3GPP TSG-RAN WG1 Meeting #118  R1-240xxxx

**Maastricht, NL, August 19th – 23rd, 2024**

**Agenda Item: 9.4.2.2**

**Title: FL summary #1 on frame structure and timing aspects for Rel-19 Ambient IoT**

**Source: Moderator (vivo)**

**Document for: Discussion, Decision**

# Introduction

This is the feature lead (FL) summary for agenda item (AI) 9.4.2.2 of frame structure and timing aspects for Rel-19 study item (SI) on solutions for Ambient IoT (Internet of Things) in NR.

The issues including questions and proposals that are in the focus of this round of the discussion are tagged **FL1 High Priority.**

# Proposals for Online discussion

**TBU**

# Synchronization

## R2D time synchronization

About R2D chip synchronization for R2D reception, many companies mentioned that the device can determine the chip length by counting the clock samples within a OOK chip or between the adjacent transition edges in the same direction in the Clock acquisition part. In addition, [32] proposed that for OOK-4, the values of M that result in similar OOK chip lengths should be avoided.

### 3.1.1 Preamble

* [16] provided the evaluation in figure 2 below and proposed that
  + The A-IoT synchronization performance by Clock-acquisition part (CAP) of preamble could be degraded with sample error rate (SER) if CP is included as part of OOK-4 waveform.
  + **Clock-acquisition part (CAP) of R2D preamble should at least include 16 chips to obtain the 5% sample error rate performance.**

图表

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Figure 2: The performance of sample error rate (SER) of [16]

* [27] provided the evaluation in figure 3-1 below and proposed that from data reception performance perspective, **residual SFO requirement after device receiving R2D preamble can be set to 10000 PPM**, given device can track the PRDCH timing along the processing of Manchester on-off chips.



Figure 3‑1: R2D data reception robustness by timing tracking based on Manchester coding of [27]

Following was agreed in RAN1#116bis

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| Agreement  For the R2D timing acquisition signal immediately preceding the transmission of a physical channel, study a preamble with at least two parts which includes a start-indicator part and a clock-acquisition part, where the start-indicator part immediately precedes the clock-acquisition part:   * Start-indicator part provides the start of the R2D transmission   + FFS: Details of start-indicator part * Clock-acquisition part provides at least the chip synchronization of the subsequent physical channel transmission   + FFS: Details of clock-acquisition part, e.g. structure, encoding, length, etc.   + FFS: Methods to determine chip duration of the subsequent physical channel transmission   + FFS: Other functionalities * Note: the preamble is considered not to be part of a physical channel * FFS: other part(s) of the preamble, if any * FFS: whether the above clock acquisition is sufficient for all devices * FFS: how to make the preamble compact |

The clock-acquisition part in the R2D preamble provides at least the chip synchronization, while it is not clear whether the clock acquisition part can be used by device to calibrate clock. The related discussions are all summarized in section 3.2.1 of this document.

### 3.1.2 Midamble

* [5], [7], [10], [11], [16], [23], [24], [39] proposed R2D transmission without midamble is studied as baseline
* [9] and [25] proposed to further study the midamble for A-IoT R2D transmissions with PIE encoding.
  + [25] For PIE encoding, a chip can be easily confused between 0 and 1 when the received signal strength is weak, given a larger coverage target of A-IoT compared to RFID, and in the presence of interference. The error will propagate in decoding the rest of the received signal. So, the study should include whether/how interference impacts the synchronization maintenance performance of R2D transmission.

It is also noted different PIE design from RFID for bit ‘0’ and ‘1’ is also discussed in AI 9.4.2.1. Considering companies’ interests, following low priority proposal can be considered.

**FL1 Low Priority Proposal 3.1.2: R2D transmission without midamble is studied as baseline.**

* **This does not preclude study of R2D transmission with midamble for PIE.**

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| **Company** | **Y/N** | **Comments** |
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### 3.1.3 Postamble

[25] observed that given the possible clock drift at a device, it may be still beneficial to also attach postamble at least for the determination of the end of PRDCH at a device.

While [11], [15], [24], [27], [39] think the need of R2D postamble is not identified at least for the purpose of timing tracking.

* if Manchester Coding is supported, it allows for precise timing tracking with each ON-OFF transition, which can correct timing errors, hence R2D postamble used for timing tracking is not needed.

The discussion on R2D postamble used for time tracking can be postponed till the decision on necessity on R2D midamble for time tracking is made.

Whether to support the R2D postamble used for device to identify the end of PRDCH transmission is discussed in section 5.2.2 of this document.

## D2R time synchronization

### 3.2.1 General

Following WA and agreements were made in RAN1#117 meeting:

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| **Working assumption on [0q] (sampling frequency) in link level simulation table**  Companies to report the Sampling frequency (e.g., 1.92Msps or other feasible values if any)  Initial SFO (Sampling Frequency Offset) (Fe):   * (M) Randomly select a value from the range of [0.1 ~ 1] \*10^4 ppm for device 2, * (M) Randomly select a value from the range of [0.1 ~ 1] \* 10^5 ppm for device 1, * (O) Randomly select a value from the range of [0.1 ~ 1] \*10^5 ppm for device 2, * FFS: Optionally evaluate a fixed value SFO for device 1 and 2 * Note: For random selection, the value is randomly selected per simulation drop, according to a uniform distribution * Note: Above values are only for sampling purpose. * FFS other values * Note: Above assumptions are only for LLS evaluation purpose only for R2D and [D2R].   The timing drift ΔT over a time T is modelled as ΔT = ±Fe \* T.   * Note: Accuracy can be improved after clock calibration for at least device 2.  FFS applicable for device 1 * Note: SFO after clock calibration can be applied to Fe. * FFS other models   CFO for device 2b.   * [100ppm/200ppm/1000ppm, 0.1ppm/s]”   Note: Above assumptions are for LLS evaluation purpose only  Agreement (RAN1#117)  Study whether/how an A-IoT device can count the time with sufficient accuracy (with a certain timing error due to SFO) at least for the purposes related to TDM(A) (if needed), and if so for how long after receiving an R2D transmission. |

**Following D2R time synchronization issues are interrelated and discussed by companies. The understanding and consensus on these issues further determines**

* **The D2R preamble design**
* **Whether and how many D2R midamble and/or postamble is needed for fine timing recovery**
* **The feasibility on FDMA of multiple D2R transmissions**

### 3.2.1.1 Issue#1: The required SFO estimation accuracy at reader

* [3] discussed that for a PDRCH transmission, the amount of midambles may depend on the 1) transmission length or 2) the residual timing error or both.
* [14] provides the simulation result in figure 10 to compare the performance for SFO mitigation of case (i) where only preamble is used and case (ii) jointly using preamble + postamble. [14] observed that the “preamble + postamble” scheme has better performance on residual SFO elimination (from 104 level to 103 level at SNR=10dB) and about 3dB gain in SNR when the BLER is 10% compared with “preamble only” scheme.

图表, 折线图

描述已自动生成

Fig. 10 Comparison on residual SFO elimination performance b/w preamble only and preamble+postamble case of [14]

* [27] observed in the simultion figure 3-2 that to confine D2R data reception performance loss, smaller residual SFO is required for longer TBS transmission, as can be checked in the below figure (500 PPM for 96 bits, 100 PPM for 400 bits, and 50 PPM for 1000 bits).

图表

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Figure 3‑2: D2R performance w.r.t. different TBS and residue SFO values of [27]

* [32] presented in Figure 12 the evaluation result for D2R BLER performance with clock synchronization error with the device side SFO assumption of [0.1 - 1] \* 105 ppm and observed that Reader chip synchronization for D2R reception may require estimation accuracy of 103 ppm or less for demodulation, such as ML detection, depending on D2R length, coding scheme, etc.



Fig. 12 D2R BLER performance with the presence of clock frequency error

### 3.2.1.2 Issue#2: Solutions to achieve the required D2R timing accuracy

There are two approaches to achieve the required D2R timing accuracy.

* **Approach 1: Device does not handle SFO, Reader acquires device clock for D2R accurately [4], [7], [11], [16?], [32]**
* **Option 1: reader estimates the device clock frequency by checking cross-correlation between the received D2R preamble and the known D2R preamble generated with large number of SFO hypotheses.** [11], [16?], [32]
* **Option 2: reader estimates the device clock frequency by measuring the time gap between two known sequences (preamble and midamble/postamble) associated with the D2R transmission.** [4], [7], [11], [32]
  + [4], [7] provides further detailed steps on D2R timing correction
    - Step 1: the reader roughly estimated the SFO and timing based on the preamble.
    - Step 2: based on the estimated SFO and timing, the reader search the postamble within a proper range and find the timing information of the postamble.
    - Step 3: based on the timing (sample index / position) of preamble and postamble, the reader can decide the SFO and find the right position of each D2R data symbols.
* **Approach 2: Device calibrates the clock before D2R transmission to some extent; then reader estimates the residual SFO. [11], [13], [16], [27?], [31], [32]**
* [27]: Device is able to track timing effectively. For A-IOT reader, comparing the estimated time offset between D2R preamble and R2D preamble with the known time offset can be used to derive and compensate SFO. Given X-us time error of D2R preamble detection by the reader and Y-us time offset between R2D and D2R preambles, D2R residue SFO can be derived as X/Y \* 10^6 PPM.

For above two approaches, [32] provides LLS in figure 13 and figure 14 and observed following:

* With SFO of [0.1 – 1] \* 105 ppm, it would be difficult for a reader to estimate the device clock frequency with the accuracy of 103 ppm or less only based on the D2R preamble
  + Even with very large number of clock frequency hypotheses, the target accuracy may not be achievable
* With SFO of [0.1 – 1] \* 104 ppm, a reader would be able to estimate the device clock frequency with the accuracy of 103 ppm or less, based on the D2R preamble, by reasonable implementation
  + Reasonable number of clock frequency hypotheses can achieve the target accuracy

Figure 13 below shows average clock frequency estimation error at reader in ppm as a function of average SNR in dB. The device clock frequency error of [0.1 - 1] \* 105 ppm is assumed.

 

(a) Sequence length = 7



(b) Sequence length = 15

Fig. 13 Clock frequency estimation error (device SFO [0.1 – 1] \* 105 ppm) of [32]

Figure 14 below shows average clock frequency estimation error at reader in ppm as a function of average SNR in dB. The device clock frequency error of [0.1 - 1] \* 104 ppm is assumed.



(a) Sequence length = 7



(b) Sequence length = 15

Fig. 14 Clock frequency estimation error (device SFO [0.1 – 1] \* 104 ppm) of [32]

### 3.2.1.3 Issue#3: feasibility for device to calibrate clock

* [13] proposed that device may calibrate its timing counting and synchronization by comparing external signal and internal clock.
* [15] discussed a device may know the phase of its clock is advanced or delayed through the calibration with R2D signal.
* [16] The A-IoT device can take the received timing of the R2D signal as the reference time for the backscattering or transmitting the D2R signal.
* [25] study a solution when multiple devices are multiplexed, e.g., providing a time interval in which devices can fallback to receive R2D synchronization signal and re-calibrate its clock.
* [31] Device performs D2R resource determination and D2R TX based on post-sync SFO, which is updated by monitoring/reception of the latest R2D sync signal.
* [32] further discussed the feasibility of device clock calibration and observed following and proposed to study device clock calibration as it is essential for FDMA of D2R transmissions.
  + Error of sampling clock frequency can be identified by measuring the number of clock samples for a given duration using the sampling clock and compare it with the expected number of samples if ideal clock is used
  + Achievable accuracy of clock calibration depends at least on (1) length of time duration for clock calibration and (2) clock frequency (longer time duration, higher clock frequency, better accuracy)
  + Two options are identified:
    - Opt.1: A device changes the clock frequency directly, e.g., by using DCO [38].
    - Opt.2: A device updates the number of clock samples for a D2R chip/bit without changing the clock frequency.

In addition, [25], [32] disussed the SFO impacts on the performance of FDMA of mutiple D2R transmissions.

* [25] observed that it is very challenging at the reader to adjust the clock based on multiple concurrent midambles received from different devices experiencing different clock drift for FDMA or CDMA cases and propose to study the impact of synchronization misalignment between devices and possible solutions for synchronization drift from multiplexed devices.
* [32] provides LLS in figure 16 and observed following:
* With SFO of [0.1 – 1] \* 104 ppm, FDMA for D2R causes around 3dB degradation from ideal the case with no SFO
  + FDMA for D2R is feasible if SFO of [0.1 – 1] \* 104 ppm is achievable
* With SFO of [0.1 – 1] \* 105 ppm, FDMA for D2R causes around 8dB degradation from the case with SFO of [0.1 – 1] \* 104 ppm, even if perfect SFO estimation is enabled by reader
* Reducing SFO from [0.1 – 1] \* 105 ppm by device (e.g., clock calibration) is essential



Fig. 16 BLER performance of FDMAed D2R transmissions with SFO at devices and perfect SFO estimations at reader of [32]

Given all above, following proposals can be considered.

**FL1 High Priority Proposal 3.1-1: Study following two options for D2R time synchronization, including identification of the target estimation accuracy for reader to perform D2R demodulation.**

* **Option 1: device does not calibrate the clock, reader acquires device clock for D2R accurately**
* **Option 2: device calibrates the clock before D2R transmission to some extent and reader estimates the residual SFO**
* **Note above clock calibration can be done by device updating the number of clock samples for a D2R chip/bit without changing the clock frequency.**

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| **Company** | **Y/N** | **Comments** |
| Qualcomm | Y | We prefer Option 2. However, given we have not yet discussed this, we are fine to keep the two options for further discussions.  For this discussion, we suggest to update the proposal as follows.  **Study following two options:**   * **Option 1: device transmits D2R with the initial SFO. Reader estimates the device clock frequency for D2R waveform generation and detects/demodulates/decodes the received D2R transmission.**   + **FFS: how D2R signal should be designed to facilitate reader’s estimation of device clock frequency for D2R waveform generation** * **Option 2: device calibrates the device clock frequency for D2R waveform generation by using R2D signal and transmits D2R with the residual SFO. Reader estimates the device clock frequency for D2R waveform generation and detects/demodulates/decodes the received D2R transmission.**   + **FFS: how R2D signal should be designed to facilitate device clock calibration**   + **FFS: how device calibrates the clock and its achievable accuracy**   + **FFS: how D2R signal should be designed to facilitate reader’s estimation of device clock frequency for D2R waveform generation** |
| OPPO | OK | Generally, we are fine with these two classifications of options. Similar to QC, we also prefer Option 2, as the device should be able to use the received timing of the R2D signal as the reference time for the backscattering and active transmission of D2R signal.  Regarding proposal update, we think QC’s suggestion is helpful in terms of understanding the options and setting aspects that need to be studied further under each option. Modifying on top of QC’s version, here is our suggestion (e.g., as D2R waveform generation is unclear to us in this context).  **Study following two options of time synchronization for D2R signal transmission and reception, in order for the reader to perform estimation of device clock frequency and demodulation of the D2R signal.**   * **Option 1: device transmits D2R with an initial SFO. Reader estimates the ~~device clock~~ frequency ~~for~~ of the received D2R transmission for detection/demodulation/decoding. ~~waveform generation and detects/demodulates/decodes the received D2R transmission~~**   + **FFS: how D2R ~~signal~~ transmission should be designed to facilitate reader’s estimation of the ~~device clock~~ frequency ~~for~~ of the received D2R transmission** * **Option 2: device calibrates the device clock frequency for D2R ~~waveform generation~~ transmission by using R2D signal and transmits D2R with ~~the~~ a potential residual SFO. Reader estimates the ~~device clock~~ frequency ~~for~~ of the received D2R transmission for detection/demodulation/decoding. ~~waveform generation and detects/demodulates/decodes the received D2R transmission~~**   + **FFS: how R2D signal should be designed to facilitate the clock frequency calibration at the device**   + **FFS: how device calibrates the clock frequency based on a R2D signal and what is the ~~its~~ achievable accuracy**   + **FFS: how D2R ~~signal~~ transmission should be designed to facilitate reader’s estimation of the ~~device clock~~ frequency ~~for~~ of the received D2R transmission** |
| InterDigital | Y | Option 2 seems preferable. |

### 3.2.2 Midamble

**On the necessity/benefits of using a midamble,**

* + [11] observed that whether D2R midamble is needed for timing/frequency tracking for long D2R transmission length depends on factors like whether device can correct the timing by the received R2D transmission and whether reader can try a large number of SFO hypotheses, and the timing error/drift at device side etc.
  + [12], [39] observed that the gain of midamble, can be dependent on the used line encoding scheme, message size and demodulation assumption at the reader.
  + [15] proposed to clarify the basic assumption on whether coherent detection is considered as the baseline for D2R reception.
  + [36] proposed the TB size for PDRCH transmission should be decided before we can discuss further details regarding the use of midamble or postamble.

**Not necessary:**

* + **C1: It is sufficient by preamble to derive the timing and frequency offset of the PDRCH proposed not to consider midamble for D2R transmission.** 
    - [16]
  + **C2: For the purpose of timing tracking, the midamble is not necessary if line code is used in D2R transmission.**
    - [15], [23]
  + **C3: If the non-coherent detection is adopted for D2R reception, the benefit from midamble may be minor.** 
    - [11], [15]
  + **C4: If the D2R transmission packet size is not large, preamble could be used to do the channel estimation.** 
    - [11], [15]
  + **C6: D2R midamble for the other purpose, e.g., channel estimation or interference estimation is not considered.**
    - [39]

**Necessary and/or beneficial**

* + **P1: At least for a long data packet, mid-amble would be necessary for D2R transmissions.** 
    - [2], [4], [5], [7], [9], [13], [17], [20], [25], [27]
  + **P1’: Midamble is only needed when D2R TBS is large and FEC coding is adopted.**
    - [23]
  + **P2: Edge detection - based timing acquisition is not possible because of the low backscattered signal power of the D2R transmission.**
    - [4], [5], [7],
  + **P3: Serves as a reference signal to** **achieve channel and interference estimation.** 
    - [4], [5], [7], [9], [15], [17]
  + **P4: Decreases the memory requirement of the reader, and enables pipelined processing of the reception.**
    - [4]
  + **P5: Improves the postamble correlation peak detection performance of the reader, if D2R postamble is supported and used.**
    - [4]
  + **P6: The midamble may be necessary if line code is not used in D2R transmission to improve the SNR in the correlation peak detection for synchronization.**
    - [15]

In addition, [4] provides the decoding performance of PDRCH reception for coherent detection with/without midamble with 10% SFO assumption as shown in Figure 10, and observes following:

* The midamble is essential when the packet size is large, e.g., >96bits with low overhead and obvious performance gain, while the midamble is not needed when the packet size is small, e.g., <96bits with a non-negligible overhead and non-obvious performance gain
* When a PDRCH that is 400-bit payload with a 16-bit CRC, with Manchester encoding and an 1/3 rate FEC encoder is evenly divided to 4 parts with 3 midambles and each part is no longer than 100ms, the simulation results shows no error floor at 10% and 1% BLER. Similarly, when the PDRCH is equally divided in to 3 parts with 2 midambles and each part is ~111 ms, the simulation results shows that there is an error floor at 1% BLER

图表, 折线图

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Figure 1. The decoding performance of PDRCH reception with/without midamble from [4]

Given the issues discussed in section 3.2.1, it seems premature to conclude on under what conditions D2R midamble is needed. However, let’s try following proposal.

