**3GPP TSG RAN WG1 #116 R1-240XXXX**

**Changsha, Hunan Province, China, April 15th – 19th, 2024**

**Source: Moderator (CMCC)**

**Title:** **FL summary #1 for Ambient IoT evaluation**

**Agenda: 9.4.1.1**

**Document for:** **Discussion & Decision**

# Background

A new SI for ambient IoT is started[26]. This document summarizes the contributions [1 - 25] for AI 9.4.1.1 in RAN1#116. The issues/proposals in this document are marked with [open]/[closed], or [high]/[medium]/[low] priority (for the current meeting)

# Online proposals

# Discussions

## General

### Terminologies

Note: the following is used in this document,

**Device 1**: *~1 µW peak power consumption, has energy storage, initial sampling frequency offset (SFO) up to 10X ppm, neither DL nor UL amplification in the device. The device’s UL transmission is backscattered on a carrier wave provided externally.*

**Device 2a**: *≤ a few hundred µW peak power consumption, has energy storage, initial sampling frequency offset (SFO) up to 10X ppm, both DL and/or UL amplification in the device. The device’s UL transmission is backscattered on a carrier wave provided externally.*

**Device 2b**: *≤ a few hundred µW peak power consumption, has energy storage, initial sampling frequency offset (SFO) up to 10X ppm, both DL and/or UL amplification in the device. The device’s UL transmission is generated internally by the device.*

**Ambient IoT device:** *simply as ‘D’*

**Ambient IoT reader:** *simply as ‘R’,*

* *‘R’ is base station for topology 1.*
* *‘R’ is intermediate node for topology 2.*

**R2D (Forward link)**:

* *It is for R-to-D communication. For topology 1, it denotes the downlink communication, i.e., BS-to-AIoT device. For topology 2, it denotes the intermediate node to AIoT device communication.*

**D2R (Reverse link)**:

* *It is for D-to-R communication. For topology 1, it denotes the uplink communication, i.e., AIoT device -to-BS. For topology 2, it denotes the AIoT device to intermediate node communication.*

**CW:** *carrier wave*

**CW2D:** *CW node to Ambient IoT device link.*

**RF-EH:** *RF energy harvesting*

**PRDCH:** *Physical Reader-to-Device Channel*

**PDRCH:** *Physical Device-to-Reader Channel*

**D1T1:** *Deployment scenario 1, Topology 1*

**D2T2:** *Deployment scenario 2, Topology 2*

### [H]General Evaluation Methodology

#### Related Tdoc Proposals

The following is agreed in RAN1#116

Agreement

For this study item, the coverage evaluation methodology is based on the following steps.

For an evaluation scenario

* For each of the link *i*,
  + Step 1: Obtain the required SINR for the physical channels under target scenarios and service/reliability requirements if **Budget-Alt2** is used for this link *i*.
  + Step 2: Obtain the receiver sensitivity using the method **Budget-Alt1** (if a predefined threshold is assumed to derive the receiver sensitivity)or **Budget-Alt2** (if no predefined threshold is assumed to derive the receiver sensitivity).
  + Step 3: Obtain the coverage performance for link *i* based on the receiver sensitivity from step 2 and link budget template.
* The coverage results for each link are provided.
* FFS: what links are evaluated besides R2D and D2R (e.g., RF-EH)
* FFS whether/how to model the interference
* FFS: for which device(s) a predefined threshold is assumed

Note the following alternatives for obtaining receiver sensitivity are defined,

* **Budget-Alt1:** receiver sensitivity is derived by a predefined threshold and no LLS is needed for link budget calculation
  + The results rely on the received sensitivity and maximum transmit power, and directly calculate the maximum distance / pathloss based on these values and other related parameters. The link-level simulation (LLS) performances, such as required SINR can be satisfied for such case and no LLS is needed for link budget calculation.
* **Budget-Alt2:** receiver sensitivity is derived by required SINR which is given by LLS results
  + The results rely on link-level simulation results, e.g., required SINR which corresponds to detail LLS assumptions (e.g., BW, coding, data rate). And based on the required SINR, the received sensitivity can be calculated and then the maximum distance / pathloss can be derived.
  + Note: For noise power, a noise figure value needs to be provided.

The Tdoc proposals are as follows,

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| **CATT** | **Proposal 17:** **The RF-EH link should be evaluated if the activation/energy harvesting threshold is higher than the data reception threshold.**  **Proposal 18: If the evaluation of RF-EH link is needed, budget-Alt1 can be used. The activation threshold can be defined as the minimum power to activate the internal circuit or components of A-IoT device to start to work.**  **Proposal 19: Budget-Alt 2 should be used in the coverage evaluation for D2R and R2D link.**  **Proposal 20: Additional sensitivity loss should be considered in the link budget template. The specific definition and calculation method should be given by RAN4.** |
| **Apple** | ***Proposal 4: For the link budget coverage analysis, in order to keep the scope limited, following baseline assumptions can be considered:***   * ***R2D transmission in DL spectrum in topology 1*** * ***R2D transmission in UL spectrum in topology 2*** * ***D2R transmission in UL spectrum for both topology 1 and topology 2*** * ***CW transmission in UL spectrum for all scenarios, with 23 dBm as CW Tx power for all scenarios*** |
| **CMCC** | **Proposal 5: For device 1, RF energy harvesting is considered. FFS for device 2a/2b.**  **Proposal 6: For the target performance metric, both the link budget of RF energy harvesting (if used), R2D, and D2R link are calculated.**   * **For RF-EH and R2D, Budget-Alt1 is used to obtain receiver sensitivity at least for device 1 and device 2a, and further discuss device 2b.** * **For D2R communication, Budget-Alt2 is used to obtain receiver sensitivity.** |
| **China Telecom** | ***Proposal 1: For coverage evaluation, the performance of RF-EH link needs to be considered at least for device 1 and device 2a.***  ***Proposal 2: Use Budget-Alt1 for device 1’s and device 2a’s RF-EH link*** ***evaluation and Budget-Alt2 for device’s R2D link and D2R link evaluation.*** |
| **Comba** | **Proposal 1**  **Supports both budget-Alt1 and budget-Alt2 methods for analyzing A-Iot coverage, but budget-Alt2 takes into account physical layer design such as bandwidth, receiver algorithm, BLER, etc. budget-Alt2 computs coverage more efficiently.** |
| **Ericsson** | 1. Based on the RAN plenary outcome [8], the study of the energy harvesting signal/waveform is outside the scope of the SI in Rel-19. 2. The assessment of the EH link can be excluded from the link budget evaluations. |
| **Qualcomm** | ***Proposal 2: For coverage (link budget) analysis***   * ***For each scenario, perform link budget analysis for three links including CW/EH, R2D, and D2R.*** |
| **FutureWei** | ***Proposal 2: No other links (e.g. RF-EH) besides R2D and D2R need to be evaluated.***  ***Proposal 3: For Device 1 and Device 2a, in R2D link, the receiver sensitivity is the maximal of the receiver sensitivity of Budget-Alt1 and Budget-Alt2. For D2R link using the receiver sensitivity from Budget-Alt2.*** |
| **Huawei** | ***Proposal 6: The study does not include RF energy harvesting in the deployment scenarios.***  ***Proposal 7: The study assumes downlink spectrum for the R2D transmission in D1T1.***  ***Proposal 8: In D1T1, the study assumes the following spectrum for both CW2D and D2R transmission.***   * ***D1T1-A: DL spectrum (Case 1-1)*** * ***D1T1-B: UL spectrum (Case 1-4)***   ***Proposal 9: The study assumes 900 MHz as the baseline of carrier frequency for the coverage and coexistence evaluations of Ambient IoT.*** |
| **IITK, IITH** | **Proposal 1:** The evaluation methodology of AIoT should consider both R2D and D2R links. |
| **MediaTek** | **Observation 5: Based on the clarification made in RAN plenary #103, the design of EH signal/waveform is out of SI scope of Rel-19, while the link budget calculation for EH link can still be performed if the necessity is justified.**    **Observation 6: For device type with EH only from RF, the link budget of reader-to-device is limited by the activation threshold of the EH circuity, i.e., a EH-limit case. While for device type with EH from more than RF, the link budget of reader-to-device is limited by the sensitivity power of the device, i.e., a communication-limit case.**  **Proposal 15: For link budget calculation, RF-EH link should be evaluated at least for device type with EH only from RF (e.g., device 1).**  **Proposal 16: For device type with EH only from RF (EH-limit case), a predefined threshold can be used for link budget calculation of reader-to-device, i.e., Budget-Alt1.**   * **FFS value for the predefined threshold, e.g., -20dBm.**   **Proposal 17: For device type with EH from more than RF (communication-limit case), a required SNR/SINR based on LLS output is necessary to calculate the sensitivity of device for link budget calculation of reader-to-device, i.e., Budget-Alt2.**   * **FFS whether/how to model the interference, e.g., a predefined value, or based on SLS output.** |
| **NEC** | **Proposal 1: Consider the evaluation requirements of use cases relevant to Indoor inventory for Ambient IoT study.**  **Proposal 2: Uplink coverage performance needs to be evaluated for each scenario associated with backscatter communication.** |
| **Nokia** | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | **Proposal 1: RAN1 to consider the down selection of the topology-agnostic focus evaluation cases listed in Table 1 for the Rel-19 Study. Both topologies should be considered, with special attention on ensuring that all necessary assumptions to carry out a thorough study of topology 2, as per proposed focus evaluation cases, are considered and agreed on.**  Table 1: Proposed focus evaluation cases A, B & C   |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | **Focus evaluation cases:** | **A** | **B** | **C** | | **Device Type:** | 1 (backscatter) | X |  | X | |  | 2a (backscatter) | X |  | X | |  | 2b (active) |  | X |  | | **Spectrum:** | In-band | X | X | X | |  | Guard-band |  |  |  | |  | Standalone band |  |  |  | | **Backscatter type:** | CWE = Reader |  |  |  | |  | CWE != Reader | X | X |  | |  | CWE != Readers |  |  | X | | **Representative use cases:** | rUC1 | X | X |  | |  | rUC4 |  |  |  | |  | Positioning |  |  | X | | |
| **DOCOMO** | **Proposal 1: For the coverage evaluation of A-IoT, Budget-Alt2 in the agreement of RAN1#116 should be considered as the baseline.** |
| **OPPO** | Proposal 1: The coverage for RF-EH link should be evaluated.  **Proposal 2: Budget-Alt1 should be used for the coverage evaluation for RF-EH, -25~-30dBm can be considered in this evaluation.**  **Proposal 3: Budget-Alt1 should be used for device with RF envelope, -45dBm/-30dBm should be considered as the threshold for device with/without LNA.**  **Proposal 4: Budget-Alt2 should be used for device with IF or zero-IF detector.** |
| **Vivo** | **Proposal 4: For device type 1, both RF EH link and R2D data link should be evaluated, for device type 2, only R2D data link need to be evaluated.**  **Proposal 5: For RF EH link, Budget-Alt1 is used for link budget calculation, for R2D data link, Budget-Alt2 is used for link budget calculation.** |
| **Xiaomi** | ***Proposal 4: R2D and D2R links should be separately evaluated.***  ***Proposal 5: The evaluation for link D2R can be decoupled with the CW2D link for device 1 and device 2a, assuming the Tx power of device 1/2a is -30dBm.***  ***Proposal 6: No dedicated evaluation is needed for CW2D link.*** |
| **ZTE** | ***Proposal 3: For coverage distance, the following links need to be evaluated for Ambient IoT:***   * ***Energy harvesting for Device 1*** * ***Downlink detection for Device 1, 2a and 2b*** * ***Backscatter link detection for Device 1 and 2a*** * ***Active uplink detection for Device 2b*** |

#### Discussion (round 1)

Budget-Alt1 or Budget-Alt 2

R2D

* Budget-Alt1: Apple, CMCC, Comba, Qualcomm, OPPO, vivo, ZTE, FutureWei(device 1), Huawei(RF ED)， Ericsson, Nokia
* Budget-Alt2: CATT, China Telecom, Comba, MediaTek, DOCOMO, FutureWei(device 2), Huawei(IF/ZIF receiver), Xiaomi

D2R: most companies prefer Budget-Alt 2 as the candidate method.

#### [High][P3.1.2-(1)-v1]

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| **Proposals:**  For R2D link in the coverage evaluation,   * *Budget-Alt1* is used if receiver architecture is RF ED   + FFS: value(s) of the predefined threshold * Otherwise, *Budget-Alt2* is used.   For D2R link in the coverage evaluation,   * *Budget-Alt2* is used. |

RF-EH

* The reason RF-EH is not evaluated since according to the RAN plenary outcome [8], the study of the energy harvesting signal/waveform is outside the scope of the SI in Rel-19. Hence, the study does not include RF energy harvesting in the deployment scenarios.
* The reason RF-EH is considered since companies think there is a case the activation/energy harvesting threshold is higher than the data reception threshold.

RF-EH link is not evaluated for coverage evaluation:

* CMCC(device2a/2b), Ericsson, Huawei, FutureWei,

RF-EH link is evaluated for coverage evaluation:

* CATT, CMCC(device 1), China Telecom (device 1/2a), Qualcomm, MediaTek(device 1), OPPO, vivo, ZTE(device 1)

#### [High][P3.1.2-(2)-v1]

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| **Proposals**  **WayFoward-RF-EH-1:**  RF-EH is not included in the coverage evaluation. State this fact in the TR conclusion.  **WayFoward-RF-EH-2:**  For coverage evaluation for device 1, RF-EH link is considered to be evaluated by using *Buldget-Alt1*.   * FFS: value(s) of the predefined threshold   **WayFoward-RF-EH-3:**  For coverage evaluation for device 1 and device 2, RF-EH link is considered to evaluated by using *Buldget-Alt1*.   * FFS: value(s) of the predefined threshold |

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| **Company** | **Comments** |
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## Remaining design targets / performance metrics

RAN SID task RAN1 to discuss the followings

1. Conclude at least the following aspects of design targets left to WGs in Clause 5 (RAN design targets) of TR 38.848 [RAN1].
   * Clause 5.3: Applicable maximum distance target values(s)
   * Clause 5.6: Refine the definition of latency suitable for use in RAN WGs
   * Clause 5.8: 2D distribution of devices

RAN#103 agreement

**Proposal 5v2**

* RAN design targets for user experienced data rate, maximum message size, and moving speed of device: those can be used as assumptions in coverage evaluations, i.e. the coverage evaluations are done under the conditions that meet those targets.
* Evaluations of RAN design targets for latency and connection/device density are allowed by the Rel-19 SID and observations on those evaluations can be captured in the TR38.769
* Note: this is as per the SID: “*NOTE: Assessment performance of the design targets is within the study of feasibility and necessity of proposals in the following objectives, e.g. by inspection of reference implementations in the field, simulations, analytically*.”

### [H]Refine the definition of latency suitable for use in RAN WGs

#### Related Tdoc Proposals

Related Tdoc proposals are as follows,

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| **Apple** | ***Proposal 2: For the design targets for supporting ambient IoT devices for the indoor use-cases of inventory and command, definition of the latency is refined as:***   * ***For inventory use case: The time interval between the time that the inventory request is sent from BS/intermediate UE and the time that the inventory report is successfully received at BS/intermediate UE*** * ***For command use case: The time interval between the time that the DL command is sent from BS/intermediate UE and the time that the command is successfully received at A-IoT device.*** |
| **CATT** | **Proposal 14: The latency for A-IoT should be defined for a single device.** |
| **CMCC** | **Refine the definition of latency suitable for use in RAN WGs**   * **For inventory use case:**    + **The time interval between the time that the inventory request is sent from BS/intermediate UE and the time that the inventory report is successfully received at BS/intermediate UE.** * **For command use case:**    + **The time interval between the time that the DL command is sent from BS/intermediate UE and the time that the commands successfully received at A-IoT device.** * **FFS the components (e.g., processing time at BS and/or A-IoT device) to be included in the calculation of latency.** * **Note: the latency definition is for a A-IoT device.** |
| **China telecom** | *Proposal 7: Define different latency composition methods for different traffic types*   * *For DT traffic, the latency is composed of triggering transmission time and processing time .* * *For DO-DTT traffic, the latency is composed of triggering transmission time , processing time* *, and data transmission time .* |
| **Ericsson** | 1. Definition of the latency is as follows:  * For inventory use case: The time interval between the time that the inventory request is sent from BS/intermediate UE to a A-IoT device and the time that the inventory report is received at BS/intermediate UE from the A-IoT device. * For command use case: The time interval between the time that the DL command is sent from BS/intermediate UE and the time that the data command is received at a A-IoT device. * Processing delay at the BS/intermediate UE and A-IoT device is included in the calculation of latency. * FFS other components till RAN2 agrees on the message flow between BS/intermediate UE and the A-IoT device. * Note: the latency definition is for a A-IoT device. * Note: Time for energy harvesting is not included in the definition of latency. |
| **Qualcomm** | ***Proposal 3: Define following latency for the study of unicast communication and inventory procedure.***   * ***Inventory Latency/completion time: the time required for a reader to successfully read [Z]% of A-IoT devices for a given number of reachable A-IoT devices by the reader (by unicast communication). FFS Z=95%*** |
| **Huawei** | ***Proposal 3: Refine the definition of latency as “Time from the beginning of the query/triggering message transmission from basestation or intermediate node to a device, to the end of the reported message transmission from the device to basestation or intermediate node”.*** |
| **Interdigital** | **Proposal 4: Define Latency for IoT device 1 or 2a as the time from the querying of IoT device by BS or intermediate node (e.g., UE) via CW signal to the time of backscattered message reception by BS or intermediate node (e.g., UE) from IoT device.** |
| **MediaTek** | **Proposal 25: The maximum distance target is set separately for device 1 and device 2a&2b**   * **For device 1, the maximum distance target is lower than 20 m** * **For device 2a&2b, the maximum distance target is higher than 20m** |
| **OPPO** | **Proposal 6: The latency of DO-DTT traffic is defined as the time from the triggering message arriving at the [MAC] layer of the reader to the moment when the response from the A-IoT device received by the reader. The latency of DT traffic is defined as the time from the data arriving at the [MAC] layer of the reader to the moment when the data is received by the A-IoT device.** |
| **Samsung** | Proposal 12. Definition of the latency is refined as follows:   * For the inventory use case: the time interval between the time that the inventory request is sent from a reader and the time that the inventory message from a tag is successfully received at the reader.   + The successful reception means that the reader has a successful CRC check in the inventory message. * For the command use case: the time interval between the time that the command is sent from a reader and the time that the command is successfully received at a tag.   + The successful reception means that the tag has a successful CRC check in the command. * The processing time is not included in latency. |
| **Spreadtrum** | ***Proposal 2:*** ***The definition of latency is different for indoor inventory and indoor command***   * ***For indoor inventory, the latency is the duration from the time of the query/triggering transmission from the reader to the device (s), to the time of the response reception from the device (s) to the reader, which also include the latency of contention based access.*** * ***For indoor command, the latency is the duration from the time of the R2D transmission from the reader to the device, to the time of the D2R response reception from the device to the reader.*** |

#### Discussion (round 1)

The current TR38.848 has the following description of the latency definition. And it is agreed in SID that RAN WGs can refine a definition of latency suitable for their work within the above.

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| **5.6 Latency**  The one-way end-to-end maximum latency targets, as defined in TR 22.840, are:  - Longer latency target: 10 seconds  - Shorter latency target: 1 second  A use case is assigned to a latency target according to TR 22.840. RAN WGs can refine a definition of latency suitable for their work within the above.  NOTE: The time for charging the Ambient IoT device storage (if present) is not included in the latency defined above. Time for energy harvesting, charging, etc. is regarded as an implementation issue only.  NOTE: the one-way end-to-end maximum latency is assumed to also include query/triggering time. |

For evaluation of the latency, during the RAN#103, the following is agreed,

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| **Proposal 5v2**   * RAN design targets for user experienced data rate, maximum message size, and moving speed of device: those can be used as assumptions in coverage evaluations, i.e. the coverage evaluations are done under the conditions that meet those targets. * Evaluations of RAN design targets for latency and connection/device density are allowed by the Rel-19 SID and observations on those evaluations can be captured in the TR38.769 * Note: this is as per the SID: “*NOTE: Assessment performance of the design targets is within the study of feasibility and necessity of proposals in the following objectives, e.g. by inspection of reference implementations in the field, simulations, analytically*.” |

After reviewing Tdoc proposals, most companies have similar proposal definition with the following things to be clarified,

* Processing delay/time is included in the description or not. (No: Samsung Yes: Ericsson)
* Ericsson proposed that other RAN2 related components should be included.
* Many companies clarify that the latency defined here is for a single device.

#### [H][P3.2.1-(1)-v1]

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| **Proposal**:  Definition of the latency is refined as follows,   * For inventory use case:   + The time interval between the time that the inventory request is sent from BS/intermediate UE to a A-IoT device and the time that the inventory report is [successfully] received at BS/intermediate UE from the A-IoT device. * For command use case:   + The time interval between the time that the DL command is sent from BS/intermediate UE and the time that the command is [successfully] received at A-IoT device. * Note: the latency definition is for a A-IoT device. * Note: Time for energy harvesting before the inventory/command start is not included in the definition of latency. |

* Many companies (Qualcomm, CMCC, CATT, Lenovo, LGE, OPPO, Samsung, ZTE) thinks an evaluation for multiple devices by taking the device density into account should be considered. Few companies (Huawei) think the study does not include the overall latency of the inventory of multiple devices. Please see section 3.2.4 for the new metric.

For evaluation of the latency for a device, the current TR38.848 has the following description of the latency.

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| **6.1.6 Latency**  Feasibility of latency was reported typically by comparing a message size to a data rate, for example 5 kbps / 1000 bit = 200 ms latency for the largest message size at the target peak rate. Feasibility would also depend on a consideration of signalling procedures and possible random access-like procedure. |

Some companies suggest to further evaluate latency considering necessary components (e.g., processing time at BS and/or A-IoT device) to be included in the calculation (Ericsson). While (Samsung) suggests the processing time is not included in latency.

#### [M][P3.2.1-(2)-v1]

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| **Proposal**:   * FFS the components to be included in the calculation of latency.   + Companies are encouraged to provide a template/table to include each component for latency calculation till RAN1#117 meeting.   + Potential components are as follows for example,     - Processing delay at the BS/intermediate UE and A-IoT device,     - Components for the message flows,     - triggering transmission time,     - processing time,     - data transmission time,     - etc. |

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| **Company** | **Comments** |
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### [M]Applicable maximum distance target values(s) (TR38.848 Clause 5.3)

#### Related Tdoc Proposals

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| **CMCC** | The applicable maximum distance target values can be decided depending on the evaluation results of the link budget. |
| **Comba** | **It is recommended to consider setting different coverage targets in the target range of 10-50 meters for A-IoT devices with different power consumption, as determined by RAN1 after A link budget assessment.** |
| **Huawei** | ***Proposal 1: The target maximum distance can be different between device 1 and device 2a/2b.***  ***Proposal 2: Detailed target maximum distance for Ambient IoT device of each power consumption level is determined within the range of 10-50 m by link budget evaluations.*** |
| **Interdigital** | **Proposal 3: Support multiple distance target value(s) based on scenario and IoT device type.** |
| **LGE** | ***Proposal 1: On coverage of Ambient IoT devices,***   * ***device ii supports maximum distance up to 50 m*** * ***device i supports maximum distance up to X m (FFS X, 10 m X < 50m)*** * ***Note: devices i and ii are as described in General Scope of the SID*** |
| **OPPO** | **Proposal 5: Distance target for Device 1 is [10m, 20m], for Device 2a with backscattering is [20 m, 50m), for type 2b with active transmission is 50m.** |
| **Spreadtrum** | ***Proposal 1: Maximum distance target should be set separately for Device 1, Device 2a, and Device2b respectively, jointly considering different deployment scenarios as well.*** |

#### Discussion (round 1)

Different Target

* Most companies think maximum distance target can be set separately for device 1/2a/b respectively.
* Some companies [IDC, Spreadtrum] think this can be set separately by different scenarios
* Apple, Huawei and CMCC think RAN1 can be further refine/decided based on link budget study

Candidate distance by proposal

* Device 1: 10m, 20m
* Device 2a: 50m,
* Device 2b: 50m,

#### [M][P3.2.2-v1]

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| **Conclusion**:   * The maximum distance target can be set separately for device 1 and 2a/2b respectively * FFS detail values and RAN1 can further decide the target within in the range of [10m, 50m] after link budget study. * FFS set different values for different scenarios |

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| **Company** | **Comments** |
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### Connect density/Device distribution(TR38.848 Clause 5.8)

See section 3.3.2

### Inventory time

#### Related Tdoc Proposals

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| **Qualcomm** | ***Proposal 8: RAN1 introduces inventory traffic model as follows.***   * ***Periodic inventory request from A-IoT server with periodicity of [15] min.*** * ***Reader generation multiple inventory queries over multiple rounds to read A-IoT devices.***   + ***The query generation timing depends on the random-access procedure.*** * ***Reader generates multiple queries until inventory timer expires, or reader decides to stop inventory process early (due to no more reading).***   ***Proposal 13***   * ***RAN1 to perform evaluation of inventory process considering following aspects in evaluation.***   + ***Indoor scenario***   + ***Single Reader / [multiple Readers]***   + ***Multiple A-IoT devices***   + ***Pathloss only channel model / [fading channel]***   + ***Energy harvesting model***   + ***Power consumption model***   + ***Inventory procedure***   ***Proposal 9: RAN1 consider RF energy harvesting in its inventory evaluation.***  ***Proposal 10: RAN1 to use PCE curve (or table) to study the impact of charging during inventory process.***  ***Proposal 11: RAN1 to capture sensitivity in the PCE curve or table for evaluation purpose.*** |
| **CMCC** | **And the following performance metrics and evaluations are proposed,**  ***Inventory completion time***   * **The following performance metric is considered for evaluation purpose only,**   + ***Inventory completion time for multiple devices [s]***     - **For inventory use case, the ‘Inventory completion time for multiple devices’ is defined as the time a reader successfully read [Z]% of A-IoT devices for a given number of reachable A-IoT devices by the reader**   **- FFS: Z**   * + **Note: evaluations are expected to be provided by numeric analysis rather than by system-level simulations.**   + **Company to report**     - **R2D and D2R data rate**     - **random access schemes**   **message size and etc.** |
| **CATT** | **Proposal 21: Numerical analysis can be used in delay evaluation for A-IoT.** |
| **Huawei** | Regarding the overall latency of the inventory of multiple devices, it is not included in the objectives of the SID, and not included in the RAN design targets defined in Rel-18 Ambient IoT as well. Consequently, no performance assessment is needed on this parameter, considering there is not even a definition of the design target for it. According to the guide of “strive to minimize evaluation cases in RAN1” in the SID, it is recommended not to study a new aspect, so as to avoid increased workload in Rel-19.  ***Proposal 4: The study does not include the overall latency of the inventory of multiple devices.*** |
| **Lenovo** | ***Proposal 6: RAN1 should evaluate the number of devices to be inventorized in a given area in an inventory round, considering***   * ***Collision due to the number of devices participating in an inventory round.*** * ***Target latency considering the energy harvesting within the inventory round.*** |
| **LGE** | ***Proposal 2: For RAN1 study purpose, consider RF energy harvesting time and its impact on device availability.***   * ***E.g., For latency evaluation for an inventory for multiple devices (e.g., inventory completion time), potential impact of energy harvesting on device availability for transmission and reception procedures can be considered.*** |
| **OPPO** | Proposal 21: The latency evaluation is done under the condition that target on device density is met, “Inventory completion time for multiple devices” defined in R1-2401735 is used as the performance metric for the evaluation. |
| **Samsung** | Proposal 14. The total latency across all devices within the coverage can be used as the performance metric for the latency and connection/device density evaluation. |
| **ZTE** | ***Proposal 9: The following latency can be defined and evaluated for Ambient IoT.***   * ***Command completion time for single device*** * ***Inventory completion time for single device*** * ***Inventory completion time for multiple devices*** |

#### Discussion (round 1)

* Many companies (Qualcomm, CMCC, CATT, Lenovo, LGE, OPPO, Samsung, ZTE) thinks an evaluation for multiple devices by taking the device density into account should be considered.
* Huawei think the study does not include the overall latency of the inventory of multiple devices.
* Qualcomm proposed to include RF energy and PCE curve (or table) in the study of inventory evaluation.
* Lenovo and LGE thinks for latency evaluation for an inventory for multiple devices (e.g., inventory completion time), potential impact of energy harvesting on device availability for transmission and reception procedures can be considered.

