[RAN93e-R18Prep-05] XR evolution - Version 0.0.5
RAN

3GPP TSG RAN#93e RP-211655

Electronic Meeting, September 13 - 17, 2021

Source: XR evolution moderator (Nokia)

Title: Moderator's Summary for Discussion [RAN93e-R18Prep-05] XR evolution

Document for: Information

1 Initial round - now closed.

1.1 KPIs and QoS

Please provide your views on work needed in the area of KPIs and QoS for XR using the feedback for below.

Feedback Form 1: KPIs and QoS

1 – VODAFONE Group Plc The results of the R17 studies are not yet available, but we anticipate that there may be system level QoS aspects that need to be improved in R18 to make AR (uplink video) and Cloud Gaming work better, e.g. a) Linking of downlink GTP-U packets together (each video picture frame is around 60 kbytes and arrives at the base station as 20 independent IP packets. It is likely that a transmission failure of one of these IP packets makes the transmission of the rest of the video frame useless.) b) Unequal Error Protection (some IP packets might have much more important information in them than others. Extra GTP-U headers could signal this to the RAN and enable better radio resource utilisation) This would lead to work for SA2, SA4, RAN 3 and CT4.
2 – Futurewei R17 XR evaluation XR is still ongoing. We support study in the area of KPIs and QoS for XR. New QoS or QoS management enhancements may be identified to enable application-oriented QoS control. Some of the work areas that can be considered are active queue management of DRBs, N:M mapping from QoS flow to DRBs and congestion condition exposure to rate-adaptive multimedia applications. For more details, please refer to RWS-210040.
3 – InterDigital From Rel-17 SI, an XR application can consist of multiple traffic streams in UL/DL (e.g. video, user pose, control, metadata). Within each traffic stream, different PDUs may belong to the same frame or application data unit (ADU) and require different data forwarding treatment during transmission depending on the importance/priority of the ADU. In this case, it can be beneficial for being able to identify and differentiate the QoS at various granularities (e.g. per-application, per data stream, per-ADU, per-PDU) and flexibly schedule the data in different DRBs/LCHs for meeting the respective QoS requirements.

4 – CATT

The KPI was identified in Rel-17 XR study. RAN1 used the 5GI entries for XR specified by SA4 and SA2 as the base for the evaluation of XR service. Thus, the QoS and KPI from Rel-17 XR study should be the base for the XR work in Rel-18

5 – China Mobile Com. Corporation

Although R17 SI is still ongoing, several areas can be foreseen to be enhanced in terms of KPI and QoS,

1. More granular QoS differentiation, assuming frames with different importance are mapped to the same QoS flow.
2. Frame level QoS enhancement where a frame may contain multiple packets for radio transmission.
3. New XR related QoE value generated by the mobile device which is used for RAN optimization such as scheduling enhancement.

6 – AT&T

We would like to see an emphasis on system-level KPIs such as radio resource utilization given that in practice XR applications will coexist with other types of traffic with various QoS levels. It is important to both guarantee per-user QoS and ensure overall system stability/efficiency and any enhancements to help the network identify and manage these tradeoffs would be welcome.

7 – Apple Europe Limited

In our view, UE power saving and system capacity should be prioritized.

How to acquire/propagate QoS information concerning a data flow requires study from both SA and RAN. We propose the WI should identify and specify if needed, the set of QoS parameters for XR including how to signal them and how to optimize the system for bursty traffic characteristics exposed by XR (in interaction with SA2). More discussion is provided in RWS-210500.

8 – Asia Pacific Telecom co. Ltd

KPI, QoS, and traffic model of XR/CG are currently studying and will be identified by R-17 SI. It is observed that the XR/CG application comprises several traffic streams with different characteristics. How to meet the QoS requirement for each traffic stream and/or each XR/CG application should be considered in the scope of R-18. QoS differentiation by more flexibility scheduling the UL/DL data at different granularities is one of the wayforwards.

9 – vivo Mobile Communication Co.

We think new 5QI values and enhanced QoS management for XR need to be studied and specified.

