**3GPP TSG RAN-WG1 Meeting #117 R1-24xxxxx**

**Fukuoka, Japan, May 20-24, 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: R1-24…

# R2D

## R2D waveform [ACTIVE]

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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

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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
		- 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
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Companies have expanded a little on the detail of the methods that might fit into Method Type 1 and Method Type 2, so FL here attempts to group the sub-cases further. This is with a view to prioritizing or selecting among them after further discussions on feasibility and pros/cons, etc., in terms of the aspects identified in the previous agreement.

**Proposal 2.1.1a(I): For potential down-selection of the design for Method Type 1, study the following regarding CP location[length] determination for Method Type 1:**

* + **Alt1: CP length of each OFDM symbol is known by device**
	+ **Alt 2: Device does not distinguish exact CP length among different OFDM symbols**
	+ **Alt 3: Invalid duration between transition edges are avoided by device**
* **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.**

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| **Company** | **Views** |
| EURECOM | It is unclear to us why we need to down-select between Alt 1 and Alt 2. Knowledge of CP at the receiver can be implementation-specific. Some designs may work without others estimate CP from a known signal, e.g. preamble.  |
| Qualcomm | Method Type 1 requires device to know CP location. It is not clear how Alt.2 works in general. However, device needs to know CP location and length before device performs Method Type 1. It would be good to discuss (1) how a device identifies CP location and length, and (2) how the device discard samples corresponding to the identified CP.So we suggest to update the proposal as follows. Note that we think this is a discussion of Method Type 1 details – not a kind of down selection.**For ~~potential down-selection of the~~ design for Method Type 1, study the following regarding CP location determination for Method Type 1:*** **~~Alt 1:~~ Device behavior after CP location related information is known by device~~, before starting decoding~~**
	+ **Alt 1-1: CP length of each OFDM symbol is known by device**
	+ **Alt 1-2: Device does not distinguish exact CP length among different OFDM symbols**
* **~~Alt 2:~~ How a device identifies CP location related information i~~s not known by device before starting decoding~~**
* **Companies are encouraged to clarify the CP identification and removal method used and implementation aspects such as SFO assumption and its handling 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.**
 |
| Vivo | For method type-1, key point is, how device know/identify where is CP and then remove CP. For Alt2, the current wording is a bit unclear how device can remove CP impact. If the intention is to cover vivo’s solution, our solution is CP location is derived by device by identification of irregularly short interval between 2 adjacent edges. Different from Alt 1-1 and 1-2, our solution does not need device to know the CP length 4.67 or 5us, it only needs device to compare the chip length with a threshold based on normal chip length obtained by preamble part. According to some existing implementation, e.g., ‘Manchester Coding Basics, [Atmel-9164-Manchester-Coding-Basics\_Application-Note.pdf (microchip.com)](https://ww1.microchip.com/downloads/en/Appnotes/Atmel-9164-Manchester-Coding-Basics_Application-Note.pdf)’, device can identify and drop invalid chip if the chip duration is too short. Our solution is based on similar logic. Considering our solution is also a kind of CP location known by the device, we think it can be a sub-alternative of Alt 1. We suggest to add Alt 1-3: ‘CP location is derived by device by identification of irregularly short interval between 2 adjacent edges’.  |
| xiaomi | We don’t support this proposal. We think method type1 is not feasible, because method type1 requires nearly perfect synchronization, but device with the SFO impact cannot achieve exactly synchronization. |
| Samsung | Both Alt 1-2 and Alt 2 looks like simple assumptions with neither when/why it is applied or which device behaviour it will lead to.Alt 2 were already discussed during offline. On Alt 1-2, we prefer to add consequent UE behaviour to make it more clear, e.g. as follows, if that is the intention:**Alt 1-2: Device uses a common assumption of CP length for each OFDM symbol, and does not distinguish exact CP length among different OFDM symbols** |
| ZTE, Sanechips | In addition to the impact of M value, we think the SFO also has impact on the CP removal, so the following bullet is suggested to be added:* **Companies are encouraged to report the values of SFO and SFO detection methods for evaluations.**
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| IDCC | We agree that CP, in some cases, can be identified by irregular intervals between the rising and falling edges. But in some cases, depending on the value of M, the intervals may be similar in duration. For these cases, additional solutions are needed. For example, the set of Ms can be limited. The device may also know the value of M. |
| Huawei, HiSilicon | We are fine with the proposal. Alt2 may have some restrictions for applicable cases but list as a candidate is OK. |

**Proposal 2.1.1b(I): For potential down-selection of the design for Method Type 2, study the following options regarding subcarrier orthogonality:**

* **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**
* **Alt 1-2: Ensure a transition edge occurs at the start/end of the CP, and no transition edge occurs during the CPOther potential methods are not precluded**
* **Alt 2: Method Type 2 does not retain subcarrier orthogonality**
* **E.g., CP is copied from the beginning of an OFDM symbol**
* **E.g., split CP insertion among the chips of an OFDM symbol**
* **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.**

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| **Company** | **Views** |
| Qualcomm | The proposal looks good starting point. We think this is not for potential down-selection – we think this is a detail of the study of Method Type 2.**For ~~potential down-selection of the~~ design for Method Type 2, study the following options ~~regarding subcarrier orthogonality~~:** |
| vivo  | We object Alt 2. In our understanding, in last meeting, the argument to not support ‘No CP’ is also applicable to Alt 2, i.e., non-orthogonality between NR and AIOT transmission. Besides, there is no benefit of Alt 2 than NO CP, e.g., lower spectrum efficiency, additional effort to add CP.  |
| xiaomi | We are generally fine with this proposal.We support Alt1-1. We are confused about the Alt 1-2, does it mean the transition edge locates before the CP?Meanwhile, we do not support the alt2, because if the subcarrier orthogonality is not retained, the in-band deployment cannot be achieved. |
| Samsung | On alt 1-2, we considering the issue includes not only whether a transition edge of line-code codeword exists at CP boundary, but also whether there are other transition edges inside the CP interval. We suggest the following update:* **Alt 1-2: Ensure the transition edge of a line-code codeword occurs at the CP boundary, and no transition edge of a line-code codeword occurs within the CP**
 |
| IDCC | We prefer solutions that maintain orthogonality. |
| Futurewei | The two alternatives under Alt 1 (i.e., Alt 1-1 and Alt 1-2) should be considered under two different conditions and may both be considered depending on the values of M supported. The Alt 1-1 should be considered for small values of M whereas Alt 1-2 should be considered for large values of M.  |
| DOCOMO | We are fine with the proposal and we believe Alt.1 should be applied at least to in-band operation. |
| Huawei, HiSilicon | We prefer not to pursue Alt 2 and focus on Alt 1 for further study.We understand orthogonality is the reason we started from OFDM-based waveform. |

### Waveform(s)

Although it is possible that the R2D waveform generation may be not specified, it will have in e.g. RAN4 certain time domain characteristics that ensure it is ‘good’. For evaluation purposes in RAN1, it seems we need to agree on how we will model the generation. Hence FL suggests as follows for DFT-s-OFDM:

Note that the below is an attempt to harmonize understanding of signal generation among companies for evaluation purposes. It does not imply any specification of the reader’s signal generation.