**FL1 Low priority proposal 3.2.2-1: Agree following observation**

* **With 10% SFO, for PRDCH with 400-bit payload and 16-bit CRC, midamble is needed to achieve 10% BLER target for reader using coherent detection.**

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| **Company** | **Y/N** | **Comments** |
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**Determination of D2R midamble**

* [2], [3], [24]: RAN1 to support indication/configuration of mid-amble for D2R transmissions by a reader.
* [4]: The interval of PDRCH for inserting the midamble is recommended to be configurable, e.g., ~100ms intervals.
* [10]: The midamble length, overhead and other information can be indicated based on a pre-configured threshold or Indicated by the R2D control information.
* [14] Midamble can be inserted once in-between every two L chips/bits of D2R transmission segments
* [25] one-bit indicator in the preamble for the existence of the midamble depending upon the TBS

**FL Low Priority Proposal 3.2.2-2: In case D2R midamble is supported, the presence, location and the number of D2R midable is based on**

* **Option 1: reader’s indication**
* **Option 2: predefined conditions**
* **Note above option 1 and option 2 may not be mutually exclusive.**

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| **Company** | **Y/N** | **Comments** |
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**D2R midamble design**

* [4]: D2R midamble based on binary sequences is supported to decrease receiver complexity and improve reception performance for longer PDRCH transmissions
* [5]: To reduce complexity, the fixed sequence can be considered, e.g., the sequence is same as preamble.
* [24]: Define each of preamble, midamble, and postamble to be distinguished from each other if midamble and/or postamble are additionally included.

### 3.2.3 Postamble

* [4], [5], [7], [14], [17], [34], [35] proposed to support D2R postamble that is to be used by the reader to counter the large SFO and achieve fine timing recovery. In addition, the postamble can also be used for channel estimation of PDRCH. While,
* [2], [11] considers that mid-amble could be used to estimate the timing offset.
* [16] it is sufficient by preamble to derive the timing and frequency offset of the PDRCH.

Given issues discussed in section 3.2.1 and 3.2.2, the discussion on whether/how postamble is needed for D2R timing recovery is postponed for now.

About whether to support the D2R postamble used for device to identify the end of PDRCH transmission (TBS indication) is for different purpose and should be discussed separately. Please see section 5.2.1 of this document.

# Energy harvest on device availability for Tx/Rx procedures

For energy harvesting time, based on following agreements in RANP#103, it is assumed to be up to several tens of seconds.

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| Proposal 2   * Confirm that study of design of energy harvesting signal/waveform is out of SI scope in Rel-19 * The potential impact of energy harvesting on device availability for transmission and reception procedures can be considered for the study [RAN2, RAN1]   + Duration of one device’s unavailability due to charging by energy harvesting can be assumed up to several tens of seconds     - Note: this value can be revisited in future RAN plenary meetings, if necessary   + TR 38.848 clause 5.6 statement on latency remains the case with respect to a single device, i.e.: “*NOTE: The time for charging the Ambient IoT device storage (if present) is not included in the latency defined above. Time for energy harvesting, charging, etc. is regarded as an implementation issue only.*”   + No SID revision is necessary |

Proposal (from draft folder) in RANP#104

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| * RAN WGs are directed to study energy harvesting impacts in the following way:   + Device 1 is assumed to have two states: ON, OFF   + Device 2a/2b is assumed to have three states: ON, OFF, SLEEP   + Identify function(s) of the device that can be assumed supported and assumed not supported in each of the above device states, subject to:     - ON state supports at least: transmission, reception for communication     - OFF state does not support at least: transmission, reception for communication     - OFF state supports at least: energy harvesting     - SLEEP state supports at least:       * maintaining a memory content from ON state       * Maintaining a timer (RAN1 to discuss purpose(s) of timer)     - SLEEP state does not support at least: transmission     - No additional physical layer signals/channels specific to support of SLEEP are introduced   + Identify reader knowledge / control of the above states   + Approximately identify durations of the above device states, by company reports. RAN1 is not required to establish a consensus model.     - Companies can structure their report(s) of durations in their preferred way     - No modeling of device/component (dis)charging characteristics     - This part is aimed to be completed in RAN1#118, with RAN#105 to review progress and finalize if necessary   + RAN1 & RAN2 co-lead |

## 4.1 General directions

About the potential impact of device unavailability due to charging by energy harvesting, many contributions discussed the ON, OFF, SLEEP State, and also state transitions, transition conditions etc.

* [1] proposed following possible state transition events in Table 3 in case sleep state is defined

**Table 3. Summary of** **possible state transition events of [1]**

|  |  |  |  |
| --- | --- | --- | --- |
| Label | Current state | New state | Event |
| eOFF-SLEEP | OFF | SLEEP | Not supported |
| eOFF-ON | OFF | ON | Device fully charged |
| eON-SLEEP | ON | SLEEP | 1. Scheduling information indicates next opportunity for ON state operations is at some future time  2. Device has insufficient energy to perform ON states operations |
| eON-OFF | ON | OFF | Device has insufficient energy to retain its memory content |
| eSLEEP-ON | SLEEP | ON | 1. Sufficiently charged to perform ON state operations  2. Scheduling information (from the last ON state) indicates device can return to ON state |
| eSLEEP-OFF | SLEEP | OFF | Device has insufficient energy to retain its memory content |

* [25] discussed different device types may have different sets of states, as described in the figure 9



Figure 9 Device energy state transition of [25]

* [3] proposed in addition on ON, OFF, SLEEP state, FFS monitoring state that is the device can receive wake-up type of signaling and it is not charging.
* [31] proposed to define three device states and state transitions so that reader can know when/how long device is available.
* [16] proposed it is enough for A-IoT device operation procedure to define the A-IoT ON state and A-IoT OFF state; and it is not necessary to define a sleeping state as the DRX type transmission.
* [26], [28] roposed to define wake-up and sleep two states/modes for A-IoT device and study on conditions for A-IoT enters each mode is required.
* [27] proposed two device states, ON and OFF, are introduced for device 1 and device 2a/2b. In detail,
  + For device 1:
    - ON state: The available energy is enough for supporting transmission and reception. Device can maintain a clock and perform RF EH
    - OFF state: The available energy is not enough for supporting transmission and reception. Device can perform RF EH only
    - Transfer from OFF to ON: based on the available energy level
    - FFS whether the available energy of device 1 can always be assumed enough during inventory round(s)
  + For device 2:
    - ON state: The available energy is enough for supporting transmission and reception. Device can maintain a clock and perform EH (from more than RF)
    - OFF state: The available energy is not enough for supporting transmission and reception. Device can maintain a clock and perform EH (from more than RF)
      * Note: EH of Device 2 is large enough during OFF state to maintain a clock
    - Transfer from OFF to ON: based on device clock or available energy level
      * Note: The clock can be utilized for controlling OFF state duration for device 2

Given above and some companies also propose that the proposal from RANP#104 can be considered as starting point, hence following proposal is made.

**FL1 High Priority Proposal 4.1-1: Study energy harvesting impacts in the following way:**

* **Device 1 is assumed to have two states: ON, OFF**
* **Device 2a/2b is assumed to have three states: ON, OFF, SLEEP**
* **Identify function(s) of the device that can be assumed supported and assumed not supported in each of the above device states, subject to:**
  + **ON state supports at least: transmission, reception for communication**
  + **OFF state does not support at least: transmission, reception for communication**
  + **OFF state supports at least: energy harvesting**
  + **SLEEP state supports at least:**
    - **maintaining a memory content from ON state**
    - **Maintaining a timer (RAN1 to discuss purpose(s) of timer)**
  + **SLEEP state does not support at least: transmission**
  + **No additional physical layer signals/channels specific to support of SLEEP are introduced**
* **Identify reader knowledge / control of the above states**
* **Approximately identify durations of the above device states, by company reports. RAN1 is not required to establish a consensus model.**
  + **Companies can structure their report(s) of durations in their preferred way**
  + **No modelling of device/component (dis)charging characteristics**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Qualcomm |  | We are fine to use RAN#104 proposal as a starting point. We have some suggestions.  Devices 1, 2a, and 2b were defined to have different power consumptions and Tx/Rx architectures. Whether to have SLEEP state does not need to be tied with the device types. Whether the SLEEP state has to be tied with device types can be discussed once we understand the SLEEP state better. Therefore, we suggest to delete the device types from the first 2 bullets.  Regarding the last sub-bullet of the 3rd bullet, we see many companies propose to consider this. Further, this maybe contradicting with the 4th bullet. Therefore, we think it is better to leave it out for now.  Another comment is regarding the last bullet. We understand this bullet exists in RAN plenary proposal. However, if we carefully look at this bullet, it is not crystal clear what “durations of the above device states” means. Our understanding is that this bullet tries to consolidate the methodology of the study and hence is not part of the energy harvesting impacts. We are open to discuss this bullet further but suggest to do it separately from the proposal.  Given the above, we suggest following updates.  **Study energy harvesting impacts in the following way:**   * **Case 1: Device ~~1~~ is assumed to have two states: ON, OFF** * **Case 2: Device ~~2a/2b~~ is assumed to have three states: ON, OFF, SLEEP** * **Identify function(s) of the device that can be assumed supported and assumed not supported in each of the above device states, subject to:**   + **ON state supports at least: transmission, reception for communication**   + **OFF state does not support at least: transmission, reception for communication**   + **OFF state supports at least: energy harvesting**   + **SLEEP state supports at least:**     - **maintaining a memory content from ON state**     - **Maintaining a timer (RAN1 to discuss purpose(s) of timer)**   + **SLEEP state does not support at least: transmission**   + **~~No additional physical layer signals/channels specific to support of SLEEP are introduced~~** * **Identify reader knowledge / control of the above states** * **~~Approximately identify durations of the above device states, by company reports. RAN1 is not required to establish a consensus model.~~**   + **~~Companies can structure their report(s) of durations in their preferred way~~**   + **~~No modeling of device/component (dis)charging characteristics~~** |
| OPPO |  | We are quite in favor of firstly defining device operational states (ON/OFF/SLEEP) at this beginning stage of energy harvesting discussion. But before we are clear about all the supported/assumed functionalities under each device operational state, it is premature at this stage to assume the two state (ON/OFF) and the three states (ON/OFF/SLEEP) are only supported by a certain device type. To some extent, the supported number of states (ON/OFF or ON/OFF/SLEEP) may be an implementation decision (e.g., device type 1 may very well support the three states in the end by the manufacturer). To this end, we suggest at this stage to focus on studying “what are the operational states can be supported by a device” and “what are the core functionalities should be supported under each device operational state”.  Until we are clear about the definition of the device operational states and operation of device energy harvesting behaviours, it is also premature to limit “No additional physical layer signals/channels specific to support of SLEEP are introduced” already. If recall correctly, some proposals involve new signaling (e.g., some sort of indication or information), while some proposals reuse existing signals/channels (e.g., TAS, preamble). In the end, this could be one of factors in deciding which energy harvesting solution design to go with.  Furthermore, different energy harvesting solution designs may or may not require the reader to have knowledge or control of device operational states. Similar to the last point, this could be also one factor in deciding which energy harvesting solution design to go with in the end. Hence, we don’t need to limit the study options at this early stage. Let’s study and discuss different possible solutions before making limitations.  Lastly, the duration of device operational states may depend on different factors, e.g., reader’s scheduling/coordination, device decision, number of devices to be inventoried, and etc. And many of them are not quantifiable, based on reader’s decision, depends on device discharge rate, and etc. As such, companies would not be able to report the durations. We suggest to remove this bullet as well.  Therefore, we suggest the following modifications.  **Study at least the following operational states (not RRC states) in a device and identify device function(s) that are assumed to be support and/or not supported in each state ~~energy harvesting impacts in the following way~~:**   * **~~Device 1 is assumed to have two states: ON, OFF~~** * **~~Device 2a/2b is assumed to have three states: ON, OFF, SLEEP~~** * **~~Identify function(s) of the device that can be assumed supported and assumed not supported in each of the above device states, subject to:~~**   + **ON state supports at least: transmission and reception for communication, energy harvesting (if not RF based), maintaining a memory content, maintaining at least one timer**   + **OFF state does not support at least: transmission and reception for communication, maintaining a memory content from ON state, maintaining a timer**   + **OFF state supports at least: energy harvesting**   + **SLEEP state supports at least:**     - **maintaining a memory content from ON state**     - **Maintaining a timer (RAN1 to discuss purpose(s) of timer)**     - **Energy harvesting**   + **SLEEP state does not support at least: transmission and reception for communication**   + **~~No additional physical layer signals/channels specific to support of SLEEP are introduced~~** * **~~Identify reader knowledge / control of the above states~~** * **~~Approximately identify durations of the above device states, by company reports. RAN1 is not required to establish a consensus model.~~**   + **~~Companies can structure their report(s) of durations in their preferred way~~**   + **~~No modelling of device/component (dis)charging characteristics~~** |
| InterDigital |  | Fine with QC’s modifications |

In addition, the solutions to reduce the negative impacts on device availability for transmission and reception procedures due to energy harvest proposed by companies are generally aligned with the following directions.

* Direction 1: Device and vertical deployment use appropriate energy source and capacitor size to maximize the device availability, by implementation.
* Direction 2: Define at least ON and SLEEP states for a device and reader can control the transition between the ON and SLEEP state.

Therefore, following proposal can be considered.

**FL1 High priority proposal 4.1-2: For the study of the potential impact of device unavailability due to charging by energy harvesting, the following directions are captured in TR 38.769:**

* **Direction 1: Device and vertical deployment use appropriate energy source and capacitor size to maximize the device availability, by implementation.**
* **Direction 2: Define at least ON and SLEEP states for a device and reader can control the transition between the ON and SLEEP state.**

|  |  |  |
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| **Company** | **Y/N** | **Comments** |
| Qualcomm |  | On direction 1:  Larger capacitor size in general does not alleviate the unavailability issue. The larger capacitor size is, the longer the unavailable duration becomes (for charging from ‘turn-off’ threshold to ‘turn-on’ threshold as shown below and in [32]).    The ratio between available duration and unavailable duration is same for different capacitor size, and large capacitor size cannot contribute to maximize the device availability. In [32], we propose deep-sleep duty-cycle monitoring (DS-DCM), which essentially shortens the discharging duration. We see device availability improvement by DS-DCM (= shortening the discharging duration).  Regarding vertical deployment, for sure, densely deploying energy sources maximizes the availability at the expense of cost (both capex and opex). It is fair to describe this fact in direction 1. |
| OPPO | No | On Direction 1, besides the energy source and storage capacitor size, there are other factors that will influence/impact the device availability (e.g., device distance to the energy source, Tx power of the energy source, device energy harvesting efficiency/rate, device energy consumption/discharge rate, etc.). Furthermore, by implementation, there are other factors that will have significant impact to the device availability (e.g., how often / periodicity of the scheduling or control from the reader, how many devices are intended for inventory in a round of inventory process, and etc.). We feel there are many assumptions of the operation behind this Direction 1. Until they are clarified and listed, we don’t think a top-level / generalized description should be captured in the TR.  On Direction 2, firstly this is in contradiction with “Proposal 4.1-1”, where it is proposed to define at least 3 device states. Furthermore, in many proposed energy harvesting solutions, the reader does not need to have knowledge or control of the device operational states. In fact, the transition between the ON and SLEEP states of a device may be determined by the device itself (e.g., based on a selected inventory process for access) or based on device implementation (e.g., a power-ON threshold).  Overall, the description for both Direction 1 and Direction 2 should be updated according to its intention/motivation, rather than some detailed operation. |
| InterDigital | Y |  |

## 4.2 Direction details

### 4.2.1 For direction 1

The proposals/observations for direction 1 generally assumes that reader does not know and cannot control device states, targeting for no specification impacts.

* [1] assume that the reader has no knowledge about the device state. By implementation, it can be assumed that
  + Devices are fully charged before inventory begins
  + Devices deferred to a later time window are fully charged at the beginning of that time window
  + The time window size is set such that devices have enough energy to sustain operation within the window
* [4] propose to capture the following observation in the TR under Direction 1:
  + RF energy harvesting is not a suitable way to deploy devices with short discharge times. Other ambient sources, e.g. indoor lighting, vibration, etc. which are pervasive and continuous, and provide higher energy conversion, should be used.
  + The discharge time is in the order of milli seconds, which is not enough for the device to complete an entire inventory round.
  + Increasing the capacitor size results in a high leakage current, resulting in a slow charging or continuous discharging, deeming RF energy as an unsuitable energy source.
  + RF energy harvesting is a suitable way to deploy devices with long discharge times, and the reader’s scheduling implementation is able to appropriately handle the duration of an inventory round, resulting in no special handling being required from a RAN1 perspective.
  + The reader by implementation maintains the maximum time between the Paging messages as ≤ Tdischarge/2, ensuring that the device can switch to its ON duration after charging completely, receive the Paging message and complete the entire inventory procedure before running out of charge.
  + The device maintains a state flag using an ultra-low power latch during the OFF duration such that the device does not perform inventory repeatedly after it completes a charging cycle.
  + Any failed reception of Paging messages during the device charging time is handled by the higher layer re-access procedure.
* [5] prefer to standardize only Device 1 in Rel-19. Energy harvesting related procedures need more time to do insight investigation and will be specified in Rel-20 together with new A-IoT scenarios and A-IoT services. [5] observed that Reader can assume that Device 1 is always available, but Device 2cannot be assumed always available if only RF sources for energy harvesting is supported.
* [6] proposed following enable device to harvest sufficient energy
* Reader or CW transmitter transmits a continuous CW signal.
* A separate time slot TCW should be allocated before initiating the PRDCH frame to provide the required energy to the device, ff the reader is unable to transmit continuous CW signal simultaneously along with the PRDCH signal
* [7] observed that direction 1 is applicable to device 1 with larger capacitor size (e.g., 10 uF), whose sustainable time can be up to several seconds and direction 1 has no specification impact from both reader and device perspective.
* [14] proposed RAN1 continue the physical layer design without considering the impacts of energy harvesting as first priority, if time is allowed after the most important physical layer design have been completed, RAN1 can start the study of energy harvesting.
* [25]: For device 1, if an energy harvesting signal is contiguously provided during an inventory process, it is assumed that the devices have sufficient energy to complete the inventory process and there is no need for separate consideration for device 1 due to the potential impact of the device unavailability for charging.
  + A discharging time, i.e., operation time, can be analysed for a given energy storage size, while a choice of an exact energy storage size is an implementation issue.
  + A deployment can ensure that the devices are equipped with a sufficient energy storage size by setting a requirement to a vendor supplying the devices for a target deployment scenario, such that it can be guaranteed that devices do not run out of energy while it is in an inventory process.
* [27] Mechanism for indicating Capability 2 is introduced, while Capability 1 is default device capability reader assumes for a device before Capability 2 indication is received.
  + Capability 1: Device OFF to ON switch is based on energy level harvested
  + Capability 2: Device OFF to ON switch is based on device clock counting
* [32]: Deep-sleep based duty-cycle monitoring ensures enough amount of energy in the storage all the time and RF energy harvesting without false-alarm during deep-sleep
  + Whenever the device is ON, there can be sufficient amount of energy in the storage to support A-IoT communications with reader
  + Duty-cycle periodicity depends on Rx power, RF energy harvesting efficiency, etc, and is not controlled by the device

Given all above, following proposal can be considered.

