**3GPP TSG RAN-WG1 Meeting #119 R1-24xxxxx**

**Orlando, USA, 18-22 November, 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]))

For RAN1#119, some of the endorsed TPs from RAN1#118bis are updated per company requests. There is the usual comments table beneath such updates, but there is no need for general “yes/OK” etc. inputs. It’s sufficient for the involved companies to correct any mistakes.

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.

## Versions

FLS #1: R1-24xxxxx

# R2D

## R2D waveform

### 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

Agreement RAN1#117Study 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 RAN1#118bis*{A TP was agreed. Omitted here.}* |

#### Round 1

For CP handling, a lot of TP were agreed and captured into the TR in last meeting. From reading papers to this meeting, feature lead noticed two things.

One is that several companies keep the proposal in their papers to consider only normal CP for the study. Referring to RAN1#118 (Maastricht), feature lead indeed had such a ‘**Proposal 2.1.1a(I)’** in the summary (R1-2407249) which seems fine with that proposal from all the replies at that time but it was pointed out that it’s a natural consequence of only having agreed to NR SCS of 15 kHz. Hence FL thinks no specific proposal is needed.

Another is a few companies want to add more observations into the structure of TR which basically having two types of the text proposal: about detail design solutions or about high level views to agreed framework of alternatives including simulation observations. Feature lead would keep the same approach in last meeting that details of solution design related to things among which further down-selection belongs to any potential normative phase. Thus, here only takes text proposal updating about the later one.

In addition, 3 company mentions also the potential benefit from different CP handling alternatives. Feature lead understand the intention, however, the logic not having bullet of benefit was because they are implied by absence of an impact and we would have to state/repeat many obvious things about e.g. OFDM waveforms, etc. Overall, in above sense, the following update is proposed which collected from papers.

**Proposal 2.1.1(I): Capture the following TP update into TR 38.769**

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| *…(unchanged parts omitted)…*For Method Type 1, at least for Alt M1-1, device needs to be aware of or determine the boundary of an OFDM symbol (i.e. the beginning of an OFDM symbol) to determine CP location, including the start and the length of CP. Alt M1-1 and/or Alt M1-2 (if both are supported) can be up to device implementation which may depend on M values.- Some sources [R1-9421-1], [R1-9421-4], [R1-9421-3], [R1-9421-15], [R1-9421-14], [R1-9421-25], [R1-9421-28], [R1-9421-22], [R1-9421-31] [R1-9421-6], [R1-9421-21], [R1-9421-27] report device needs to be aware of or determine the boundary of an OFDM symbol (i.e. the beginning of an OFDM symbol) to determine CP location- Some sources [R1-9421-8], [R1-9421-5], [R1-9421-9], [R1-9421-1] report the device implementation may depend on *M* valuesFor Alt M1-1, the potential impacts are discussed as follows:- Some sources [R1-9421-1], [R1-9421-5], [R1-9421-6], [R1-9421-8], [R1-9421-25], [R1-9421-28] report that CP handling of Alt M1-1 can be used for both small and large *M* values for OOK-4, while [R1-9421-8] reports that for large M values Alt M1-1 is used in combination with Alt M1-2. - Some sources [R1-9421-3], [R1-9421-32] report that CP handling of Alt M1-1 is challenging to be used for large *M* values for OOK-4 considering large SFO and [R1-9421-8], [R1-9421-18] report that CP handling of Alt M1-1 may not completely remove CP samples due SFO impact.- Among of them, [R1-9421-5] show that the performance loss of PRDCH carrying 20 bits due CP handling is negligible at 10% BLER even for large *M* values (e.g. *M*=24) under large SFO (e.g. 104-105 ppm). Sources [R1-9421-8], [R1-9421-32] show some performance loss due CP handling for both small (M=4) and large *M* values (*M*=24) under large SFO (e.g. 104-105 ppm ) while [R1-9421-32] shows [1~2 dB] loss compare to no CP case for *M*<24, and an error floor at BLER=10% for *M*=24.- Some sources [R1-9421-9], [R1-9421-18] report that the device needs additional complexity to handle CP, while other sources [R1-9421-5], [R1-9421-25] reports that it is feasible in terms of implementation complexity based on transition edge detection.- One source [CATT] report that the device might remove the wrong portion of the CP part of the OFDM symbol due to timing error, which could introduce the false rising/falling edge for the subsequent OOK demodulation.For Alt M1-2, the potential impacts are discussed as follows:- Some sources [R1-9421-1], [R1-9421-4], [R1-9421-9], [R1-9421-3], [R1-9421-5], [R1-9421-6], [R1-9421-8], [R1-9421-32], [R1-9421-18], [R1-9421-25], [R1-9421-27], [CATT] report that CP handling of Alt M1-2 cannot be used for large M values, e.g. *M*>8, while [R1-9421-8] reports that for large *M* values Alt M1-2 is used in combination with Alt M1-1.- One source [R1-9421-22] report that CP handling of Alt M1-2 can be used for both small and large *M* values (e.g. *M*>8) if with the knowledge of OFDM symbol boundaries.- Among of them, [R1-9421-8] show that the performance of Alt M1-2 is not applicable for large M values (e.g. *M*=24) under large SFO (e.g. 104 ppm).For Method Type 2, two approaches regarding subcarrier orthogonality are studied:Alt M2-1: Method Type 2 retains subcarrier orthogonality, i.e. CP is copied from the end of an OFDM symbol.Alt M2-1-1: The first OOK chip(s) and the last OOK chip(s) in an OFDM symbol are the same.Alt M2-1-2: 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.Alt M2-2: Method Type 2 does not retain subcarrier orthogonality.For Method Type 2, depending on the design, the chip duration generation of OOK-4 for *M*-chip per OFDM symbol transmission could possibly be determined by:- M, and the length of OFDM symbol with CP- M, and the length of OFDM symbol without CP- Depending on detailed solutions, chip duration may or may not be constant. - ~~One~~ Some sources [R1-9421-28][Huawei] report that non-constant OOK chip duration may impact performance, while some other source [R1-9421-32] report that non-constant OOK chip duration does not impact performance.For Alt M2-1, the potential impacts are discussed as follows,- Some sources [R1-9421-5], [R1-9421-9], [R1-9421-8], [R1-9421-33], [R1-9421-21], [R1-9421-11], [R1-9421-18], [R1-9421-3], [Sony] report that CP handling of Alt M2-1 cannot be used for large M values (e.g. *M*>8). Source [Ericsson] report that for M>8, the CP size becomes comparable to that of the normal OOK chip, and hence it would be challenging to identify the invalid transition caused by CP. Sources [CATT] report that if chip duration is comparable to CP duration, CP could not be identified as the invalid chip by the A-IoT device, e.g., M>8.- Some sources [R1-9421-1], [R1-9421-6], [R1-9421-28], [R1-9421-32] report that CP handling of Alt M2-1 can be used for both small and large M values.- Among of them, some sources [R1-9421-6], [R1-9421-32] show the performance of Alt M2-1 for small (*M*=4) and large M values (*M*=24) under large SFO (e.g. 105 ppm).- Some sources [R1-9421-28], [R1-9421-9], [R1-9421-32] report that CP handling of Alt M2-1 may result in non-constant OOK chip duration around CP. Source [Huawei] report that due non-constant OOK chip duration around CP, Alt M2-1 has ~1dB worse performance than Alt M1-1 at BLER 10% and BLER 1% when it used for small M value (e.g., M = 6).- Some sources [R1-9421-3], [R1-9421-5], [R1-9421-11], [R1-9421-32], [R1-9421-22], [R1-9421-4], [R1-9421-27] report that CP handling of Alt M2-1-1 would increase the overhead and reduce spectral efficiency.- Some sources [R1-9421-25], [R1-9421-1], [R1-9421-9] report that CP handling of Alt M2-1-1 may not be completely transparent to the device thus add additional complexity.- Source [CATT] report that if chip duration is significantly different from CP length, M2-1-2 would be complicated to be used for removing false transition edge occurring at the end of the CP. And M2-1-2 would require high complexity of A-IoT device implementation if it is used for the R2D preamble.For Alt M2-2, the solutions and potential impacts are discussed as follows,- [R1-9421-8], [R1-9421-12], [R1-9421-11], [R1-9421-21] report solutions for Alt M2-2 (e.g. CP is copied from the start of OFDM symbol or do not insert CP to OFDM symbol). - [R1-9421-3], [R1-9421-5], [R1-9421-6], [R1-9421-10], [R1-9421-32], [R1-9421-25], [R1-9421-28], [R1-9421-4], [R1-9421-9], [R1-9421-22], [R1-9421-27] report that CP handling of Alt M2-2 would cause interference to NR, while [R1-9421-8] reports single PRB guard band would be sufficient to handle interference. - Sources [R1-9421-5], [R1-9421-25], [R1-9421-28], [R1-9421-31], [R1-9421-9], [R1-9421-22], [R1-9421-27] report that CP handling of Alt M2-2 would increase the transmitter complexity.*…(unchanged parts omitted)…* |