**Proposal 2.1.2a(I): 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.**
	* **M may be different in different OFDM symbols, depending on other agreements.**
2. **A chip is represented by L samples, L = N’/M. [?CATT, Apple]**
	* **Companies to report L, and how the chip is represented.**
3. **An N’-points DFT (e.g. N’=128) is performed to obtain the frequency domain signal.**
	* **Companies to report N’. N’ modulo M = 0.**
	* **[Mention that N’ does not have to equal # subcarriers]**
4. **The frequency domain signal FFT-shifted to be centered on DC, and the central X elements are mapped to the X subcarriers of Btx,R2D; [Use N’ subcarriers?]**
5. **Zero padding is added on both sides of the obtained X-length frequency signal to create a total N-length frequency domain signal.**
6. **An N-points IDFT is performed to obtain the time domain signal.**
7. **CP samples are added according to the definition in TS 38.211 section 5.3.1, i.e.** $T\_{symb,l}^{μ}=\left(N\_{u}^{μ}+N\_{CP,l}^{μ}\right)T\_{c}$**.**

**CATT: Could have an N’-points IDFT, no zero padding. And have N’=X? State # of points at each step?**

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| **Company** | **Views** |
| Qualcomm | In general, the proposal formulates one way of the R2D waveform generation. On the other hand, we think some details relate to the CP handling discussion and those may impact on the waveform generation. For example,* CP handling may result in different OOK chip length across OOK chips in an OFDM symbol before CP addition or after CP addition.
* CP handling may result in different number of M across OFDM symbols.
* CP handling may require in CP addition that is not based on TS38.211 section 5.3.1.
 |
| vivo | We are generally fine to align waveform generation for evaluation purpose. However, we have clarification questions/comments on some steps: 1. Relation between DFT size and IFFT size. The proposal restricts the same size of DFT and IFFT size, but in our understanding, it is possible that DFT size is smaller than IFFT size, e.g., DFT size is same as total number of REs of R2D signal (X), while IFFT size can be larger. So, we suggest to use N’ and N separately for DFT and IFFT size, and it’s up to company report the value of N’ and N, which can be same or different.
2. In step 2: after up sampling, a scrambling sequence (overlaid OFDM sequence not carrying information as discussed in LP-WUS) to flat the spectrum can be applied. It can be up to company report whether scrambling sequence is applied.
3. In step 5: whether zero padding is needed depends on whether IFFT size is larger than number of REs for R2D. In other words, step 5 may or may not needed depending on relation between X and IFFT size N. It can be up to company report.

Besides, if it is only for evaluation purpose, is it to be discussed in 9.4.1.1 rather than 9.4.2.1?  |
| OPPO | This procedure is too detail for discussion at current stage. Furthermore, it is also related to CP handling method. For example, for some CP handling method, the length of first chip after CP insertion is same as rest M-1 chips. So that the length of first before CP insertion is shorter than other M-1 chips, which conflicts with 2nd step of this proposal. Therefore, we propose to discuss this proposal later after CP handling is clear.  |
| ZTE, Sanechips | In addition to the offline discussion:1. A response to the comments above: Different from detection method with LP WUS, the scrambling sequence is not needed for Ambient IoT R2D;
2. Step 4: the DC has specific meaning for the frequency placement of signal/channel generation. For the Ambient IoI, such a restriction of frequency placement is not needed.
3. Step 7, it depends on the CP handling discussion above.
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| IDCC | In step 2, upsampling repeats the chips, so the sequence input to the DFT contains only 1s and 0s. In general, as in the offline, each chip can be represented by a sequence, e.g., ZC. So, instead of upsampling, we prefer each chip to be represented by L samples.In step 3, the DFT size should be equal to L. The benefit of keeping the DFT and IDFT sizes are not clear. If the DFT size is N’ (equal to IDFT size), then we should clarify how the N’-DFT of L samples are taken. Are the L samples padded with zeros, or do we upsample L samples (i.e., by inserting zeros between samples) to N’ samples? In step 4, taking only the center X samples may not be accurate if in step 3 we apply zero-padding. |
| Huawei, HiSilicon | We are supportive of the intention of FLS proposal to align the assumption of waveform generation among companies for evaluation purpose.A-IoT device has to use raising/falling edge detection which requires the time domain OOK signal having good enough shape from transmitter side. Different waveform generation may have different time domain shape which impact the OOK performance on edge detection. Align waveform generation is helpful for companies to compare evaluation results.According to Monday’s offline discussion, we observed that companies may have concerns to limit the generation to up-sampled and N’-point DFT where N’ is larger than X. We understand there might be different way to generate waveform but the goal should be retaining good time domain OOK shape for edge detection. Thus we are trying to suggest the following update:**Proposal 2.1.2a(I): 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 potentially up-sampled or represented to L samples, L = N’/M.**
	* **Companies to report L.**
3. **An N’-points DFT (e.g. N’=128 or equal to X) is performed to obtain the frequency domain signal.**
	* **Companies to report N’. N’ modulo M = 0.**
4. **If N’ greater than X, except the X elements mapped to the X subcarriers of Btx,R2D ~~The frequency domain signal FFT-shifted to be centered on DC, and the central are mapped to the X subcarriers of B~~~~tx,R2D~~~~;~~ ~~Zero padding is added on both sides of the obtained X-length frequency signal~~ others are zero padding to create a total N’-length frequency domain signal.**
5. **~~FFT-shift is reversed.~~ An N~~’~~-points IDFT is performed to obtain the time domain signal.**
6. **CP samples are added according to the definition in TS 38.211 section 5.3.1, i.e.** $T\_{symb,l}^{μ}=\left(N\_{u}^{μ}+N\_{CP,l}^{μ}\right)T\_{c}$**.**
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For CP-OFDM generation, there are no specific proposals available. Proponents may wish to provide them, or we can focus on DFT-s-OFDM from now on.

**Proposal 2.1.2b(I): For R2D evaluation purposes, the R2D waveform for CP-OFDM is generated as: FFS details.**

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| **Company** | **Views** |
| EURECOM | For the CP-OFDM, we may follow the LP-WUS generation. |
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## 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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| AgreementFor R2D study OFDM-based waveform with subcarrier spacing of 15 kHz, *B*tx,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))
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### *M* values

It is already agreed that when *M*=1, we use OOK-1. Thus values for *M*>1 apply to OOK-4. There are comments that we should know something about data rate before deciding M, but since the two go together this does not seem to be a strict precondition.

Note that in UHF RFID, Tari ≥ 6.25 μs (for two chips) equating to a data rate approx. 107 kbps with PIE encoding.

**Proposal 2.2.1a(I): For 15 kHz SCS for R2D:**

* **Study at least the following pairs of {*M*, *B*tx,R2D}**
* **Study at least the data rates implied by the corresponding line code(s), if selected in other agreements**
* **FFS: In case CP handling alters the number of chips per OFDM symbol, values M’ *=* M ± 1 (M>1)**

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|  |  | **(Illustrative, may depend on other design details)** |
| ***M*** | **Btx,R2D # of PRBs (on a 2SB assmpt).** | **kilochips/s** | **kbps Manchester encoded** | **kbps PIE encoded with example of 0:1 = 2-chip:4-chip encoding** |
| **1** | 1 | 14 | 7 | 4.67 |
| **2** | 1 | 28 | 14 | 9.33 |
| **4** | 1 | 56 | 28 | 18.67 |
| **6** | 1 | 84 | 42 | 28 |
| **8** | 2 | 112 | 56 | 37.33 |
| **12** | 2 | 168 | 84 | 56 |
| **16** | 3 | 224 | 112 | 74.67 |
| **24** | 4 | 336 | 168 | 112 |
| **[32]** | [6] | 448 | 224 | 149.33 |