**FL1 High priority proposal 4.2.1-1: Capture followings for Direction 1 in TR 38.769**

* **Observation#1: RF energy harvesting is a suitable way to deploy devices with long discharge times, and the reader’s scheduling implementation is able to appropriately handle the duration of an inventory round, resulting in no special handling being required from a RAN1 perspective.**
* **Observation #2: The reader by implementation ensuring that the device can switch to its ON duration after charging completely, receive the Paging message and complete the entire inventory procedure before running out of charge.**
* **Observation #3: RF energy harvesting is not a suitable way to deploy devices with short discharge times. Other ambient sources, e.g. indoor lighting, vibration, etc. which are pervasive and continuous, and provide higher energy conversion, should be used.**
* **Observation#4: It is expected that Direction 1 has no or less specification impact from both reader and device perspective.**
* **Any other observations do you think is agreeable?**

**For above observations, which one(s) should be captured for Direction 1 in TR 38.769?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Observations** | **Comments** |
| Qualcomm |  | Regarding observation #1: Discharging time duration depends on the capacitor size and device power consumption. For a given device, we suppose longer discharging time is achievable by larger capacitor size. However, as we pointed out in 4.1-2, larger capacitor size does not improve device availability. Therefore, we think the observation is not correct. The observation should be “longer discharging time can increase the probability of inventory completion after the device joins inventory”  Regarding observation #2: This is correct. However, it should be noted that it would take a whole until the device is charged completely, and hence, the reader may need to continue the inventory over a tens of seconds after it starts inventory processes so that the device is fully charged and receives a Paging message from the reader, as illustrated below and explained in [32].    Regarding observation #3: need to clarify what are the “devices with short discharging times” that the RF energy harvesting is “not suitable”. From our point of view, RF energy harvesting is still suitable for device 2a/2b. These devices consume larger power than device 1, but the power consumption of these devices is not maximum most of the time. Only for some processes (e.g., active transmission) and only for a short duration, it consumes large power.  Regarding observation #4: we need to discuss 4.1-2 first. |
| OPPO |  | * **Observation#1: RF energy harvesting is a suitable way to deploy devices with long discharge times, and the reader’s scheduling implementation is able to appropriately handle the duration of an inventory round, resulting in no special handling being required from a RAN1 perspective.** * **Observation #2: The reader by implementation ensuring that the device can switch to its ON duration after charging completely, receive the Paging message and complete the entire inventory procedure before running out of charge.** * **Observation #3: RF energy harvesting is not a suitable way to deploy devices with short discharge times. Other ambient sources, e.g. indoor lighting, vibration, etc. which are pervasive and continuous, and provide higher energy conversion, should be used.** * **Observation#4: It is expected that Direction 1 has no or less specification impact from both reader and device perspective.**   On Observation #1: For devices with “long discharge time”, firstly what is the definition of “long discharge time” (e.g., in the order of a few seconds or tens of seconds)? I assume this is intended for Device type 1 with low energy consumption rate (~1uW), so that the energy stored in the capacitor depletes slowly or the device is able to sustained a long operation time. However, when a sufficiently large capacitor is embedded in a Device type 2, it can also have a long sustainable operation time = long discharge time. Then in this sense, does it mean RF energy harvesting is suitable for both Device type 1 and 2? On the main point, we don’t think RF energy harvesting should be associated with the discharge time of a device. When the received RF power for charging is high (e.g., short separation distance, high TX power), the energy conversion rate will be high, then it is also suitable for devices with short discharge time. On the contrary, when the energy conversion rate is low, even if the device is discharging slowly (i.e., when energy harvesting rate < device discharge rate), RF energy harvesting would not work. Therefore, this such generalized statement is not accurate.  On Observation #2: It is questionable that a reader can ensure that a device can switch to ON state after fully charged. The switching to ON state in a device, in many instances, is based on device implementation (e.g., turn-ON threshold is 80%, 90% or 100%. It is more like “a device can switch to ON state when it is fully charge”. But we suggest to modify this observation as: “**The reader by implementation can ensure that the Paging message is transmitted within a device’s ON state and allow the device to go through a round of inventory process before running out of charge.**” This does not mean the device is able to complete the entire inventory process, which may involve the whole 4-step procedure. Because the device may experience TX collision and receive no response from the reader. But it is still be able to participate in a round of inventory process (with failure result). Additionally, we should also capture the drawback of this Direction 1, where **the signaling overhead of transmitting Paging messages is high when the device ON state is short and the number of devices that can be inventoried per round of inventory process is expected to be small**.  On Observation #3: As commented earlier for Observation #1, when the RF energy conversion rate is high, it is still suitable for devices with “short discharging time”. Furthermore, a short discharging time does not mean a long charging time either. If duty-cycle monitoring based solution is used by a device, a short discharging time means “shortened available time”, but the energy storage level could still be high. Furthermore, indoor lighting and vibration does not always mean feasible in a warehouse / factory or devices in a box, and does not equate to pervasive and continuous, and provide higher energy conversion. Every type of energy source has its own limitation. We should avoid this generalized statement.  On Observation #4: we also think that 4.1-2 needs to be discussed first. |
|  |  |  |

In addition, some companies provide qualitative analysis or examples on the solutions; some companies provide the evaluation results to prove the effectiveness of the proposed solutions. **For reference, Appendix A of this document provides the summary on the solutions and/or evaluations proposed by companies.** Therefore, following is proposed to collect companies’ views.

**FL1 High priority proposal 4.2.1-2: For Direction 1 that Device and vertical deployment use appropriate energy source and capacitor size to maximize the device availability, by implementation, following can be the template to capture the solutions proposed by companies.**

|  |  |
| --- | --- |
| **Source** | **Details** |
| **Source [x]** | **Solution description**  **Observations or Analysis or Evaluations** |
| **Source [y]** | **Solution description**  **Observations or Analysis or Evaluations** |

**Any comments?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Qualcomm |  | We are OK with the table, but the text of 4.2.1-2 should be updated based on the discussion on 4.1-2 (e.g., capacitor size should not be a solution to maximize the device availability). |
| OPPO |  | After seeing this proposal, we think the order of discussion should be 4.1-2, then 4.2.1-2, then 4.2.1-1. The observation (4.2.1-1) should be the last step, after seeing all the solution descriptions.  But this table format is OK. The title for Direction 1 still needs to be updated. |
|  |  |  |

### 4.2.2 For direction 2

The proposed solutions for direction 2 are about on how reader control device states, e.g., state transitions between ON and SLEEP at least during random access procedure. In detail:

* [1] proposed following for device availability considerations
  + Support a group ID field in the L1 R2D control information to indicate when devices in the group are scheduled for monitoring R2D transmission.
    - The devices of the group not scheduled can enter the SLEEP state. The next decode indicates when a device can receive additional information when a group is expected to be scheduled for monitoring R2D transmission.
  + Support preamble counting in the SLEEP state allows a reader to perform Uu operations without affecting the device in the SLEEP state.
    - When the count of preambles reaches the target, the device can transition to the ON state when it is charged
* [4] propose following under Direction 2:
  + Study on-demand shifting of states where the reader controls the device to switch to the ON state from the SLEEP state using an indicator which would inform the device of the duration it has to remain in the SLEEP state.
    - * The ON and OFF durations are determined by device implementation.
      * The SLEEP state duration is determined based on the received indicator.
* [7], [12] proposed optimization for sleep state can be considered both before and during an inventory round.
  + [7]: To enable the device entering SLEEP state before an inventory round, study the solution that the reader sends indication of the potential starting time or remaining time of the future inventory command.
  + [7]: To enable the device entering SLEEP state during an inventory round, study solutions on how/when device respond to the reader for contention-based random access. For example,
    - The reader sends additional indication to inform the slot counter decrement process.
    - The device randomly selects an ON state during the inventory round to respond.
    - The device reports when activated before inventory, and the response occasion during the inventory round is determined by the reporting occasion.
  + [12]: before inventory / command process starts, periodic transmissions of R2D preamble should be studied to coordinate or schedule inventory / command processes among the devices, to minimize collision probability and to reduce device power consumption from blind monitoring.
  + [12]: after inventory / command process starts), RAN1 should consider enhancing the slot-SLOHA access mechanism in the following potential areas for enabling device energy harvesting.
    - Filter-out unnecessary access time slots (ATSs) for reception.
    - Fixed length or a minimum time duration for an access time slot (ATS);
    - Reduced device wake-up time to monitor select/query message (Msg. 0) and perform count-down function.
    - Assisted, coordinated or scheduled selection of an access time slot (ATS).
* [17] proposed duty cycle is not considered before random access procedure. While during random access procedure, duty cycle based on periodic detection can be considered for Ambient IoT device to reduce energy consumption.
* [19] proposed to study of advanced power management techniques to optimize energy use, including duty cycling, low power modes, and energy efficient hardware designs.
  + For duty cycle design, enabling the adaptive duty cycle based on energy forecast, knowledge of TR2D\_min, TR2D\_max, TD2R\_min, and TD2R\_max etc.
* [20]: AIoT supports functionality allowing predictability of a device activity cycle from reader perspective, by broadcasting information to indicate to a device how to adjust timing of its activity cycle.
* [25] proposed to study a solution for extending the sustainable operation time of device 2 considering its power consumption.
  + The state transitions to or from the OFF states can be based on an energy level of the device, which can be on implementation issue. While the state transitions between ON and PS states need to be studied as it involves a monitoring behavior of a device, which may be a potential scope of specification.
  + RAN1 to study device state transitions during inventory process, e.g., considering minimum and maximum time between trigger messages, to extend the device operation time.
* [27] Mechanism for indicating Capability 2 is introduced, while Capability 1 is default device capability reader assumes for a device before Capability 2 indication is received.
  + Capability 1: Device OFF to ON switch is based on energy level harvested
  + Capability 2: Device OFF to ON switch is based on device clock counting
* [28], [32]: Duty-cycle monitoring enables sustained and longer duty-cycle monitoring and RF energy harvesting without false-alarm during sleep
  + During sleep, the device retains memory and keeps clock working so that duty-cycle periodicity is controlled
* [30]: Study how to quantify the unavailable time windows of a device, which should at least include the time duration when the reader is communicating with other device(s).
* [31]: proposed to define three device states and state transitions so that reader can know when/how long device is available.

Given all above, following proposal can be considered.

**FL1 High priority proposal 4.2.2-1: Capture followings for Direction 2 in TR 38.769**

* **Observation#1: There is a need to study a solution for extending the sustainable operation time for devices with short discharge times and long charge time by harvesting only RF energy.**
* **Observation #2: The state transitions to or from the OFF states can be based on an energy level of the device, which can be on implementation issue. On the other hand, the state transitions between ON and SLEEP states need to be studied as it involves a monitoring behavior of a device, which may be a potential scope of specification.**
* **Observation #3: Following benefits are achievable by reader controlling the device’s state transition between the ON and SLEEP.**
* **Avoiding very long unavailable time duration after the reader starts inventory. Since the consumed energy in the energy storage in each available time duration is quite limited, the time duration that a device is unavailable for RF energy harvesting is short.**
* **Keeping large amount of energy in the storage all the time. Whenever a device joins inventory, the energy storage is (almost) full. This avoids the case where, a device joins inventory but the remaining amount of energy is not sufficient.**
* **Any other observations do you think is agreeable?**

**For above observations, which one(s) should be captured for Direction 2 in TR 38.769?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Observations** | **Comments** |
| Qualcomm |  | Regarding observation #1: same as earlier comments, shortened discharging time can be a solution to improve the device availability. We are OK with “There is a need to study a solution for extending the sustainable operation time” without “for devices with short discharge times and long charge time by harvesting only RF energy”.  Regarding observation #2: As we presented in [32] (part of DS-DCM), device to control state transmission between ON and OFF can also be a solution to improve device availability. Therefore, both state transitions (ON – OFF and ON - SLEEP) should be studied.  Regarding observation #3: we think these are benefits of duty-cycle operation using state transition between ON and SLEEP (light-sleep) or using state transition between ON and OFF (deep-sleep), that should be carried out until the device receives a Paging message. A device shortens the available time duration (= discharging duration) so that the RF energy harvesting time (= charging duration) can also be shortened. Separately, once it receives the Paging message and joins the inventory, the device can utilize SLEEP state to reduce the probability that the device is fully discharged before the device successfully completes the joined inventory. |
| OPPO |  | * **Direction 2: Define at least ON and SLEEP states for a device and reader can control the transition between the ON and SLEEP state.** * **Observation#1: There is a need to study a solution for extending the sustainable operation time for devices with short discharge times and long charge time by harvesting only RF energy.** * **Observation #2: The state transitions to or from the OFF states can be based on an energy level of the device, which can be on implementation issue. On the other hand, the state transitions between ON and SLEEP states need to be studied as it involves a monitoring behavior of a device, which may be a potential scope of specification.** * **Observation #3: Following benefits are achievable by reader controlling the device’s state transition between the ON and SLEEP.** * **Avoiding very long unavailable time duration after the reader starts inventory. Since the consumed energy in the energy storage in each available time duration is quite limited, the time duration that a device is unavailable for RF energy harvesting is short.** * **Keeping large amount of energy in the storage all the time. Whenever a device joins inventory, the energy storage is (almost) full. This avoids the case where, a device joins inventory but the remaining amount of energy is not sufficient.**   Regarding observation #1: Since the description covers both devices with “short discharge times and long charge time”, there is no need to mention them. In our view, the need to study a solution for extending the sustainable operation time for a device should came from an observation where the sustainable operation time of a device is shorter than an expected duration of a round of inventory/command process. This perhaps should be established first, since many companies have reported the values in their contributions for this meeting.  Regarding observation #2: Currently, the description of this observation contains something of either an implementation issue or topics for further study. We think once RAN1 has more discussions on these issues/topics, then the outcomes can be captured.  Regarding observation #3: As commented earlier, the transition between ON and SLEEP states may not need to be controlled by the reader (some schemes do while others don’t). To us, the 1st and 2nd sub-bullet are similar and related to each other. Before the inventory starts, the ON state duration for a device is kept short for monitoring and decoding (i.e., more time for energy harvesting in the SLEEP state), so that a large amount of energy in the storage is kept in a device. Once the inventory starts, a (almost) full amount of energy can be used for the inventory process. By doing so, this can avoid a long unavailable time duration needed for the device to recharge energy during the inventory process.  We **propose to include an observation #4**: After an inventory process starts, the device continues to conserve and recharge energy in the SLEEP state during time slots where the device does not need to participate (i.e., time slots that are not selected by the device or scheduled by the reader). By doing so, the device will be able to retain most or all of its energy in the storage for communicating with the reader when the time comes (i.e., in the selected or scheduled time slot). |
|  |  |  |

In addition, some companies provide qualitative analysis or examples on the solutions; some companies provide the evaluation results to prove the effectiveness of the proposed solutions. **For reference, Appendix A of this document provides the summary on the solutions and/or evaluations proposed by companies.** Therefore, following is proposed to collect companies’ views.

**FL1 High priority proposal 4.2.2-2: For Direction 2 that define at least ON and SLEEP states for a device and reader can control the transition between the ON and SLEEP state, following can be the template to capture the solutions proposed by companies.**

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| --- | --- |
| **Source** | **Details** |
| **Source [x]** | **Solution description**  **Observations or Analysis or Evaluations** |
| **Source [y]** | **Solution description**  **Observations or Analysis or Evaluations** |

**Any comments?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Qualcomm |  | We are OK with the table but before that we need to fix what the direction 2 is. |
| OPPO |  | Similar comment for Direction 1, we think the order of discussion for Direction 2 should be 4.1-2, then 4.2.2-2, then 4.2.2-1. The observation (4.2.2-1) should be the last step, after seeing all the solution descriptions.  But this table format is OK. The title for Direction 2 still needs to be updated. |
|  |  |  |

**On whether to support periodic signal during the A-IoT communication (inventory or command) from device perspective**, companies’ views are following:

* **A dedicated periodic signal has not been justified compared to other designs for Rel-19, and is not necessary or deprioritize the periodic signal for the study** [1], [4], [7], [14], [22]
  + A-IoT device may not be able to maintain synchronization and timing with the network since it is in a power-off state for charging in most of the time.
  + Large resource overhead by dense periodic sync. signal transmission to compensate the large SFO
  + Additional power consumption at both device and reader side
  + More specification efforts for periodic sync. signal design and device behaviors/procedures

* **Need to study the periodic signal** [3], [9], [20], [31], [32], [34]
  + Extend device availability time and reduce the outage probability
  + Minimize access collisions among the devices, improve the inventory efficiency
  + At least applied to active device [34]
  + To support DO-A traffic [3]

## 4.3 Impacts on scheduling/processing timeline

**General**

* [6] proposed the CW transmission window for charging/recharging the device should be included in the timing aspects.
* [19] proposed to Study on A-IoT charging duration awareness to the reader and study of advanced power management techniques to optimize energy use, including duty cycling, low power modes, and energy efficient hardware designs.
* [21] proposed the A-IoT signalling protocol allows for device charging time during an ongoing signalling exchange.
* [24] proposed to study energy storage status based on CW provision and their impact on the scheduling and timing, the timing relationship between the CW transmission, the R2D control information transmission, and the single or multiple D2R transmission(s).
* [33] suggested to specify the energy harvest procedures with certain timeline restrictions to avoid the energy harvest proceeding in undesired time slot. A stripped-down mode without the dynamic adjustments for energy harvest can be prior to carry and try in R19.
* [34] proposed to consider the energy harvesting time due to unavailability of device for the time intervals (between R2D and D2R; between D2R and R2D; between two consecutive R2Ds; between two consecutive D2Rs) within inventory round.

