**3GPP TSG RAN-WG1 Meeting #118 draft\_R1-2407248**

**Maastricht, Netherlands, 19-23 August, 2024**

**Source: Moderator (Huawei)**

**Title:****Feature Lead Summary #1 for 9.4.2.1: “Ambient IoT – General aspects of physical layer design”**

**Document for:** **Discussion and decision**

**Agenda item: 9.4.2.1**

# Introduction

According to the chair’s agenda, this feature lead summary will cover discussions on:

* Waveform ([R2D](#_R2D_waveform_[ACTIVE]); [D2R](#_D2R_waveform_[ACTIVE]))
* Modulation ([R2D](#_R2D_modulation_[ACTIVE]); [D2R](#_D2R_modulation_[ACTIVE]))
* Coding
	+ Line coding ([R2D](#_R2D_line_coding); [D2R](#_D2R_line_coding)), channel coding / repetition ([R2D](#_R2D_FEC_/); [D2R](#_D2R_FEC_/))
	+ CRC (jointly [for R2D and D2R](#_CRC))
* Multiple access ([R2D](#_R2D_multiple_access); [D2R](#_D2R_multiple_access))
* Time-domain definitions ([R2D](#_R2D_numerology); [D2R](#_D2R_numerology_[INACTIVE]))
* Bandwidth ([R2D](#_R2D_bandwidths_[ACTIVE]); [D2R](#_D2R_bandwidths_[ACTIVE]))

Proposal X.Y(z) is in Section X.Y, where (z) a Roman numeral I, II, III, IV, V, …, is the version of that proposal.

Proposals for online sessions will be added to Section 5 ([link](#_Proposals_for_online_1)).

Decisions are authoritatively in the chair notes, and may be copied into Section 6 ([link](#_Summary)) from time to time.

Previous meetings’ decisions are in Annex A ([link](#_Annex_A_–)).

## Versions

FLS #1: R1-2407248

# R2D

## R2D waveform

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| Agreement RAN1#116A-IoT DL study includes an OFDM-based waveform from A-IoT R2D (reader-to-device) perspective. * Depending on what modulation(s) are decided to be studied:
	+ Study whether/how to handle CP at transmitter/device/design
* Study other characteristics of the OFDM waveform, e.g.:
	+ CP-OFDM
	+ DFT-s-OFDM
	+ Etc.
	+ The type of OFDM waveform is transparent to A-IoT device.

Other waveforms from DL transmitter’s perspective can be proposed, and further discussion will consider whether or not they are included in the study. |

### CP handling [ACTIVE]

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| Agreement RAN1#116bisFor R2D CP handling for OFDM based OOK waveform:* For potential down-selection, study among the following candidate methods
	+ Method Type 1: Removal of CP at device without specified transmit-side
		- …
	+ Method Type 2: Ensure the CP insertion of OFDM-based waveform will not introduce false rising/falling edge between the last OOK chip in OFDM symbol (n-1) and the first OOK chip in OFDM symbol n.
		- …
	+ [Other method types are not precluded]

Agreement RAN1#117Study the following regarding CP location/length determination for Method Type 1:* + Alt 1: Device assumes same CP length for each OFDM symbol, i.e. does not distinguish exact CP length among different OFDM symbols
	+ Alt 2: duration between transition edges is utilized by device to determine CP location/length, i.e. if the duration appears to be invalid based on known chip duration
* Companies are encouraged to clarify the CP removal method used and implementation aspects for the device
* Evaluations are encouraged to be performed for a small value of M, e.g. 4 and a large value of M, e.g. 24, at least by comparison to the case where the CP length of each OFDM symbol is known by device
* Companies should report the values of SFO, and SFO detection methods used in evaluations

AgreementStudy the following options regarding subcarrier orthogonality for Method Type 2:* Alt 1: Method Type 2 retains subcarrier orthogonality (i.e. CP copied from the end of an OFDM symbol)
* Alt 1-1: The first OOK chip(s) and the last OOK chip(s) in an OFDM symbol are the same
	+ FFS: whether this alternative applies if CP length is longer than the chip duration
* Alt 1-2: Ensure a transition edge occurs only at the start or only at the end of the CP, and no transition edge occurs during the CP
* Other potential methods are not precluded
* Alt 2: Method Type 2 does not retain subcarrier orthogonality
* Proponents to bring further details to RAN1#118
* Evaluations and discussions are encouraged to be performed for a small value of M, e.g. M = 4 and a large value of M, e.g. M = 24.
* Companies should report the values of SFO, and SFO detection methods used in evaluations
 |

#### Round 1

RAN1 has identified methods and alternatives under each method for CP handling of OFDM based OOK waveform. Based on the inputs from papers, feature lead would like to continue discuss the followings on this topic.

Some companies suggest to focus on normal CP and do not consider extended CP since extended CP is only defined for 60 kHz SCS in legacy NR. Feature lead think it is good to clarify this. Further, considering the scope of R19 is for indoor scenario, it seems reasonable to focus on normal CP for the study.

**Proposal 2.1.1a(I): For R2D CP handling of OFDM based OOK waveform, normal CP is considered in the study.**

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| **Company** | **Views** |
| TCL | Agree with this proposal. |
| LGE | Okay |
| Qualcomm | We have the same understanding. We are fine to agree the proposal, but we think it is also OK not to discuss this – RAN1 already made agreement that SCS 15kHz is the baseline, and this implies that normal CP is the only choice (unless RAN1 makes another agreement to include 60kHz). |
| IDCC | Ok. |
| Panasonic | Support |
| Spreadtrum | OK to exclude extended CP in R19.Just for clarification, from our understanding, the distinction for whether to consider extended CP only impacts Method Type 1 for CP handling, no need for Method Type 2.  |
| Ericsson | Ok |
| Samsung | OK |
| DOCOMO | OK |
| Lenovo | support |
| xiaomi | we are fine with this proposal. |

Although companies have their own interest/support on different methods on this topic, it seems not necessary to have an immediate down-selection in this rather detailed area. Feature lead would like to continue discuss for each method.

For CP handling Method type 1, at least for Alt 1, some companies pointed out in their papers that the device has to know the OFDM boundary (beginning of OFDM symbol) to determine the CP location. And some companies propose that preamble can provide a reference to device to detect the boundary of OFDM symbol. This seems a step device cannot avoided.

**Proposed Observation 2.1.1b(I): For R2D CP handling Method 1, at least for Alt 1, device needs to be aware of the boundary of OFDM symbol (i.e. beginning of the OFDM symbol) to determine CP location**

* **How device is aware the boundary (e.g. by using R2D preamble) would be considered under normative details (if any)**

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| **Company** | **Views** |
| TCL | Agree with this proposal. |
| LGE | Okay |
| Qualcomm | In our understanding, a device needs to be aware, not only of the boundary of OFDM symbol, but also of lengths of OFDM symbol and CP. The number of clock counts of OFDM symbol and CP depend on the device SFO and therefore, the device should be able to identify its SFO before it starts CP handling. We would like to confirm if this is the common understanding.  |
| Spreadtrum | We prefer to remove the sub-bullet. As at this stage, it is not clear which method or which Alt. will be adopted for CP handling, talking **normative** may cause some misleading issue. |
| Ericsson | The device needs to be aware of the boundary of the OFDM symbol and the lengths of the OFDM symbols, which could be challenging due to SFO |
| Samsung | We are OK in principle with the proposal. Regarding the detailed methods, the device may be aware of each OFDM symbol boundary, or may be aware of slot/half-slot boundary and calculates OFDM symbol boundary by its own timer. Therefore, we suggest the following modification:**How device is aware of or determines the boundary ~~(e.g. by using R2D preamble)~~ would be considered under normative details (if any)** |
| DOCOMO | We prefer to clarify the assumptions on Method Type 1 Alt.1 first. Per our understanding, for Method Type 1 Alt.1, device can determine the CP location by counting the clock while it can be still possible by transition edge detection, i.e., the same as Alt.2. We would like to check whether Alt.1 corresponds to the former one, i.e., clock count.In addition, we also prefer to clarify the assumption on how to assume that CP length is the same among OFDM symbols. Per our understanding, it is possible that only non-long CP is assumed, i.e., slot length is different from that in legacy NR or long CP exists but is ignored by device, i.e., slot length is the same as legacy NR. |
| Lenovo | A very accurate clock synchronization is needed for M1A1. So how device knows the slot/symbol boundary should be considered firstly. |
| xiaomi | For the method 1, the feasibility and accuracy need be evaluated, because it is difficult for device to be aware of the boundary of OFDM symbol precisely due to SFO issue and asynchronization system in AIOT. So we make revision with the bule part: **Proposed Observation 2.1.1b(I): For R2D CP handling Method 1, at least for Alt 1, device needs to be aware of the boundary of OFDM symbol (i.e. beginning of the OFDM symbol) to determine CP location*** **How device is aware the boundary (e.g. by using R2D preamble) would be considered under normative details (if any)**
* **The feasibility and accuracy need be evaluated**
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Companies have different understanding on Method type 2. It seems the basic assumption of Method 2 (and its essential difference to Method 1) is device is not aware of CP location.

**Proposed Observation 2.1.1c(I): For R2D CP handling Method 2, device does not to be aware of the boundary of OFDM symbol (i.e. beginning of the OFDM symbol) to demine CP location**

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| **Company** | **Views** |
| TCL | Agree with this proposal. |
| LGE | Maybe true for M<=8. But for M > 8, Method 2 may also need to be aware of the OFDM symbol boundary. |
| Qualcomm | Agree with the observation. |
| Spreadtrum | From our understanding, this observation may not appropriate. To achieve a correct CP handling by Method type 2, the abnormal length should be identified. From this aspect, recognition of OFDM boundary is also needed. |
| Ericsson | Agree with the observation, but Method 2 comes at the cost of spectrum inefficiency and does not retain subcarrier orthogonality. |
| Samsung | Generally OK. We also suggest the following modification: **device ~~does not to~~ may not be aware of**, to make this proposal more compatible of different variants. |
| DOCOMO | We agree with the observation. |
| Lenovo | Yes.  |
| xiaomi | We support this observation. |

For CP handling Method type 1 - Alt 2, some companies pointed out it may only work for small M values, and when M is going to be large it would be challenge for Alt 2. Hence Alt 2 can be used together with Alt 1 by device implementation when necessary. Feature lead think since both A1t1 and Alt 2 are up to device to handle the CP at receiver side, it seems indeed a device implementation choice thus no need to have any restriction here.

**Proposal 2.1.1d(I): For R2D CP handling Method 1, device can use Alt 1 and/or Alt 2 which is up to device implementation.**

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| **Company** | **Views** |
| TCL | Okay |
| LGE | Okay |
| Qualcomm | If a device support Method Type 1 Alt.1 with sufficient accuracy for OFDM symbol boundary, OFDM length, and CP length identification, it is not clear to us why Alt.2 is necessary. |
| Spreadtrum | Fine with this proposal. |
| Ericsson | Ok |
| Samsung | It is unclear whether (at least) Alt 2 needs to modify line coding waveform. If so, we are not sure if this proposal could work well. This proposal may needs to be postponed after further discussion on details of how Alt 1/2 is implemented. |
| DOCOMO | One thing should be discussed is impact of the difference on CP length among OFDM symbols. Per our understanding, the same CP length is assumed among OFDM symbols for Alt.1 while can be different for Alt.2. It is better to discuss/compare Alt.1 and Alt.2 considering the difference on CP length among OFDM symbols. |
| Lenovo | Clock synchronization accuracy should be considered firstly. |
| xiaomi | The same comment with the Observation 2.1.1b, the feasibility and accuracy of method 1 needs be evaluated firstly. |

For CP handling Method type 2, proponents give their high-level or detail design. Feature lead think during the study item, focus on high level stuffs would be a proper way to continue the discussion. Whatever Alt 1 or Alt 2 under Method type 2 based on reading papers, one key point is whether the CP part is considered into chip duration. Some companies clearly show their views that the chip duration should be equally divided by OFDM symbol duration without CP. While in some companies’ design the CP part is considered as part of chip duration, thus the chip duration would be equally divided by OFDM symbol duration and including CP. Some companies point out the CP handling of Method 2, at least for Alt 1, may cause chip duration non-constant for device receiving.

**Proposal 2.1.1e(I): For R2D CP handling Method 2, for potential down-selection, the OOK chip duration generation is determined by the following:**

* **Option 1: M, and the length of OFDM symbol without CP**
	+ **FFS: Impact on device to handle non-constant chip duration around CP**
* **Option 2: M, and the length of OFDM symbol with CP**

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| **Company** | **Views** |
| TCL | We prefer option 2. In addition, for option 2, the impact of SFO at device’s may be considered to device the chip duration. Thus, we suggest adding one FFS for option 2:**Proposal 2.1.1e(I): For R2D CP handling Method 2, for potential down-selection, the OOK chip duration generation is determined by the following:*** **Option 1: M, and the length of OFDM symbol without CP**
	+ **FFS: Impact on device to handle non-constant chip duration around CP**
* **Option 2: M, and the length of OFDM symbol with CP**
	+ **FFS: Impact of SFO on device to handle non-constant chip duration**
 |
| LGE | Okay |
| Qualcomm | Perhaps, it is good to look at how each proposal generates OOK chips.  |
| Spreadtrum | We prefer Option 1. |
| Samsung | Generally OK. We would like to further clarify, is the intention to perform down-selection between option 1 or 2, or RAN1 can finally support both? |
| DOCOMO | We support the proposal for further study and our understanding is option 2 for now.In our view, the key difference of Method Type 2 from Method Type 1 is that whether device should be aware of CP location, i.e., whether device should discard the samples of CP. For Method Type 2, it is not necessary for device to discard CP samples, and hence it is preferable that chip length is uniform including CP length while chip length should be uniform without CP length for Method Type 1. |
| Lenovo | Support. |
| xiaomi | We support the option2. For the method2, CP is transparent to the device, and device not needs to distinguish the CP and OOK chip, so the chip duration would be equally divided by OFDM symbol duration and including CP. |

For CP handling Method type 2 Alt 2, some companies request to further clarify whether to continue this direction and want to revisit the original purpose of OFDM-based waveform. Some directly show to not support this direction. While a few companies request to revisit why CP insertion is needed for A-IoT and some companies give their non-orthogonal design. It is a common understanding that OFDM-based OOK waveform was selected at the beginning for the purpose of synergy with existing NR system, i.e. keep same DL waveform with legacy NR OFDM and utilizing existing 5G hardware by reading inputs.