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| **Company** | **Sourcing companies can check if this is correct?** |
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## R2D modulation

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| Agreement on updated TP RAN1#118bisTable 6.1.1.x-1 is a starting point for study of *M* values and the associated minimum *B*tx,R2D value. The reader can use any transmission bandwidth greater than or equal to the minimum *B*tx,R2D value.Note: Depending on further study, the maximum value of *M* may be less than 32.Note: The performance can be better when transmission bandwidth greater than the minimum *B*tx,R2D, depending on device processing and transmit power constraint.Table 6.1.1.x-1: Starting point for *M* values and the associated minimum *B*tx,R2D value

|  |  |
| --- | --- |
| ***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 |

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### M values [ACTIVE]

#### Round 1

From studying the papers to this meeting, there seems only a few proposals to update TP on the minimum *B*tx,R2D value in the row of M=24 and M=32 with justification by referring simulation observations: 2 companies suggest change from 2 PRBs to 3 PRBs for M=24, and from 3 PRBs to 4 PRBs for M=24.

Other changes on the M values-set or etc. and how to perform potential down-selection are not expected to be needed during the SI, given the “minimum values” basis we made the table agreement. Companies would discuss reasons for certain M values they want in a normative stage when the M values is going to be down-selection if any.

Hence, FL will check on updating minimum *B*tx,R2D value on row of M=24 and M=32, but since this is not needed to finish the SI, we can leave to WI if there is disagreement.

**Proposal 2.2.1(I): Capture the following TP update into TR 38.769**

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| *…(unchanged parts omitted)…*Table 6.1.1.x-1 is a starting point for study of *M* values and the associated minimum *B*tx,R2D value. The reader can use any transmission bandwidth greater than or equal to the minimum *B*tx,R2D value.Note: Depending on further study, the maximum value of *M* may be less than 32.Note: The performance can be better when transmission bandwidth greater than the minimum *B*tx,R2D, depending on device processing and transmit power constraint.Table 6.1.1.x-1: Starting point for *M* values and the associated minimum *B*tx,R2D value

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

*…(unchanged parts omitted)…* |

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| **Company** | **Any objection?** |
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## 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.

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

Agreement RAN1#118bis*{A TP was agreed. Omitted here.}* |

### Round 1

It seems a number of companies want to conclude the study by stating that Manchester coding is used as the baseline for R2D line codes. While the FL understands that there are also companies that want to use PIE encoding depending on the source of the RF energy harvesting signal and whether other energy sources are present, capturing Manchester codes as a baseline does not preclude comparing the necessity/benefits of PIE to the baseline. Hence, the FL attempts the following proposal.

**Proposal 2.3(I): Manchester coding is the baseline for R2D line codes.**

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| **Company** | **Views**  |
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## R2D FEC / repetition [ACTIVE]

### Round 1

For R2D FEC, Proposal 2.4.1a(I) containing the company observations on R2D FEC from the previous meeting was stable, but unfortunately omitted when the proposals were presented in the online session. Hence, the following TP is proposed, along with one company’s view on the increased complexity and memory requirements that has been included (marked in green).

**Proposal 2.4.1a(I): For R2D FEC, adopt the TP below in Section 6.1.1.x.1 of TR 38.769:**

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| \*\*\*unchanged parts omitted\*\*\*6.1.1.x.1 Channel coding and CRCPRDCH without FEC is studied as the baseline, with evaluations performed by comparison to this baseline. The study assumes PRDCH can attach a CRC, where the baseline design is using a 6-bit or 16-bit CRC with polynomials as per TS 38.212 [R1-3]. A baseline of no CRC attachment is also included. For the study of CRC designs, see Clause 6.1.0.2.Sources [Huawei], [TCL], [Vivo], [ZTE], [Samsung], and [Apple] provide justifications for not having R2D FEC beyond the baseline, with the following observations:* Sources [Huawei], [ZTE] and [Fujitsu] state that FEC decoders require complicated arithmetic or logical operations which are too complicated to be implemented in device 1.
* Sources [ZTE] and [Samsung] state that it would be difficult for a device to implement a FEC decoder due to its low power consumption.
* Source [Huawei] and [Fujitsu] state that FEC decoder procedures such as the de-interleaving operation or route metric caching require volatile memory of a certain size with a certain reading/writing throughput, which cannot be supported by device 1.
* They also mention that the received signal power at the device can be relatively high (e.g., >-60 dBm), making the receiver sensitivity not the bottleneck of the link budget for target coverage, even for device 2b, thus questioning the necessity of R2D FEC.

Sources [Ericsson] and [Qualcomm] provide the following justifications for using FEC in R2D for device 2b:* Source [Ericsson] claims that CC with small constraint lengths (e.g., 3 or less) offer a substantial performance gain over uncoded transmission, especially in a fading environment, with reasonable complexity. CC with explicit tail-biting transmission to aid decoding may be suitable for R2D.
* Source [QC] claim that even simple block code (e.g., Golay, RM) with hard decisions can significantly reduce the required SNR for achieving a target BLER e.g., 1%.

\*\*\*unchanged parts omitted\*\*\* |

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| **Company** | **Views / anything missing?** |
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For R2D repetitions, similarly, Proposal 2.4.1b(I) from the previous meeting was stable, but unfortunately omitted when the proposals were presented in the online session. The following is the same TP, with the addition of a supporting company (marked in green).

There is a further TP shown below on new observations, separated for convenience of commenting.

**Proposal 2.4.1b(I): For R2D repetitions, adopt the TP below in Section 6.1.1.x.2 of TR 38.769:**

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| \*\*\*unchanged parts omitted\*\*\*6.1.1.x.2 RepetitionRegarding R2D repetitions, it is reported by sources [R1-9421-11] (only for R2D control, if supported), [R1-9421-12], [R1-9421-32], [R1-9421-13], [R1-9421-21], [R1-9421-19], [R1-9421-28] and [R1-9421-30] that R2D repetitions should be supported. The following are observations regarding the different types of repetition that should be supported.… …\*\*\*unchanged parts omitted\*\*\*On the other hand, it is reported by sources [Nokia], [Ericsson], [Huawei], [CMCC],] and [Vivo] that R2D repetitions should not be supported, giving justifications:* Source [Nokia] mention that the transmission power of a R2D transmission is typically much greater than its corresponding D2R transmissions, and if the R2D transmission has coverage issues, then the corresponding D2R transmission would not reach the reader. Hence it should be considered for D2R transmissions alone.
* Source [Ericsson] say that not supporting R2D repetition can be the baseline.
* Source [CMCC], [LG] and [Xiaomi] include that the decision to support R2D repetitions can be based on whether the activation threshold is a bottleneck according to the coverage evaluations.
* Source [CMCC] and [Huawei] also comment that from a device perspective, especially device 1 with low complexity and memory storage, it is not possible to combine multiple repetitions.