**Assistant information from device**

* [7] proposed to consider the device to report when activated before inventory, and the response occasion during the inventory round is determined by the reporting occasion.
* [20] proposed due to insufficient stored energy or additional processing time requirement, A-IoT device can indicate minimum time required before transmission of a response to a reader request.
* [19] proposed that for non-fully charged device, power charging time should be considered. Either reader waits the worst case of the charging time, which can be inefficient or to have some charging status report from the device.
* [24] proposed the device can report its energy storage status to the reader.

**Packet segmentation**

* [9] proposed to consider following
  + - energy aware transmission of payload segmentation from Ambient IoT device in D2R communication
    - energy harvesting time in the scheduling/processing timings (TD2R\_D2R\_min and TD2R\_min) to transmit the remaining payload segments due to insufficient energy and the device can do energy harvesting between the segments.
* [22] proposed PDRCH could be divided into multiple sub-transmission with guard period between them, when the transmission duration is larger than a threshold that A-IoT device needs to do energy harvesting during guard period.
* [24] proposed reply types may be defined according to the device’s energy storage capacity. E.g., if the device’s energy storage capacity is sufficient, a reply type that transmits D2R data at once can be used, and if the device’s energy storage capacity is not sufficient, a reply type that transmits D2R data divided into several can be used.

The issue on whether to count device energy harvest time into the scheduling/processing timeline was briefly discussed in the last meeting. Due to following,

* A reader cannot know the charging completion time of a device since the charging time depends on many factors including at least capacitor size, distance between devices and RF EH source, charging efficiency, etc.
* The energy harvest time is assumed to be up to several tens of seconds

It seems difficult and complex to include the charging time to the scheduling/processing timeline for TR2D and TD2R such kind of immediately reply. Therefore, following proposal can be the starting point for discussion.

**FL1 Low Priority Proposal 4.3: At least following time intervals do not consider the energy harvest time as baseline.**

* **The time interval between a R2D transmission and the corresponding D2R transmission following it.**
* **The time interval between a D2R transmission and the corresponding R2D transmission following it.**

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| **Company** | **Y/N** | **Comments** |
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# Scheduling and timing relationships

* 1. Timing relations related aspects

**About clarification on time between R2D and D2R or vice versa is the between the “end” of one transmission and the “start” of the next transmission, it should be clarified. But at this time being, it is difficult to make such clarification. FL proposed to study and clarify “the end” and “the start” of the transmission after the R2D and D2R waveform, basic resource allocation unit e.g., chip or bit symbol, time-domain frame structure design e.g., whether the start and/or end of the R2D transmission needs to be aligned with OFDM symbol boundary etc., become clearer.**

### Issue#1: Timing for D2R response to R2D

Agreement (RAN1#117)

Study the following options for the time interval between a R2D transmission and the corresponding D2R transmission following it:

* Option 1: Define a maximum time TR2D\_max between a R2D transmission and the corresponding D2R transmission following it, so that the device transmits D2R transmission within [TR2D\_min, TR2D\_max].
  + FFS: maximum time is common or different for different A-IoT devices
  + FFS: maximum time for different traffic types/command types (e.g. DT or DO-DTT) and/or different use case (e.g., Inventory or Command)
* Option 2: The corresponding D2R transmission timing TR2D following a R2D transmission is determined based on the control information in the R2D transmission, where TR2D ≥ TR2D\_min
  + FFS the maximum value(s) for TR2D

Among two options, companies views are following:

**Both options can be considered:**

* [1], [13], [30], [24] for time interval between a R2D transmission and the corresponding D2R transmission following it, option 1 is always required for the minimum requirement. Option 2 can be used if the D2R transmission timing is indicated by the reader; otherwise, the device transmits as soon as it is able in [TR2D\_min, TR2D\_max].
* [6], [20], [21]considers both Option 1 and Option 2 can be supported for A-IoT, which may also depend on A-IoT device type or capability.
* [10], [21], [31], [39] consider option 2 can be used for contention free access or scheduling based D2R transmission and option 1 can be used for contention based access.
* [14] considers option 2 is more feasible for TDMA of multiple D2R transmissions scheduled by one R2D transmission.

**Option 1 is preferred:**

* [4] observes for option 2 that long delayed scheduling to facilitate TDMA is not feasible for devices due to the necessity of a large guard time, resulting in loss of peak data rate and poor resource utilization efficiency. It also requires an additional timer at the device, which is detrimental to the power consumption and complexity of the device.
* [26], [28] support opt.1 as baseline and FFS on opt.2.
  + The overhead and feasibility of Opt.2 depends on several factors, such as a time gap between the R2D command and the last PDRCH in the intended use case, and a sustainable timing accuracy of sampling clock after adjusting it based on the received R2D command.

**Option 2 is preferred**

[11], [12], [15], [16], [17], [27], [35] prefers option 2.

* [11], [12] observed that option 2 is beneficial from resource efficiency perspective and the reader is expecting response from several devices (TDMA and/or FDMA).
* [15] option 2 can enhance interference coordination between AIoT devices and normal NR UEs.
* [16] considers it is unnecessary to define the maximum time TR2D\_max between the end of a R2D transmission and the start of the corresponding D2R transmission.
* [27] RAN1 design allows flexible indication of the time offset between R2D preamble and D2R preamble to adapt the residue SFO at reader side.
  + - To support maximum TBS no smaller than 96 bits, Option 2 is supported, i.e., The corresponding D2R transmission timing TR2D following a R2D transmission is determined based on the control information in the R2D transmission.

In addition,

* [11], [21] observed that timing uncertainty increases the further away a D2R response is from its corresponding R2D command signal and timing for D2R response should account for the clock uncertainty / time drift caused by the SFO.
* [21] proposed that timing parameters TR2D\_min and TR2D\_max are signalled.
* [24] proposed to clarify for option 1 how to provide the maximum time TR2D\_max and/or the minimum time TR2D\_min, e.g., predefined or provided dynamically via R2D control information.
* [30] The time unit is the minimum R2D chip duration allowed by the system

For study the timing for D2R response to R2D, following proposal and question are made.

**FL1 High Priority Proposal 5.1.1-1: Further study the two options for the time interval between a R2D transmission and the corresponding D2R transmission following it, including following**

* **Time unit for the time interval** 
  + **E.g., One or multiple R2D or D2R Chip length(s), R2D or D2R information bit length etc.**
* **Whether/how to address timing error for a D2R transmission caused by the initial/residual SFO of the scheduled device**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Qualcomm | Y |  |
| OPPO | OK | Generally fine with the proposal. Some suggestions on the wording, and one modification (since a D2R transmission may not be always scheduled by the reader, e.g., Msg. 1).  **Further study at least the following two ~~options for~~ aspects of the time interval between a R2D transmission and the corresponding D2R transmission following it, including following**   * **Time unit for the time interval**    + **E.g., One or multiple R2D or D2R Chip length(s), R2D or D2R information bit length etc.** * **Whether/how to address timing error ~~for~~ of a D2R transmission caused by the initial/residual SFO ~~of the scheduled~~ in a device** |
| InterDigital | Y |  |
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**FL1 Medium Priority Question 5.1.1-2: What is the time unit for defining or indicating the time interval between a R2D transmission and the corresponding D2R transmission following it?**

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| **Company** | **Y/N** | **Comments** |
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### Issue#2: Timing for R2D response to D2R

[1] proposed to have additional clarification on when TD2R\_max is used and what is intended device behavior is needed.

[4], [5], [6], [7], [10], [11], [14], [23], [26], [30], [31], [34], [39] proposed to facilitate the Device’s expected PRDCH reception, e.g., to avoid long and uncertain waiting time for PRDCH reception, a maximum time interval TD2R\_max between a D2R transmission and the corresponding R2D transmission following it should be defined.

* [30] proposed TR2D can also be determined based on the control information in the R2D transmission scheduling the D2R transmission.

In case the expected R2D respond is not received within TD2R\_max, device behaviour is also discussed by companies

* [4], [8], [13], [30]: allow the device to assume it is possible to enter a lower-power state if the reader is not going to respond to it.
* [11], [14]: a device determines the potential state transition.

Therefore, following proposal can be considered.

**FL1 High Priority proposal 5.1.2: When a R2D transmission in response to a D2R transmission is expected (e.g., A-IoT Msg2 response to A-IoT Msg1) for the A-IoT device, define a maximum time TD2R\_max between the D2R transmission and the corresponding R2D transmission following it, so that the R2D transmission timing is expected to be within [TD2R\_min, TD2R\_max].**

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| **Company** | **Y/N** | **Comments** |
| OPPO | Y |  |
| InterDigital | Y |  |

### Issue#3: Timing gap between D2R and D2R (**TD2R\_D2R\_min**)

[4], [39] proposed to clarify the case for the time interval between D2R and D2R transmission before studying the value(s) of it.

[11], [20], [24] proposed the device acknowledges the reception of R2D transmission by indicating whether it needs more time to prepare the D2R transmission, similar as in-process reply in RFID.

Based on the discussions in RAN1#116bis meeting, the TD2R\_D2R\_min usage proposed by companies include following:

* Use case 1. Different segments of PDRCH
* Use case 2. Energy harvesting
* Use case 3. Similar as in-process reply in RFID that for some R2D commands, a device replies firstly to Reader that it needs more time for processing/ preparation followed by the corresponding D2R response to the R2D command.

**FL1 Low Priority Question 5.1.3: Do you support to study TD2R\_D2R\_min and TD2R\_D2R\_max that are the minimum and maximum time between two different consecutive PDRCH transmissions from the same A-IoT device at least for use case 3 that similar as in-process reply in RFID?**

* **Any other use case you prefer to study?**

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| **Company** | **Y/N** | **Comments** |
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### Other aspects

**About the values for the minimum/maximum processing time**

It may be premature to discuss the detailed values without knowing the applicable data/chip rates, sampling rate, message contents or command types to be transmitted/received for A-IoT devices and Reader. Therefore, the discussion related to the exact values can be deprioritized for this meeting.Following views are summarized for information:

* [4] propose the values from ISO 18000-6C UHF RFID are a reference for further study TR2D\_min, and TR2D\_R2D\_min, and the value of TR2D\_min is assumed to be higher than the value used in RFIDs to account for the complicated processing in Ambient IoT devices.
* [4], [7] propose for TD2R\_min and TD2R\_maxthat is related to the reader’s processing latency, the impact on the existing BS implementation e.g. ms-level time is included in the study. [2] proposed A-IoT features of RAN1 study should not require any implementation restriction especially for the existing gNB/UE.
* [20] observed that device processing time can include the time needed to collect information from surrounding environment e.g., using sensors.
* Same or different processing time for different A-IoT devices:
  + [5], [7], [12], [14] proposed that common processing time for different A-IoT devices.
  + [4], [10], [20], [17], [21], [24], [30], [34], [39] considers different processing time for different A-IoT devices
    - [4]: Different TR2D\_max values can be defined for different devices in order to account for their differing transmitter processing times.
* Same or different processing time for different traffic types/command types (e.g., DT or DO-DTT) and/or different use case (e.g., Inventory or Command):
  + [3], [10], [7], [20], [17], [21], [24], [30], [34] proposed to consider different processing time
  + [5], [12] propose RAN1 to prioritize a common processing time for different traffic types/command types.
  + [14] proposed to postpone the discussion after RAN2 has decided all of the candidate R2D Commands and the potential reply types.
    - [12] also mentioned that TD2R\_min and TR2D\_R2D\_min may be different for different topologies

**About timing aspects related to Topology 2**

* [24] proposed to consider following for Topology 2
* How to determine the timing of the R2D synchronization signal from intermediate node (applying the UL TA) to Ambient IoT devices.
* For the case where an intermediate node (UE) requires UL sync re-adjustment to gNB, consider to study whether to provide longer timing (compared to normal UEs) during RACH procedure to ensure UL sync re-adjustment time for the intermediate node.

**About timing aspects related to deployment scenarios**

* [24] proposed to consider following
* Time delay for forwarding of the received D2R signal/channel from the reader/ intermediate node (i.e., R2) for D2R reception to the reader/ intermediate node (i.e., R1) for R2D/CW transmission, in the case where the R1 and R2 are different.
* time delay for frequency retuning in device between R2D reception and D2R transmission, in the case where the FDD spectrums (i.e., DL band or UL band) for the R2D transmission and the D2R transmission are different.

Comments, if any.

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| --- | --- |
| **Company** | **Comments** |
|  |  |

* 1. Scheduling related aspects

### 5.2.1 Reader’s identification of the end of PDRCH transmission

For the reader to acquire the end of PDRCH transmission, some companies think it is necessary to identify whether there is a case where the reader does not know the end/length/TBS of the PDRCH for option 1 and option 2 selection.

Companies’ views for the two options are summarized below.

**Option 1:** D2R postamble immediately follows the PDRCH is considered by [5], [9], [10], [14], [17], [24], [30], [35]

* [9], [14], [17]: for the case that the reader lacks knowledge of the packet size

**Option 2:** Based on control information is considered by [2], [4], [6], [8], [9], [10], [11], [12], [14], [16], [22], [24], [25], [26], [30], [32], [39]

* [2], [39]: the baseline assumption is to use R2D control information with lower miss/false-detetcion probability.
* [8]: FFS control information in R2D or D2R transmission. D2R control information may be beneficial in term of simplified operation and reduced power consumption in case reader does not know the payload size.
* [4], [11], [14], [16]: The reader knows the TBS and the amount of time domain resources required for the PDRCH transmission and can use this information to figure out when the transmission is supposed to end since it scheduled the transmission
* [12]: postamble needs more resources for transmission, and add latency delay to the decoding; possibly using the D2R control information in D2R preamble
* [10]: The end occasion indicated by D2R control information should be deprioritized in the current stage.
* [32]: R2D can indicate the code or format of the D2R to indicate the end of D2R, but D2R postamble for reader chip synchronization for D2R reception is for different purpose and hence should be discussed separately

In addition, [9], [10], [14], [24], [30] consider supporting both options and different options can be used for different cases or based on reader’s indication.

* [9]: option 2 can be used for scheduling-based D2R transmission
* [14]: option1/option2 depends on whether reader know the transmission length of D2R response, whether there is/in which case the reader can know the length of D2R response is up to other WG’s discussion.
* [10]: support option1, option 2 can be used for some scenarios. E.g., RN16 scheduled by Msg.0
* [24]: reader can indicate whether to include postamble in the D2R transmission via R2D control information. If the reader indicates not to include a postamble, the end of D2R transmission can be included in the R2D control information (or D2R control information).
* [30]: proposed to consider a combination of two options, e.g. to minimize impact of mis-detection of the postamble and correctly determine timing for a subsequent R2D reception even in case of not successfully receiving/decoding the R2D control information

At least for traffic types DO-DTT and DT with focus on rUC1 (indoor inventory) and rUC4 (indoor command), the baseline design should be that reader knows the TBS/transmission length. Therefore, following is proposed.

**FL1 High Priority Proposal 5.2.1-1: At least for traffic types DO-DTT and DT with focus on rUC1 (indoor inventory) and rUC4 (indoor command), RAN1 studies the TBS of PDRCH indicated or derived by R2D control information as baseline.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Details/Comments** |
| Qualcomm | Y |  |
| OPPO | Y |  |
| InterDigital |  | Suggest rewording as “RAN1 studies the TBS of PDRCH **dependent on at least** R2D control information as baseline”. Other WG’s should determine whether the data will always be available or not for the prioritized use cases. |

### 5.2.2 Device’s identification of the end of PRDCH transmission

**For Option 1 that R2D postamble immediately follows the PRDCH to indicate or derive the end of the PRDCH,**

* **The claimed necessities/benefits for Option 1 are following:**
* **P1: It implicitly indicates the TBS with higher efficiency**
  + [4], [5], [9], [17]: Considering the message size can be up to about 1000 bits, i.e., 125 bytes, then about 7 bits are needed to indicate the TBS in granularity of bytes.
* **P2: No need to predefine the set of possible TB sizes in standards, it can support any TBS.** 
  + [4], [5], [9]
* **P3: Postamble is necessary in the case of short data packet, since the device may not have enough time to finish processing the R2D control information.** 
  + [2], [5]
* **P4: further assist timing synchronization as well as indicate the end** 
  + [14], [25]
* **P5: better forward-compatibility for more dynamic PRDCH payload size in future use cases other than inventory and command**
  + [26]
* **The claimed unnecessities/concerns for Option 1 are following**
* **C1: For R2D data transmission (e.g., R2D command has a specific structure) with a fixed length, no need for an explicit indication through a postamble** 
  + [8], [10], [11], [32], [34]
* **C2: More device power consumption and detection failure if device miss/false-detects the postamble** 
  + [8], [11], [16], [22], [23]
* **C3: Additional signal needs to be defined and to be detected by the device**
  + [12]
* **C4: If the payload size of the subsequent D2R/R2D data transmission is configured/indicated by readers to devices** 
  + [11], [32], [34]
* **C5: For indoor inventory and command use cases, the introduction of R2D postamble only for certain (limited type of) PRDCH transmissions that have variable payload is questionable** 
  + [11], [32]
* **C6: More resources are needed for the postamble transmission, and adding latency delay to the decoding** 
  + [12]

**For Option 2 that based on R2D control information to indicate or derive the end of the PRDCH**

* **The claimed necessity/benefits for Option 2 are following:**
* **P1: For smaller or fixed TBS, Option 2 can be used to mitigate the postamble overhead** 
  + [11], [25], [32]
* **P2: More robust, Lower miss/false-detection probability compared to option 1** 
  + [8], [11], [16], [22], [23]
* **P3: Since the R2D transmission will include a control information, it is preferred to indicate the transmission duration using the R2D control information** 
  + [11], [12], [32]
* **P4: No additional power consumption caused by the miss detection compared to option 1** 
  + [23]
* **P5: Option 2 for its simplicity and effectiveness** 
  + [12]
* **The claimed unnecessity/concerns for Option 2 are following**
* **C1: bit- or byte-level TBS indication can lead to a large padding overhead** 
  + [4], [9], [17]
* **C2: Processing time for control information may not be enough for short data packet** 
  + [2], [5]
* **C3: Need to predefine the set of possible TB sizes in standards** 
  + [9], [5]
* **C4: Less flexible to accommodate the variation of PRDCH payload size (e.g., due to presence of D2R control information, future extension)**
  + [26]
* **C5: Need to predefine a separate PRDCH format for end indication and device would have to perform blind detection of the different formats**
  + [4]

[2], [7], [25], [30] proposed to consider both options,

* [2]: Option 1 is for short data packet, option 2 is for long data packet, the reader guarantees a minimum processing time of control information, and the control information field is ahead of the data packet
* [7]: Option 1 is the baseline and Option 2 can be used for small TBS to further mitigate the postamble overhead.
* [30]: consider combination of the above Option 1 and Option 2 to minimize impact of postamble miss-detection and correctly determine timing for a subsequent R2D reception even if control information is incorrectly decoded
* [25]: option2 is baseline, and option1 can be additionally used given the possible clock drift at a device at least for PRDCH