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| **Company** | **Views – especially:** 1. **Any entries your company objects?**
2. **Any other** **{*M*, *B*tx,R2D} your company thinks essential to support?**
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| EURECOM | We are generally fine with this kind of table. However, some combinations, e.g. M=6, 1 PRB, will result in very short chips and are hence extremely sensitive to timing errors and multi-path propagation.  |
| Qualcomm | We do not have a problem with the set of M values in the proposal. However we wonder whether double sideband modulation is the baseline for R2D. This should be discussed before determining the necessary bandwidth for each M. |
| vivo | For (i), we object M=16& 24 &32, which results in on OOK chip smaller than CP duration. For (ii), a couple of comments: (1) for ***B*tx,R2D** > 1 PRB, it is also possible to smaller M values (2) ***B*tx,R2D** can be up to 12 PRBs. So we suggest to revise 2nd column (***B*tx,R2D** ) of 1st ~4th rows to ‘1~12’, revise 2nd column (***B*tx,R2D** ) of 5th ~ 6th rows to ‘2/4/6/8/10/12’, Besides, we are not sure why we need to bundle this discussion with double sideband modulation. We suggest to remove ‘for double sideband modulation’ before we make progress on proposal 2.2.2a(I) to separate these two issues.  |
| Samsung | We wonder the necessity and performance of large M values e.g. M>16, especially considering CP handling and SFO impact. If companies show strong motivation to study that, we can live with it, but feel negative for now. |
| ZTE, Sanechips | For the main bullet, we don’t see the need to restrict the R2D transmission is 2SB or 1SB. More important issue is to choose a proper combination of RBs and M value to make sure the performance can meet the coverage and data rate requirements. Hence, the following is suggested for the main bullet:**For 15 kHz SCS for ~~double sideband~~ R2D modulation:**For the combination of M and Btx,R2D # of PRBs, i.e. {M, Btx,R2D # of PRBs}={16, 3} and {32, 6}, Btx,R2D # of REs can not be evenly divisible by M. We think that it should be clarified that the specific frequency resource allocation for the cases of {M, Btx,R2D # of PRBs}={16, 3} and {32, 6}.Moreover, we think that other combinations should not be precluded. For example, {M, Btx,R2D # of PRBs}={6, 2}, {6, 4}, {8,4} and {16,4} can be considered. |
| IDCC | We are in general fine with the values. For larger M values, we may first discuss the CP issue. |
| DOCOMO | We are fine to study values of M up to 32.However, we are not sure how the pair of {M, *B*tx,R2D} is derived in the table and need clarification. We also tend to agree with companies that the assumption on SSB/DSB should be discussed separately. |
| Huawei, HiSilicon | The table looks fine and we are supportive of FLS proposal. |

### Single / double sideband modulation

The proposals in the papers seem to offer M values for a 2SB modulation. There is not information yet for single sideband. Hence, FL suggests we begin design for 2SB and, if companies can provide details for 1SB, it can be also considered, since this characteristic of the R2D transmission is transparent to the device.

**Proposal 2.2.2a(I): Double sideband modulation is the first assumption for design.**

* **Single sideband modulation can be further studied, e.g. by providing detail values of {*M*, *B*tx,R2D} association, and waveform generation method.**

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| **Company** | **Views** |
| EURECOM | OK |
| Qualcomm | We wonder whether double sideband modulation is the baseline for R2D. This should be discussed before determining the necessary bandwidth for each M. |
| Wiliot | We do not agree. R2D should be SSB (as it is not a backscattered transmission). |
| vivo | We are still not clear about the relation between M value and double sideband modulation. By reading tdoc, it seems some company proposed only M=6 can achieve DSB, while proposal 2.2.1(a) include many M values other than 6 for DSB. More explanation on the relation of M and DSB would be appreciated.  |
| xiaomi | We support this proposal.We don’t support the single sideband, for intermediate UE as the reader, the complexity at the UE is increased with generation of the single sideband signal, it might require additional BB pass filter at the UE. |
| Samsung | OK with the proposal |
| ZTE, Sanechips | As we commented before, we don’t see the need to restrict the R2D transmission is 2SB or 1SB. More important issue is to choose a proper combination of RBs and M value to make sure the performance can meet the coverage and data rate requirements. |
| IDCC | Fine with the proposal. |
| DOCOMO | In our view, both DSB and SSB should be studied for each device type. We are also wondering the relation between M value and DSB/SSB assumption. |
| Huawei, HiSilicon | We think DSB is enough but can live with FLS proposal. |

## R2D line coding [ACTIVE]

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| **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.
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Removing the parts of the RAN1#116bis proposal that are now handled elsewhere; and FL noting from papers: the general convention for Manchester line coding; and that PIE, if used, is primarily motivated by having a longer high voltage duration, we have:

**Proposal 2.3a(I): The study assumes the following codewords:**

* **For Manchester encoding:**
	+ **bit 0→chips{01}, bit 1→chips{10}**
* **For PIE:**
	+ **bit 0→chips{10}, bit 1→chips{1110}.**
* **Note: The SI intends to further down-select between Manchester encoding and PIE.**

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| **Company** | **Views** |
| EURECOM | Concerning Manchester Coding, there is a significant SNR gain if multiple bits are encoded jointly. For instance, M=4, bits{00}🡪chips{0001}, bits{01}🡪chips{0010}, bits{10}🡪chips{0100} and bits{11}🡪chips{1000} will result in a single ON chip per OFDM symbol where all transmit power is concentrated, hence a 3dB SNR gain compared to encoding the 2 bits separately resulting in 2 ON chips.Therefore, we suggest to add multi-bit Manchester Encoding to the proposal. |
| Qualcomm | We prefer to have at least prioritization for Manchester coding. Otherwise, all the studies for R2D, including CP handling, M values of OOK-4, preamble/midamble/postamble discussion, etc, would be doubled. |
| Vivo  | For Manchester coding, theoretically, both **bit 0→chips{01}, bit 1→chips{10} and bit 0→chips{10}, bit 1→chips{01}** can be used. In LP-WUS and also other systems such as 802.11ba, it is assumed {10} for 0 and {01} for 1, because it can be simply a XOR operation of clock and bit information. So we suggest to use **bit 0→chips{10}, bit 1→chips{01}**For PIE coding, we are fine.  |
| xiaomi | We support this proposal. |
| IDCC | Agree with Vivo that for Manchester, we can use 0 🡪 falling edge and 1🡪 rising edge. |
| Futurewei | We would like to suggest adding a note that different codewords may be considered for CP handling. For example, to consider Alt 1-1 under **Proposal 2.1.1b(I),** at least the following codewords may be considered to satisfy the condition in that alternative at least for M = 4, 8* **For Manchester encoding:**
	+ **bit 0→chips{x00xx11x}, bit 1→chips{x11xx00x}, x** $\in \left\{0,1\right\}$
* **For PIE:**
	+ **bit 0→chips{1001}, bit 1→chips{11111001}.**

Therefore, we suggest the following modification**Proposal 2.3a(I): The study assumes the following codewords:*** **For Manchester encoding:**
	+ **bit 0→chips{01}, bit 1→chips{10}**
* **For PIE:**
	+ **bit 0→chips{10}, bit 1→chips{1110}.**
* **Note: The SI intends to further down-select between Manchester encoding and PIE.**
* **Note: Different codewords may be considered for CP handling**
 |
| DOCOMO | Support. |
| Huawei, HiSilicon | We are fine with the proposal. |

The general level of support seems to be for Manchester encoding to be preferred, since the availability of energy from RF to the level of several tens of seconds of charging time is not provided by the PIE codewords.

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| EURECOM | If the R2D data transmission is NOT used for energy harvesting, i.e. to power the receiver circuit like in passive RFID tags, then Manchester coding is preferred over PIE.  |
| Qualcomm | Agree with the proposal. |
| vivo | Support |
| xiaomi | We think PIE shall also be the candidate. For the energy harvesting time is up to several ms, the PIE can provide the energy efficiently. |
| Samsung | The motivation in RFID of using PIE for DL is for energy harvesting. A-IoT have similar issues, i.e. whether and how R2D signals needs to support energy harvesting.Therefore, we think the source of R2D energy harvesting needs to be decided at first. Given that no consensus on energy assumption, excluding PIE is not a wise decision for now. |
| ZTE, Sanechips | Okay with **Proposal 2.3b(I).** |
| DOCOMO | Support. |
| ETRI | Support the proposal. |
| Huawei, HiSilicon | We are fine with the proposal. |

## 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
 |

In RAN1#116bis, there was concern on the necessity of repetition in the physical layer for R2D, and no agreement was reach either way. In this meeting, most companies do not mention a need to support it, whatever the definition(s), but a couple of companies raise it. It may be better to come back to this if a coverage shortage is found in 9.4.1.1 evaluations.