**Proposal 2.1.1f(I): For R2D CP handling Method 2 Alt 2, revisit and check views among companies whether RAN1 continues to pursue the study on this non-orthogonality direction.**

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| **Company** | **Views** |
| LGE | Okay |
| Qualcomm | We are fine to continue to pursue the study on Method 2 Alt. 2. At least, we think it is reasonable to capture this as an option of R2D waveform generation, especially if/when reader does not need to follow CP-based OFDM waveform generation (e.g. standalone deployment).For D2R, we assume it is common understanding that CP-based OFDM demodulation is not applicable at reader receiver (i.e., CP removal is not applicable). Therefore, strictly speaking, A-IoT cannot be fully compatible with legacy OFDM framework anyway. In other words, regardless of which CP handling to be adopted for R2D, the reader cannot use CP-OFDM receiver for D2R.  |
| Panasonic | We think it is worth studying the non-orthogonality direction.Small frequency gaps around the R2D BW can be useful to avoid the interference. Furthermore, for A-IoT especially for the indoor base station, reuse of exiting hardware would be limited in any way. |
| Spreadtrum | No. Considering the additional ISI and ICI, we do not prefer to further study Alt 2 of Method type 2. |
| Ericsson | We do not support the non-orthogonality direction. |
| Samsung | We are open to study pros/cons of the non-orthogonality direction. |
| DOCOMO | We don’t see the strong motivation to peruse Method Type 2 Alt.2 further. |
| Lenovo | New CP insertion mechanism may lead additional complexity. |
| xiaomi | We are fine with this proposal.We do not support the Method 2 Alt 2, the co-existence between the NR and AIOT is not allowed by this method, and the legacy OFDM transmitter cannot be reused to AIOT by this method.  |

**Proposal 2.1.1g(I): For R2D CP handling Method 2 Alt 2, if continue the study, the following are considered**

* **Option 1: CP is copied from the start of OFDM symbol**
* **Option 2: Do not insert CP to OFDM symbol**

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| **Company** | **Views** |
| LGE | Okay |
| Qualcomm | We think Option 1 or Option 2 can be up to the reader transmitter. |
| Panasonic | Support |
| Ericsson | These options can be up to transmitter implementation. |
| Samsung | We think there exists other options to further reduce the impact of non-orthogonality, e.g. CP is copied from the end of OFDM symbol when no false rising/falling edge is introduced, otherwise CP is copied from the start of OFDM symbol. |
| DOCOMO | While we don’t see the strong need to consider Method Type 2 Alt.2, we agree that the options if it is further studied. |
| Lenovo | Complexity should be considered. |
| xiaomi | The same comment with the Proposal 2.1.1f.  |

#### Round 2

Added the suggestion from Samsung.

DOCOMO: This can apply to any CP-length in the symbol.

**Proposed Observation 2.1.1b(II): For R2D CP handling Method 1, at least for Alt 1, device needs to be aware of the boundary of OFDM symbol (i.e. beginning of the OFDM symbol) to determine CP location**

* **How device is aware of or determines the boundary ~~(e.g. by using R2D preamble)~~ would be considered under normative details (if any)**

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| **Company** | **Views** |
| Futurewei | Support |
| Lenovo | OK. |
| Huawei, HiSilicon | OK |
| Qualcomm | We agree with Xiaomi that the methodology, feasibility, and accuracy need to be evaluated. |

There was a missing word:

**Proposed Observation 2.1.1c(II): For R2D CP handling Method 2, device does not need to be aware of the boundary of OFDM symbol (i.e. beginning of the OFDM symbol) to demine CP location**

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| **Company** | **Views** |
| Futurewei | An editorial comment: “… to demine CP location” -> “… to determine CP location”The proposal is fine.  |
| ZTE, Sanechips | For R2D CP handling Method 2, since no additional transition edge is introduced by the CP (at least for smaller M values), the device does not need to be aware of the precise CP location. Consequently, the performance of the R2D link remains unaffected by any imprecision in locating the CP. In addition, for the cases of larger values of M (e.g., M = 24,32), a potential incomplete transition edge may be introduced by CP in a very low possibility. However, if the device can determine the CP location, it can beneficially circumvent the potential incomplete transition edges within the CP, thereby enhancing the detection performance. |
| Huawei, HiSilicon | OK.We believe this is why we have method 2 and method 1 from the beginning. |
| Qualcomm | OK |

If the concern is only about alt 2, we can do this:

**Proposal 2.1.1d(II): For R2D CP handling Method 1, device can use Alt 1 and/or Alt 2 (if both alternatives are supported) which is up to device implementation.**

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| **Company** | **Views** |
| Futurewei | The proposal is fine since Alt 1 and Alt 2 complement each other. For example, Alt 2 can detect the CP length accurately compared with Alt 1 when M is small (or the chip duration is longer than the CP length). However, if the CP length is indistinguishable from the CP duration, then Alt 1 can be applied.  |
| CMCC | Some clarifications on the intention of this proposal.First, we are not quite confident that if both alternatives are supported, it can be entirely up to device implementation. At least our understanding is that, for smaller M (e.g., M < 8), this could be true. However, with larger M values, as CP can cover multiple chips, we don’t think Alt. 2 is fully transparent to the device, and cannot be entirely up to device implementation.Second, my understanding is that even with this proposal, we will still need to discuss potential down-selection of both alternatives, because the two alternative has different impact on reader side. Then, why not just first discuss on supporting of either or both alternatives? |
| Huawei, HiSilicon | OK.Although we understand there are some restrictions to apply Alt2, but it is OK up to device implementation |

Seems no changes needed here yet.

**Proposal 2.1.1e(II): For R2D CP handling Method 2, for potential down-selection, the OOK chip duration generation is determined by the following:**

* **Option 1: M, and the length of OFDM symbol without CP**
	+ **FFS: Impact on device to handle non-constant chip duration around CP**
* **Option 2: M, and the length of OFDM symbol with CP**

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| **Company** | **Views** |
| FL | No need to repeat from round 1 |
| Futurewei | We do not support down-selection at this point for the following reasons:1. When the required information data rate is low (e.g., M<=8 per OFDM symbol), Option 2 allows the possibility for the device to operate without needing to know anything about the OFDM symbol CP. See Proposal 2 of [R1-2405802](http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_118/Docs/R1-2405802.zip).

When the required information data rate is high (e.g., M>8 per OFDM symbol), 1) is not possible, Option 1 allows possibility for the generated signal to have constant OOK symbol period without uneven transitions caused by the CP process. See Proposal 5 of [R1-2405802](http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_118/Docs/R1-2405802.zip). |
| ZTE, Sanechips | According to our evaluations on CP handling Method 1 and Method 2, if device supports Method 2, incorporating CP removal (even in the cases that CP location is not precisely known), the performance outcomes are optimal. Therefore, whether to support Option 1 or Option 2 is up to devices’ implementation on CP removal (maybe there is only remaining Option 1). That is to say, for CP handling Method 2, the OOK chip duration is still determined by the length of OFDM symbol without CP if device supports CP removal or CP handling Method 2 can ensure constant chip duration including CP.According to the above analysis, we suggest that the following modifications for Method 2 can be considered.**Proposal 2.1.1e(I): For R2D CP handling Method 2, for potential down-selection, the OOK chip duration generation is determined by the following:*** **Option 1: M, and the length of OFDM symbol without CP**
	+ **FFS: Impact on device to handle non-constant chip duration around CP, e.g., by CP removal**
* **Option 2: M, and the length of OFDM symbol with CP**
	+ **Note: no support of CP removal**
 |
| Huawei, HiSilicon | OK.We don’t think ZTE’s update is correct since Method 2 does not require CP handling by device side. If device has to remove CP then we are wondering whether it is belonging to Method 2 or not. |
| Qualcomm | We still do not understand how this proposal is used/helpful for potential down selection. We need to look at each actual solutions under Method 2. |

FL continues this proposal, but since Alt 2 is agreed for study already, if there is not consensus to stop, then this does not need agreeing.

**Proposal 2.1.1f(II): For R2D CP handling Method 2 Alt 2, revisit and check views among companies whether RAN1 continues to pursue the study on this non-orthogonality direction.**

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| **Company** | **Views** |
| FL | No need to repeat from round 1 |
| Futurewei | Should be deprioritized |
| Huawei, HiSilicon | We are OK to deprioritize this.All the discussion of CP handling is due OFDM based waveform which is for the purpose of synergy with legacy system, if using OFDM based waveform but not retaining orthogonally then we lost the original spirit of OFDM waveform. |
| Qualcomm | We prefer to continue study of Method 2 Alt. 2. |

FL adds Samsung’s option (as option 3), to see if other companies can agree to study it.

**Proposal 2.1.1g(II): For R2D CP handling Method 2 Alt 2, if continue the study, the following are considered**

* **Option 1: CP is copied from the start of OFDM symbol**
* **Option 2: Do not insert CP to OFDM symbol**
* **Option 3: CP is copied from the end of OFDM symbol when no false rising/falling edge is introduced, otherwise CP is copied from the start of OFDM symbol.**

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| **Company** | **Views** |
| Futurewei | Option 2 seems to make more sense. If orthogonality issue is to be ignored, then the A-IoT signal and other NR signal would be combined in time domain after the regular iFFT+CP insertion process. In such case, A-IoT signal generation does not have to use CP OFDM. |
| Huawei, HiSilicon | If RAN1 decide to continue, we are OK to list options for further discussion. |
| Qualcomm | Can be up to the reader transmitter. |

### Waveform(s) [ACTIVE]

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| AgreementFor R2D evaluation purposes, the R2D waveform for DFT-s-OFDM is generated as follows:1. The time domain OOK signal is the M chips of one OFDM symbol.
2. A chip is represented (e.g. upsampled) by L samples
	* Companies to report L
3. An N’-points DFT is performed on the samples of one OFDM symbol to obtain the frequency domain signal.
	* Companies to report N’, e.g. N’=128 or equal to X
4. Map the frequency domain signal obtained by N’-points DFT to the X subcarriers of Btx,R2D.
	* Companies report how to map and report X
5. An N-points IDFT is performed to obtain the time domain signal.
	* Companies to report N, and how value was selected

Note: companies report whether/how CP samples are added. |

#### Round 1

The previous meeting described a common basis for waveform generation of DFT-s-OFDM, which companies have used for various analyses in this agenda item. Some point out that CP-OFDM can also be used without impacting the device. For SI purposes, it can be sufficient to capture these points in the TR. (Note that the waveform generation of RAN1#117 is already in the updated draft).

**Proposal 2.1.2a(I): Capture in the TR that for OFDM-based OOK waveform generation, CP-OFDM and DFT-s-OFDM are both feasible, and which is used is transparent to the device, via reader implementation choice.**

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| **Company** | **Views** |
| TCL | There is different maximum transmission power defined in NR for DFT-s-OFDM and CP-OFDM if UE as reader. Considering different coverage requirement for device 1/2, we suggest DFT-s-OFDM can be as baseline to further study and FFS CP-OFDM in this stage.  |
| LGE | Okay |
| Qualcomm | We would like to get some clarifications:1. Is the “CP-OFDM” for OOK-1, or also for OOK-4 with M > 1?
2. If this is transparent to the device, what is the implication of this statement in the TR?
 |
| IDCC | We have similar question as Qualcomm. Is DFT-s-OFDM used for OOK-4 and OFDM for OOK-1? |
| Spreadtrum | Fine with this proposal. |
| Ericsson | Similar view as Qualcomm |
| Samsung | OK |
| DOCOMO | We share the similar comment with QC. |

#### Round 2

FL has same understanding as QC. But it matters also if other companies do, so FL leaves this one open.