In UHF RFID, most of the Interrogator to Tag commands has one field of “command code”, by the “command code”, the Tag knows the R2D transmission length. For A-IoT, at least for traffic types DO-DTT and DT with focus on rUC1 (indoor inventory) and rUC4 (indoor command), it is not clear about companies’ views on whether similar i.e., for many of PRDCH transmissions, ‘command code’ like control field should be specified and the numbers of bits for the R2D commands are to be specified. Therefore, following question is made:

**FL1 High Priority Question 5.2.2-1: At least for traffic types DO-DTT and DT with focus on rUC1 (indoor inventory) and rUC4 (indoor command), for most of the PRDCH transmissions, whether a “command code” like control field and the number of bits for the R2D command similar as those defined in UHF RFID should be specified?**

* **Please also give reasons for your answers.**

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| **Company** | **Y/N** | **Comments** |
| Qualcomm |  | We do not think a particular agreement is necessary on this; we can discuss R2D command/format types necessary for A-IoT operation one by one. However, in general, we guess not many commands/types/formats of PRDCH transmissions contains a transport block with a variable payload size, and each command/type/format of PRDCH transmission would have a command/type/format ID so that the device can identify what it is. |
| OPPO |  | Tend to agree with QC, it’s a bit too early to discuss these details. |
| InterDigital |  | This seems reasonable but may require progress from other WG’s. |

**FL1 Medium Priority Proposal 5.2.2-2: At least for PRDCH transmission carrying a R2D command that has a unique size corresponding to the R2D command, A-IoT device can** **determine or derive the end of PRDCH transmission.**

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| **Company** | **Y/N** | **Comments** |
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### 5.2.3 R2D chip length indication

For R2D chip length indication, it was agreed in the RAN#117 meeting

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| --- |
| Agreement  For R2D, the clock-acquisition part of the R2D time acquisition signal is used to determine the OOK chip duration   * + FFS: Pattern design to support determination of chip duration |

* [3], [4], [5], [8], [7], [11], [16], [18], [28], [30], [32]: The clock-acquisition part of R2D timing acquisition signal (e.g., R2D preamble) preceding the PRDCH indicates the information of chip length used for the following PRDCH transmission.
  + [5], [8], [7] proposed that same chip duration of clock-acquisition part of the preamble is applied for PRDCH transmission including control information and data packet.
    - some floating chip length are also allowed due to CP insertion [7].
  + **Meanwhile**, [3] [12] proposed that the coding/chip length for control and data can be different
    - [3] preamble indicates the chip length of R2D control information, while a different chip duration for PRDCH can be indicated in R2D control information.
    - [12] proposed that separately encoding for control information and data payload in PRDCH to pursue different reliability
* [24]: By R2D preamble(s) similar as RFID that preamble/frame sync includes DL symbol length or by PRDCH payload

Therefore, following low questions are asked for further progress:

**FL1 Medium Priority Question 5.2.3-1: Whether it is necessary and What is the pros and cons for having different OOK chip duration for R2D control and R2D data transmission?**

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| **Company** | **Necessity?**  **（Y or N）** | **Pros:**  **Cons:** |
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### 5.2.4 D2R chip length indication

For D2R chip length indication,

* [5], [8], [26], [28], [30], [34], [39]: by R2D control information.
  + [8]: prioritize the chip duration indication of D2R transmission using explicit indication in the L1 control information in PRDCH
  + [34]: D2R chip duration can be indicated as an integer multiple or fraction of R2D chip duration
* [7], [24]: Combination of R2D preamble and R2D control information
  + [7]: the smallest time unit of resource allocation for D2R is the period of square wave for SFS modulation, therefore this information should be provided in control information of PRDCH. The baseline chip duration before applying SFS can either be derived from R2D preamble or R2D control information

In addition, [5] considers it may NOT be necessary/desirable to (re-)indicate the D2R chip length for each and every PDRCH transmission and proposed two directions:

* Direction 1, each R2D control information before D2R transmission carries the D2R chip length. In other word, each R2D control information carried the D2R chip length for the following one D2R transmission.
* Direction 2, partial R2D control information before D2R transmission carries the D2R chip length. In other word, partial R2D control information carried the D2R chip length for the following multiple D2R transmission.

Based on above, following is proposed.

**FL1 High Priority Proposal 5.2.4-1: RAN1 studies following options for the D2R chip length identification before applying small frequency shift**

* **Option 1: by R2D preamble**
* **Option 2: by R2D control information**

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| **Company** | **Y/N** | **Comments** |
| Qualcomm |  | We are not sure the meaning of “before applying small frequency shift”. A chip of a D2R must be after applying small frequency shift.  Regarding the options, we think the combination of Opt.1 and Opt.2 should also be a candidate. |
| OPPO |  | Generally OK with these two options. But we also have the same question as QC on “what is the meaning of before applying small frequency shift?”  We also suggest to change the word “identification” 🡺 “determination”. |
| InterDigital |  | OK - we can delete the “before applying small frequency shift” to simplify. |

### 5.2.5 Other scheduling information

**For R2D transmission,**

[4] proposed that there is no need to indicate MCS, since for PRDCH, only OOK is applied, while FEC code is not supported; While other companies discussed following potential scheduling information may or may not be needed for R2D transmission:

* MCS related information/parameters for different use cases and channel condition are proposed by [2], [7], [12], [17],
  + Coding scheme and coding rate, [12], [17],
  + Chip rate/chip length [7]
* TBS related information/parameters [5], [7], [12], [32]
  + ‘command code’ like control field is to be specified and the numbers of bits for R2D commands are to be specified [32]
  + [12]: time resource (starting position or ending position)
    - **From FL: TBS is related to the discussion in section 5.2.2 Device’s identification of the end of PRDCH transmission**
* [4], [5], [7] mentioned that R2D scheduling timing between the R2D control information and the R2D data transmission is NOT needed as long as
  + the scheduling information and the corresponding R2D data transmission are in same burst [7]
  + the starting time of the PRDCH is indicated by the R2D timing acquisition signal, while the chip length is indicated by the clock acquisition part of this signal [4].
  + TDRA can be derived from preamble and TBS/postamble [5]
  + **From FL: should be common understanding by following agreement**

Agreement

For the R2D timing acquisition signal immediately preceding the transmission of a physical channel, study a preamble with at least two parts which includes a start-indicator part and a clock-acquisition part, where the start-indicator part immediately precedes the clock-acquisition part:

* **Start-indicator part provides the start of the R2D transmission**
  + FFS: Details of start-indicator part

* [4], [5] mentioned that frequency domain location for PRDCH is NOT needed as the envelope detection used by Ambient IoT devices convert the RF signal at any frequency within the effective band to baseband
* Destination ID/AIoT Device ID/device identification/Group ID [1], [2], [12], [17]
  + [1] proposed that a device ID in R2D control information allows a device to **avoid decoding** a PRDCH transmission and save energy, group ID to indicate **when devices in the group should monitor R2D**
  + [2] proposed that instead of sending device ID in the control signals, a specific sequence can be used to indicate the intended device

**From FL: For cast type or Destination ID/AIoT Device ID/device identification/Group ID, it is noted that RAN2#125bis agreed following**

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| **Agreement**  **2 We will study the support for access triggering for a single device, group of devices, or all devices. RAN2 to discuss the contention-based and contention-free access procedures and detailed solutions.** |

* Repetition if supported [5], [17]
* Device type [17]
* Reader ID [17]

Given above, only one medium priority proposal is made:

**FL1 Medium Priority Proposal 5.2.5-1: Indication of Frequency domain location for PRDCH demodulation is NOT needed for A-IoT device using envelope detection.**

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| **Company** | **Y/N** | **Comments** |
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**For D2R transmission**

The following was agreed in RAN1#117 meeting:

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| **Agreement**  Scheduling information of PDRCH transmission is provided by a corresponding PRDCH. |

* [4] proposed that each PRDCH contains the scheduling information for its following PDRCH in a higher-layer message. **In contrast**, several companies [8][35] suggested that the scheduling information for PDRCH could be included in the L1 layer. Specifically, [8] proposed prioritizing the chip duration indication of D2R transmission by explicitly indicating it in the L1 control information within PRDCH.
* **From FL: whether the control information should be L1 or L2 is up for discussion in agenda 9.4.2.3.**

**For potential scheduling information required for D2R transmission,**

* MCS related information/parameters [2], [4], [5], [8], [7], [12], [13], [17], [26], [28], [30], [34], [39] with the following details:
  + Modulation [2], [12], [5], [8], [7], [34], [39]
  + Coding scheme and coding rate [5], [7], [12], [17], [34], [39]
  + Chip length [4], [5], [8], [17], [26], [28], [30], [34]
    - **From FL: chip length is related to the discussion in section 5.2.4, D2R chip length indication**
* TBS related information/parameters [4], [8], [12], [13], [32], [39]
  + ‘command code’ like control field is to be specified and the numbers of bits for any D2R transmission responding to a R2D transmission are to be specified [32]
    - **From FL: TBS is related to the discussion in section 5.2.1 Reader’s identification of the end of PDRCH transmission**
* Time domain resource allocation (TDRA) related information/parameters [2], [4], [5], [7], [11], [12], [14], [17] , [20], [21], [34], [39] with the following details:
  + Time domain resource [2], [4]
    - [2] mentioned that the timing should be indicated to another reader receiving PDRCH if CW node is a different than the reader
    - [4] amount of time resources
  + Timing of transmission [5], [7], [9], [14], [25], [27], [34], [35]
    - [27] time offset between R2D preamble and D2R preamble
    - [9] timing information can avoid the transmission collision among multiple devices for CFRA
    - [14] a set of {Starting offset, length} or only {starting offset} defined for sub-occasion(s) is used for the D2R time domain indication for CBRA, the specific sub-occasion associated with the device ID for CFRA
    - [25] timing delay parameters for a specific device or group of devices
    - [10] for CFRA, start timing is provided, an interval is provided otherwise
    - [7] reader provide time offset for D2R to allow TDMA
  + The number of slots for each round of the slotted-Aloha procedure [20]
  + Target number of R2D preamble counts for inventory [1]
    - **From FL: Time domain resource allocation is related to the discussion in section 5.1.3 Timing for D2R response to R2D and TDMA of multiple PDRCH transmission**
* Frequency domain resource allocation (FDRA) related information/parameters [2], [4], [5], [7], [11], [12], [14], [17], [21], [34], [39]
  + [7], [21] Small Frequency Shift (SFS) modulation or Uplink frequency offset
  + [14] {BLF, M} pairs for CBRA, separate frequency domain resource associated with the device ID for CFRA
* Repetition related aspects [5] , [8], [7], [13], [17], [34], [39]
  + **From FL: It was agreed to study D2R transmission in the physical layer using repetition.**
* Destination ID/AIoT Device ID/device identification/Group ID [8], [12], [17], [39], where [12] does not differentiate R2D or D2R
* Additional parameters (e.g., Divide Ratio and the value of “Q”) [14]
* Mapping between random ID and group ID [1]
  + [1] mentioned that a device in the group scheduled to perform inventory remains in the ON while others goto sleep
* device type [17]

Given above and FL proposal in previous section, i.e., Proposal 5.2.1-3 for D2R postamble, following proposal can be considered:

**FL1 Medium Priority Proposal 5.2.5-2: Study necessary scheduling information for a PDRCH transmission, at least including following:**

* **Modulation**
* **Coding scheme(s) and coding rate**
* **Number of repetitions**
* **Time domain resource for the PDRCH transmission**
* **Frequency domain resource for the PDRCH transmission**
* **FFS other necessary information**

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| **Company** | **Y/N** | **Comments** |
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* Regarding the scheduling type [12]
  + [12] proposed to support dynamic scheduling (DG), while de-prioritize SPS and Configured Grant (CG) based scheduling
* Regarding the cast type
  + [9], [25], [17], [39] discussed support study PRDCH providing a dedicated command to a specific A-IoT device, and PRDCH providing a common command to a set of A-IoT device
  + **From FL: For cast type, it is noted that RAN2#125bis agreed following**

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| **Agreement**  **2 We will study the support for access triggering for a single device, group of devices, or all devices. RAN2 to discuss the contention-based and contention-free access procedures and detailed solutions.** |

[11] discussed that L1 D2R control information is not well justified, while some companies [20], [22], [26] discussed the potential D2R control information, with the following rationales/use cases:

* [20], [22], [26] proposed to study information reporting from device
* Aknowledgement to R2D transmission [20], [26],
  + acknowledging the reception of signal adjusting timing of activity cycle[20]
  + at least study on ACK/NACK corresponds to PRDCH transmission [26]
* Indicates minimum time required before transmission of a response [20]
  + indicate whether device needs more time to prepare the D2R transmission (e.g. due to delay to acquire data from high layer or charging)
* Message size/status related information if reader may not be aware of the exact status/payload of the D2R [12]，[20], [22]
  + On acquiring the end of a PDRCH transmission at the reader, it is proposed to be based on D2R control information (possibly using the D2R preamble) [12]
  + D2R payload and/or transmission duration [20]
  + ratio based indication, which is defined as device remaining data size over the previous indicated/scheduled data size for more efficent D2R scheduling [22]

**Scheduling aspects related to Topology 2**

* [24] proposed to consider following for Topology 2
* time delay for forwarding of the received D2R signal/channel from the reader/ intermediate node (i.e., R2) for D2R reception to the reader/ intermediate node (i.e., R1) for R2D/CW transmission, in the case where the R1 and R2 are different.
* time delay for frequency retuning in device between R2D reception and D2R transmission, in the case where the FDD spectrums (i.e., DL band or UL band) for the R2D transmission and the D2R transmission are different.
* studying whether to provide longer timing (compared to normal UEs) during RACH procedure to ensure UL sync re-adjustment time for the intermediate node
* [9] proposed that
  + same downlink synchronization signals/channels are designed for gNB in Topology 1 and UE in Topology 2, device does not need to differentiate whether a detected synchronization signal/channel is from a gNB or a UE
  + Study how to configure UE in Topology 2 for providing synchronization services to ambient IoT
  + Study radio resource allocation mechanism for intermediate node in Topology 2
* [31] discussed some issues related to intermediate UE’s behaviors for Topology 2.
  + How to schedule intermediate UE’s transmission/reception in communication with A-IoT UE, e.g., scheduling DCI.
  + Reporting behavior after communication b/w intermediate UE and A-IoT UE, e.g., how to schedule reporting timing/resource from intermediate UE, which contents to be reported, etc.
  + SCS/BWP switching rule if required, e.g., whether the existing BWP switching mechanism is used when SCS of signal for A-IoT UE is different.
  + Processing time requirement b/w scheduling and transmission at intermediate UE, including SCS switching and/or waveform switching aspects.
  + Overlap handling at intermediate UE, e.g., UL transmission vs PRDCH reception.

**Comments, if any**

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| **Company** | **Y/N** | **Comments** |
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# Random access

Based on the chair’s guidance, it is not in the scope of RAN1 to define the random-access procedure. RAN1 can study physical resources allocation for random-access procedure.

In RAN2#126 meeting, the following agreements were reached for access procedure.

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| **Agreements on “4 step” RA**  1. A-IoT Msg1: the device sends an ID to the reader. ID is a **random ID** generated by device (FFS how it is generated, e.g. randomly generated or generated based on Device ID). FFS on ID size. This doesn’t preclude any other RAN1 agreed information  2. A-IoT Msg2: the reader echos the ID received in Msg1. Further information may be included in mgs2 based on RAN1 agreements  3. A-IoT Msg3: device sends Device ID and/or any other upper layer data (depending on upper layer request)  4. The device considers the contention resolution as successful, if the Msg2 including the same random ID in Msg1 is received. RAN2 assumes the size of random ID in Msg1 should be sufficient for contention resolution purpose.  5. “Msg4” (i.e. the subsequent R2D transmission after D2R transmission) does not need to be always sent in random access. “Msg4” can be considered to handle the Msg3 transmission failure (due to various reasons). “Msg4” usage/presence can be further discussed.  RAN2 will not use “Msg4” term for further discussion of the random access.  **Agreements on 2 step CBRA**  1. A-IoT Msg1: The device sends Device ID and/or any other upper layer data (depending on upper layer request). FFS what **device ID** is and whether an additional random ID is needed. This doesn’t preclude any other RAN1 agreed information  2. A-IoT Msg2: the reader may echo some information from Msg1. FFS what some information is. “Msg2” usage/presence can be further discussed  **Agreement on CFRA**  From reader perspective, contention-free access procedure we will study single and multi-device case (depending on RAN1 discussion).  **Agreements on paging**  1 RAN2 will study the following cases for AIoT paging message:   * a message containing an ID of a single A-IoT device. * a message containing a group ID that maps to multiple A-IoT devices. * a message that does not contain an ID, i.e., addressed for all devices that can receive the AIoT message. * a message containing multiple IDs of A-IoT devices. Need to confirm the need for this use case based on SA2 discussion.   What device ID and group ID and scenarios is depending on SA2 discussion.  2 AIoT paging message indicate information from which the device can determine resources to be used for response (D2R message). FFS how (e.g. implicit/explicit/configured/preconfigured) and what resources (dedicated and/or shared) are provided to the device taking into account RAN1 discussion.  3 From RAN2 perspective, we assume the device can receive as long as there is enough energy. We will wait for RAN1 further progress on device monitoring details. |

Therefore, we can use the terminology which are already agreed by RAN2 in the following discussions. Like A-IoT paging message, Msg1, Msg2, Msg3, ID, random ID, device ID etc.

## Resource determination for Msg1

### 6.1.1 TDMA

* [31] discussed entire concept of resource allocation for contention-based access. In detail, following is proposed

|  |
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| * **Discuss entire concept of resource allocation for contention-based access.**   + **Alt 1: One-level approach**     - **All devices that are matched with the indicated ID in a D2R trigger attempt to transmit D2R corresponding to the trigger**   + **Alt 2: Two-level approach**     - **Level-1: Each device that is matched with the indicated ID in a D2R trigger determines:**       * **Alt 2-1: whether a D2R is transmitted within the corresponding level-1 resource or not, or**       * **Alt 2-2: which level-1 resource is used for D2R corresponding to the trigger**     - **Level-2: When transmitted in a Level-1 resource, level-2 resource is determined within the level-1 resource**     - **FFS: which resource level is selected based on slotted-ALOHA**     - **FFS: which resource level is assumed in the agreement reached at the last meeting**     Fig. 5: Alternatives of entire resource allocation concept for contention-based access of [31] |

From FL’s understanding, about two-level approach is kind of concept of “slot” and “sub-slot within the slot” for slotted-ALOHA based access. From FL’s understanding, RAN1 will focus on the “sub-slot” level (level-2 of [31]) that is how time/frequency resource is allocated/determined by one R2D transmission (A-IoT paging or Msg2). Whether and how “slot” (level-2 of [31]) is determined will be decided by RAN2 as procedure of random access. If you have different understanding, please comment here.