#### [H][P3.2.4-v1]

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| **Proposal**:   * The following performance metric is considered for evaluation purpose only,   + *Inventory completion time for multiple A-IoT devices [s]*   + For inventory use case, the ‘*Inventory completion time for multiple A-IoT devices*’ is defined as the time a reader successfully read [Z]% of A-IoT devices for a given number of reachable A-IoT devices by the reader   + FFS: Z = {99%(Mandatory), 90%(Optional)}   + Company to report     - Random access schemes     - R2D and D2R data rate     - Message size     - Device distribution, [near, middle, far] = [TBD%, TBD%, TBD%] |

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| **Company** | **Comments** |
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### Others

* Device power consumption
* Device complexity
* ~~Coverage~~
* User experienced data rate
* Maximum message size
* ~~Latency~~
* Positioning accuracy
* ~~Connection/device density~~
* Moving speed of device

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| **Apple** | ***Proposal 1: For the design targets for supporting ambient IoT devices for the indoor use-cases of inventory and command, consider following design target values (also for evaluation purpose):***   |  |  | | --- | --- | | **Design Target** | **Value** | | Device’s power consumption | Lower-category: ~1µW of peak power consumption  Higher-category: few hundreds of µW of peak power consumption | | Device’s complexity | Lower-category: comparable to UHF RFID ISO18000-6C (EPC C1G2)  Higher-category: orders-of-magnitude lower than NB-IoT | | Coverage range | Initial range of 10-50ms, can be further refined based on link budget study | | User-experience data rate | At least 2 Kbps | | Maximum message size | Up to 1000 bits | | Latency | E2E DL/UL latency of 1-10 seconds | | Positioning accuracy | 1~3 meters @ 90% indoor location | | Connection/device density | 150 devices/100m2 | | Device’s mobility | Up to 3Kmph | |
| **CATT** | **Proposal 15: KPIs to be considered for evaluation are the link level performance, coverage, latency and coexistence.** |
| **China Telecom** | **Proposal 6: Define different data rate requirements for different capabilities of devices**  **- The date rate is 0.1kbps~x1 kbps for device 1/2a, and x2 kbps~5kbps for device 2b.**  **- The value of x1 and x2 can be further discussed.** |
| **Qualcomm** | ***Proposal 4: Introduce random and cluster model in device distribution.***  ***Proposal 5: Adopt following KPIs for evaluation purpose.***   * ***Unicast Latency (sec)*** * ***Inventory Latency (sec)*** * ***Inventory reading speed (#/sec)*** * ***Device power/energy consumption (W/J)***   ***Proposal 8: RAN1 introduces inventory traffic model as follows.***   * ***Periodic inventory request from A-IoT server with periodicity of [15] min.*** * ***Reader generation multiple inventory queries over multiple rounds to read A-IoT devices.***   + ***The query generation timing depends on the random-access procedure.*** * ***Reader generates multiple queries until inventory timer expires, or reader decides to stop inventory process early (due to no more reading).*** |
| **Lenovo** | ***Proposal 1: Consider the candidate target peak power consumption for the passive Ambient IoT device type 2B containing amplification and storage between 300 to 500 µW.***  ***Proposal 2: Consider the candidate target peak power consumption for the active Ambient IoT device type 2A containing amplification and storage within 500 µW.***  ***Proposal 3: For evaluating Ambient IoT, consider candidate maximum TBS for UL transmission:***   * ***100-150 bits for Passive device Types 1, 2B*** * ***200-250 bits for Active device Type 2A***     ***Proposal 4: Consider long latency target of 10 seconds considering latency of inventory and actuator command use case requirement is provided as several seconds.***   * ***Evaluate the energy harvesting within the inventory process and its impact on latency***   ***Proposal 5: RAN1 assumes symmetric 2D distribution of Ambient IoT devices where each Ambient IoT device placed horizontally 0.8m apart and 1.5m vertically apart containing up to 3 vertical racks.*** |

## Deployment scenarios for coverage and coexistence evaluation

### Scenarios definition

#### Related Tdoc Proposals

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| **Apple** | ***Proposal 3: For the evaluation purpose, consider following 6 scenarios, based on D1T1 and D2T2 that are already agreed:***   * ***D1T1-CW1: Indoor reader (BS) <-> Indoor device, and indoor CW node is same as reader*** * ***D1T1-CW2: Indoor reader (BS) <-> Indoor device, and indoor CW node is different than the reader, but inside of topology*** * ***D1T1-CW3: Indoor reader (BS) <-> Indoor device, and indoor CW node is different than the reader, and outside of topology*** * ***D1T2-CW1: Outdoor BS <- -> Indoor reader (UE) <-> Indoor device, and indoor CW node is same as reader*** * ***D1T2-CW2: Outdoor BS <- -> Indoor reader (UE) <-> Indoor device, and indoor CW node is different than reader, but inside of topology*** * ***D1T2-CW3: Outdoor BS <- -> Indoor reader (UE) <-> Indoor device, and indoor CW node is different than reader, and outside of topology***   ***Proposal 5: For link budget evaluations for device type 1, for budget-Alt1, following table can be used as a reference for the assumptions:*** |
| **CMCC** | **Proposal 1: Study and evaluate the cases D1T1-A1/A2/B/C, D2T2-A1/A2/B/C in Table 2.1-1 in R1-2402565 for the coverage/link budget study.**  **Proposal 2: Further discuss and prioritize cases in Table 2.1-1 in R1-2402565. Propose D1T1-A1/A2/B and D2T2-B as the most interested cases for further coverage evaluation.** |
| **Ericsson** | 1. Use the links’ spectrums listed in Table 2 for LLSs and coverage assessments of D1T1 scenarios for device 1 and device 2a (passive devices).   Table : Links’ spectrums for D1T1 scenarios   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **Scenario** | **D1T1-A1/A2 Case 1-1** | **D1T1-A1/A2 Case 1-2** | **D1T1-B: Case 1-4** | **D1T1-C** | | **Assumptions** | CW2D in DL, D2R in DL, R2D in DL spectrum | CW2D in UL, D2R in UL, R2D in DL spectrum | CW2D in UL, D2R in UL, R2D in DL spectrum | D2R in UL, R2D in DL spectrum |  1. Use the links’ spectrums listed in Table 3 for LLSs and coverage assessments of D2T2 scenarios for device 1 and device 2a (passive devices).   Table : Links’ spectrums for D2T2 scenarios   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **Scenario** | **D2T2-A1/A2 Case 2-2** | **D2T2-B  Case 2-3** | **D2T2-B: Case 2-4** | **D2T2-C** | | **Assumptions** | CW2D in UL, D2R in UL, R2D in UL spectrum | CW2D in DL, D2R in DL, R2D in UL spectrum | CW2D in UL, D2R in UL, R2D in UL spectrum | D2R in UL, R2D in UL spectrum | |
| **Qualcomm** | ***Proposal 6: RAN1 to agree scenarios captured in above Table 1 for further discussion of coverage evaluation.***  Table Evaluation scenarios  A screenshot of a computer  Description automatically generated |
| **FutureWei** | ***Observation 8: The difference between D1T1-A and D1T1-B is the CW node. In D1T1-B case it has better CW interference cancelation due to the fact that R and CW nodes are separated,***  ***Observation 9: The difference between D2T2-A and D2T2-B is the CW node. In D2T2-B case it has better CW interference cancelation due to the fact that R and CW node are separated,*** |
| **Huawei** | ***Proposal 7: The study assumes downlink spectrum for the R2D transmission in D1T1.***  ***Proposal 8: In D1T1, the study assumes the following spectrum for both CW2D and D2R transmission.***   * ***D1T1-A: DL spectrum (Case 1-1)*** * ***D1T1-B: UL spectrum (Case 1-4)***   ***Proposal 11: The study assumes uplink spectrum for the R2D transmission in D2T2.***  ***Proposal 12: The study assumes UL spectrum for both CW2D and D2R transmission in both D2T2-A and D2T2-B.*** |
| **Intel** | **Proposal 1:**   * For Topology 1, the following deployment scenario can be prioritized.   + R2D is transmitted in the DL spectrum   + D2R and CW signal are transmitted in the UL spectrum * Further study whether R2D channel/signal can be transmitted in the UL spectrum.   **Proposal 2:**   * For Topology 1, the following deployment scenario can be prioritized.   + For A-IoT device 1 and 2a, gNB serves as reader for R2D and D2R, while external node serves as CW source   + For A-IoT device 2b, gNB serves as reader for R2D and D2R   **Proposal 3:**   * For Topology 2, the following deployment scenario is prioritized.   + R2D, D2R and CW signal are transmitted in the UL spectrum   **Proposal 4:**   * For Topology 2, the following deployment scenario can be prioritized.   + For A-IoT device 1 and 2a, UE serves as reader for R2D and D2R, and external node serves as CW source   + For A-IoT device 2b, UE serves as reader for R2D and D2R * Further study on the deployment scenario where UE serves as reader for R2D, D2R and CW source for A-IoT device 1 and 2a |
| **Lenovo** | ***Proposal 9: Evaluate the feasibility of in-band Ambient IoT communication within the FDD-UL spectrum to avoid switching between FDD-UL and FDD-DL bands.***  ***Proposal 10: Study the Ambient IoT communication in the NR standalones and NR/LTE guard bands with duplexing spacing of < 2MHz between FDD-DL and FDD-UL frequency for Ambient IoT DL and UL communication.***  ***Proposal 11: For topology 2, the intermediate node i.e., UE communicates with the Ambient IoT device using the FDD-UL spectrum.***  ***Proposal 12: For topology 2, consider studying FDD like operation for Ambient IoT device.***  ***Proposal 13: For both topology 1 and topology 2 evaluate internal and external carrier wave transmission. On the spectrum of carrier wave transmission and backscattered signal evaluate following cases considering different interference scenarios, frequency shifting capability and harmonized spectrum for topology 1 and topology 2,***   * ***Case 1: Carrier wave transmission on DL spectrum and corresponding backscattering transmission on UL spectrum*** * ***Case 2: Carrier wave transmission on DL spectrum and corresponding backscattering transmission on DL spectrum*** * ***Case 3: Carrier wave transmission on UL spectrum and corresponding backscattering transmission on UL spectrum*** * ***Case 4: Carrier wave transmission on UL spectrum and corresponding backscattering transmission on DL spectrum*** |
| **LGE** | ***Observation 1: For D1T1-A (indoor BS + indoor AIoT device, CW inside topology), based on the agreements in AI 9.4.2.4, the case where all transmissions (R2D/CW/D2R) are in either DL or UL spectrum can be studied.***  ***Observation 2: For D1T1-B (indoor BS + indoor AIoT device, CW outside topology), based on the agreements in AI 9.4.2.4, the following two cases can be studied:***   * ***Case 1) R2D in DL spectrum and CW/D2R in UL spectrum*** * ***Case 2) All (R2D/CW/D2R) in UL spectrum (Case 2 is common to D1T1-A and D1T1-B)***   ***Proposal 3: For Deployment scenario 1 with topology 1, for D1T1-A1/A2/B/C, at least the spectrum deployment scenario in which all the transmissions (R2D/CW/D2R) are in UL spectrum should be evaluated for coverage and coexistence.***   * ***The scenario in which R2D is in DL spectrum and D2R(/CW) is in UL spectrum can also be evaluated for the case where device 2b coexists with devices 1/2a with the CW outside topology.***   ***Observation 3: For D2T2-A (outdoor BS + Indoor Intermediate UE + Indoor AIoT device, CW inside topology), based on the agreements in AI 9.4.2.4, the case where all transmissions (R2D/CW/D2R) are in UL spectrum can be studied.***  ***Observation 4: For D2T2-B (outdoor BS + Indoor Intermediate UE + Indoor AIoT device, CW outside topology), based on the agreements in AI 9.4.2.4, the case where all transmissions (R2D/CW/D2R) are in UL spectrum can be studied.***  ***Proposal 4: For Deployment scenario 2 with topology 2, for D2T2-A1/A2/B/C, only the spectrum deployment scenario in which all the transmissions (R2D/CW/D2R) are in UL spectrum is evaluated for coverage and coexistence.*** |
| **MediaTek** | **Observation 7: For D1T1-A1, whether R1 and R2 are same or different BS may have different impact on link budget calculation and interface design.**  **Proposal 18: For D1T1-A1, it should be clarified whether R1 and R2 are same or different BS.**  **Proposal 19: Regarding the link budget calculation for D1T1, prioritize the scenarios of D1T1-A1, D1T1-A2 and D1T1-B.**  **Observation 8: Whether RF-EH functionality is undertaken by a CW2D transmission, or an individual RF-EH transmission may have the following impacts:**   * **Link budget assumption, e.g., max transmission power** * **Whether CW2D transmission is essential for device 2b**   **Proposal 20: For RF-EH functionality, it should be clarified whether it is undertaken by a CW2D transmission, or an individual RF-EH transmission.**  **Proposal 21: No prioritized order between D1T1 and D2T2 regarding link budget calculation.**  **Proposal 22: Regarding the link budget calculation for D2T2, prioritize the scenarios of D2T2-A1, D2T2-A2 and D2T2-B.** |
| Nokia | **Proposal 1: RAN1 to consider the down selection of the topology-agnostic focus evaluation cases listed in Table 1 for the Rel-19 Study. Both topologies should be considered, with special attention on ensuring that all necessary assumptions to carry out a thorough study of topology 2, as per proposed focus evaluation cases, are considered and agreed on.**  Table 1: Proposed focus evaluation cases A, B & C   |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | **Focus evaluation cases:** | **A** | **B** | **C** | | **Device Type:** | 1 (backscatter) | X |  | X | |  | 2a (backscatter) | X |  | X | |  | 2b (active) |  | X |  | | **Spectrum:** | In-band | X | X | X | |  | Guard-band |  |  |  | |  | Standalone band |  |  |  | | **Backscatter type:** | CWE = Reader |  |  |  | |  | CWE != Reader | X | X |  | |  | CWE != Readers |  |  | X | | **Representative use cases:** | rUC1 | X | X |  | |  | rUC4 |  |  |  | |  | Positioning |  |  | X | |
| **DOCOMO** | **Observation 1: For Deployment scenario 1 with topology 1, the following scenarios can be considered for evaluation of coverage and coexistence;**   * **D1T1-A: indoor BS + indoor A-IoT device, CW inside topology**   + **D1T1-A1: different node for CW/R2D and D2R**     - **CW node and Reader in D2R are different**     - **CW node and Reader in R2D are same**     - **Reader in R2D and Reader in D2R are different**   + **D1T1-A2: same CW node and Reader node for CW, D2R and R2D**   + **R2D: At least it should be considered that R2D is transmitted in DL spectrum to follow the legacy NR operation from regulation perspective.**   + **CW and D2R: Case 1-1 or Case 1-2 can be applied.**   + **Only for device 1 and device 2a.**   + **FFS: The case when CW and D2R is transmitted in different carrier** * **D1T1-B: indoor BS + indoor A-IoT device, CW outside topology**   + **R2D: At least it should be considered that R2D is transmitted in DL spectrum to follow the legacy NR operation from regulation perspective.**   + **CW and D2R: Case 1-4 is applied.**     - **CW node: Considering that the CW is transmitted in UL spectrum, at least it should be considered that CW node is UE.**   + **Only for device 1 and device 2a.**   + **FFS: The case when CW and D2R is transmitted in different carrier** * **D1T1-C: indoor BS + indoor A-IoT device with active UL transmission**   + **R2D: At least it should be considered that R2D is transmitted in DL spectrum to follow the legacy NR operation from regulation perspective.**   + **D2R: At least it should be considered that D2R is transmitted in UL spectrum to follow the legacy NR operation from regulation perspective.**   + **Only for device 2b.**   **Observation 2: For Deployment scenario 2 with topology 2, the following scenarios can be considered for evaluation of coverage and coexistence;**   * **D2T2-A: outdoor BS + Indoor Intermediate UE + Indoor A-IoT device, CW inside topology**   + **D2T2-A1: different node for CW/R2D and D2R**     - **CW node and Reader in D2R are different**     - **CW node and Reader in R2D are same**     - **Reader in R2D and Reader in D2R are different**   + **D2T2-A2: same CW node and Reader node for CW, D2R and R2D**   + **R2D: At least it should be considered that R2D is transmitted in UL spectrum to follow the legacy NR operation from regulation perspective.**   + **CW and D2R: Case 2-2 is applied.**   + **Only for device 1 and device 2a.** * **D2T2-B: outdoor BS + Indoor Intermediate UE + Indoor A-IoT device, CW outside topology**   + **R2D: At least it should be considered that R2D is transmitted in DL spectrum to follow the legacy NR operation from regulation perspective.**   + **CW and D2R: Case 2-3 or case 2-4 can be applied.**     - **CW node:**        * **If Case 2-3 is applied, at least it should be considered that CW node is BS.**       * **If Case 2-4 is applied, at least it should be considered that CW node is UE.**   + **Only for device 1 and device 2a.**   + **FFS: The case when CW and D2R is transmitted in different carrier** * **D2T2-C: outdoor BS + Indoor Intermediate UE + Indoor A-IoT device with active UL transmission**   + **R2D: At least it should be considered that R2D is transmitted in UL spectrum to follow the legacy NR operation from regulation perspective.**   + **D2R: At least it should be considered that D2R is transmitted in UL spectrum to follow the legacy NR operation from regulation perspective.**   + **Only for device 2b.**   **Proposal 1: Discuss the potential down-selection of deployment scenario for evaluation of coverage and coexistence considering the following aspects;**   * + - * **Requirement on A-IoT device**       * **Impacts on the current regulatory**       * **Self-interference at BS (for topology 1) and intermediate UE (for topology 2)**       * **Interference from legacy Tx**   **Proposal 2: At least following deployment scenario should be considered for evaluation of coverage and coexistence;**   * **For Topology 1,**    + **for device 1 and 2a, D1T1-B should be considered.**   + **for device 2b, D1T1-C should be considered.** * **For Topology 2**   + **for device 1 and 2a, D2T2-A1 should be considered.**   + **for device 2b, D2T2-C should be considered.** * **FFS: Other deployment scenario** |
| **SONY** | **Proposal 1**: **A unified approach is used for R2D link budget analysis for D1T1 scenarios, considering different activation thresholds for different device types**.  **Observation 1**: **An advantage introduced by the D1T1-A1 scenario is that the reader BS may enjoy minimized direct-link interference incurred by the CW transmitted by the other BS. We note that this holds especially for a system in which the backscattered signal occupies the same frequency band as the CW, e.g., an A-IoT device modulates its information through on-off keying (OOK) scheme.** |
| **Spreadtrum** | ***Proposal 3: All D1T1-A/B/C should be considered in both coexistence and coverage evaluations.***  ***Observation 1: D2T2-A1 will complicate A-IoT system design, as different nodes for CW2D/R2D and D2R need promptly coordination to support inventory use case, especially huge spec. impact is expected for D2T2-A1.***  ***Proposal 4: Down-prioritize D2T2-A1 scenario for coverage and coexistence evaluation.*** |
| **Vivo** | **Table 1 Scenarios for coverage evaluation**   |  |  |  | | --- | --- | --- | | **Case** | **Diagram of the scenario** | **Description of the scenario** | | **D1T1-A1** |  | * CW inside topology 1 * different node for CW2D/R2D and D2R * ‘CW’ in CW2D and ‘R’ in D2R are different * ‘CW’ in CW2D and ‘R’ in R2D are same * ‘R’ in R2D and ‘R’ in D2R are different | | **D1T1-A2** |  | * CW inside topology 1 * same ‘CW’ and ‘R’ node for CW2D, D2R and R2D * Only for device 1 and device 2a | | **D1T1-B** |  | * CW outside topology 1 * ‘CW’ in CW2D and ‘R’ in D2R are different * ‘CW’ in CW2D and ‘R’ in R2D are different * ‘R’ in R2D and ‘R’ in D2R are same * Only for device 1 and device 2a | | **D1T1-C** |  | * Only for device 2b * R2D in DL spectrum * D2R in UL spectrum | | **D2T2-A1** |  | * CW inside topology 2 * Different node for CW2D/R2D and D2R * ‘CW’ in CW2D and ‘R’ in D2R are different * ‘CW’ in CW2D and ‘R’ in R2D are same * ‘R’ in R2D and ‘R’ in D2R are different | | **D2T2-A2** |  | * CW inside topology 2 * same ‘CW’ and ‘R’ node for CW2D, D2R and R2D * R2D in UL spectrum * Only for device 1 and device 2a | | **D2T2-B** |  | * CW outside topology 2 * ‘CW’ in CW2D and ‘R’ in D2R are different * ‘CW’ in CW2D and ‘R’ in R2D are different * R2D in UL spectrum * Only for device 1 and device 2a | | **D2T2-C** |  | * Only for device 2b * R2D in UL spectrum * D2R in UL spectrum | | Notes:   * CW transmission spectrum is up to company report. * D2R is in the same spectrum as CW2D, if large frequency shift is not supported. * R2D transmission spectrum is up to company report, if not defined in this table. | | |   **Proposal 2:**  **Definition of the scenarios is needed for coverage evaluation**   * Adopt **Table 1** in R1-2402242 for scenarios for coverage evaluation. |
| **Xiaomi** | ***Proposal 1: The link between the gNB and the intermediate UE for the topology 2 is not included in the evaluation.***  ***Proposal 2: Support the following candidate scenarios, i.e. D1T1-S1/S2/S3, D2T2-S1/S2/S3,***  ***For device 1 and device 2a, for CW inside topology***   * ***S1: R2D reader = D2R Reader = CW Node***   ***For device 1 and device 2a, for CW outside topology***   * ***S2: R2D reader = D2R Reader, and CW Node is a separate node other than the reader***   ***For device 2b***   * ***S3: R2D reader = D2R Reader, and no CW Node.***   ***Proposal 3: Operating spectrum of the device should be large enough to cover both DL and UL spectrum, so that device can support to transmit and receive on either DL or UL spectrum.*** |
| **ZTE** | Table 1 Spectrum deployments for Ambient IoT   |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | **Case A** | **Case B** | **Case C** | **Case D** | | **Device type** | Device 1/2a | Device 1/2a | Device 1/2a | Device 2b  FFS: Device 2a with large frequency shift | | **R2D** | D1T1:  UL spectrum (H\*Note 1),  DL spectrum (L\*Note 2) | D1T1:  UL spectrum (H),  DL spectrum (L) | D1T1: DL spectrum | D1T1/D2T2: DL spectrum | | D2T2: UL spectrum | D2T2: UL spectrum | D2T2: UL spectrum | | **CW2D** | D1T1:  UL spectrum (H),  DL spectrum (L) | D1T1:  UL spectrum (H),  DL spectrum (L) | D1T1: UL spectrum | N/A | | D2T2: UL spectrum | D2T2: UL spectrum | D2T2:  UL spectrum(H) | | **D2R** | D1T1:  UL spectrum (H),  DL spectrum (L) | D1T1:  UL spectrum (H),  DL spectrum (L) | D1T1: UL spectrum | D1T1/D2T2: UL spectrum | | D2T2: UL spectrum | D2T2: UL spectrum | D2T2:  UL spectrum(H) | | Note 1: “H” denotes high priority.  Note 2: “L” denotes low priority. | | | | |      |  |  |  |  | | --- | --- | --- | --- | | D1T1-A | D1T1-B | D1T1-C | D1T1-D | | D2T2-A | D2T2-B | D2T2-C | D2T2-D |   Figure 1 Deployment scenarios for Ambient IoT  ***Proposal 1: Deployment scenarios in Table 1 should be considered with high and low priority for Rel-19 Ambient IoT.*** |

#### Discussion (round 1)

In CW sub-agenda (9.4.2.4), a list of CW cases are agreed for further study. It is referred and described in the coverage/coexistence evaluation as well.

ZTE, DOCOMO, LGE, Lenovo, Huawei, Qualcomm, Ericsson expressed their preference. And some companies (Nokia, CMCC) wants to down-select to some prioritized scenarios.

#### [H][P3.3.1-v1] D1T1 and D2T2

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| **Scenario** | **CW Inside/outside topology** | **Diagram of the scenario** | **Description of the scenario** | **Device 1/2a/2b** | **CW spectrum** | **D2R spectrum** | **R2D spectrum** |
| **D1T1-A1** | CW inside topology |  | * CW node inside topology 1 * ‘CW’ in CW2D and ‘R2’ in D2R are different * ‘CW’ in CW2D and ‘R1’ in R2D are same * ‘R1’ in R2D and ‘R2’ in D2R are different | Device 1, 2a | Case 1-1 (inside topology, DL)  Case 1-2 (inside topology, UL) | Same as CW | DL (CMCC, Ericsson, Qualcomm, Huawei, Intel, DOCOMO, vivo)  UL (LGE, ZTE) |
| **D1T1-A2** |  | * CW node inside topology 1 * same ‘CW’ and ‘R’ node for CW2D, D2R and R2D | Same as D1T1-A1 | Same as CW | Same as D1T1-A1 |
| **D1T1-B** | CW outside topology |  | * CW node outside topology 1 * ‘CW’ in CW2D and ‘R’ in D2R are different * ‘CW’ in CW2D and ‘R’ in R2D are different * ‘R’ in R2D and ‘R’ in D2R are same | Case 1-4 (outside topology, UL) | Same as CW | Same as D1T1-A1 |
| **D1T1-C** | No CW |  | * No CW Node. | Device 2b | N/A | UL | DL |
| **D2T2-A1**  (Qualcomm, CMCC, Spreadtrum wants to deprioritize) | CW inside topology |  | * CW node inside topology 1 * ‘CW’ in CW2D and ‘R2’ in D2R are different * ‘CW’ in CW2D and ‘R1’ in R2D are same * ‘R1’ in R2D and ‘R2’ in D2R are different * BS communicates with R1 and R2 | Device 1, 2a | Case 2-2 (inside topology, UL) | Same as CW | UL |
| **D2T2-A2** |  | * CW node inside topology 1 * same ‘CW’ and ‘R’ node for CW2D, D2R and R2D * BS communicates with R | Same as D2T2-A1 | Same as CW | UL |
| **D2T2-B** | CW outside topology |  | * CW node outside topology 1 * ‘CW’ in CW2D and ‘R’ in D2R are different * ‘CW’ in CW2D and ‘R’ in R2D are different * ‘R’ in R2D and ‘R’ in D2R are same * BS communicates with R | Case 2-3 (inside topology, DL)  Case 2-4 (inside topology, UL) | Same as CW | DL (Qualcomm, DOCOMO)  UL (Ericsson, Qualcomm, Huawei, Intel, LGE, vivo, ZTE) |
| **D2T2-C** | No CW |  | * No CW Node. * BS communicates with R | Device 2b | N/A | UL | UL (Majority)  DL (Qualcomm) |
| Notes:   * D2R is in the same spectrum as CW2D. FFS D2R is in different from CW2D spectrum if large frequency shift is assumed. | | | | | | | |

FFS: Further down-selection or prioritization of the scenarios.

