (CFO) should be considered in the evaluation.
	+ Details are provided by each company

|  |  |
| --- | --- |
| Company | Comment |
| InterDigital | Do not support. Since all TRPs are connected to a same BBU, considering residual CFO/Timing error is not needed. |
| Lenovo/MotM | We agree CFO should be considered |
| Samsung | Do not agree to consider timing mismatch/CFO as baseline since we haven’t aligned models for those impairments. Different conclusions would be made depending on the chosen models. |
| Huawei, HiSilicon | Do not support. Although we agree the evaluation need to be as close as the practical scenarios, however, the implementation is much difference between companies for this issue, and till now there is no proper modeling on this issue, so to simplify the evaluation, we may not consider it here.  |
| Intel | We think it would be good to consider RF impairments esp for gNB pre-compensation schemes. On the other hand, not to complicate evaluations we proposed to add RF impairment modelling as optional component that can be considered by companies.  |

# TRP antenna element model

Three companies proposed antenna element models for HST evaluations.

* Alt 1: CMCC [12]

Table 1: Antenna radiation pattern for TRP with 2Tx

|  |  |
| --- | --- |
| Parameter | Values |
| Antenna configuration | 2Tx: [Mg, Ng, M, N, P]=[1, 1, 1, 1, 2],one-to-one mapping between antenna elements and TXRUs |
| Vertical cut of the radiation power pattern (dB) for a single antenna element | with , and  |
| Horizontal cut of the radiation power pattern (dB) for a single antenna element | with ,  and  |
| 3D radiation power pattern (dB) for a single element |  |
| Maximum directional gain of an antenna element *GE,max* | 20.5 dBi |

Table 2: Antenna radiation pattern for TRP with 8Tx

|  |  |
| --- | --- |
| Parameter | Values |
| Antenna configuration | 8Tx: [Mg, Ng, M, N, P]=[1, 1, 1, 4, 2],one-to-one mapping between antenna elements and TXRUs |
| Vertical cut of the radiation power pattern (dB) for a single antenna element | with , and  |
| Horizontal cut of the radiation power pattern (dB) for a single antenna element |  |
| 3D radiation power pattern (dB) for a single element |  |
| Maximum directional gain of an antenna element *GE,max* | 17.5 dBi |

* Alt 2: Ericsson [15], Qualcomm [19]
	+ Use table Table A.2.1-10 in TR 38.802

|  |  |  |
| --- | --- | --- |
| **Radiation power pattern of a single antenna element for RRH** | Vertical cut of the radiation power pattern (dB) |  |
| Horizontal cut of the radiation power pattern (dB) |  |
| 3D radiation power pattern (dB) |  |
| Maximum directional gain of an antenna element *GE,max* | 8 dBi |

**Possible offline conclusion #9.4:**

* Down-select between Alt 1 and Alt 2 in RAN1#102-e meeting
* Companies are encouraged to provide their preference regarding two alternatives in the table below

|  |  |
| --- | --- |
| Company | Comment |
| Lenovo/MotM | We support Alt 1. |
| Samsung | Support Alt2.  |
| Huawei, HiSilicon | Support Alt.1 |
| Intel | Alt 1 for FR1 and Alt 2 for FR2 |

# TRP antenna orientation

Two companies provided additional clarifications regarding TRP antenna pointing direction in HST deployment, i.e., “The gNB antenna boresight could direct to the middle point on the railway between two TRPs”

**Possible offline conclusion #9.5:**

* Down select between the following two alternatives in RAN1#102-e:
	+ Alt 1 [12]
		- Antenna horizontal half power beam direction points to the midpoint between the two TRPs
		- Antenna vertical upper half power beam direction points to the midpoint between the two TRPs
	+ Alt 2 [19]
		- Antenna downtilt and azimuth directions point to the midpoint between the two RRHs
* Companies are encouraged to provide their preference regarding two alternatives in the table below

|  |  |
| --- | --- |
| Company | Comment |
| Lenovo/MotM | We support Alt 2 |
| Huawei, HiSilicon | Support Alt.1 |
|  |  |
|  |  |

# FFS issues in CDL-based channel model for HST

One company [12] provided additional clarifications for CDL-based channel model to address one of the FFS issue raised in email discussion before RAN1#102-e. The proposed changes are highlighted below.

|  |
| --- |
| CDL based channel model proposal for HST: Combination of the CDL channel model in TR38.901 and the 4-tap channel model in TS36.101 Annex B.3A could be considered. As illustrated in figure below, 2-tap channel model for simplicity could be assumed which is similar to RAN4’s 4-tap assumption in order to reflect the characteristic of SFN-based transmission, and for each tap, CDL channel model in TR38.901 could be used to model the effect of the directional antenna of gNB.* + The delay for k’th TRP is modified as`

where  is the delay of k’th TRP, which can be derived aswhere is the delay of the n’th channel cluster as in Table 7.7.1-1~7.7.1-5 in 38.901, and assume the location of the k’th TRP is xk, and the UE’s location is y(t).The delay spread for different TRPs could be modeled as different.* + The normalized power for k’th TRP is modified as