**Proposal 2.1.2a(I): Capture in the TR that for OFDM-based OOK waveform generation, CP-OFDM and DFT-s-OFDM are both feasible, and which is used is transparent to the device, via reader implementation choice.**

* **CP-OFDM and DFT-S-ODFM can both be used for any value of M**

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| **Company** | **Views** |
| Huawei, HiSilicon | We it should be clarified how reader to performs CP-OFDM with M>1 |
| Qualcomm | Agree with Huawei.  |

## R2D modulation [ACTIVE]

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| Agreement RAN1#116A-IoT DL study includes OOK from DL transmitter’s perspective.* For an OFDM waveform, assume OOK-1 for single-chip per OFDM symbol transmission, and OOK-4 for M­-chip per OFDM symbol transmission, starting from definitions in TR 38.869.
	+ FFS value(s) of M.
	+ FFS: Any changes needed from the definitions in TR 38.869.
	+ FFS: Exact definition of chip
* If other DL waveforms are included, further elaboration of the transmitter’s OOK generation would be needed.
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| Agreement RAN1#116For R2D study OFDM-based waveform with subcarrier spacing of 15 kHz, Btx,R2D is ≤ [12] PRBs and is down-selected among:* Alt 1: Including 180 kHz, 360 kHz, and FFS other values
* Alt 2: Integer multiple(s) of 180 kHz (FFS: what integer(s))
* Alt 3: Integer multiple(s) of the subcarrier spacing (FFS: what integer(s))
 |

### M values

#### Round 1

It is already agreed that when M=1, we use OOK-1. Thus, values for M>1 apply to OOK-4.

Companies propose sets of inequalities relating M and BW values, effectively establishing views on the minimum number of PRBs needed for a given M. FL observes basically converged views on the minimum B for some M values, and will attempt to narrow down the set where different minimum values exist. The table implies in certain rows that the minimum is set assuming the reader uses 1SB transmission, and hence if 2SB transmission is used the reader will simply use a larger number of PRBs than the minimum (although this does not prevent using a larger number for some other reason).

**Proposal 2.1.2a (I): Please companies indicate their views on M values and minimum transmission BW for each M value.**

* **Reader can use any R2D bandwidth >= *B*tx,R2D**
* **FFS: In case CP handling alters the number of chips per OFDM symbol, whether values M’ = M ± 1 (M>1)**

|  |  |
| --- | --- |
| ***M*** | Minimum ***B*tx,R2D # of PRBs** |
| **1** | 1 |
| **2** | 1 |
| **4** | [1 or 2] |
| **6** | 1 |
| **8** | [2 or 4 or 6] |
| **12** | 2 |
| **16** | 2 |
| **24** | [2 or 3] |
| **32** | 3 |

|  |  |
| --- | --- |
| **Company** | **Views** |
| Qualcomm | We still think better to make the progress first before fixing min *Btx,R2D*. The reasons are following:1. The FL proposal tries to make a decision on minimum necessary number of RBs for each value of M that the reader can use. For example, 1-RB for M=6 and 2-RBs for M=12. These bandwidths for the M values result in smooth time-domain waveform that do not have very clear OOK edges. We would like to confirm if the edges filtered by the min necessary transmission bandwidth proposed above can work for accurate OFDM boundary detection, OOK chip duration identification, and if feasible, clock calibration.
2. As FL pointed out, different CP handling may require different number of RBs.
 |
| Spreadtrum | From our understanding, the M value supported should be discussed with whether to support chip level repetition. If chip level repetition is supported, we believe that there is no need to support such many M values, and the long chip length (small M value) can be achieved by chip level repetition with small length chip (large M value). Of course, if chip level repetition is not supported, multiple M values should be considered.Regarding the 1st bullet, should it be “**Reader can use any transmission R2D bandwidth >=minimum *B*tx,R2D**”? In our opinion, the bandwidth used by reader is ***B*tx,R2D,** and the value given in the table is the minimum value that can be used. |
| Ericsson | Similar view as Qualcomm |
| xiaomi | The clarification on the FFS is needed. We think the number of chips per OFDM symbol is depended on the date rate, rather than the cp handling method. |
|  |  |

**Proposal 2.1.2a (I): ~~Please companies indicate their views on M values and minimum transmission BW for each M value~~.**

* **The following table is a starting point for *M* values and the associated minimum Btx,R2D value**
* **Reader can use any R2D bandwidth >= minimum *B*tx,R2D**
* **FFS: Impacts, if any, of CP handling solutions~~, whether values M’ = M ± 1 (M>1)~~**

|  |  |
| --- | --- |
| ***M*** | Minimum ***B*tx,R2D # of PRBs** |
| **1** | 1 |
| **2** | 1 |
| **4** | 1 |
| **6** | 1 |
| **8** | 2 |
| **12** | 2 |
| **16** | 2 |
| **24** | 2 |
| **32** | 3 |

#### Round 2

(TBD after online)

### Single / double sideband modulation

#### Round 1

Companies do not seem to have strong preferences about this, preferring to imply what can be done by the (M, Btx\_R2D) pairings.

**Proposal 2.2.2a(I): R2D transmission can be either double sideband or single sideband, up to Reader implementation. The TR records this statement, and no further study is needed in RAN1.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | Fine. |
| LGE | Okay |
| Qualcomm | We would like to understand in which case reader generates double sideband signal. |
| IDCC | Ok. |
| Panasonic | Support |
| Spreadtrum | Fine with this proposal in principle. From our point of view, single sideband modulation can potentially improve the spectrum efficiency, thus this additional observation on the benefits of single sideband modulation could be captured in the TR. |
| Samsung | OK |
| DOCOMO | In our view, at least SSB is considered for R2D but we are not sure why DSB should be considered for R2D. |
| Lenovo | OK |
| xiaomi | We do not support this proposal, R2D waveform is based on OFDM rather than the double sideband or single sideband. |

#### Round 2

DCM: Some papers describe that DSB can give better waveform characteristics than SSB. Since it is transparent to the device, it does not seem any need to downselect or deprioritize. Hence FL does not change the proposal.

**Proposal 2.2.2a(II): R2D transmission can be either double sideband or single sideband, up to Reader implementation. The TR records this statement, and no further study is needed in RAN1.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| Futurewei | OK |
| Huawei, HiSilicon | OKWe think leave flexibility for reader implementation is fine. |
| Qualcomm | We suggest following: **Whether double sideband or single sideband for R2D transmission is up to Reader implementation. No further study is needed in RAN1.** |

## R2D line coding [ACTIVE]

|  |
| --- |
| **Agreement** RAN1#116For R2D, line codes studied are: Manchester encoding and pulse-interval encoding (PIE).* FFS: Mapping(s) from bit(s) to line-code codewords
* FFS: Time domain definition of e.g., chips and relation to OFDM symbols, resource allocation unit, etc.

Agreement RAN1#117The study assumes the following bit to chip mapping for Manchester encoding: * + bit 0→chips{10}, bit 1→chips{01}
* FFS: Variant of the above for CP handling
 |

### Round 1

It seems PIE is motivated mainly for energy harvesting at this point, while most companies are fine with Manchester. So we can combine them as follows, if companies can compromise. The FFS on CP handling looks possible to take under the CP design part.

**Proposal 2.3a(I): Use Manchester line coding for R2D.**

* **FFS whether PIE line coding, and any enhancements for Manchester line coding are considered based on the outcome of energy harvesting discussions in 9.4.2.2**

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | okay |
| LGE | We prefer to capture in the TR details of PIE and then discuss which one to support during the discussion on conclusion/recommendation, or in the WI phase with pros and cons. |
| Qualcomm | Can the proposal be something like “Manchester coding is the baseline for R2D”? |
| Panasonic | Support |
| Spreadtrum | We support to delete the sub-bullet and prefer no PIE coding for R19 A-IoT. First of all, make a down-selection can reduce device complexity, device does not need to support two line coding decoder. Secondly, the unequal length of two codewords in PIE result in variable data size, which may lead to low efficiency and poor performance compared with Manchester encoding. In addition, additional CP handling method is needed for PIE. Lastly, the proponents of PIE coding would be beneficial for device energy harvesting, while it is uncertain whether it is an valid benefit as many companies have stated that device in ON state will not be charged in 9.4.2.2.  |
| Ericsson | Ok |
| Samsung | In our understanding the discussion of 9.4.2.2 may focus on how the device availability/unavailability will impact overall frame structure or timing procedure, we are not sure whether the outcome of energy harvesting can benefit the progress of the line coding discussion in this agenda. Considering the limited time, we prefer to study both Manchester and PIE for the motivation of energy harvesting in parallel. Therefore, we suggest the following update: **Proposal 2.3a(I): ~~Use Manchester line coding for R2D.~~*** **Use Manchester line coding for R2D. ~~FFS whether PIE line coding, and~~ Study if any enhancements for Manchester line coding are considered ~~based on the outcome of energy harvesting discussions in 9.4.2.2~~**
* **Study PIE for R2D for energy harvesting including bit to chip mapping, conditions of using PIE, etc.**
 |
| DOCOMO | We agree to prioritize the study of Manchester encoding over PIE but prefer to make an observation for comparison of Manchester encoding and PIE.Considering that the detailed RF signal design for RF energy harvesting is out of the scope, FFS is a bit unclear for us how the discussion of energy harvesting discussion is related to the support of PIE and enhancement on Manchester encoding. |
| Lenovo | We support both Manchester and PIE for R2D. |
| xiaomi | We support this proposal. |
| ZTE, Sanechips | Propose to update as **“Use Manchester line coding for R2D as baseline”.** |

### Round 2

Reformulated proposal based on the comments, and the version of PIE from LG’s paper.

**Proposal 2.3a(II): For R2D line coding**

* **Manchester coding is the baseline.**
* **The study assumes the following bit to chip mapping for PIE: bit {0} → chips{10}, bit{1}→chips{1110}**

|  |  |
| --- | --- |
| **Company** | **Views** |
| CMCC | Thanks for the effort of FL.We are OK with this proposal, as long as we still open the door for PIE.Regarding the potential codewords of PIE for further study, we think that the bit to chip mapping function from UHF RFID is fine. Additionally, although we don’t provide explicit proposal of bit to chip mapping function, we actually show simulation results of PIE with equal bit to chip mapping method, and we would like to suggest the following modifications:**Proposal 2.3a(II): For R2D line coding*** **Manchester coding is the baseline.**
* **The study assumes the following bit to chip mapping for PIE:**
	+ **Unequal length PIE: bit {0} → chips{10}, bit{1}→chips{1110}**
	+ **Equal length PIE: bit{0} → chips{111010}, bit{1} → chips{101110}**
 |
| Huawei, HiSilicon | We are supportive of the proposal. For the FFS, PIE encoding provided instantaneous RF energy to the device in RFID, and this may not be necessary since the device has energy storage. Only if it has been identified in 9.4.2.2 that such instantaneous RF energy is necessary for the device to remain available to perform inventory procedures would we need to discuss it with regards to energy harvesting. Otherwise, it has been shown that Manchester codes outperform PIE due to the uncertain transmission length in the PIE, where the error detection of one information bit may result in the error propagation for the detection of subsequent bits and the error detection of the overall data length. |
| Qualcomm | We prefer to delete the 2nd bullet. |

## R2D FEC / repetition [ACTIVE]

|  |
| --- |
| **Agreement** RAN1#116Regarding FEC, R2D with no forward error-correction code (FEC) is studied as baseline.* Evaluations would be by comparison to this baseline

Agreement RAN1#117Define repetition types for study purposes as follows:* Block level: All the bits received from higher layers and/or physical layer (according to what is present) after CRC attachment (if used) are blockwise repeated Rblock times
* Bit level type 1: Each bit after CRC attachment (if used) is repeated Rbit times
* Bit level type 2: Each bit after both CRC attachment (if used) and FEC (if used) is repeated Rbit times
* Chip level: Each chip after line coding (if used) or after square wave modulation (if used) is repeated Rchip times
	+ NOTE: Equivalent to extending the duration of each chip by Rchip times
 |

### Round 1

There is support among a small number of companies to study FEC for R2D under various constraints, but in particular its application only to device 2b. Whether this can be considered part of a harmonized design with minimized differences where necessary can be discussed.

**Proposal 2.4a(I): Companies to propose whether R2D FEC for only device 2b is compatible with SID stipulation of “*a harmonized air interface design with minimized differences (where necessary)*”.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| Qualcomm | We acknowledge the statement of the SID. Nevertheless, we think it is good to keep the FEC possibility for device 2, considering that the target link budget is different for device 1 and device 2. |
| Spreadtrum | No FEC for R2D for all devices to achieve harmonized air interface design, which is beneficial to reduce complexity for both Reader and device.  |
| Ericsson | Since Device 2 is likely to be associated with more challenging targets for coverage and capacity, we think it is reasonable to consider R2D FEC for Device 2. R2D FEC may be prohibitively complex for Device 1 but not for Device 2. |
| DOCOMO | Based on the agreement that the target distance can be different among device types, whether to apply FEC to compensate the coverage can be different among device types accordingly. R2D FEC can be further studied based on the evaluation results on link budget calculation for device 2b. |
| Lenovo | OK |
| xiaomi | No.We think this is not harmonized design, so we propose FEC for R2D is not studied.  |

Where R2D repetitions are proposed for study, the rationale is based on coverage, interference, etc., while some companies think there is no need to support this function in R2D, even based on link budget/receiver sensitivity. Now there are some evaluation results in 9.4.1.1, companies are invited to consider the necessity of studying this function, under a compromise of limiting the repetition types considered.

