3GPP TSG-RAN2 Meeting #119-e R2-220xxxx

eMeeting, 17-26 August 2022

Agenda Item: 8.5.1

Source: Qualcomm

Title: Summary of [Post119-e][261][XR] Reply LS to SA2 on UE power savings for XRM services

Document for: Discussion and Decision

# **Introduction**

This report provides a summary of the following post-meeting email discussion:

* [Post119-e][261][XR] LS to SA2 on XR power saving (Qualcomm)

Scope: Answer SA2 LS on UE power saving (in [R2-2206966](https://www.3gpp.org/ftp/TSG_RAN/WG2_RL2/TSGR2_119-e/Docs/R2-2206966.zip)) according to RAN2 agreements.

Intended outcome: Approved LS.

Deadline: Short

The deadlines for this discussion are the following:

* **August 31th 1200 UTC:** deadline forcompanies’ feedback;
* **August 31th 1800** **UTC**: the rapporteur will provide a summary and a draft LS for review;
* **September 1st 2400 UTC**: deadline for companies’ feedback on the draft LS.

# **Contact information**

|  |  |  |
| --- | --- | --- |
| Company | Name | Email |
| Qualcomm | Linhai He | linhaihe@qti.qualcomm.com |
| Vodafone | Alexey Kulakov | Alexey.kulakov1@vodafone.com |
| Apple | Ralf Rossbach | rrossbach@apple.com |
| OPPO | Shukun Wang | wangshukun@oppo.com |
| Fujitsu | Sue Yi | yisu@fujitsu.com |
| Intel | Marta Martinez Tarradell | marta.m.tarradell@intel.com |
| Lenovo | Joachim Löhr | jlohr@lenovo.com |
| vivo | Chenli | Chenli5g@vivo.com |
| Meta | Yee Sin Chan | yeesinchan@fb.com |
| Xiaomi | Yanhua Li | Liyanhua1@xiaomi.com |
| CATT | Pierre Bertrand | pierrebertrand@catt.cn |

# **Discussion**

## Background

In its LS [1], SA2 requested RAN1 and RAN2 to reply which type of information should be provided to RAN for UE power saving enhancements for XRM services:

|  |
| --- |
| **Overall Description:**  TR38.838 evaluates the impact of power saving schemes on the performance of XR applications and identify potential enhancements under RAN2 responsibility. Specifically, the following power saving features have been identified:  - CDRX enhancements  - PDCCH monitoring enhancements  It understood that these enhancements require assistance information from the network whose specification falls under SA2 responsibility.  In 3GPP SA WG2 Meeting #S2-149E, new key issue was agreed for TR 23*.700-60* to study potential enhancements for power consumption considering traffic pattern of media services in the scope of FS\_XRM. It was agreed as follows:   * Which information (e.g., XR/media traffic characteristics, traffic pattern and statistics), if any, is needed by the RAN from the CN and/or the UE to enhance power management (i.e., CDRX)? If needed, how such information is collected?   NOTE: This Key issue requires collaboration with RAN WGs.  SA2 wants to request RAN1, RAN2 which type of information will be useful for the RAN for power saving enhancements for XR applications.  **ACTION:** SA2 kindly asks RAN1, RAN2 to take the above information into account and clarify which type of information should be provided to the RAN for power saving enhancements for XR applications. |

RAN1 provided the following information in their reply LS [2]:

|  |
| --- |
| RAN1’s understanding is that RAN2 will also discuss the XR-awareness and decide what information from core network to RAN is helpful for XR-specific traffic handling. This reply LS is only from RAN1 perspective, and RAN1 expects SA2 to take into account response from both RAN1 and RAN2. In context of SA2 LS, RAN1 discussed what type of information from the core network to RAN could be helpful for the enhancement of XR-specific UE power management, if feasible, and identified following possible candidates for each XR application flow:   * PDU set periodicity and start time of the first PDU of a PDU set: this can be helpful for e.g., configuring the periodicity and start time of CDRX or PDCCH monitoring to match with traffic period. * PDU set end indication or indication of the last PDU in a PDU set: this can be helpful for gNB, e.g., to indicate the UE to dynamically skip PDCCH monitoring once the last PDU of the PDU set is delivered. * PDU set level QoS parameters including priority and [air interface] delay budget of a PDU set: this can help the gNB to select suitable CDRX parameters (e.g., periodicities) that enable fulfilling the delay requirements for a given flow. It also helps with UE power saving, e.g., by reducing retransmission or by early dropping of a PDU that exceeds the delay deadline. Additionally, it can also be helpful for efficient radio resource management by gNB for capacity improvement. * PDU set size (number of bits) or number of PDUs in a PDU set: RAN1’s understanding is that in comparison to the statistical information, real-time or dynamic information provided to gNB, if possible, can help scheduler make more efficient scheduling decision to enable UE power saving. * PDU set identity and relationship information among PDUs within the same PDU set: gNB can use this information for early PDU dropping as mentioned above. * Jitter information such as the range of the jitter (minimum and maximum value): Here jitter refers to packet arrival time variation at gNB for DL direction. gNB could use this information to configure parameters of UE power saving schemes, e.g., CDRX OnDuration and Active Time or PDCCH monitoring duration for handling of the jitter. |

In this email discussion, we discuss **from RAN2’s perspective** what type of information should be provided to RAN for UE power savings.

## Summary of submitted proposals

Several companies have submitted proposals on what information should be included in the reply LS to SA2. They are summarized in Table 1.

