3GPP TSG RAN WG1 Meeting #121 **R1-2503725**
St. Julian's, Malta, May 19th – 23th, 2025

Agenda Item:	9.4.1
Source:	EURECOM
Title:	Discussion on Physical Channel Design and Modulation Aspects for Ambient-IoT
Document for:	Discussion and Decision

1. Introduction

The WI item scope has been agreed in [1] with the RAN1 scope defined below:

RAN1 Scope: **RP-243326**

- PRDCH and PDRCH, which are the only physical channels in R2D and D2R, respectively.
- R2D and D2R signal(s)
- Multiplexing/multiple access in R2D is by only TDMA, and in D2R is by only TDMA and FDMA.
- R2D supports only OOK-4 modulation, one solution for CP handling. D2R backscattering supports only OOK and BPSK modulations.
- R2D transmission supports only the Manchester line code in TR 38.769
- D2R transmission supports:
    - Either the Manchester line code in TR 38.769 or no line code (one to be down-selected); and
    - A corresponding small frequency shift method according to the options in TR 38.769.
- R2D does not support FEC. D2R supports only convolutional code with generator polynomials as per TS 36.212 (unless RAN1 decides to use other generator polynomials by RAN1#120bis).
- PRDCH and PDRCH both support transmission without CRC, and with CRC as per the generator polynomials in TS 38.212 (unless RAN1 decides to use other generator polynomials by RAN1#120bis) for 6-bit CRC and 16-bit CRC. Cases to use which length of CRC, or no CRC, to be decided in RAN1.
- D2R supports physical layer repetition transmission. R2D does not support physical-layer repetition transmission.

This contribution focuses on modulation aspects and waveform design for the R2D (downlink) channel/signal.

2. R2D Waveform

It has been agreed that "R2D supports only OOK-4 modulation" [1]. That is, the time domain OOK sequence is DFT precoded and mapped to the corresponding frequency resources.

In the previous meeting, the following agreement has been reached

> Agreement: **RAN1#120-bis**
>
> From reader perspective, for the needed certain specification of DFT-s-OFDM waveform generation for OOK-4 modulation:
>
> - An example is provided below, which does not presume any specific reader implementation:
>   - Step 1: The time domain OOK signal is the M chips of one OFDM symbol
>   - The specification only needs to reflect that one OFDM symbol contains M chips
>   - Step 2: A chip is represented (e.g. upsampled) by L samples
>   - The specification only needs to reflect that one chip contains L samples as the input to N'-points DFT
>   - Step 3: An N'-points DFT is performed on the samples of one OFDM symbol to obtain the frequency domain signal.
>   - The specification only needs to reflect that there is an N'-points DFT operation, where N' = M*L
>   - Step 4: Map the frequency domain signal obtained by N'-points DFT to the X subcarriers of $B_{tx,R2D}$
>   - The specification only needs to reflect that N' >= X, where X is corresponding to the $B_{tx,R2D}$
>   - Step 5: An N-points IDFT is performed to obtain the time domain signal.
>   - The specification only needs to reflect that there is an N-points IDFT operation
> - Note: other examples were provided in contributions to RAN1#120bis, e.g. in annex 2 of R1-2502160
> - From the example above, some normative specification related to at least step 1 and step 5 are needed.
>   - Note: RAN1 to consider whether an information annex could describe other steps
>   - Note: some normative RAN1 specification text about waveform is assumed to be needed for RAN4 requirements definition
>   - Note: the specification also needs to reflect the timing of the CP insertion operation.

Since it is common understanding that the ON-sequence is not specified and up to reader implementation, we suggest to directly refer to the time-domain signal $r_m(l)$ with $l = 0,1,\ldots,L-1$, where L is the chip length and $m = 0,1,\ldots,M-1$ is the m^{th} chip in the OFDM symbol. This signal $r_m(l)$ can be different for every chip depending on the encoded bit sequence that it modulates. The input to the DFT is the concatenation of all $r_m(l)$.

3. R2D CP Handling

The following has been agreed:

Agreement:	**RAN1#120-bis**

For the below agreement, further update on the followings

Agreement

For further down-selection among CP handing which retains subcarrier orthogonality, at least for PRDCH, at least Method Type 1 is supported

- For supported M values <= 12
  - RAN1 will not further pursue additional CP handling design
- For supported M values > 12
  - RAN1 will further down-select one from the followings
    - Option 1: Candidate 3 of M2-1-1 (as per agreements from RAN1#120)
      - ~~Insert padding chips only at the end OOK chips of OFDM symbol~~
      - The last 2 out of M OOK chips at the end of an OFDM symbol are always 'ON'
    - Option 3: RAN1 will not further pursue additional CP handling design

It is our preference to use Method Type 1 irrespectively of the M value. Potential enhancements can be deferred to a future release if required.

Proposal 1: Support only Method Type 1 for all M.

4. R2D Chip Duration

There has been a lot of discussion during the last meeting. However, we maintain our view that the chip duration requires a simple definition independent from any additional impairments. In our view, the chip duration C should be defined independently of the CP as $C = \frac{1}{SCS}\frac{1}{M}$. If a potential CP-handling method modifies C this can be captured as $C' = f(C)$, i.e. some function $f()$ that modifies the original chip duration C.

Proposal 2: Define chip duration as $\boldsymbol{C = \frac{1}{SCS}\frac{1}{M}}$.

5. Conclusion

In this contribution, the following proposals and observations have been made:

Proposal 1: Support only Method Type 1 for all M.

Proposal 2: Define chip duration as $\boldsymbol{C = (1/SCS)/M}$.

6. References

[1] RP-243326, "New Work Item: Solutions for Ambient IoT (Internet of Things) in NR", RAN1 Vice-chair (Huawei), RAN#106, Dec 2024

[2] TR 38.769, "Study on solutions for ambient IoT (Internet of Things)", V19.0.0, Dec 2024.