(D2R repetition is discussed in Section 3.4).

**Proposal 2.4a(I): R2D transmissions are assumed to not use repetitions as baseline.**

* **Note: Repetitions can be discussed if justified based on the coverage evaluation results.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| EURECOM | Coverage extension techniques will likely be required. So better not agree on anything for moment. |
| Qualcomm | We think the proposal is not necessary – anyway no repetition should be baseline. However we think we also should consider repetitions for all device types. This, combined with bit scrambling, is a simple yet efficient method to improve the robustness against interference,  |
| vivo | Support  |
| xiaomi | We don’t support this proposal. Our simulation result demonstrates that the R2D has coverage problem, so the it is necessary to study the repetition for R2D transmission. |
| OPPO | We have evaluated the performance of repetition, and the result show the benefit of repetition. So we propose to support repetition for R2D transmission.  |
| Samsung | Not support this proposal. Coverage issue was raised by several companies as well as gain of repetition. For companies which show little interest on repetition, they can provide their own results with no repetition, but making such proposal with no repetition as baseline may not be good attitude to discover it. |
| ZTE, Sanechips | We think that it should not preclude the code rate of lower code rate and repetition schemes. |
| IDCC | We can discuss this issue after coverage analysis. |
| DOCOMO | We are fine to consider repetition for R2D but fine with the baseline as no repetition. |
| Huawei, HiSilicon | We are fine with the proposal. |

FL does not currently see sufficient support for detailed further study of other FECs for R2D, and since the coverage evaluation results may not show any need, does not develop a proposal at this time.

## R2D and D2R CRC [VOID]

**See Section 4.**

## R2D multiple access [ACTIVE]

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.**

|  |  |
| --- | --- |
| **Company** | **Views – FL does not see a way to reasonably deny this conclusion!** |
| xiaomi | Support. |
| Huawei, Hisilicon | We agree with the proposal. |
|  |  |

In terms of specific details of TDMA, it seems there is little raised in papers as needing further effort in this agenda item, since it will follow naturally as a consequence of timing relationship definitions, system access procedure, etc. Nonetheless, there is one general level constraint proposed as follows.

**Proposal 2.6b(I): Study whether it is necessary to define a guard time between successive transmissions in the time domain to account for device SFO**

|  |  |
| --- | --- |
| **Company** | **Views – including if this should be considered under another agenda item** |
| Qualcomm | Some detailed discussions are necessary on this (not just limited to account for device SFO). |
| vivo | Guard time is needed to count for device SFO. In addition, the successive transmissions in the proposal are for consecutive R2D transmissions, if so, we suggest to add R2D after successive. From our understanding, the guard time mainly accounts for device processing time, in addition to device SFO. Details can be discussed under 9.4.2.2. |
| xiaomi | Support. |
| OPPO  | Not understand the motivation of this proposal. Further clarification is needed. How to understand “successive transmission”? it is for two adjacent R2D transmission (including preamble and control part(if supported), or adjacent transmission such as R2D control part and PRDCH, or adjacent transmission of preamble and following R2D transmission? |
| Samsung | OK |
| ZTE, Sanechips | In our view, the guard time is being discussed under the Section 9.4.2.2. Or it needs to be clarified that the difference between definitions of guard time and the transmission timing discussed in Section 9.4.2.2. |
| Futurewei | Support to study whether it is necessary to define a guard time. |
| DOCOMO | We support to study whether/how large guard time is necessary. |
| Huawei, Hisilicon | In our understanding, the guard time between successive transmissions has been included in the study of timing relationship, which are TR2D\_R2D\_min and TD2R\_D2R\_min. |

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 2.6c(I): Regarding potential FDMA for R2D:**

* **Alt 1: Do not study for Rel-19.**
* **Alt 2: List aspects that require study for feasibility / benefits / necessity analysis, for all devices**

|  |  |
| --- | --- |
| **Company** | **Views** **If your company prefers Alt 2, appreciated if you can list some relevant aspects** |
| xiaomi | We support this proposal.We prefer alt1, it is not feasible for R2D FDM, because device cannot distinguish two signals based on envelope detection. |
| OPPO | We support alt 2. In our view, if device support BPF, it is feasible to support FDMA among devices. The following aspects can be considered for further study:* Bandwidth of each R2D transmission;
* RF bandwidth of device’s filter;
* Whether guardband is needed for adjacent R2D transmission in frequency domain;
 |
| Samsung | We don’t believe FDMA for R2D can be feasible at least if we keep a consistent design for device 1/2a/2b. Alt 1 is OK and we disagree with Alt 2. |
| Futurewei | FDMA might be feasible for Device 2b with IF-ED and Zero IF receivers. Alt 2 is fine to list instead of study.  |
| DOCOMO | We are fine with the proposal and prefer Alt.2 for IF-ED and ZIF device. |
| ETRI | Support. Prefer Alt 1. |
| Huawei, Hisilicon | We prefer Alt 1.FDMA is infeasible for devices with RF-ED receiver, as narrowband RF band-pass filter is too complicated and power consuming for Ambient IoT devices. Considering the typical traffic model of inventory, in which almost all the R2D messages are small size, the R2D capacity should not be the bottleneck, which does not need to be improved by FDMA. |

## 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 |

Deriving from the previous FL proposals, there are proposals to establish that the transmitter perspective, i.e. for specification purposes, should define a basic time unit that is equal to what is used in NR, i.e. *Tc*. Perhaps it only has applicability to evaluation purposes for knowing how to generate a R2D waveform commonly in simulators. Hence, see Section 2.1.2 instead.

In the previous meeting, FL attempted to define chips by reference to the line code they represented. A number of companies this time have suggested that instead it is more convenient to refer to the unit of baseband (OOK) modulation.

FL agrees, and thinks we need two stages in the definition. First, what does a chip represent?; second, what is a chip’s duration?

FL anticipates there may be question on what is a modulated symbol in the below proposal. The answer is that it’s that part of the output OFDM waveform which results from the various transform steps that are performed on one line code chip.

**Proposal 2.7.2a(I): In R2D, the smallest time unit of resource allocation is a line-code chip**

* **A line-code chip corresponds to one modulated symbol, e.g. according to agreed OOK modulation.**
* **Line-code chip duration = (1/M) × OFDM symbol duration, FFS: without or with CP duration.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| EURECOM | This looks agreeable to us. However, what does coding have to do with the definition? The chip duration is (1/M) x OFDM duration, which depends only on the OOK modulation parameter M. Hence, we propose to remove “line-code” in the definition. Moreover, the chip duration should be defined WITHOUT CP duration. |
| xiaomi | For the second sub-bullet, to reuse DL transmitter, CP needs to be considered, so the first OOK chip includes the CP part. Therefore, we make the following update: **Proposal 2.7.2a(I): In R2D, the smallest time unit of resource allocation is a line-code chip*** **A line-code chip corresponds to one modulated symbol, e.g. according to agreed OOK modulation.**
* **Line-code chip duration = (1/M) × (OFDM symbol duration), ~~FFS: without or with CP duration.~~**
	+ **The first OOK chip includes the CP part**
 |
| ZTE, Sanechips | In our view, chip duration is equal to (1/M) × OFDM symbol duration. Please clarify that the difference between line-code chip duration and chip. Moreover, for R2D signal such as preamble, or postamble if any, the line code may not be applied. |
| Futurewei | The proposal is fine as a starting point. |
| Huawei, Hisilicon | We agree with the proposal.Regarding the FFS, the OFDM symbol duration does not include the CP duration for the calculation of the chip duration, as device can skip the CP during its line code decoding by transition edge detection. |

## R2D bandwidths [ACTIVE]

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| --- |
| **Agreement** RAN1#116At least the following bandwidths for R2D are defined for the purpose of the study:* Transmission bandwidth, *B*tx,R2D from a Reader perspective: The frequency resources used for transmitting R2D
* Occupied bandwidth, *B*occ,R2D from a Reader perspective: The frequency resources used for transmitting R2D, and potential guard band
* Bocc,R2D ≥ *B*tx,R2D
	+ FFS: Further constraint(s) e.g. Bocc,R2D = *B*tx,R2D.
	+ Possible values of each bandwidth are FFS
 |
| AgreementFor R2D study OFDM-based waveform with subcarrier spacing of 15 kHz, *B*tx,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 *B*tx, R2D, see section 2.2.1.