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| **Company** | **Comments** |
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### Topology and distributions assumptions

#### Related Tdoc Proposals

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| **CATT** | Table 7: Evaluation assumptions of system and radio channel   |  |  |  | | --- | --- | --- | | **Parameters** | **Assumptions** | | | **Deployment scenario 1**  **with topology 1** | **Deployment scenario 2**  **with topology 2** | | Deployment modeling | InF-DH, InF-SH | InF-DL | | gNB configuration | 8 m | 1.5m for InF-DL | | UE drop | 2D distribution, uniform dropping for indoor | | | A-IoT drop | 2D distribution, uniform dropping for indoor | | | Carrier frequency | 900 MHz | | | Pathloss model | LOS and NLOS | | | Channel model | TDL-D/E for LOS, TDL-A/C for NLOS  Delay spread = 10ns, 30ns | | | Frequency stability | 104 ~ 105 ppm | |   **Proposal 11: InF-SH model defined in TR 38.901 should also be used in the coverage evaluation for A-IoT.**  **Proposal 12: Delay spread of 10ns or 30ns can be used in LLS.** |
| **CMCC** | **Table 2.2-1: Assumptions for the distribution**   |  |  |  | | --- | --- | --- | | **Parameter** | **Values for DIT1** | **Values for D2T2** | | Scenario | InF-SH, InF-DH | * Alt 1: InF-DL * Alt 2: Indoor-open office | | Hall size | InF-SH: 300x150 m  InF-DH: 120x60 m | InF-DL:300x150 m  IOO: 120x50 m | | Room height | 10 m | 10m  3m(IOO ceiling height) | | Sectorization | None | None | | BS antenna configurations | 1 element (vertically polarized), Isotropic antenna gain pattern | 1 element (vertically polarized), Isotropic antenna gain pattern | | UT antenna configurations | 1 element (vertically polarized), Isotropic antenna gain pattern | 1 element (vertically polarized), Isotropic antenna gain pattern | | BS deployment | 18 BSs on a square lattice with spacing D, located D/2 from the walls.  - for the small hall (L=120m x W=60m): D=20m  - for the big hall (L=300m x W=150m): D=50m    BS-height = 8 m for for InF-SH and InF-DH | * UE height = 1.5 m * FFS intermediate UE dropping | | device distribution | AIoT devices drop   * Device Height= 1.5 m * Alt 1 (baseline): Uniformly distribution * Alt 2 (optional): Cluster-based distribution | * Alt 1 (baseline): Uniformly distribution * Alt 2 (optional): Cluster-based distribution | | Carrier frequency | 900MHz | 900MHz |   **Proposal 3: Adopt the topology and AIoT device distributions in Table 2.2-1 of R1-2402565 for coverage studies.** |
| **China telecom** | ***Proposal 3: For D1T1, support to evaluate InF-SH scenario with a lower priority.***  ***Proposal 4: For D1T1 and D2T2, consider both LOS and NLOS in both R2D and D2R links.*** |
| **Comba** | For the evaluation purpose, and scenarios for D1T1, indoor scenario (such as indoor factory InF) layout could be considered as starting point. |
| **Ericsson** | 1. For Topology 1, use the BS and A-IoTs distributions in Table 4 as the initial reference for system-level simulations, capacity, and coexistence evaluations.  * FFS on the other possible distributions for A-IoT devices.  1. 2D distributions of topology 2 is for further study. 2. The distribution of CWTs is considered for further study.   Table : Assumptions 2D distributions of BS and A-IoTs   |  |  | | --- | --- | | **Parameter** | **Distribution** | | **BS deployment** | d  18 BSs on a square lattice with spacing D, located D/2 from the walls. [TR 38.901]   * For the small hall, we can choose the parameter D and adjust the hall size to guarantee that any A-IoT device remains within a maximum distance of 10 meters from a BS. To achieve this, we focus on the A-IoT device farthest from all surrounding BSs, particularly the one positioned in the middle of the four BSs located at the corners of a square (as indicated by the red dot in the figure). Therefore, to ensure that the distance is less than 10 meters, the distance between the BSs, D, can be set to 14 meters. Considering 18 BSs in the hall, the hall size can be computed accordingly.   for the small hall (L=84m x W=42m): D=14m   * for the big hall (L=300m x W=150m): D=50m | | **A-IoT devices** | Uniform distribution of the A-IoT devices A-IoT device height = 1.5 m  Number of A-IoTs = Total area × density   * for the small hall = 3528 m² × 1.5 A-IoT devices/m² = 5,292 A-IoT devices * for the big hall= 45000 m² × 1.5 A-IoT devices/m²= 67,500 A-IoT devices | |
| **Qualcomm** | A diagram of a network  Description automatically generated  Figure Layout for indoor warehouse for topology 1  A diagram of a network  Description automatically generated  Figure Layout of indoor warehouse for topology 2  ***Proposal 7: RAN1 considers InF layout and channels as a starting point to model indoor warehouse with additional modeling of cluster.***   * ***Cluster is defined as fixed rectangular area where devices uniformly located inside with random heights.***   ***Proposal 4: Introduce random and cluster model in device distribution.*** |
| **Huawei** | ***Proposal 5: 2D uniform distribution over the indoor service area is assumed for Ambient IoT device, with a device density of 150 devices/100 m2.***  **Table 1 Deployment scenario assumptions for D1T1**   |  |  |  | | --- | --- | --- | | Carrier Frequency | | 900 MHz | | Layout | Hall size (L x W) | L(m) x W (m) = 120 m x 60 m | | ISD (D) | 20 m | | BS antenna height | | 8 m | | Device antenna height | | 1.5 m | | Device mobility (horizontal plane only) | | 3 kph | | Device distribution | | 2D uniform |   ***Proposal 10: For deployment scenario 1 with Topology (1), capture Table 1 into TR as the further deployment scenario assumptions for D1T1.***  **Table 2 Deployment scenario assumptions for D2T2**   |  |  | | --- | --- | | Carrier Frequency | 900 MHz | | Room size | 120 (m) x 50 (m) | | Intermediate UE dropping | Select one from {10m, 20m} | | Intermediate UE antenna height | 1.5 m | | Device antenna height | 1.5 m | | Device mobility (horizontal plane only) | 3 kph | | Device distribution | 2D uniform |   ***Proposal 13: For deployment scenario 2 with Topology (2), capture Table 2 into TR as the further deployment scenario assumptions for D2T2.*** |
| **Interdigital** | Table 1: Coverage Evaluation Assumptions for Deployment Scenario 1 – Topology 1   |  |  | | --- | --- | | Parameter | Values | | Scenario | InF-DH (LOS/NLOS based on distance-dependent probability) | | Hall Size | 120x60 m | | Room Height | 10 m | | Sectorization | None | | BS Antenna Configuration | 1 element (vertically polarized), Isotropic antenna gain pattern | | IoT Device Antenna Configuration | 1 element (vertically polarized), Isotropic antenna gain pattern | | BS Reader Deployment | 18 BSs on a square lattice with spacing D, located D/2 from the walls.  - for the small hall (L=120m x W=60m): D=20m | | BS Reader Height | 8 m | | BS Reader Transmit Power | 23 dBm in UL spectrum and 33 dBm in DL spectrum (other values are not precluded) | | IoT Device Distribution | * Option 1: Uniformly dropped, Option 2: Uniformly dropped within circles of radius R around each BS, where R is determined according to coverage analysis. * Minimum inter-IoT device 2D distance of 1 m * Device Density = 150 devices per 100 m2 | | IoT Device Height | 1.5 m | | IoT Device Association | Based on Pathloss or RSRP | | IoT Device Noise Figure | 9 dB | | Carrier frequency | 900 MHz |   Table 2: Coverage Evaluation Assumptions for Deployment Scenario 2 – Topology 2   |  |  | | --- | --- | | Parameter | Values | | Scenario | InF-DL (LOS/NLOS based on distance-dependent probability) | | Hall Size | 120x60 m | | Room Height | 10 m | | Intermediate Node (UE) Antenna Configuration | 1 element (vertically polarized), Isotropic antenna gain pattern | | IoT Device Antenna Configuration | 1 element (vertically polarized), Isotropic antenna gain pattern | | UE Reader Deployment | Option1: 18 UEs on a square lattice with spacing D, located D/2 from the walls. (Similar to InF BS deployment)  - for the small hall (L=120m x W=60m): D=20m    Option2: 18 UEs uniformly dropped within the 2D plane of the hall | | UE Reader Height | 1.5 m | | UE Reader Transmit Power | 23 dBm in UL and DL spectrum (other values are not precluded) | | IoT Device Distribution | * Option 1: Uniformly dropped, Option 2: Uniformly dropped within a circles of radius R around each UE, where R is determined according to coverage analysis. * Minimum inter-IoT device 2D distance of 1 m * Minimum UE-IoT device 2D distance of 1 m * Device Density = 150 devices per 100 m2 | | IoT Device Height | 1.5 m | | IoT Device Association | Based on Pathloss or RSRP | | IoT Device Noise Figure | 9 dB | | Carrier frequency | 900 MHz |   **Proposal 1: Support coverage evaluation in InF-DH environment for D1T1 scenario and InF-DL environment for D2T2 scenario.**  **Proposal 2: Coverage evaluations and link budget calculations assume both LOS/NLOS pathloss or NLOS pathloss only to account for worst-case propagation conditions in NLOS case.**  **Proposal 5: RAN1 to select between two options for distribution of devices:**   * **Option 1: All devices are uniformly dropped.** * **Option 2: All devices are divided in groups (per BS). Each group is uniformly dropped within a circle of radius R around the BS, where R is determined according to coverage analysis.** |
| **OPPO** | **Proposal 10: The 150 devices per 100 m2 are uniformly distributed for the indoor scenario.** |
| **Samsung** | Proposal 1. For evaluation purpose, adopt a uniform tag dropping approach as the baseline tag distribution.  Proposal 2. For evaluation purpose, study appropriate values for the minimum distance between tags. |
| **SONY** | **Proposal 2**: **Link budget for D1T1-A1 scenario should be conducted based on the agreed assumptions of the indoor BS deployment. For example, m for big hall and for small hall, etc. denotes the distance between two adjacent indoor BSs. This means that the distance between the CWE and the reader (both are BSs) is and thus the device should ideally communicate with both.** |
| **Vivo** | |  |  |  |  | | --- | --- | --- | --- | | **Parameter** | **Assumptions for D1T1** | **Assumptions for D2T2** | | | Scenario | InF-DH | InH-office | InF-DL | | Channel model | TR 38.901 InF-DH | TR 38.901 InH-office | TR 38.901 InF-DL | | Hall size | 120x60 m | 120 x50 m | 300x150 m | | Room height | 10 m | 3m | 10 m | | Sectorization | None | | | | BS deployment | 18 BSs on a square lattice with spacing D, located D/2 from the walls.   * L=120m x W=60m; D=20m * BS height = 8 m | 12 BSs on a square lattice with spacing D, located 15m from the walls.   * L=120m x W=50m; D=20m * BS height = 3m | 18 BSs on a square lattice with spacing D, located D/2 from the walls.   * L=300m x W=150m; D=50m * BS height = 1.5 m | | Intermediate UE dropping | - | Alt 1   * Intermediate UE drop uniformly distributed over the horizontal area   Alt 2   * Intermediate UE drop like BS deployment | | | Device distribution | Device Height= 1.5 m  AIoT devices drop uniformly distributed over the horizontal area  Number of A-IoTs = Total area × density  for the small hall = 7200 m² × 1.5 A-IoT devices/m² = 10,800 A-IoT devices | Device Height= 1m  AIoT devices drop uniformly distributed over the horizontal area  Number of A-IoTs = Total area × density  for the small hall = 6000 m² × 1.5 A-IoT devices/m² = 9,000 A-IoT devices | Device Height= 1.5m  AIoT devices drop uniformly distributed over the horizontal area  Number of A-IoTs = Total area × density  for the big hall = 45000 m² × 1.5 A-IoT devices/m² = 67,500 A-IoT devices |   **Observation 1: The existing BS deployment in TR38.901 cannot provide seamless coverage AIoT devices**   * **There are only 47% AIoT devices which received RSRP is more than -30dB when BSs are on a square lattice with spacing D=20m.** * **Inventory successful rate can be more than 99% when an intermediate UE moves through a regular route with multiple measurement points, at expense of increased latency.** * **About 10dB gain at 99% successful access rate can be achieved with UE intermediate node, and the 10dB gain can be regarded as gain in service coverage, which is brought by UE mobility.**   **Observation 2:**  **For indoor scenario, UE intermediated node can be used as supplementary means to BS readers to improve the probability of successful inventory.**  **Proposal 3:**  **Adopt the assumptions in Table 2 in** R1-2402242 **for BS/UE/AIoT device distributions.** |
| **ZTE** | Table 2 Assumptions of Ambient IoT deployment scenarios   |  |  |  | | --- | --- | --- | | **Parameters** | **Values** | | | **D1T1** | **D2T2** | | Carrier Frequency | 900 MHz | | | Pathloss model | InF-DH LOS/NLOS | InH-Office LOS/NLOS | | Room size (W x L) | 120 m x 300 m | 50 m x 120 m | | Inter-Site Distance (D) | 50 m | N/A | | BS/Intermediate node antenna height | 8 m | 1.5 m | | AIoT device antenna height | 1.5 m | 1 m | | AIoT device distribution | Uniform | |     Figure 1 BS layout for D1T1 |
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#### Discussion (round 1)

**Topology**

Several companies propose the followings for the evaluation,

For D1T1,

* InF-DH: [CMCC][Ericsson][Huawei][InterDigital][OPPO][CATT][China Telecom][vivo][ZTE]
* InF-SH: [Ericsson][CATT][CMCC]

For D2T2,

* InF-DL: [CATT][CMCC][Qualcomm][InterDigital][vivo]
* Indoor-open Office: [CMCC][Huawei][vivo][ZTE]

Hence, FL suggest to go with InF-DH for D1T1 and both InF-DL/IOO for D2T2.

**AIoT device distributions**

* Uniform distribution: [CATT][CMCC][Ericsson][Huawei][InterDigital][OPPO][Lenovo][Qualcomm][Samsung][vivo][ZTE]
* Clustered [Qualcomm][InterDigital]
  + [InterDigital] Uniformly dropped within circles of radius R around each BS, where R is determined according to coverage analysis.
  + [Qualcomm] Cluster is defined as fixed rectangular area where devices uniformly located inside with random heights.

A diagram of a network

Description automatically generated

**Intermediate UE dropping**

Vivo proposed the following alternatives,

Alt 1

* Intermediate UE drop uniformly distributed over the horizontal area

Alt 2

* Intermediate UE drop like BS deployment

**Carrier frequency**

Refer to link budget template

**Pathloss model**

Refer to link budget template

#### [H][P3.3.2-1-v1] Topology

**Proposal:**

The following layout is used for evaluation purpose,

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| **Parameter** | **Assumptions for D1T1** | **Assumptions for D2T2** | |
| Scenario | InF-DH | InH-office | InF-DL |
| Hall size | 120x60 m | 120 x50 m | 300x150 m |
| Room height | 10 m | 3m | 10 m |
| Sectorization | None | | |
| BS deployment / Intermediate UE dropping | 18 BSs on a square lattice with spacing D, located D/2 from the walls.   * L=120m x W=60m; D=20m * BS height = 8 m | * L=120m x W=50m; * Intermediate UE height = 3m   Intermediate UE dropping  Alt 1   * Intermediate UE drop uniformly distributed over the horizontal area   Alt 2: Intermediate UE drop like BS deployment   * 12 intermediate UEs on a square lattice with spacing D, located 15m from the walls. | * L=300m x W=150m; * Intermediate UE height = 1.5 m   Intermediate UE dropping  Alt 1   * 18 Intermediate UE drop uniformly distributed over the horizontal area   Alt 2: Intermediate UE drop like BS deployment   * 18 intermediate UEs on a square lattice with spacing D, located D/2 from the walls. |
| Device distribution | Device Height= 1.5 m  AIoT devices drop uniformly distributed over the horizontal area  Number of A-IoTs per Reader = Total area × density / #of Readers  for the small hall = 7200 m² × 1.5 A-IoT devices/m² / 18= 600 A-IoT devices / Reader | Device Height= 1.5 m  AIoT devices drop uniformly distributed over the horizontal area  Number of A-IoTs per Reader = Total area × density / #of Readers  for the small hall = 6000 m² × 1.5 A-IoT devices/m² / 12 = 750 A-IoT devices / Reader | Device Height= 1.5m  AIoT devices drop uniformly distributed over the horizontal area  Number of A-IoTs per Reader = Total area × density / #of Readers  for the big hall = 45000 m² × 1.5 A-IoT devices/m² /18 = 3,750 A-IoT devices / Reader |
| Device mobility (horizontal plane only) | 3 kph | 3 kph | 3 kph |

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| **Company** | **Comments** |
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### Others

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| **Company** | **Comments** |
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## Link budget calculation for coverage

### Interference modelling

#### CW interference modelling

##### Related Tdoc proposals

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| **Source** | **Proposal** |
| Ericsson | Proposal 11 Different values for spatial isolation/CW cancellation should be considered depending on whether the deployment is monostatic (T1D1-A2, T2D2-A2) or bistatic and whether CWT is inside or outside of the topology (T1D1-A1/B, T2D2-A1/B).  Proposal 12 For CW interference modeling, CWModel-Alt 1 in Proposal (a) in FLS [6] can be a starting point. |
| HW/Hisilicon | ***Proposal 29: Companies report the assumptions on the carrier-wave waveform, the received carrier-wave interference power, and the capability of RF interference cancellation, so as to derive the residual interference power to be modelled in the link-level simulations for D2R link.*** |
| Nokia/NSB | **Proposal 3: Study how to model CW interference in D2R link.** |
| ZTE | ***Proposal 4: Based on the self-interference modelling in TR 38.858, the receiver sensitivity can be derived by the following approach:***   * ***Acquire the residual self-interference power. Calculate the receiver sensitivity loss based on the residual power. The receiver sensitivity loss is assumed as an additional decrement to receiver sensitivity.*** |
| vivo | **Proposal 12: Calculate the receiver sensitivity [2L] by considering degradation caused by CW interference.**  **Observation 3: To model receiver sensitivity loss at receiver of backscatter signal, following parameters should be reported.**   * **Spatial isolation between CW source and receiver of backscatter signal;** * **RF IC capability at the receiver of backscatter signal, if applicable.**   **Proposal 16: For the parameter 2K (CW cancellation), use the following formula to calculate the CW cancellation capability.**   * **For monostatic: (CW cancellation) [2K] = Spatial isolation [2K1] + [2K2]** * **For bistatic: (CW cancellation) [2K] = Spatial isolation [2K3] +** **beam nulling [2K4] + RF-IC suppression [2K2]**   **Proposal 17: Add row [2L1] to count receiver sensitivity loss when calculating Receiver Sensitivity [2L] for D2R.**  **Proposal 26: Carrier wave for backscatter transmission should be modelled in link level simulation.**  **Proposal 27: Ratio between backscatter signal power and interference power from carrier wave, can be modelled to reflect the power difference between desired backscatter signal and interference signal.** |
| OPPO | **Proposal 13: If CW node is inside topology, receiver sensitivity is calculated according to the required SINR, noise power, and CW interference, where the strength of CW interference should be discussed in 9.2.2.4. CW wave interference is NOT simulated in the LLS.**   * **Proposal 14: If CW node is outside topology, the CW interference is simulated in the LLS.** |
| CATT | * **Proposal 10: The effect of interference should be evaluated via LLS to reflect the impact of different interference types and signal design.** |
| CMCC | **Proposal 9: For CW interference modelling in coverage evaluation,**   * **For CW inside topology with monostatic D2R backscatter, CW interference can be considered in link budget calculation**   + **Obtain the remaining CW interference after CW interference cancellation from CW node by Tx power and CW cancellation capability, and calculate the minimum receiver sensitivity by taking remaining CW interference into consideration** * **For CW outside topology or CW inside topology with bistatic D2R backscatter, assuming CW has no impact to the receiver sensitivity loss.** |
| NEC | * **Proposal 3: Discuss the evaluation methodology for modelling the self-interference due to the DL carrier wave transmission in receiving UL from the IoT devices for backscatter communication.** |

##### Discussion (Round 1)

The carrier wave interference can be reflected in link budget calculation, which may have impact on the determination of uplink receiver sensitivity for backscatter communication. CW interference can be inside or outside the topology (i.e., monostatic or bistatic).

Usually, the CW interference will be achieved considering the following 3 methods,

* *Component-1*: spatial isolation / circulator / directional coupler
* *Component-2*: interference cancellation in RF front-end
* *Component-3*: digital baseband processing, e.g., high-pass filtering, reconstructing-then-subtracting the interference

It is obvious that *Component-1* and *Component-2* are considered in the link-budget calculation but not in LLS (i.e., Alt1). How to account the *Component-3* has different views by companies.

How to model CW interferences for coverage evaluation has been discussed and two alternatives are proposed.

* Alt. 1: The digital baseband processing of CW self-interference handling is not modelled in link level simulation (LLS). It is included in the link budget analysis by reporting the CW calculation capability value.
  + (9) Ericsson, ZTE, vivo, OPPO (for CW inside topology), CMCC, NTT DOCOMO, Qualcomm, Interdigital, Xiaomi
    - [Ericsson] considers different values for CW cancellation/spatial isolation can be considered for different deployment and topology, and the CW cancellation value can be reported by company
    - [Ericsson], [CMCC], [InterDigital], [Qualcomm] thinks CW interference after CW interference cancellation can be included in the calculation of receiver sensitivity.
    - [ZTE], [vivo] propose to acquire the residual self-interference power according to Rel-18 SFBD self-interference modelling in TR 38.858, the receiver sensitivity loss caused by intermodulation is also modelled.
    - [OPPO] thinks receiver sensitivity can be calculated based on CW interference for CW inside topology, while for CW outside topology, CW interference can be simulated in LLS.
    - For bistatic cases (D1T1-A1/B, D2T2-A1/B), [Ericsson], [CMCC], [InterDigital] think CW has no impact to the receiver sensitivity loss.
    - [Xiaomi] mentioned that considering the waveform simplicity of CW, very good or even ideal self-interference cancellation can be expected at network side.
* Alt. 2: Model the digital baseband processing of CW self-interference handling in link level simulation (LLS). Do not include digital baseband processing of CW interference handling capability in the link budget analysis when reporting the CW calculation capability value.
  + (8) HW/Hisilicon, Nokia/NSB, vivo, OPPO (for CW outside topology), CATT, MediaTek, Qualcomm, IIT Kanpur
    - Most companies want to support Alt 2 think whether/how to model the interference for getting the required SINR can be further discussed. But lack of detailed methodologies being shown.
    - From FL’s understanding,
      * if CW interference is as a special interference component to be considered in LLS, then LLS may need to report both SNR and SIR\_CW.
      * And detailed characteristics of *Component-3* CW is also need to be discussed, which so far it is unknown and much complicated.
      * One of the Carrier-wave interference suppression at baseband processing is shown in [Huawei]’s contribution, including carrier-wave parameters estimation, High-pass filtering, MMSE-IRC, which need to be aligned with companies.

Hence, considering the fact above and for further progress, FL suggest the group to consider Alt 1.

In addition, a few companies explicitly discuss on whether to consider cross-link CW interferences in the coverage evaluation. For example, vivo, CMCC and NTT DOCOMO think that only self-interference matters and should be considered. For cases where CW outside topology or CW inside topology with bistatic D2R transmissions, with ~ 60 dB spatial isolation, the CW interference has no impact on the receiver sensitivity. In contrast, OPPO, MediaTek and Qualcomm think that both CW self-interference and cross-link interference should be considered in the evaluation.

**[H][P3.4.1.1-(1)-v1]**

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| **Proposal:**  For coverage evaluation,   * In the case of CW inside topology with monostatic backscatter   + The digital baseband processing of CW self-interference handling is not modelled in link level simulation (LLS). It is included in the link budget analysis by reporting the CW calculation capability value. * In the case of CW outside topology or CW inside topology with bistatic backscatter   + Assuming CW has no impact to the receiver sensitivity loss. |

Regarding how to calculate the minimum receiver sensitivity by taken CW cancellation into account, two ways are proposed.

* Alt 1: One is to derived the remaining CW interference after CW interference cancellation from a value.
* Alt 2: Another is proposed by vivo to divided the CW cancellation capability into several parts, such as follows,

**Proposal 16: For the parameter 2K (CW cancellation), use the following formula to calculate the CW cancellation capability.**

* **For monostatic: (CW cancellation) [2K] = Spatial isolation [2K1] + [2K2]**
* **For bistatic: (CW cancellation) [2K] = Spatial isolation [2K3] +** **beam nulling [2K4] + RF-IC suppression [2K2]**

FL suggest to go Alt 1.

**[H][P3.4.1.1-(2)-v1]**

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| **Proposal:**   * + For CW inside topology, the following approach is used to derive minimum receiver sensitivity,     - Obtain required SINR from LLS as [2G],     - Obtain the remaining CW interference [2K1] after CW interference cancellation from CW node Tx power [1E1], antenna gain [1E2] and CW cancellation capability [2K].     - Obtain the minimum receiver sensitivity [2L] according to the following formula,       * , where dB2lin(\*) is function that converts dB to linear value.     - FFS: companies to report CW cancellation capability [2K] or agreed on a value(s) |

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| **Company** | **Comments** |
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#### Other interference

Some companies consider to model the multi-cell interference and NR/LTE interference in the evaluation.

* [Nokia] thinks for R2D link, co-channel interference and adjacent channel interference can be modelled as additional noise
* [Spreadtrum], [ZTE], [vivo], [OPPO], [CATT], [Samsung] thinks interference caused by the coexistence with NR/LTE needs to be analysed, and [ZTE], [OPPO] suggest the interference and co-existence can be evaluated by RAN4.
* [CATT] thinks effect of different interference in A-IoT, including self-interference for monostatic system, direct link interference for bistatic system and multi-device cross-interference, should be evaluated via LLS.
* [NEC] propose to investigate CLI for receiving backscatter UL transmission due to interfering DL transmission(s) from nearby reader(s).
* [Qualcomm] observed that link performance is still severely impacted by strong ACI.

FL suggest to handle this in coexistence section.