**Proposal 2.4b(I):**

* **For R2D transmissions, the necessity of at least bit-level repetitions is studied based on potential need for coverage enhancements according to the coverage evaluations.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | In our understanding, any repetition is not necessary for at least device 1 and 2a because of the limited detection and demodulation capability. In addition, reader can control the transmission power to meet coverage requirement. |
| LGE | Okay |
| Qualcomm | For clarification, does this proposal essentially means that for R2D, RAN1 does not consider block-level repetition and chip-level repetition? |
| Spreadtrum | Support |
| Ericsson | Ok |
| Samsung | OK |
| DOCOMO | We support to study the potential necessity of repetition for R2D. Whether it should be bit-level or block-level needs further study. |
| Lenovo | Both bit-level and block-level repetition should be studied in this phase. |
| xiaomi | If we study the repetition of R2D, it is better to align the simulation assumption firstly, and then proves whether R2D is bottleneck channel and needs some coverage enhancements.  |
| ZTE, Sanechips | Compared with bit-level repetition, we think block-level repetition provides more diversity gain since the encoded bits are distributed in a larger time span. Therefore, we think block level repetition should be supported.Moreover, since the data rate target can be as low as 1kbps, in this case, repetition is needed to achieve this target. |

### Round 2

FL keeps this proposal open, since it needs more than 3 inputs.

**Proposal 2.4a(I): Companies to propose whether R2D FEC for only device 2b is compatible with SID stipulation of “*a harmonized air interface design with minimized differences (where necessary)*”.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| FL | No need to repeat |
| Huawei, HiSilicon | Since the SID has to be followed and respected, supporting R2D FEC only for device 2b would definitely result in a disharmonized design since it is not possible for device 1 to support the complex decoding of FEC.R2D FEC is not even needed even for device 2b because the RX signal power is relatively high and is not expected to be the bottleneck of the link budget for target coverage. Since we focus on indoor use cases, for device 2a/b, the bottleneck is not the digital baseband, but the analog part.  |
|  |  |

**Proposal 2.4b** seems suitable for online discussion.

## R2D and D2R CRC [VOID]

**See Section 4.**

## R2D multiple access [ACTIVE]

|  |
| --- |
| AgreementFrom RAN1 perspective, at least when a response is expected from multiple devices that are intended to be identified, an A-IoT contention-based access procedure initiated by the reader is used.AgreementFor A-IoT contention-based access procedure, at least slotted-ALOHA based access is studied. |

### Round 1

Given the agreements on slotted-ALOHA, and the nature of discussions in Changsha, FL thinks we should simply accept that TDMA is supported, and move to its details. It seems in this agenda item,

**Conclusion 2.6a(I): Due to the agreements in RAN1 and RAN2 related to support of slotted-ALOHA, time-domain multiple access of R2D transmissions is already supported.**

There are a few discussions about whether FDMA is needed or feasible in a harmonized design, but the overall view of RAN1 is directly clear. Hence FL requests views.

**Proposal 2.6b(I): FDMA for R2D between readers is feasible from the RAN1 perspective by deployment implementation, and hence is not studied further in RAN1.**

* **Aspects, if any, related to reader coexistence are assumed to be handled, if needed, by RAN4 according to their own decisions.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| LGE | Okay |
| Qualcomm | We are OK with the proposal. |
| IDCC | Ok. |
| Spreadtrum | Support |
| Ericsson | Ok |
| Samsung | OK |
| DOCOMO | We support the consideration of FDM among readers. |
| Lenovo | OK |
| xiaomi | We think the FDMA for R2D between readers is not feasible. Because the RF envelope detection is applied to A-IoT device for R2D signal reception, it is not capable for a device to simultaneously extract different R2D signals from different readers if the operation bandwidth of device is very wide, which is the typical case especially for device 1.  |

**Proposal 2.6c(I): Regarding potential FDMA for R2D among different devices by one reader:**

* **For devices with RF envelope detectors, FDMA is not feasible and is not studied.**
* **For devices with IF envelope and ZIF detectors, discuss whether potential support of FDMA is compatible with the SID stipulation of “*a harmonized air interface design with minimized differences (where necessary)*”.**

|  |  |
| --- | --- |
| Company | Views  |
| TCL | Agree with this proposal. |
| LGE | We suggest the following changes.**Proposal 2.6c(I): Regarding potential FDMA for R2D among different devices by one reader:*** **For devices with RF envelope detectors, FDMA is not feasible from RAN1 perspective and therefore is not studied in RAN1.**
* **For devices with IF envelope and ZIF detectors, discuss whether potential support of FDMA is compatible with the SID stipulation of “*a harmonized air interface design with minimized differences (where necessary)*”.**
 |
| Qualcomm | We wonder why there are differences between (1) FDMA for R2D between readers and (2) FDMA for R2D for different devices from the same reader. If (1) is considered feasible by implementation, (2) can also be considered feasible by implementation? |
| Panasonic | For the first bullet, "not feasible" is from the device perspective or from the reader perspective? "FDMA" or not is rather system perspective. We are not sure the meaning of the proposal well. |
| Spreadtrum | Our preference is no FDMA for R2D for all devices considering harmonized design. |
| Ericsson | Ok |
| Samsung | We consider the support of R2D FDMA among different devices are unclear yet, and it may introduce too much work load at least for Rel-19 study. Therefore, the 2nd sub-bullet seems pre-matured for discussion. RAN1 should justify the support of devices’ FDMA and then discuss other related issues. |
| DOCOMO | We agree with the comment from QC.For RF-ED, we agree with the proposal.For IF and ZIF, considering that the target coverage can be larger for device 2 than device 1 based on the previous agreement about the target distance, the number of device which is accommodated by one reader can be larger for device 2 than that of device 1. In that sense, FDM by one reader for R2D can be considered only for IF and ZIF device. |
| Lenovo | FDMA should be not excluded in this phase.  |
| xiaomi | For a harmonized air interface design, we propose the FDMA for R2D among different devices by one reader is not supported.  |

### Round 2

The Panasonic response suggests going up by one level, and clarifying that readers are just considered to be separate A-IoT systems in RAN1.

**Proposal 2.6b(II): Readers are each treated as a separate A-IoT system from the RAN1 perspective. If FDMA of R2D is implemented by planning of the multiple systems together with the devices is an implementation matter.**

* **Capture this in the TR.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| Futurewei | OK |
| Huawei, HiSilicon | We have a comment on the “separated A-IoT system” for clarification.From the perspective of device, the R2D signals parallelly arriving at a device will be mixed after RF-ED, no matter from a single reader or different readers. To avoid the performance degradation or even failed receiving, the frequency interval between the parallel R2D transmissions should be larger than the RF-ED bandwidth of devices. In other words, the “separated A-IoT system” means the reader(s) and device(s) of each A-IoT system use different frequency band from the other system(s), with the frequency interval between adjacent frequency bands larger than the RF-ED bandwidth of devices. |
| Qualcomm | OK |
|  |  |

And some of the comments to 2.6c suggest generalizing some wording:

**Proposal 2.6c(II): Regarding potential FDMA for R2D among different devices by one reader, i.e. within an A-IoT system:**

* **Further study the implications of feasible reader operation if devices with RF envelope detectors are assumed to support FDMA.**
* **FFS: For devices with IF envelope and ZIF detectors, discuss whether potential support of FDMA is compatible with the SID stipulation of “*a harmonized air interface design with minimized differences (where necessary)*”.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| Futurewei | What is the motivation for the first bullet to further study the implications of feasible reader operation for devices with RF envelope detectors? |
| Huawei, HiSilicon | As clarified in our comment to Proposal 2.6b(II), the devices with RF-ED cannot support FDMA in one A-IoT system with a single frequency band. Regarding the FDMA between different A-IoT systems, it purely depends on the deployment solution, which does not to be studied in RAN1.Regarding the R2D FDMA for devices with IF envelope and ZIF detectors, another issue to be considered is the power splitting between parallel R2D transmissions, which reduces the transmit power of each transmission. Considering the limited transmit power of either indoor BS or intermediate UE, both the coverage and transmission efficiency of each R2D transmission will be reduced in the case of FDMA. Based on the above, we suggest no FDMA for R2D transmission. |
| Qualcomm | We think the proposal should be simpler:**Regarding potential FDMA for R2D among different devices by one reader, i.e. within an A-IoT system:*** **~~Further s~~Study ~~the implications of~~ feasibility~~le~~ for ~~reader operation if~~ devices with RF envelope detectors are assumed to support FDMA.**
* **Study potential support of FDMA ~~FFS: F~~for devices with IF envelope and ZIF detectors, considering ~~discuss whether potential support of FDMA is compatible with~~ the SID stipulation of “*a harmonized air interface design with minimized differences (where necessary)*”.**
 |

## R2D time-domain definitions

### Subcarrier spacing(s) [INACTIVE]

|  |
| --- |
| AgreementR2D study includes subcarrier spacing of 15 kHz, from the reader perspective, for OFDM-based waveform.* Inclusion in the study of subcarrier spacing of 30 kHz is FFS.
 |

There is little further discussion of 30 kHz SCS, so FL defers bringing a further proposal relating to it.

### Time unit(s) [ACTIVE]

|  |
| --- |
| Agreement RAN1#116bis |

#### Round 1

The following is a compression of the previous meeting proposals, by decoupling the time definition of a chip from resource allocation, at first. Then, second, how to have a common basis for what is the granularity of resource allocation. Details of possible other amounts of resource allocation would be in 9.4.2.2.

**Proposal 2.7.2a(I): In R2D, a chip:**

* **Corresponds to one modulated symbol, e.g. according to agreed OOK modulation.**
* **Chip duration = (1/M) × {OFDM symbol duration excluding CP part} OR {OFDM symbol duration including CP part} according to Proposal 2.1.1d.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | In our understanding, the value of chip duration could at least the impact of device’s SFO. Thus, we suggest adding one subbullet for FFS**Proposal 2.7.2a(I): In R2D, a chip:*** **Corresponds to one modulated symbol, e.g. according to agreed OOK modulation.**
* **Chip duration = (1/M) × {OFDM symbol duration excluding CP part} OR {OFDM symbol duration including CP part} according to Proposal 2.1.1d.**
* **FFS: Impact of SFO on device to handle non-constant chip duration**
 |
| LGE | Okay |
| Qualcomm | We would like to confirm: (1) does the proposal exclude CP handling options that result in variable OOK chip lengths within an OFDM symbol? (2) does the proposal allow CP handling options that result in variable OOK chip lengths across OFDM symbols with the restriction that the OOK chip length is constant within an OFDM symbol? |
| IDCC | We think it is clearer if chip duration definition excludes CP part. |
| Spreadtrum | Support this proposal and prefer to define **chip duration = (1/M) × {OFDM symbol duration excluding CP part}** |
| Ericsson | It is clearer if Chip duration is defined as (1/M) × (OFDM symbol duration excluding CP part). |
| Samsung | Generally OK but we prefer to make details open to ensure different variants of waveform due to CP handling. |
| DOCOMO | Support the proposal in general but referred proposal should be Proposal 2.1.1e per our understanding.Meanwhile proposal 2.1.1d discusses only for CP handing Method Type 2, the same discussion on chip length, i.e., whether CP part is included in chip or not is necessary for CP handling Method Type 1. In our view, for chip duration;(1/M) × {OFDM symbol duration excluding CP part} should be applied to Method Type 1 while (1/M) × {OFDM symbol duration including CP part} should be applied to Method Type 2. |
| Lenovo | OK |
| xiaomi | We support this proposal. We prefer Chip duration = {OFDM symbol duration including CP part} as comment on the Proposal 2.1.1d.  |
|  |  |

**Proposal 2.7.2b(I): The smallest unit of resource allocation in R2D is [at least] corresponding to:**

* **Option 1: All the chips of one modulated symbol.**
* **Option 2: One chip of a modulated symbol.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | Fine |
| Qualcomm | We suggest to update the main text as follows.**The smallest time unit ~~of resource allocation~~ in R2D is [at least] corresponding to:*** **Option 1: All the chips of one line code codeword ~~modulated symbol~~.**
* **Option 2: One chip of a line code codeword ~~modulated symbol~~.**
 |
| Spreadtrum | Support  |
| Ericsson | Ok |
| Samsung | Regarding option 1, we would like to clarify if the intention is resource allocation is based on a number of modulated symbols. If so, we would like to check how to handle the case that end of a R2D transmission (e.g. end of last code chip) is non-aligned with OFDM symbol boundary. |
| DOCOMO | OK |
| Lenovo | Support. |
| xiaomi | We support the option2. For the option1, the definition of the modulated symbol needs to be clarified.  |

#### Round 2

To TCL: The chip duration is a fixed quantity from the perspective of the transmitter. The SFO causes the device to have a slightly incorrect number of samples within the duration.

To answer Qualcomm: I think if the value of M changes, e.g. to M+1, then, the proposal is automatically changing its calculation. Essentially this proposal “does not care” how the value of M is arrived at. Concretely, do you have a proposal to change?

DOCOMO: I think you proposal would follow naturally from 2.1.1e, if I understood you correctly.

**Proposal 2.7.2a(II): In R2D, a chip:**

* **Corresponds to one modulated symbol, e.g. according to agreed OOK modulation.**
* **Chip duration = (1/M) × {OFDM symbol duration excluding CP part} OR {OFDM symbol duration including CP part} according to Proposal 2.1.1e.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| xiaomi | We support this proposal. We prefer Chip duration = {OFDM symbol duration including CP part} as comment on the Proposal 2.1.1d.  |
| ZTE, Sanechips | Partially agree with the proposal.In our views, when M is not equal to 2^n, the value of {OFDM symbol duration excluding CP part} does not divide evenly by M. Therefore, we prefer that **Chip duration = {OFDM symbol duration including CP part} according to Proposal 2.1.1d**.**Proposal 2.7.2a(I): In R2D, a chip:*** **Corresponds to one modulated symbol, e.g. according to agreed OOK modulation.**
* **Chip duration = ~~(1/M) × {OFDM symbol duration excluding CP part} OR~~ {OFDM symbol duration including CP part} according to Proposal 2.1.1d.**
 |
| Huawei, HiSilicon | Support. |
| Qualcomm | OK with the proposal. |

For this, Qualcomm your comment in the previous meeting to the equivalent proposal 2.7.2.a(II) in R1-2405441 was as follows. It was the reason I altered the wording this time. Hence I cannot take your change until you clarify your thinking! But I will include the time domain.