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

# D2R

## D2R waveform [ACTIVE]

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 waveform(s) is/are such that they can be used by all devices 1/2a/2b.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| Qualcomm | We think this needs some discussion. Essentially, devices that generates carrier wave internally do not need to enable small frequency shift via MMS or square wave. Whether the D2R waveform must be exactly same or can be different for different device types needs some discussions. |
| Wiliot | We disagree. The waveforms are different between a backscatterer transmitting DSB and active device transmitting SSB (even if both using e.g. OOK or MSK) |
| xiaomi | We think device 1 and device 2a can use the same waveform which is unmodulated single tone or multiple unmodulated single tone. For device 2b, the device can use the different waveform with the device 1 and device 2a, because the device 2b has high ability.  |
| Futurewei | If the D2R waveform refers to the unmodulated single tone, then it is feasible to be used by all devices 1, 2a, 2b.  |
| Huawei, HiSilicon | We are fine with FLS proposal. |

## 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
 |

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, some companies mentioned different BFSK in their papers while similar number of 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:

**Proposal 3.2.1(I):**

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

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| --- | --- |
| **Company** | **Views** |
| Qualcomm | We would like to know general understanding here. More specifically, we would like to understand whether this proposal is to make an agreement on baseband data modulation schemes, or backscatter modulation schemes.If the intention is to discuss baseband modulation schemes, then it is not clear why we will further discuss D2R line coding. So, our understanding is that the first bullet is intended to discuss backscatter coefficient modulations.If the first bullet is to discuss backscatter coefficient modulations, then it is not clear why FSK is part of this proposal. FSK should be one baseband data modulation scheme and is not relevant to backscatter coefficient modulations. |
| Wiliot | We do not believe device 2b nor device 2a nor device 1 can transmit BPSK within SID defined limitations. We are OK with either variants 2-4 for Binary FSK. We propose:Study for all devices the following for D2R baseband modulation, for potential down-selection:* OOK (with an additional line code for device 1 and device 2a)
* MSK
 |
| vivo | We are fine with 1st bullet. For -BFSK, we support **Variant 5** |
| xiaomi | We only support the OOK and Binary PSK. FSK has the lowest resource utilization because this scheme occupies doubled frequency resource than PSK and OOK,so it is not preferred. |
| Samsung | OK with the proposal. |
| IDCC | Fine with the proposal. |
| Futurewei | The proposal is fine.  |
| Ericsson | We are fine to identify MSK or GFSK or GMSK at this meeting as the one variant of BFSK to study further. No further down-selection or prioritization is needed at this point. |
| Huawei, HiSilicon | We think OOK and BPSK should be the basic D2R modulation for devices.The BFSK is still unclear in many aspects which has been analysed in our paper. We are OK to list potential candidates for further strive identify. If it is going to down select, our preference is go with Variant 5. |

### Single / double sideband

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.

**Proposal 3.2.2a(I): 2SB modulation is supported.**

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

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| --- | --- |
| **Company** | **Views** |
| Qualcomm | OK with the proposal (probably better to replace “supported” by “considered”).  |
| vivo | Fine with the proposal.We share same view with FL that 1SB is infeasible at least for device 1/2a, while 1SB may be feasible for device 2b.  |
| xiaomi | We support the 2SB.1SB signal is not preferred, the complexity on device is high with additional BB pass filter to generate 1SB signal. |
| Samsung | OK with the proposal. |
| ZTE, Sanechips | The following is suggested**2SB modulation is supported for D2R transmission.** |
| IDCC | Ok with the proposal. |
| Futurewei | Support since 2SB has lower complexity than 1SB generation at the device. |
| Huawei, HiSilicon | We don’t see any problem that stop all devices supporting 2SB. Thus we are fine with FLS proposal. |

## D2R line coding [ACTIVE]

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| --- |
| **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
 |

It seems there is sufficient commonality to define the basic codewords for the D2R line codes, and this is done in Proposal 3.3a, which is some kind of reference set of codewords, to be used in a next step, Proposal 3.3b for small frequency-shift.

There is the related proposal in Section 3.7 which defines the further detail of time duration.

**Proposal 3.3a(I): The study assumes the following codewords corresponding to an information bit 0 or bit 1, before considering potential small frequency-shifting:**

* **For Manchester encoding:**
	+ **bit 0→chips{01}, bit 1→chips{10}**
* **For FM0:**
	+ **If the immediately previous chip is 1, bit 0 → chips {01}, otherwise bit 0 → chips {10}.**
	+ **If the immediately previous chip is 1, bit 1 → chips {00}, otherwise bit 1 → chips {11}.**
* **For Miller:**
	+ **According to Figure 6-12 of UHF RFID standard.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| EURECOM | Concerning Manchester Coding, there is a significant SNR gain if multiple bits are encoded jointly. For instance, M=4, bits{00}🡪chips{0001}, bits{01}🡪chips{0010}, bits{10}🡪chips{0100} and bits{11}🡪chips{1000} will result in a single ON chip per OFDM symbol where all transmit power is concentrated, hence a 3dB SNR gain compared to encoding the 2 bits separately resulting in 2 ON chips.Therefore, we suggest to add multi-bit Manchester Encoding to the proposal. |
| Qualcomm | OK |
| vivo  | For Manchester coding, similar as comment for R2D, **bit 0→chips{10}, bit 1→chips{01}** is slightly preferred. For FM0, why don’t we also direct use Figures in RFID? Figure 6-8 & 6-9 of UHF RFID standard  |
| xiaomi  | We are fine with this proposal.We are confused whether the two sub-bullets under the FM0 are for down selection. |
| Samsung | For FM0, the codeword generation method in the proposal is different with the FM0 generator state diagram in RFID, and we are unclear with the motivation. The RFID generation method benefits from voltage transition existed at boundary of code-chips, thus can have better performance than it shown in the proposal. |
| IDCC | Similar comment regarding Manchester as before (0🡪 falling edge, 1🡪 rising edge). Agee that for FM0 we can use the RFID specification. |
| Futurewei | OK |
| DOCOMO | We are fine with the proposal. |
| ETRI | Fine with the proposal. |
| Huawei, HiSilicon | We are fine with the proposal. |

**Proposal 3.3b(I): For Manchester and Miller line codes, small frequency-shifts are produced using repetition of the codewords within the same time duration corresponding to an information bit.**