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| **Company** | **Comments** |
| Nokia | Proposal 4: For R2D link budget, add an interference-to-noise (I/N) parameter to model interference. A receiver sensitivity degradation, dB, should be added to the receiver sensitivity for MPL calculation. |
| Spreadtrum | Proposal 10: The interference between A-IoT link and NR legacy Uu link needs to be analyzed for coexistence evaluation.  Proposal 11: The impact of CW on A-IoT D2R reception and NR UL reception needs to be considered in coexistence evaluation. |
| ZTE | Proposal 10: For coexistence of Ambient IoT and NR/LTE, out-of-band leakage, device frequency selectivity and inter-cell interference can be evaluated in RAN4. |
| vivo | Observation 9: If matching network with 180kHz is applied before RF ED, at least 15dB and 10dB power boosting for AIOT R2D over NR is needed for 1PRB and 12PRBs guard band case respectively, when AIOT device with RF ED FDMed co-exists with in-band NR signal.  Observation 10: If matching network with 5MHz is applied before RF ED, at least 30dB and 28dB power boosting for AIOT R2D over NR is needed for 12PRB and 26PRBs guard band case respectively, when AIOT device with RF ED FDMed co-exists within band NR signal.  Proposal 33: Co-existence between AIOT R2D and NR is feasible only when AIOT signal boost the power over NR. Whether the required power boosting is feasible can be studied by RAN4.  Observation 11: If narrow bandwidth matching network or narrow bandwidth RF filter bandwidth can be implemented, CW and R2D transmission should be limited within the bandwidth to ensure receiving DL command and RF energy harvesting at AIoT device, which will reduce deployment flexibility for AIoT in frequency at NW side.  Observation 12: For AIoT D2R link of the device type with 1μW power consumption, backscatter signal may be overwhelmed by in-band emission signal from NR UL.  Observation 13: The impact of adjacent channel leakage power from NR UL transmission is negligible.  Proposal 34: The UL co-existence between AIoT and NR should be further studied considering the impact of in-band emission and adjacent channel leakage power from NR UL. |
| OPPO | Observation 1: Transmission from A-IoT devices may interfere NR reception due to its poor filtering capability, A-IoT devices may also be interfered by NR Uu transmission when receiving R2D signals from gNB or intermediate node due to the inability to accurately filter.  Proposal 18: Co-existence evaluation is conducted by RAN4 based on the input on evaluation assumptions from RAN1. |
| CATT | Proposal 7: Self-interference due to DL transmission and cross interference due to simultaneous transmission of multiple A-IoT devices should be considered in the modelling of UL reception at gNB/UE.  Proposal 10: The effect of interference should be evaluated via LLS to reflect the impact of different interference types and signal design.  Proposal 23: Spectrum utilization, inter-channel interference with NR signals should be considered in both in-band and guard band deployment scenarios. |
| Samsung | Proposal 9. For evaluation purpose, study the following interference scenarios to understand the impact of the coexistence with the legacy NR system with SLS and/or LLS.   * NR DL to R2D interference * Tag to NR UE interference * NR UE to tag interference * Carrier wave to tag and NR UE interference for non-co-located node for CW and gNB * Carrier wave to tag interference for co-located node for CW and reader/gNB   Proposal 10. Study the various factors that can influence coexistence interference.   * Guard band between two systems * Deployment of NR UEs * Self-interference blocking capacity * Etc.   Proposal 11. Study how to model coexistence interference in link-level simulations. |
| NEC | Observation 5: For the scenarios which require deployment of large number of IoT devices (e.g. automobile manufacturing), a reader may experience high CLI in receiving UL transmission from an IoT device due to interfering DL transmission(s) from nearby reader(s)  Proposal 5: Investigate the CLI for receiving backscatter UL transmission for the scenario where a large number of IoT devices and readers are deployed within a manufacturing site. |
| Qualcomm | Observation 15: Increasing Q factor can improve link performance. But, link performance is still severely impacted by strong ACI. |

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| **Company** | **Comments** |
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### Pathloss model

#### Related Tdoc proposals

**Tdoc proposals**

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| **Source** | **Proposals** |
| Ericsson | Proposal 13 RAN1 consider the following pathloss model:  • T1D1: CWT inside the topology: InF-DH, NLOS for all links  • T1D1: CWT outside the topology: InF-DH, NLOS for PRDCH, PDRCH, and both NLOS and LOS for CWT2D  • T2D2: CWT inside the topology: InF-DL, NLOS for all links  • T2D2: CWT outside the topology: InF-DL, NLOS for PRDCH, PDRCH, and both NLOS and LOS for CWT2D |
| Huawei | Proposal 18: The study assumes only InF-DH NLOS channel model for the coverage evaluation of D1T1.  Proposal 19: The study assumes only InH-Office LOS channel model for the coverage evaluation of D2T2. |
| FUTUREWEI | Proposal 5: in D1T1 case, using the higher loss from both LOS and NLOS to each link evaluation.  Proposal 6: in D2T2 case, using factory InF-DL defined in TR 38.901 for the path loss model and using the higher loss from both LOS and NLOS to each link evaluation. |
| Spreadtrum | Proposal 6: For D1T1, InF-DH NLOS defined in TR38.901 can be used. For D2T2, InF-DL NLOS defined in TR38.901 with 1.5m antenna height for intermediate-UE can be used. |
| ZTE | Proposal 2: For coverage evaluation, InF-DH LOS/NLOS for D1T1 and InH-Office LOS/NLOS for D2T2 are used for pathloss model. |
| vivo | Proposal 1: InH-LOS and InF-DL-LOS for D2T2 and InF-DH-NLOS for D1T1 can be considered as pathloss model for coverage range calculation. TDL-A 30ns can be used as starting point for link level simulation. |
| OPPO | Proposal 8: For D1T1 NLOS is used for each link, LOS is up to companies to evaluate. InF-SH is not mandated.  Proposal 9: For D2T2 InF-DL and NLOS are used, other models are up to companies. |
| CATT | Proposal 11: InF-SH model defined in TR 38.901 should also be used in the coverage evaluation for A-IoT. |
| China Telecom | Proposal 3: For D1T1, support to evaluate InF-SH scenario with a lower priority.  Proposal 4: For D1T1 and D2T2, consider both LOS and NLOS in both R2D and D2R links. |
| CMCC | Proposal 8: The following pathloss model can be used in the coverage evaluation   * For D1T1, InF-DH NLOS defined in TR38.901 is used, and InF-SH can also be considered. * For D2T2, InF-DL NLOS defined in TR38.901 is used. |
| InterDigital | Proposal 1: Perform coverage evaluation in InF-DH environment for D1T1 scenario and InF-DL environment for D2T2 scenario.  Proposal 2: Coverage evaluations and link budget calculations assume both LOS/NLOS pathloss or NLOS pathloss only to account for worst-case propagation conditions. |
| MediaTek | Observation 9: For D1T1, pathloss model of InF-SH is not very suitable for an indoor factory scenario with large and dense devices deployed.  Observation 10: For D1T1, the selectin on pathloss model of InF-DH LOS or NLOS depends on the specific assumptions on the height and deployment of the components in the scenario, e.g., reader, clutter, device, and CW emitter, etc.  Proposal 23: For D1T1, slightly prefer a unified pathloss model for coverage evaluation, e.g., InF-DH NLOS  Proposal 24: For D2T2, slightly prefer a unified pathloss model for coverage evaluation, e.g., InF-DL NLOS. |
| Qualcomm | Proposal 12: Make following choice for pathloss model.   * For D1T1, use NLOS * For D2T2, InH-Office with LOS |

#### Discussion (round 1)

During the online discussion in RAN1#116, the following is agreed,

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| Agreement  The following pathloss model is used in the coverage evaluation.   * For D1T1,   + InF-DH defined in TR38.901 is used.   + Decide which of the following is used for each link,     - NLOS     - LOS   + FFS: InF-SH * For D2T2, down-select from the following path loss models   + InF-DL defined in TR38.901 where the BS path loss model is reused for intermediate-UE with antenna height of 1.5m   + InH-Office model defined in TR38.901, (a.k.a, InH\_B in Report ITU-R M.2412-0) where the BS path loss model is reused for intermediate-UE with antenna height of 1.5m   + Decide which of the following is used for each link,     - NLOS     - LOS |

The path loss model for coverage distance calculation have been discussed by companies

* For D1T1,
* InF-DH path loss model in TR 38.901 is assumed by [Ericsson], [Huawei], [FUTUREWEI], [Spreadtrum], [ZTE], [vivo], [OPPO], [CATT], [China Telecom], [CMCC], [xiaomi], [InterDigital], [MediaTek], [Qualcomm]
  + - NLOS model is used by: [Ericsson], [Huawei], [Spreadtrum], [vivo], [OPPO], [CMCC], [MediaTek](slightly prefer), [Qualcomm]
    - NLOS/LOS is considered by: [ZTE], [CATT], [China Telecom], [xiaomi], [InterDigital]
    - [Ericsson] also proposed both NLOS and LOS can be considered for CW2D when CW outside topology
    - [FUTUREWEI] propose to use the higher loss from LOS and NLOS
* InF-SH path loss model is considered by [CATT]
* For D2T2,
* InF-DL path loss model in TR 38.901 is assumed by (12) [Ericsson], [FUTUREWEI], [Nokia], [Spreadtrum], [vivo], [OPPO], [CATT], [China Telecom], [CMCC], [xiaomi], [InterDigital], [MediaTek]
  + - NLOS model is used by: [Ericsson], [Spreadtrum], [OPPO], [CMCC], [InterDigital], [MediaTek]
    - LOS is used by: [vivo]
    - LOS/NLOS is considered by: [CATT], [China Telecom], [xiaomi]
    - [FUTUREWEI] propose to use the higher loss from LOS and NLOS
    - [Ericsson] also proposed both NLOS and LOS can be considered for CW2D when CW outside topology
* InH-Office model is assumed by (5) [Huawei], [ZTE], [vivo], [China Telecom], [Qualcomm]
  + - LOS model is used by: [Huawei], [vivo], [Qualcomm]
    - NLOS/LOS is used by: [ZTE], [China Telecom]

Most companies are proposing using the model defined from TR38.901. The LOS probability defined in TR38.901 is as follows,

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| InF-SL  InF-SH  InF-DL  InF-DH | where  The parameters , , and are defined in Table 7.2-4 |
| Indoor - Open office |  |
| Indoor - Mixed office |  |

By calculating the LOS probability for different scenarios InF-DH, InF-DL, InH-Office, the following is proposed.

#### [High][P3.4.2-v1]

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| **Proposals:**  For D1T1,   * InF-DH NLOS model defined in TR38.901 is used as pathloss model in coverage/coexistence evaluation.   For D2T2,   * InF-DL and InH-Office model defined in TR38.901is used as pathloss model in coverage/coexistence evaluation,   + NLOS if InF-DL is used   + LOS if InH-Office is used |

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| **Company** | **Comments** |
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### Device Tx Power for backscatter

#### Related Tdoc Proposals

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| **Qualcomm** | ***Introduce balanced MPL which balances R2D MPL and D2R MPL. and accordingly maximize distance.***  **Balanced MPL / distance**   * Since D2R link computation assumes device tx power at sensitivity level. Thus, this could potentially make D2R link be bottleneck link (i.e., R2D distance > D2R distance). * In balanced MPL/distance calculation, half of sum MPL (L = (R2D MPL + D2R MPL)/2) is calculated first. Then, mid point rx power L between Reader EIRP and Reader D2R sensitivity is computed; R = Reader EIRP – L. * K = max(R, dev sensitivity - device ant gain + dev mod loss + cable loss) * This allows shorter link to increase and longer link to decrease making them be balanced. * In monostatic case, balanced MPL maximizes min(R2D MPL, D2R MPL). |
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#### Discussion (round 1)

#### [H][P3.4.3-v1]

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| Proposal：  **For D1T1-A2, D2T2-A2, (i.e., monostatic backscatter)**   * The Device Tx Power is calculated by assuming CW2D/R2D MPL = D2R MPL.   **For D1T1-A1, D2T2-A1 (i.e., bistatic backscatter)**   * The Device Tx Power is calculated by assuming CW2D MPL = D2R MPL.   **For D1T1-B, (i.e., bistatic backscatter)**   * Company report CW2D distance (m), CW node Tx antenna gain (dBi), CW node Tx power (dBm)   **For D2T2-B, (i.e., bistatic backscatter)**   * Company report CW2D distance (m), CW node Tx antenna gain (dBi), CW node Tx power (dBm) |

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| **Company** | **Comments** |
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### Overall Link budget template

#### Related Tdoc Proposals

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| **Source** | **Observation/Proposal** |
| Huawei | Proposal 15: Both the number of transmit or receive TxRUs and antenna elements are assumed to be 2 or 4 (optional) for an indoor Ambient IoT BS.  Proposal 16: Both the number of transmit or receive chains and antenna elements are assumed to be 1 for an Ambient IoT device.  Proposal 17: Both the number of transmit or receive chains and antenna elements are assumed to be 1 or 2 (if CPE) for an intermediate UE.  Proposal 20: For Ambient IoT device based on RF envelope detection, the receiver sensitivity can be reported per company by inspection of reference implementations in the field.  Proposal 21: The coverage evaluation focuses on PRDCH and PDRCH.  Proposal 22: Capture the link budget template in Table 3 for the coverage evaluation of Ambient IoT into the TR.  Proposal 33: The transmit power of an indoor Ambient IoT BS in D1T1 is assumed to be no lower than 35 dBm EIRP (e.g., 33 dBm transmit power and 2 dBi antenna gain), which corresponds to the the set of e.g. {33, 38} dBm without antenna gain for the evaluations.  Proposal 34: The antenna gain of an indoor Ambient IoT BS is assumed to be reported from the set of {2, 8} dBi.  Proposal 35: The noise figure of indoor Ambient IoT micro-BS in D1T1 is assumed to be 5 dB.  Proposal 36: The transmit power of an intermediate UE in D2T2 is assumed to be 23 dBm, with the antenna gain of 0 dBi.  Proposal 37: The noise figure of an intermediate UE in D2T2 is assumed to be 7 dB.  Proposal 38: The reflection loss of Device 1 is assumed to be -6 dB or 0 dB for OOK or BPSK, respectively.  Proposal 39: The reflection amplification gain of Device 2a can be reported by companies from the set of {10, 20} dB.  Proposal 40: For Device 2b, the maximum transmit power is assumed to be -10 dBm or -20 dBm.  Proposal 41: For Device 1, Budget-Alt1 is recommended for the evaluation of the receiver sensitivity, which is assumed to be e.g. -36 dBm.  Proposal 42: For Device 2 with RF-ED receiver, Budget-Alt1 is recommended for the evaluation of the receiver sensitivity, which is assumed to be e.g. -46 dBm.  Proposal 43: For Device 2 with IF-ED or ZIF receiver, Budget-Alt2 is recommended for the evaluation of the receiver sensitivity, which can be calculated based on a noise figure of 24 dB or [30] dB. |
| FUTUREWEI | Observation 6: in the link budget template Item 1H and Item 1L apply to both Device 1 and Device2a.  Observation 7: it is observed that Device 1 is more balanced while Device 2a is D2R link limited. This is due to the fact that Device 1 has a much higher activation level compared to Device 2a’s receiver sensitivity level.  Observation 8: The difference between D1T1-A and D1T1-B is the CW node. In D1T1-B case it has better CW interference cancelation due to the fact that R and CW nodes are separated,  Observation 9: The difference between D2T2-A and D2T2-B is the CW node. In D2T2-B case it has better CW interference cancelation due to the fact that R and CW node are separated,  Proposal 2: No other links (e.g. RF-EH) besides R2D and D2R need to be evaluated.  Proposal 3: For Device 1 and Device 2a, in R2D link, the receiver sensitivity is the maximal of the receiver sensitivity of Budget-Alt1 and Budget-Alt2. For D2R link using the receiver sensitivity from Budget-Alt2.  Proposal 4: For Device 2b, Both R2D and D2R links use the receiver sensitivity from Budget-Alt2.  Proposal 5: in D1T1 case, using the higher loss from both LOS and NLOS to each link evaluation.  Proposal 6: in D2T2 case, using factory InF-DL defined in TR 38.901 for the path loss model and using the higher loss from both LOS and NLOS to each link evaluation.  Proposal 7: Merge Item 1H and Item 1L in the link budget template proposed in [17].  Proposal 8: include Item 1H in Item 1M calculation of Device 2a, i.e.  Device type 2(backscatter):  Proposal 9: remove Item 1L in Item 1M calculation of Device 2b, i.e.  Device type 2(active):  Proposal 10: For RF envelope based devices due to no narrow band RF filter at the front of the devices the bandwidth to calculate noise power should be at least the system bandwidth, denoted by Item 4C, for R2D links. See Table 3.  Proposal 11: For coverage of Deployment D1T1-A adopt the evaluation assumptions listed in Table 3 for Device 1 and Device2a Ambient IoT devices.  Proposal 12: For coverage of Deployment D1T1-B adopt the evaluation assumptions listed in Table 4 for Device 1 and Device2a Ambient IoT devices.  Proposal 13: For coverage of Deployment D1T1-C adopt the evaluation assumptions listed in Table 5 for Device 1 and Device 2a Ambient IoT devices.  Proposal 14: For coverage of Deployment D2T2-A, D2T2-B and D2T2-C adopt the evaluation assumptions listed in Table 6-8 for Device 1, Device 2a and Device2b Ambient IoT devices. |
| Nokia | Proposal 4: For R2D link budget, add an interference-to-noise (I/N) parameter to model interference. A receiver sensitivity degradation, dB, should be added to the receiver sensitivity for MPL calculation.  Observation 3: In case of backscattering transmission, item 1E of the link budget template should be received CW power at the Ambient IoT device.  Proposal 5: Add “Received CW power for devices 1/2a” to the description of item 1E in the link budget template.  Proposal 6: Evaluate D2R coverage for backscattering Devices 1 and 2a in two cases. A pessimistic case when the received CW power at the device barely reaches the device’s activation threshold. A optimistic case where the CW source is in close proximity to the device.  Proposal 7: For R2D link, the required SNR or SINR from LLS is calculated based on the total signal, noise, interference powers within the Rx filter bandwidth.  Proposal 8: Include analysis of Ambient IoT device form-factor/industrial design constraints and associated impact on antenna performance, link budget, and polarization mismatch over frequency in the RAN1 study.  Proposal 9: Adopt the assumptions in Table 6 for R2D link-level simulations. |
| Spreadtrum | Proposal 5: For device 1 and device 2a, the transmission power of device is determined by the CW transmission power and the transmission loss of CW.  Proposal 6: For D1T1, InF-DH NLOS defined in TR38.901 can be used. For D2T2, InF-DL NLOS defined in TR38.901 with 1.5m antenna height for intermediate-UE can be used.  Proposal 7: Table 1 is adopted for Link budget parameters and values of coverage evaluation. |
| ZTE | Proposal 3: For coverage distance, the following links need to be evaluated for Ambient IoT:   * Energy harvesting for Device 1 * Downlink detection for Device 1, 2a and 2b * Backscatter link detection for Device 1 and 2a * Active uplink detection for Device 2b   Proposal 4: Based on the self-interference modelling in TR 38.858, the receiver sensitivity can be derived by the following approach:   * Acquire the residual self-interference power. Calculate the receiver sensitivity loss based on the residual power. The receiver sensitivity loss is assumed as an additional decrement to receiver sensitivity.   Proposal 5: The above link budget template can be adopted for Ambient IoT coverage evaluation. |
| vivo | Proposal 4: For device type 1, both RF EH link and R2D data link should be evaluated, for device type 2, only R2D data link need to be evaluated.  Proposal 5: For RF EH link, Budget-Alt1 is used for link budget calculation, for R2D data link, Budget-Alt2 is used for link budget calculation.  Proposal 6: For Tx EIRP of R2D signal/channel, following assumptions can be considered   * For CW transmitted from BS or a separate CW source, 24dBm Tx power, and 5dB antenna gain, and total 29dBm Tx EIRP can be assumed. * For UE intermediate node also used as CW source, 23dBm(PC3)/26dBm(PC2) can be assumed.   Proposal 7: The parameter 1C (CW total loss) and 1J (Ambient IoT on-object antenna penalty) can be removed.  Proposal 8: The distance between AIoT device and CW source is considered in link budget template.  Proposal 9: For Tx EIRP of carrier wave, following assumptions can be considered   * For CW transmitted from gNB or a separate CW source on DL spectrum, 24 dBm Tx power, 5 dBi antenna gain, and total 29 dBm Tx EIRP can be assumed. * For UE intermediate node also used as CW source for CW transmission on UL spectrum, 23dBm(PC3)/26dBm(PC2) can be assumed. * For CW transmitted from gNB on UL spectrum, total 23 dBm Tx EIRP can be as starting point.   Proposal 10: For AIoT transmission based on backscatter, -6~-8dB return loss can be assumed for return loss, and 10~15dB gain can be assumed for reflection amplifier.  Proposal 11: For device 2b with active AIoT UL transmission, -10dBm Tx power can be assumed as starting point.  Proposal 12: Calculate the receiver sensitivity [2L] by considering degradation caused by CW interference.  Proposal 13: For the parameter 1E(Total Tx Power for occupied BW) for device1 and 2a, consider the parameter 1E2(CW source to AIoT pathloss(dB)) when calculate 1E for D2R   * 1E = CW Tx power [1A] + CW Tx antenna gain [1B] - CW source to AIoT pathloss [1E2]   Proposal 14: For the parameter 1M(EIRP) for D2R, the parameter 1L(modulation factor) need to be removed when calculating the parameter 1M. Besides, whether the parameter of 1H(Ambient IoT backscatter loss (dB)) is counted for D2R for device 2a with reflection amplifier should be clarified.   * Device 1(backscatter): EIRP [1M] = Total Tx Power for occupied BW [1E] + Tx antenna gain [1G]- backscatter loss [1H] * Device 2a (backscatter with reflection amplifier): EIRP [1M] = Total Tx Power for occupied BW [1E] + Tx antenna gain [1G] – [backscatter loss [1H]] + backscatter amplifier gain [1K]   Proposal 15: Change description “Occupied bandwidth” to “Transmission bandwidth” for parameter 1F, which is used to determine the transmit power for R2D according to the power density and bandwidth.  Proposal 16: For the parameter 2K (CW cancellation), use the following formula to calculate the CW cancellation capability.   * For monostatic: (CW cancellation) [2K] = Spatial isolation [2K1] + [2K2] * For bistatic: (CW cancellation) [2K] = Spatial isolation [2K3] + beam nulling [2K4] + RF-IC suppression [2K2]   Proposal 17: Add row [2L1] to count receiver sensitivity loss when calculating Receiver Sensitivity [2L] for D2R.  Proposal 18: Adopt link budget template in the Table 5 of R1-2402242 for AIoT coverage evaluation. |
| OPPO | [Proposal 1: The coverage for RF-EH link should be evaluated.](#_Toc163124284)  [Proposal 2: Budget-Alt1 should be used for the coverage evaluation for RF-EH, -25~-30dBm can be considered in this evaluation.](#_Toc163124285)  [Proposal 3: Budget-Alt1 should be used for device with RF envelope, -45dBm/-30dBm should be considered as the threshold for device with/without LNA.](#_Toc163124286)  [Proposal 4: Budget-Alt2 should be used for device with IF or zero-IF detector.](#_Toc163124287)  [Proposal 12: Considering the values given in Table 1 of R1-2402328 for link budget calculation.](#_Toc163124295) |
| CATT | Proposal 17: The RF-EH link should be evaluated if the activation/energy harvesting threshold is higher than the data reception threshold.  Proposal 18: If the evaluation of RF-EH link is needed, budget-Alt1 can be used. The activation threshold can be defined as the minimum power to activate the internal circuit or components of A-IoT device to start to work.  Proposal 19: Budget-Alt 2 should be used in the coverage evaluation for D2R and R2D link.  Proposal 20: Additional sensitivity loss should be considered in the link budget template. The specific definition and calculation method should be given by RAN4. |
| China Telecom | Proposal 5: At least the following parameters and values can be a starting point for further discussion on link budget template.   |  |  | | --- | --- | | Parameter | Value | | Center frequency (GHz) | 800MHz/1.8GHz/2.1GHz for FDD | | CW Tx power (dBm) | 33dBm for indoor BS, FFS value for other cases | | Total Tx Power for occupied BW (dBm) | 33dBm for indoor BS  FFS Tx power values for devices | | Occupied bandwidth (Hz) | 180kHz | | Device activation threshold (dBm) | -30dBm for device 1, FFS value for other device types | |
| CMCC | Proposal 5: For device 1, RF energy harvesting is considered. FFS for device 2a/2b.  Proposal 6: For the target performance metric, both the link budget of RF energy harvesting (if used), R2D, and D2R link are calculated.   * For RF-EH and R2D, Budget-Alt1 is used to obtain receiver sensitivity at least for device 1 and device 2a, and further discuss device 2b. * For D2R communication, Budget-Alt2 is used to obtain receiver sensitivity.   Proposal 7: Link budget for communications between reader and device can be calculated respectively as below，   * MPLEH= Transmitter Tx power – Device receive sensitivity (Device EH activation threshold) + Transmitter antenna gain + Receiver antenna gain + Multi-node gain (if any) – shadowing fading margin – polarization loss * MPLR2D = Transmitter Tx power – Device receive sensitivity (Device RX activation threshold) + Transmitter antenna gain + Receiver antenna gain – shadowing fading margin – polarization loss * MPLD2R\_Backscatter = Device received CW power - Receiver sensitivity+ Transmitter antenna gain + Receiver antenna gain - backscatter loss(or +amplification)– shadowing fading margin – polarization loss * MPLD2R\_Active = Device Tx power – Receiver sensitivity+ Transmitter antenna gain + Receiver antenna gain – shadowing fading margin – polarization loss   Proposal 8: The following pathloss model can be used in the coverage evaluation   * For D1T1, InF-DH NLOS defined in TR38.901 is used, and InF-SH can also be considered. * For D2T2, InF-DL NLOS defined in TR38.901 is used.   Proposal 9: For CW interference modelling in coverage evaluation,   * For CW inside topology with monostatic D2R backscatter, CW interference can be considered in link budget calculation   + Obtain the remaining CW interference after CW interference cancellation from CW node by Tx power and CW cancellation capability, and calculate the minimum receiver sensitivity by taking remaining CW interference into consideration * For CW outside topology or CW inside topology with bistatic D2R backscatter, assuming CW has no impact to the receiver sensitivity loss.   Proposal 10: Adopt the link budget template in Table 2.4-1 for link budget evaluation in Ambient IoT. |
| xiaomi | Proposal 4: R2D and D2R links should be separately evaluated.  Proposal 5: The evaluation for link D2R can be decoupled with the CW2D link for device 1 and device 2a, assuming the Tx power of device 1/2a is -30dBm.  Proposal 6: No dedicated evaluation is needed for CW2D link.  Proposal 7: The recommended parameters for link budget template in Table 1 can be considered. |
| NEC | Observation 2: The coverage of backscatter communication is generally uplink limited and hence it is crucial to evaluate the uplink coverage performance for different scenarios.  Proposal 2: Uplink coverage performance needs to be evaluated for each scenario associated with backscatter communication.  Proposal 3: Discuss the evaluation methodology for modelling the self-interference due to the DL carrier wave transmission in receiving UL from the IoT devices for backscatter communication.  Proposal 4: Study the performance of the case where a reader using backscatter communication receives interfering UL transmission from multiple IoT devices within its range. |
| Apple | Proposal 4: For the link budget coverage analysis, in order to keep the scope limited, following baseline assumptions can be considered:   * R2D transmission in DL spectrum in topology 1 * R2D transmission in UL spectrum in topology 2 * D2R transmission in UL spectrum for both topology 1 and topology 2 * CW transmission in UL spectrum for all scenarios, with 23 dBm as CW Tx power for all scenarios   Proposal 5: For link budget evaluations for device type 1, for budget-Alt1, following table can be used as a reference for the assumptions: |
| MediaTek | Observation 8: Whether RF-EH functionality is undertaken by a CW2D transmission, or an individual RF-EH transmission may have the following impacts:   * Link budget assumption, e.g., max transmission power * Whether CW2D transmission is essential for device 2b   Observation 11: RF CBW is more suitable for calculating the (effective) noise power.  Observation 12: If on-object antenna penalty is considered in link budget calculation, it should be used for both R2D and D2R links.  Observation 13: For the coverage evaluation of reader-to-device, the link budget of RF-EH link calculated based on the activation threshold of the EH circuity is the bottleneck compared to the R2D link calculated based on the sensitivity of the device.  Observation 14: Without considering the impact of interference, a good coverage performance can be obtained for R2D link due to a lower sensitivity power.  Proposal 15: For link budget calculation, RF-EH link should be evaluated at least for device type with EH only from RF (e.g., device 1).  Proposal 16: For device type with EH only from RF (EH-limit case), a predefined threshold can be used for link budget calculation of reader-to-device, i.e., Budget-Alt1.  • FFS value for the predefined threshold, e.g., -20dBm.  Proposal 17: For device type with EH from more than RF (communication-limit case), a required SNR/SINR based on LLS output is necessary to calculate the sensitivity of device for link budget calculation of reader-to-device, i.e., Budget-Alt2.  • FFS whether/how to model the interference, e.g., a predefined value, or based on SLS output.  Proposal 18: For D1T1-A1, it should be clarified whether R1 and R2 are same or different BS.  Proposal 19: Regarding the link budget calculation for D1T1, prioritize the scenarios of D1T1-A1, D1T1-A2 and D1T1-B.  Proposal 20: For RF-EH functionality, it should be clarified whether it is undertaken by a CW2D transmission, or an individual RF-EH transmission.  Proposal 21: No prioritized order between D1T1 and D2T2 regarding link budget calculation.  Proposal 22: Regarding the link budget calculation for D2T2, prioritize the scenarios of D2T2-A1, D2T2-A2 and D2T2-B. |
| Sony | Observation 3: When the material that the device is attached to is reflective, e.g., metal, deploying type-2a devices or active devices is required to ensure the successful command reception. Type 1 devices are not compatible with the D1T1 scenario.  Observation 4: Given that the excitation threshold of type-ii (a) device is -40 dBm and the reader sensitivity is -115 dBm, type 2a device can well support the D2R link in the D1T1-A2 scenario.  Observation 5: Type 2a devices are required for D1T1-B, where the UE is deployed as external CWE, in order to achieve successful device excitation.  Observation 6: Type 2b devices are required easily achieve the link budget for the D1T1-C scenario.  Proposal 1: A unified approach is used for R2D link budget analysis for D1T1 scenarios, considering different activation thresholds for different device types.  Proposal 2: Link budget for D1T1-A1 scenario should be conducted based on the agreed assumptions of the indoor BS deployment. For example, D=50 m for big hall and D = 8,14 for small hall, etc. D denotes the distance between two adjacent indoor BSs. This means that the distance between the CWE and the reader (both are BSs) is D and thus the device should ideally communicate with both.  Proposal 3: For backscattering devices, i.e., type 1 and type 2a devices, an on-object antenna penalty in both R2D and D2R links is considered. RAN1 assumes 0.9 dB for cardboard sheet and 10.4 dB for aluminium slab as on-object antenna penalties. |
| Lenovo | Proposal 14: Consider higher transmit power in the UL spectrum for the fixed ceiling mounted node  Proposal 15: For the evaluation of Ambient IoT, consider BS station sensitivity of -90dBm, passive Ambient IoT sensitivity without amplification of -20dBm, passive Ambient IoT sensitivity with amplification of -30dBm, and sensitivity active Ambient IoT of -45dBm.  Proposal 16: For link budget calculation and evaluation of Ambient IoT performance the parameters in following table can be considered.  Proposal 17: Consider the candidate evaluation coverage target for Type 1 Ambient IoT device with no amplification ~20 m and the emitter to device distance for carrier wave is < 5m.  Proposal 18: Consider the candidate evaluation coverage target for Type 2B Ambient IoT device with amplification and backscattering < 40m.  Proposal 19: The effect of absorption loss, polarization miss-match, modulation factor on coverage for passive Ambient IoT device should be considered.  Proposal 20: For evaluating passive Ambient IoT devices, consider different pulse length and the effect of time error on UL signal at the BS.  Proposal 21: For evaluating passive Ambient IoT devices, consider the effect of modulation factor on UL signal.  Proposal 22: For active Ambient IoT devices, evaluate both UL and DL coverages considering the sensitivity at the device as limiting factor for defining the target coverage. |
| Qualcomm | Observations 2   * Topology 1   + In D1T1-A1, comparing Case 1-1 and Case 1-2, transmitting CW in FDD-UL spectrum reduces CW tx power by 10dB, which recues both R2D and D2R link MPL by 10dB, which significantly reduces distance.   + In D1T1-A2, the D2R link is bottleneck due to BS’s interference cancellation capability.   + D1T1-B scenario is similar to D1T1-A1.   + D1T1-C scenario is free from interference cancellation and support higher tx power of -20dBm, showing the largest MPL and distance. * Topology 2   + D2T2-A provides the shortest distance of 2m.   + D2T2-B (Case 2-4) provide <10m distance.   + D2T2-C provides larger distance (36.8m) than that from D2T2-A and D2T2-B.   Proposal 1: RAN1 to agree on coverage analysis excel sheet attached.  Proposal 2: For coverage (link budget) analysis   * For each scenario, perform link budget analysis for three links including CW/EH, R2D, and D2R. * Further study the feasibility of IC capability at gNB and UE. If necessary, get input from RAN4 on; e.g., whether such interference exist, whether/how interference could be cancelled, IC capability, etc. * Introduce balanced MPL which balances R2D MPL and D2R MPL. and accordingly maximize distance. |
| Comba | Proposal 1  Supports both budget-Alt1 and budget-Alt2 methods for analyzing A-Iot coverage, but budget-Alt2 takes into account physical layer design such as bandwidth, receiver algorithm, BLER, etc. budget-Alt2 computs coverage more efficiently.  Proposal 4  If the optional coverage evaluation Alt-2 is used, the maximum distance can be used directly as a coverage evaluation metric. |
| IIT Kanpur, IITM | Proposal 1: The evaluation methodology of AIoT should consider both R2D and D2R links.  Proposal 2: Interrogation signals from transmitter node or CW node in AIoT should be modelled in the evaluation, including signal generation, waveform and modulation, channel coding.  Proposal 3: In the RAN1 study, some hardware impairment like impact of antenna performance, link budget, polarization mismatch and absorption loss over frequency should be included in the analysis of AIoT device. |