Table 1. A summary of proposals from companies

|  |  |  |
| --- | --- | --- |
| Type of information for RAN | Media unit | Proponents |
| Traffic pattern (e.g. periodicity, start time of media unit) | Burst | [3] |
| PDU set | [4], [6], [8], [10], [12] |
| Unspecified | [5], [13, [14] |
| Jitter information of media unit (e.g. range, mean, variance of jitter in the start time of a media unit) | Burst | [3] |
| PDU set | [4], [6], [7] , [8], [10], [12] |
| Unspecified | [5], [13], [14] |
| Size information of media unit (e.g. avg and max size) | Burst | [3] |
| PDU set | [4], [5], [8], [10], [12], [14] |
| Unspecified |  |
| Boundary indication of media unit (e.g. end of burst, last PDU in a PDU set) | Burst | [3], [7] |
| PDU set | [4], [6], [12], [13] |
| Information for identifying a media unit (e.g. sequence number) | Burst | [3], [13] |
| PDU set | [4], [10], [12], [13] |
| QoS requirements for media units (e.g. priority, PSDB, PSER) | PDU set | [4], [5], [6], [7], [8], [10], [12], [13] |
| Relationship information of media unit (e.g. dependency among PDUs within a PDU Set or between PDU sets) | PDU set | [4], [6], [12], [13] |
| Explicit indication and conditions for delivery vs discard of a media unit | PDU  PDU set | [9]  [12] |
| Transmission alignment or synchronization tolerance | XR traffic flow | [13], [14] |

## Discussion

The rapporteur observes that most companies share similar views in what type of information is useful to RAN, e.g. traffic pattern, jitter statistics, size information, boundary indicators, etc. However, companies have different views on which type of media unit that such information should be defined for, e.g. whether the information is for a PDU Set or a Data Burst.

To facilitate the discussion, the definition of these two different media units are copied from [11] below:

* **PDU Set**: A PDU Set is composed of one or more PDUs carrying the payload of one unit of information generated at the application level (e.g. a frame or video slice for XRM Services, as used in TR 26.926 [27]).
* **Data Burst**: A set of data multiple PDUs generated and sent by the application in a short period of time. (NOTE: A Data Burst can be composed by one or multiple PDU Sets).

With the above definitions, the rapporteur’s understanding is that XR traffic periodicity is defined based on the number of UL/DL periodic bursts per second. With some codec implementation, one video frame is encoded into a single PDU Set. While in some other codec implementations, one video frame is divided into multiple slices and each of the slices is encoded into a PDU Set. In this case, the group of PDU Sets associated with that video frame forms a Data Burst.

Based on the above observations, the rapporteur suggests that we organize our discussion in the following way:

* We first discuss whether a type of information (e.g. traffic pattern, jitter statistics, etc) is useful to RAN. The list of possible types of information selected based on those summarized in Table 1.
* For each type of information, we select which type of media unit (e.g. PDU Set vs Data Burst) this information is defined for. Moreover, how often this type of information should be signalled to RAN, e.g. whether it is static (e.g. defined in specs), semi-static (e.g. network configuration) or dynamic (e.g. via user-plane signaling).
* When companies comment, please do indicate which parameter(s) of that information they prefer (e.g. for traffic pattern, a parameter can be periodicity) and justifications for your preference. (e.g. useful for configuring DRX). A parameter without proper justification will be deprioritized.

**Q1. Do you think traffic pattern is useful to RAN for UE power savings?**

If you do, which type of media unit do you think should be used to define traffic pattern?

* Option 1. PDU Set;
* Option 2. Data Burst.

In your comment, please indicate which traffic pattern parameters you prefer (e.g. periodicity, start time, etc of your preferred media unot) and justification for your preference.