\*\*\*unchanged parts omitted\*\*\* |

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| **Company** | **Views / anything missing?** |
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For R2D repetitions, in addition to the observations that were agreed to be captured in the TR in the last meeting, the following TP handles the inclusion of observations that have been provided by companies in this meeting.

**Proposal 2.4.1c(I): For R2D repetitions, adopt the TP below in Section 6.1.1.x.2 of TR 38.769:**

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| \*\*\*unchanged parts omitted\*\*\***Bit-level repetition**Positive observations:- Source [R1-9421-3] state that bit level repetition can be studied if coverage enhancement of the R2D link is required.- Source [R1-9421-12] state that bit level repetition where every input bit repeated for 8 times before Manchester coding could have ~4dB gain when compared with no repetition. They claim using Manchester codes with repetitions require a simple structure and consumes extremely low power.- Source [R1-9421-28] state that bit level repetitions with scrambling is required since the former would improve the link budget and the latter would add extra randomness to the information bits, providing gain by suppressing the interference. They also claim that repetitions can be used in devices that cannot soft combine the repetitions, and majority-based detection would offer gain for these devices.Negative observations:- Source [R1-9421-9] state that since envelope detection is used for R2D reception, bit level repetition may not provide expected gain for the reception.- Source [R1-9421-8] state that though it may be feasible, it increases the device’s processing complexity for reception, e.g., combination, repetition parameters determination.* Source [Fujitsu] state that repetition gain of a bit-level repetition, which requires additional standardization effort to define necessary control information, mainly comes from the energy accumulation of the signal, and should be similar with the achievable gain by directly lowering the chip rate/reducing the M value, which does not require this additional effort.

**Block-level repetition**Positive observations:- Source [R1-9421-32] state that at least for large TBs, repeatedly transmitting the TB multiple times consecutively provides time diversity gain and increases the probability that at least one of the repetitions can be successfully decoded.* Source [ZTE] further state that the device can perform the block-wise detection without chase combination of the repeated blocks so that block-level repetition may not need additional buffer and increase the complexity and cost.
* Source [Fujitsu] state that block-level repetition can obtain a bigger repetition gain than that achieved by bit- or chip-level repetition, and can enjoy both the time diversity gain and the gain of energy accumulation.

Negative observations- Source [R1-9421-8] state that considering limited capability and cost for an A-IoT device, block level repetition for R2D should be excluded.* Source [Fujitsu] state that block-level repetition additionally requires a very large volatile memory to store all received repetitions of one block.

**Chip-level repetition**Positive observations:- Source [R1-9421-9] state that it may be useful for R2D transmission coverage and can be considered to generate a lower data rate than 7kbps.- Source [R1-9421-30] state that chip-level repetition increases the chip duration, improving the edge detection at the receiver, thereby having a ~2dB performance increase when compared to bit level repetitions.Negative observations:- Sources [R1-9421-3], [R1-9421-8] and [R1-9421-11] state that chip-level repetition is equivalent to long chip transmission, i.e., by using a smaller modulation index, and therefore, there is no need to support this option.* Source [Fujitsu] state that repetition gain of a chip-level repetition, which requires additional standardization effort to define necessary control information, mainly comes from the energy accumulation of the signal, and should be similar with the achievable gain by directly lowering the chip rate/reducing the M value, which does not require this additional effort.

\*\*\*unchanged parts omitted\*\*\* |

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| **Company** | **Views / anything missing?** |
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## R2D and D2R CRC [VOID]

**See Section 4.**

## R2D multiple access [ACTIVE]

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| 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

There are a few more observations that could be captured from tdoc analysis for R2D multiple access, and FL proposes as follows in the same style as RAN1#118bis.

**Proposal 2.6a(I): Add the following TPs to the TR:**

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| 6.1.1.x R2D multiplexingFor R2D, time-domain multiplexing is the baseline. Code-domain multiplexing is not considered for device 1/2a/2b. Frequency-domain multiplexing is not considered for the devices with an RD-ED receiver (see Clause 5). For device 2b with IF-ED or ZIF receivers, the study considered the following technical aspects:**Table 6.1.1.x-1: Observations on the feasibility and necessity of FDM for Device 2b**

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| **Aspects to be considered for feasibility/benefit** | **Observations** |
| **Inventory completion time** | Sources [R1-9421-3], [R1-9421-22], [R1-9421-4], [R1-9421-12] state that FDM is beneficial to reduce the inventory completion time, especially considering more devices per reader due to the larger maximum distance for Device 2b.Source [vivo] state that inventory latency reduction would be limited, due to difficulty of allocating frequency resources efficiently for Msg2 by reader with uncertainty of number of successful Msg 1, and difficulty of informing an A-IoT device R2D frequency location other than Msg2. |
| **Device implementation** | Sources [R1-9421-18], [R1-9421-27], [R1-9421-3], [R1-9421-22], [R1-9421-12] state that channel selection may be performed by a narrowband filter (IF filter or BB filter) after the mixer for Device 2b, if the LO accuracy is sufficiently good.Source [Panasonic] states that narrowband RF filtering at device side to realize R2D FDM would be challenging considering reception performance and complexity, while such filtering would also limit the deployment scenario supported by device.Sources [R1-9421-34], [R1-9421-24], [R1-9421-6], [R1-9421-2], [R1-9421-5] state that it would be challenging for a device using an RF-ED receiver architecture to distinguish the different incoming signal fall into the RF BW without narrowband RF filtering which may cause increasing device implementation complexity and power consumption.Source [R1-9421-3] states that the larger R2D responses are harder for the devices to process in the case of TDM+FDM/TDM only for D2R/R2D, respectively. |
| **Spectrum utilization** | Source [R1-9421-34] state that the spectral efficiency may be impacted by the guard band across the FDMed R2D transmissions to multiple devices.Source [Ericsson] state that the spectrum utilization can still be higher for non-RF-ED based devices if FDM is used, despite guard bands.Source [vivo] state that spectrum efficiency improvement would be limited, due to difficulty of allocating frequency resources efficiently for Msg2 by reader with uncertainty of number of successful Msg 1, and difficulty of informing an A-IoT device R2D frequency location other than Msg2. |
| **Coverage (in the case of single reader)** | Source [R1-9421-5] states the R2D link budget of a reader is decreased due to the power splitting between the parallel R2D channels.Source [R1-9421-3] states the coverage target of Device 2b is still larger than that of Device 1 (with RF-ED architecture). |
| **Reader implementation (in the case of single reader)** | Source [R1-9421-5] states that additional interference suppression may be needed to deal with the intermodulation between the parallel R2D transmissions. |
| **Harmonized design for all devices** | Sources [R1-9421-26], [R1-9421-9], [R1-9421-19], [Spreadtrum] state that it is not appropriate to include FDM only for Device 2b, while Device 1 and 2a cannot support it.Source [vivo] state that non-harmonized resource allocation for different device types complicates the system design.Source [Ericsson] state that a deployment supporting a combination of RF-ED devices and non-RF ED devices can be harmonized by TDMA’ing different types of R2D time slots, where some time slots can support only a single frequency occasion while other time slots support multiple frequency occasions. |

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## R2D time-domain definitions

There was an agreement in RAN1#118bis regarding the correspondence between a chip and a modulated symbol in D2R for at least OOK and BPSK.

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| AgreementIn D2R, a chip corresponds to one modulated symbol at least for OOK and BPSK.* FFS: the definition for MSK.
 |

For the correspondence between a chip and modulation in R2D, several companies make the same proposal as for D2R which seems reasonable. The difference in the wording is because of the OFDM step included in R2D.

**Proposal 2.7a(I): In R2D, a chip corresponds to one OOK symbol.**

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On R2D chip duration, during RAN1#118bis and earlier, FL tried capturing a few calculation methods. This proved undesirable because it required capturing a lot of solution-specific cases which essentially were just derivations of the designs for CP handling.