#### Discussion (round 1)

**Table. 3.4.2. Link budget template (version 116bis-r1)**

#### [H][P3.4.4-v1]

*<Editor Notes: >*

* *Changes have been marked red in comparison to Table 3.4.2 in the Final 9.4.1.1 Feature Lead Summary (R1-2401874) at the RAN1#116 meeting*
* *The item numbers can be re-indexed once the table has stabilized.*
* *The last column (‘comments’) is only for information and will be deleted in the future.*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **No.** | **Item** | **Reader-to-Device** | | **Device-to-Reader** | | | **Comments (to be removed)** |
| **(0) System configuration** | | | | | | | |
| [0A] | Scenarios | D1T1-A1/A2/B/C  D2T2-A1/A2/B/C | | D1T1-A1/A2/B/C  D2T2-A1/A2/B/C | | | Will be updated and aligned with the proposal P3.3.1 |
| [0A1] | CW case | N/A | | 1-1/1-2/1-4/2-2/2-3/2-4 | | | Will be updated and aligned with the proposal P3.3.1 |
| [0B] | Device 1/2a/2b | Device 1/2a/2b | | Device 1/2a/2b | | |  |
| [0C] | Center frequency (GHz) | 900MHz | | 900MHz | | | * 900MHz: [Ericsson], [Huawei], [FUTUREWEI], [Nokia], [Spreadtrum], [ZTE], [vivo], [OPPO], [Samsung], [CMCC], [NEC], [InterDigital], [Apple], [MediaTek], [Sony], [Qualcomm], [IIT Kanpur, IITM] * 800MHz, 1.8GHz, 2.1GHz: [China Telecom] * 700MHz: [Xiaomi] * Sub 1GHz: [Lenovo] |
| **(1) Transmitter** | | | | | | | |
| ~~[1A]~~ |  |  | |  | | |  |
| ~~[1B]~~ |  |  | |  | | |  |
| ~~1C~~ | ~~FFS: CW total loss~~ | ~~N/A~~ | | ~~FFS: 3dB~~  ~~Note: only applicable for device 1/2a~~ | | | * 0 dB: [Ericsson] * Removed by: [Huawei], [vivo], [CMCC], [InterDigital] |
| [1D] | Number of Tx antenna elements / TxRU/ Tx chains modelled in LLS | For BS:  - 2(M) or 4(O) antenna elements for 0.9 GHz  For Intermediate UE:  - 1(M) or 2(O) (if CPE with 26/29 dBm) | | 1 | | | For BS:   * 1: [FUTUREWEI] (D1T1-B), [Samsung], [InterDigital] * 2: [Ericsson], [Huawei], [FUTUREWEI] (D1T1-A, D1T1-C), [Spreadtrum], [vivo], [xiaomi], [NEC], [MediaTek], [Qualcomm], [IIT Kanpur, IITM] * 4: [Huawei], [Spreadtrum], [xiaomi], [NEC] * 64 antenna elements, 1Tx chains: [CATT]   For UE:   * 1: [Huawei], [FUTUREWEI], [Nokia], [Spreadtrum], [vivo], [Samsung], [xiaomi], [NEC], [InterDigital] * 2: [Ericsson], [Huawei](if CPE), [Spreadtrum], [xiaomi], [NEC], [Qualcomm] * 32 antenna elements, 1Tx chains: [CATT]   For device:   * 1: [Ericsson], [Huawei], [FUTUREWEI](D1T1-A, D1T1-B, D2T2), [Nokia], [Spreadtrum], [vivo], [CATT], [Samsung], [MediaTek], [Qualcomm], [IIT Kanpur, IITM] * 2: [FUTUREWEI](D1T1-C) |
| [1E] | Total Tx Power (dBm) | * For BS in DL spectrum for indoor   + 33dBm * For UL spectrum for indoor,   + 23dBm (M)   + FFS: 26dBm(O) | | * For device 1/2a:   + D2R-CWRxPower-Alt1:     - Company to report CW Tx/Rx power together with CW2D distance (see [1E1]~[1E5])   + D2R-CWRxPower-Alt2:     - Balanced MPL/distance (see [1E1]~[1E5], and subject to [1E3] = = [4B]) * For device 2b:   + D2R-dev2bTxPower-Alt1: -10 dBm(M)   + D2R-dev2bTxPower-Alt2: -20 dBm(O)   *<Editor Note: see section3.4.5 for D2R-CWRxPower alternatives>* | | | For R2D, BS   * 23 dBm: [CATT], [Samsung](UL), [Qualcomm](UL) * 24 dBm: [vivo] * 26 dBm: [Ericsson], [ZTE], [Samsung](UL) * 29 dBm: [ZTE] * 30 dBm: [Samsung](DL), [Lenovo] * 33 dBm: [Ericsson], [Huawei], [FUTUREWEI], [Spreadtrum], [ZTE], [OPPO], [Samsung](DL), [China Telecom], [CMCC], [xiaomi], [NEC], [InterDigital], [MediaTek], [Sony], [Qualcomm](DL), [IIT Kanpur, IITM] * 38 dBm: [Huawei]   For R2D intermediate UE:   * 23 dBm: [Ericsson], [Huawei], [FUTUREWEI], [Nokia], [Spreadtrum], [ZTE], [vivo], [OPPO], [CATT], [Samsung], [CMCC], [xiaomi], [NEC], [InterDigital], [Lenovo], [Qualcomm] * 26 dBm: [ZTE], [Samsung] * 26/29 dBm: [xiaomi](if CPE)   For D2R,  For D2R backscatter, there are different assumptions on the Tx power of AIoT device1, 2a   * [Ericsson], [Huawei], [Nokia], [Spreadtrum], [vivo], [CATT], [Samsung], [CMCC], [InterDigital], [Sony], [IIT Kanpur, IITM] consider the total Tx power of AIoT device depends on the CW power received at AIoT device for backscatter. There are different assumptions on transmit power of CW, deployment of CW node and device   + [Ericsson] consider fixed distance between CW node and device   + [Nokia] use activation threshold as the minimum received CW power for D2T2-A1, A2.   + [InterDigital] assumes -24dBm with 5.54 m emitter-tag distance for both device 1 and device 2a   + Huawei proposed to report the received CW power directly (e.g., -46dBm) * [ZTE] consider the Tx power is larger than or equal to Device receiver sensitivity for Device 1/2a; * [OPPO] consider [-25dBm~-30dBm] Tx power for device 1/2a * [Xiaomi] assumes the Tx power of device 1/2a is a fixed value such as -30dBm * [MediaTek] uses the predefined defined activation threshold of -20dBm as the Tx power of D2R * [Qualcomm] assumes Tx power is the same as sensitivity-modulation loss (6dB)   For device 2b(active)   * -20 dBm: [Huawei], [FUTUREWEI], [OPPO], [Qualcomm] * -13 dBm: [Ericsson] * -10 dBm: [Ericsson], [Huawei], [Nokia], [ZTE], [vivo], [xiaomi], [InterDigital], [Sony], [Lenovo] |
| [1E1] | CW Tx power (dBm) | N/A | | * 23dBm for UL spectrum, FFS 26dBm * 33dBm for DL spectrum   Note: only applicable for device 1/2a | | | CW transmission power can be different based on detailed deployment.   * 23 dBm: [Ericsson](CW in UL), [FUTUREWEI], [Nokia], [Spreadtrum](UL), [vivo], [Samsung](UL), [CMCC], [xiaomi](UL), [NEC](UL), [InterDigital], [Apple], [Qualcomm](UL) * 24 dBm: [vivo] * 26 dBm: [Ericsson](CW in DL), [Samsung](UL) * 30 dBm: [Samsung](DL) * 33 dBm: [Ericsson](CW in DL), [Spreadtrum](DL), [Samsung](DL), [China Telecom], [CMCC], [xiaomi](DL) [NEC](DL), [Sony], [Qualcomm](DL) * Removed by: [Huawei] |
| [1E2] | CW Tx antenna gain (dBi) | N/A | | * Company to report   + UE Tx ant gain, or   + BS Tx ant gain   Note: only applicable for device 1/2a | | | * 0 dBi: [Ericsson], [vivo], [Samsung], [CMCC](UE), [xiaomi](UE), [NEC] * 2 dBi: [FUTUREWEI](D1T1-B), [CMCC](BS), [InterDigital], [Sony](UE) * 3 dBi: [Samsung] * 5 dBi: [Spreadtrum](BS as CW emitter), [vivo] * 6 dBi: [FUTUREWEI](D1T1-A, D2T2-A), [Nokia], [Samsung], [xiaomi](BS), [Sony](BS) * 7 dBi: [Ericsson] * Removed by: [Huawei] |
| [1E3] | CW2D distance (m) | N/A | | * For D2R-CWRxPower-Alt1:   + [Company to report] * For D2R-CWRxPower-Alt2:   + Calculated   Note: only applicable for device 1/2a | | | * Balanced MPL [Qualcomm] * 2m: [Nokia](D2T2-B) * 5m: [Ericsson], [vivo] * 10m: [vivo], [CMCC] * 15m: [vivo] |
| [1E4] | CW2D MPL (dB) | N/A | | Calculated  Note: only applicable for device 1/2a | | | Based on path loss model   * Considered by: [Ericsson], [Nokia], [Samsung] * [Samsung] assumed InF-DH LOS for D1T1 and InF-SH LOS for D2T2 |
| [1E5] | CW received power (dBm) | N/A | | Calculated  Note: only applicable for device 1/2a | | |  |
| [1F] | Bandwidth used for the evaluated channel (Hz) | 180k | | D2R-TxBW-Alt1: 15k (M)  D2R-TxBW-Alt2: 180k (O) | | | For R2D   * 180kHz: [Ericsson], [Huawei], [Spreadtrum], [vivo], [OPPO], [China Telecom], [CMCC], [InterDigital], [MediaTek] * 1.25MHz: [CATT]   For D2R   * 15kHz: [Huawei], [Spreadtrum], [CMCC], [MediaTek] * [5kHz×4]: [OPPO] * 180kHz: [Ericsson], [vivo], [InterDigital] * 360kHz: [Qualcomm] * 1.25MHz: [CATT] |
| [1G] | Tx antenna gain (dBi) | * For BS for indoor, FFS: [2 / 5 / 6 / 8]dBi * For intermediate UE, 0 dBi | | * For A-IoT device, 0dBi | | | For BS   * 0 dBi: [Ericsson], [Samsung] * 2 dBi: [Huawei], [CMCC], [InterDigital], [IIT Kanpur, IITM] * 3 dBi: [ZTE], [OPPO], [Samsung], [Qualcomm] * 4 dBi: [MediaTek] * 5 dBi: [Spreadtrum], [vivo] * 6 dBi: [FUTUREWEI], [Nokia], [ZTE], [Samsung], [xiaomi], [Apple], [Sony], [Lenovo] * 7 dBi: [Ericsson] * 8 dBi: [Huawei] * 9 dBi: [Lenovo] * 12 dBi: [Lenovo]   For intermediate UE   * 0 dBi: [Ericsson], [Huawei], [FUTUREWEI], [Spreadtrum], [ZTE], [vivo], [OPPO], [Samsung], [CMCC], [xiaomi], [NEC], [Apple] * 2 dB: [InterDigital] * 3dBi: [ZTE], [Qualcomm] * 6 dBi: [Lenovo]   For Ambient IoT device,   * -3 dBi: [Ericsson], [OPPO], [Qualcomm] * -1 dBi: [Nokia] * 0 dBi: [Huawei], [FUTUREWEI], [Spreadtrum], [ZTE], [vivo], [CATT], [Samsung], [CMCC], [xiaomi], [NEC], [InterDigital], [MediaTek], [IIT Kanpur, IITM] * 2dBi: [Sony] * 0~2 dBi: [Lenovo] |
| [1H] | Ambient IoT backscatter loss (dB)  Note: due to, e.g.,   * impedance mismatch * Modulation factor | N/A | | * OOK: 6dB * PSK: 0dB   Note: Only for device 1  FFS: for device 2a | | | * [Huawei], [FUTUREWEI], [Samsung], [CMCC], [Sony] think modulation factor can be merged in this item * [FUTUREWEI], [Lenovo] think this also needed for calculation of device 2a * 0 dB: [Huawei](BPSK), [CMCC](BPSK) * 2 dB: [Samsung](BPSK) * 5 dB: [OPPO], [CMCC](OOK), [Lenovo] * 6 dB: [Ericsson], [Huawei](OOK), [FUTUREWEI](device 1, 2a), [Nokia], [Spreadtrum], [CATT], [Samsung](OOK), [xiaomi], [InterDigital], [Sony], [IIT Kanpur, IITM] * 6~8 dB: [vivo] * 8 dB: [Apple], [MediaTek] * 10 dB: [Lenovo] |
| [1J] | Ambient IoT on-object antenna penalty | N/A | | * 0.9dB or removed | | | * 0.9: [Ericsson], [FUTUREWEI](device1, 2a), [Nokia], [Spreadtrum], [ZTE], [OPPO], [Samsung], [xiaomi], [InterDigital], [Sony] * 10.4 for aluminum: [Samsung], [Sony] * Removed by: [Huawei], [vivo], [CMCC], [xiaomi]   + [Huawei], [xiaomi] think it can be counted in antenna gain |
| [1K] | Ambient IoT backscatter amplifier gain (dB) | N/A | | * R2D-Dev2a-Gain-Alt1:10 dB (M) * R2D-Dev2a-Gain-Alt2:15 dB (O)   Note: Only for device 2a | | | * 10 dB: [Huawei], [FUTUREWEI], [Spreadtrum], [Samsung], [CMCC], [xiaomi], [InterDigital], [Sony], [Lenovo], [Qualcomm] * 10~15 dB: [vivo], [CATT] * 15 dB: [Nokia], [OPPO], [Lenovo] * 20 dB: [Ericsson], [Huawei] |
| ~~1L~~ | ~~Modulation factor (dB)~~  ~~Note: due to modulation schemes~~ | N/A | | * FFS : [0/-3/-6] dB depending on modulation schemes   Note: Only for device 1? | | | * -3 dB: [CATT](double-sideband modulation) * -6 dB: [Ericsson], [Nokia], [ZTE], [InterDigital], [MediaTek], [Qualcomm] * 0.5/0.25: [Lenovo] * Removed by: [Huawei], [FUTUREWEI], [Samsung], [CMCC]   + Already included in the backscatter loss   FL suggest to merge [1H] and [1L] in [1H] |
| [1N] | Cable, connector, combiner, body losses, etc. (dB) | FFS | | FFS | | | For R2D   * 1 dB: [MediaTek] * 3dB: [Qualcomm]   For D2R   * 1 dB: [MediaTek], [Qualcomm] |
| [1M] | EIRP (dBm) | Calculated | | Calculated | | |  |
| **(2) Receiver** | | | | | | | |
| [2A] | Number of receive antenna elements / TxRU / chains modelled in LLS | Same as [1D]-D2R | | Same as [1D]-R2D | | | For BS:   * 1: [FUTUREWEI](D1T1-B, D1T1-C), [Samsung], [InterDigital] * 2: [Ericsson], [Huawei], [FUTUREWEI] (D1T1-A), [Spreadtrum], [vivo], [xiaomi], [MediaTek], [Qualcomm], [IIT Kanpur, IITM] * 4: [Huawei], [Spreadtrum], [xiaomi]   For UE:   * 1: [Huawei], [FUTUREWEI](D2T2-B, D2T2-C), [Nokia], [Spreadtrum], [Samsung], [xiaomi], [InterDigital] * 2: [Ericsson], [Huawei](if CPE), [FUTUREWEI](D2T2-A), [Spreadtrum], [xiaomi], [Qualcomm]   For device:   * 1: [Ericsson], [Huawei], [FUTUREWEI](D1T1-B, D1T1-C, D2T2-B, D2T2-C), [Nokia], [Spreadtrum], [vivo], [Samsung], [xiaomi], [InterDigital], [MediaTek], [Qualcomm], [IIT Kanpur, IITM] * 2: [FUTUREWEI](D1T1-A, D2T2-A), [vivo] |
| [2B] | Bandwidth used for the evaluated channel (Hz) | 180k | | D2R-RxBW-Alt1: 15k (M)  D2R-RxBW-Alt2: 180k (O) | | | Need to clarify the bandwidth to calculate noise power is system bandwidth, occupied bandwidth or transmission bandwidth  For R2D   * 180kHz: [Ericsson],[Huawei], [Spreadtrum], [vivo](device2b), [OPPO], [CMCC], [InterDigital], [MediaTek], [IIT Kanpur, IITM] * 720kHz: [FUTUREWEI] * 5MHz: [Nokia] * 20MHz: [vivo](device1)   For D2R   * 15 kHz: [Spreadtrum], [CMCC], [MediaTek], [IIT Kanpur, IITM] * 15 kHz transmission BW + 2x1.5 kHz guard interval: [Huawei] * [5kHz×4]: [OPPO] * 180kHz: [Ericsson], [vivo], [InterDigital] * 720kHz: [FUTUREWEI] * 5MHz: [Nokia] |
| [2B1] | RF CBW (Hz) | FFS:   * 10MHz * 20MHz | | Irrelevant | | | [MediaTek] thinks RF CBW is more suitable for calculating the (effective) noise power, and 10MHz is assumed for R2D and D2R  [FUTUREWEI]For RF envelope based device, use system bandwidth to calculate noise power   * 20MHz: |
| [2C] | Receiver antenna gain (dBi) | same as [1G]-D2R | | Same as [1G]-R2D | | | For BS   * 0 dBi: [Ericsson], [Samsung] * 2 dBi: [Huawei], [OPPO], [CMCC], [InterDigital], [IIT Kanpur, IITM] * 3 dBi: [Samsung], [Qualcomm] * 4 dBi: [MediaTek] * 5 dBi: [Spreadtrum], [vivo] * 6 dBi: [FUTUREWEI], [Samsung], [xiaomi] * 7 dBi: [Ericsson] * 8 dBi: [Huawei]   For intermediate UE   * 0 dBi: [Ericsson], [Huawei], [FUTUREWEI], [Spreadtrum], [vivo], [Samsung], [CMCC], [xiaomi], [MediaTek], [IIT Kanpur, IITM] * 2dBi: [OPPO], [InterDigital] * 3dBi: [Qualcomm] * 6 dBi: [Nokia]   For Ambient IoT device,   * -3 dBi: [Ericsson], [OPPO], [Qualcomm] * -1 dBi: [Nokia] * 0 dBi: [Huawei], [FUTUREWEI], [Spreadtrum], [ZTE], [vivo], [Samsung], [CMCC], [xiaomi], [NEC], [InterDigital], [IIT Kanpur, IITM] * 2 dBi: [Sony] |
| [2X] | Cable, connector, combiner, body losses, etc. (dB) | FFS | | FFS | | | For R2D   * 1 dB: [MediaTek]   For D2R   * 1 dB: [MediaTek] |
| [2D] | Receiver Noise Figure (dB) | FFS: 20dB or 24dB or 30dB for RF-ED | | For BS as reader   * 5dB   For UE as reader   * 7dB | | | For R2D  For Ambient IoT device if use Budget-Alt2   * 15 dB: [CATT] * 20 dB: [Ericsson](D2T2), [FUTUREWEI], [vivo], [xiaomi], [InterDigital], [MediaTek] * 24 or [30] dB: [Huawei](for Budget-Alt2)   For D2R  For BS   * 5 dB: [Ericsson], [Huawei], [FUTUREWEI], [Spreadtrum], [vivo], [CATT], [Samsung], [CMCC], [InterDigital], [MediaTek], [Qualcomm] * 6 dB: [xiaomi], [Lenovo] * 9dB: [IIT Kanpur, IITM], [Lenovo]   For intermediate UE   * 7 dB: [Ericsson], [Huawei], [FUTUREWEI], [Nokia], [Spreadtrum], [vivo], [CATT], [Samsung], [InterDigital], [Qualcomm] * 9 dB: [CMCC], [xiaomi], |
| [2E] | Thermal Noise(dBm/Hz) | -174 | | -174 | | | * -174: [Ericsson], [Huawei], [FUTUREWEI], [Nokia], [Spreadtrum], [vivo], [CMCC], [xiaomi], [InterDigital], [MediaTek], [Qualcomm], [IIT Kanpur, IITM] |
| [2F] | Noise Power (dBm) | Calculated | | Calculated | | |  |
| [2G] | Required SNR | Reported by company, see section [xxx] for LLS assumptions | | Reported by company, see section [xxx] for LLS assumptions | | |  |
| [2H] | Device activation threshold | For device 1 (RF-ED),  FFS:{-30dBm ~ -36dBm}  For device 2 if RF-ED is used  -45dBm  For device 2 if RF-ED is not used  N/A | | N/A | | | For EH   * -35 dBm: [Qualcomm] * -30 dBm: [vivo], [CMCC] * -24dBm: [xiaomi] * -20 dBm: [MediaTek]   For device 1:   * -36 dBm: [CMCC] * -35 dBm: [Ericsson](R2D), [Qualcomm] * -30 dBm: [FUTUREWEI], [OPPO], [Samsung], [China Telecom], [xiaomi], [InterDigital] * -25 dBm: [Nokia], [Sony] * -24 dBm: [Ericsson](CW2D), [Apple] * -20 dBm: [MediaTek]   For device 2a   * -45 dBm: [FUTUREWEI], [Nokia], [OPPO], [CMCC], [xiaomi], [InterDigital], [Qualcomm] * -40 dBm: [Samsung], [Sony]   For device 2b:   * -45 dBm: [Nokia], [xiaomi], [InterDigital], [Qualcomm] * -40dBm: [Samsung] * Removed by: [Huawei]   The list may not be complete. |
| [2J] | Budget-Alt1/ Budget-Alt2 | See section 3.4.5 for usage of this item | | Budget-Alt2 | | | Alt2 may be not suitable for AIoT device based on RF ED  For EH:   * Alt1: [vivo], [OPPO], [CATT], [China Telecom], [CMCC], [MediaTek]   For R2D:   * Alt1: [Ericsson], [Huawei] (device 1 and device 2 with RF-ED), [Nokia], [Spreadtrum], [ZTE], [OPPO ](RF-ED), [Samsung], [CMCC] (device 1, 2a), [InterDigital], [Apple], [Qualcomm] (device 1, 2a) * Alt2: [Huawei](device 2 with IF-ED or ZIF), FUTUREWEI (device 2), [Spreadtrum], [vivo], [OPPO](IF or ZIF), [CATT], [Samsung], [China Telecom], [xiaomi], [MediaTek], [Qualcomm](device 2) * Maximal of Alt1 and Alt2: FUTUREWEI(device 1, 2a)   For D2R   * Alt1: [Ericsson], [Nokia], [ZTE], [InterDigital], [Apple] * Alt2: [Huawei], [FUTUREWEI], [Spreadtrum], [vivo], [OPPO], [CATT], [Samsung], [China Telecom], [CMCC], [xiaomi], [MediaTek], [Qualcomm] |
| [2K] | CW cancellation (dB) | N/A | | For [monostatic backscatter], FFS   * [140dB for BS] * [120dB for UE]   For [bistatic backscatter]   * Assuming CW has no impact to the receiver sensitivity loss. | | | For D1T1-A2 (for BS),   * 150dB: [CMCC] * 140dB: [Ericsson], [FUTUREWEI], [OPPO], [InterDigital] * 130dB: [Qualcomm] * 80dB: [vivo]   For D2T2-A2 (for UE)   * 130dB: [CMCC] * 120dB: [Ericsson], [FUTUREWEI], [InterDigital] * 110dB: [Qualcomm] * 66dB: [vivo] * 0dB: [OPPO]   For D1T1-B(for BS),   * 200dB: [FUTUREWEI] * 81.21 dB: [vivo] * 191dB: [Qualcomm](CW2R pathloss+CW-IC)   For D2T2-B(for UE)   * 200dB: [FUTUREWEI] * 85.99dB: [vivo] * 171dB: [Qualcomm](CW2R pathloss+CW-IC) * Removed by: [Huawei] (modelled in the LLS) |
| [2K1] | Remaining interference (dB) | Calculated | | Calculated | | | Considered by: [Ericsson] |
| [2K2] | Receiver sensitivity loss(dB) | Calculated | | Calculated | | | For D1T1-A2 (for BS),   * 10.82dB/0.2 dB: [vivo]   For D2T2-A2 (for UE)   * 17.52dB: [vivo]   For D1T1-B(for BS),   * 1.08 dB: [vivo]   For D2T2-B(for UE)   * 0.43dB: [vivo] |
| [2L] | Receiver Sensitivity (dBm) | If RF-ED, refer to [2H]  Otherwise, Calculated | | Calculated | | | For R2D, if use Budget-Alt1  For EH   * -35 dBm: [Qualcomm] * -30 dBm: [vivo], [CMCC] * -25 dBm: [ZTE]   For device 1:   * -45 dBm: [Apple] * -40 dBm: [OPPO], [Samsung] * -36 dBm: [Huawei], [CMCC], [IIT Kanpur, IITM] * -35 dBm: [Ericsson], [Spreadtrum], [ZTE], [Qualcomm] * -30 dBm: [FUTUREWEI], [vivo], [InterDigital] * -25dBm: [Nokia],   For device type 2a:   * -55dBm: [Ericsson] * -45 dBm: [FUTUREWEI], [Nokia], [Spreadtrum], [ZTE], [CMCC], [InterDigital], [Qualcomm] * -40 dBm: [Samsung]   For device 2b:   * -85 dBm: [Ericsson] * -55 dBm: [ZTE] * -45dBm: [Nokia], [InterDigital] * -40dBm: [Samsung]   For D2R, if use Alt1  For BS:   * -120 dBm: [InterDigital] * -113.81 dBm: [InterDigital](D1T1-A2) * -112 dBm: [Apple] * -106 dBm: [ZTE] * -100 dBm: [Ericsson] * -97.3/-95.6 dBm: [Ericsson](D1T1-A2) * -95 dBm:   For intermediate UE   * -100 dBm: [Ericsson] * -97 dBm: [InterDigital], [Apple] * -95 dBm: [ZTE] * -92.88dBm: [InterDigital](D2T2-A2) * -82.5dBm: [Ericsson](D2T2-A2) |
| **(3) System margins** | | | | | | | |
| [3A] | Shadow fading margin (function of the cell area reliability and lognormal shadow fading std deviation) (dB) | According to the propagation model and scenario. See section 3.4.4. | | According to the propagation model and scenario. See section 3.4.4. | | | For D1T1   * 4.8 dB: [Ericsson] * 4.48 dB: [Ericsson] * 4.3 dB: [ZTE] * 4dB: [Huawei], [FUTUREWEI], [ZTE], [vivo], [OPPO], [CMCC], [xiaomi], [InterDigital], [MediaTek], [Qualcomm], [IIT Kanpur, IITM]   For D2T2   * 3dB: [ZTE], [vivo] * 4dB: [Nokia], [Qualcomm] * 7 dB: [CMCC] * 7.2dB: [FUTUREWEI], [xiaomi], [InterDigital] * 8dB: [Ericsson], [ZTE] |
| [3B] | polarization mismatching loss (dB) | 3 dB | | 3 dB | | | * 0dB: [xiaomi] * 3 dB: [Ericsson], [Huawei], [FUTUREWEI], [Nokia], [Spreadtrum], [ZTE], [vivo], [OPPO], [Samsung], [CMCC], [InterDigital], [MediaTek], [Sony], [Qualcomm], [IIT Kanpur, IITM],[Lenovo] |
| [3C] | BS selection/macro-diversity gain (dB) | 0 dB for data transmission | | 0 dB | | | * 6dB: [vivo], [CMCC], assuming multiple BS sending CW for RF-EH in DL spectrum * 0 dB: [Ericsson], [FUTUREWEI], [Nokia], [Spreadtrum], [ZTE], [vivo], [OPPO], [CMCC], [xiaomi], [InterDigital], [MediaTek] |
| [3D] | Other gains (dB) (if any please specify) | Reported by companies | | Reported by companies | | | * 0 dB: [Ericsson], [FUTUREWEI], [Nokia], [Spreadtrum], [ZTE], [vivo], [OPPO], [CMCC], [MediaTek], [Qualcomm], [IIT Kanpur, IITM] * 10dB: [vivo](D2T2-UE mobility gain) |
| **(4) MPL / distance** | | | | | | | |
| 4A | MPL (dB) | Calculated | | Calculated | | |  |
| 4B | Distance (m) | Calculated | | Calculated | | | The coverage distance calculation based on path loss model |