* **Details FFS**

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| --- | --- |
| **Company** | **Views** |
| Qualcomm | For Miller of UHF RFID, small frequency-shifts are produced by XOR between Miller basis and square wave with higher frequency. Therefore, it does not make sense to consider repetition of the codewords.For Manchester, if we enable small frequency shift, it also makes sense to follow the same way, i.e., the Manchester encoded waveform is XORed with square wave with higher frequency. For example, if Manchester coded chips is {01} and square wave for frequency shift is {0101}, the resultant waveform is {0011} \* {0101} = {1001}.  |
| vivo | Not sure ‘using repetition of the codewords within the same time duration corresponding to an information bit’ is accurate description for Miller line code. For Miller-X, it is generated by multiplying square waves in a bit period with the coded bit. For information bit ‘1’, it can be seen that 8 chips for the information bit in case of M=4 it is not a repetition of the case of M=2, e.g., for ‘001’, [off on off on on off on off] for M=4 vs [off on on off] for M=2case, because the transition in the middle of the coded bit leads to different repetitions. Actually, the repetition within a bit period is square wave, not repetition of codewords. In our understanding, small frequency shift can be generated by adjusting BLF, which is applicable for FM0, Manchester coding and Miller. But FM0 does not support code extension as in by RFID. In other words, FM0 can not support different small frequency shift while keeping same data rate.  |
| xiaomi | We support this proposal. |
| OPPO | It is not clear about “**time duration corresponding to an information bit**”. Further clarification is needed.  |
| Samsung | For Miller encoding, we also consider “using repetition of the codewords” does not make sense. For Manchester encoding, we can accept to justify performance of this solution, but it’s too early to directly make an agreement. |
| IDCC | We agree with Qualcomm that frequency shift is enabled by subcarrier modulation (the same concept as in OFDM where modulation symbol is shifted to a specific frequency by modulating with a corresponding subcarrier). Repetition of a codeword cannot be generalized, it is just a results of a special case. So, we prefer to use subcarrier modulation method. |
| Huawei, HiSilicon | We are fine with the proposal. |

**Proposal 3.3c(I): The study does not further consider FM0 line encoding.**

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| --- | --- |
| **Company** | **Views** |
| Qualcomm | OK with the proposal. But does this mean that for M=1, the only solution of D2R line coding is Manchester coding? |
| vivo | Considering FM0 has better performance than Miller, we think FM0 can still be useful at least when FDMA is not used.  |
| xiaomi | Yes.We think two kinds of Line code is sufficient. |
| Samsung | It unclear whether “The study” means small frequency shifts or the total D2R line encoding. If the intention is the latter case, we don’t think it is good way to exclude FM0 encoding in the current stage, given that FM0 encoding has its benefits in some scenarios. |
| IDCC | Agree that maybe first we should have some more analysis. |
| Huawei, HiSilicon | We are fine with the proposal. |

The following is FL’s effort to describe the square-wave generation based proposal at similar level of detail as using line codes, to achieve equivalent functions, that being FL’s understanding of the idea. Proponents are welcome to correct the proposal in their responses.

**Proposal 3.3d(I): The study of ‘no line code’ assumes that an information bit is XOR’d with a square wave having a frequency such that a desired small frequency shift, equivalent to one achievable using a line code in Proposal 3.3a + 3.3b, is achieved.**

* **Details FFS**

|  |  |
| --- | --- |
| **Company** | **Views** |
| Qualcomm | The modulation of “no line coding” is enabled in the following way:* A bit is modulated by amplitude(s), frequency(ies), and/or phase(s) of the square wave with the certain frequency
	+ E.g., with a square wave with the frequency 2f where f is 1/(bit length), bit-1 and bit-0 are modulated as follows:
		- OOK: bit-1 => {0101}, bit-0 => {0000}
		- FSK: bit-1 => {0101}, bit-0 => {0011} (a bit modification needed for MSK)
		- PSK: bit-1 => {0101}, bit-0 => {1010}

Whether the above is identical to any of the options in proposal 3.3a and 3.3b is not yet clear.For D2R, so far we do not see a proposal or evaluation result that uses features of line coding. Almost all companies consider coherent receiver or non-coherent receiver that uses correlation. We still do not see a critical need of line coding for D2R. |
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## 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 |

|  |
| --- |
| **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 |

### Repetition

The agreement in RAN1#116bis left “repetition” undefined, and companies have kindly provided various definitions. FL collects them there, so we can have a common basis of further discussion. There is a following proposal to choose among them.

**Proposal 3.4.1a(I): Define for study purposes repetition types as follows:**

* **Block level or PDRCH-level: The whole block of bits received from higher layers is repeated Rblock times before other physical-layer processing**
* **Bit level: Each bit after CRC attachment (if used) is repeated Rbit times**
	+ **NOTE: Equivalent to line-code codeword level repetition**
* **FEC codeword level: Each set of bits in a codeword after FEC encoding is repeated Rfec times**
	+ **NOTE: For a rate 1/R convolutional code, a codeword is R consecutive coded bits**
* **Chip level: Each chip after line coding is repeated Rchip times**
	+ **NOTE: Equivalent to extending the duration of each chip by Rchip times**

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| --- | --- |
| **Company** | **Views** |
| Qualcomm | On the first bullet, it would be clearer to delete “or PDRCH-level”.  |
| vivo | A couple of clarification questions: 1. Is ‘Block level or PDRCH-level’ same as TB-level repetition? What’s the motivation of doing repetition before other physical-layer processing, e.g., before adding CRC ?

Not sure bit level repetition is same as codeword level repetitions. For example, if ‘1’ is repeated 2 times before line coding, do we expect transition between these repetitions or no transition? If no transition, it implies a long high voltage or long low voltage.  |
| xiaomi | we are fine with this proposal. |
| Samsung | OK with the proposal at high level |
| IDCC | Fine with the proposal. |
| Huawei, HiSilicon | We are fine with the proposal. |

Based on the papers, FL understands that according to above definitions, chip-level is the same as having longer chips or lower M value, hence does not seem to be necessary to include as a repetition method. There is only one company proposing FEC codeword level repetition. Hence the following proposal:

**Proposal 3.4.1b(I): The study supports at least block-level and bit-level repetition for D2R.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| Qualcomm | OK. Suggest to replace “supports” by “includes”. |
| vivo | OK |
| xiaomi | We support block level repetition. Because for bit-level repetition, the benefit is not minor. Because one bit is decoded incorrectly which causes that the whole TB also be decoded incorrectly. |
| Samsung | OK |
| DOCOMO | Support. |
| Huawei, HiSilicon | We are fine with the proposal. |

### FEC

For convolutional code, 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 shortening its 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 3.4.2a(I): For convolutional codes, the LTE convolutional code polynomials are the baseline. Other designs can be studied subject to:**

* **Constraint length of each shift register is not longer than in LTE, i.e. constraint length K ≤ 7.**
* **Code rate is not higher than in LTE, i.e. code-rate R ≤ 1/3.**
* **FFS other details, e.g. shift-register initialization/termination.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| Qualcomm | We think it is premature to setup baseline. We think it is reasonable to say LTE TBCC is a reference to discuss D2R channel coding schemes. Regarding constraint length, we see different pros/cons of longer/shorter variants. We would like to keep it open for now. Another important aspect is interleaver. We understand it is quite difficult to enable full brown interleaver for A-IoT D2R. Nevertheless, we would like to keep FFS to see if it is possible to enable a simple interleaving method. |
| Huawei, HiSilicon | We are fine with the proposal. |
|  |  |

For “FFS if other FEC candidates/methods will be studied”, there are not enough proposals to justify bringing a specific proposal for others at this time.

## 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. |

To understand the pros and cons of frequency-domain multiple access and code-domain multiple access for D2R transmissions, FL collects the technical aspects to be considered from papers.