Fortunately, we already have the following sentence captured in the TR:

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| *For Method Type 2, depending on the design, the chip duration generation of OOK-4 for M-chip per OFDM symbol transmission could possibly be determined by:**- M, and the length of OFDM symbol with CP**- M, and the length of OFDM symbol without CP**- Depending on detailed solutions, chip duration may or may not be constant.*  |

Considering all the above, FL suggests we conclude that chip duration, like detailed CP handling design, is a normative phase detail.

**Proposed Conclusion 2.7b(I): Since R2D chip duration is a consequence of CP handling design, it is not studied further in RAN1, and is left to a later phase.**

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## R2D bandwidths [INACTIVE]

The remaining points in papers can be taken as normative phase details. Hence no FL proposals seem needed here.

# D2R

## D2R waveform [ACTIVE]

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| Agreement RAN1#118bisThe D2R baseband signal (as distinct from the internal or external carrier wave) is non-OFDM. |

### Round 1

By studying the papers, one company [11] ask to understand how the baseband waveform is converted to the RF waveform for device 2b. They see two options which is actually up-converting the baseband waveform either to a single RF frequency tone, or to two RF frequency tones. Feature lead would like to check views from companies for this.

**Proposal 3.1(I): For D2R with device 2b, the baseband waveform can be formed only by using a traditional up-converter with a single frequency tone, or it can have the same options as the external CW.**

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## D2R modulation [ACTIVE]

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| Agreement RAN1#116bisStudy 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

Agreement RAN1#118* OOK and Binary PSK for baseband modulation are feasible for D2R for all devices.
* The variant of Binary FSK to study further for all devices is identified as MSK (and not GMSK)
	+ FFS: whether MSK is feasible for all devices

Agreement RAN1#118bis2SB modulation is feasible for D2R transmission for all devices. * Feasibility and necessity of 1SB would depend on the impacts due to issues including: device-side filtering requirements (i.e. image suppression), RF resource usage / spectral efficiency, etc.

Agreement RAN1#118bis*{A TP on MSK was agreed. Omitted here}.* |

### Round 1

Studying from the papers to this meeting, seems no more new inputs except one company [29] propose DBPSK modulation. Feature lead acknowledge the proposal, but the level of interest is not sufficient to justify a FL proposal and it seems to be out of scope of the agreement made in previous meetings where no DBPSK is written in the closed-ended list.

There are only a few new observations on MSK using impedance switching in some papers, here just to have a simple proposal to add those information into the TP updating, the source company name will be further replaced by reference papers submitted to this meeting.

**Proposal 3.2(I): Capture the following TP update into TR38.769**

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| *…(unchanged parts omitted)…*For all devices, the following D2R baseband modulations are studied:- OOK- Binary PSK- Binary FSK, as MSK (and not GMSK)OOK and BPSK for baseband modulation are feasible for D2R for all devices.- Sources [R1-9421-3], [R1-9421-11], [R1-9421-28], [R1-9421-16] report that MSK is feasible in some way:- [R1-9421-3], [R1-9421-11] say it is feasible for all devices, for example when it is implemented with multiple impedances switching- [R1-9421-28] say that it would be implemented as square-wave MSK for devices 1 and 2a, and sine-wave MSK for device 2b- For device 1 and 2a this type of MSK does not have continuous phase- [R1-9421-3] say that benefits include lower sidelobes than OOK and BPSK, and lower BER than OOK and same BER as BPSK - Sources [R1-9421-5], [R1-9421-2], [R1-9421-9], [R1-9421-7], [R1-9421-8], [R1-9421-10], [R1-9421-23] report that MSK is either infeasible or should be deprioritized for all devices.- [R1-9421-5], [R1-9421-9], [R1-9421-7], [R1-9421-8], [R1-9421-2], [R1-9421-10], [R1-9421-23] say that MSK is less spectrally efficient than OOK and BPSK because there are issues due to poor phase accuracy in the device- [R1-9421-5], [R1-9421-7], [R1-9421-2], [R1-9421-8], [R1-9421-10] say that MSK would increase reader and device complexity- [R1-9421-8] say that MSK performance for device 2b would materially degrade due to CFO- [TCL] say that it is difficult to modulate MSK signal using impedance switching due to the implementation complexity, including frequency mapping and phase continuation. [Xiaomi] say that if multiple impedances switching are applied to maintain the phase continuity, it violates the principle of low device cost.*…(unchanged parts omitted)…* |

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| **Company** | **Sourcing companies can check if this is ok?** |
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## D2R line coding

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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

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

Agreement RAN1#118For 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.

Agreement RAN1#118bis*{A TP was agreed. Omitted here}.* |

### Line code types [ACTIVE]

#### Round 1

For D2R line codes, the FL observes that while some companies had recommended the use of Manchester codes as baseline, others had also expressed their support for Miller codes. However, no company has indicated support for FM0, while one company stated that it should not be supported at all. Hence, the FL proposes the following:

**Proposal 3.3.1(I): For D2R line codes, FM0 is deprioritized.**

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### Small frequency shift [ACTIVE]

#### Round 1

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| Agreement RAN1#118Small frequency shifts for D2R are studied for OOK and BPSK:* + For applying with 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.
			* Companies to report how they perform multiplying for option 2
	+ For applying with 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 using a square-wave corresponding to the small frequency-shift.
	+ Potential purposes include:
		- FDMA of D2R, if supported
		- CW interference avoidance, if supported
* Note: small frequency shifts for D2R are studied for the same potential purposes for relevant identified BFSK variant(s)

Agreement RAN1#118bisFor small frequency shifts in D2R using Manchester line codes by repetition of the codewords within the same time duration T­b corresponding to an information bit (Option 1), each Manchester codeword is repeated by a codeword repetition number R, where R = Tb/(2 \* chip length), such that the amount of small frequency shift in Hz is R/Tb = 1/(2 \* chip length).Agreement RAN1#118bisFor small frequency shifts in D2R using Manchester line codes by multiplying the codeword with a square wave corresponding to the small frequency shift (Option 2), the multiplication is performed according to the following options:* One option is that the multiplication operation is an XOR operation between Manchester codeword corresponding to the information bit and the square wave for the small frequency shift.
* Another option is that the multiplication operation is an XNOR operation between Manchester codeword corresponding to the information bit and the square wave for the small frequency shift.

Agreement RAN1#118bisRegarding small frequency shift factor, capture in the TR that:* For study purposes
	+ For BPSK and OOK, the small-frequency-shift factor is defined as the ratio of bit length to two times the chip length
	+ The value of small-frequency-shift factor depends on details of design, which according to proposals considered could be e.g.
		- The repetition number of Manchester codeword within one information bit duration
		- The M value of Miller in Figure 6-12 of UHF RFID standard
		- The number of square-wave periods within one information bit duration

Agreement RAN1#118bisFor small frequency shifts in D2R, the following observations are captured in TR 38.769:*{Remainder of TP omitted}* |

FL observes that a few companies had submitted observations for small frequency shifts being applied to the different line codes. FL has avoided the capturing of single company observations; the following TP includes observations from multiple companies.

**Proposal 3.3.2a(I): For small frequency shifts in D2R, adopt the TP below in Section 6.1.2.x.1 of TR 38.769:**

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| 6.1.2.x.1 Small frequency shifts\*\*\*unchanged parts omitted\*\*\*Sources [R1-9421-1], [R1-9421-8], [Huawei] and [R1-9421-28] state that Manchester codeword repetitions within the same time duration corresponding to an information bit is equivalent to bit-level repetitions within the same duration prior to Manchester encoding. Sources [CMCC] and [Vivo] state that option 1 has a more concentrated spectrum, and requires lesser bandwidth as compared to Option 2. Source [Vivo] further states that while Option 1 and option 2 show similar BLER performance for single device case, Option 1 outperforms Option 2 with FDMA, especially with presence of 105 ppm SFO. Option 1 can achieve additional gain for coverage evaluation due to lower effective noise power.Sources [R1-9421-8], [R1-9421-32] and [R1-9421-13] state that the output waveform for Manchester line codes by Option 2 introduces a phase reversal of the output waveform in the middle of the time duration corresponding to an information bit as compared to Option 1.\*\*\*unchanged parts omitted\*\*\* |

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It is the FL’s understanding that the discussions on small frequency shifts can be concluded, since there are no pending FFSs and the observations reported by companies have been captured in the TR. However, there have been proposals to capture the amount of small frequency shift achieved by Manchester coding option 2 and the no line code case from one company each. To this regard, the FL has captured these in the following proposals, in an attempt to check if this is agreeable to companies.