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **Your preference**  (Op1/Op2/No) | **How traffic pattern info should be signalled?**  (static/semi-static/dynamic) | **Comments**  (Any specific traffic pattern parameter(s) you prefer and justification for your preference) |
| Qualcomm | Option 2 | Semi-static | We think that as far as power savings is concerned, Data Burst is a more appropriate media unit than PDU set. This is because the periodicity for which DRX configuration is based on should be the periodicity of video frames. Depending on the type of codec used, a frame may be encoded into one PDU Set or multiple PDU Sets. In either case, according to SA2’s definition (see above), the PDU Set(s) associated with a video frame form a Data Burst.  We think periodicity of Data Burst is useful for RAN to configure DRX cycle length. And **nominal** start time of a Data Burst can be used by RAN as a reference when configuring DRX start offset. |
| Vodafone | Option2 and Option 1 |  | We think that Data Burst is a good unit for DRX setting, but we also believe that knowing the information about PDU sets is important to in order to be able to treat different bursts in a different way depending on their e.g. priority to each other or PDB requirements. |
| Apple | Option 1 | Semi-static for the typical case, but with dynamic adjustments where needed | Data burst related assistance information already exists (and can be extended, e.g., to include burst end time), but what needs to be added for XR is a notion of PDU sets. We expect data burst related information will continue to be available, including burst parameters such as burst size, arrival time, start/stop etc.  In traditional packet based QoS, traffic information (as in TSCAI) assists the RAN to correlate data bursts of different QoS flows to adjust scheduling and power saving related parameters for one UE. With XR, we assume the QoS model will extend to include groups of packets, where periodicity, arrival time (start/stop), sequence and size of PDU sets become important factors to schedule and utilize radio resources on a finer granularity.  Periodicity is also input to CG/SPS scheduling, and it needs to map with the amount and type of radio resources required per PDU set (e.g., level of reliability), as well as its size, arrival time and timing such as start/stop. This has a direct impact on UE active time.  Even if data burst information is not available the RAN can derive the data burst related information from PDU sets, but PDU set related information we cannot derive from data bursts. |
| OPPO | Option 2 | Semi-static | Data burst is useful for the valid DRX operation control for better UE power saving, e.g. data burst length, period, starting/ending point and so on. |
| Fujitsu | Option 1 | Semi-static | We think that if we only consider power saving, the parameter set per data burst may be enough. However, we may need parameter set per PDU set for XR awareness and capacity improvement anyway. These parameters could be unified. In this manner, we slightly prefer Opt 1.  We think periodicity, start time, jitter, size information, end indication of the media unit are the traffic pattern parameters needed. |
| Intel | Dependent on SA2/SA4 input | Semi-static | We understand that it is helpful from RAN side to get traffic pattern information (which may also include some information of the periodicity, start, end or length). FFS if this is in PDU set and/or data burst level. |
| Lenovo | Option 1/2 | Semi-static | For TSCAI introduced in R16 IIOT the data burst related traffic information is provided, e.g. PDUs of a burst are having same QoS and are carried on same QoS flow. However, for XR, we are not sure all PDU sets in a data burst will be carried on the same QoS flow, therefore using PDU set as unified media unit to define the traffic pattern e.g., periodicity and start time of (first) PDU set of data burst is slightly preferred even if data burst – e.g. a video frame - may be comprised of more than one PDU set. |
| vivo | Option2 | Semi-static | Agree with Qualcomm the periodicity for which DRX configuration is based on should be the periodicity of video frames. While a video frame is corresponding to one data burst.  We assume DRX configuration should be provided based on some statistical characteristics of data burst, so semi-static is enough.  The periodicity and start time of Data Burst are useful for RAN to configure DRX parameters: DRX cycle and start offset, respectively. |
| Meta | Option 2 | Semi Static | For DRX operation, data burst is more appropriate for traffic pattern characterization. |
| Xiaomi | depends on SA2/SA4 | Semi-static/dynamic | The type of media unit (e.g. PDU Set vs Data Burst) depends on how SA2/SA4 to how to model the application traffic. As mentioned above, one video frame is encoded into a single PDU Set or one video frame is divided into multiple PDU Sets. So the traffic of periodicity would be the generation rate of the frame, it would be the generation rate of PDU Set or PDU Sets(if the frame is divided into multiple PDU Sets in burst).  Currently, we can take the agreement as work assumption unless we get more input from SA2/SA4.   * RAN2 to adopt the current SA2 definition of PDU Set as an application media unit as working assumption, subjected to further guidance from SA2 and SA4.   We think the following traffic pattern parameters can be considered for the following reasons:  Periodicity: which is useful for RAN to configure DRX cycle;  End indication: which can help gNB to terminate the active time when no data is expected.  PDB: which can help the gNB to select suitable CDRX parameters and helpful for efficient radio resource management by gNB for capacity improvement;  Jitter range: which can help gNB for configuring CDRX OnDuration and Active Time.  We are hesitate to choose the start time and packet size as the following reasons:  Start time: gNB can use the time that the packets arrived as the start time;  Packet size: the motivation of real-time or dynamic information provided to gNB is not that convincing as gNB can use the IAT timer for variable packet size handling.  Some pattern parameters can be Semi-statically configured from AMF to gNB(e.g., Periodicity) which some can be dynamic (e.g., End indication) |
| CATT | Option 1 | Semi-static | We agree with Apple and Lenovo that data burst periodicity and arrival time of a given flow in either DL or UL are already provided to RAN in TSC Assistance Information since R16 (TS23.501). But the PDU set provides a finer granularity that will be needed anyways e.g. to allow mapping different PDU sets distributed in time across a data burst to different SPS/CG configurations.  In addition, in case of stream aggregation e.g. audio + video, the resulting burst traffic pattern may not be nicely periodic and no single DRX configuration will allow addressing all PDU sets during the on-duration only. On the contrary, each individual PDU set stream (e.g. video or audio) is expected to be periodic and can be addressed by SPS/CG, even outside the DRX on-duration. So we think, in addition to the legacy burst periodicity and start time, the periodicity and start time of a PDU set stream will be helpful for RAN to configure both DRX and SPS/CG appropriately. |
| LGE | Option 2 | Semi-static/dynamic | In our understanding, PDU set is the unit relevant to application layer internal usage, Data burst is the unit relevant to actual transmission. The provided information for power saving should be more related to actual transmission.  We think if the periodicity of burst data per UL/DL is provided, RAN can configure DRX configuration to fit the data characteristics. |

**Q2. Do you think jitter information is useful to RAN for UE power savings?**

If you do, which type of media unit do you think should be used to define traffic pattern?

* Option 1. PDU;
* Option 2. PDU Set;
* Option 3. Data Burst.

In your comment, please indicate which jitter parameter(s) you prefer (e.g. range, mean, variance of start time of your preferred media unit) and justification for your preference.

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **Your preference**  (Op1/Op2/Op3/No) | **How jitter info should be signalled?**  (static/semi-static/dynamic) | **Comments**  (Any specific jitter parameter(s) you prefer and justification for your preference) |
| Qualcomm | Option 3 | Semi-static | From power savings’ perspective, we think only the jitter of the start of a Data Burst matters most, because once UE enters DRX active time, jitters of individual PDUs matter less.  We do not think jitter for an individual PDU, PDU Set or Data Burst can be predicted ahead of its arrival. Therefore, only statistics of jitters can be provided to RAN. So semi-static signaling is a good way to provide jitter information to RAN.  Among available statistics, we think range of jitters probably is sufficient for RAN to use. |
| Vodafone | Not applicable |  | DL Jitter is important, but we are not sure if this value can come from CN as we believe that most Jitter might be highly influenced by the last mile of the transmission to the gNBs which might be different from site to site. |
| Apple | Option 2 | Semi-static for the typical case, but with dynamic adjustments where needed | It is conceivable that PDU sets of different type (e.g., importance) can be mapped to different CG/SPS, thus jitter information at the granularity of PDU sets in our view appears preferred over jitter information of data bursts.  Parameters helpful to adjust DRX cycles and resource allocation: Probability distribution, max range, mean. |
| OPPO | Not sure | Not sure, | it depends on reason of jitter, e.g. due to the channel condition or due codec?  If the semi-static jitter information can be provided or predicted by CN, it is useful. We are not sure how to predict the jitter if the jitter is dynamic. |
| Fujitsu | Option 2 | Semi-static | We think that the range of jitters is needed for design of C-DRX enhancement. The jitter range in PDU set level has a finer granularity than that of the data burst and may give more flexibility to DRX enhancement. We don’t think the jitter for each PDU is necessary and helpful. We already have the following agreement.   * XR awareness discussion in RAN2 should consider PDU set characteristics and how to use the information available on those (for UL and/or DL). Can also consider how to handle data bursts. |
| Intel | Dependent on SA2/SA4 input |  | We understand that jitter information is important and could be helpful in the three levels for RAN but whether/how it can be provided requires SA4/SA2 input. |
| Lenovo | Option 2/3 | Semi-static | According to SA4 the jitter information provided to the RAN will be only statistics of jitters. Therefore, we assume that the jitter information, e.g. (max range of jitter), will be some semi-static information for PDU Set or Data Burst per QoS flow. We are not sure that there will be actually a difference whether the jitter information is defined per PDU Set or data burst. |
| vivo | Option3 | Semi-static | Jitter of Data Burst starting time is most relevant for power saving.  We assume jitter for one PDU or PDU set cannot be predicted, while only some statistical characteristics can be obtained based on the received packets. Thus, we think semi-statis is enough.  Regarding the detailed parameters, we think the jitter range for starting time is helpful for RAN to configure DRX on duration. |
| Meta | Option 3 | Semi-static | Jitter information is useful for optimizing DRX configuration. As we mentioned previously it should be based on data burst, although we are not sure if SA2 is able to provide a reliable information on jitter. |
| Xiaomi | Depends on Q1 | Semi-static | Yes, jitter can help gNB for configuring CDRX OnDuration and Active Time.  Agree that statistics of jitter is sufficient and the statistics of jitter is semi-static |
| CATT | Option 2 | Semi-static | Assuming different PDU sets streams are mapped on different frame types e.g. on I and P frames, different tile types e.g. user viewport / non-viewport or different stream types e.g. video and audio, they will likely have different QoS requirements, and so potentially different jitter characteristics. Jitter range can be a good starting point.  Note that in R16, SA2 already included the jitter in the arrival time of a data burst to RAN since it is defined as “*The latest possible time when the first packet of the data burst arrives at either the ingress of the RAN (downlink flow direction) or the egress interface of the UE (uplink flow direction)*” (TS23.501). Meaning SA2 assumes feasible to estimate the jitter to RAN. |
| LGE | Option 3 | Semi-static | As mentioned in Q1, Data burst related information is useful for power saving.  We don’t think jitter is predictable, so the range information based on statistics is enough. |