*“*

|  |  |
| --- | --- |
| *Qualcomm* | *We are not sure why we have to use a line-code chip as the smallest time unit of resource allocation.**For example, suppose we use Manchester coding. We think there is no case where a device is allocated with a resource corresponding to one line-code chip, which is {0} or {1} of bit-1 {01} or bit-0 {10}.* |

*“*

Samsung: The proposal does not explain this point about non-alignment to OFDM symbol, so it would be something additional you can bring up. It seems at home in 9.4.2.2, where Lihui has a proposal.

**Proposal 2.7.2b(II): The smallest time unit of resource allocation in R2D is [at least] corresponding to:**

* **Option 1: All the chips of one modulated symbol.**
* **Option 2: One chip of a modulated symbol.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| xiaomi | We support the option2. For the option1, the definition of the modulated symbol needs to be clarified.  |
| ZTE, Sanechips | Partially agree with the proposal.In our views, the definition of the smallest time unit of resource allocation, the duration of codeword, i.e. the product of the number of bits of a codeword and the line-code chip duration, can be used as an option.Moreover, the term “modulated symbol” needs to be clarified.**Proposal 2.7.2b(I): The smallest unit of resource allocation in R2D is [at least] corresponding to:*** **Option 1: All the chips of one modulated symbol.**
* **Option 2: One chip of a modulated symbol.**
* **Option 3: All the chips of one codeword.**
 |
| ETRI | OK with the proposal. |
| Huawei, HiSilicon | We support Option 2.Considering the potential designs for R2D preamble and postamble, it is uncertain that line code will be used. It is more suitable to use a single chip as the smallest unit of resource allocation. |
| Qualcomm | Reply to FL: We are consistent. We do not understand why the smallest time unit is the unit **of resource allocation**. We agree the smallest time unit is either Option 1 or Option 2, but whether it is the smallest time unit **of resource allocation** is a separate issue. We think the smallest time unit of resource allocation would be larger than Option 1 or Option 2. The previous question is still valid (ZTE may have the same confusion): it is not clear what the “modulated symbol” is. We thought this is “a line code codeword” and hence suggested the change in round 1. If not, clarification is necessary. |

## R2D bandwidths [ACTIVE]

|  |
| --- |
| **Agreement** RAN1#116At least the following bandwidths for R2D are defined for the purpose of the study:* Transmission bandwidth, Btx,R2D from a Reader perspective: The frequency resources used for transmitting R2D
* Occupied bandwidth, Bocc,R2D from a Reader perspective: The frequency resources used for transmitting R2D, and potential guard band
* Bocc,R2D ≥ Btx,R2D
	+ FFS: Further constraint(s) e.g. Bocc,R2D = Btx,R2D.
	+ Possible values of each bandwidth are FFS
 |
| Agreement RAN1#116bisFor R2D study OFDM-based waveform with subcarrier spacing of 15 kHz, Btx,R2D is ≤ [12] PRBs and is down-selected among:* Alt 1: Including 180 kHz, 360 kHz, and FFS other values
* Alt 2: Integer multiple(s) of 180 kHz (FFS: what integer(s))
* Alt 3: Integer multiple(s) of the subcarrier spacing (FFS: what integer(s))
 |

For Btx, R2D, see section 2.2.1.

For Bocc,R2D, or potential Bsys,R2D, existence would depend on FDMA discussions, hence FL defers making proposal(s) here for the time being.

# D2R

## D2R waveform [ACTIVE]

### Round 1

It seems companies may have different understanding on D2R waveform for different devices. First, feature lead understand we are talking about baseband waveform and modulation here rather CW waveform in 9.4.2.4. How the baseband waveform and modulation is converted from baseband to RF carrier (by DUC or impedance switching) is a separate implementation issue. Thus we focus on baseband concept.

Many companies propose to have same D2R waveform as defined in 9.4.2.4 for CW waveform for all devices, while one company mentions in their paper that the device 2b can be same as device 1/2a using square wave or have an individual sine wave. A common part should be using single-carrier/single-tone waveform for D2R baseband waveform rather OFDM based waveform. Whether the single-carrier/single-tone waveform is generated by square-wave or sine-wave is a second level issue.

In this agenda item, most companies think this should apply to device 2b, i.e. internally-generated carrier wave, and several say that it should be the same as the externally-generated carrier wave in agenda 9.4.2.4. Hence FL pauses this until further progress in 9.4.2.4.

**Proposal 3.1a(I): The D2R baseband waveform is single-carrier waveform and it can be used by all devices 1/2a/2b, i.e. it is non-OFDM based.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | Okay. |
| LGE | Okay |
| Qualcomm | We think this should be discussed under 9.4.2.4. |
| IDCC | Ok. |
| Panasonic | Share the view with Qualcomm. |
| Spreadtrum | Yes. It would be beneficial for harmonized design. |
| Ericsson | Similar view as Qualcomm |
| DOCOMO | OK |
| Futurewei | OK |
| Lenovo | OK |
| xiaomi | We support this proposal. |
| ETRI | OK |
| Huawei, HiSilicon | OK |

## D2R modulation [ACTIVE]

### Modulation scheme(s)

|  |
| --- |
| AgreementStudy for all devices the following for D2R baseband modulation, for potential down-selection:* OOK
* Binary PSK
* Binary FSK
	+ Strive to identify one variant of Binary FSK to study further
 |

#### Round 1

In this agenda item, most companies talk about OOK and BPSK. Some companies propose to prioritize OOK and a few companies propose to prioritize BPSK including study phase shaping. For BFSK, a few companies mentioned different BFSK in their papers while a bit more companies propose to deprioritize or not study BFSK.

Companies are hence invited to give their views on the variants and, if they wish to, which one they think should be studied further (or otherwise to indicate no further study). Thus, FL proposes the following, trying to also consider the concerns on “backscatter” vs “baseband modulation” raised in Fukuoka:

**Proposal 3.2.1(I):**

* **OOK and Binary PSK are used for D2R for all devices.**
	+ **FFS: Whether/how pulse shaping of Binary PSK and impact to devices**
* **Strive to identify one variant of Binary FSK for D2R for all devices among the following:**
	+ **Variant 1: Frequency offset being a function of symbol rate**
	+ **Variant 2: MSK (and not GMSK)**
	+ **Variant 3: GFSK**
	+ **Variant 4: GMSK**
	+ **Variant 5: Deprioritize/not study further**

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | 2FSK has better BER performance than OOK. However, large power consumption and large return loss may be generated. When frequency changing is small, the aliasing between different bit information will generate. In our understanding, **variant 5 is okay at least for device 1 and 2a**. |
| LGE | On one variant for BFSK, further study on potential enhancements for BFSK for better spectral efficiency is needed before the discussion on down-selection on the D2R modulation scheme. In addition, as better coexistence with other features of AmIoT devices are important as well, Variant 1 can also be studied. So we think Variant 1/2/3/4 can be further studied. |
| Qualcomm | We have a comment on “backscatter” vs “baseband modulation” part under Proposal 3.3.2a(I). We think it is better to discuss these together.Other than the above, we have following comments:1. Need to understand whether the sub-bullet of the 1st bullet, pulse shaping for BPSK, is for backscattering or for carrier wave modulation (or for both). If it is only for carrier wave modulation, it is better to clarify that.
2. Is it correct understanding that OOK and BPSK here are for modulating each chip after small frequency shift, while Binary FSK here is for modulating each bit before small frequency shift?
 |
| IDCC | Our understanding is that modulation can be implemented during backscatter and in baseband. For example, PSK can be implemented using line code and backscatter modulation can be based on OOK. Does this proposal differentiate between these two types of modulation, or is it common? |
| Spreadtrum | Fine with this proposal. |
| Ericsson | BPSK implementation may be challenging for Device 2b. We suggest considering only OOK as baseline for all device types. |
| DOCOMO | We are open to study BFSK. |
| Lenovo | OK |
| xiaomi | We are fine for the OOK and Binary PSK.We do not support the FSK, because resource efficiency of FSK is lower. |
| ZTE, Sanechips | To support FSK modulation, frequency shift is required by A-IoT. For small frequency shift by A-IoT, it is similar with line code-based subcarrier modulation. However, due to the low synchronization accuracy of A-IoT device, the resultant frequency shift error can be far larger than the SFO. For large frequency shift with tens of MHz, it requires mixer, oscillator, and PLL/FLL. However, these component requirements exceed device type 1’s capability. In our views, at least for device 1 and 2a, **Variant 5: Deprioritize/not study further** is proposed. |
| ETRI | Fine with the proposal. |
| Huawei, HiSilicon | We prefer Variant 5.We don’t see any problem that all devices support both OOK and BPSK. But it is not the case for FSK. |

### Single / double sideband

#### Round 1

It seems companies have identified that 1SB modulation cannot be supported by the hardware available in all devices, and hence think that 2SB should be supported. It is not clear whether 1SB can be incorporated into a harmonized design at this stage, and FL suspects it may cause complications in other proposals such as small frequency-shifting by line-code or square wave. For the sake of minimizing cases, and harmonizing the design, FL suggests we take 2SB at this stage. This proposal is the same as at end of RAN1#117.

**Proposal 3.2.2a(I): 2SB modulation is supported for D2R transmission for all devices.**

* **FFS if 1SB can be supported by all, or any, devices, taking account of other issue such as how to achieve small frequency shift.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | If 1SB is supported, device implementation (e.g., extra block to suppress one SB) and reader implementation (e.g., RF filter only) can be considered when large FS is supported for device 2a. In this case, we think 1SB can not be achieved for small frequency. |
| LGE | Okay |
| Qualcomm | The discussion should be whether to enable optimization for devices that support single SB D2R transmission. From our point of view, we think it is not necessary to exclude single SB, at least for now. If we come up with solutions to support of single SB D2R transmission with minimal impact, that must be great for A-IoT standard.  |
| IDCC | Ok. |
| Panasonic | Support |
| Spreadtrum | Fine with this proposal. 1SB is too complex for ambient IoT devices. |
| Ericsson | Ok |
| Samsung | OK |
| DOCOMO | At least 2SB should be considered for all devices while 1SB should be FFS for device 2. In addition, we prefer to have a guidance the feasibility on 1SB for D2R should be discussed in which agenda item 9.4.1.2 or 9.4.2.1? |
| Futurewei | The proposal is fine as a starting point. |
| Lenovo | OK |
| xiaomi | We support this proposal. |
| Huawei, HiSilicon | OK |

## D2R line coding [ACTIVE]

|  |
| --- |
| **Agreement**For D2R, study: Manchester encoding, FM0 encoding, Miller encoding, no line coding.* FFS: Mapping(s) from bit(s) to line-code codewords
* FFS: How to achieve small frequency shift in baseband and/or FDM(A) among devices
* Aspects to study include:
	+ Spectrum shape
	+ Complexity
	+ Power consumption
	+ BER, BLER
	+ Resilience to SFO
	+ If there is any relation to CFO

Agreement RAN1#117The study assumes the following bit to chip mapping for Manchester encoding: * + bit 0→chips{10}, bit 1→chips{01}
* FFS: Variant of the above for CP handling
 |

### Line code types

#### Round 1

FL proposes first to complete the definition of the line codes based on the existing standards, since this was almost agreed in Fukuoka.

**Proposal 3.3.1a**

* **For D2R line codes, the study assumes the following codewords corresponding to an information bit 0 or bit 1, before considering potential small frequency-shifting:**
	+ **For FM0:**
		- **According to Figures 6-8 and 6-9 of UHF RFID standard**
	+ **For Miller:**
		- **According to Figure 6-12 of UHF RFID standard.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | Okay. For Miller coding, different subcarrier coefficient may be considered combined with MCS/BLF.  |
| LGE | Okay |
| Qualcomm | We are OK with the proposal. |
| IDCC | Ok. |
| Spreadtrum | Fine with the proposal. |
| Ericsson | Ok |
| Samsung | OK |
| DOCOMO | OK |
| Futurewei | OK |
| Lenovo | OK |
| ETRI | OK |
| Huawei, HiSilicon | Ok to adopt the mapping from RFID. |

### Small frequency shift

#### Round 1

For small frequency shift, based on the different line codes, the following methods seem to be proposed.