**Proposal 3.3.2b(I): For small frequency shifts in D2R using Manchester line codes by multiplying the Manchester codeword with a square wave corresponding to the small frequency-shift, each information bit Tb includes Rs number of square wave periods, where Rs = Tb/(2 \* chip length), such that the amount of small frequency shift in Hz is Rs/Tb = 1/(2 \* chip length).**

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| **Company** | **Is this ok to add, or not needed?** |
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**Proposal 3.3.2c(I): For small frequency shifts in D2R using a square-wave corresponding to the small frequency-shift and no line codes, each information bit Tb includes Rs number of square wave periods** **generated by 2R OOK chips [0, 1, 0, 1, ..] or BPSK chips [-1, +1, -1, +1, …], such that the amount of small frequency shift in Hz is Rs/Tb.**

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| **Company** | **Is this ok to add, or not needed?** |
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## D2R FEC / repetition

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| 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

Agreement RAN1#117For D2R, study at least block-level and bit-level repetition type 1 and type 2.RAN1#118bis*TPs were agreed. Omitted here.* |

### Repetition [ACTIVE]

#### Round 1

FL observes that companies have submitted more observations under block and bit level repetitions, but some of them seem to introduce a variant or an enhancement to the already defined repetition schemes, and hence have not been captured. Only the performance related observations have been captured in the following TPs.

**Proposal 3.4.1(I): For D2R block level repetitions, adopt the TP below in Section 6.1.2.x.3 of TR 38.769:**

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| \*\*\*unchanged parts omitted\*\*\*6.1.2.x.3 RepetitionFor definitions of repetition types, see Clause 6.1.0. For D2R, at least block-level and bit-level repetition type 1 and type 2 are studied.**Block-level repetition**\*\*\*unchanged parts omitted\*\*\*Performance comparisons- Source [R1-9421-5] state that block level repetition yields ~2.5 dB performance gain compared with bit level type 2 due to the additional time diversity gain for the combination of decoding. - Source [R1-9421-10] state that block level repetition provides ~4dB performance gain @1% BLER compared with bit level type 1.- Source [R1-9421-32] state that block level repetition provides ~6dB performance gain @10% BLER compared with no repetitions and the performance between block level repetition and bit level repetition type 2 is the same.- Source [R1-9421-8] state that the performance difference between block level repetition and bit level repetition without CW hopping is minor, while block level repetition outperforms bit level repetition with CW hopping.- Sources [R1-9421-11] and [R1-9421-32] state that bit level repetition and block level repetition have similar performance in the AWGN channel but block level repetition could achieve more time diversity gain than that of bit level type 2 in a fading channel.* Source [Xiaomi] state that for the no FEC case, block level repetition provides ~5dB gain at 1% BLER when compared with bit level type 1 repetition.

\*\*\*unchanged parts omitted\*\*\* |

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### FEC [ACTIVE]

#### Round 1

FL observed companies have submitted simulation results to be added in Table 6.1.2.x.1-1 for D2R FEC. The following TP handles the addition of these additional simulation results, shown only for the affected rows of the table.

**Proposal 3.4.2(I): For D2R FEC, update Table 6.1.2.x.1-1 of Section 6.1.2.x.1 of TR 38.769 as follows:**

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| \*\*\*unchanged parts omitted\*\*\*Table 6.1.2.x.1-1: Summary of study on D2R FEC

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| Option # | CC Design | Pros | Cons |
| Baseline | Constraint length 7Code rate 1/3 | [R1-9421-8] Decoding performance is increased by ~3dB@10% BLER, when compared to no CC but with repetitions.[R1-9421-8] Decoding performance is increased by ~7dB@10% BLER, when compared to no CC or repetitions.[R1-9421-27] Decoding performance is increased by 6.23dB@10% BLER with 2RX, when compared to no CC or repetitions.[R1-9421-27] Decoding performance is increased by 6.42dB@10% BLER with 4RX, when compared to no CC or repetitions.[R1-9421-11] Decoding performance is increased by ~2dB@10% BLER, when compared to LTE CC-TBCC with code rate 1/2.[R1-9421-16] Decoding performance is increased by ~2.5dB@1% BER, when compared to code rate 1/2. [R1-9421-10] Decoding performance is increased by ~1.5dB@1% BLER, when compared to constraint length 4, code rate 1/3[R1-9421-10] Decoding performance is increased by ~2.5dB@1% BLER, when compared to constraint length 6, code rate 1/3[Nokia] Decoding performance is increased by 3 dB@ 10% BLER with 2 RX, when compared to no CC or repetitions |  |
| 1 | Constraint length 4Code rate 1/2 – 1/4 | [R1-9421-3] Code rate 1/2: Detection performance is increased by 3dB@10% BLER, when compared to no CC or line codes. | [R1-9421-9] Code rate 1/2: Decoding performance is decreased by ~0.86dB@10% BLER, when compared to constraint length 7, code rate 1/2.[R1-9421-32] Code rate 1/2: Decoding performance is decreased by ~1dB@10% BLER, when compared to constraint length 7, code rate 1/2.[R1-9421-32] Code rate 1/4: Decoding performance is decreased by ~1.4dB@10% BLER, when compared to constraint length 7, code rate 1/4.[CATT] Code rate 1/2, 1/3, TBCC: Decoding performance is decreased by ~1dB@10% BLER, when compared to baseline with TBCC. |

\*\*\*unchanged parts omitted\*\*\* |

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| **Company** | **Sourcing companies can check if this is ok?** |
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## D2R CRC [VOID]

Section 4.1 will take R2D and D2R CRCs together.

## D2R multiple access [ACTIVE]

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| Agreement RAN1#116bisStudy time-domain multiple access of D2R transmissions. Further details, including pros/cons, are FFS.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.Whether code-domain multiple access is feasible and necessary for D2R transmissions for all devices is FFS.Agreement RAN1#118bis*{A set of TPs was agreed. Omitted here}.* |

### Round 1

FL suggests to update the TR text here on the same basis as in RAN1#118bis by capturing what companies report or adjust.