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

* **Maximum supported small frequency shift**
	+ **Note: The detailed design of small frequency shifting is discussed in Section 3.3.**
* **The impact of SFO**
* **The impact of harmonics in the backscattered signal**
* **The potential gain of D2R transmission efficiency by FDMA comparing to only TDMA**

|  |  |
| --- | --- |
| **Company** | **Views**  |
| Qualcomm | We consider it is also good to understand how D2R receiver de-multiplexes the (asynchronously received) FDMAed D2R transmissions. This must not be like OFDMA-based de-multiplexing. Same question for CDMAed D2R transmissions. |
| Vivo | support, but need some clarification. Another aspect to consider/clarify is, TDMA and FDMA means multiple TDMed/FDMed D2R transmission scheduled/triggered by one R2D control information, or it can also by multiple R2D control information, i.e., one-to-multiple scheduling or one-to-one scheduling.  |
| xiaomi | We think the FDM between the devices with large frequency shifting (e.g., from DL to UL, or from UL to DL) shall also be studied, so we make the following update:**Proposal 3.6a(I): For frequency-domain multiple access of D2R transmissions, study at least the following aspects:*** **Maximum supported small frequency shift**
	+ **Note: The detailed design of small frequency shifting is discussed in Section 3.3.**
* **Large frequency shifting （**e.g., from DL to UL, or from UL to DL**）**
* **The impact of SFO**
* **The impact of harmonics in the backscattered signal**
* **The potential gain of D2R transmission efficiency by FDMA comparing to only TDMA**
 |
| Samsung | OK |
| ZTE, Sanechips | For the frequency-domain multiple access of D2R transmissions, another point worth investigating is the collision impact on the transmission performance in access procedure. Unlike TDMA where the number of slots per frame determines the collision probability between transmissions from different UEs, the FDMA approach can only rely on the number of small frequency shifts supported, ranging for {M=2,4,8}, the collision probability for two concurrent transmissions within the same slot is at least 50% which degrades largely the overall performance.Moreover, the impact of timing offset and frequency offset, how to use the time-frequency resource to carry information and the clarification of FDM parameters should be considered for the study of FDM of D2R transmission. Therefore, the proposal is modified as followings:**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**
	+ **Note: The detailed design of small frequency shifting is discussed in Section 3.3.**
* **The impact of SFO/frequency offset**
* **The impact of harmonics 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**
 |
| Futurewei | A question for clarification: Is the proposal applicable to Device 1, 2a and 2b? * The first sub-bullet is only applicable to Device 1 since it refers to “Maximum supported small frequency shift”
* The other sub-bullets are applicable to all devices

Large frequency shift is still under discussion in AI 9.4.1.2. for Device 2a.  |
| Huawei, Hisilicon | We agree with the proposal. |

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

* **How CDMA is used for D2R transmissions carrying information in the same time-frequency resource**
* **The impact of SFO**
* **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**

|  |  |
| --- | --- |
| **Company** | **Views**  |
| Qualcomm | We consider it is also good to understand how D2R receiver de-multiplexes the (asynchronously received) CDMAed D2R transmissions. |
| xiaomi | support |
| Samsung | OK |
| ZTE, Sanechips | In the previous meeting, it was agreed to study the feasibility of CDM and we provides simulation results to justify the feasibility of CDM under the cases of SFO and power difference between devices. In addition, our understanding towards the first bullet is whether the CDMA is used by applying spreading code to data or replacing the data with sequences, but we are confused what 'in the same t-f resource' refers to here. If it means applying the same t-f resource as TDMA or FDMA, then we believe this should apply to the previous proposal as well.The following is suggested:**Proposal 3.6b(I): For considering feasibility and necessity of code-domain multiple access of D2R transmissions for all devices, study at least the following aspects:*** **How CDMA is used for D2R transmissions carrying information (e.g. spreading the data, replacing data with spreading sequence, or via sequence) ~~in the same time-frequency resource~~**
 |
| DOCOMO | We are supportive to study CDMA and we would like to note that spectrum spread with pseudo orthogonality which does not require complete orthogonality can be a good candidate for the CDMA scheme with such large SFO of A-IoT device. |
| Huawei, Hisilicon | We agree with the proposal. |

## 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 |

As with R2D, we should define what is a chip, and try to be independent of each type of line code, based on the submitted papers. In D2R, the chip duration has a relationship with the possibility of a small frequency shift, by methods within Manchester and Miller linecodes. FL would like to take that discussion in section 3.3 and in this proposal produce a generally-applicable definition.

Hence, in option 1 below, FL believe it is likely to be necessary to come back in a second stage to define what the calculation is exactly, depending on which line code.

**Proposal 3.7a(I): In D2R, the smallest time unit of resource allocation is a (line code) chip**

* **A (line code) chip corresponds to one modulated symbol**
* **(Line-code) chip duration is:**
	+ **Option 1: Calculated according to the transmission bandwidth and amount of a small frequency shift.**
		- **FFS: The detailed bandwidth, e.g., double sideband transmission bandwidth, or, BLF.**
		- **FFS: Exact calculation details according to line code design, e.g.** $\frac{a reference chip length corresponding to Btx,D2R}{frequency-shifting factor}$
	+ **Option 2: One of a pre-defined set of pulse time durations.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| Qualcomm | This depends on whether to use D2R line coding, and whether or not device 2b D2R waveform generation is identical to the backscatter devices. |
| xiaomi | We think reader needs to know the chip length for the D2R transmission, and the chip length for the D2R transmission can be different or same with the chip length for R2D transmission. And for option2, we understand the pulse duration is the chip duration, so we make the following update:**Proposal 3.7a(I): In D2R, the smallest time unit of resource allocation is a (line code) chip*** **A (line code) chip corresponds to one modulated symbol**
* **(Line-code) chip duration is:**
	+ **Option 1: Calculated according to the transmission bandwidth and amount of a small frequency shift.**
		- **FFS: The detailed bandwidth, e.g., double sideband transmission bandwidth, or, BLF.**
		- **FFS: Exact calculation details according to line code design, e.g.** $\frac{a reference chip length corresponding to Btx,D2R}{frequency-shifting factor}$
	+ **Option 2: One of a pre-defined set of ~~pulse~~ chip time durations.**
 |
| Huawei, Hisilicon | We agree with the definition of chip, and prefer Option 1 for the calculation of the chip duration. The exact chip duration can be determined corresponding to the D2R transmission bandwidth and the detailed frequency shifting method. |
|  |  |

## D2R bandwidths [ACTIVE]

|  |
| --- |
| AgreementThe following bandwidths for D2R are defined for the purpose of the study:* Transmission bandwidth, *B*tx,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, *B*occ,D2R: The transmission bandwidth plus the potential associated intra A-IoT guard-bands totalling *B*guard,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 >= *B*tx,D2R
	+ Possible values of each bandwidth are FFS
 |

### Bandwidth sizes

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 single tone. 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 *B*occ,D2R of the D2R transmission 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**

**NOTE: Carrier wave is internal or external to device as appropriate.**

**Proposal 3.8.1b(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**

**NOTE: Carrier wave is internal or external to device as appropriate.**

**Proposal 3.8.1c(I): For Bguard,D2R, companies are invited to propose values which:**

* **Would be necessary due to SFO value X**
* **Would support narrowband filtering by e.g. IF band-pass filter or BB low-pass filter with negligible performance impact at the D2R receiver**