**Proposal 3.3.2a(I): Small frequency shifts for D2R are studied:**

* + **For Manchester line codes**
		- **Option 1: By repetition of the codewords within the same time duration corresponding to an information bit.**
		- **Option 2: By multiplying the Manchester codeword with a square wave corresponding to the small frequency-shift.**
	+ **For Miller line codes, by multiplying the Miller codeword with a square wave corresponding to the small frequency-shift, according to Figure 6-13 of UHF RFID standard.**
	+ **For FM0, small frequency shift is not defined**
	+ **If no D2R line code is used, by multiplying the backscatter waveform with BPSK square-wave modulation.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| LGE | For the Options for Manchester line codes, using the same mechanism, i.e., square-wave modulation, for all the cases is preferred. |
| Qualcomm | The proposal clarifies the options well. However, we would like to point out that Option 1 of Manchester line codes is no longer Manchester line codes, and is identical to the last bullet “if no D2R line code is used, by multiplying the backscatter waveform with BPSK square-wave modulation”.1. Suppose we have Manchester coding that makes bit-0 => chips{10} and bit-1 => chips{01}. Suppose we have a small frequency shift for the line code codewords. For example, bit-0 can be chips {10101010} after small frequency shift, and bit-1 can be chips {01010101} after small frequency shift.
2. We assume the baseband modulation is performed per chip after small frequency shift. Therefore,
	* With OOK, the bit-0 becomes chips {1 0 1 0 1 0 1 0} and bit-1 becomes chips {0 1 0 1 0 1 0 1}
	* With BPSK, the bit-0 becomes chips {1 -1 1 -1 1 -1 1 -1} and bit-1 becomes chips {-1 1 -1 1 -1 1 -1 1}
3. Both resultants are BPSK square wave modulation with no line coding.
	* Bit-0 => chips {1 0 1 0 1 0 1 0} is a square wave with 180 degrees, and bit-1 => chips {0 1 0 1 0 1 0 1} is the same square wave with 0 degrees. This is BPSK square wave modulation.
	* Bit-0 => chips {1 -1 1 -1 1 -1 1 -1} is a square wave with 180 degrees, and bit-1 => chips {-1 1 -1 1 -1 1 -1 1} is the same square wave with 0 degrees. This is BPSK square wave modulation.
	* Reader can remove DC component of the received signal before demodulation. Then both of the above are identical from reader point of view.
 |
| IDCC | We think for Manchester, Option 2 is the natural extension similar to Miller. Manchester codewords are generated using Manchester encoding and then shifting in frequency using subcarrier modulation. Also, we think Option 1 and square wave modulation can be viewed as line code NRZ multiplied by a square wave. |
| Spreadtrum | Fine with the proposal. |
| Lenovo | Support. |
| xiaomi | For Manchester line codes, we support the option1.Option1 is feasible according to the simulation result in our contribution, and the spectrum of different devices transmission can be separated well in the frequency domain. |
|  |  |

**Proposal 3.3.2a(I): Small frequency shifts for D2R are studied for OOK and BPSK:**

* + **For Manchester line codes**
		- **Option 1: By repetition of the codewords within the same time duration corresponding to an information bit. FFS how to define this repetition.**
		- **Option 2: By multiplying the Manchester codeword with a square wave corresponding to the small frequency-shift.**
	+ **For Miller line codes, ~~by multiplying the Miller codeword with a square wave corresponding to the small frequency-shift,~~ according to Figure 6-13 of UHF RFID standard.**
	+ **For FM0, small frequency shift is not defined**
	+ **If no D2R line code is used, by multiplying the backscatter waveform with a bipolar square-wave.**
	+ **Potential purposes include:**
		- **FDMA of D2R, if supported**
		- **CW interference avoidance if supported**
		- **Frequency hopping of D2R if supported**

Backscatter waveform?

## D2R FEC / repetition [ACTIVE]

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| --- |
| **Agreement RAN1#116bis**A-IoT D2R study of FEC includes at least convolutional codes.* Comparisons are encouraged to compare to the case of no FEC
* FFS details of convolutional codes, such as polynomial(s), shift-register termination, etc.
* FFS if other FEC candidates/methods will be studied.

**Agreement RAN1#116bis**Study D2R transmission in the physical layer using repetitionNote: Discussions regarding higher-layer repetitions are up to RAN2 |

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| **Agreement RAN1#116bis****From 9.4.2.3:**For PDRCH generation at the device, at least following blocks are studied as the baseline:* CRC bits are appended if there is non-zero length CRC
	+ Note: CRC details discussed in agenda item 9.4.2.1
* Coding
	+ Exact coding methods within the coding block, e.g. with/without line coding and/or FEC discussed under agenda 9.4.2.1
	+ Note: If no line coding is used, there may be an additional block (e.g. square wave generator) before/after modulation block
* Modulation
* Note: Other blocks could be added if agreed

 PDRCH generationAgreement RAN1#117Define repetition types for study purposes as follows:* Block level: All the bits received from higher layers and/or physical layer (according to what is present) after CRC attachment (if used) are blockwise repeated Rblock times
* Bit level type 1: Each bit after CRC attachment (if used) is repeated Rbit times
* Bit level type 2: Each bit after both CRC attachment (if used) and FEC (if used) is repeated Rbit times
* Chip level: Each chip after line coding (if used) or after square wave modulation (if used) is repeated Rchip times
	+ NOTE: Equivalent to extending the duration of each chip by Rchip times

Agreement RAN1#117For D2R, study at least block-level and bit-level repetition type 1 and type 2. |

### Repetition

#### Round 1

FL notes the ZTE proposal for adding a type of repetition to the study, however this appears to be what Proposal 3.4.1a(I) from RAN1#117 described as “FEC codeword level”, which was eliminated during the discussions, as shown in R1-2405441.

Apart from this, it seems we have adequately defined repetition in D2R for the tine being, as the papers do not conclusively propose down-selecting within the existing agreement. FL will return to this question if demand arises.

|  |  |
| --- | --- |
| **Company** | **Views** |
|  |  |
|  |  |

### FEC

#### Round 1

For convolutional codes, companies describe that the length of the shift register and the code rate interact for performance and device encoding complexity. There are suggestions to re-use directly the LTE convolutional code, or to consider a very limited set of shorter constraint length, i.e. the shift register length. Since complexity is also affected by how many shift registers are involved, i.e. the code-rate, that point is also discussed.

**Proposal 3.4.2(I): For D2R FEC, the LTE convolutional code polynomials are a reference. Other designs can be studied subject to:**

* **Constraint length K = 7 or K=6 for further study.**
* **Mother code-rate R = 1/6, 1/4, 1/3, 1/2 for further study**
* **FFS other details, e.g. final code rate by puncturing, shift-register initialization/termination.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | Fine. |
| LGE | Okay |
| Qualcomm | We are OK with the proposal. |
| IDCC | Ok. |
| Spreadtrum | We support to directly re-use the LTE convolutional code.  |
| Samsung | OK |
| DOCOMO | OK |
| Lenovo | OK. |
| ZTE, Sanechips | okay |
| Huawei, HiSilicon | We agree with the principle of the proposal, but prefer to directly reuse the LTE convolutional code design with constraint length = 7 and a code rate of 1/3 in order to simplify discussions and avoid increasing the workload.Regarding the shift register initialization, we prefer that the that the end state of the shift registers is the same as the initial state of the shift registers, similar to TBCC, but at the same time, consider enhancements to optimize the channel encoding process at the device. |

## D2R CRC [VOID]

Section 4.1 will take R2D and D2R CRCs together.

## D2R multiple access [ACTIVE]

|  |
| --- |
| AgreementStudy time-domain multiple access of D2R transmissions. Further details, including pros/cons, are FFS.AgreementStudy frequency-domain multiple access of D2R transmissions, at least by utilizing a small frequency-shift in baseband. Further details, including pros/cons, are FFS.AgreementWhether code-domain multiple access is feasible and necessary for D2R transmissions for all devices is FFS. |

### Round 1

In this and the last meeting, companies have discussed the factors that influence the performance and feasibility of FDMA and CDMA for D2R. Since we did not agree the list of points to study, these are updated based on some changes in the papers, over the versions at end of RAN1#117.

**Proposal 3.6a(I): For frequency-domain multiple access of D2R transmissions, study at least the following aspects:**

* **How FDMA is used for D2R transmissions carrying information**
* **Maximum supported small frequency shift for Device 1**
	+ **Note: The detailed design of small frequency shifting is discussed in Section 3.3.**
* **Large frequency shifting feasibility for the purposes of FDMA, i.e. from FDD-UL to FDD-DL or vice-versa**
* **The impact of SFO/frequency offset: higher value of X produces higher BLER degradation from the ideal case of perfect SFO.**
* **The impact of harmonics and spectral leakage in the backscattered signal**
* **The potential gain of D2R transmission efficiency by FDMA comparing to only TDMA**
* **The impact of frequency resource collision**
* **The impact of timing offset between devices**
* **Clarify the candidate set of FDM related parameters, e.g. the value of M for line code or square wave**

|  |  |
| --- | --- |
| **Company** | **Views**  |
| TCL | If reader sends two-tone CW (w1 and w2) to device, reader will receive different frequency D2R transmission from device if FDMA is considered, while 3rd intermodulation interference (figure as shown below) near the center frequency of two tone CW, which will impact this D2R signal in this channel. Thus, we suggest one subbullet for this proposal:**Proposal 3.6a(I): For frequency-domain multiple access of D2R transmissions, study at least the following aspects:*** **How FDMA is used for D2R transmissions carrying information**
* **Maximum supported small frequency shift for Device 1**
	+ **Note: The detailed design of small frequency shifting is discussed in Section 3.3.**
* **Large frequency shifting feasibility for the purposes of FDMA, i.e. from FDD-UL to FDD-DL or vice-versa**
* **The impact of SFO/frequency offset: higher value of X produces higher BLER degradation from the ideal case of perfect SFO.**
* **The impact of harmonics and spectral leakage in the backscattered signal**
* **The impact of 3rd intermodulation interference at least in A2 scenarios**
* **The potential gain of D2R transmission efficiency by FDMA comparing to only TDMA**
* **The impact of frequency resource collision**
* **The impact of timing offset between devices**
* **Clarify the candidate set of FDM related parameters, e.g. the value of M for line code or square wave**
 |
| Spreadtrum | Support this proposal with minor modification below.**Proposal 3.6a(I): For frequency-domain multiple access of D2R transmissions, study at least the following aspects:*** **How FDMA is used for D2R transmissions carrying information**
* **Maximum supported small frequency shift for Device 1/2a**
	+ **Note: The detailed design of small frequency shifting is discussed in Section 3.3.**
* **Large frequency shifting feasibility for Device 2a for the purposes of FDMA, i.e. from FDD-UL to FDD-DL or vice-versa**
* **The impact of SFO/frequency offset: higher value of X produces higher BLER degradation from the ideal case of perfect SFO.**
* **The impact of harmonics and spectral leakage in the backscattered signal**
* **The potential gain of D2R transmission efficiency by FDMA comparing to only TDMA**
* **The impact of frequency resource collision**
* **The impact of timing offset between devices**

**Clarify the candidate set of FDM related parameters, e.g. the value of M for line code or square wave** |
| Ericsson | Ok |
| Futurewei | Support |
| Lenovo | OK |
| xiaomi | For the sixth sub-bullet, the motivation of making the comparison between the TDMA and FDMA needs be clarified, we think both TDMA and FDMA are feasible and can be supported. |
| ETRI | OK |
| Huawei, HiSilicon | We generally support the proposal, except the third and the eighth bullet.Regarding the third bullet, the large frequency shift is not used for FDMA in our understanding. There is concern on the supported accuracy and granularity of frequency shifting for the large frequency shifter, which is expected to be difficult to support FDMA efficiently.Regarding the eighth bullet, each of the FDMed D2R transmissions will be filtered independently at the D2R receiver. In this case, the timing offset between the parallel D2R transmissions should have no impact on the link performance. |

**Proposal 3.6b(I): For considering feasibility and necessity of code-domain multiple access of D2R transmissions for all devices, [study OR list] at least the following aspects:**

* **How CDMA is used for D2R transmissions carrying information in the same time-frequency resource**
* **The impact of SFO: if all devices have X = 3 to 4, CDMA may be feasible. If all devices have X = 4 to 5, CDMA is not feasible at least without methods to mitigate the impact.**
* **The impact of timing offset between devices**
	+ **Note: The timing offset can be caused by the different processing time and sampling frequency offset between devices.**
* **The number of codes with required correlation properties in a set**
	+ **Note: The corresponding code length should also be reported.**
* **The potential gain of D2R transmission efficiency by CDMA comparing to only TDMA**
* **Which messages of RAN2’s defined procedures CDMA could be applicable to**
* **Impact on latency vs. the latency target due to e.g. lengths of spreading sequences**

|  |  |
| --- | --- |
| **Company** | **Views**  |
| TCL | To avoid more complexity operation in device side to generate code word, we think CDMA should be down-selected at least for device 1 and 2a. |
| Ericsson | Perhaps the formulation “for all devices” ought to be replaced with “for each device type”. If the device types are associated with very different targets for coverage and capacity, they may have very different needs for multiplexing.A bullet could be added regarding what variants of CDMA to consider. But perhaps it is already covered by the first bullet? |
| DOCOMO | For the impact on SFO, it should be discussed based on the assumption of details on CDMA, e.g., orthogonal code or pseudo orthogonal code. It is premature to conclude CDMA is not feasible for device which has X=4 to 5. |
| Huawei, HiSilicon | We suggest at most taking the “list” option from the proposal, i.e. to just the aspects. There is no need of CDMA and we do not think it can work for all devices. As a matter of compromise “listing” the aspects can be acceptable if really needed. In addition, we should list:1. The impact of CFO also has to be considered for Device 2b.

How to perform timing acquisition and SFO/CFO estimation/correction to the CDMed D2R transmissions. |

## D2R time-domain definitions [ACTIVE]

|  |
| --- |
| **Agreement RAN1#116bis****From 9.4.2.3:**For PDRCH generation at the device, at least following blocks are studied as the baseline:* CRC bits are appended if there is non-zero length CRC
	+ Note: CRC details discussed in agenda item 9.4.2.1
* Coding
	+ Exact coding methods within the coding block, e.g. with/without line coding and/or FEC discussed under agenda 9.4.2.1
	+ Note: If no line coding is used, there may be an additional block (e.g. square wave generator) before/after modulation block
* Modulation
* Note: Other blocks could be added if agreed

 PDRCH generation |

### Round 1

The papers appear to essentially refer to these two options for defining a chip in D2R. Option 2 would seem to anyway require companies to settle on how to do the pre-defining, which would itself rely on a common calculation method. Thus FL presume that option 1 is the default choice, but if companies want to give values for Option 2 (together with justifications) we can consider it.