- Since XR services demand high data rate, low latency and high reliability, with the characteristics of various packet/frame size, non-integer periodicity and jitter, current 5QI values in IP packet level cannot well reflect the characteristic of XR services. To make XR services operating in NR network more efficiently, frame level QoS requirement for XR is needed.
- Besides, XR services include multiple types of data, e.g. I-frame or P-frame for video stream, audio stream, pose and control stream, etc. Different streams may correspond to different QoS flows and may have different QoS requirements. Currently, different QoS flows are independent. However, for multiple streams of XR services, there needs to dependency among different streams of XR, e.g.

decoding of P-frame may need the previous I-frame. Hence, the dependency and potential synchronization for multiple streams of XR are needed.

- RAN, SA2 and SA4 are all involved and cooperation is required for introducing of new 5QI value(s) for XR services. The new 5QI value(s) is required to be delivered from CN to RAN. Subsequently, RAN can further study some potential improvement accordingly e.g., adaptive scheduling.

10 – DOCOMO Communications Lab.

We are open to study KPIs and QoS for XR. Rel-17 XR study is ongoing and KPIs are not clear for Rel-18 XR enhancements.

11 – Facebook

Both KPI or QoS should bee application-aware. That iis KPI or QoS should be tied to applications or quality of experience due to the different sensitivities to e.g. packet error rates.

12 – HuaWei Technologies Co.

We largely share the views from VDF and CMCC. For XR services, it is more important to evaluate the end user experience as these interactive and immersive features are pursuing real perceptive feelings. In current RAN1 study, a baseline KPI is agreed based on PER and PDB, which may not be enough to reflect the user experience.

Therefore it is desirable to identify a KPI that can reflect the impact of network transmission on user experience in XR services, which can be better used for network planning and optimization or even scheduling. Since different frames may have different importance due to error propagation, loss/delay of packets in different frames in the refresh interval may result in different impacts on the user experience even if they have the same PER and PDB. In summary some information specific to XR can also be considered in such a KPI to reflect the user experience more accurately, e.g., frame rate, refresh interval of I-frame, and codec type. To define such a KPI, cooperation among 3GPP working groups, e.g., RAN2/3 (e.g. QoE) and SA4, is needed.

Proposal: Study and specify XR QoE/KPI that can reflect the impact of network transmission on XR user experience for better evaluating of XR transmission over NR.

- Identify the XR-specific information for XR QoE/KPI, e.g., frame rate, refresh interval of I-frame, etc.

RAN awareness of the defined KPIs, e.g. RAN-visible QoE related enhancements in RAN3.

13 – LG Electronics Inc.

For XR, it is important to support different QoS handling within one packet stream. The differentiation may be performed per QoS flow or per DRB basis. Radio scheduling may also need to be improved based on the QoS differentiation of each packet.

KPIs and QoS used for Rel-17 XR_eval SI can be reused as baseline and additional XR-specific KPIs and QoS can be discussed if needed.

14 – Lenovo Information Technology

We support to have E2E QoS Framework enhancements and more granular QoS differentiation, which includes multiple data streams per-application (burst/ADU/frame), importance/priority of packets identification and synchronization among multiple data streams. Coordination with SA2 is needed.

It is good to consider application performance evaluation e.g., a new QoE metric can be defined. Coordination with SA4 is needed.

15 – Beijing Xiaomi Mobile Software

Many enhancements in the area of KPIs and QoS for XR have both impact on RAN and SA specifications. If an enhancement is considered to be included in RAN XR workscope, it should be also supported by Rel-18 SA. Tight cooperation between RAN and SA is needed. Now, the evaluation work in XR SI is still going on. The necessity and benefit of the approved enhancement should be confirmed by the evaluations.

16 – Intel K.K.

We also think that the KPIs identified in Rel-17 XR study can be used as baseline and more emphasis can be given on identifying suitable QoS requirements. Since existing QoS framework already enables QoS requirement awareness in RAN, e.g., based on QoS flow, additional information from CN, etc, we think a study can be conducted to extend existing QoS framework to support the traffic awareness at RAN or enhance the Uu interface to achieve this. We also support CMCC's proposal on more granular QoS differentiation.