**Q3. Do you think size information (e.g. number of PDUs in a PDU set or number of PDU Sets in a Data Burst) is useful to RAN for UE power savings?**

If you do, which type of media unit do you think this size information should be for?

* Option 1. PDU Set;
* Option 2. Data Burst.

In your comment, please indicate which parameter(s) of size information you prefer (e.g. number of PDUs in a PDU Set or a Data Burst) and justifications for your preference.

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **Your preference**  (Op1/Op2/No) | **How size info should be signalled?**  (static/semi-static/dynamic) | **Comments**  (Any specific parameter(s) of size information you prefer and justification for your preference) |
| Qualcomm | See comment | dynamic | No strong view.  In our understanding, size information is more useful for capacity improvement than UE power savings.  Since XR traffic often has variable frame sizes, it is more efficient to signal sizing information in-band via user-plane signaling. |
| Vodafone | See comments | dynamic | We think the size of information might be used to adapt C-DRX setting |
| Apple | Option 1 | See comment | The (dynamic) amount of data to be transmitted affects the resources required and indirectly the UE active time / power.  In addition, semi-static information of the nominal mean PDU set size info along with its estimated statistical distribution can be useful.  Another aspect is that generally the number of PDUs in a PDU set is good to be conveyed, especially as it can bear opportunities to enable early dropping of packets and thus prevent wasting transmission power for useless information. The same applies to the structure in a setup with multiple PDU sets in case, for example, the I-frame is lost. |
| OPPO | Not sure | Not sure | If the size is total packet size or number PDU of one PDU set or data burst, we cannot see how to use this kind of information for UE power saving. But if the size is time period of data burst, it is useful for DRX operation. |
| Fujitsu | Option 1 | Dynamic | Number of PDUs in a PDU set may be helpful for better scheduling/packet discarding and achieve power saving and capacity improvement. How to signal the size info is FFS. |
| Intel | Dependent on SA2/SA4 input | Dynamic or semi-static | We understand the size information is a useful information from RAN side. Depending on the kind of XR application, we understand this information may vary or not over time (with dependency on SA4 check). |
| Lenovo | See comment | dynamic | We think Q3 and Q4 should be discussed together. The intention is to determine the boundary of e.g. a video frame. The size of a PDU set together with a PDU set ID or sequence number may help NW to judge whether data from UPF is completely received or not.  Indicating the boundary per PDU set could help with dropping PDUs of a PDU set for which the PSDB is exceeded or going to be exceeded soon. If boundary is indicated per PDU set, number of PDU Sets in a Data Burst could be useful for power saving (e.g., to help gNB end the active time or do PDCCH skipping) |
| vivo | No | See comment | We have no idea how size information can be used by RAN.  If RAN is informed about the semi-static size information, e.g. the nominal mean PDU set size, we wonder what is the expected benefit? If RAN configures UE according to the semi-static size, whether there is any issue when the size of an incoming PDU Set/data burst diverse from the semi-static size?  If RAN is informed about the dynamic size information, e.g. CN counts the number of PDUs in a PDU set/data burst and informed RAN about the number in PDU header, does it implies CN needs to buffer the received DL PDUs from XR server until a whole PDU set/data burst is received by CN, then CN can set the “number of PDUs” field in PDU header and send the PDUs to RAN? If this is the case, we think extra delay is introduced. |
| Meta | Option 1 | dynamic | Size information for burst data can be derived through combining the sizes for PDU Sets. Potentially it can help resource allocation and DRX optimization |
| Xiaomi | Depends on Q1 | dynamic | Not preferred.  The motivation of real-time or dynamic information provided to gNB is not that convincing as gNB can use the IAT timer for variable packet size handling.  If signal sizing information in-band via user-plane signalling would really make UE’s implementation very complex… |
| CATT | Option 1 | dynamic | Video packet size is expected to vary by +/- 50% (TR 38.838) so is the PDU set size and considering that “*packets of one PDU set need to be jointly processed for XR traffics*” (SA2) it is important that RAN is aware of each individual PDU set size. And this can only be provided in-band. Signalling details can be further discussed and/or left to SA2, but SA2’s preliminary options seem to make sense: “*the PDU set SN, the packet SN within PDU set, the total packet number of the PDU set or the last packet indication should be provided to 5G system for each packet*”. |
| LGE | No |  | We don’t think that the number of PDU/PDU set is useful from power saving point of view. |

**Q4. Do you think boundary indication for a media unit (e.g. indication for end of a PDU Set or a Data Burst) is useful to RAN for UE power savings?**

If you do, which type of media unit do you think this size information should be for?