Thus the main discussion should be whether the definition within option 1 is suitable.

**Proposal 3.7a(I): In D2R, a chip**

* **Corresponds to one modulated symbol**
* **Chip duration is:**
	+ **Option 1:** $\frac{a reference chip length corresponding to Btx,D2R}{frequency-shifting factor}$
		- **FFS: Definition of the reference chip length based on e.g. BLF, 2SB bandwidth**
	+ **Option 2: One of a pre-defined set of pulse time durations.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| Spreadtrum | We agree with the definition of chip and prefer Option 1.  |
| xiaomi | For the option1, the definition of the “frequency-shifting factor” needs be clarified. For the DSB, chip length = 1/ (2 ×BLF), so we propose to add the option 3 with the blue part:* + **Option 3: For the DSB, chip length = 1/ (2 ×BLF).**
 |
| ZTE, Sanechips | In our views, the chip duration is related to the bandwidth under the case of D2R transmission without frequency shift, i.e. a chip duration=2/(Btx,D2R) for double sideband modulation |
| Huawei, HiSilicon | Support |

**Proposal 3.7b(I): The smallest unit of resource allocation in D2R is [at least] corresponding to:**

* **Option 1: All the chips corresponding to one bit before line coding or square wave multiplication.**
* **Option 2: One of the chips corresponding to one bit before line coding or square wave multiplication.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| Spreadtrum | Support  |
| xiaomi | We prefer the option2.For the option1, if the bit level repetition with the different repetition number is applied, the unit of resource allocation is variational, but option2 is constant, which is benefit on simplifying the resource allocation.  |
| Huawei, HiSilicon | We prefer Option 2. Considering the potential baseband processing e.g. chip-level timing acquisition, the corresponding time unit should be based on a single chip. Correspondingly, it is more convenient to define the smallest unit of resource allocation as a single chip. |

## D2R bandwidths [ACTIVE]

|  |
| --- |
| AgreementThe following bandwidths for D2R are defined for the purpose of the study:* Transmission bandwidth, Btx,D2R: The frequency resources scheduled by a reader for a D2R transmission from one device.
	+ FFS in agenda 9.4.2.3: how frequency resources scheduled by a reader are determined
* Occupied bandwidth, Bocc,D2R: The transmission bandwidth plus the potential associated intra A-IoT guard-bands totalling Bguard,D2R
	+ Note: this guard band is not for coexistence with NR/LTE
* If/how to define guard band for coexistence between A-IoT D2R and NR/LTE is up to RAN4.
* Bocc,D2R >= Btx,D2R
	+ Possible values of each bandwidth are FFS
 |

### Bandwidth sizes

#### Round 1

For bandwidth sizes in D2R, it would be possible to face complications if we try to define their values wrt potential multi-single tone CW, due to the gap between the multiple tones. Hence, based on how FL understands the papers, the suggestion is to define them wrt to just one (or each of the) single tone(s). This should then be general across whether the tones are used by multiple CW nodes for multiple devices (somehow), or apply to one device.

**Proposal 3.8.1a(I) For Btx,D2R of the D2R transmissions associated with one/each single-tone of a carrier-wave:**

* **The bandwidth counts the main lobes on the two sides of one/each single-tone of a carrier-wave for DSB modulation**
	+ **NOTE: Carrier-wave is internal or external to device as appropriate.**
* **The bandwidth equals 2 / (Chip\_length** $×$ **Frequency-shift factor) for DSB modulation**
	+ **Frequency-shift factor equals the repetition number of line code for small frequency shifting by line coding**
	+ **FFS the value of frequency-shift factor for small frequency shifting by square-wave**
* **FFS the SSB modulation case**

****

**Proposal 3.8.1b(I): For the study of FDMA, *B*occ,D2R of the D2R transmission associated with one/each single-tone of a carrier wave:**

* ***B*occ,D2R includes ≥99% power of the D2R transmission, with harmonics being taken into account**
* **The** **guard band *B*guard,D2R would be necessary due to SFO**
* **The** **guard band *B*guard,D2R would be necessary due to CFO for Device 2b**
* **The guard band *B*guard,D2R is around the main lobes on the two sides of one/each single-tone of a carrier-wave for DSB modulation**
	+ ***B*occ,D2R does not count the unoccupied bandwidth between the two main lobes**
	+ **FFS the SSB modulation case**

|  |  |
| --- | --- |
| **Company** | **Views on Proposals 3.8.1a, b** |
| TCL | Okay with this proposal. |
| Spreadtrum | Support  |
| Futurewei | Support |
| Lenovo | OK |
| Xiaomi | For the Proposals 3.8.1a, we support this proposal. |
| Huawei, HiSilicon | Support |

Given the sizes of *B*tx,D2R or *B*occ,D2R, the size of *B*occ,D2R or *B*tx,D2R, respectively, can be determined according to the corresponding size of *B*guard,D2R. Considering the value of *B*tx,D2R and chip length are mutually determined, it is convenient define the candidate sizes of *B*tx,D2R rather than *B*occ,D2R.

**Proposal 3.8.1c(I) For Btx,D2R of the D2R transmissions associated with one/each single-tone of a carrier wave, it can be:**

* **Alt 1: An integer number of PRBs**
* **Alt 2: An integer multiple of SCS**

|  |  |
| --- | --- |
| **Company** | **Views on Proposals 3.8.1c** |
| TCL | Okay |
| LGE | Okay |
| Spreadtrum | We prefer Alt 2.Considering the value with integer multiple of SCS can achieve more flexibility for D2R transmission and integer number of PRBs can also composed of 12 times integer multiple of SCS, Option 2 is more preferred. |
| Ericsson | Ok |
| Samsung | OK |
| DOCOMO | OK |
| Futurewei | OK |
| Xiaomi | We support the Alt2.It is possible that D2R transmission bandwidth can be less than 1 PRB in the Ambient IoT. So Alt2 is preferred to support both sub-PRB transmission and the bandwidth larger than one PRB transmission. |
| ETRI | OK |
| Huawei, HiSilicon | We prefer Alt2.Sub-PRB transmission is helpful to improve the spectrum efficiency for the D2R transmission of e.g. the devices in worse coverage. There should be a certain values smaller than one-PRB for Btx,D2R. Alt2 can support both the cases of sub-PRB and PRB-level transmission bandwidth. |

# R2D and D2R

## CRC [ACTIVE]

|  |
| --- |
| **Agreement** RAN1#116R2D study assumes use of CRC. FFS which CRC generator polynomial(s) are assumed, and if any cases are included with no CRC.* FFS: Association, if any, between down-selected CRC(s) and message size, considering at least false-alarm rate target
 |
| **Agreement** RAN1#116D2R study assumes use of CRC. FFS which CRC generator polynomial(s) are assumed, and if any cases are included with no CRC.* FFS: Association, if any, between down-selected CRC(s) and message size, considering at least false-alarm rate target
 |

|  |
| --- |
| Agreement RAN1#116BISStudy* baseline: using 6 bits and 16 bits CRC with polynomials from TS 38.212, or no CRC, for PRDCH
* baseline: using 6 bits and 16 bits CRC with polynomials from TS 38.212, or no CRC, for PDRCH
* FFS: details when different CRC lengths or no CRC may be used
* FFS: other 6 bits and 16 bits CRC with different polynomials than from TS 38.212
 |

### Round 1

For the details when different CRC lengths or no CRC may be used, some companies discussed about the design aspects. Proposals seem to be to support no CRC for short messages to save the CRC overhead while some proposed no CRC is used for message with high importance to improve the robustness of the system and others to use separate CRCs for payload and control information carried by PRDCH or PDRCH.

FL updates the proposals from Fukuoka, and suggests that if companies are not ready to down-select particular values for X and Z, then we can at least collect the feasible/reasonable options, and could defer detailed down-selection to a potential normative phase, if/when there is one.

**Proposal 4.1a(I): For PRDCH/PDRCH transmissions with CRC, the used CRC length depends on the number of bits Z before CRC, i.e. CRC-6 for Z<=X bits, while CRC-16 for Z > X bits**

* **Option 1: X = 16**
* **Option 2: X = 24**
* **Option 3: X = 57 (*FL is not sure if ZTE mean 57 or 114 bits*)**

**Note: This does not preclude PRDCH/PDRCH transmissions also without CRC.**

|  |  |
| --- | --- |
| **Company** | **Views, including value of X** |
| Spreadtrum | Support Option 2. |
| ZTE, Sanechips | FL captures our proposal correctly and we have the following modifications:* **Option 3: X = 57 ~~(~~*~~FL is not sure if ZTE mean 57 or 114 bits~~*~~)~~**
 |
| Huawei, HiSilicon | We support option 2 where X = 24. Based on our analysis, the probability of undetected errors increases when using CRC-6 for larger TBS of greater than 24. Using CRC-16 for TBS>24 offers a good balance between the error detection performance and resulting overhead. |

For the study of potentially not having CRC in some cases, there are two cases: that either it is for the smallest messages, or for some certain ‘less critical’ transmissions. However, there are not many details in papers, so FL requests more specific inputs.

FL notes that the message(s)/channel(s) case will depend on the detail design of system access procedure messages. Now that RAN2 have started defining ‘random access’ messages, we could attempt to see which in RAN1 may have no CRC – companies can make suggestions, and FL will see if the discussion is advanced enough to prepare further level of detail at this time.

**Proposal 4.1b(I): For further study of possibly using no CRC in some cases:**

* **Study applicable maximum number of bits Z=Y < X**
	+ **Option 1: Z = 14**
* **Study potentially applicable message(s)/channel type(s)**
	+ **Companies can proposed candidate message(s) from e.g. those defined so far by RAN2**

|  |  |
| --- | --- |
| **Company** | **Views, including value of Z** |
| Spreadtrum | Our first preference is the direction of second bullet, e.g., QueryRep/ACK messages in inventory procedure., also can accept the direction of first bullet |
| ZTE, Sanechips | Considering the CRC overhead, we have the following additional option for Z.**Proposal 4.1b(I): For further study of possibly using no CRC in some cases:*** **Study applicable maximum number of bits Z=Y < X**
	+ **Option 1: Z = 14**
	+ **Option 2: Z = 20**
* **Study potentially applicable message(s)/channel type(s)**
	+ **Companies can proposed candidate message(s) from e.g. those defined so far by RAN2**
 |
| Huawei, HiSilicon | We would prefer to wait until RAN2 completes the identification of the candidate messages, their respective purposes and sizes before we determine which ones do not use CRC. |

For whether to use CRCs other than those in TS 38.212, there is only one proposal to do so (ZTE). Hence FL would wait to see other companies adopting this direction before attempting to agree on moving away from the baseline.

## Scrambling

### Round 1

If there is to be scrambling seems to be first handled in this agenda item and if supported, then reflected in updates the codec diagrams in 9.4.2.3. There are very few proposals, so FL assumes companies have not seen the need.

On a technical basis, since the main purpose of scrambling is to avoid long runs of all-1 or all-0, due to the DC characteristic and difficult clock recovery, the function of scrambling seems to have been adequately replaced by line codes or square-wave multiplication. It seems we can minimize the effort here.

**Proposal 4.2(I): Do not study support of scrambling for R2D and D2R.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| xiaomi | We support this proposal. Share the similar view with the FL.  |
| Huawei, HiSilicon | We agree with the FL since scrambling would result in the decoding complexity being increased drastically at the device, and would be unsuitable for device 1. |
|  |  |

# Proposals for online sessions

## Tues AM

**Proposal 2.1.2a(I-offline): The following table is a starting point for *M* values and the associated minimum *B*tx,R2D value**

* **Reader can use any R2D bandwidth >= minimum *B*tx,R2D**
* **FFS: Impacts, if any, of CP handling solutions**

|  |  |
| --- | --- |
| ***M*** | Minimum ***B*tx,R2D # of PRBs** |
| **1** | 1 |
| **2** | 1 |
| **4** | 1 |
| **6** | 1 |
| **8** | 2 |
| **12** | 2 |
| **16** | 2 |
| **24** | 2 |
| **32** | 3 |

For the following, FL may update the wording around “backscatter waveform” before online, based on some offline comments.