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| **Company** | **Y/N** | **Comments** |
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* [4] proposed that for D2R transmission during access procedures in TDMA manner, **each R2D only determines one T-F resource to be used for the following D2R transmission corresponding to that R2D.** One example is given in Figure 15 of [4].



Figure 15. An example of TDMA for 4-step access

* [5], [6], [7], [9], [11], [25], [27], [31], [39] proposed to study to enable TDMA or slotted ALOHA without “N R2D transmissions for N time slots” to improve spectrum/energy efficiency.
* [14] considers at least for the deployment where only has device 2, the device can perform TDM within one access occasion. FFS for the deployment where has device 1
* [5], [25] proposed to study whether necessary to introduce extra R2D signalling for time tracking between different time domain resource for TDMA and/or FDMA of multiple Msg1 D2R transmissions.

Based on above, following proposal can be considered for Msg1 first. Whether to support Msg3 with the same mechanism depends on the discussion in section 6.2.

**FL1 High priority Proposal 6.1.1-1: Study TDMA of Msg.1 transmissions from multiple devices corresponding to the same A-IoT paging message for contention-based access, including following**

* **What is the unit for resource allocation in time domain?**
* **How does reader allocate the time domain resource for the TDMA of Msg.1 transmissions**
* **How does device determine the time domain resource for the Msg.1 transmission**
* **How to address the timing error for adjacnet Msg1 transmissions caused by the initial/residual SFO of the device?**

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| **Company** | **Y/N** | **Comments** |
| Qualcomm | Y |  |
| OPPO | OK | Generally fine with this proposal. Some suggestions of modification from us:  **Study TDMA of Msg.1 transmissions from multiple devices corresponding to the same A-IoT paging message for contention-based access, including following**   * **What is the unit for resource allocation in time domain (e.g., Msg. 1 sequence length in chips or bits)?** * **How ~~does reader allocate~~ the time domain resources are allocated for the TDMA of Msg.1 transmissions (e.g., pre-defined or by the reader)?** * **How does a device determine the time domain resource for the Msg.1 transmission (e.g., based on device processing capability or indicated by the reader)?** * **Whether/How to address the timing error for adjacnet Msg1 transmissions caused by the initial/residual SFO of the device?** |
| InterDigital |  | Generally fine with the above. One question is what “A-IoT paging message” means, is it referring to only the very first R2D transmission of the procedure, or also to possible subsequent R2D transmissions (QueryRep-like)? |

**On details of time domain resource determination for TDMA of D2R transmission by the same R2D transmission**

* [7] proposed for TDMA of Msg1, the candidate time resources should be provided before the inventory round starts, including at least the time positions for each candidate resource within the slot.
* [9] proposed to consider grouping of one or more Tx and Rx resources for R2D and D2R communications within an occasion and use slotted aloha method to select the occasion as shown in figure 10.



Figure 10: Illustration of grouping of resources and selection of occasion using slotted aloha method from [9]

* [11] proposed following two options based on the two options agreed for D2R response timing. Figure 4-1 and 4-2 give examples for the two options.
  + Option 1: Extension of the time window based solution to TDMed Msg1 transmission: introducing/defining a main time window [TD2Rstart, TD2Rend] that covers all the TDMed Msg1 resources/transmission
  + Option 2: Indication based where multiple Msg1 transmission timing is indicated by Paging

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| * 图片包含 文本    描述已自动生成 * 4-1a: Same size/length for 1st and 2nd sub-windows | 4-1b: Different size/length for 1st and 2nd sub-windows |

Fig 4-1: Illustration for Option 1 that a main time window covers all the TDMed Msg1 resources/transmission of [11]



Fig 4-2: Illustration for Option 2 that multiple Msg1 response timing is indicated by Paging of [11]

* [13]: When there are multiple of the window of [TR2D\_min, TR2D\_max] are configured and which window is used is up to the device, it corresponds to slotted-ALOHA access and these different starting timing are the start of “slots” or “transmission occasions”.
* [14] proposed that{Starting offset, length} or only {starting offset} is used for the D2R time domain indication and the number of sub-occasions in one access occasion should be limited due to timing drift caused by SFO.
* [7], [14] For TDMA and FDMA of multiple Msg1 in one slot, devices can random select one of the candidate resource for Msg1.
* [20] proposed reader transmits an indication of the slot start for every M slot(s) of the slotted-Aloha based contention-based access procedure and devices with high SFO prioritize the selection of D2R resources in the N slots following a R2D transmission. FFS the value of N.
* [24] for D2R response timing option 1, a separate time offset may be indicated to each device so that the transmission timing window determined by each device does not overlap; for D2R response timing option 2, the reader may indicate TR2D differently for each device to perform TDMA.
* [27] one R2D schedule multiple D2Rs, where a small gap is maitained between two D2R transmissions

### 6.1.2 FDMA

For D2R transmission during access procedures in FDMA manner, almost all companies share the view that each R2D can determine more than one frequency resource to be used for the following D2R transmissions corresponding to that R2D. One example is given in Figure 16 of [4].

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Figure 16. An example of FDMA for 4-step access of [4]

**Regarding frequency resource determination for Msg.1**

* + [7] proposed for FDMA of Msg1, the candidate frequency resources should be provided before the inventory round starts, including at least the SFS (small frequency shift) frequencies for each candidate resource.
  + [14] proposed one frequency domain resource can be defined as one {BLF, M} pair for frequency domain resource allocation in D2R, where BLF represent the backscatter link frequency and M represent the coding rate or the baseband waveform multiplied by a square-wave at M times the symbol rate.



Figure 2 Single side-band illustration of the frequency domain resources for FDM operation of [14]

* + [11] proposed
  + For device 1/2a with D2R backscattered on a CW, different backscatter-link frequency (BLF) values indicated by R2D control information is used to allocate different frequency resources
  + For device 2b with internally generated D2R transmission, it is straightforward to indicate the different FDMed frequency resource by R2D control information.
  + [12] For frequency domain multiple access of D2R transmissions, it could also be configured to different A-IoT devices through different frequency domain resource units through frequency offset.
  + [23]
  + For contention-based random access FDMed resource allocation, reader uses the Q value to indicate all the 2Q RO candidates, and the RO candidates are numbered in the frequency domain first and then in the slot/occasion in an access round. Each device randomly selects one RO candidate to send msg1.
  + For contention-free random access FDMed resource allocation, the paging devices can be associated with the RO candidates. The devices in the paging list correspond to the RO candidates in turn, and the RO candidates are first numbered in the frequency domain, and then in the time slots/occasions in the access round. Each device uses a dedicated RO candidate to send msg1.
  + [20] proposed
  + for contention-based access, reader indicate multiple sets of parameters for the D2R frequency resource/channel determination, and each device randomly select one set of parameters to obtain its own D2R frequency resource/channel.
  + for contention-free access, if the R2D command is target for more than one device, the reader can explicitly indicate the parameter for the D2R frequency resource/channel determination to each device.

Given above, following proposal is made:

**FL1 High priority Proposal 6.1.2-1: Study FDMA of Msg.1 transmissions from multiple devices corresponding to the same A-IoT paging message for contention-based access, including following**

* **How does reader allocate the frequency domain resource for the FDMA of Msg.1 transmissions**
* **How does device determine the frequency domain resource for the Msg.1 transmission**

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| **Company** | **Y/N** | **Comments** |
| Qualcomm | Y |  |
| OPPO | OK | Similar to our comments provided for the TDMA case, we suggest the following modifications.  **Study FDMA of Msg.1 transmissions from multiple devices corresponding to the same A-IoT paging message for contention-based access, including following**   * **How ~~does reader allocate~~ the frequency domain resources are allocated for the FDMA of Msg.1 transmissions (e.g., pre-defined or by the reader)?** * **How does a device determine the frequency domain resource for the Msg.1 transmission (e.g., based on device frequency shifting capability or indicated by the reader)?**   **<< Several contributions proposed to study CDMA of Msg. 1 transmissions and have shown results and study outcomes that it is feasible. We suggest the FL of this agenda item to include this topic / technical aspect for discussion in RAN1. >>** |
| InterDigital | Y |  |

## Msg2 related aspects

For Msg2 in response to multiple TDMed/FDMed Msg1 that is triggered by one A-IoT paging, following should be discussed.

**Aspect#1: Msg2 contains only one or more than one response**

* [5], [7], [11], [25], [32] proposed to study following options on how Msg3 is scheduled by Msg2
  + - Opt.1: A Msg2 contains a single R2D response to echo one ID received in A-IoT Msg1
    - Opt.2: A Msg2 contains multiple R2D responses to echo all IDs received in A-IoT Msg1
    - Opt.3: A Msg2 can contain one or more than one R2D responses to echo one or more than one ID(s) received in A-IoT Msg1, which is determined by the Reader
* [6] proposed Msg2 may include contention resolution ID and Msg3 scheduling information for multiple A-IoT devices.

**Above different options may have different impacts on the time duration for Msg2 monitoring (e.g., Msg2 monitoring window) Aspect#2 discussed below, scheduling timing/information for Msg3 (e.g., whether to support TDMA of multiple Msg3 by a Msg2).**

Therefore, following proposal can be considered.

**FL1 High Priority Proposal 6.2-1: Study following options for Msg2 in response to multiple Msg1 transmisisons that is triggered by one A-IoT paging message.**

* + **Option 1: A Msg2 contains a single R2D response to echo one ID received in A-IoT Msg1**
  + **Option 2: A Msg2 contains multiple R2D responses to echo all IDs received in A-IoT Msg1**
  + **Option 3: A Msg2 can contain one or more than one R2D responses to echo one or more than one ID(s) received in A-IoT Msg1, which is determined by the Reader**

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| **Company** | **Y/N** | **Comments** |
| Qualcomm | Y |  |
| OPPO |  | In our understanding, this aspect falls under RAN2’s study and discussion scope. Maybe it is worthwhile to clarify this aspect with RAN2 first. |
| InterDigital | Y |  |

**Aspect#2: Msg2 monitoring and Msg3 scheduled by Msg2**

[5], [6], [11], [31], [32] discussed Msg2 monitoring window and timing for Msg3 transmission, especially for the case that multiple TDMed/FDMed Msg1 transmissions are scheduled by the same A-IoT paging message. In detail,

* [11] proposed to study following two options for for a device to determine the Msg.2 reception timing in case one A-IoT paging schedules multiple TDMed/FDMed Msg1, as shown in figure 5-1
  + Opt.1 Common time window based: the starting time for the Msg2 response time window is TD2R\_min after the “last” Msg1 time domain resource that is scheduled by the A-IoT paging.
  + Opt.2 Independent Time window: the starting time for the Msg2 response time window is determined based on the control information in the A-IoT paging.
  + For both options, the length/duration for Msg2 response time window can be pre-defined and/or indicated.

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| 5-1a: Same size/length for 1st and 2nd sub-windows | 文本  中度可信度描述已自动生成  5-1b: Different size/length for 1st and 2nd sub-windows |

Figure 5-1: illustration on options for the Msg2 response time window of [11]

* [31] and [32] proposed to discuss the timing relations for the following transmissions after multiple TDMed/FDMed Msg1 scheduled by the same A-IoT paging message as shown in Figure 26
  + Option 1: device transmits the Msg3 after the “last” Msg2 transmission (Fig 26 (a) and (b)). In other word, the device cannot transmit Msg3 until ot receives the “last” Msg2
  + Option 2: device transmits the Msg3 immediately after the correspoding Msg2 transmission (Fig 26 (c))

 

Fig. 26 msg-2[s] follow msg-1s and msg-3s follow msg-2[s] of [32]



Fig. 26 (c) msg-2 and msg-3 for a msg-1 are back-to-back (immediate) of [32]

Based on above, following proposal can be considered.

**FL1 High Priority Proposal 6.2-2: Study followings for Msg2 and Msg3 transmissions in case multiple Msg1 transmisisons is triggered by one A-IoT paging message.**

* + **How Msg3 is scheduled by Msg2, at least including the resource allocation**
  + **How does device monitor Msg2 transmission after it transmits Msg1, including starting time and time duration for Msg2 monitoring**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Qualcomm | Y | Potential TDMA/FDMA, same as for Msg-1, should also be studied. |
| OPPO |  | Potential TDMA/FDMA/**CDMA** of Msg. 3, same as for Msg. 1, should also be studied. |
| InterDigital | Y |  |

## Others

**CDMA:**

* [7], [9], [12], [16], [17], [32] discussed CDM is feasible and proposed to study further
  + [7] discussed that code sequences can be provided in PRDCH providing triggering for random access procedure(e.g., msg0)
  + [9] provides simulation showing that binary modulated orthogonal sequence, e.g., Golay sequence, can tolerate timing error by selecting a suitable cyclic shift spacing
  + [12] provides simulation showing 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)
  + [17] provides the simulation results to show that the access efficiency of Q-selection based on CDM data exceeds 2 times that of Q-selection
  + [32] gives a bunch of simulations with different power variations and SFO hypotheses
* **Meanwhile,** [4] discussed that CDMA cannot work because the large SFO at device side will break the sequences orthogonality. And it is uncertain that the reusing of the same resource between devices can compensate the reduced spectrum efficiency per device

**The resource determination for CDMA of D2R transmissions can be discussed after feasibility of CDMA of multiple D2R transmission is proved in AI 9.4.2.1. Therefore, related discussion is deprioritized in this meeting.**

**Other enhancements**

* [17] proposed to study the enhanced slot based anti-collision algorithm, e.g. Q-selection + BTree.
* [25] proposed to study a collision handling mechanism to improve the success rate of the tags with collision by allocating some additional e.g., FDM’ed or CDM’ed resources (as Type II RA in Figure 6) resources to those collided tags.



Figure 6 A collision handling process via random access of [25]

Comments if any.

|  |  |
| --- | --- |
| **Company** | **Comments** |
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# DO-A Gap

According to the following objective in the SID, the part(s) of the harmonized air interface design insufficient for the DO-A use case need to be identified.

|  |
| --- |
| *From RP-240826 [13]*  …   1. Traffic types DO-DTT, DT, with focus on rUC1 (indoor inventory) and rUC4 (indoor command).  * From RAN#104, the study will assess whether the harmonized air interface design (per bullet ‘A’ above) can address the DO-A (Device-originated autonomous) use case, only to identify which part(s) of the harmonized air interface design (per bullet ‘A’ above) is/are not sufficient for the DO-A use case.   … |

[3] observed that DO-A traffic type is more appealing for sensor use case and discussed the potential differentiating aspects from synchronization, random access (RA), scheduling and timing perspective for the different traffic types.

* Synchronization
  + Unlike A-IoT devices using DO-DTT traffic type, A-IoT devices using DO-A traffic type may not be able to rely on an R2D transmission prior to D2R transmission for timing correction.
  + Periodic synchronization signals, if supported, can be used for the A-IoT devices using DO-A traffic type. Another alternative is to have periodic R2D transmissions, which can assist DO-A transmissions.
* RA
  + The different traffic types can be based on the same procedure, with the extension that an A-IoT device using DO-A traffic type can determine whether and/or when to do a D2R transmission based on the availability of data to transmit.
* Scheduling and timing
  + A-IoT devices using DO-A traffic type will need the scheduling information for a potential D2R transmission to be provided somehow, e.g., signaled in a periodic R2D transmission providing D2R transmission opportunities.
  + One possible approach is to provide the DO-A scheduling information in a periodic paging request.
    - Each periodic paging request grants the device to carry out a D2R transmission during a certain time window following the paging request.
    - Periodic synchronization signals could potentially be transmitted within the time window, allowing for a longer time window and less frequent periodic paging requests.

[4] proposed to capture the following missing mechanisms/schemes to support DO-A traffic by the Ambient IoT air interface for inventory and command:

* Device-triggered access procedure.
  + Either an inventory or a command starts from a paging message from reader to one or multiple devices
* Common resources for access occasion.
  + The resource(s) for the access occasion(s) are indicated in the paging message. It is in the way of “on-demand” resource allocation, rather than the semi-static configuration in NR/LTE.
  + Devices does not achieve, and cannot maintain, synchronized timing with the reader. The resource of each access occasion may need to be indicated by an R2D message ahead of it.
* Optionally, buffer-size report for D2R data
  + Not sure that there will be buffer size report to support the use cases of inventory and command in R19, as the message size of the D2R data could be indicated by e.g. core network

**FL1 High Priority Question 7-1: Do you agree to capture following aspects that the harmonized air interface design for DO-DTT, DT with focus on rUC1 (indoor inventory) and rUC4 (indoor command) are not sufficient for the DO-A use case?**

**Aspect #1: Synchronization**

* Unlike A-IoT devices using DO-DTT traffic type, A-IoT devices using DO-A traffic type may not be able to rely on an R2D transmission prior to D2R transmission for timing correction.

**Aspect #2: Device triggered access procedure**

* Either an inventory or a command starts from a A-IoT paging message from reader to one or multiple devices. Unlike A-IoT devices using DO-DTT traffic type, for A-IoT devices using DO-A traffic type, the resource and scheduling information for a potential D2R transmission may not need to be indicated by an R2D message ahead of it.

**Aspect #3: Buffer-size report for D2R data**

* It is not sure that there will be buffer size report to support the use cases of inventory and command in R19, as the message size of the D2R data could be indicated by e.g. core network.

**Any other aspect(s)?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Which aspects**  **(#1, #2, #3, #4?)** | **Comments** |
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# Time domain frame structure for A-IoT

* 1. Alignment between R2D and NR frame structure

**On whether to align the end of R2D transmission with OFDM symbol boundary**

**From waveform generation perspective**

* [4], [5], [10], [12], [15], [17], [18] **support the alignment** to ease the generation of an OFDM waveform
* [12] beneficial for reducing the TBS indication granularity to OFDM symbol level
* [4], [15] proposed to include padding before the R2D waveform generation for PRDCH, when the generated number of chips for the PRDCH do not fully occupy the last OFDM symbol for DFT-s-OFDM-based transmitter where the time sequence/signal is processed by the DFT and IFFT module in order as shown in following figure.