* Option 1. PDU Set;
* Option 2. Data Burst.

In your comment, please indicate what type of boundary indication you prefer (e.g. end of a PDU Set or a Data Burst) and justifications for your preference.

For this question, the rapporteur’s understanding is that it is not possible to signal boundary information to RAN in a static or semi-static manner. Please indicate in your comments if you have a different view.

|  |  |  |
| --- | --- | --- |
| **Company** | **Your preference**  (Op1/Op2/No) | **Comments**  (Any specific type of boundary indication you prefer and justification for your preference) |
| Qualcomm | Option 2 | We think end of burst indication is very useful for RAN because it can use the indication to terminate DRX active time once all data in a video frame has been successfully sent to UE. Given short periodicities of XR traffic (e.g. 11ms) and typical range of jitters (e.g. 4~6ms), UE may not be able to get much sleep in a cycle if UE replies on expiry of DRX Inactivity Timer to enter sleep. Hence enhancements such as end-of-burst indication can help RAN timely terminate UE’s DRX active time and thus enable more UE power savings.  Since this indication is needed only after all data in a video frame has been received at RAN, this indication should be based on Data Burst instead of PDU Set, i.e. the last PDU Set in a Data Burst carries end-of-burst indication. |
| Vodafone | Option 1 & 2 | We see the need for “end of burst indication”, but as the burst might contain multiple PDUs belonging to multiple PDU set, It would be useful to know when the PDU sets ends and so, potentially being able to terminate “activity time” earlier compared to only doing it based on Burst information. It should also be noted that the “end” of the burst or PDU set could also be provided by indication of the “first” packet+ number of packets in the set |
| Apple | Option 1 & 2 | End of data burst indication could be given semi-statically for example by indicating the latest time the last packet could arrive. Along the same lines we think other data burst parameters such as arrival time would continue to be useful as well.  Boundary indications for PDU sets are important to enable the RAN and the UE to precisely synchronize multiple flows and/or align the activity on multiple flows, as well as ensure transmission occasions are optimally spaced apart to avoid prolonged UE active time.  Setup of appropriate DRX cycles and selection of suitable resources are additional examples with a power saving effect. Identification of the boundary of a PDU set could be achieved in several ways, for example, through an end-marker indication, a PDU set tag number, PDU set type (importance), sequence number etc. |
| OPPO | Option 2 | We think “end of burst indication” is needed for DRX operation and it can indicate the end of active of DRX. |
| Fujitsu | Option 1 | The end of a PDU set is useful at least for terminating the DRX active time. SA2 has defined that **PDU Set content criterion (PSCP)** refers to criteria based on which a recipient can determine whether the PS can be considered successfully delivered or not. We think that the end of a PDU set is useful for the PSCP. |
| Intel | Dependent on SA2/SA4 input | This boundary information depends to how the PDU set and the data burst are defined. This is also inter-related to the other parameter discussed in this offline e.g. traffic pattern discussed in Q1 and size information discussed in Q3. In general, we understand it can be helpful at both levels from RAN side e.g. to minimize the time that UE needs to be monitoring of PDCCH and to optimize the scheduling at RAN level. |
| Lenovo | Option 1/2 | Same comments in Q1 and Q3. |
| vivo | Option 2 (and option 1 acceptable) | End of burst indication can be used by RAN to indicate UE to early terminate DRX active time, rather than waiting for time out for DRX timer.  Regarding option 1, we think it could also be useful for RAN to terminate the activity time tentatively. Once the next PDU set arrival, the UE could wake up for the following reception, e.g. by wake up signaling. |
| Meta | Option 2 | From power saving point of view, End of Burst should be used for DRX active time termination |
| Xiaomi | Either 1 or 2 can be considered | End indication: which can help gNB to terminate the active time when no data is expected which is good.  The End indication of PDU Set can help gNB use PDCCH skipping for micro-sleep while the End indication of PDU Sets (bursts) can help gNB use MAC CE for a longer sleep. |
| CATT | Option 1 | For similar reasons as provided to Q3. Same comment as Q3 regarding signalling details. |
| LGE | Option 2 | For downlink, End of burst may be useful for RAN to determine to terminate the DRX active time.  For uplink, the UE may indicate end of burst by transmitting an indication. |

**Q5. Do you think information for identifying a media unit (e.g. sequence number for PDU Sets or Data Bursts) is useful to RAN for UE power savings?**

If you do, which type of media unit do you think information for identifying a media unit should be for?

* Option 1. PDU Set;
* Option 2. Data Burst.

In your comment, please indicate what type of information you think is useful in identifying a media unit (e.g. sequence number of PDUs in a PDU Set or sequence number of PDU Sets in a Data Burst) and justifications for your preference.

For this question, the rapporteur’s understanding is that it is not possible to signal information for identifying a media unit to RAN in a static or semi-static manner. Please indicate in your comments if you have a different view.