**Proposal 3.3.2a(I): Small frequency shifts for D2R are studied for OOK and BPSK:**

* + **For Manchester line codes**
		- **Option 1: By repetition of the codewords within the same time duration corresponding to an information bit. FFS how to define this repetition.**
		- **Option 2: By multiplying the Manchester codeword with a square wave corresponding to the small frequency-shift.**
	+ **For Miller line codes, according to Figure 6-13 of UHF RFID standard.**
	+ **For FM0, small frequency shift is not defined**
	+ **If no D2R line code is used, by multiplying the backscatter waveform with a bipolar square-wave.**
	+ **Potential purposes include:**
		- **FDMA of D2R, if supported**
		- **CW interference avoidance if supported**
		- **Frequency hopping of D2R if supported**

**Proposal 3.3.1a**

* **For D2R line codes, the study assumes the following codewords corresponding to an information bit 0 or bit 1, before considering potential small frequency-shifting:**
	+ **For FM0:**
		- **According to Figures 6-8 and 6-9 of UHF RFID standard**
	+ **For Miller:**
		- **According to Figure 6-12 of UHF RFID standard.**

**Proposal 3.4.2(I): For D2R FEC, the LTE convolutional code polynomials are a reference. Other designs can be studied subject to:**

* **Constraint length K = 7 or K=6 for further study.**
* **Mother code-rate R = 1/6, 1/4, 1/3, 1/2 for further study**
* **FFS other details, e.g. final code rate by puncturing, shift-register initialization/termination.**

**Proposal 2.1.1a(I): For R2D CP handling of OFDM based OOK waveform, normal CP is considered in the study.**

**Proposal 2.4b(I):**

* **For R2D transmissions, the necessity of at least bit-level repetitions is studied based on potential need for coverage enhancements according to the coverage evaluations.**

# Summary

The agreements reached were as follows:

# References

1. R1-2405802 Discussion on physical layer design for Rel-19 Ambient IoT devices FUTUREWEI
2. R1-2405820 General aspects of physical layer design for Ambient IoT Nokia
3. R1-2405826 General aspects of physical layer design for Ambient IoT Ericsson
4. R1-2405852 On general aspects of physical layer design for Ambient IoT Huawei, HiSilicon
5. R1-2405912 Discussion on general aspects of physical layer design for Ambient IoT Spreadtrum Communications
6. R1-2405968 Discussion on general aspects of physical layer design for Ambient IoT TCL
7. R1-2405989 Discussion on general aspects of A-IoT physical layer design CMCC
8. R1-2406082 Discussion on Physical Layer Design for Ambient-IoT EURECOM
9. R1-2406091 Discussion on general aspects of physical layer design for Ambient IoT China Telecom
10. R1-2406186 Discussion on General Aspects of Physical Layer Design vivo
11. R1-2406242 Discussion on general aspects of physical layer design of A-IoT communication OPPO
12. R1-2406288 Discussion on physical layer design of Ambient IoT Xiaomi
13. R1-2406315 Consideration on general aspects of physical layer Fujitsu
14. R1-2406372 Discussion on general aspects of physical layer design CATT
15. R1-2406405 Discussion on general aspects of physical layer design for Ambient IoT ZTE Corporation, Sanechips
16. R1-2406445 On General Physical Layer Design Considerations for Ambient IoT (internet of things) Applications Lekha Wireless Solutions
17. R1-2406474 General aspects of Ambient IoT physical layer design Sony
18. R1-2406557 Discussion on general aspects of ambient IoT physical layer design NEC
19. R1-2406600 General aspects of physical layer design for Ambient IoT Panasonic
20. R1-2406604 General aspects of Ambient IoT physical layer design LG Electronics
21. R1-2406654 Considerations on general aspects of Ambient IoT Samsung
22. R1-2406728 Discussion on general aspects of physical layer design ETRI
23. R1-2406773 General aspects of physical layer design MediaTek Inc.
24. R1-2406813 Discussion on the physical layer design aspects for Ambient IoT devices Lenovo
25. R1-2406840 On general physical layer design aspects for AIoT Apple
26. R1-2406878 Discussion on general aspects of physical layer design Sharp
27. R1-2406892 On the general aspects of physical layer design for Ambient IoT InterDigital, Inc.
28. R1-2406934 Study on general aspects of physical layer design for Ambient IoT NTT DOCOMO, INC.
29. R1-2407033 General aspects of physical layer design Qualcomm Incorporated
30. R1-2407088 Discussion on General aspects of physical layer design CEWiT
31. R1-2407119 General aspects of physical layer design for Ambient IoT ITL
32. R1-2407131 Discussion on General aspects of physical layer design of AIoT IIT Kanpur, Indian Institute of Tech (M)

# Annex A – Previous Decisions

## RAN1#116, Athens, February 2024

Agreement

A-IoT DL study includes an OFDM-based waveform from A-IoT R2D (reader-to-device) perspective.

* Depending on what modulation(s) are decided to be studied:
	+ Study whether/how to handle CP at transmitter/device/design
* Study other characteristics of the OFDM waveform, e.g.:
	+ CP-OFDM
	+ DFT-s-OFDM
	+ Etc.
	+ The type of OFDM waveform is transparent to A-IoT device.

Other waveforms from DL transmitter’s perspective can be proposed, and further discussion will consider whether or not they are included in the study.

Agreement

A-IoT DL study includes OOK from DL transmitter’s perspective.

* For an OFDM waveform, assume OOK-1 for single-chip per OFDM symbol transmission, and OOK-4 for M­-chip per OFDM symbol transmission, starting from definitions in TR 38.869.
	+ FFS value(s) of M.
	+ FFS: Any changes needed from the definitions in TR 38.869.
	+ FFS: Exact definition of chip
* If other DL waveforms are included, further elaboration of the transmitter’s OOK generation would be needed.

**Agreement**

For R2D, line codes studied are: Manchester encoding and pulse-interval encoding (PIE).

* FFS: Mapping(s) from bit(s) to line-code codewords
* FFS: Time domain definition of e.g., chips and relation to OFDM symbols, resource allocation unit, etc.

**Agreement**

Regarding FEC, R2D with no forward error-correction code (FEC) is studied as baseline.

* Evaluations would be by comparison to this baseline

**Agreement**

**R2D study assumes use of CRC. FFS which CRC generator polynomial(s) are assumed, and if any cases are included with no CRC.**

* **FFS: Association, if any, between down-selected CRC(s) and message size, considering at least false-alarm rate target**

**Agreement**

**D2R study assumes use of CRC. FFS which CRC generator polynomial(s) are assumed, and if any cases are included with no CRC.**

* **FFS: Association, if any, between down-selected CRC(s) and message size, considering at least false-alarm rate target**

**Agreement**

At least the following bandwidths for R2D are defined for the purpose of the study:

* Transmission bandwidth, Btx,R2D from a Reader perspective: The frequency resources used for transmitting R2D
* Occupied bandwidth, Bocc,R2D from a Reader perspective: The frequency resources used for transmitting R2D, and potential guard band
* Bocc,R2D ≥ Btx,R2D
	+ FFS: Further constraint(s) e.g. Bocc,R2D = Btx,R2D.
	+ Possible values of each bandwidth are FFS

## RAN1#116bis, Changsha, April 2024

Agreement

Study time-domain multiple access of D2R transmissions. Further details, including pros/cons, are FFS.

Agreement

Study frequency-domain multiple access of D2R transmissions, at least by utilizing a small frequency-shift in baseband. Further details, including pros/cons, are FFS.

Agreement

Whether code-domain multiple access is feasible and necessary for D2R transmissions for all devices is FFS.

Agreement

The following bandwidths for D2R are defined for the purpose of the study:

* Transmission bandwidth, Btx,D2R: The frequency resources scheduled by a reader for a D2R transmission from one device.
	+ FFS in agenda 9.4.2.3: how frequency resources scheduled by a reader are determined
* Occupied bandwidth, Bocc,D2R: The transmission bandwidth plus the potential associated intra A-IoT guard-bands totalling Bguard,D2R
	+ Note: this guard band is not for coexistence with NR/LTE
* If/how to define guard band for coexistence between A-IoT D2R and NR/LTE is up to RAN4.
* Bocc,D2R >= Btx,D2R
	+ Possible values of each bandwidth are FFS

Agreement

For D2R, study: Manchester encoding, FM0 encoding, Miller encoding, no line coding.

* FFS: Mapping(s) from bit(s) to line-code codewords
* FFS: How to achieve small frequency shift in baseband and/or FDM(A) among devices
* Aspects to study include:
	+ Spectrum shape
	+ Complexity
	+ Power consumption
	+ BER, BLER
	+ Resilience to SFO
	+ If there is any relation to CFO

Agreement

A-IoT D2R study of FEC includes at least convolutional codes.

* Comparisons are encouraged to compare to the case of no FEC
* FFS details of convolutional codes, such as polynomial(s), shift-register termination, etc.
* FFS if other FEC candidates/methods will be studied.

Agreement

Study

* baseline: using 6 bits and 16 bits CRC with polynomials from TS 38.212, or no CRC, for PRDCH
* baseline: using 6 bits and 16 bits CRC with polynomials from TS 38.212, or no CRC, for PDRCH
* FFS: details when different CRC lengths or no CRC may be used
* FFS: other 6 bits and 16 bits CRC with different polynomials than from TS 38.212

Agreement

Study D2R transmission in the physical layer using repetition

* Note: Discussions regarding higher-layer repetitions are up to RAN2.

Agreement

R2D study includes subcarrier spacing of 15 kHz, from the reader perspective, for OFDM-based waveform.

* Inclusion in the study of subcarrier spacing of 30 kHz is FFS.

Agreement

For R2D study OFDM-based waveform with subcarrier spacing of 15 kHz, Btx,R2D is ≤ [12] PRBs and is down-selected among:

* Alt 1: Including 180 kHz, 360 kHz, and FFS other values
* Alt 2: Integer multiple(s) of 180 kHz (FFS: what integer(s))
* Alt 3: Integer multiple(s) of the subcarrier spacing (FFS: what integer(s))

Agreement

For R2D CP handling for OFDM based OOK waveform:

* For potential down-selection, study among the following candidate methods
	+ Method Type 1: Removal of CP at device without specified transmit-side
		- FFS: How device determines the CP location
		- FFS: Impact on feasibility of device SFO
		- FFS: relation to M, if any
	+ Method Type 2: Ensure the CP insertion of OFDM-based waveform will not introduce false rising/falling edge between the last OOK chip in OFDM symbol (n-1) and the first OOK chip in OFDM symbol n.
		- FFS: Whether/how to arrange that OOK chips have equal length after CP insertion
		- FFS: relation to M, if any
		- FFS: Detail of relationship to line code codewords
		- FFS: Impact on feasibility of device SFO
	+ [Other method types are not precluded]
* Study of the methods should include e.g.:
	+ CP impact on R2D timing acquisition, and decoding & performance of PRDCH
	+ Reader and device implementation complexities
	+ Interference between R2D and NR DL/UL if in the same NR band
	+ Spectrum efficiency

Agreement

Study for all devices the following for D2R baseband modulation, for potential down-selection:

* OOK
* Binary PSK
* Binary FSK
	+ Strive to identify one variant of Binary FSK to study further

## RAN1#117, Fukuoka, May 2024

Agreement

Study the following regarding CP location/length determination for Method Type 1:

* + Alt 1: Device assumes same CP length for each OFDM symbol, i.e. does not distinguish exact CP length among different OFDM symbols
	+ Alt 2: duration between transition edges is utilized by device to determine CP location/length, i.e. if the duration appears to be invalid based on known chip duration
* Companies are encouraged to clarify the CP removal method used and implementation aspects for the device
* Evaluations are encouraged to be performed for a small value of M, e.g. 4 and a large value of M, e.g. 24, at least by comparison to the case where the CP length of each OFDM symbol is known by device
* Companies should report the values of SFO, and SFO detection methods used in evaluations

Agreement

Study the following options regarding subcarrier orthogonality for Method Type 2:

* Alt 1: Method Type 2 retains subcarrier orthogonality (i.e. CP copied from the end of an OFDM symbol)
* Alt 1-1: The first OOK chip(s) and the last OOK chip(s) in an OFDM symbol are the same
	+ FFS: whether this alternative applies if CP length is longer than the chip duration
* Alt 1-2: Ensure a transition edge occurs only at the start or only at the end of the CP, and no transition edge occurs during the CP
* Other potential methods are not precluded
* Alt 2: Method Type 2 does not retain subcarrier orthogonality
* Proponents to bring further details to RAN1#118
* Evaluations and discussions are encouraged to be performed for a small value of *M*, e.g. *M* = 4 and a large value of *M*, e.g. *M* = 24.
* Companies should report the values of SFO, and SFO detection methods used in evaluations

**Agreement**

Define repetition types for study purposes as follows:

* Block level: All the bits received from higher layers and/or physical layer (according to what is present) after CRC attachment (if used) are blockwise repeated Rblock times
* Bit level type 1: Each bit after CRC attachment (if used) is repeated Rbit times
* Bit level type 2: Each bit after both CRC attachment (if used) and FEC (if used) is repeated Rbit times
* Chip level: Each chip after line coding (if used) or after square wave modulation (if used) is repeated Rchip times
	+ NOTE: Equivalent to extending the duration of each chip by Rchip times

**Agreement**

For D2R, study at least block-level and bit-level repetition type 1 and type 2.

**Agreement**

For R2D evaluation purposes, the R2D waveform for DFT-s-OFDM is generated as follows:

1. The time domain OOK signal is the M chips of one OFDM symbol.
2. A chip is represented (e.g. upsampled) by L samples
	* Companies to report L
3. An N’-points DFT is performed on the samples of one OFDM symbol to obtain the frequency domain signal.
	* Companies to report N’, e.g. N’=128 or equal to X
4. Map the frequency domain signal obtained by N’-points DFT to the X subcarriers of Btx,R2D.
	* Companies report how to map and report X
5. An N-points IDFT is performed to obtain the time domain signal.
	* Companies to report N, and how value was selected

Note: companies report whether/how CP samples are added.

**Agreement**

The study assumes the following bit to chip mapping for Manchester encoding:

* + bit 0→chips{10}, bit 1→chips{01}
* FFS: Variant of the above for CP handling