*<Editor Notes: Note 1 will be updated once the table has stabilized >*

**Note1: calculated values in the Table XXXX are derived according to the followings, （To be updated）**

* 1E
  + For D2R, and device 1/2(backscatter), whether this value is need (not regarded as an input variable but regarded as indirect variable), or based on backscatter activation power threshold
* 1M
  + For R2D,
  + For D2R,
    - Device 1:
    - Device 2a:
    - Device 2b:
* 2F:
* 2L
  + For R2D and Budget-Alt1, [2L] = [2H]
  + For R2D and Budget-Alt2, [2L] = [2G]+[2F]
  + For D2R and Budget-Alt2, Refer to section [xxx] (Proposal [P4-3])
* 4A
* 4B is derived from pathloss model
  + Refer to section [XXX] (Proposal [P4-3-2])

**Note2: (M) denotes the value is mandatory to be evaluated. (O) denotes the value can be optionally evaluated.**

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| **Company** | **Comments** |
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## Link level simulation assumptions

There are a great number of companies (Ericsson, HW/Hisilicon, vivo, CMCC, Nokia/NSB, CATT, ZTE, xiaomi, OPPO, China Telecom, Samsung, NEC, Lenovo) discuss on LLS for coverage evaluation. Meanwhile, several companies (CMCC, Nokia/NSB, CATT, ZTE, Lenovo, MTK) also consider using LLS for performance evaluation on PHY layer designs.

### Sampling frequency offset (SFO) and timing error modelling

#### Related Tdoc proposals

Based on the submitted contributions in this meeting, companies provide their views on sampling frequency offset, the views are somehow diverged.

* Some companies (e.g., Ericsson, HW/Hisilicon, vivo, CMCC, Qualcomm) considers that a single SFO assumption should be adopted for all in the link level simulation. On the other hand, other companies (e.g., ZTE, OPPO, Samsung) suggest different SFO assumptions for different device types.
* Regarding the SFO value, HW/Hisilicon and vivo propose to use 105 ppm, while other companies propose to consider a value within a range, e.g., from 104~105 ppm.
* Many companies discuss the timing drift model.
* A few companies (e.g., Ericsson, ZTE, Qualcomm) also considers CFO model for device 2b.

The observations/proposals are summarized as follows:

|  |  |
| --- | --- |
| **Source** | **Proposal** |
| Ericsson | Table : SFO, sampling rate, timing drifted error, CFO, frequency drift, and frequency drifted error for PRDCH   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | **Device** | **Rx architecture** | **SFO (Fe)Note 1**  **(clock generator)** | **Sampling rate**  **[MHz or Msps]** | **Timing drifted error (ΔT)Note 2** | **CFONote 3, 4**  **(LO max frequency error)** | **Frequency drift (F’)** | **Frequency drifted error (ΔF)Note 5** | | 1 | RF-ED | Initial: 1e4~1e5 ppm  Post-sync: 20 ppm | > 2\*BWOOK | ΔT = ±Fe \* T | N.A. | N.A. | N.A. | | 2a | RF-ED | Initial: 1e4~1e5 ppm  Post-sync: 20 ppm | > 2\*BWOOK | ΔT = ±Fe \* T | N.A. | N.A. | N.A. | | ZIF/IF-ED  (LO/FLL) | Initial: 1e4~1e5 ppm  Post-sync: 20 ppm | > 2\*BWOOK | ΔT = ±Fe \* T | Initial: 1e4~1e5 \* 1e1 ppm  Post-sync: 20 ppm | FFS | ΔF = ±F' \* T1 | | 2b | RF-ED | Initial: 1e4~1e5 ppm  Post-sync: 20 ppm | > 2\*BWOOK | ΔT = ±Fe \* T | N.A. | N.A. | N.A. | | ZIF/IF-ED  (LO/PLL) | Initial: 1e4~1e5 ppm  Post-sync: 20 ppm | > 2\*BWOOK | ΔT = ±Fe \* T | Initial: 1e4~1e5 \* 1e0 ppm  Post-sync: 20 ppm | FFS | ΔF = ±F' \* T1 | | Note 1: The initial errors assume RC/LC/ring oscillators. For Xtal, the error can be much lower (1e1 to 1e2 ppm).  Note 2: The relationship between the SFO (Fe) and corresponding timing drift (ΔT) over a time(T) is ΔT = ±Fe \* T.  Note 3: For LO/FLL, total error is RC/LC oscillator \* FLL error = 1e4~1e5 ppm \* 1e1. For Xtal, error = 1e1~1e2 ppm \* 1e1.  Note 4: For LO/PLL, total error is RC/LC oscillator \* PLL error = 1e4~1e5 ppm \* 1e0 (PLL error can be considered negligible). For Xtal, error = 1e1~1e2 ppm \* 1e0.  Note 5: The relationship between a drifted frequency error(ΔF), frequency drift ( F') over a time (T) is ΔF = ±F' \* T | | | | | | | |   Table 6: SFO, sampling rate, timing drifted error, CFO, frequency drift, and frequency drifted error for PDRCH   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | **Device** | **Tx architecture** | **Clock error (Fe)Note 1**  **(clock generator)** | **Frequency error** | **Timing drifted error (ΔT)Note 2** | **Frequency drift (F’)** | **Frequency drifted error (ΔF)Note 3** | **CFO@CWT** | | 1 | Backscattering  (with small frequency shift) | Initial: 1e4~1e5 ppm  Post-sync: 20 ppm | ΔF = ±Fe \* fBB | ΔT = ±Fe \* T | FFS | ΔF = ±F' \* T | ±100 Hz | | 2a | Backscattering  (with small frequency shift) | Initial: 1e4~1e5 ppm  Post-sync: 20 ppm | ΔF = ±Fe \* fBB | ΔT = ±Fe \* T | FFS | ΔF = ±F' \* T | ±100 Hz | | Backscattering  (with large FDD frequency shift) | Initial: 1e4~1e5 ppm  Post-sync: 20 ppm | ΔF = ±Fe \* fFS | ΔT = ±Fe \* T | FFS | ΔF = ±F' \* T | ±100 Hz | | 2b | Active transmission | Initial: 1e4~1e5 ppm  Post-sync: 20 ppm | ΔF = ±Fe \* fC | ΔT = ±Fe \* T | FFS | ΔF = ±F' \* T | N.A. | | Note 1: The initial errors assume RC/LC/ring oscillators. For Xtal, the error can be much lower (1e1 to 1e2 ppm).  Note 2: The relationship between the SFO (Fe) and corresponding timing drift (ΔT) over a time(T) is ΔT = ±Fe \* T.  Note 3: The relationship between a drifted frequency error(ΔF), frequency drift ( F') over a time (T) is ΔF = ±F' \* T | | | | | | | | |
| HW/Hisilicon | ***Proposal 28: The SFO can be modelled as continuously accumulated timing drift of ∆T = Fe × T in the link-level simulations, with the number of Fe set to a random selection from {-105 ppm, 105 ppm} per transmission.*** |
| Futurewei | ***Observation 5: The sampling frequency deviation for a local oscillator is about 3% to 5% after compensation.*** |
| ZTE | ***Proposal 6: The*** ***following is suggested in the modeling of timing error of Ambient IoT device.***   * ***For device type 1: SFO is between [104 ~ 105] ppm;*** * ***For device type 2a: SFO is between [103 ~ 104] ppm;*** * ***For device type 3: using CFO model defined in TR38.869 and assume maximum frequency offset [50 or 100] ppm, frequency drifting [0.1] ppm/s.***   ***Proposal 7: The*** ***following two options are provided to model the SFO impact on the R2D transmission***   * ***Option 1: D2R chip duration varies on a per-chip basis*** * ***Option 2: variation of D2R chip duration is the same across one D2R transmission*** |
| vivo | In our understanding, sampling frequency may be different for R2D reception and D2R transmission. For D2R transmission, since the AIoT device need to modulate miller or FM0 coded in certain backscatter frequency based on impedance switching, the switching frequency is obtained by further divide of the local clock, and additional sampling error is introduced in the stage[12], and only applicable to D2R link. It may be up to 22%(depending on the switching frequency), according to the RFID spec. Hence, we suggest that the sampling frequency offset is ~10%[10^5 ppm] for D2R link.  **Proposal 30: Sampling Frequency Offset is 10^5 ppm.** |
| OPPO | **Proposal 15: For Device 1 or 2a the SFO is in the range of 104 ~ 105 ppm, for Device 2b the SFO is <1000ppm.** |
| CMCC | **Proposal 11: The following sampling frequency offset are considered in the evaluations,**   |  |  | | --- | --- | | **Parameter** | **Values** | | **Sampling Frequency** | * **Initial Sampling Frequency Offset (SFO) [104 ~ 105] ppm** * **Sampling frequency = 1.92 MHz** |   **Note:**   * **The relationship between the SFO (Fe) and corresponding timing drift (ΔT) over a time(T) isΔT = ±Fe \* T** * **When the power is off for the device, the oscillator for sampling is no longer running and the device does not maintain any time reference.** |
| Samsung | Proposal 3. The following sampling frequency offset are considered in the link level simulation.   * Initial sampling frequency offset (SFO) for device 1 and device 2a = [104~105] ppm * Initial sampling frequency offset (SFO) for device 2b = [103~104] ppm   Proposal 4. The relationship between an SFO and the corresponding number of samples for the demodulating one symbol (N) can be *N*=*T*×*R* ±⌈*SFO×R*⌉ where T denotes one symbol duration and R is the sampling rate.  Proposal 5. 1.92Msps is considered in the link level simulation as the sampling rate for tag. |
| MediaTek | **Proposal 6: RAN1 should clarify whether initial SFO depends on different Device type, e.g., 104ppm-105ppm for Device 1 and 2a, and 10X-100Xppm for Device 2b.** |
| Qualcomm | ***Proposal 19: RAN1 to consider following three different clock types captured in the Table 8.***  Table Clock assumption for A-IoT devices   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Clock # | Description | Applicable  device types | Clock speed | Power  consumption | Accuracy | | Clock 1 | Sampling for sync signal detection.  Light sleep w/ memory retention | Device 1, 2a, 2b | [10s] kHz to [1]MHz | <<1uW | Initial sampling frequency offset (SFO)  [1 ~ 10]% error  i.e.,  10^4 ~ 10^5 ppm | | Clock 2 | Frequency shift for backscattering | Device 1, 2a | A few [1] MHz | <1uW  <10s uW | [1~5]% error before calibration.  [This could be potentially calibrated based on sync signal/preamble] | | Clock 3 | Reference clock for generating carrier frequency for active device. | Device 2b | A few [1] MHz | 10s ~ 100 uW | [1~5]% before calibration (by frequency sync signal)  After calibration target: [50]ppm | |

#### Discussion (round 1)

Based on the inputs, the following proposal is formulated.

**[H][P3.5.1-(1)-v1]**

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| **Proposal**  In the link level simulation, consider the following sampling frequency offset and timing drift model in baseband processing,   * Initial sampling frequency offset (Fe) is [FFS: a value between 104 ~ 105] ppm. * Sampling frequency is [1.92] MHz. * The timing drift ΔT over a time T is modelled as ΔT = ±Fe \* T.   + FFS: the timing drift in a transmission is random determined as either Fe \* T or - Fe \* T. |

**[H][P3.5.1-(2)-v1]**

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| **Proposal:**  In the link level simulation, consider the following carrier frequency offset and timing drift model for device 2b   * reusing CFO model defined in TR 38.869 (option 1 or 2 in Table 6.2-3) or * reusing CFO model defined in TR 38.869 but with new value for maximum CFO [> 200 and <1000] ppm, and frequency drifting rates [> 0.1] ppm/s. |

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| **Company** | **Comments** |
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### Modelling of carrier wave interference

For devices with UL backscatter transmissions, the coverage may be impacted by interferences caused by carrier wave transmissions. Some companies would like to have CW interference to be simulated in LLS.

Please see section 3.4.2.1 by jointly considering LLS and link budget analysis with regards to modelling CW interference.

### Channel model

#### Related Tdoc Proposals

From reviewing the submitted contributions in this meeting, companies provide their views on the channel model used in the link level simulation, more details can refer to the link level simulation assumption table in Section 3.5.7.1. Majority views propose that TDL-A should be considered as baseline for link level simulation.

The observations/proposals are shown as follows:

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| --- | --- |
| **Source** | **Proposal** |
| **Ericsson** | Proposal 14 Consider channel modeling of PDRCH independently from the CWT2D link.  Proposal 15 For the cases CWT inside topology consider TDL-A for all the links. For CWT outside of topology consider TDL-A for PRDCH and PDRCH; TDL-D and TDL-A for CW2D. |
| **CMCC** | Proposal 13: For link level performance evaluation, the following channel models are assumed,   * Chanel models TDL-A as in TR 38.901, assuming a delay spread of 20ns and speed of 1km/h. * FFS: Other channel model, e.g., two-hop channel model (convolution of two TDL-C channel). * FFS: Impact of backscattering from both devices and environment. |
| **MediaTek** | Proposal 11: Consider the following channel assumptions: A channel model (TDL-A), additive white Gaussian noise (AWGN) |

#### Discussion (round 1)

The companies’ view are as follows,

TDL model

* TDL-A NLOS
  + (12) [Ericsson, for R2D], [HW/Hisilicon], [Nokia/NSB], [Spreadtrum], [ZTE], [vivo], [CMCC], [CATT], [Samsung], [MediaTek], [Qualcomm], [Comba]
* TDL-C NLOS
  + (7) [Futurewei], [Nokia/NSB], [Spreadtrum], [ZTE], [CATT], [xiaomi], [Comba]
* TDL-D LOS
  + (5) [Ericsson, for CW2D], [HW/Hisilicon], [CATT], [Qualcomm], [Comba]
* TDL-E LOS
  + (1) [CATT]
* AWGN
  + (2) [Ericsson], [MediaTek]

Delay spread

* 300 ns [Ericsson], [xiaomi]
* 143 ns [HW/Hisilicon, TDL-A]
* 100 ns [Ericsson]
* 39 ns [Futurewei], [Qualcomm]
* 30 ns [Ericsson], [Nokia/NSB], [vivo], [CATT], [Samsung], [xiaomi]
* 20 ns [CMCC], [HW/Hisilicon, TDL-D], [MediaTek]
* 10 ns [CATT]

To FL’s understanding, the differences between TDL-A/B/C/D/E channel models are that TDL-A/B/C represent channel profiles for NLOS, and TDL-D/E represent that for LOS. In addition, TDL-A/D represent channel profiles for indoor scenarios, and TDL-B/C/E represent that for outdoor scenarios.

Note that both D1T1 and D2T2 consider indoor scenarios, therefore, TDL-A or TDL-D should be considered in the simulation at most. For D1T1, majority views think that NLOS is more reasonable in the deployment, and TDL-A can be considered as the baseline. For D2T2, companies have diverse views on LOS and NLOS, in which cases TDL-D can also be considered if LOS is assumed. According to the pathloss model, In-Office appears to have a high likelihood of being LOS.

In summary, the following is proposed,

**[H][Proposal 3.5.3-v1]**

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| **Proposal:**  In the link level simulation, considering the following channel model,   * For D1T1, TDL-A channel model is used for R2D link, and for D2R link. * For D2T2,   + TDL-A channel model is used for R2D link, and for D2R link if InF scenario is considered,   + TDL-D channel model is used for R2D link, and for D2R link if InH-Office scenario is considered, * FFS delay spread for each case. * Note: The D2R link is considered to be independent to CW2D link. |

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| **Company** | **Comments** |
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### Decoding algorithm

#### Related Tdoc Proposals

A few companies discuss examples on decoding algorithm for R2D data reception, so that further alignment can be pursued on the link level evaluation.

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| --- | --- |
| **Source** | **Proposal** |
| **OPPO** | **Proposal 16: Detecting ascending/descending edges is considered as the baseline approach for timing based OOK Manchester/PIE decoding.** |
| **CMCC** | **Proposal 15: Timing based Manchester decoding approach by capturing ascending/descending edges is adopted for link level performance evaluation.** |

#### Discussion (round 1)

From FL’s understanding, it is necessary to have some consensus on PIE/Manchester decoding approach at this stage. Ambient IoT devices may not be feasible to perform average operation among multiple samplings and finding ascending/descending edges for decoding is the simplest and most power efficient approach. In this sense, the impact of SFO on the R2D demodulation and decoding performance may not be considered in the link level simulation.

Therefore, the following proposal is formulated:

**[M][P3.5.4-v1]**

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| The approach for detecting ascending and descending edges is considered for OOK based line coding for R2D within the link level simulation. |

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| **Company** | **Comments** |
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### SINR calculation

#### Related Tdoc Proposals

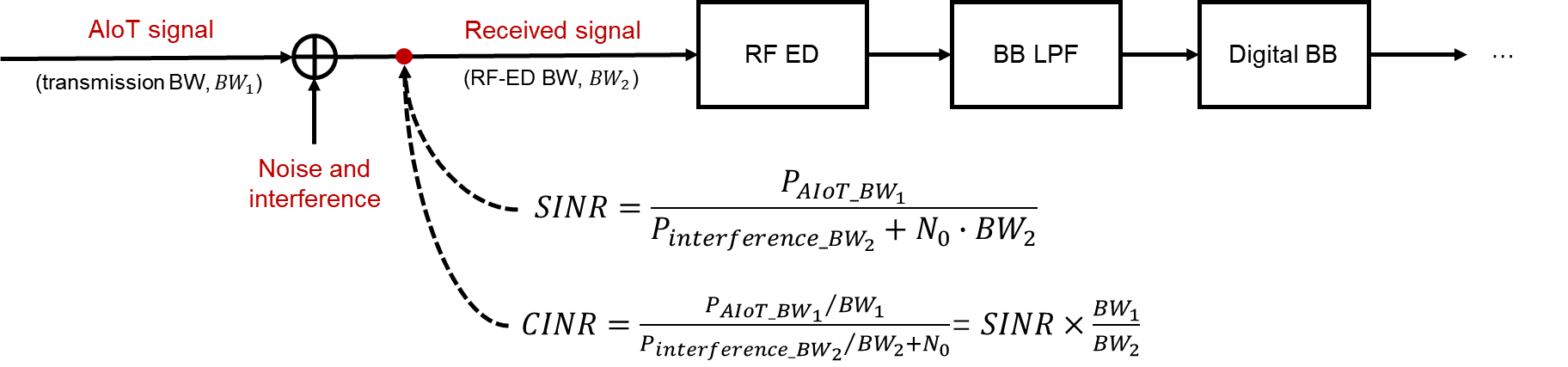
Several companies discuss on the SINR calculation in link level simulation. The observations/proposals are summarized as follows:

|  |  |
| --- | --- |
| **Source** | **Proposal** |
| Nokia/NSB | **Proposal 7: For R2D link, the required SNR or SINR from LLS is calculated based on the total signal, noise, interference powers within the Rx filter bandwidth.**  **Proposal 4: For R2D link budget, add an interference-to-noise (I/N) parameter to model interference. A receiver sensitivity degradation, dB, should be added to the receiver sensitivity for MPL calculation.** |
| vivo | **Observation 4**: **For backscatter transmission, the received power of the carrier wave at AIoT device varies across simulation samples due to different channel fading, resulting the transmission power of backscatter signal is also varied across simulation samples for a given SNR.**  **Proposal 28: To get constant SNR for simulation samples with different channel fading, the backscatter signal should be normalized at AIoT device.** |
| OPPO | **Proposal 17: The SINR for R2D link is defined as the ratio of signal power received in the BW of BB LPF to the noise and interference power in the BW of BB LPF, the baseline BW of BB LPF is discussed in 9.4.1.2.** |
| CATT | **Proposal 16: In link level simulation for A-IoT, both DL and UL SNR should be considered for dual link, the** **SINR calculation is the direct calculation of the Tx power from the A-IoT device over the noise.** |
| CMCC | **Proposal 14: The SINR for R2D link is calculated as the ratio of the followings,**   * **Signal power received in the whole Ambient IoT device Rx filter band/signal occupied bandwidth** * **Noise and interference power in the whole Ambient IoT device Rx filter band/signal occupied bandwidth** |
| MediaTek | **Proposal 12: Additionally evaluate detection performance assuming ASCS and ACS, FFS interference modeling** |

#### Discussion (1st round)

For D2R, the LLS is simulated in baseband. Traditional way of LLS can be used. For R2D for RF ED receiver, the LLS may be implemented in a different way. Based on the inputs, FL suggest to align the understanding of SINR calculation in the LLS for R2D.

* SINR definition for R2D where the transmission bandwidth of AIOT signal is not the same as the noise and/or interference bandwidth. For this issue, FL understands that for coverage evaluation, if Budget-Alt 1 is used in the link budget calculation, the alignment of SINR definition among companies are not required. But it should be noticed that alignment of SINR definition may be useful for coexistence evaluation of NR interferes AIOT R2D reception. Therefore, it is suggested to discuss on it. In FL’s views, there may have two ways to consider signal to interference plus noise ratio in the LLS, as shown below:
  + Option 1: Compute SINR. SINR, computed before the matching network, is defined as the ratio of signal power in the transmission bandwidth (BW1) to the noise and interference power in the RF channel bandwidth (BW2). In this option, 0 dB indicates that the signal power in BW1 is the same as the interference and noise power in BW2, but the signal power spectral density is BW2/BW1 times of the interference and noise spectral density.
  + Option 2: Compute carrier to interference plus noise (CINR). CINR is defined as the ratio of signal power spectral density in the transmission bandwidth (BW1) to the interference noise power spectral density in the RF channel bandwidth (BW2). It is equivalent to the SINR after BB LPF. In this option, 0 dB indicates that the signal power spectral density is the same as the interference and noise power spectral density, but the interference and noise power in BW2 is BW2/BW1 times of signal power in BW1.
  + Note that with the same assumption of transmission bandwidth and RF channel bandwidth, CINR (in linearity) is BW1/BW2 times less than SINR (in linearity).



**Figure 3.5.5 Illustration of SINR calculation for LLS (R2D)**

* SINR definition for D2R where the transmission power of backscatter signal varies from the reception power of CW. For this issue, as proposed in Section 3.5.3.2 that D2R channel model is independent of the CW2D link, FL understands that the transmission power is normalized at the device side for computing SINR for D2R link is straightforward.

Therefore, the following proposal is formulated:

**[H][P3.5.5-v1]**

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| * For the R2D LLS for RF-ED, down-select from the following:   + Option 1: report SINR in LLS. SINR is defined as the ratio of signal power received in the transmission bandwidth to the noise and interference power received in the device RF channel bandwidth.   + Option 2: report CINR in LLS. CINR is defined as the ratio of signal power spectral density in the transmission bandwidth to the noise and interference power spectral density in the device RF channel bandwidth. * Note: For the R2D LLS for IF/ZIF receiver and D2R LLS, the SINR is defined as the ratio of signal power to the noise and interference received in the transmission bandwidth and reported. |

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| **Company** | **Comments** |
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### Envelop detector model and comparator model

#### Related Tdoc Proposals

Based on reviewing contributions submitted in this meeting, Qualcomm discusses that since envelop detection receiver would be a good candidate for all device types, therefore, the envelop detector model is proposed to be considered in the link level simulation. In addition, a realistic comparator model considering comparator bias and ambiguity is proposed to reflect the phenomenon that the operating SNR of Ambient IoT devices restricted by the activation threshold or sensitivity is much higher compared to typical SNR values.