|  |  |  |
| --- | --- | --- |
| **Company** | **Your preference**  (Op1/Op2/No) | **Comments**  (which type of information for identifying a media unit you prefer and justification for your preference) |
| Qualcomm | Option 1 | We think sequence numbers for PDU Sets are useful to have. At least they are needed to help end-of-burst indication work in a robust way, e.g. in case there is an out-of-order delivery, RAN needs to use sequence number of PDU Sets to identify there is a gap in received PDU Sets and not to prematurely terminate DRX active time.  We don’t expect bursts in different frames would be mixed in the same DRX cycle and hence sequence number for Data Bursts are not needed. |
| Vodafone | Option 1 and Option 2 | Sequence number is one approach and it is useful, but we think we should not select between PDU set and Data Burst |
| Apple | Option 1 | To identify PDU sets in a given order, a sequence number, tag or ID that is common to all PDUs in the PDU set can help achieve in-sequence delivery of PDU sets. Moreover, an ability to distinguish PDUs that belong to the same PDU Set is desired to identify the first PDU of a new PDU Set and the last PDU of the PDU Set. Information that would be useful are ‘number of packets in a PDU set’, a ‘sequence number for each packet in the PDU set’, the ‘type of PDU set’ (importance). Also, the ‘size of the PDU set’, and the expected slice or frame sequence or PDU set structure in a GOP, and information about the number of linked PDU sets. All of this information can avoid unnecessary dropping of packets, deliver packets in the required order, assign additional resources in a setup where only a few packets are outstanding for a PDU set when the configured radio resource is already exhausted, e.g., to avoid unnecessary retransmissions and tune scheduling and radio transmission parameters accordingly. |
| OPPO |  | First, it is not clear whether the PDU set in one data burst is in order delivery in GTP tunnel from core network or not. If it is in order delivery in GTP tunnel, we cannot see the necessary for have this sequence number from UE power saving point of view, and end-of-burst indication is enough, otherwise, we think the sequence number is needed.  It should be clarified the sequence number space, i.e. the sequence number is unique in xxx. |
| Fujitsu | Option 1 | We think that the sequence number of a PDU set is useful for determining PDU Set content criterion. |
| Intel | Option 1 | This information could be helpful to identify PDUs within a given PDUs and for potential dependencies across PDU sets (even if this may not be addressed until future releases) |
| Lenovo | Option 1 | The PDU set SN may help NW to judge whether data from UPF is completely received or not in case of out of order transmission. Being able to identify a PDU set can allow RAN also to apply early termination of unnecessary data and avoid unnecessary retransmissions and adapt scheduling and radio transmission parameters accordingly. |
| vivo | Option 1/2 | Both “sequence number of PDUs in a PDU Set” and “sequence number of PDU Sets in a Data Burst” are useful. It can be used for CN to indicates dependency information within one PDU set or among PDU Sets.  For example, CN can indicate the decoding of current PDU (e.g. SN #3) needs information in PDU with SN #2 in the same PDU set. Hence, if the transmission of PDU #2 fails, RAN could discard PDU #3 accordingly for power saving. |
| Meta | Option 1 | Sequence numbers for PDU Sets can be useful in out of order delivery or networks with large jitters. |
| Xiaomi | No strong view | We also think the end indicator is sufficient. |
| CATT | Option 1 | Agree with Qualcomm. Signalling details can be further discussed and/or left to SA2, but SA2’s preliminary options seem to make sense: “*the PDU set SN, the packet SN within PDU set, the total packet number of the PDU set or the last packet indication should be provided to 5G system for each packet*”. |
| LGE | No | We don’t think that the sequence number is useful from power saving point of view. |

**Q6. Do you think QoS requirements for media units (e.g. PDSB, PSER) are useful to RAN for UE power savings?**

If you do, which type of media unit do you think this size information should be for?

* Option 1. PDU;
* Option 2. PDU set.

In your comment, please indicate what type(s) of QoS requirements you think is useful (e.g. PSDB and/or PSER for PDU Set) and justifications for your preference.

For this question, as QoS requirements are defined by SA2, the rapporteur’s view is that we do not need to discuss how they should be defined/configured/signaled. Please indicate in your comments if you have a different view.

|  |  |  |
| --- | --- | --- |
| **Company** | **Your preference**  (Op1/Op2/No) | **Comments**  (Any specific QoS requirements you prefer and justification for your preference) |
| Qualcomm | See comments | QoS requirements for PDU Sets are important, but we expect the legacy QoS framework enhanced with PDUS specific QoS parameters will be signalled during session establishment. And SA2 have been discussing them. Hence RAN2 do not need to request SA2 to study them in this LS. |
| Vodafone | Option 1 | I think the LS is asking about useful parameters for energy savings and we should list them and QoS requirements belong to such parameters. The granularity is in our view per PDU set |
| Apple | See comment | We think the QoS characteristics of a PDU set (such as delay budget, latency, reliability, priority, survival time, error rate, max packet, max frame size, transmission rate/distribution, etc.) are relevant to fulfil QoS requirements of the E2E service. RAN can use this information to optimize processing and transmission opportunities, which may have a power saving impact. |
| OPPO |  | We think Qos related information is useful for XR service, and it will aid the network to scheduling the data in a valid time period, it may impact the DRX indirectly, but it is not necessary information for DRX operation.  But if the Qos related information will aid the network to discard the PDU, it will be useful for UE power saving, but no impact the DRX operation directly. |
| Fujitsu |  | Agree with Qualcomm. |
| Intel | Option 2 (see comment) | We understand that the new QoS information would be “per PDU set” (i.e. for option 1, our understanding is that this QoS information at PDU level is already possible in legacy QoS framework). However RAN2 should wait for SA2 decision on how QoS framework may be updated e.g. how to incorporate delay/error per PDU set and how it may work/relate with current delay/error rate requirements associated with a given QoS flow. |
| Lenovo | Option 2 | PDU set [air interface] delay budget of a PDU set also allows power saving gains e.g., by selecting suitable CDRX parameters and by reducing unnecessary retransmissions or applying early dropping. It should be included in LS. |
| vivo | See comment | In our understanding, the following QoS characteristics are useful:  For PDU: PDB, importance, priority, dependency  For PDU set: PSDB, importance, priority, dependency  QoS requirements for PDU and PDU set could be used for RAN to enhance the scheduling or transmission, which is benefit for UE power saving, too. |
| Meta | Option 2 | Enhancing the QoS granularity to Per PDU Set QoS is an important part for SA2 study. Probably not impact on DRX operation. However, it can help other power saving schemes such as discard policy. |
| Xiaomi | See comments | PDB which can help the gNB to select suitable CDRX parameters and helpful for efficient radio resource management by gNB for capacity improvement. Whether we are going to have Packet set granularity QoS (e.g., PDSB, PSER) depends on SA2. |
| CATT | Option 2 | Assuming different PDU sets streams are mapped on different frame types e.g. on I and P frames, or different stream types e.g. video and audio, they will likely have different QoS requirements. |
| LGE | No | We don’t think that Qos requirement is useful from power saving point of view.  In our understanding, it may be useful for XR specific capacity improvement. |

**Q7. Do you think relationship information between media units (e.g. between PDUs within a PDU Set or between PDU Sets) is useful to RAN for UE power savings?**

In your comment, please indicate what type(s) of relationship information (e.g. between PDUs within a PDU Set, or between PDU Sets) between media units you think is useful and justifications for your preference.