FFS: Use of 3D distance for calculation of Pk* + To generate the modified angle parameters, the scaling method mentioned in subclause 7.7.5.1 in TS 38.901 is used

where could be assumed, and of the k’th TRP is the AOD, AOA, ZOD and ZOA of LOS direction derived based on the locations and antenna heights of UE and TRPs.~~FFS: Further clarifications to and~~  is the tabulated CDL ray angle is the rms angular spread of the tabulated CDL including the offset ray angles, calculated using the angular spread definition in Annex A in TS 38.901 is the mean angle of the tabulated CDL, calculated using the definition in Annex A in TS 38.901 is the desired mean angle is the desired rms angular spread is the resulting scaled ray angle.of the k’th TRP is the AOD, AOA, ZOD and ZOA of LOS cluster derived by the locations and antenna heights of UE and TRPs. If is used to denote the distance between UE and TRP1. For AOD1 of TRP1, For AOA1 of TRP1, For AOD2 of TRP2, For AOA2 of TRP2, For ZOD1 of TRP1, For ZOD1 of TRP2, For ZOA2 of TRP1 ,  For ZOA2 of TRP2, Fig. 1. Simplified and updated HST-SFN channel model for evaluationThe gNB antenna boresight could direct to the middle point on the railway between two TRPs. CDL-D and CDL-E channels models are recommended for evaluations. |

**Possible offline conclusion #9.6:**

* Adopt TP for CDL based channel model
* Note: Companies are encouraged to share their preference on the other FFS issue, i.e., use of the 3D distance for calculation of Pk

|  |  |
| --- | --- |
| Company | Comment |
| Lenovo/MotM | OK to adopt the CDL-based model in [12] |
| Huawei, HiSilicon | OK with the proposed modeling for HST in the evaluation, but we do not think it should be a TP to change CDL models. |
| Intel | OK with TP for CDL-based HST channel model |
|  |  |

# Other comments

Please provide other comments related to evaluation assumptions of HST scenario that should be considered in RAN1#102-e meeting.

|  |  |
| --- | --- |
| Company | Comment |
| InterDigital | There seem to be a divergent in views expressed by companies in terms of the type of UE for HST evaluation. Some companies are assuming a UE as a handset while some other companies are considering a CPE type of the UE.Given that these two types of UEs1. can experience very different channels, i.e., outdoor-indoor versus outdoor-outdoor,
2. may have different levels of complexity, power consumption, and processing capabilities, for example, a CPE type of UE may be able to process an SFN-TRS while a handset type UE cannot,
3. can imply different situations/conditions for beamforming, UE orientation/rotation,
4. many of solutions for a CPE type UE may be group-based while handset type UE may often require UE-specific handling,

we would like to propose to have one type of UE as the main target or the higher priority type for this evaluation. |
| Huawei, HiSilicon | The antenna ports at gNB side should include “8 ports” cases, which is a practical deployment in current network. |
| Intel | We think that some parameters related to UL transmissions should be defined for evaluation of gNB based pre-compensation schemes. Considering that parameter of such scheme may be part of the proposal it is necessary that proponents to clarify them to understand impact on the system. Propose to include a row stating that “UL transmission assumptions, if used, should be provided by company” |
|  |  |

# References

[1] R1-2005367, Evaluation and discussion on HST-SFN schemes, vivo

[2] R1-2005458, Discussion on Multi-TRP HST enhancements, ZTE

[3] R1-2005486, Enhanced M-TRP for HST-SFN, InterDigital, Inc.

[4] R1-2005564, Considerations on HST-SFN operation for multi-TRP, Sony

[5] R1-2005592, Enhancement to support HST-SFN deployment scenario, FUTUREWEI

[6] R1-2005687, Discussion on enhancements on HST-SFN deployment, CATT

[7] R1-2005753, Discussion on HST-SFN deployment, NEC

[8] R1-2005862, On HST SFN enhancements, Intel Corporation

[9] R1-2005925, Enhancements for HST-SFN deployment, Lenovo, Motorola Mobility

[10] R1-2005987, Enhancements on HST-SFN deployment, OPPO

[11] R1-2006132, Enhancements on HST-SFN, Samsung

[12] R1-2006204, Enhancements on HST-SFN deployment, CMCC

[13] R1-2006261, Discussion on enhancements on HST-SFN deployment, Spreadtrum Communications

[14] R1-2006394, Enhancements on Multi-TRP for high speed train in Rel-17, Huawei, HiSilicon

[15] R1-2006475, Enhancement on HST-SFN deployment, Ericsson

[16] R1-2006503, Views on Rel-17 HST enhancement, Apple

[17] R1-2006600, Enhancements on HST-SFN deployment, LG Electronics

[18] R1-2006722, Discussion on HST-SFN deployment, NTT DOCOMO, INC.

[19] R1-2006794, Enhancements on HST-SFN deployment, Qualcomm Incorporated

[20] R1-2006847, Enhancements for HST-SFN deployment, Nokia, Nokia Shanghai Bell