Figure 12. Example of alignment with an OFDM symbol of [4]

* [5] based on Reader’ s implementation to make this alignment. For example, padding “0” or padding with repeated partial of R2D signal



Figure 1. Example of alignment with NR symbol or slot boundary of [5]

* [10], [17] proposed to use the flexible postamble to pad the last OFDM symbol and make it into an integer symbol to perform the alignment of the last OFDM symbol.
* [10], [17] Properly design the TBS and code rate to ensure that R2D transmission terminated at the end of OFDM symbol, The data rate value that is not divisible by the number of OFDM symbols per millisecond is better to be avoided
* Meanwhile, [7], [11], [14], [33] proposed that the end of R2D transmission is unnecessary to be aligned with the boundary of an NR symbol as the alignment reduce scheduling efficiency
* [11] the end of R2D transmission from Reader perspective may or may not be aligned with the boundary of an NR OFDM symbol (including the CP) for in-band/guard-band operation
* [7] From reader point of view, it can pad zeros or other bits based on its implementation, but from device point of view, it does not care what is following after the end of R2D transmission as it stops monitoring
* [33] keeping the end of R2D transmission aligned with an OFDM symbol is not efficient due to the varied and numerous data packages.
* In addition, [4], [14], [35] slot level alignment may not be needed as it may reduce efficiency of R2D transmission/scheduling. [39] mentioned whether the end of R2D transmission is aligned with the boundary of an NR symbol, the impact of CP handling should be considered

**FL1 Low priority question 8.1-1: Do you agree that for R2D waveform generation using DFT-s-OFDM-based transmitter, to align with the OFDM symbol boundary, padding at the end of R2D transmission is needed when the generated number of chips for the R2D transmission do not fully occupy the last OFDM symbol?**

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| **Company** | **Y/N** | **Comments** |
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**From understanding of the end of R2D transmission perspective**

On whether the “end” of a R2D transmission is aligned with OFDM symbol boundary or not, the views from companies are diverged. **It has impact on timeline discussions.**

* [4]: The “end” of R2D transmission should not consider the padding part as shown in following figure. In other word, the end of the R2D transmission is not needed to be aligned with the OFDM symbol boundary.



Figure 13 from [4]

* [16]: When the A-IoT device detects the R2D signal aligned with the boundary of the NR OFDM symbol, the A-IoT device would derive the time synchronization from the DL synchronization signals which is aligned with the boundary of OFDM symbol or mini-slot of NR frame structure. In this case, the A-IoT device can take the received timing of the R2D signal as the reference time for the backscattering or transmitting the D2R signal. The transmitting time of the D2R signal is set based on the reference time, indicated by the DL control information in multiple of OFDM symbols.
* [15]: To align the end of R2D transmission with boundary of an NR symbol, only limited TBS can guarantee the R2D transmission is fully occupied the OFDM symbols using DFT-s-OFDM based waveform generation.

In order to have an aligned understanding on the “end” of R2D transmission, from both reader and device perspective, it may be related to whether device can know the OFDM symbol boundary or not, which may also be related to whether/how device handles the CP [39]. For preference collection, one low priority question is raised.

**FL1 Low priority question 8.1-2: Whether the end of R2D transmission needs to be aligned with the OFDM symbol boundary?**

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| **Company** | **Y/N** | **Comments** |
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* 1. Alignment between D2R and NR frame structure

**On whether to align the D2R reception/transmission with NR symbol and/or symbol boundary**

[4], [5], [8], [7], [10], [11], [14], [24], [28], [33], [35], [37], [39] proposed Rel-19 A-IoT study **does not** assume that the start and the end of a D2R reception is aligned with an NR time boundary.

* + [14] asynchronized transmission is starting point
  + [33] mentioned that aligning with NR symbol or NR slot boundary in D2R transmission is thankless considering timing drift
  + [33] proposed that dynamic guardian symbols can address the issues arising from the lack of alignment
  + [11] proposed from the transmitter i.e., device and the receiver i.e., Reader perspective, the start of D2R transmission or reception cannot be assumed to be aligned with NR OFDM symbol boundary within the CP range. In addition, for D2R transmission, A-IoT device does not apply and maintain the timing advance (TA).
  + [7] observed following:
    - For D2R transmission only consider [TR2D\_min, TR2D\_max], it is impossible to align the D2R transmission within the NR symbols and/or slots.
    - For D2R transmission with an indicated time gap from R2D transmission, it is up to gNB or intermediate UE whether to align the D2R transmission within the NR symbols and/or slots. Furthermore, the impact of large SFO should be considered to verify the feasibility of such alignment among different devices.
  + [37]: controlling the start of D2R transmission being located within an expected slot, instead of alignment of symbol boundary

While,

[16] proposed that frame structure of the “backscattered/self-generated” D2R signals should be the same as that of R2D signals, in which the D2R transmission reference time would be aligned with the boundary of OFDM symbol or mini-slot.

* + A-IoT device can take the received timing of the R2D signal as the reference time for the backscattering or transmitting the D2R signal. The backscattering or transmitting time of the D2R signal is set based on the length of TTI, which is defined as the transmission time interval of A-IoT channels/signals including the preamble and the interrogation signal in the DL, and is multiple of OFDM symbols.

[31] Proposed to study alignment between the D2R reception and a NR time boundary (NR symbol/slot boundary).

* + Assume that post-sync SFO is much smaller than the initial SFO.
  + R2D sync signal is transmitted periodically during potential D2R TX occasions. a device monitors the most recent one before D2R transmission. This design is illustrated below.



Fig. 3: Periodic R2D sync signal for highly-time aligned system of [31]

* + Acceptable timing drift Te\_max is determined based on the LLS performance
  + With a post-sync SFO value, it is clarified how long actual timing drift Te <= Te\_max is achievable
  + Conclude whether (A) periodic R2D sync signal during potential D2R TX occasions is defined for re-sync per T, or (B) the time alignment design is not supported

[18] Apply alignment mechanisms in specific scenarios to minimize the impact of non-aligned D2R transmissions on system performance.

Given the majority interests, following proposal can be considered.

**FL1 Low priority Proposal 8.2: The D2R transmission can be controlled by the reader to be confined within one or multiple expected slot(s), instead of alignment of OFDM symbol boundary**

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| **Company** | **Y/N** | **Comments** |
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* 1. Resource allocation and Chip definition/length

**Resource allocation unit**

* [4], [5], [11], proposed that the smallest time unit for resource allocation is defined as OOK symbol/chip length.
* [10] Both the first and last symbol occupied by D2R transmission should be regarded as the allocated reception time unit of gNB



Figure 1 Illustration of time resource allocation on the gNB side of [10]

* [16] proposed that TTI (transmission time interval) of the A-IoT signals as the unit of the transmission resource in time domain should be defined in the A-IoT system design and the TTI should be fixed at a number of lengths based on the number of TBS sizes.
  + Option 1: The granularity of the TTI of the R2D signal is the NR OFDM symbol.
  + Option 2: The granularity of the TTI of the R2D signal is the mini-slot with 2, 3, or 7 symbols or slot with 1ms at 15kHz SCS.
* [39] proposed to support different chip durations for D2R transmission and different chip durations for R2D transmission.
* [3] preamble indicates the chip length of R2D control information, while a different chip duration for PRDCH can be indicated in R2D control information.
* [12][17] proposed that separately encoding for control information and data payload in PRDCH to pursue different reliability

For the chip definition, chip length and potential values e.g., M for OOK-4, from FL understanding, it is related to the FFS “FFS: Time domain definition of e.g., chips and relation to OFDM symbols, resource allocation unit, etc.” agreed in AI 9.4.2.1, hence can be discussed in that Agenda.

Any comments?

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| **Company** | **Y/N** | **Comments** |
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**Maximum duration of a single PRDCH/PDRCH, definition of TB**

[31]: proposed to clarify the max duration of a single PRDCH/PDRCH and definition of TB.

* Understanding #1: A TB is defined with the whole of a ‘message’ with 96 ~ 1000 bits, and a single PRDCH/PDRCH continues until completion of transmitting the whole
* Understanding #2: The max time duration for a single PRDCH/PDRCH is defined in a certain range (e.g., 14 NR symbols, X chips, etc.), and a ‘message’ with 96 ~ 1000 bits is divided into multiple PRDCHs/PDRCHs when the message size is not enough for a single PRDCH/PDRCH. This is NR-like mechanism.



Figure 6 of [31]

Any comments?

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
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# Agreements achieved in RAN1#118

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|  |  |  |  |
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# Appendix

# Appendix A Companies proposals or evaluations on detailed solutions to reduce the energy harvest impacts

## Source 1 [1]

* **Solution**

[1] provided functions of different state in table 2, state transition in figure 2 and proposed to support preamble detection to provide timing in the SLEEP state and support devices with two states and devices with three-states.

Table 2. Some characteristics of device states in RAN#104 proposal. Red text indicates our proposal.

|  |  |  |  |
| --- | --- | --- | --- |
| Function | OFF state | ON state | SLEEP state |
| Support of transmission | No | Yes | No |
| Support of reception | No | Yes | preamble detection |
| Support of energy harvesting | Yes | Yes | Yes |
| Support of memory content from the ON state |  |  | Yes |
| Support of maintaining a timer |  |  | Yes |

OFF

SLEEP

ON

eOFF-ON

eOFF-SLEEP

eON-OFF

eSLEEP-OFF

eON-SLEEP

eSLEEP-ON

Fig. 2. Simple state transition diagram

[1] provided an example of device supporting three states starting from the OFF state for the inventory case.

* After the device transitions from the OFF state to the ON state, it is fully charged.
* In the ON state, a device receives an inventory command from a reader. A device can generate a random ID that will be used when the device transmits A-IoT Msg1.
  + A device can receive mapping information how to associate the random ID to a group ID. In addition, information also includes a target number of preamble counts when that group is expected to perform inventory.
  + A device in the groups not scheduled to perform inventory immediately can enter the SLEEP state and count the number of detected preambles.
  + A device in the group scheduled to perform inventory remains in the ON state and completes its inventory steps.
  + When the next mapping information is transmitted is indicated by the next decode field in the L1 R2D control information.
* In the SLEEP state, the device just counts R2D preambles while harvesting energy. When the count of preambles reaches the target, the device can transition to the ON state when it is charged.
  + Depending on implementation, a device can receive the PRDCH to determine the next decode opportunity and continue to be in the SLEEP state.
  + It is possible that a device can miscount the number of preambles and transition from the SLEEP state early or late. The group ID in the L1 R2D control information indicates if the group (i.e., device) is scheduled to perform inventory at the time. If the group ID indicates the group is not scheduled, a device can use the next decode field to determine when the next mapping information is scheduled. The device can enter the SLEEP state until then. The next mapping information provides an updated target number when the group is expected to perform inventory.
  + It is possible that the device missed the opportunity for transmitting A-IoT Msg1. The reader can schedule another pass for devices that missed inventory.
* In the ON state, devices in the group scheduled for transmitting A-IoT Msg1 within the next window of R2D transmissions is assumed to have sufficient energy to continue the contention access procedure. It is up to reader implementation to manage the number of devices in this group and ensure that devices are available.
* **Analysis and Observations**

[1] observed following and proposed to support a group ID field in the L1 R2D control information to indicate when devices in the group are scheduled for monitoring R2D transmission for Ambient IoT device availability according to example of inventory for a three-state device.

Observation 1. By implementation, it can be assumed that

* Devices are fully charged before inventory begins
* Devices deferred to a later time window are fully charged at the beginning of that time window
* The time window size is set such that devices have enough energy to sustain operation within the window

Observation 2: For device availability considerations, supporting preamble counting in the SLEEP state allows a reader to perform Uu operations without affecting the device in the SLEEP state.

## Source 2 [4]

* **Solutions**

[4] provided two directions as following:

* + Direction 1 - Device and vertical deployment use appropriate energy source and capacitor size to ensure that the device is always available.
  + Direction 2 - Specify when reader can perform inventory, and when device may be available.
* **Analysis and Observations**

Direction 1 - Device and vertical deployment use appropriate energy source and capacitor size

* 
* **Figure 20. An example of inventory procedure**



(a) Charging time of 12 s for the first device



(b) Charging time of 42 s for the second device

Figure 21. A life cycle of several processes for devices

Proposal 29: We propose to capture the following observation in the TR under Direction 1:

* RF energy harvesting is a suitable way to deploy devices with long discharge times, and the reader’s scheduling implementation is able to appropriately handle the duration of an inventory round, resulting in no special handling being required from a RAN1 perspective.
* The reader by implementation maintains the maximum time between the Paging messages as ≤ Tdischarge/2, ensuring that the device can switch to its ON duration after charging completely, receive the Paging message and complete the entire inventory procedure before running out of charge.
* The device maintains a state flag using an ultra-low power latch during the OFF duration such that the device does not perform inventory repeatedly after it completes a charging cycle.
* Any failed reception of Paging messages during the device charging time is handled by the higher layer re-access procedure.

Direction 2 – Device performs energy harvesting to avoid the device being unavailable

* Device states:
  + ON state – Device is fully operational – it can transmit and receive communication messages, run a clock, maintain memory.
  + OFF state – Device is not operational – it cannot transmit or receive any messages, nor run a clock. In this state, the device performs energy harvesting and can maintain an inventory flag for a reasonable amount of time.
  + SLEEP state – Device is semi-operational – it cannot transmit or receive communication messages, but it can run a clock and perform energy harvesting. It may also maintain memory.
* Solution using on-demand shifting between states：
  + The approach is for the reader to transmit an indicator, that would indicate the time left for the inventory procedure to start and for the device to receive a Paging or Query message.
  + The indicator is transmitted frequently but not periodically

应用程序

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Figure 22. Device receives first indicator after Paging message

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Figure 23. Device receives fourth indicator after Paging message

图形用户界面, 应用程序, 电子邮件

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Figure 24. Device receives fourth indicator after Paging message

Proposal 31: For Direction 2, we propose an on-demand shifting of states where the reader controls the device to switch to the ON state from the SLEEP state using an indicator which would inform the device of the duration it has to remain in the SLEEP state.

* The ON and OFF durations are determined by device implementation.
* The SLEEP state duration is determined based on the received indicator.

## Source 3 [7]

* **Solutions**

[7] provided two frameworks as following:

* + Framework 1: The device keeps in ON state after being fully charged and enters OFF state when run out of the available energy. The reader transmits inventory commands frequently to ensure that the device can be inventoried during ON state.



Figure 2: Illustration of framework 1

* + Framework 2: The device can be in SLEEP state before or during an inventory round. The reader cannot control the device state before inventory and can control the device state during inventory.



Figure 3: Illustration of device randomly ON



Figure 4: Device can enter SLEEP state before inventory

* **Analysis and Observations**

[7] provided some observations and proposals according to two frameworks.

Framework 1

Observation 3: Framework 1 has no specification impact from both reader and device perspective.

Observation 4: Framework 1 is applicable to device 1 with larger capacitor size (e.g., 10 uF), whose sustainable time ca be up to several seconds.

Framework 2

Observation 5: A reader does not know the charging time of a device, and cannot control when the device is ON, since the charging time depends on many factors including distance between devices and RF EH source, charging efficiency, etc.

Observation 7: For SLEEP state before inventory, the device needs to run a low accurate clock to count the remaining time, and to harvest energy if the RF power is larger than the power consumed for clock running.

Proposal 5: To enable the device entering SLEEP state before an inventory round, study the solution that the reader sends indication of the potential starting time or remaining time of the future inventory command.

Proposal 6: To enable the device entering SLEEP state during an inventory round, study solutions on how/when device respond to the reader for contention-based random access. For example,

* The reader sends additional indication to inform the slot counter decrement process.
* The device randomly selects an ON state during the inventory round to respond.
* The device reports when activated before inventory, and the response occasion during the inventory round is determined by the reporting occasion.

## Source 4 [9]

* **Solutions**

[9] provided procedure of inventory: The Ambient IoT device can periodically wake up to monitor for the Query command within the inventory round and once the inventory of the Ambient IoT device is finished, the Ambient IoT may sleep until the end of the inventory round. The Ambient IoT device might need to maintain minimum power consumption within the inventory round to maintain the RAM memory from erasing. Hence duty cycle-based operation needs to be supported within the inventory round as shown in figure 1.

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Figure 1 Illustration of Duty cycle-based operation of Ambient IoT device in an inventory round

* **Evaluation and Observations**

[9] observed following and proposed to consider studying scheduling of Ambient IoT device by taking into consideration the available energy at the capacitor and the received power.

* + From Figure 2, the minimum capacitance size to sustainably operate the device within an inventory round varies with the received power i.e., E2H link budget.
  + From Figure 4, the required minimum capacitance size to sustainably operate the Ambient IoT device in a slotted Aloha scheme is 15µF.
  + From Figure 5, the minimum required capacitance size to achieve certain outage probability can be relaxed using energy aware scheduling.

|  |  |
| --- | --- |
| Figure 2: Outage probability of Ambient IoT device type 2 for different capacitance sizes and received power | Figure 4: Outage probability as a function of capacitance sizes considering slotted Aloha |
| Figure 5: Comparison of outage for different scheduling mechanism for Ambient IoT devices | |

## Source 5 [11]

* **Solutions**

[11] provided three duty cycle schemes and two options for Reader to transmit the R2D e.g., A-IoT paging

duty cycle schemes:

* Scheme 1: Device without sleep state and with fully off state (i.e., ‘w/o sleep w fully off’ for short)
* Scheme 2: Device without sleep state and with partially off state (i.e., ‘w/o sleep w partially off’ for short)
* Scheme 3: Device with sleep state and under reader control (i.e., ‘w/o sleep w R2D control’ for short)

Two options for Reader to transmit the R2D:

* Option 1: Reader transmits the PRDCH periodically (i.e., call ‘P-R2D Tx’ for short)
* Option 2: Reader transmits the PRDCH multiple times on demand (i.e., call ‘A-R2D Tx’ for short)
* **Evaluation and Observations**

[11] observed following and proposed to Reader transmits the PRDCH multiple times to handle the devices that missed the PRDCH reception due to charging, device is assumed to have two states: ON, OFF for option 1. And Reader provides R2D signals or PRDCH indicating the wake-up time occasion/duration or sleep time occasion/duration to extend A-IoT device availability, device is assumed to have three states: ON, OFF, SLEEP for option 2.