**Proposal 4.6(I): Update section 6.1.2.x.1 of the TR on D2R multiple access:**

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| D2R multiple access6.1.2.x.1 Multiple access schemesTime-domain multiple access, and frequency domain multiple access at least by using a small frequency shift in baseband are studied. Whether code-domain multiple access is feasible and necessary for all devices is FFS.Time-domain multiple access is the baseline. Sources [R1-9421-9], [R1-9421-11], [R1-9421-3], [R1-9421-1], [Nokia], state that the benefit of TDMA is the low implementation complexity for both device and reader, while the inventory efficiency may be relatively low for TDMA only, and sources [R1-9421-27], [R1-9421-22], [R1-9421-24], [CATT], [Nokia], [Qualcomm], state that the guard interval, if supported, between consecutive D2R transmissions from different devices depends on the SFO after clock calibration.According to sources [R1-9421-3], [R1-9421-9], [R1-9421-11], [R1-9421-35], [R1-9421-27], [R1-9421-1], [R1-9421-5], [R1-9421-25], [Nokia], the potential benefit of frequency-domain multiple access is to increase the transmission efficiency and reduce collisions, while the cons include more complicated frequency resource management and reception processing at reader according to source [R1-9421-9], and potentially increased power consumption for devices according to sources [R1-9421-11], [R1-9421-17], [R1-9421-12], [Nokia]. It is observed that the performance of FDMA may be impacted by the following aspects.- Large SFO of device- Sources [R1-9421-28], [R1-9421-32] state that large SFO (e.g. up to 105 ppm) produces higher BLER degradation due to inter-device interference than a smaller (e.g. up to 104 ppm) or the ideal case of zero SFO. Source [Qualcomm] states that under the case of the large SFO (e.g. up to 105 ppm), two among four devices using small frequency shifts have BLER floor and cannot achieve BLER 1%. Source [R1-9421-32] state that under the case of the large SFO (e.g. up to 105 ppm), two FDMA-ed devices induce about 0.6~1dB performance loss compared to single device.- Source [R1-9421-5] state that the large SFO (e.g. up to 105 ppm) has little impact (e.g., ≤1dB) on the performance of FDMA between multiple devices.- Sources [R1-9421-8] think that sufficient gap between D2R transmissions should be reserved to accommodate frequency error caused by SFO/CFO- Sources [R1-9421-17] think that the required guard band size increases for higher switching frequencies for passive devices.- Source [CMCC] observed that the performance gap among 10% SFO and 1% SFO (residual) is similar compared FDMA with no FDMA, e.g., about 0.5dB @ 10% BLER, i.e., the performance gap among 10% SFO and 1% SFO (residual) is irrelevant to whether FDMA scheme is used or not.- Source [Huawei] state that large SFO (e.g. up to 105 ppm) has little impact on the link performance of FDMA, as it is observed that the performance gap between 10% and 1% SFO is negligible in the case of FDMA among 4 devices.- Timing offset between devices- Sources [R1-9421-25] state that timing offset results in a degradation of up to ~4 dB and the loss varies for different devices depending on the level of experienced interference- Maximum range of small frequency shift- Sources [R1-9421-24] think that the frequency gap among devices will impact the interference, which is highly depends on the small frequency shift capability, i.e., how large the frequency shift can be via small frequency shift.- Harmonics in the backscattered signal- Sources [R1-9421-8] state that FDMA is feasible by proper frequency resource allocation not using odd harmonic frequency of FDMed D2R transmissions.- Potential intermodulation spectral leakage in the backscattered signal- Frequency resource collision- Source [Sony] thinks that if the guard band size between D2R transmissions is fixed, allocating passive devices with large SFO to frequency shifts closer to the A-IoT carrier frequency and either (1) passive devices with smaller SFO or (2) active devices to frequency shifts further from the A-IoT carrier frequency reduces frequency resource collision.- Number of multiplexed devices- Source [R1-9421-32] reports that performance loss increases with the increase of device number. Besides, for FDMA detection at reader side, there is about 1.5 - 3dB performance loss from 6 FDMA-ed devices compared to single device.- Source [Sony] thinks that the potential number of multiplexed devices depends in the maximum rate of frequency switching.- Source [Sony] thinks that if the guard band size depends on the SFO capability of the device, the number of multiplexed devices can be increased if passive devices with large SFO are allocated frequency shifts closer to the A-IoT carrier frequency and passive / active devices with smaller SFO are allocated frequency shifts further from the A-IoT carrier frequency.According to sources [R1-9421-11], [IIT], [R1-9421-12], [R1-9421-32], [Nokia], CDMA can improve the resource utilization efficiency without increasing the device complexity significantly. Sources [R1-9421-27] thinks CDMA would help the multiplexing among readers and it can alleviate the cross-link interference. Source [R1-9421-12] thinks CDMA is also beneficial for the latency reduction and success rate improvement of access procedure. Source [CATT] thinks that the CDMA scheme is mostly used for the signals without carrying information. However, sources [R1-9421-18], [R1-9421-26], [R1-9421-3], [R1-9421-1], [R1-9421-5], [R1-9421-6], [R1-9421-8], [Nokia] show concerns on the necessity and feasibility of CDMA, especially considering the limited capability (e.g., large SFO/CFO) of Ambient IoT devices and the cost (additional memories to store a set of codewords at device) versus benefits. In detail, the observations are as follows. **Impact of SFO on the performance of CDMA**In the case of large SFO (e.g., 105 ppm):- Source [R1-9421-6] think that the orthogonality between different codes/sequences will be severely disrupted, as the large SFO will accumulate an additional sampling error of 10 points of 100 points.- Source [R1-9421-8] think that the increased inter-device interference would materially degrade D2R performance, e.g., increased false alarm rate and miss detection probability, which in turn reduce spectrum efficiency even lower than the case of simple TDMA. - Source [R1-9421-1] think that the accurate timing and power control required by CDMA are far-fetched for Ambient IoT devices, referring to the IS-95 CDMA system.- Source [R1-9421-32] state that CDM-ed MA has comparable or better performance than FDM-ed MA under different SFO assumptions (i.e., 0/1E3~1E4/1E4~1E5) and device numbers (i.e., 1/2/3). Source [R1-9421-32] state that CDMA by mapping Manchester encoded bit or convolutional encoded bit with 4-length orthogonal code is feasible for D2R transmission carrying 20 information bits. * Source [ZTE] state that convolutional codes and BPSK modulation for the CDMA improve the D2R transmission performance with multiple multiplexing devices. Source [ZTE] state that for D2R transmission with TBS16+CRC0, the performance difference between the CDMA scheme using 4-length orthogonal code for 4 devices and the repetition scheme for single device at 1%BLER is less than 0.5dB~~, and the CDMA scheme has 1~2dB SNR gain at 1%BLER compared with FDMA scheme at the same multiplexing device numbers~~. While for D2R transmission with TBS96+CRC16, the performance difference between the CDMA scheme with 4-length orthogonal code for 4 devices and the repetition scheme for single device at 1%BLER is also less than 0.5dB~~, and the CDMA scheme has 1~2.5dB SNR gain at 10%BLER compared with FDMA scheme at the same multiplexing device numbers~~.

- Source [Qualcomm ~~R1-9421-28~~] state that CDMA for msg-1 enables multiplexing large number of msg-1 sequences even when power variation is [-9dB, +9dB], while quite large number of SFO hypotheses is necessary at reader to achieve reasonable false-alarm and miss detection probabilities with the SFO of [0.1 – 1] \* 105 ppm.- Source [R1-9421-5] state that correlation properties of sequences are severely damaged with the SFO of 105 ppm. Besides, D2R receiver fails to estimate the SFO of each of the parallel D2R transmissions for the SFO of 105 ppm.- Source [R1-9421-12] state that CDM of RACH preambles using either m-sequences or Gold sequences of length 63 is feasible and preambles from multiple devices can be clearly detected by the reader, even in challenging conditions (SFO = 5%, SNR = 0dB). For 1% missed-detection rate, simulation results showed that m-sequences and Gold sequences are able to achieve this performance level when SNR is about -24dB and -23dB, respectively.In the case of relatively smaller SFO (e.g., 104 ppm), * Source [Qualcomm ~~R1-9421-28~~] state that CDMA for msg-1 enables multiplexing large number of msg-1 sequences even when power variation is [-12dB, +12dB] ~~when power variation is within [-3, +3] dB~~ for the SFO of [0.1 – 1] \* 104 ppm with reasonable number of SFO hypotheses at reader.