For this question, the rapporteur’s understanding is that it is not possible to signal relationship information between media units in a static or semi-static manner. Please indicate in your comments if you have a different view.

|  |  |  |
| --- | --- | --- |
| **Company** | **Your preference**  (Yes/No) | **Comments**  (which type of relationship information between media units you prefer and justification for your preference) |
| Qualcomm | No | We think such information is more related to differentiated handling of PDU Sets and capacity improvement than UE power savings. So RAN2 do not need to include them in this LS. |
| Vodafone | Yes | As the burst can include PDUs from different PDU sets, it would be important to know the relation between PDU sets, but if that contributes for UE battery savings is FFS |
| Apple | Yes | Without sequence numbering the packets in a PDU set may be delivered out of order causing unnecessary retransmission of a whole PDU set (rather than selected PDUs in the PDU set), e.g., in scenarios where in-sequence delivery is required, thus not only capacity but also power is wasted. |
| OPPO | Maybe | If this kind of information can aid the network to discard the PDU, then it is useful for UE power saving. E.g. if I frame is lost, then the B/P frame in the same GOP can be discarded. |
| Fujitsu | Maybe no | It is unclear that this relationship information between media units can benefit power saving. |
| Intel | Yes | We understand that getting dependency information of PDUs within a PDU set, or across PDU sets can be helpful for UE and/or RAN to enable efficient mechanism to handle the related PDUs and PDU set e.g. to discard PDUs before (re)sending them, to avoid unnecessarily wait of a related PDUs, to increase robustness of importance and/or dependent PDUs. On summary, we understand that this information is helpful from RAN2 side although which/how this information can be visible would depend on SA2/SA4 conclusion. |
| Lenovo | Yes | The relationship information between PDU Sets is also related to power saving, e.g. if aPDU set is correlated to another PDU set for which transmission failed, unnecessary power consumption can be avoided (E.g. in case a I-frame is lost, associated B/P- frames can be discarded). This covers both UL and DL transmissions of a PDU set. |
| vivo | Yes, both between PDUs within a PDU Set and between PDU Sets | See our answer in Q5:  For example, CN can indicate the decoding of current PDU (e.g. SN #3) needs information in PDU with SN #2 in the same PDU set. Hence, if the transmission of PDU #2 fails, RAN could discard PDU #3 for UE power saving.  Similarly, CN can also indicate the decoding of current PDU set (e.g. SN #3) needs information in PDU set with SN #2. Hence, if the transmission of PDU set #2 fails, RAN could discard PDU set #3 for UE power saving. |
| Meta | Maybe | Depends on what kind of information can be provided by SA2 |
| Xiaomi | Maybe | Dropping all relevant IP packets belonging to a PDU Set can be further considered. |
| CATT | Yes | Discarding/ignoring PDUs in a PDU set (in case failure of earlier PDUs would disallow recovering the whole PDU set) allows letting the UE go to sleep earlier. Unlike Rapporteur, we think this can be indicated in a semi-static manner commonly for a group (or stream) of PDU sets for example via the PSCR parameter, see also Q8. |
| LGE | No | We don’t think that the relationship information is useful from power saving point of view.  In our understanding, it may be useful for XR specific capacity improvement. |

**Q8. Do you think any explicit indications and/or conditions for RAN to decide on delivery vs discard of a media unit would be useful for UE power savings?**

If you do, which type of media unit do you think such type of indications and/or condition sshould be for?

* Option 1. PDU;
* Option 2. PDU Set.

In your comment, please indicate what type(s) of indication and/or conditions you prefer and justifications for your preference.

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **Your preference**  (Op1/Op2/No) | **How such indications or conditions should be signalled?**  (static/semi-static/dynamic) | **Comments**  (Any specific type(s) of indication and/or conditions you prefer and justification for your preference) |
| Qualcomm | Option 1 | Semi-static | On downlink, we do not think such explicit indications and/or conditions are needed for UE power savings, because they are needed only in RAN’s scheduling operation.  On uplink, if a PDU has no delay budget left (i.e. becomes late), then it may be subject to discard to avoid unnecessary transmissions and thus unnecessary UE power consumption. We think network can configure whether UE should perform such discard for a DRB and, if enabled, a delay budget for UE to check whether a DPU is late or not. |
| Vodafone | Option 2 | dynamic | In UL we agree with Qualcomm, but on DL, I am not sure, why the gNB should send the packets which could be discarded and we should also think about re-transmissions of such packets as it would cause the UE to wake up. |
| Apple | Option 1 & 2 | See comment | We think that explicit indications can be useful not only in UL but also in DL. Examples: Dynamic indication of critical packets in a PDU set; dynamic indication of control information; semi-static indication of critical PDU sets in a group of pictures. A higher reliability may be needed for certain PDUs or PDU sets depending on the situation or e.g., the remaining delay budget, to avoid a loss of the whole PDU set, thus, to avoid a waste of transmission power.  Moreover, a semi-static indication on how many lost packets an application can tolerate in a PDU set has relevance not only to capacity but also to power. |
| OPPO | Option 1 and 2 |  | We think it is useful for power saving if the data is discarded for both DL and UL.  We also think the dynamic indication and semi-static indication are needed for different case, e.g. different type of PDU set. |
| Fujitsu | Option 2 | Semi-static/dynamic | We think that explicit indications and/or conditions on delivery/discard for a PDU set is useful for determining PDU Set content criterion. |
| Intel | See comment | Semi-static. FFS on dynamic (see comment) | This question seems very much inter-related to the response to previous Q7.  We understand this information on how to treat PDUs within a PDU set can be helpful in both DL and UL side for UE and/or gNB to act accordingly (with solutions still to be discussed by RAN2)  Dynamic kind of info. may also be needed e.g. if the discard behaviour were different btwn different PDU sets. SA4 input may be required for this. |
| Lenovo | Option 2 | Semi-static | Early discarding indication per QoS flow is a useful parameter from power saving perspective. Depending on the implementation at XR application all PDUs in a PDU Set (PS) are handled by the application layer as whole. In this case, if some PDUs of a PDU Set from UPF are missing, i.e not correctly received, the remaining PDUs of the PDU set should be discarded since they are not of any use. Similar observation can be drawn for cases when the PSDB is exceeded for PDUs of a PDU set. |
| vivo | Option 1 & 2 | See comment | We assume the explicit indication can be useful for both UL and DL.  Delay budget (PSDB for PDU set and PDB for PDU) information can be configured for UL and DL via semi-static configuration.  Dependency information between PDUs and PDU sets can be informed to RAN for DL via dynamic signaling.  With these kind of indication, RAN could decide to delivery or discard, which is benefit for UE power saving. |
| Meta | Option 2 |  | It’s stated in SA2’s PDU Set definition that PDU Set may or may not be recoverable depends on application layer implementation. It’s important for this information to be indicated to minimize unnecessary transmission in the air interface. Saving both radio resource and power. |
| Xiaomi | Either 1 or 2 can be considered | Semi-static/dynamic | Dropping all relevant IP packets belonging to a PDU Set can be further considered considering the dependency within a PDU set or between PDU sets. |
| CATT | Option 1 | Semi-static | Same view as Qualcomm for UL + we also think it is useful for DL as it can allow a UE to go to sleep earlier (see Q7). A parameter like, for example, the PDU Set Content Ratio (PSCR) discussed in SA2 can be used for that purpose. |
| LGE | No |  | We don’t think that the indication is useful from power saving point of view. |