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| **Source** | **Proposal** |
| Qualcomm | ***Proposal 16: For link level evaluation, RAN1 adopt following envelop detection ED model with squaring operation of input signal followed by low pass filtering as below.***  A black background with a black rectangle and two squares  Description automatically generated  ***Proposal 17: RAN1 to adopt the practical comparator model captured in Table 7 for link evaluation.***  Table Practical comparator’s input output relation [22]   |  |  | | --- | --- | | Model | Output | | Practical | # | |  | | : probability of high level output | | |

#### Discussion (1st round)

It can be further discussed till we reached consensus on Budget-Alt or Budget-Alt2 is adopted for R2D.

**[M][Proposal 3.5.6-v1]**

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| For link level evaluation,   * An envelope detection model with squaring operation of input signal followed by low pass filtering is modelled. * A practical comparator model is modelled as follows:  |  |  | | --- | --- | | Model | Output | | Practical | # | |  | | : probability of high level output | | |

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| **Company** | **Comments** |
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### Others

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| **Source** | **Proposal** |
| Qualcomm | ***Observation 3: The choice of Q factor in matching network determines the selectivity and bandwidth of A-IoT device.***  ***Proposal 15: RAN1 and RAN4 to study the impact of Q factor in A-IoT link performance and energy harvesting; reasonable value of Q, pro/con of using high/low Q factor considering frequency in band(s) across operators.***  **Proposal 4: For R2D link budget, add an interference-to-noise (I/N) parameter to model interference. A receiver sensitivity degradation, dB, should be added to the receiver sensitivity for MPL calculation.** |

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| **Company** | **Comments** |
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### Overall Link level simulation assumption

#### Related Tdoc Proposals

Based on the submitted contributions in this meeting, the following parameters are considered in link level simulation:

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| **Parameters** | | **Assumptions by sources** |
| **R2D and D2R common parameters** | | |
| Carrier frequency | | * Refer to link budget template |
| SCS | | * 15 kHz [Ericsson], [Futurewei], [Nokia/NSB], [OPPO], [CATT], [Samsung], [MediaTek], [Qualcomm], [CMCC], [xiaomi] * 30 kHz [Futurewei], [Nokia/NSB], [Qualcomm], [IIT Kanpur] |
| Block structure | | * Payload + CRC [xiaomi], [MediaTek] * Preamble for sync + payload + CRC [vivo], [CMCC], [Qualcomm], [Comba] |
| CRC | | * CRC-5 [Qualcomm, D2R] * CRC-6 [CMCC] * CRC-8 [vivo, R2D] * CRC-16 [vivo, D2R], [Qualcomm, D2R], [Comba] |
| Channel model | | * TDL-A NLOS [Ericsson, for R2D], [HW/Hisilicon], [Nokia/NSB], [Spreadtrum], [ZTE], [vivo], [CMCC], [CATT], [Samsung], [MediaTek], [Qualcomm], [Comba] * TDL-C NLOS [Futurewei], [Nokia/NSB], [Spreadtrum], [ZTE], [CATT], [xiaomi], [Comba] * TDL-D LOS [Ericsson, for CW2D], [HW/Hisilicon], [CATT], [Qualcomm], [Comba] * TDL-E LOS [CATT] * AWGN [Ericsson], [MediaTek] |
| Delay spread | | * 300 ns [Ericsson], [xiaomi] * 143 ns [HW/Hisilicon, TDL-A] * 100 ns [Ericsson] * 39 ns [Futurewei], [Qualcomm] * 30 ns [Ericsson], [Nokia/NSB], [vivo], [CATT], [Samsung], [xiaomi] * 20 ns [CMCC], [HW/Hisilicon, TDL-D], [MediaTek] * 10 ns [CATT] |
| Device velocity | | * 1 km/h [CMCC], [MediaTek] * 3 km/h [Ericsson], [HW/Hisilicon], [Futurewei], [Nokia/NSB], [Spreadtrum], [ZTE], [vivo], [CATT], [Samsung], [xiaomi], [Apple], [Comba] * 10 km/h [CATT, optional] |
| Number of Tx/Rx chains for Ambient IoT device | | * 1 [Ericsson], [HW/Hisilicon], [Futurewei], [Nokia/NSB], [Spreadtrum], [ZTE], [vivo], [Samsung], [CMCC], [CATT], [MediaTek], [Qualcomm], [Comba] * 2 [Qualcomm, for FDD DL and UL respectively] |
| BS | Number of antenna elements | * 1 antenna element [Futurewei], [Samsung], [MediaTek] * 2 antenna elements [Ericsson], [Nokia/NSB], [HW/Hisilicon], [Spreadtrum], [ZTE], [vivo] * 4 antenna elements, [Ericsson], [HW/Hisilicon], [Spreadtrum], [ZTE], [MediaTek] * 64 antenna elements [CATT] |
| Number of TXRUs | * 1 [CATT], [Futurewei], [Samsung] * 2 [Ericsson], [HW/Hisilicon baseline], [Nokia/NSB], [Spreadtrum], [ZTE], [vivo] * 4 [Ericsson], [HW/Hisilicon optional], [Spreadtrum], [ZTE] |
| Intermediate UE | Number of antenna elements | * 1 [Ericsson], [HW/Hisilicon], [Futurewei], [Nokia/NSB], [Spreadtrum], [ZTE], [vivo], [Samsung], [MediaTek] * 2 [Ericsson], [HW/Hisilicon], [Spreadtrum], [ZTE], [MediaTek], * 4 [Ericsson], [MediaTek] * 32 [CATT] |
| Number of TXRUs | * 1 [Ericsson], [HW/Hisilicon], [Futurewei], [Nokia/NSB], [Spreadtrum], [ZTE], [vivo], [CATT], [Samsung] * 2 [Ericsson], [HW/Hisilicon], [Spreadtrum], [ZTE] * 4 [Ericsson] |
| Reference data rate | | * 0.1 kbps [Ericsson], [HW/Hisilicon], [Spreadtrum], [ZTE], [Samsung], [Comba] * 2 kbps [Apple] * 5 kbps [vivo, D2R] * 10 kbps [vivo, R2D] * 14 kbps ~ 112 kbps [Futurewei] * 5~640 kbps [Qualcomm, for D2R] |
| Message size | | * 96 bits [HW/Hisilicon], [Nokia/NSB], [Spreadtrum], [ZTE], [vivo, D2R], [Samsung], [Comba] * 500 bits [Ericsson, D2R] * 16 bits ~ 128 bits [Futurewei] * 48 bits [vivo, R2D] * 20/40/80 bits [CMCC] * 1000 bits [Apple] * 16, 32, 64, 128, 512, 1024 bits [Qualcomm] * 28/56/140 bits [IIT Kanpur] * 100~150 bits [Lenovo, device 1/2a] * 200~250 bits [Lenovo, device 2b] |
| BLER target | | * 1% [Futurewei], [Nokia/NSB], [Spreadtrum], [ZTE], [vivo], [Samsung], [MediaTek], [Qualcomm], [Comba] * 10% [Ericsson], [HW/Hisilicon] |
| Sampling frequency | | * 1.92 MHz [Nokia/NSB, device 1], [vivo, device 1], [Samsung], [CMCC], [MediaTek], [Comba], [IIT Kanpur, device 1] * 3.84 MHz [Nokia/NSB, device 2], [vivo, device 2] * 1 MHz [Futurewei], [Qualcomm, device 1] * 10 MHz [Qualcomm, device 2] |
| Drifting model | | * Timing drift ∆T = Fe × T, Fe ∈ [-105 ppm, 105 ppm] [HW/Hisilicon] * Reuse model in TR 38.869 with new drifting rate (e.g., drifting rate >= 100 ppm/s) [Qualcomm] |
| Phase noise | | * Company to report [Qualcomm, device 1/2a, e.g., < 2.5% jitter; device 2b, e.g., refer to modelling in IEEE 802.11ba] |
| **R2D specific parameters** | | |
| Transmission bandwidth | | * 180 kHz (1 PRB) [Ericsson], [Futurewei], [Nokia/NSB], [Spreadtrum], [vivo], [ZTE], [OPPO], [CATT], [Samsung], [CMCC], [xiaomi], [MediaTek], [Qualcomm, for 15 kHz SCS], [Comba] * 360 kHz (2 PRBs) [Ericsson, optional], [Futurewei], [Nokia/NSB], [xiaomi], [Qualcomm, for 15 kHz SCS] * 720 kHz (4 PRBs) [Ericsson, optional], [Futurewei], [xiaomi], [Qualcomm, for 15 kHz SCS] * 1.08 MHz (6 PRBs) [Ericsson, optional] * 1.25 MHz [CATT] * 1.44 MHz (8 PRBs) [Futurewei], [Qualcomm, for 15 kHz SCS] * 4.32 MHz [vivo], [IIT Kanpur] * 360 kHz ~ 4.32 MHz [Qualcomm, for 30 kHz SCS] |
| RF filter bandwidth | | * 20 MHz [Ericsson], [ZTE], [OPPO], [Qualcomm], [IIT Kanpur] * 35 MHz [Ericsson] * 10 MHz [Spreadtrum], [OPPO], [Samsung], [CMCC], [MediaTek], [Comba] * 5 MHz [Nokia/NSB] |
| BB BPF/LPF filter order | | * 1 [MediaTek] * 3 [Spreadtrum], [Qualcomm] * 5 [Spreadtrum], [vivo], [Qualcomm] |
| BB BPF/LPF filter cutoff frequency | | * 90 kHz [Spreadtrum], [MediaTek] * 2\*chip rate [vivo] |
| Waveform | | * OOK waveform generated by OFDM modulator [Ericsson], [Futurewei], [Spreadtrum], [ZTE], [vivo], [CATT], [Samsung], [CMCC], [xiaomi], [MediaTek], [Qualcomm, FFS time/frequency domain sequence and random phase], [Comba] |
| Modulation | | * OOK-1/OOK-4 [Ericsson], [Futurewei], [Spreadtrum], [ZTE], [vivo, M = 2 for OOK-4], [CATT], [Samsung, FFS M for OOK-4], [CMCC], [xiaomi], [MediaTek], [Qualcomm, M = 1/2/4 and FFS M=8/16/32 for OOK-4], [Comba], [IIT Kanpur] * ASK [CATT] |
| Line code | | * Manchester [Ericsson], [Futurewei], [Nokia/NSB], [Spreadtrum], [ZTE], [vivo], [CATT], [Samsung], [CMCC], [xiaomi], [MediaTek], [Qualcomm], [Comba], [IIT Kanpur] * PIE [Ericsson], [Futurewei], [Nokia/NSB], [Spreadtrum], [ZTE], [CATT], [Samsung], [CMCC], [xiaomi], [Qualcomm, FFS], [Comba], * None [Qualcomm] |
| FEC | | * None [Ericsson], [Spreadtrum], [ZTE], [vivo], [Samsung], [MediaTek], [Qualcomm], * Repetition [Qualcomm] * Golay [Qualcomm, FFS] |
| ADC bit width | | * 1 bit [Ericsson, device 1], [Futurewei, device 1], [Nokia/NSB, device 1], [Spreadtrum, device 1], [ZTE, device 1], [vivo, device 1], [Samsung], [xiaomi], [Qualcomm, device 1], [IIT Kanpur, device 1] * 2 bits [xiaomi] * 4 bits [Ericsson, device 2], [Futurewei, device 2], [Nokia/NSB, device 2], [Spreadtrum, device 2], [ZTE, device 2], [vivo, device 2], [xiaomi], [Qualcomm, device 2], [Comba] |
| Power boosting | | * 0/3/6/9 dB or according to guard RBs [Qualcomm] * 6/10 dB [OPPO] |
| **D2R specific parameters** | | |
| Transmission bandwidth  (w.r.t. D2R data rate) | | * Determined by modulation scheme and data rate [Samsung] * 15 kHz [CMCC] * 180 kHz [Futurewei] * 360 kHz [Futurewei] * 720 kHz [Futurewei] * 1.25 MHz [CATT] * 1.44 MHz [Futurewei] |
| D2R Waveform | | * Backscatter modulated wave [Spreadtrum, device 1/2a], [ZTE], [Samsung, device 1/2a], [Qualcomm, modulated square wave] * Single carrier [Spreadtrum, device 2b], [ZTE], [CATT], [Samsung, device 2b], [xiaomi] |
| Waveform (CW) | | * Unmodulated single tone [HW/Hisilicon], [Qualcomm] * Multi-tone [Qualcomm] |
| Modulation | | * OOK [Ericsson], [Futurewei], [Spreadtrum], [ZTE], [CATT], [Samsung], [xiaomi], [Qualcomm], [Comba] * ASK [Futurewei], [CATT], [Qualcomm] * PSK [Ericsson], [Futurewei], [Samsung], [Qualcomm], [Comba, FFS] * FSK [Ericsson], [CATT], [Comba, FFS] |
| Line code | | * Miller [Ericsson], [Futurewei], [Spreadtrum], [ZTE], [vivo], [CATT], [Samsung], [CMCC], [Qualcomm], [Comba] * FM0 [Ericsson], [Futurewei], [Spreadtrum], [ZTE], [CATT], [Samsung], [CMCC], [Qualcomm], [Comba] * Manchester [Ericsson], [Futurewei], [ZTE], [CATT], [Samsung], [CMCC], * None [Qualcomm] |
| FEC | | * CC [Ericsson], [Spreadtrum], [ZTE], [CATT], [Samsung], [CMCC], [Qualcomm], [Comba] * None [Ericsson], [Spreadtrum], [ZTE], [vivo], [Samsung] |
| ADC bit width | | * 11 bits [Futurewei, reader], [vivo, reader] |

#### Discussion (1st round)

Based on the inputs, the following proposal is formulated:

**[H][P3.5.7-v1]**

The following table of coverage evaluation assumptions in link level simulation is considered as start point.

**Table: Coverage evaluation assumptions**

|  |  |  |
| --- | --- | --- |
| **Parameters** | | **Assumptions** |
| **R2D/D2R common parameters** | | |
| Carrier frequency | | Refer to link budget template |
| SCS | | 15 kHz as baseline |
| Block structure | | Preamble + payload + CRC, to reported by companies |
| Channel model | | *<Editor’s Note: Refer to Proposals in section 3.5.3>* |
| Delay spread | | [30, 150] ns |
| Device velocity | | 3 km/h |
| Number of Tx/Rx chains for Ambient IoT device | | 1 |
| BS | Number of antenna elements | [2 or 4] |
| Number of TXRUs | [ 2 or 4] |
| Intermediate UE | Number of antenna elements | [1 or 2] |
| Number of TXRUs | [1 or 2] |
| Reference data rate | | [0.1] kbps |
| Message size | | [96] bits |
| BLER target | | 1%, 10% |
| Sampling frequency | | *<Editor’s Note: Refer to Proposals in section 3.5.1>* |
| **R2D specific parameters** | | |
| Transmission bandwidth | | 180 kHz as baseline |
| FFS: RF-ED bandwidth | | [X MHz] |
| FFS: BB LPF | | [X]-order Butterworth filter with cutoff frequency at [Y] kHz |
| Waveform | | OOK waveform generated by OFDM modulator |
| Modulation | | OOK  Companies to report, e.g., OOK-1, OOK-4 with M chips per OFDM symbol |
| Line code | | Companies to report, e.g., Manchester, PIE |
| FEC | | No FEC as baseline |
| ADC bit width | | 1-bit for device 1  4-bit for device 2 |
| **D2R specific parameters** | | |
| Transmission bandwidth  (w.r.t. D2R data rate) | | 15 kHz as baseline |
| Waveform (CW) | | Companies to report waveform, e.g., unmodulated single tone, multi-tone |
| Modulation | | Companies to report modulation, e.g., OOK, PSK |
| Line code | | Companies to report, e.g., Miller, FM0, Manchester |
| FEC | | Companies to report, e.g., CC, No FEC |
| ADC bit width | | Companies to report, e.g., 11-bit |
| **Other assumptions** | | |
| Other assumptions | | To be reported by company |
| Note:   * Companies to report required SINR according to BLER target. | | |

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| **Company** | **Comments** |
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## LS to RAN4

#### Related Tdoc Proposals

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| [Ericsson] | **Observation 3 RAN1 focuses on defining the deployment scenarios and identifying the key system parameters.**  **Proposal 17 If RAN1 reaches consensus, send an LS to RAN4 with basic evaluation assumptions.** |
| [CMCC] | **Proposal 16: RAN1 discuss and decide RAN1 interested deployment scenarios within Table 2.1-1, then send an LS to RAN4 and RAN4 to evaluate the Ambient IoT to NR coexistence.** |
| [Qualcomm] | * Following values are tentative assumptions, which requires further study on its feasibility and dependency on type of CW interference.   + BS: [130]dB   + UE: [110]dB * ***Further study the feasibility of IC capability at gNB and UE. If necessary, get input from RAN4 on; e.g., whether such interference exist, whether/how interference could be cancelled, IC capability, etc.***   ***Proposal 15: RAN1 and RAN4 to study the impact of Q factor in A-IoT link performance and energy harvesting; reasonable value of Q, pro/con of using high/low Q factor considering frequency in band(s) across operators.***  A graph of a function  Description automatically generated  Figure Antenna frequency amplitude response |

#### Discussion (round 1)

*<Editor’s Note: will be updated>*

Some companies think an LS is needed to be sent to RAN4 about the following aspects,

* Ask RAN4 to take the RAN1 evaluation assumptions into account, [Ericsson]
* Ask RAN4 to take RAN1 deployment scenarios and CW assumptions into account, [CMCC]

Qualcomm also ask RAN1 and RAN4 to study the impact of Q factor in A-IoT link performance and energy harvesting; reasonable value of Q, pro/con of using high/low Q factor considering frequency in band(s) across operators. Energy harvesting for Q factor may be out of SI scope. And Q factor which are more related to receiver architecture and FL suggest to discuss in 9.4.1.2 first.

Qualcomm asks to get input from RAN4 about whether/how CW interference could be cancelled, IC capability. FL suggest to discuss this issue in 9.4.2.4 first.

When the above items are ready, FL suggest to prepare an LS and send it to RAN4

**[M][P3.6-v1]**

*<Editor Notes: draft proposal for LS, will be updated in the future>*

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| RAN1 is conducting studies on coverage and coexistence studies and the following is agreed,  *<Editor Notes: copy agreements for scenarios definition>*  *<Editor Notes: copy agreements for CW cases>*  *<Editor Notes: copy agreements for Topology >*  RAN1 agrees the following assumptions for coverage evaluation for a link budget analysis,  *<Editor Notes: copy agreements for link budget >*  RAN1 agrees the following assumptions for link level simulation,  *<Editor Notes: copy agreements for LLS >*  RAN1 kindly asks RAN4 to take the above into consideration. |

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| **Company** | **Comments** |
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## Others

### Coexistence

#### Related Tdocs

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| [Samsung] | Proposal 8. RAN 1 studies the coexistence scenario where the base station can operate for NR and AIoT systems.  Proposal 9. For evaluation purpose, study the following interference scenarios to understand the impact of the coexistence with the legacy NR system with SLS and/or LLS.   * NR DL to R2D interference * Tag to NR UE interference * NR UE to tag interference * Carrier wave to tag and NR UE interference for non-co-located node for CW and gNB * Carrier wave to tag interference for co-located node for CW and reader/gNB   Proposal 10. Study the various factors that can influence coexistence interference.   * Guard band between two systems * Deployment of NR UEs * Self-interference blocking capacity * Etc.   Proposal 11. Study how to model coexistence interference in link-level simulations. |
| **[OPPO]** | Proposal 18: Co-existence evaluation is conducted by RAN4 based on the input on evaluation assumptions from RAN1. |
| **[Spreadtrum]** | ***Proposal 9: Support coexistence evaluation for spectrum deployment in-band to NR, in guard-band to LTE/NR, in standalone band(s).***  ***Proposal 10: The interference between A-IoT link and NR legacy Uu link needs to be analyzed for coexistence evaluation.***  ***Proposal 11: The impact of CW on A-IoT D2R reception and NR UL reception needs to be considered in coexistence evaluation.*** |
| ***[vivo]*** | **Observation 9: If matching network with 180kHz is applied before RF ED, at least 15dB and 10dB power boosting for AIOT R2D over NR is needed for 1PRB and 12PRBs guard band case respectively, when AIOT device with RF ED FDMed co-exists with in-band NR signal.**  **Observation 10: If matching network with 5MHz is applied before RF ED, at least 30dB and 28dB power boosting for AIOT R2D over NR is needed for 12PRB and 26PRBs guard band case respectively, when AIOT device with RF ED FDMed co-exists within band NR signal.**  **Proposal 33: Co-existence between AIOT R2D and NR is feasible only when AIOT signal boost the power over NR. Whether the required power boosting is feasible can be studied by RAN4.**  **Observation 11: If narrow bandwidth matching network or narrow bandwidth RF filter bandwidth can be implemented, CW and R2D transmission should be limited within the bandwidth to ensure receiving DL command and RF energy harvesting at AIoT device, which will reduce deployment flexibility for AIoT in frequency at NW side.**  **Observation 13: The impact of adjacent channel leakage power from NR UL transmission is negligible.**  **Proposal 34: The UL co-existence between AIoT and NR should be further studied considering the impact of in-band emission and adjacent channel leakage power from NR UL.** |
| ***[Xiaomi]*** | ***Proposal 8: The evaluation cases illustrated in Table 3/4/5 can be considered for the co-existence evaluation.***  ***Proposal 9: The ACLR, ACS, ACIR or SINR degradation can be used as the metrics for the co-existence evaluation*** |
| ***[ZTE]*** | ***Proposal 10: For coexistence of Ambient IoT and NR/LTE, out-of-band leakage, device frequency selectivity and inter-cell interference can be evaluated in RAN4.***  ***Proposal 11: For in-band deployment, Ambient IoT can be allocated at the edge of frequency band.*** |
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#### Discussion (round 1)

*<Editor’s Note: will be updated>*

Many companies agree that the coexistence between Ambient IoT and NR/LTE should be studied. Some companies (OPPO, ZTE, vivo(power boosting)) think it should be studied in RAN4. Samsung thinks the interference scenarios studies to understand the impact of the coexistence with the legacy NR system are by SLS and/or LLS.

During the April meeting, RAN4 is about to start the coexistence study, which will involve conducting a system level simulation (SLS) to assess the SINR, received power and etc. In light of RAN1’s upcoming link level simulation (LLS) for A-IoT, the feature lead recommends that RAN4 focuses on the SLS for coexistence while RAN1 proceeds with the LLS. This coordinated approach will provide direction for our future work. Furthermore, a liaison statement (LS) to RAN4 should be prepared and communicated to ensure that all parties are kept informed about these plans.

**[H][P3.7.1-v1]**

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| **Conclusion:**  For coexistence evaluations, it is RAN1 understanding that,   * RAN4 conducts coexistence studies,   + RAN4 can refer to link level simulation results conducted by RAN1 if needed, including e.g., BLER target and its corresponding required SNR, for both R2D and D2R link. * The tasks of both RAN4 and RAN1 are to be carried out in parallel. |

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| **Company** | **Comments** |
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### Evaluation results

#### Coverage results

##### Related Tdoc Proposals

[Ericsson] provides initial coverage evaluation for different scenarios of T1 and T2, different transmission cases of CW, considering CWT to D distance, and gives some initial observation on whether 10m coverage can be achieved.

[Huawei] provides one example of link budget calculation for Device 1 in D1T1, with 27m coverage distance

[ZTE] provides some initial coverage evaluation results to check the bottleneck channel and whether the design target can be achieved.

[OPPO] provides initial link budget evaluation for Device 1.

[CMCC]provides some link budget evaluation for different topology assumptions, different devices types, and makes observation for the bottleneck link and coverage distance.

[xiaomi] provides somel ink budget evaluation on different topology assumptions, different devices types, and makes observation for different links and coverage distance for LOS/NLOS.

[InterDigital, Inc.]provides some link budget evaluation and make observations about limited link, comparison about inside and outside CW, and comparison about topology 1 and 2

[Apple] provides some link budget results based on budget-Alt1 for different scenarios and CW deployment cases and makes observations on the bottleneck link and coverage distance.

[MTK] provides some link budget results for D1T1-A, CW inside @DL spectrum (case 1-1) and makes observation about the bottleneck link and maximum distance target.

[Sony] gives link budget analysis for D1T1 R2D link and for D2R link in different D1T1 scenarios, i.e., D1T1-A1, D1T1-A2, D1T1-B and D1T1-C considering on-object antenna penalty and make some observations on whether different devices types can meet the coverage range.

[Qualcomm] provides link budget results for different scenarios of T1 and T2, and different links, and propose to agree on the coverage analysis excel sheet attached, and also propose to perform link budget analysis for three links including CW/EH, R2D, and D2R, study the feasibility of IC capability at gNB and UE, and introduce balanced MPL which balances R2D MPL and D2R MPL.

[IIT Kanpur, Indian Institute of Technology Madras] provides coverage evaluation for monostatic and Bistatic case, for backscatter and active devices, for different Emitter-to-Ambient IoT distances, for different Modulation factors, different Absorption loss, with and without amplification power and make observations.