**Impact of CFO on the performance of CDMA for Device 2b**- Source [R1-9421-5] state that codeword detection at D2R receiver fails considering non-coherent demodulation has to be used due to the quick phase rotation caused by the residual CFO of e.g. 10s or 100s of Hz after CFO estimation and correction.**Impact of timing offset between CDMed D2R transmissions on the performance of CDMA for Device 2b**- Source [R1-9421-31] state that binary modulated orthogonal sequence such as Golay sequence can tolerate timing error by selecting a suitable cyclic shift spacing.- Source [R1-9421-12] state that it is possible to detect multiple transmitters with timing difference and power difference among devices.- Source [R1-9421-24] think that poor synchronization performance in time and frequency domain of device would degrade the code orthogonality and thus results in a bad cross-correlation performance.- Source [R1-9421-21] think that the different propagation delays from devices may also degrades decoding performance.- Source [R1-9421-32] state that the negative impact of asynchronization can be mitigated with some enhancements, e.g. enhanced synchronization sequence and enhanced detection method at reader/BS side, e.g., sliding window based detection and setting constraints on the start of D2R transmission.**The impact of power variation between devices on the performance of CDMA is studied as follows.**- Source [Qualcomm ~~R1-9421-28~~] state that the larger power variation of at least up to [-9dB, +9dB] can be addressed by reader receiver and CDMA can achieve significant throughput gain for msg-1 ~~severely degrades the capacity of CDMA for msg-1~~.- Source [R1-9421-32] state that the greater the disparity in received power among multiple devices, the better performance will be obtained by SIC receiver with CDM-based multiple access scheme.Except the impact of SFO/CFO of devices, whether CDMA provides benefit is also studied as depending on the length of the orthogonal or pseudo-orthogonal code and the number of available codes for parallel D2R transmissions:- Source [R1-9421-3] think that using spreading sequence can lead to transmitting a larger number of bits which can be extremely inefficient considering that the devices are extremely power inefficient. - Source [R1-9421-3] think that CDMA might be too complex to implement in A-IoT devices, which might involve complexities with generating orthogonal sequences.- Source [R1-9421-24] think that a large device density (e.g., 150 devices per 100 m2 for indoor scenarios per TR) requires a long code sequence, which is challenging for the device with limited buffer size.- Source [R1-9421-2] think that CDMA leads to higher power consumption and lower data rate.- Source [R1-9421-8] think that the usable number of binary sequences would be much smaller due to impairment such as timing/frequency error and interference.- Source [R1-9421-12] state that in comparison to RN16, when Msg. 1 is transmitted using RACH preamble m-sequences or Gold sequences, the number of usable binary sequences that can be used is large since the base sequence design from LTE and NR can be reused.- Source [R1-9421-12] state RN16 cannot tolerate collision for any one of its bits. Once collided, the bit sequence is changed and became non-detectable. On the other hand, m-sequences and Gold sequences are able to tolerate transmission overlap.- Source [R1-9421-32] state that CDMA by mapping Manchester encoded bit or convolutional encoded bit with 16-length or 64-length orthogonal code improve the D2R transmission performance and multiplexing capacity compared with using 4-length orthogonal code for mapping. Source [ZTE] state that for D2R transmission with TBS16+CRC0 under the assumption of SFO being 1E4~1E5, the performance difference between the CDMA scheme with 64-length orthogonal code for 4 devices and the repetition scheme for single device at 1%BLER is about 1dB~~, and the CDMA scheme has about 2.5dB SNR gain at 1%BLER compared with FDMA scheme at the same multiplexing device numbers~~.- Source [R1-9421-32] state that BPSK modulation and convolutional code for the CDMA further improve the D2R transmission performance with multiple multiplexing devices ~~and multiplexing capacity~~ compared with OOK based modulation. Source [ZTE] state that for D2R transmission with TBS16+CRC0 under the assumption of SFO being 1E4~1E5 and using convolutional codes and BPSK modulation, the performance difference between the CDMA scheme using 16-length or 64-length orthogonal code for 6 devices and the repetition scheme for single device at 1%BLER is less than 1dB~~, and the CDMA scheme has about 9dB SNR gain at 1%BLER compared with FDMA scheme at the same multiplexing device numbers~~. |

## D2R time-domain definitions [ACTIVE]

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| **Agreement RAN1#118bis**In D2R, a chip corresponds to one modulated symbol at least for OOK and BPSK.* FFS: the definition for MSK.
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### Round 1

For the FFS on the chip-to-symbol definition for MSK, FL finds only one company makes a proposal [26]. However, that definition (“the chip duration for MSK can be defined as one modulated symbol for bit 0”) seems to be difficult since it does not itself define a modulated symbol, and rests on particular assumptions of MSK symbols. Since MSK is FSK, the definition evidently depends on normative-style details of how to define the underlying FSK. Since no other companies have raised the issue for the SI, FL proposes to treat the FFS as to be resolved when/if specifying MSK for A-IoT.

**Proposed conclusion 3.7.1a(I): No further discussion is needed in the SI for the FFS on “the definition for MSK” from RAN1#118bis.**

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In RAN1#118bis, we discussed whether to include in the TR definitions of D2R chip duration. Based on the tdocs submitted to RAN1#119 and the discussions during RAN1#118bis, the proposals and observations on chip duration calculations are summarized as follows.

FL requests final views on whether to have something of this in the TR. If it is not agreeable, we can leave it to result from normative phase decisions. This would turn out to be a similar outcome as proposed for R2D.

**Proposal 3.7.1b(I): Capture in the TR that the following chip duration calculations have been studied:**

* **Method 1: Calculated according to the transmission bandwidth, and depending on the line code repetition number. [CMCC][FUTUREWEI][Spreadtrum][vivo][ZTE]**
* **E.g., 2/(R\*Btx,D2R) and 1/( R\*Btx,D2R) for 2SB and 1SB transmission, respectively [Ericsson][Xiaomi]**
* **E.g., D2R chip duration is calculated for 2SB transmission as follows [Huawei]**
	+ **For Manchester code option 1 or no D2R line code used (using a square wave to the SFS), chip duration = 2/ (R\*Btx,D2R) where R ≥ 1**
	+ **For Manchester code option 2 or Miller code, chip duration = 2/ (Btx,D2R) for R = 1, chip duration = 4/(R\*Btx,D2R), for R > 1**
* **Method 2: One of a pre-defined set of pulse time durations. [Lenovo][vivo]**
* **E.g., D2R chip duration is an integer multiple (or fraction) of R2D chip duration, where a reference SCS (e.g. the R2D SCS) is used as the basis for the value of D2R chip duration. [Sharp]**
* **E.g., D2R chip length is calculated from bit length, which can be one from a set of pre-defined values [LGE] [Qualcomm][FUTUREWEI]**

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## D2R bandwidths [ACTIVE]

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| 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

RAN1#118bis*{A TP was agreed, which is omitted here.}* |

### Bandwidth sizes

Paper [28] says device 2b could potentially have different D2R bandwidth characteristics, if it does not use line codes in the way that devices 1/2a do, e.g. it may instead use ‘direct modulation of the internally generated carrier wave’. However, the generation methods for device 2b seem to be left as a normative detail not discussed in detail in any paper. Hence, FL considers capturing the statements in the TR at the same level of detail they are proposed.

**Proposal 3.8.1(I): Capture in the TR:**

* **“Since device 2b has internal carrier-wave generation, the 2SB and/or 1SB Btx,D2R and Bocc,D2R can be affected by how it performs D2R modulation/line-coding, and whether it applies small frequency shift in the same way as devices 1/2a.”**

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# R2D and D2R

## CRC [ACTIVE]

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| **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
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| **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
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| 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

Agreement RAN1#118bis*A TP was agreed. Omitted here.* |

### Round 1

For the value of a threshold on selecting CRC-6 or CRC-16 depending on the TBS, companies seem to be converging on a single value of X=24, but FL thinks this can now be left to normative details, since it could depend on what CRC(s) selected.

Companies provided an updated preference of the polynomial used for CRC-16, as well as updated results for the CRC evaluations table 6.1.0.2-1. The following proposals 4.1(a) and 4.1(b) cover both these additions.