17 – Spreadtrum Communications

Since KPI and QoS are discussed in RAN1, the related enhancements shall include the agreements in RAN1. We think KPI and QoS shall be based on a group of packets, for example, the multiple packets of one video frame.

18 – MediaTek Inc.

XR/CG traffic is **LLeMBB** (low-latency eMBB) traffic a) displaying within the **same application frame-dependent QoS requirements** and **inter-frame dependencies** (e.g. I- vs P- frames) and b) putting a high pressure on **system capacity and mobility**.

Issues pertaining to **data rate fluctuation**, **jitter**, **congestion** and **packet dropping** have direct impact on user experience; in view of the above need **frame-related handling in the QoS framework i.e. handling of frame-dependent QoS and inter-frame dependencies across the system incl. at the Access Stratum**.

This work should be conducted in close coordination with SA2.

19 – Sony Europe B.V.

Rel-17 XR study is still ongoing and may not be clear what parameters and KPIs that needs to be enhanced based on ongoing improvements done in related work items like UE power save, and URLLC.

Further KPI and QoS aspects should be based on Rel-17 work including input from SA4.

We think QoS aspects support AR2, with heavy uplink traffic may need to be improved.

KPI should be related to UE power consumption and capacity, considering Packet Delay Budget as studied in Rel-17 XR study item.

20 – Ericsson LM

5G KPI and QoS framework has been well defined in a generic way so that we think system capacity and UE power saving should be prioritized in Rel-18.

General comment on XR: Our view is to have a SI followed by a WI in Rel-18.

21 – Qualcomm Korea

The latency and reliability QoS parameters in 5G systems are specified for traffic in terms of "packets" (e.g. Packet Delay Budget: PDB, Packet Error Rate: PER). On the downlink, the packets correspond to the packet data unit on the N6 interface inbound towards the UPF. These packet data units are typically IP packets and so the packets correspond to IP payload. However, as indicated in our comments for the next question (or Section 1.2 below), XR and Cloud Gaming applications consume data in a minimum granularity that is different from IP packets, referred to as "Application Data Unit" (ADU), e.g., video frame or video slice. The QoS parameters specified in terms of packets do not adequately capture the application requirements, which are typically in terms of ADUs.

· First, applications can have a certain ADU error rate (AER) requirement, where AER is the percentage of ADUs in error in a specified measurement window.

· Second, applications can have a certain delay requirement on an ADU (ADU delay budget: ADB), that cannot be adequately translated into packet delay budget requirements.

· Third, not all bits within an ADU are equally significant. For example, if the application implements an application-level error correction, then the application client only consumes a certain fraction of the bits of an ADU, and the remaining bits need not be transmitted to improve capacity. The treatment of bits within an ADU can be specified via a QoS parameter called ADU content policy (ACP).

In addition to ADU based QoS enhancements, latency is a key KPI for XR that can further benefit from 3GPP enhancements. The latency KPI of interest to XR and Cloud Gaming applications is the end-to-end latency. End-to-end latency comprises Server-to-5G latency, 5G latency, and UE-to-Application latency.However, in the current framework, only 5G system latency can be specified and any short-term variations in the other components can affect the end-to-end latency. As such, we propose an extension of the latency KPI to incorporate end-to-end latency requirements, the constituent components, and means for 5G system to adapt to meet the end-to-end latency even with variation in other components.

22 – Nokia Corporation

Currently Rel. 17 SI continues to study the KPI related mobility and coverage. It is important to have results to identify the necessary enhancements to better support XR applications.

XR applications may generate multiple types of frames and/or multiple types of data streams within the same flow with different characteristics and QoS requirements. Thus, studying the new QoS characteristic for QoS Flows and 5QIs defined for interactive XR and gaming services is useful since it can further improve, e.g., the gNB RRM decisions, including scheduling decisions.

For example, new assistance information related to pose information accuracy would help in improving resource reservation and management. There is also a benefit in e.g., defining a maximum presentation latency (the time between the first HTTP request and the last HTTP response for a burst of data). This in its turn can enable scheduling prioritization and improve resource allocation.