**Note: For Device 1 and 2a, Bguard,D2R corresponds to the unmodulated single-tone carrier-wave.**

**Note: The required frequency gap between the tones in the multiple unmodulated single-tone carrier-wave is studied in 9.4.2.4.**

|  |  |
| --- | --- |
| **Company** | **Views on Proposals 3.8.1a, b, c** |
| vivo | OK with proposal 3.8.1.a to define ***B*occ,D2R** per single tone. For 3.8.1.b, considering the transmission bandwidth is determined by data rate, which may or may not be an integer number of PRBs or REs, so both Alt 1 and Alt 2 is not correct. Or, do we expect to restrict the data rate to align with integer number of PRBs or REs? For proposal 3.8.1c, for guard band, in addition to SFO, don’t we need to consider of spectrum leakage, harmonics ? Besides, Guard band also needs to consider CFO for device 2b.  |
| xiaomi | For the Proposal 3.8.1a and Proposal 3.8.1c, we think the design of guard band is up to RAN4, this can be postponed when RAN4 has conclusion about the guard band.Proposal 3.8.1b ,we support the alt2, because the transmission bandwidth can smaller than one PRB according the calculation. |
| Futurewei | OK. For NR in-band operation, prefer Alt 1: An integer number of PRBs for Proposal 3.8.1a(I) and Proposal 3.8.1b(I). |
| Huawei, Hisilicon | We agree the proposal for Bguard,D2R, and prefer Alt 2 for Btx,D2R.As the power of the backscattered signal or the transmit power of Device 2b is expected to be low (e.g., ≤-10 dBm), coverage enhancement techniques is needed to improve the D2R link budget. Sub-PRB transmission is helpful to achieve efficient coverage enhancement for the devices in bad coverage. To achieve appropriate peak data rate, the transmission bandwidth larger than 1 PRB should also be supported. The integer multiple of SCS for Btx,D2R conveniently include both the above cases.The corresponding value of Bocc,D2R for each Btx,D2R can be further determined by considering the aspects described in Proposal 3.8.1(C). |

# 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
 |

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.

**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**

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

|  |  |
| --- | --- |
| **Company** | **Views, including value of X** |
| OPPO | It needs to clarify if repetition is applied to block or information bit, whether the Z represented the number of bits after repetition or not? |
| Samsung | OK with the spirit. Considering payload sizes are not finally agreed yet, we prefer to add brackets for the exact value, and maybe not necessarily to list the two options now. |

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, which belong primarily to RAN2, so would keep this at high-level in RAN1 for the time being at least.

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

* **Companies to identify potentially applicable maximum number of bits Z=Y < X**
* **Companies to identify potentially applicable message(s)/channel type(s)**

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

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.

# Proposals for online sessions

## Tuesday AM

FL: Tracking shows changes after the Mon & Tue offlines.

**Proposal 2.1.1a(II): For potential down-selection of the design for Method Type 1, study the following regarding CP location/length determination for Method Type 1:**

* + **Alt 1: CP length of each OFDM symbol is known by device**
	+ **Alt 2: Device assumes same CP length for each OFDM symbol, i.e. does not distinguish exact CP length among different OFDM symbols**
	+ **Alt 3: Invalid duration between transition edges is utilized by device to determine CP location/length**
* **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.**
* **Companies should report the values of SFO, and SFO detection methods used in evaluations**

**Proposal 2.1.1b(II): For potential down-selection of the design for Method Type 2, study the following options regarding subcarrier orthogonality:**

* **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**
* **Alt 1-2: Ensure a transition edge occurs at the start/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**
* **E.g., CP is copied from the beginning of an OFDM symbol**
* **E.g., split CP insertion among the chips of an OFDM symbol**
* **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**

**Proposal 3.2.2a(II): 2SB modulation is supported for D2R.**

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

**Proposal 3.4.1a(II): Define for study purposes repetition types as follows:**

* **Block level: The whole block of bits received from higher layers is repeated Rblock times before other physical-layer processing**
* **Bit level: Each bit after CRC attachment (if used) is repeated Rbit times**
	+ **NOTE: Equivalent to line-code codeword level repetition**
* **FEC codeword level: Each set of bits in a codeword after FEC encoding is repeated Rfec times**
	+ **NOTE: For a rate 1/R convolutional code, a codeword is R consecutive coded bits**
* **Chip level: Each chip after line coding is repeated Rchip times**
	+ **NOTE: Equivalent to extending the duration of each chip by Rchip times**

**Proposal 3.4.1b(I): The study supports at least block-level and bit-level repetition for D2R.**

**Proposal 3.3a(II): The study assumes the following codewords corresponding to an information bit 0 or bit 1, before considering potential small frequency-shifting:**

* **For Manchester encoding:**
	+ **bit 0→chips{01}, bit 1→chips{10}**
* **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.**

# Summary

# References

1. R1-2403842 General aspects of physical layer design for Ambient IoT Ericsson
2. R1-2403860 Discussion on physical layer design for Rel-19 Ambient IoT devices FUTUREWEI
3. R1-2403881 Discussion on general aspects of physical layer design for Ambient IoT TCL
4. R1-2403888 General aspects of physical layer design for Ambient IoT Nokia
5. R1-2403954 On general aspects of physical layer design for Ambient IoT Huawei, HiSilicon
6. R1-2404005 Discussion on Physical Layer Design for Ambient-IoT EURECOM
7. R1-2404028 Discussion on general aspects of physical layer design for Ambient IoT Spreadtrum Communications
8. R1-2404117 Considerations on general aspects of Ambient IoT Samsung
9. R1-2404179 Discussion on General Aspects of Physical Layer Design vivo
10. R1-2404286 On general physical layer design aspects for AIoT Apple
11. R1-2404345 On General Physical Layer Design Considerations for Ambient IoT (internet of things) Applications Lekha Wireless Solutions
12. R1-2404403 Discussion on general aspects of physical layer design CATT
13. R1-2404429 Discussion on general aspects of physical layer design for Ambient IoT China Telecom
14. R1-2404458 Discussion on general aspects of A-IoT physical layer design CMCC
15. R1-2404502 General aspects of physical layer design for Ambient IoT Sony
16. R1-2404556 Discussion on general aspects of physical layer design for Ambient IoT ZTE, Sanechips
17. R1-2404592 Consideration on general aspects of physical layer Fujitsu
18. R1-2404620 Discussion on physical layer design of Ambient IoT Xiaomi
19. R1-2404674 Discussion on general aspects of ambient IoT physical layer design NEC
20. R1-2404743 General aspects of physical layer design for Ambient IoT Panasonic
21. R1-2404775 Discussion on general aspects of physical layer design ETRI
22. R1-2404870 Discussion on general aspects of physical layer design of A-IoT communication OPPO
23. R1-2404890 General aspects of Ambient IoT physical layer design LG Electronics
24. R1-2404941 Discussion on the physical layer design aspects for Ambient IoT devices Lenovo
25. R1-2404959 Discussion on general aspects of physical layer design for Ambient IoT InterDigital, Inc.
26. R1-2404962 Discussion on general aspects of physical layer design Sharp
27. R1-2405044 Study on general aspects of physical layer design for Ambient IoT NTT DOCOMO, INC.
28. R1-2405078 General aspects of physical layer design MediaTek Inc.
29. R1-2405124 Discussions on general aspects of physical layer design for Ambient IoT Ruijie Networks Co. Ltd
30. R1-2405157 General aspects of physical layer design Qualcomm Incorporated
31. R1-2405216 Discussion on physical layer design for Ambient IoT Comba
32. R1-2405224 General aspects of physical layer design for Ambient IoT ITL
33. R1-2405242 Discussion on General aspects of physical layer design CEWiT
34. R1-2405269 Ambient IoT – General aspects of physical layer design, performance for uplink modulation Wiliot Ltd.
35. R1-2405298 Discussion on General aspects of physical layer design for 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, *B*tx,R2D from a Reader perspective: The frequency resources used for transmitting R2D
* Occupied bandwidth, *B*occ,R2D from a Reader perspective: The frequency resources used for transmitting R2D, and potential guard band
* Bocc,R2D ≥ *B*tx,R2D
	+ FFS: Further constraint(s) e.g. Bocc,R2D = *B*tx,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, *B*tx,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, *B*occ,D2R: The transmission bandwidth plus the potential associated intra A-IoT guard-bands totalling *B*guard,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 >= *B*tx,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.

**R1-2403678** Feature Lead Summary#3 for 9.4.2.1: “Ambient IoT – General aspects of physical layer design” Moderator (Huawei)

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, *B*tx,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