**Proposal 4.1a(I): For CRC, adopt the TP below in Section 6.1.1.x.1 of TR 38.769:**

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| 6.1.0.2 CRC\*\*\*unchanged parts omitted\*\*\*For the CRC generator polynomials: Sources [R1-9421-7], [R1-9421-12], [R1-9421-10], [R1-9421-11], [R1-9421-21] recommend that the same polynomials from TS 38.212 are reused, giving justifications:- Sources [R1-9421-11], [R1-9421-12] state that the polynomials from TS 38.212 were already carefully and thoroughly evaluated and ensured in the NR channel coding design, so there is no need of considering other polynomials.- Source [R1-9421-10] states that the device complexity is increased when different polynomials are introduced for the D2R transmission.- Source [R1-9421-7] states that link performance is significantly impacted by the CRC lengths, and not the CRC polynomials, hence the polynomials from TS 38.212 should be used. On the other hand, sources [R1-9421-32], [R1-9421-28], [TCL] and [Panasonic] recommend that the same polynomial for CRC-6 $\left(g\_{CRC6}\left(D\right)=\left[D^{6}+D^{5}+1\right]\right) $from TS 38.212 is reused, but a new polynomial for CRC-16 is introduced, $g\_{CRC16}\left(D\right)=\left[D^{16}+D^{11}+D^{6}+D^{5}+1\right]$, incorporating the CRC-6 polynomial, giving justifications:\*\*\*unchanged parts omitted\*\*\* |

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**Proposal 4.1b(I): For CRC, adopt the TP below in Table 6.1.0.2-1 of Section 6.1.1.x.1 of TR 38.769:**

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| \*\*\*unchanged parts omitted\*\*\*Table 6.1.0.2-1: CRC evaluations

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|  | CRC-6 | CRC-16 |
| TBS | Source | CRC overhead | PFA or Pud | Source | CRC overhead | PFA or Pud |
| 8 bits | [R1-9421-5] | 43%  | ~10^(-8) Pud @10-3 BER | [R1-9421-5] | 67%  | ~10^(-11) Pud @10-3 BER |
| 12 bits | [R1-9421-3][R1-9421-28] | 33% 33% | ~10^(-2) PFA~10^(-8) Pud @10-3 BER | [R1-9421-3][R1-9421-28] | 57% 57% | ~10^(-5) PFA~10^(-11) Pud @10-3 B~~L~~ER |
| 16 bits | [R1-9421-5] | 27%  |  | [R1-9421-5] | 50%  |  |
| [R1-9421-32][R1-9421-28] | 27%27% | ~10^(-7) Pud @10-3 BER | [R1-9421-32][R1-9421-28] | 50%50%  | ~10^(-10) Pud @10-3 BER |
| 24 bits | [R1-9421-5] | 20%  | ~10^(-6) Pud @ 10% BLER and 2.7dB SNR | [R1-9421-5] | 40%  | ~10^(-9) Pud @10% BLER and 2.8dB SNR |
| [R1-9421-3][R1-9421-32][R1-9421-28] | 20% 20%20% | ~10^(-2) PFA~10^(-7) Pud @10-3 BER | [R1-9421-3][R1-9421-28] | 40% 40% | ~10^(-5) PFA~10^(-10) Pud @10-3 B~~L~~ER |
| 32 bits | [R1-9421-5][R1-9421-32][R1-9421-28] | 16% 16%16% | ~10^(-5) Pud @10-3 B~~L~~ER | [R1-9421-5][R1-9421-32][R1-9421-28] | 33% 33%33%  | ~10^(-10) Pud @10-3 B~~L~~ER |
| 40 bits | [R1-9421-5][R1-9421-32][R1-9421-28] | 13% 13%13% | ~10^(-5) PFA @10% BLER~10^(-4) Pud @10-3 B~~L~~ER  | [R1-9421-5][R1-9421-32][R1-9421-28] | 29% 29%29% | ~10^(-10) Pud @10-3 B~~L~~ER |
| 48 bits | [R1-9421-3][R1-9421-32][R1-9421-28] | 11% 11%11% | ~10^(-2) PFA~10^(-5) PFA @10% BLER~10^(-4) Pud @10-3 B~~L~~ER  | [R1-9421-3][R1-9421-32][R1-9421-28] | 25% 25%25% | ~10^(-5) PFA~10^(-10) Pud @10-3 B~~L~~ER |
| 96 bits | [R1-9421-5][R1-9421-3][R1-9421-32][R1-9421-28] | 6% 5% 6%6%  | ~10^(-2) PFA~10^(-4) Pud @10-3 B~~L~~ER | [R1-9421-5][R1-9421-3][R1-9421-32][R1-9421-28] | 14% 14% 14%14% | ~10^(-5) PFA~10^(-9) Pud @10-3 B~~L~~ER |
| 128 bits | [R1-9421-32][R1-9421-28] | 4% 4% | ~10^(-3) Pud @10-3 B~~L~~ER | [R1-9421-32][R1-9421-28] | 11%11% | ~10^(-9) Pud @10-3 B~~L~~ER |
| 256 bits | [R1-9421-5][R1-9421-28] | 2%2%  | ~10^(-3) Pud @10-3 B~~L~~ER | [R1-9421-5][R1-9421-28] | 6%6%  | ~10^(-9) Pud @10-3 B~~L~~ER |

\*\*\*unchanged parts omitted\*\*\* |

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# Proposals for online sessions

# Summary

The meeting made the following agreements. Refer to the chair’s notes for a definitive version.

# References

1. R1-2409359 Discussion on general aspects of physical layer design for Ambient IoT TCL
2. R1-2409364 General aspects of physical layer design for Ambient IoT Nokia
3. R1-2409388 General aspects of physical layer design for Ambient IoT Ericsson
4. R1-2409418 On general aspects of physical layer design for Ambient IoT Huawei, HiSilicon
5. R1-2409513 Discussion on general aspects of A-IoT physical layer design CMCC
6. R1-2409535 Discussion on Physical Layer Design for Ambient-IoT EURECOM
7. R1-2409552 Discussion on general aspects of physical layer design for Ambient IoT ZTE Corporation, Sanechips
8. R1-2409598 Considerations for general aspects of Ambient IoT Samsung
9. R1-2409637 Discussion on general aspects of physical layer design for Ambient IoT Spreadtrum, UNISOC
10. R1-2409682 Discussion on General Aspects of Physical Layer Design vivo
11. R1-2409801 On remaining general physical layer design aspects for AIoT Apple
12. R1-2409864 Discussion on general aspects of ambient IoT physical layer design NEC
13. R1-2409897 Discussion on physical layer design of Ambient IoT Xiaomi
14. R1-2409942 Discussion on general aspects of physical layer design CATT
15. R1-2409976 On General Physical Layer Design Considerations for Ambient IoT Applications Lekha Wireless Solutions
16. R1-2410001 Discussion on general aspects of physical layer design for Ambient IoT China Telecom
17. R1-2410026 On remaining open issues in Rel-19 Ambient IoT physical layer design FUTUREWEI
18. R1-2410059 Discussions on FEC/repetition in R2D and D2R Fujitsu
19. R1-2410092 Discussion on general aspects of physical layer design of A-IoT communication OPPO
20. R1-2410225 Physical layer design of Ambient IoT Sony
21. R1-2410267 Discussion on general aspects of physical layer design ETRI
22. R1-2410287 General aspects of Ambient IoT physical layer design LG Electronics
23. R1-2410311 Discussion on physical layer design for Ambient IoT InterDigital, Inc.
24. R1-2410352 General aspects of physical layer design for Ambient IoT Panasonic
25. R1-2410372 Discussion on A-IoT physical layer design ASUSTeK
26. R1-2410390 Study on general aspects of physical layer design for Ambient IoT NTT DOCOMO, INC.
27. R1-2410416 Discussion on general aspects of physical layer design Sharp
28. R1-2410479 General aspects of physical layer design Qualcomm Incorporated
29. R1-2410515 General aspects of physical layer design MediaTek Inc.
30. R1-2410552 Discussion on the physical layer design aspects for Ambient IoT devices Lenovo
31. R1-2410591 Discussion on General aspects of physical layer design of AIoT IIT Kanpur, Indian Institute of Tech (M)