23 – ZTE Corporation

Packer error rate (PER) and air interface packet delay budget (PDB) are the KPIs. A satisfied UE is declared as if more than a certain percentage of packets are successfully transmitted within a given air interface PDB. According to evaluation results for XR capacity in RAN1#105-e meeting and RAN1#106-e meeting, different PERs or different PDBs have an impact on capacity performance to some extent.

Since multi-stream model has become one of the considered traffic model for XR service, an effective way for identifying multiple streams is to design dedicated 5QI for each of the stream. Therefore, RAN1 should report the agreed traffic models and KPIs to SA to jointly design some new 5QIs. To enable application aware XR transmission, gNB needs to be aware of sub-stream level application information including e.g., priority, PDB/PER related information. To address this, corresponding QoS token needs to be defined and

made known by the gNB. Moreover, for interactive services, it's supposed that the QoS can consider UE experience of both directions of transmission.

On the other hand, our company is open to discuss KPIs for application data unit (ADU) including e.g., ADU error ratio (AER), ADU delay budget (ADB) and etc. And we also agree with AT&T that coexistence with other types of traffic with differentiated QoS is an important aspect when it comes to enhancement in Rel-18

24 – Guangdong OPPO Mobile Telecom.

The KPI and QoS was identified in R17 XR study. And 5GI entries for XR in SA4 is the reference for XR evaluation. The KPI and QoS in R17 XR can be a starting point in R18.

25 – Orange

We are supportive of studying both KPI and QoS optimisation for XR. As an operator, XR is an important service which may require specific QoS management.

26 – Samsung Research America

We consider the identification of QoS requirements of frames within a same data flow as the most important feature for meeting XR KPIs and improving system capacity.

1.2 Application Awareness

Please provide your views on work needed in the area of Application Awareness using the feedback form below.

Feedback Form 2: Application Awareness

1 – VODAFONE Group Plc

See the QoS aspects mention in our response to Q1.

2 – Futurewei

The related evaluation observations are not yet available in R17 XR evaluation study. RAN awareness of traffic information for optimizing lower layer operation may be further studied for increasing system capacity and improving user experience. One example of such information may include awareness of packet type and deadline, this may enable more optimized scheduling of resources. Coordination of work with SA2, SA4 may be needed.

3 – InterDigital

The awareness of application layer attributes (e.g. I-frame vs. P-frame, FoV vs. non-FoV) at RAN is beneficial for improving resource utilization and capacity. Since the UE may have visibility of application layer attributes, both as the source and destination of XR traffic, the UE can provide assistance information to gNB on the presence of critical and non-critical data in buffers, number of PDUs per ADU, remaining delay budget, remaining RTT latency, etc. Such information can be useful at gNB for making scheduling decisions including whether to expedite or drop the transmission of certain PDUs in UL/DL.

4 – CATT

Application awareness had been assumed by most companies during the XR study. The XR application awareness by UE and gNB would improve the user experience of XR service, improve the NR system capacity in supporting XR services, and reduce the UE power consumption. The XR application awareness would be critical in Rel-18 XR work.

5 – AT&T

Given that certain media streams/packets of an XR service may be more critical than others for ensuring the end-user experience, enhancing mechanisms to exchange relevant RAN metrics identified in the study up to the application layer as well as relevant information about specific XR traffic characteristics within the RAN would be beneficial.

6 – AT&T

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9 – Apple Europe Limited

We assume by "application awareness", it means application awareness at RAN. While RAN is made more aware of XR traffic characteristics, such as traffic flows (video, audio, data, etc) and their periodicities and size (distributions), RAN may be able to tailor the radio processing for the traffic need, hence achieve enhancements in UE power saving and system capacity. As such application awareness is an enabler for both enhancements. Rel-18 NR enhancements for XR should be motivated by XR services' traffic characteristics, especially the multiple data flow aspects. What can be achieved for application awareness and how to achieve application awareness may require study from both RAN and SA. One possible way to provide application awareness is through UE assistance information as discussed in RWS-210500.

10 – Asia Pacific Telecom co. Ltd

If UE can anticipate the upcoming traffic pattern as well as its requirement, it's beneficial to provide some information to RAN for enhancing the scheduling efficiency, which is also advantageous at reaching the KPI/QoS. What kind of information and how to provide it to gNB can be studied in R-18 XR WI.

