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

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

**Source: Moderator (Huawei)**

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

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

**Agenda item: 9.4.2.1**

# Introduction

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

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

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

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

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

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

## Versions

FLS #1: R1-2407248

# R2D

## R2D waveform

|  |
| --- |
| Agreement RAN1#116  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. |

### CP handling [ACTIVE]

|  |
| --- |
| Agreement RAN1#116bis  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     - …   + 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#117  Study the following regarding CP location/length determination for Method Type 1:   * + Alt 1: Device assumes same CP length for each OFDM symbol, i.e. does not distinguish exact CP length among different OFDM symbols   + Alt 2: duration between transition edges is utilized by device to determine CP location/length, i.e. if the duration appears to be invalid based on known chip duration * Companies are encouraged to clarify the CP removal method used and implementation aspects for the device * Evaluations are encouraged to be performed for a small value of M, e.g. 4 and a large value of M, e.g. 24, at least by comparison to the case where the CP length of each OFDM symbol is known by device * Companies should report the values of SFO, and SFO detection methods used in evaluations   Agreement  Study the following options regarding subcarrier orthogonality for Method Type 2:   * Alt 1: Method Type 2 retains subcarrier orthogonality (i.e. CP copied from the end of an OFDM symbol) * Alt 1-1: The first OOK chip(s) and the last OOK chip(s) in an OFDM symbol are the same   + FFS: whether this alternative applies if CP length is longer than the chip duration * Alt 1-2: Ensure a transition edge occurs only at the start or only at the end of the CP, and no transition edge occurs during the CP * Other potential methods are not precluded * Alt 2: Method Type 2 does not retain subcarrier orthogonality * Proponents to bring further details to RAN1#118 * Evaluations and discussions are encouraged to be performed for a small value of M, e.g. M = 4 and a large value of M, e.g. M = 24. * Companies should report the values of SFO, and SFO detection methods used in evaluations |

#### Round 1

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

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

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | Agree with this proposal. |
|  |  |

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

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

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

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | Agree with this proposal. |
|  |  |

Companies have different understanding on Method type 2. It seems the basic assumption of Method 2 (and its essential difference to Method 1) is device is not aware of CP location.

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | Agree with this proposal. |
|  |  |

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

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | Okay |
|  |  |

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

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

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | We prefer option 2. In addition, for option 2, the impact of SFO at device’s may be considered to device the chip duration. Thus, we suggest adding one FFS for option 2:  **Proposal 2.1.1e(I): For R2D CP handling Method 2, for potential down-selection, the OOK chip duration generation is determined by the following:**   * **Option 1: M, and the length of OFDM symbol without CP**   + **FFS: Impact on device to handle non-constant chip duration around CP** * **Option 2: M, and the length of OFDM symbol with CP**   + **FFS: Impact of SFO on device to handle non-constant chip duration** |
|  |  |

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

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

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

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

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

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

### Waveform(s) [ACTIVE]

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

#### Round 1

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

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | There is different maximum transmission power defined in NR for DFT-s-OFDM and CP-OFDM if UE as reader. Considering different coverage requirement for device 1/2, we suggest DFT-s-OFDM can be as baseline to further study and FFS CP-OFDM in this stage. |
|  |  |

## R2D modulation [ACTIVE]

|  |
| --- |
| Agreement RAN1#116  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 RAN1#116  For R2D study OFDM-based waveform with subcarrier spacing of 15 kHz, Btx,R2D is ≤ [12] PRBs and is down-selected among:   * Alt 1: Including 180 kHz, 360 kHz, and FFS other values * Alt 2: Integer multiple(s) of 180 kHz (FFS: what integer(s)) * Alt 3: Integer multiple(s) of the subcarrier spacing (FFS: what integer(s)) |

### M values

#### Round 1

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

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

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

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

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

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

### Single / double sideband modulation

#### Round 1

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

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | Fine. |
|  |  |

## R2D line coding [ACTIVE]

|  |
| --- |
| **Agreement** RAN1#116  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 RAN1#117  The study assumes the following bit to chip mapping for Manchester encoding:   * + bit 0→chips{10}, bit 1→chips{01} * FFS: Variant of the above for CP handling |