In [3], it is stated that for XR traffic flows not based on PDU Sets, information including traffic periodicity, start offset of PDUs and range of jitter can be useful to RAN in DRX configurations, and the information can be semi-statically provided to RAN (e.g., at PDU/QoS flow establishment or modification).

**Q9. For XR traffic flows not based on PDU Sets, do you think it is useful to provide RAN with their periodicity, start offset of PDUs and range of jitters for UE power savings?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments**  (Please provide you preferred parameters if they are not mentioned in Q9) |
| Qualcomm | Yes | XR application can generate multiple types of traffic flows. Some of the flows may not be based on PDU sets (e.g. audio, voice, control message, etc). It is equally useful for RAN to know the traffic characteristics of those types of flows, e.g. periodicity, start offset, range of jitters in its DRX and SPS/CG configurations. |
| Vodafone | Yes | Agree with QCM |
| Apple | Yes | These types of PDU sets could be characterized as PDU sets of packet size 1. More importantly, it would be useful to describe them in a common framework because PDU sets of these flows may have a timing relation to other PDU sets (audio and video, pose information, control packets) where synchronized treatment may be required. Proper alignment of radio resources has a power benefit. |
| OPPO | Yes | Share the similar view with QC. |
| Fujitsu | Yes | Agree with Qualcomm. |
| Intel | Dependent on SA2/SA4 decision | We understand that this question depends on SA2/SA4 conclusion on whether PDU set level and/or data burst information can always be available. If there is no information available for either of them (i.e. PDU set level and/or data burst information), we understand it might be useful to get it at the PDU level. If so, FFS whether this can be handled by implementation. |
| Lenovo | Yes | Agree QC, the same motivation to introduce TSCAI from CN in R16 IIOT. |
| vivo | Yes | Agree with Qualcomm. A common framework for XR traffic flows based and not based on PDU Sets is preferred. |
| Meta | Yes | Agree with QCOM |
| Xiaomi | Yes | We agree that there are XR traffic flows not based on PDU Sets depending on codec implementation.  Periodicity, range of jitters are useful for gNB.  But for start time, no strong view. We think that gNB can use the time that the packets arrived as the start time. |
| CATT | Yes but | We are not sure why the PDU set cannot be reused in a generic manner for other flows, especially if aggregated in the same flow in CN, or mapped on the same DRB in RAN. In the end, a PDU set can just be a burst for such flows. It is an implementation choice. |
| LGE | Yes | Without PDU set, we think that the characteristics of PDU may be useful but other information is not needed. |

**Q10. Any additional information that you think is important for RAN but is not included in any of the questions above?**

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **Your preferred information** | **How should the information be signalled?**  (static/semi-static/dynamic) | **Justifications for your preferred information** |
| Intel | Importance level (e.g. critical vs no critical) | Semi-static or dynamic | We understand that it is helpful if RAN can differentiate the importance of the traffic and/or PDU set level to provide an increase of robustness when it may be required.  [LGE] We think Importance level is useful for scheduling. However, we are wondering how this importance level is related to XR power saving. |
| Apple | Synchronization between traffic flows | Semi-static | Proper activity alignment between XR traffic flows can significantly reduce UE active time; at the same time, certain flows have a synchronization requirement. We think that such information is helpful for the RAN to be provided with. |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

# **Conclusions**

(To be added later)

# References

1. R2-2204523, LS on UE Power Saving for XR and Media Services (S2-2203418; contact: Nokia).
2. R2-2206923, Reply LS on UE Power Saving for XR and Media Services (R1-2205531; contact: Qualcomm).
3. R2-2207042, Draft reply LS on UE power savings for XR and media services, Qualcomm Incorporated.
4. R2-2207117, XR awareness: RAN2 areas of interest, assumptions, and inputs to SA2 LS, Intel Corporation.
5. R2-2207509, Consideration on power saving for XR service, CATT.
6. R2-2207757, Discussion on XR-specific power saving, vivo.
7. R2-2207888, Discussion on XR-specific power saving techniques, Huawei, HiSilicon.
8. R2-2208020, XR Power Saving enhancements, Nokia, Nokia Shanghai Bell.
9. R2-3308316, Discussion of SA2 LS on UE Power Saving for XR and Media Services, Meta.
10. R2-2208680, Discussion on power saving enhancements for XR, Ericsson.
11. TR 23.700-60 v0.3.0, Study on XR (Extended Reality) and media services (Rel-18).
12. R2-2207697，Discusion of XR awareness in RAN，Lenovo
13. R2-2207429, Considerations on XR-awareness, QoS-metrics, and XR-specific traffic handling, Apple
14. R2-2207430, Power Saving for Periodical XR Traffics, Apple