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| Source | proposal |
| Ericsson | **Observation 2 Based on our coverage evaluation results, the coverage distance is less than 10 m for the following cases:**   * **Device1: (D1T1-A2, case 1-2, PDRCH), (D2T2 for all cases, PRDCH and PDRCH),** * **Device 2a: (D2T2-A2, case 2-2, PDRCH).** |
| Huawei | ***Proposal 33: The transmit power of an indoor Ambient IoT BS in D1T1 is assumed to be no lower than 35 dBm EIRP (e.g., 33 dBm transmit power and 2 dBi antenna gain), which corresponds to the the set of e.g. {33, 38} dBm without antenna gain for the evaluations.***  ***Proposal 34: The antenna gain of an indoor Ambient IoT BS is assumed to be reported from the set of {2, 8} dBi.***  ***Proposal 35: The noise figure of indoor Ambient IoT micro-BS in D1T1 is assumed to be 5 dB.***  ***Proposal 36: The transmit power of an intermediate UE in D2T2 is assumed to be 23 dBm, with the antenna gain of 0 dBi.***  ***Proposal 37: The noise figure of an intermediate UE in D2T2 is assumed to be 7 dB.***  ***Proposal 38: The reflection loss of Device 1 is assumed to be -6 dB or 0 dB for OOK or BPSK, respectively.***  ***Proposal 39: The reflection amplification gain of Device 2a can be reported by companies from the set of {10, 20} dB.***  ***Proposal 40: For Device 2b, the maximum transmit power is assumed to be -10 dBm or -20 dBm.***  ***Proposal 41: For Device 1, Budget-Alt1 is recommended for the evaluation of the receiver sensitivity, which is assumed to be e.g. -36 dBm.***  ***Proposal 42: For Device 2 with RF-ED receiver, Budget-Alt1 is recommended for the evaluation of the receiver sensitivity, which is assumed to be e.g. -46 dBm.***  ***Proposal 43: For Device 2 with IF-ED or ZIF receiver, Budget-Alt2 is recommended for the evaluation of the receiver sensitivity, which can be calculated based on a noise figure of 24 dB or [30] dB.*** |
| ZTE | ***Observation 1: For Device 1, the coverage of energy harvesting is the bottleneck among energy harvesting, DL detection and BL detection. And the maximum distance of EH is 11.1 m for D1T1 InF-DH NLOS and 4.7 m for D2T2 InH-Office NLOS.***  ***Observation 2: For Device 1, D1T1 with InF-DH NLOS can meet the coverage requirements of over 10 meters, while D2T2 with InH-Office NLOS cannot.***  ***Observation 3: For Device 2a, the coverage of BL detection is the bottleneck between DL detection and BL detection. When the power of*** ***received/incident signal is -45 dBm, the distance of DL detection reaches 105 m while the distance of BL detection is 23.5 m for D1T1 InF-DH NLOS.***  ***Observation 4: In D1T1 with InF-DH NLOS, Device 2a can achieve the DL and BL coverage requirements of 50 meters when the power of received/incident signal is -38 dBm.***  ***Observation 5: For Device 2b, the coverage of UL detection is the bottleneck between DL detection and UL detection. The maximum distances are respectively 301 m for DL detection and 244 m for UL detection in D1T1 with InF-DH NLOS.***  ***Proposal 8: The baseline simulation assumptions including candidate physical layer solutions can be defined for link-level simulation.*** |
| CMCC | **Observation 1: For device 1 in D1T1, the coverage distance would be limited by R2D link, and about 26m coverage distance can be achieved.**  **Observation 2: At least for device 2a in D1T1, the coverage distance can be approximately 68.8m limited by R2D link.**  **Observation 3: For D2R link in D1T1, larger coverage distance can be achieved in case of CW outside topology.**  **Observation 4: For D2T2, the coverage of R2D is the bottleneck due to limited transmit power (23 dBm) from intermediate UE and device activation threshold, and coverage distance is about 7.5m for device 1 and 13.5m for device 2a.**  **Observation 5: For D2R link in D2T2, when CW outside topology is used, with larger CW power received at device side, better coverage performance can be achieved.** |
| Xiaomi | ***Observation 6: Topology 1 has obviously better coverage performance than Topology 2 due to higher transmit power of gNB.***  ***Observation 7: D2R link has better coverage performance than R2D link due to better receiver sensitivity of gNB.***  ***Observation 8: Under current assumptions, coverage performance of some links can not achieve the distance target 50m.***  ***Proposal 7: The recommended parameters for link budget template in Table 1 can be considered.*** |
| InterDigital, Inc. | **Observation 1: For deployment scenario 1/topology 1, coverage is limited by the Reader-to-Device channel.**  **Observation 2: For deployment scenario 1/topology 1, CW source outside topology has better coverage than CW source inside topology.**  **Observation 3: For deployment scenario 2/topology 2, coverage is limited by the Reader-to-Device channel.**  **Observation 4: For deployment scenario 2/topology 2, CW source outside topology has better coverage than CW source inside topology.**  **Observation 5: The coverage of deployment scenario 2/topology 2 is worse than deployment scenario 1/topology 1.**  **Observation 6: IoT device Rx sensitivity is the bottleneck for achievable coverage range.**  **Observation 7: NLoS propagation loss assumption provides a worst-case estimate of coverage range.** |
| Apple | ***Observation 1: For D1T1-CW1 (CW node same as reader), R2D link is the bottleneck for device type 1***  ***Observation 2: For D1T1-CW2 (CW node same as reader, but inside topology) & D1T2-CW3 (CW node same as reader, but outside topology), D2R link is the bottleneck for device type 1***  ***Observation 3: For D2T1-CW1 (CW node same as reader), R2D link is the bottleneck for device type 1***  ***Observation 4: For D2T2-CW2 (CW node same as reader, but inside topology) & D2T2-CW3 (CW node same as reader, but outside topology), D2R link is the bottleneck for device type 1***  ***Observation 5: For D1T1-CW1 and D2T2-CW1, i.e. when CW node is same as the reader, then the reader needs to be quite closely deployed to the device ( under 10m) for device type 1***  ***Observation 6: For D1T1-CW2 and D1T1-CW3, i.e. when CW node is different than the reader, then the coverage range in the order of 100m is achievable for device type 1***  ***Observation 7: For D2T2-CW2 and D2T2-CW3, i.e. when CW node is different than the reader, then the coverage range between the reader (intermediate UE) and the device is in the order of ~20m for device type 1*** |
| MTK | **Observation 11: RF CBW is more suitable for calculating the (effective) noise power.**  **Observation 12: If on-object antenna penalty is considered in link budget calculation, it should be used for both R2D and D2R links.**  **Observation 13: For the coverage evaluation of reader-to-device, the link budget of RF-EH link calculated based on the activation threshold of the EH circuity is the bottleneck compared to the R2D link calculated based on the sensitivity of the device.**  **Observation 14: Without considering the impact of interference, a good coverage performance can be obtained for R2D link due to a lower sensitivity power.**  **Proposal 25: The maximum distance target is set separately for device 1 and device 2a&2b**   * **For device 1, the maximum distance target is lower than 20 m** * **For device 2a&2b, the maximum distance target is higher than 20m** |
| Sony | **Observation 1**: **An advantage introduced by the D1T1-A1 scenario is that the reader BS may enjoy minimized direct-link interference incurred by the CW transmitted by the other BS. We note that this holds especially for a system in which the backscattered signal occupies the same frequency band as the CW, e.g., an A-IoT device modulates its information through on-off keying (OOK) scheme.**  **Observation 2: Given that the distance between two adjacent BSs in the big hall deployment equals m, the maximum R2D range is Approx. m. This also implies that the type 1 device could only be supported in limited conditions, e.g., R2D range within and the device attached to the cardboard sheet.**  **Observation 3: When the material that the device is attached to is reflective, e.g., metal, deploying type-2a devices or active devices is required to ensure the successful command reception. Type 1 devices are not compatible with the D1T1 scenario.**  **Observation 4: Given that the excitation threshold of type-ii (a) device is dBm and the reader sensitivity is dBm, type 2a device can well support the D2R link in the D1T1-A2 scenario**.  **Observation 5: Type 2a devices are required for D1T1-B, where the UE is deployed as external CWE, in order to achieve successful device excitation.**  **Observation 6: Type 2b devices are required easily achieve the link budget for the D1T1-C scenario.**  **Proposal 1**: **A unified approach is used for R2D link budget analysis for D1T1 scenarios, considering different activation thresholds for different device types**.  **Proposal 2**: **Link budget for D1T1-A1 scenario should be conducted based on the agreed assumptions of the indoor BS deployment. For example, m for big hall and for small hall, etc. denotes the distance between two adjacent indoor BSs. This means that the distance between the CWE and the reader (both are BSs) is and thus the device should ideally communicate with both.**  **Proposal 3: For backscattering devices, i.e., type 1 and type 2a devices, an on-object antenna penalty in both R2D and D2R links is considered. RAN1 assumes dB for cardboard sheet and dB for aluminium slab as on-object antenna penalties.** |
| Qualcomm | ***Observation 1: The interference cancellation capability depends on nature/cause of interference; Tx non-linearity, Tx-to-Rx isolation, Rx non-linearity, etc.***  ***Observations 2***   * ***Topology 1***   + ***In D1T1-A1, comparing Case 1-1 and Case 1-2, transmitting CW in FDD-UL spectrum reduces CW tx power by 10dB, which recues both R2D and D2R link MPL by 10dB, which significantly reduces distance.***   + ***In D1T1-A2, the D2R link is bottleneck due to BS’s interference cancellation capability.***   + ***D1T1-B scenario is similar to D1T1-A1.***   + ***D1T1-C scenario is free from interference cancellation and support higher tx power of -20dBm, showing the largest MPL and distance.*** * ***Topology 2***   + ***D2T2-A provides the shortest distance of 2m.***   + ***D2T2-B (Case 2-4) provide <10m distance.***   + ***D2T2-C provides larger distance (36.8m) than that from D2T2-A and D2T2-B.***   ***Proposal 1: RAN1 to agree on coverage analysis excel sheet attached.***  ***Proposal 2: For coverage (link budget) analysis***   * ***For each scenario, perform link budget analysis for three links including CW/EH, R2D, and D2R.*** * ***Further study the feasibility of IC capability at gNB and UE. If necessary, get input from RAN4 on; e.g., whether such interference exist, whether/how interference could be cancelled, IC capability, etc.*** * ***Introduce balanced MPL which balances R2D MPL and D2R MPL. and accordingly maximize distance.*** |
| IIT Kanpur, Indian Institute of Technology Madras | **Observation 1: In the monostatic mode of operation, the downlink range of the AIoT device is limited by the tag receiver sensitivity.**  **Observation 2: The maximum coverage is function of the distance between the AIoT device and the CW emitter.**  **Observation 3: With amplification power, coverage can be achieved more than 25m in case of tag’s absorption loss of 4.5dB, while coverage is reduced to 18m without amplification power and absorption loss of 0.9dB.** |

[Huawei]provides some values for coverage evaluation

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| ***Base station*** | ***The transmit power of an indoor Ambient IoT BS in D1T1*** | ***{33, 38} dBm without antenna gain for the evaluations*** |
| ***The antenna gain of an indoor Ambient IoT BS*** | ***{2, 8} dBi*** |
| ***noise figure of indoor Ambient IoT micro-BS in D1T1*** | ***5 dB*** |
| Intermediate UE | ***The transmit power of an intermediate UE in D2T2*** | ***23 dBm*** |
| ***antenna gain*** | ***0 dBi*** |
| ***noise figure of an intermediate UE in D2T2*** | ***7 dB*** |
| Device | ***reflection loss of Device 1*** | ***-6 dB for OOK***  ***0 dB for BPSK*** |
| ***The reflection amplification gain of Device 2a*** | ***{10, 20} dB*** |
| ***The maximum transmit power for Device 2b*** | ***-10 dBm or -20 dBm*** |
| General Evaluation Methodology | ***Device 1*** | ***Budget-Alt1, -36 dBm.***  ***Proposal 42: For Device 2 with RF-ED receiver, Budget-Alt1 is recommended for the evaluation of the receiver sensitivity, which is assumed to be e.g. -46 dBm.*** |
|  | ***Device 2 with RF-ED receiver*** | ***Budget-Alt1, -46 dBm*** |
|  | ***Device 2 with IF-ED or ZIF receiver*** | ***Budget-Alt2***  ***noise figure : 24 dB or [30] dB.*** |

##### Discussion (no need to feedback)

According to work plan, the evaluation results will be collected in next meeting.

#### LLS performance

##### Related Tdoc Proposals

[Nokia] provides initial link level simulation for R2D link considering different sampling offsets (in ppm), payload sizes, M values to see the impact of sampling offset on detection.

[CATT] provides initial link level evaluation for R2D link with OOK modulation and for D2R link with OOK and FSK supposing TDL-C and TDL-D to see the impact of fading channel.

[Samsung] provides BLER performance of FDMA-based multiple D2R transmissions comparing with non-multiplexing case, and negligible performance degradation is observed for Miller based FDMA for the specific simulation parameters.

[CMCC] provides initial decoding performance for different length of R2D payload.

[xiaomi] provides some initial R2D LLS and observations for required SINR considering number of RBs, ADC bit, sampling rate, and line code schemes. And for D2R link the impact of sampling rates on required SINR are provided.

[MTK]provides some initial LLS performance evaluation for R2D considering RF BPF, BB LPF, and SFO to see the impact on performance.

[Qualcomm] provides initial basic evaluation results showing the impact of ASCI, Guard RB size, ACI, and practical comparator modeling to see the impacts.

[IIT Kanpur, Indian Institute of Technology Madras] provides some initial LLS decoding performance for R2D for different payload size.

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| Source | proposal |
| Nokia | **Observation 4: As the payload length increases, the impact of sampling offset degrades the detection performance.**  **Proposal 10: Consider the need for midamble if the payload size is bits to ensure reliable detection of AIoT payload.** |
| CATT | **Observation 1: The performance of OOK under LOS channel is better than NLOS channel due to the constant power of the LOS path.**  **Observation 2: FSK has better anti-fading capability than OOK because the signal strength attenuation caused by fading channel has relatively small impact on FSK demodulation.** |
| Samsung | **Observation 2.** Miller encoding scheme, 0.1% BLER can be achieved when CNR is about -3dB. With an example of FDMA-based transmissions between three devices using Miller-4, Miller-8, and Miller-16, respectively, the link level BLER performance of FDMA-based case have ~0.3dB loss compared with single use case, which is acceptable performance loss for each user**.** |
| Xiaomi | ***Observation 1:*** ***Required SINR is decreased from 13dB to 10dB with RB number increased from 1 to 4.***  ***Observation 2: For 4 RB case, required SINR is decreased from 10dB to 6dB with sampling rate increased from 960khz to 3.84Mhz.***  ***Observation 3: Required SINR is decreased by 1.5dB with quantity bits increased from 1 to 4, and with ideal quantity, the required SINR is decreased by about 2dB compared to 1 bit quantity.***  ***Observation 4: At target BLER (10^-2), the required SINR of PIE is 18dB while OOK-1 with Manchester is 10dB.***  ***Observation 5: For D2R sinuous waveform, required SINR is decreased from 13dB to 7dB with sampling rate increased from 240kHz to 3.84MHz.*** |
| MTK | **Observation 1: The BB LPF after ED may not effectively filter out noise beyond 180kHz.**  **Observation 2: A BB LPF before ED with a 180kHz bandwidth for Device 2b can remove noise beyond 180kHz and offers significantly better performance compared to a 10MHz RF BPF.**  **Observation 3: The accumulation of sample error caused by sampling frequency offset will also introduce a timing offset.**  **Observation 4: The impact of SFO degrades performance by 3dB.**  **Proposal 14: Consider the Manchester coding for estimating sampling frequency offset and timing offset.** |
| Qualcomm | ***Observation 11: ASCI has significant influence on OOK reception.***  ***Observation 12: Larger numbers of guard RBs give better performance.***  ***Observation 13: Error floor is caused by ASCI.***  ***Observation 14: Even small power boost ACI has huge impact on link performance.***  ***Observation 15: Increasing Q factor can improve link performance. But, link performance is still severely impacted by strong ACI.***  ***Observation 16: Ideal comparator model with extra noise (modeled by noise figure) couldn’t capture influence of Q value change.***  ***Observation 17: Practical model can capture change of signal voltage absolute value.*** |
| IIT Kanpur, Indian Institute of Technology Madras | **Observation 4: Link performance deteriorates when payload size or message size is increased.**  **Proposal 5: Message or payload size related to backscattering should be considered in the modelling of AIoT UL/DL signal transmission.**  **Proposal 6: In the link-level simulation, self-interference in the DL transmission and direct/cross-interference in the UL transmission should be considered in the modelling.**  **Proposal 7: Multipath effect on the transmitted OOK signal should be studied for AIoT device in LLS.** |

##### Discussion (no need to feedback)

According to work plan, the evaluation results will be collected in next meeting.

#### Coexistence results

##### Related Tdoc Proposals

[vivo] provides some evaluation on both DL and UL coexistence. For DL, observations and proposal on number of guard RBs and power boosting are made. For UL, NR in-band emission and NR adjacent channel leakage combined with link budget are analyzed to see whether the reception of of D2R will be seriously impacted.

[OPPO]provides some time and frequency domain insight for backscattered signal with OOK modulation, and observes that backscattered signal will cause interference to NR/LTE transmissions in adjacent frequency. They propose RAN1 to provide some parameters for RAN4 co-existence evaluation.

[Samsung] provides some coexistence evaluation, and observations about requirement on pulse shaping, low-pass filter, Line code design and guard band are made.

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| Source | Proposal |
| vivo | **Observation 9: If matching network with 180kHz is applied before RF ED, at least 15dB and 10dB power boosting for AIOT R2D over NR is needed for 1PRB and 12PRBs guard band case respectively, when AIOT device with RF ED FDMed co-exists with in-band NR signal.**  **Observation 10: If matching network with 5MHz is applied before RF ED, at least 30dB and 28dB power boosting for AIOT R2D over NR is needed for 12PRB and 26PRBs guard band case respectively, when AIOT device with RF ED FDMed co-exists within band NR signal.**  **Proposal 33: Co-existence between AIOT R2D and NR is feasible only when AIOT signal boost the power over NR. Whether the required power boosting is feasible can be studied by RAN4.**  **Observation 11: If narrow bandwidth matching network or narrow bandwidth RF filter bandwidth can be implemented, CW and R2D transmission should be limited within the bandwidth to ensure receiving DL command and RF energy harvesting at AIoT device, which will reduce deployment flexibility for AIoT in frequency at NW side.**  **Observation 12: For AIoT D2R link of the device type with 1μW power consumption, backscatter signal may be overwhelmed by in-band emission signal from NR UL.**  **Observation 13: The impact of adjacent channel leakage power from NR UL transmission is negligible.**  **Proposal 34: The UL co-existence between AIoT and NR should be further studied considering the impact of in-band emission and adjacent channel leakage power from NR UL.** |
| OPPO | Proposal 20: The A-IoT transmission bandwidth, transmission power, assumed guard-band size, and filtering capability of A-IoT devices should be provided to RAN4 for co-existence evaluation. |
| Samsung | **Observation 3**. On the evaluation, pulse shaping should be considered for R2D.  **Observation 4.** Study the sufficient guard between A-IOT D2R and NR UL to mitigate the interference of A-IoT D2R signal and NR UL signal.  **Observation 5.** Line code design needs to consider the interference from NR signal to avoid direct-current component in the spectrum.  **Observation 6** To mitigate the interference of NR signal, low-pass filter is needed for A-IoT Tag.  **Observation 7.** In the case of same time domain transmission power for NR DL signal and A-IoT R2D signal, for Manchester code, the performance for A-IoT R2D is acceptable without guard band, if pulse shaping is applied at transmitter side and low-pass filter is used at receiver side.  **Observation 8.** Study the required guard between A-IoT R2D signal and NR DL signal with reasonable power allocation assumption, e.g., 1:3 or lower. |

##### Discussion (no need to feedback)

According to work plan, the evaluation results will be collected in next meeting.

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| **Company** | **Comments** |
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### others

# SID

This study targets a further assessment at RAN WG-level of Ambient IoT, a new 3GPP IoT technology, suitable for deployment in a 3GPP system, which relies on ultra-low complexity devices with ultra-low power consumption for the very-low end IoT applications. The study shall provide clear differentiation, i.e. addressing use cases and scenarios that *cannot* otherwise be fulfilled based on existing 3GPP LPWA IoT technology e.g. NB-IoT including with reduced peak Tx power.

General Scope

The definitions provided in TR 38.848 are taken into this SI, and the following are the exclusive general scope:

1. The overall objective shall be to study a harmonized air interface design with minimized differences (where necessary) for Ambient IoT to enable the following devices:
2. ~1 *µ*W peak power consumption, has energy storage, initial sampling frequency offset (SFO) up to 10*X* ppm, neither DL nor UL amplification in the device. The device’s UL transmission is backscattered on a carrier wave provided externally.
3. ≤ a few hundred *µ*W peak power consumption1, has energy storage, initial sampling frequency offset (SFO) up to 10*X* ppm, both DL and/or UL amplification in the device. The device’s UL transmission may be generated internally by the device, or be backscattered on a carrier wave provided externally.

* *X* is to be decided in WGs.
* Coverage design target: Maximum distance of 10-50 m with device indoors as per TR 38.848: “*…a range that WGs can sub-select within*”.
* For Topologies 1 & 2 (UE as intermediate node under NW control) per TR 38.848, with no RRC states, no mobility (i.e. at least no cell selection/re-selection -like function), no HARQ, no ARQ.

NOTE 1: It is to be understood that “≤ a few hundred *µ*W” means WGs are not tasked with setting a particular value, and that it will be for WG discussions to determine if a presented design with corresponding power consumption satisfies the “≤ a few hundred *µ*W” requirement.

1. Deployment Scenarios with the following characteristics, referenced to the tables in Clause 4.2.2 of TR 38.848:

* Deployment scenario 1 with Topology 1
  + Basestation and coexistence characteristics: Micro-cell, co-site
* Deployment scenario 2 with Topology 2 and UE as intermediate node, under network control
  + Basestation and coexistence characteristics: Macro-cell, co-site
  + The location of intermediate node is indoor

1. FR1 licensed spectrum in FDD.
2. Spectrum deployment in-band to NR, in guard-band to LTE/NR, in standalone band(s).
3. Traffic types DO-DTT, DT, with focus on rUC1 (indoor inventory) and rUC4 (indoor command).

* From RAN#104, the study will assess whether the harmonized air interface design (per bullet ‘A’ above) can address the DO-A (Device-originated autonomous) use case, only to identify which part(s) of the harmonized air interface design (per bullet ‘A’ above) is/are not sufficient for the DO-A use case.

Transmission from Ambient IoT device (including backscattering when used) can occur at least in UL spectrum.

The following objectives are set, within the General Scope:

1. Evaluation assumptions
2. Conclude at least the following aspects of design targets left to WGs in Clause 5 (RAN design targets) of TR 38.848 [RAN1].
   * Clause 5.3: Applicable maximum distance target values(s)
   * Clause 5.6: Refine the definition of latency suitable for use in RAN WGs
   * Clause 5.8: 2D distribution of devices
3. Define necessary further evaluation assumptions of deployment scenarios for coverage and coexistence evaluations [RAN1, RAN4]
4. Identify basic blocks/components of possible Ambient IoT device architectures, taking into account state of the art implementations of low-power low-complexity devices which meet the RAN design target for power consumption and complexity. [RAN1]
5. Define link budget calculation for coverage, including whether/how to model carrier wave from node(s) inside or outside the connectivity topology.

NOTE: Assessment performance of the design targets is within the study of feasibility and necessity of proposals in the following objectives, e.g. by inspection of reference implementations in the field, simulations, analytically.

NOTE: strive to minimize evaluation cases in RAN1.

1. Study necessary and feasible solutions for Ambient IoT as prescribed in the General Scope, including decisions on which functions, procedures, etc. are needed and not needed, and ensuring at least the required functionalities in Section 6.2 of TR 38.848.

Study of positioning in Rel-19 is RAN3-led, limited to functionalities which would have no, or minimal, specification impact (note: this does not imply any decision relating to WI creation).

Study the feasibility and required functionalities for proximity determination (coordination with SA3 is required for privacy aspects).

* RAN1-led:

For the Ambient IoT DL and UL:

* + Frame structure, synchronization and timing, random access
  + Numerologies, bandwidths, and multiple access
  + Waveforms and modulations
  + Channel coding
  + Downlink channel/signal aspects
  + Uplink channel/signal aspects
  + Scheduling and timing relationships
  + Study necessary characteristics of carrier-wave waveform for a carrier wave provided externally to the Ambient IoT device, including for interference handling at Ambient IoT UL receiver, and at NR basestation.

For Topology 2, no difference in physical layer design from Topology 1.

* RAN2-led:
  + Study and decide which functions are needed for an Ambient IoT compact protocol stack and lightweight signalling procedure to enable DO-DTT and DT data transmission, and study those functions.

For example:

* + - Paging
    - Random access
    - Data transmission, including necessary radio resource control aspects, respecting the limitation in the General Scope
    - Interactions with upper layers

For functionalities not listed above, they are studied only if found essential.

* RAN3-led:
  + Identify necessary impacts on signaling and procedures for CN-RAN interface, to enable:
    - Paging
    - Device context management
    - Data transport
  + Identify RAN architecture aspects, including whether support for split architecture is necessary.
  + Identify potential solutions for locating an Ambient IoT device with no specification impact, e.g. reusing existing user location report, or minimal specification impact to convey location information to core network.
* RAN4-led:
  + Coexistence study of Ambient IoT and NR/LTE.
  + RF requirements study for Ambient IoT:
    - Ambient IoT BS transmission and reception
    - Ambient IoT Device, as per the General Scope, transmission and reception
    - Intermediate node (UE), as per the General Scope, transmission and reception

RAN2 and RAN3 are expected to identify RAN-CN functional split in coordination with SA2.

Note: This study shall target for an IoT segment well below the existing 3GPP IoT technologies, e.g. NB-IoT, eMTC, RedCap, etc. The study shall not aim to replace existing 3GPP LPWA technologies.

# Agreements

## RAN1#116

Agreement

For this study item, the coverage evaluation methodology is based on the following steps.

For an evaluation scenario

* For each of the link *i*,
  + Step 1: Obtain the required SINR for the physical channels under target scenarios and service/reliability requirements if **Budget-Alt2** is used for this link *i*.
  + Step 2: Obtain the receiver sensitivity using the method **Budget-Alt1** (if a predefined threshold is assumed to derive the receiver sensitivity)or **Budget-Alt2** (if no predefined threshold is assumed to derive the receiver sensitivity).
  + Step 3: Obtain the coverage performance for link *i* based on the receiver sensitivity from step 2 and link budget template.
* The coverage results for each link are provided.
* FFS: what links are evaluated besides R2D and D2R (e.g., RF-EH)
* FFS whether/how to model the interferenceFFS: for which device(s) a predefined threshold is assumed

Note the following alternatives for obtaining receiver sensitivity are defined,

* **Budget-Alt1:** receiver sensitivity is derived by a predefined threshold and no LLS is needed for link budget calculation
  + The results rely on the received sensitivity and maximum transmit power, and directly calculate the maximum distance / pathloss based on these values and other related parameters. The link-level simulation (LLS) performances, such as required SINR can be satisfied for such case and no LLS is needed for link budget calculation.
* **Budget-Alt2:** receiver sensitivity is derived by required SINR which is given by LLS results
  + The results rely on link-level simulation results, e.g., required SINR which corresponds to detail LLS assumptions (e.g., BW, coding, data rate). And based on the required SINR, the received sensitivity can be calculated and then the maximum distance / pathloss can be derived.
  + Note: For noise power, a noise figure value needs to be provided.

Agreement

MPL and distance is used as performance evaluation metric for link budget calculation.

* Note: the distance is derived from MPL and corresponding pathloss model.
* FFS: Pathloss model

Agreement

The following pathloss model is used in the coverage evaluation.

* For D1T1,
  + InF-DH defined in TR38.901 is used.
  + Decide which of the following is used for each link,
    - NLOS
    - LOS
  + FFS: InF-SH
* For D2T2, down-select from the following path loss models
  + InF-DL defined in TR38.901 where the BS path loss model is reused for intermediate-UE with antenna height of 1.5m
  + InH-Office model defined in TR38.901, (a.k.a, InH\_B in Report ITU-R M.2412-0) where the BS path loss model is reused for intermediate-UE with antenna height of 1.5m
  + Decide which of the following is used for each link,
    - NLOS
    - LOS

**Conclusion**

Companies are encouraged to consider Table 3.4.2 in R1-2401735 for their contributions to RAN1#116bis regarding link budget template.

# Reference

Section 9.4.1.1

1. R1-2401970 Evaluation assumptions and results for Ambient IoT Ericsson
2. R1-2402011 Evaluation methodology and assumptions for Ambient IoT Huawei, HiSilicon
3. R1-2402040 Discussion on evaluation assumptions and results for Ambient IoT devices FUTUREWEI
4. R1-2402072 Evaluation assumptions and results for Ambient IoT Nokia
5. R1-2402105 Discussion on evaluation assumptions and results for Ambient IoT Spreadtrum Communications
6. R1-2402137 Discussions on deployment scenarios and evaluation assumptions for A-IoT Intel Corporation
7. R1-2402184 Discussion on Ambient IoT evaluations ZTE, Sanechips
8. R1-2402242 Evaluation methodologies assumptions and results for Ambient IoT vivo
9. R1-2402328 Discussion on evaluation assumptions and results for A-IoT OPPO
10. R1-2402383 The evaluation methodology and preliminary results of Ambient IoT CATT
11. R1-2402466 Considerations for evaluation assuptions and results Samsung
12. R1-2402510 Discussion on evaluation assumptions and results for Ambient IoT China Telecom
13. R1-2402565 Discussion on evaluation methodology and assumptions CMCC
14. R1-2402666 Evaluation methodology and assumptions for Ambient IoT Xiaomi
15. R1-2402826 Discussion on ambient IoT evaluation framework NEC
16. R1-2402857 Evaluation assumptions for Ambient IoT InterDigital, Inc.
17. R1-2402881 Views on evaluation assumptions and link budget analysis for AIoT Apple
18. R1-2402946 On evaluation assumptions and results for A-IoT MediaTek
19. R1-2402967 Evaluation assumptions and results for Ambient IoT Sony
20. R1-2403101 Discussion on the evaluation assumptions for Ambient IoT devices Lenovo
21. R1-2403117 Discussion on Ambient IoT evaluation LG Electronics
22. R1-2403194 Evaluation Assumptions and Results Qualcomm Incorporated
23. R1-2403244 Study on evaluation assumptions for Ambient IoT NTT DOCOMO, INC.
24. R1-2403284 Evaluation assumptions for Ambient IoT Comba
25. R1-2403397 Discussion on Evaluation assumption and preliminary results for AIoT IIT Kanpur, Indian Institute of Technology Madras

Others

1. RP-234058 New SID: Study on solutions for Ambient IoT (Internet of Things) in NR Huawei (moderator, RAN1 Vice-Chair)

# History