### Round 1

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

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

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | okay |
|  |  |

## R2D FEC / repetition [ACTIVE]

|  |
| --- |
| **Agreement** RAN1#116  Regarding FEC, R2D with no forward error-correction code (FEC) is studied as baseline.   * Evaluations would be by comparison to this baseline   Agreement RAN1#117  Define repetition types for study purposes as follows:   * Block level: All the bits received from higher layers and/or physical layer (according to what is present) after CRC attachment (if used) are blockwise repeated Rblock times * Bit level type 1: Each bit after CRC attachment (if used) is repeated Rbit times * Bit level type 2: Each bit after both CRC attachment (if used) and FEC (if used) is repeated Rbit times * Chip level: Each chip after line coding (if used) or after square wave modulation (if used) is repeated Rchip times   + NOTE: Equivalent to extending the duration of each chip by Rchip times |

### Round 1

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

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

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

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

**Proposal 2.4b(I):**

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | In our understanding, any repetition is not necessary for at least device 1 and 2a because of the limited detection and demodulation capability. In addition, reader can control the transmission power to meet coverage requirement. |
|  |  |

## R2D and D2R CRC [VOID]

**See Section 4.**

## R2D multiple access [ACTIVE]

|  |
| --- |
| Agreement  From 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.  Agreement  For A-IoT contention-based access procedure, at least slotted-ALOHA based access is studied. |

### Round 1

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

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

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

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

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

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

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

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

|  |  |
| --- | --- |
| Company | Views |
| TCL | Agree with this proposal. |
|  |  |

## R2D time-domain definitions

### Subcarrier spacing(s) [INACTIVE]

|  |
| --- |
| 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. |

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

### Time unit(s) [ACTIVE]

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

#### Round 1

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

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

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | In our understanding, the value of chip duration could at least the impact of device’s SFO. Thus, we suggest adding one subbullet for FFS  **Proposal 2.7.2a(I): In R2D, a chip:**   * **Corresponds to one modulated symbol, e.g. according to agreed OOK modulation.** * **Chip duration = (1/M) × {OFDM symbol duration excluding CP part} OR {OFDM symbol duration including CP part} according to Proposal 2.1.1d.** * **FFS: Impact of SFO on device to handle non-constant chip duration** |
|  |  |

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

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | Fine |
|  |  |

## R2D bandwidths [ACTIVE]

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

For Btx, R2D, see section 2.2.1.

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

# D2R

## D2R waveform [ACTIVE]

### Round 1

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

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

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

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | Okay. |
|  |  |

## D2R modulation [ACTIVE]

### Modulation scheme(s)

|  |
| --- |
| 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 |

#### Round 1

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

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

**Proposal 3.2.1(I):**

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | 2FSK has better BER performance than OOK. However, large power consumption and large return loss may be generated. When frequency changing is small, the aliasing between different bit information will generate. In our understanding, **variant 5 is okay at least for device 1 and 2a**. |
|  |  |

### Single / double sideband

#### Round 1

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

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

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | If 1SB is supported, device implementation (e.g., extra block to suppress one SB) and reader implementation (e.g., RF filter only) can be considered when large FS is supported for device 2a. In this case, we think 1SB can not be achieved for small frequency. |
|  |  |

## D2R line coding [ACTIVE]

|  |
| --- |
| **Agreement**  For D2R, study: Manchester encoding, FM0 encoding, Miller encoding, no line coding.   * FFS: Mapping(s) from bit(s) to line-code codewords * FFS: How to achieve small frequency shift in baseband and/or FDM(A) among devices * Aspects to study include:   + Spectrum shape   + Complexity   + Power consumption   + BER, BLER   + Resilience to SFO   + If there is any relation to CFO   Agreement RAN1#117  The study assumes the following bit to chip mapping for Manchester encoding:   * + bit 0→chips{10}, bit 1→chips{01} * FFS: Variant of the above for CP handling |