* From figure 3.2-1 and 3.2-2, Generally, inventory time decreases with the increased Random Access (RA) resources for all duty cycle schemes.
* Inventory time of duty cycle scheme 3(i.e., Device w sleep w R2D control) can decrease rapidly by increasing RA resources.
* Inventory time of duty cycle Scheme 1(i.e., Device w/o sleep w fully off) is not sensitive to RA resources
* From figure 3.2-3 and 3.2-4, Generally, inventory time increases a lot with the reduced RF activation power.
* When the harvest RF energy is lower than the power consumption for device with scheme 3 (Device w sleep w R2D control), the inventory time becomes comparable or longer compared to the device with scheme 1 (Device w/o sleep w fully off) or scheme 2 (Device w/o sleep w partially off) respectively
* From figure 3.2-5 and 3.2-6, Generally, inventory time decreases with the increased number of Paging transmissions by reducing the paging Tx periodicity and/or transmitting paging aperiodically/on demand.
* Scheme 2 (Device w/o sleep w partially off) with periodic paging Tx reduces the inventory time a lot compared to the paging Tx with longer(20ms) periodicity.
* Scheme 2 (Device w/o sleep w partially off) with aperiodic paging Tx has shorter inventory time compared to Scheme 3 (Device w sleep w R2D control) for both 12ms-periodicity and 20ms-periodicity of paging Tx.

|  |  |
| --- | --- |
| Figure 3.2-1 inventory time for case 1 with 4 RA resources | Figure 3.2-2 inventory time for case 1 with 8 RA resources |
| Figure 3.2-3 inventory time for case 2 with 4 RA resources | Figure 3.2-4 inventory time for case 2 with 8 RA resources |
| Figure 3.2-5 inventory time for case 3 with 12ms paging period | Figure 3.2-6 inventory time for case 3 with 12ms paging period |

## Source 6 [12]

* **Solutions**

[12] provided two operating stages to maximize the energy storage level in a device to complete a round of inventory / command process, namely before and after an inventory/command process starts.

* Stage 1 of energy harvesting (before inventory / command process starts)
* Stage 2 of energy harvesting (after inventory / command process starts)
* **Analysis and Observations**

[12] observed and proposed following:

* From figure 2, the proposal is that for Stage 1 of energy harvesting (before inventory / command process starts), periodic transmissions of R2D preamble should be studied to coordinate or schedule inventory / command processes among the devices, to minimize collision probability and to reduce device power consumption from blind monitoring (and hence more time for energy harvesting).
* From figure 3, the observation is that according to the basic slotted-ALOHA access algorithm, a device needs to continuously monitor the DL channel for QueryRep messages (Msg. 0) from the reader to perform the count-down function. Since a device cannot perform DL reception and energy harvesting at the same time, the slotted-ALOHA access algorithm is very energy inefficient / unfriendly mechanism to A-IoT devices. And proposed to enhancing the slot-SLOHA access mechanism in the following potential areas for enabling device energy harvesting during an inventory/command process:
  + Filter-out unnecessary access time slots (ATSs) for reception;
  + Fixed length or a minimum time duration for an access time slot (ATS);
  + Reduced device wake-up time to monitor select/query message (Msg. 0) and perform count-down function;
  + Assisted, coordinated or scheduled selection of an access time slot (ATS);

Stage 1 of energy harvesting (before inventory / command process starts)



Figure 2: Periodic timing acquisition signals (preambles) for distribute devices across multiple inventory/command processes to minimize collision probability and to reduce device power consumption.

Stage 2 of energy harvesting (after inventory / command process starts)



Figure 3: Device energy harvesting after the start of an inventory / command process.

## Source 7 [17]

* **Solutions**

[17] provided the device availability by investigating the available time and the proportion of available time with and without duty-cycle.

* wo/ duty cycle
* w/ duty-cycle based on energy storage status: duty-cycle mechanism is to utilize the energy storage status to control ON and OFF states of the device. When the energy storage status is 100%, the device activates signal detection (ON state). When the energy storage status drops below a specified threshold, the device closes signal detection and enters a deep or light-sleep state (OFF state). During deep or light-sleep phase, the device is unavailable since it cannot receive and transmit signals.
* w/ duty-cycle based on periodicity:
* The BS transmits decrement commands, where a part of these decrement commands are transmitted periodically, as shown in Figure 4. The period is equal to an absolute time length, e.g. x ms.
* The device initiates detection window periodically to detect decrement commands. Each time the device detects a decrement command, it reduces the stored slot value by P, where P is the number of decrement commands transmitted in a period.
* When detection window is closed, the device can enter a light-sleep state. In light-sleep state, the device maintains the operation of a low-speed clock and memory without signal reception or transmission, thereby reducing energy consumption and conserving battery power.
* If the stored slot value is less than P, the device sequentially detects the decrement commands sent by the BS without employing the duty cycle. Each time the device detects a decrement command, it reduces the stored slot value by 1.
* When the stored slot value decreases to 0, the device transmits the Step 2 signal during the access process.。



Figure 4 Duty cycle based on periodic detection

* **Analysis and Observations**

[17] observed following and proposed to duty cycle is not considered before random access procedure and during random access procedure, duty cycle based on periodic detection can be considered for Ambient IoT device to reduce energy consumption.

* From table 1, the proportion of available time is around 13% for power consumption of 2 uW and around 0.15% for power consumption of 200 uW.
* From table 2, for duty-cycle based on energy storage status, deep-sleep based duty-cycle mode and normal mode have the same proportion of available time for a Ambient IoT device. For duty-cycle based on energy storage status, the proportion of available time in light-sleep based duty-cycle mode is lower than that in normal mode since the device still consumes energy during the light-sleep phase.

Table 1 Assessment for device availability

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **Values** | | | | | |
| Capacitance (uF) | 1 | 2 | 10 | 10 | 20 | 50 |
| Available energy in storage (uJ) | 0.25 | 0.5 | 2.5 | 2.5 | 5 | 12.5 |
| Device power consumption (uW) | 2 | | | 200 | | |
| Received RF power (dBm) | -25 | | | -25 | | |
| RF energy harvesting efficiency | 10% | | | 10% | | |
| Available time | 125 ms | 250 ms | 1.25 s | 12.5 ms | 25 ms | 62.5 ms |
| Charging time | 833 ms | 1667 ms | 8.33 s | 8.33 s | 16.67 s | 41.67 s |
| Proportion of available time | 13% | | | 0.15% | | |

Table 2 Device availability for duty-cycle based on energy storage status

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Normal (w/o duty-cycle)** | **Deep-sleep based duty-cycle** | **Light-sleep based duty-cycle** |
| Capacitance | 10 uF | | |
| Available energy in storage | 2.5 uJ | | |
| Received RF power | -25 dBm (~3 uW) | | |
| RF energy harvesting efficiency | 10% | | |
| Power consumption for ON state | ~2 uW | | |
| Power consumption for OFF state | N/A | N/A | 0.2 uW |
| Remaining available energy after ON state | 0 | 2 uJ (80%) | 2 uJ (80%) |
| Available time of ON state | 1.25 s | 0.25 s | 0.25 s |
| Unavailable time for full charging  (including sleep duration) | 8.33 s | 1.67 s | 5 s |
| Proportion of available time | 13% | 13% | 4.8% |

## Source 8 [25]

* **Solutions**

[25] provided device energy state transition in figure 9 and proposed to study solutions to extend the operation time for device 2, e.g., defining Power Saving (PS) state and associated state transitions. And for device 1, if an energy harvesting signal is contiguously provided during an inventory process, it is assumed that the devices have sufficient energy to complete the inventory process and there is no need for separate consideration for device 1 due to the potential impact of the device unavailability for charging.

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Figure 9 Device energy state transition

[25] provided energy saving solutions during inventory process in figure 10.

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Figure 10 A sequential device identification process via random access with additional timing relationship

The time interval between two consecutive triggers may be variable, e.g., a reader may early terminate the random access round, if no PDRCH transmission is successfully received, by transmitting the next PRDCH providing a trigger early. Denote by Ttrigger\_min the minimum time between any two trigger messages. Similarly, there is a maximum time between two consecutive trigger messages of an inventory process, denoted by Ttrigger\_max, assuming that the round goes successful.

* **Analysis and Observations**

[25] proposed to study device state transitions during inventory process, e.g., considering minimum and maximum time between trigger messages, to extend the device operation time.

## Source 9 [32]

* **Solutions**

|  |  |
| --- | --- |
| **Scheme** | **Description** |
| Light-sleep duty-cycle monitoring (LS-DCM) | * A device, when it is available, counts the time to identify the end of shortened available time * At the end of the shortened available time duration, the device moves to the SLEEP state * In the SLEEP state:   + The device keeps energy harvesting and may count the time duration until the time that the device should be again available   + The time count during SLEEP state may be enabled by sleep clock and a limited memory with low power consumption |
|  | |
|  | |
| Deep-sleep duty-cycle monitoring (DS-DCM) | * A device, when it is available, counts the time to identify the end of shortened available time * At the end of the shortened available time duration, the device moves to the OFF state * In the OFF state:   + The device keeps energy harvesting until the amount of energy in the storage reaches ‘Turn-on’ threshold   + No clock is running, and no regular memory is retained |
|  | |

* **Evaluation and Observations**

A graph of a number of data

Description automatically generated with medium confidence

(a) Device 1, Rx power = -28dBm

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(b) Device 1, Rx power = -32dBm

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(c) Device 2, Rx power = -28dBm

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(d) Device 2, Rx power = -32dBm

Fig. 8 Performance evaluation of inventory with and without duty-cycle monitoring

Observation 6:

* Simulation results indicate that duty-cycle monitoring is essential for A-IoT to complete inventory in a reasonable time duration
  + Duty-cycle monitoring improves the efficiency of inventory significantly for device 1
  + Duty-cycle monitoring is critical feature for inventory for device 2; otherwise reader has to keep trying inventory for several tens of seconds in blind manner

# Appendix B: Previous Agreements on Frame structure

RAN1#116:

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| --- |
| 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.  Agreement  At least the following time domain frame structure is studied for A-IoT R2D and D2R transmission.   * For R2D transmission,   + A R2D timing acquisition signal (e.g. R2D preamble) is included at least for timing acquisition and for indicating the start of the R2D transmission in time domain. * For D2R transmission,   + A D2R timing acquisition signal (e.g. D2R preamble) is included at least for timing acquisition and for indicating the start of the D2R transmission in time domain. * FFS other necessary component(s), e.g. midamble, postamble, periodic sync signal, control fields, guard period   Agreement  For further discussion, the following terminologies are used for A-IoT for studying processing time aspects:   * TR2D\_min: Minimum Time between a R2D transmission and the corresponding D2R transmission following it. * TD2R\_min: Minimum Time between a D2R transmission and the corresponding R2D transmission following it. * TR2D\_R2D\_min: Minimum Time between two different consecutive R2D transmissions to the same A-IoT device. * TD2R\_D2R\_min: Minimum Time between two different consecutive D2R transmissions from the same A-IoT device. * The study should consider at least following aspects   + Implementation restrictions for the existing BS/UE   + [Processing time is common or different for different A-IoT devices]   + [Processing time for different traffic types/command types (e.g. DT or DO-DTT) and/or different use case (e.g., Inventory or Command)] * FFS other timing aspects |

RAN1#116bis:

|  |
| --- |
| Agreement  For R2D transmission, if OFDM-based waveform is used, the start of R2D transmission from reader perspective is assumed to be aligned with the boundary of an NR OFDM symbol (including the CP) for in-band/guard-band operation.  Agreement  To determine or derive the end of PRDCH transmission, study at least following options:   * Option 1: R2D postamble immediately follows the PRDCH to indicate the end of the PRDCH. * Option 2: Based on R2D control information.   Agreement  For the reader to acquire the end of PDRCH transmission, study at least following options:   * Option 1: D2R postamble immediately follows the PDRCH * Option 2: Based on control information   Agreement  For D2R transmission, study the necessity of midamble at least for the purpose of performing timing/frequency tracking or channel estimation or interference estimation, considering at least the following:   * Modulation and Coding schemes, e.g., data modulation, line/channel coding * Receiving methods, e.g., coherent or non-coherent * D2R transmission length/packet size * Midamble overhead * Timing/frequency accuracy * Phase accuracy   Agreement  RAN1 study the R2D transmission without midamble as the baseline if Manchester encoding is used.   * FFS the necessity for the R2D transmission with midamble if PIE is used. |

RAN1#117:

|  |
| --- |
| Agreement  Study whether/how an A-IoT device can count the time with sufficient accuracy (with a certain timing error due to SFO) at least for the purposes related to TDM(A) (if needed), and if so for how long after receiving an R2D transmission.  Agreement  Scheduling information of PDRCH transmission is provided by a corresponding PRDCH.  **Conclusion**  RAN1 discussion related to the potential impact of device unavailability due to charging by energy harvesting will occur in agenda item 9.4.2.2.  Agreement  Study the following options for the time interval between a R2D transmission and the corresponding D2R transmission following it:   * Option 1: Define a maximum time TR2D\_max between a R2D transmission and the corresponding D2R transmission following it, so that the device transmits D2R transmission within [TR2D\_min, TR2D\_max].   + FFS: maximum time is common or different for different A-IoT devices   + FFS: maximum time for different traffic types/command types (e.g. DT or DO-DTT) and/or different use case (e.g., Inventory or Command) * Option 2: The corresponding D2R transmission timing TR2D following a R2D transmission is determined based on the control information in the R2D transmission, where TR2D ≥ TR2D\_min   + FFS the maximum value(s) for TR2D |

# Appendix C: Study item objectives in RP-240826

|  |
| --- |
| This study targets a further assessment at RAN WG-level of Ambient IoT, a new 3GPP IoT technology, suitable for deployment in a 3GPP system, which relies on ultra-low complexity devices with ultra-low power consumption for the very-low end IoT applications. The study shall provide clear differentiation, i.e. addressing use cases and scenarios that cannot otherwise be fulfilled based on existing 3GPP LPWA IoT technology e.g. NB-IoT including with reduced peak Tx power.  General Scope  The definitions provided in TR 38.848 are taken into this SI, and the following are the exclusive general scope:   1. The overall objective shall be to study a harmonized air interface design with minimized differences (where necessary) for Ambient IoT to enable the following devices: 2. ~1 µW peak power consumption, has energy storage, initial sampling frequency offset (SFO) up to 10*X* ppm, neither DL nor UL amplification in the device. The device’s UL transmission is backs11ered on a carrier wave provided externally. 3. ≤ a few hundred µW peak power consumption1, has energy storage, initial sampling frequency offset (SFO) up to 10*X* ppm, DL and/or UL amplification in the device. The device’s UL transmission may be generated internally by the device, or be backs11ered on a carrier wave provided externally.  * *X* is to be decided in WGs. * Coverage design target: Maximum distance of 10-50 m with device indoors as per TR 38.848: “…a range that WGs can sub-select within”. * For Topologies 1 & 2 (UE as intermediate node under NW control) per TR 38.848, with no RRC states, no mobility (i.e. at least no cell selection/re-selection -like function), no HARQ, no ARQ.   NOTE 1: It is to be understood that “≤ a few hundred µW” means WGs are not tasked with setting a particular value, and that it will be for WG discussions to determine if a presented design with corresponding power consumption satisfies the “≤ a few hundred µW” requirement.   1. Deployment Scenarios with the following characteristics, referenced to the tables in Clause 4.2.2 of TR 38.848:  * Deployment scenario 1 with Topology 1   + Basestation and coexistence characteristics: Micro-cell, co-site * Deployment scenario 2 with Topology 2 and UE as intermediate node, under network control   + Basestation and coexistence characteristics: Macro-cell, co-site   + The location of intermediate node is indoor  1. FR1 licensed spectrum in FDD. 2. Spectrum deployment in-band to NR, in guard-band to LTE/NR, in standalone band(s). 3. Traffic types DO-DTT, DT, with focus on rUC1 (indoor inventory) and rUC4 (indoor command).  * From RAN#104, the study will assess whether the harmonized air interface design (per bullet ‘A’ above) can address the DO-A (Device-originated autonomous) use case, only to identify which part(s) of the harmonized air interface design (per bullet ‘A’ above) is/are not sufficient for the DO-A use case.   Transmission from Ambient IoT device (including backs11ering when used) can occur at least in UL spectrum.  The following objectives are set, within the General Scope:   1. Evaluation assumptions 2. Conclude at least the following aspects of design targets left to WGs in Clause 5 (RAN design targets) of TR 38.848 [RAN1].  * Clause 5.3: Applicable maximum distance target values(s) * Clause 5.6: Refine the definition of latency suitable for use in RAN WGs * Clause 5.8: 2D distribution of devices  1. Define necessary further evaluation assumptions of deployment scenarios for coverage and coexistence evaluations [RAN1, RAN4] 2. Identify basic blocks/components of possible Ambient IoT device architectures, taking into account state of the art implementations of low-power low-complexity devices which meet the RAN design target for power consumption and complexity. [RAN1] 3. Define link budget calculation for coverage, including whether/how to model carrier wave from node(s) inside or outside the connectivity topology.   NOTE: Assessment performance of the design targets is within the study of feasibility and necessity of proposals in the following objectives, e.g. by inspection of reference implementations in the field, simulations, analytically.  NOTE: strive to minimize evaluation cases in RAN1.   1. Study necessary and feasible solutions for Ambient IoT as prescribed in the General Scope, including decisions on which functions, procedures, etc. are needed and not needed, and ensuring at least the required functionalities in Section 6.2 of TR 38.848.   Study of positioning in Rel-19 is RAN3-led, limited to functionalities which would have no, or minimal, specification impact (note: this does not imply any decision relating to WI creation).  Study the feasibility and required functionalities for proximity determination, which is the determination of whether BS or intermediate UE and ambient IoT device are near each other or not (coordination with SA3 is required for privacy aspects).   * RAN1-led:   For the Ambient IoT DL and UL:   * Frame structure, synchronization and timing, random access * Numerologies, bandwidths, and multiple access * Waveforms and modulations * Channel coding * Downlink channel/signal aspects * Uplink channel/signal aspects * Scheduling and timing relationships * Study necessary characteristics of carrier-wave waveform for a carrier wave provided externally to the Ambient IoT device, including for interference handling at Ambient IoT UL receiver, and at NR basestation.   For Topology 2, no difference in physical layer design from Topology 1.   * RAN2-led: * Study and decide which functions are needed for an Ambient IoT compact protocol stack and lightweight signalling procedure to enable DO-DTT and DT data transmission, and study those functions.   For example:   * Paging * Random access * Data transmission, including necessary radio resource control aspects, respecting the limitation in the General Scope * Interactions with upper layers   For functionalities not listed above, they are studied only if found essential.   * RAN3-led: * Identify necessary impacts on signaling and procedures for CN-RAN interface, to enable: * Paging * Device context management * Data transport * Identify RAN architecture aspects, including whether support for split architecture is necessary. * Identify potential solutions for locating an Ambient IoT device with no specification impact, e.g. reusing existing user location report, or minimal specification impact to convey location information to core network. * RAN4-led: * Coexistence study of Ambient IoT and NR/LTE. * RF requirements study for Ambient IoT: * Ambient IoT BS transmission and reception * Ambient IoT Device, as per the General Scope, transmission and reception * Intermediate node (UE), as per the General Scope, transmission and reception   RAN2 and RAN3 are expected to identify RAN-CN functional split in coordination with SA2.  Note: This study shall target for an IoT segment well below the existing 3GPP IoT technologies, e.g. NB-IoT, eMTC, RedCap, etc. The study shall not aim to replace existing 3GPP LPWA technologies. |