### Line code types

#### Round 1

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

**Proposal 3.3.1a**

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | Okay. For Miller coding, different subcarrier coefficient may be considered combined with MCS/BLF. |
|  |  |

### Small frequency shift

#### Round 1

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

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

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

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

## D2R FEC / repetition [ACTIVE]

|  |
| --- |
| **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 repetition  Note: 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  Agreement RAN1#117  Define repetition types for study purposes as follows:   * Block level: All the bits received from higher layers and/or physical layer (according to what is present) after CRC attachment (if used) are blockwise repeated Rblock times * Bit level type 1: Each bit after CRC attachment (if used) is repeated Rbit times * Bit level type 2: Each bit after both CRC attachment (if used) and FEC (if used) is repeated Rbit times * Chip level: Each chip after line coding (if used) or after square wave modulation (if used) is repeated Rchip times   + NOTE: Equivalent to extending the duration of each chip by Rchip times   Agreement RAN1#117  For D2R, study at least block-level and bit-level repetition type 1 and type 2. |

### Repetition

#### Round 1

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

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

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

### FEC

#### Round 1

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

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

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | Fine. |
|  |  |

## D2R CRC [VOID]

Section 4.1 will take R2D and D2R CRCs together.

## D2R multiple access [ACTIVE]

|  |
| --- |
| 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. |

### Round 1

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

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

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

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

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

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| TCL | To avoid more complexity operation in device side to generate code word, we think CDMA should be down-selected at least for device 1 and 2a. |
|  |  |

## D2R time-domain definitions [ACTIVE]

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

### Round 1

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

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

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

* **Corresponds to one modulated symbol**
* **Chip duration is:**
  + **Option 1:** 
    - **FFS: Definition of the reference chip length based on e.g. BLF, 2SB bandwidth**
  + **Option 2: One of a pre-defined set of pulse time durations.**

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

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

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

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

## D2R bandwidths [ACTIVE]

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

### Bandwidth sizes

#### Round 1

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

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

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

****

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

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

|  |  |
| --- | --- |
| **Company** | **Views on Proposals 3.8.1a, b** |
| TCL | Okay with this proposal. |
|  |  |

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

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

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

|  |  |
| --- | --- |
| **Company** | **Views on Proposals 3.8.1c** |
| TCL | Okay |
|  |  |

# R2D and D2R

## CRC [ACTIVE]

|  |
| --- |
| **Agreement** RAN1#116  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** RAN1#116  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 RAN1#116BIS  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 |

### Round 1

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

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

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

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

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

|  |  |
| --- | --- |
| **Company** | **Views, including value of X** |
|  |  |
|  |  |

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

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

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

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

|  |  |
| --- | --- |
| **Company** | **Views, including value of Z** |
|  |  |
|  |  |

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

## Scrambling

### Round 1

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

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

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

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

# Proposals for online sessions

# Summary

The agreements reached were as follows:

# References

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

# Annex A – Previous Decisions

## RAN1#116, Athens, February 2024

Agreement

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

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

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

Agreement

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

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

**Agreement**

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

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

**Agreement**

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

* Evaluations would be by comparison to this baseline

**Agreement**

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

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

**Agreement**

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

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

**Agreement**

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

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

## RAN1#116bis, Changsha, April 2024

Agreement

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

Agreement

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

Agreement

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

Agreement

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

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

Agreement

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

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

Agreement

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

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

Agreement

Study

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

Agreement

Study D2R transmission in the physical layer using repetition

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

Agreement

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

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

Agreement

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

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

Agreement

For R2D CP handling for OFDM based OOK waveform:

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

Agreement

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

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

## RAN1#117, Fukuoka, May 2024

Agreement

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

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

Agreement

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

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

**Agreement**

Define repetition types for study purposes as follows:

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

**Agreement**

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

**Agreement**

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

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

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

**Agreement**

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

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