11 – China Mobile Com. Corporation

We are supportive to further study such topic, including two areas:

1. RAN awareness of application-level information for RAN optimization

2. Application/higher layer (such as TCP) awareness of RAN level information for higher layer optimization. (Coordination with SA2 and SA4 may be needed)

12 – vivo Mobile Communication Co.

We support to study and specify features of RAN awareness transmission.

For RAN awareness transmission, we think following need to be specified.

- XR service-related information acquired by RAN, e.g. frame boundary identification, identifier of IP packets belonging to a same frame, identifier of multiple flows with different importance, synchronization information among packets or flows, packets latency, etc.
- QoS management, adaptive scheduling, adaptively packets dropping and delay aware scheduling by RAN
- XR-related information Interaction among UE, RAN, CN and application server to assist RAN scheduling/QoS management/application server adjustment, e.g., UE assistance information report, XR-specific UL transmission triggering measurement or adaptive scheduling.

The XR related information is helpful for RAN to be aware of XR characteristics, so that the network can perform smart QoS management and adaptive scheduling for the flows of XR traffic, which can improve the immersive experience for user. For instance, frame boundary identification, identifier of IP packets belonging to a same frame, packets latency can be acquired by RAN so as to RAN can adaptively do packets dropping to enhance the system capacity.

Besides, the XR-related information interaction among UE, gNB and CN/application server are also beneficial for improving XR user experience. For example, UE can report the XR service assistance information (e.g., UL traffic related information, special pose/control information) to assist gNB for UL scheduling and transmission. On the other hand, gNB could also provide some user experience-oriented information to CN and/or application server for QoS related (e.g., data-rate) adjustment/adaptation.

In addition, for XR service UE events like UL pose update may be triggered prior to DL video traffic. Hence, it could be beneficial that some XR-specific UL transmission can be used for triggering particular behavior, e.g. UL specific pose/control info trigger CSI measurement and report, UL BSR/latency info trigger adaptive scheduling.

13 – DOCOMO Communications Lab.

»We support to study it in order to ensure to ensure QoE of user for XR applications. We think leading WG can be RAN2 and secondary WG can be RAN1. Besides, there may be some potential SA impact.

14 – Facebook

- Application/XR Awareness
  - SPS/CG/DG enhancements to support XR application and services,
    - Diverse and flexible adjustment covering both low data rate applications and immersive experiences
  - Efficient inter-protocol layers information exchange

- The RAN enhancements/awareness should leverage on existing multimedia architecture, media format, protocols and ecosystems (e.g. WebRTC, 3GPP MTSI), e.g.
  - Multi-flows definitions, traffic pattern characterization, media-layer adaptivity, QoS requirements
  - Supporting both OTT-based and 3GPP IMS-based
  - Applicable to both operators and 3rd party applications

- Alignment with other working groups, e.g.
  - SA2/SA6 Edge Computing Architecture
  - SA4 work on media architecture and protocols (e.g. FS_EMSA)

15 – HuaWei Technologies Co.

The application awareness may not be a very precise term. In our view, we interpret it as E2E mechanism to ensure the frame integrity for XR data transmission. We also proposed some other QoS enhancements in Capacity section, and in general we think this application awareness should be discussed together with capacity enhancements.

From network transmission perspective, each video frame in XR services may be segmented into one or multiple packets. Packets in one video frame are correlative with each other onat application layer. Loss of one or more packets in a video frame would result in a video frame decoding failure. Such correlations among the packets belonging to the same frame in XR applications, and if it can be aware by the network, can be used for efficient scheduling and packets dropping can be done to improve the system performance for XR services.

To support the above frame integrity, We propose to specify the below mechanism for Rel-18(such E2E mechanism requires coordination with SA working groups, which can proceed in parallel in RAN and SA)

Proposal: Specify E2E frame level integrated transmission to enhance the capacity, including

- Frame level QoS management, e.g. frame error rate, frame delay budget, etc.

- Identify the packets belonging to one video frame.

- Efficient radio resource management according to the above information to guarantee the frame integrity.

16 – LG Electronics Inc.

Application awareness is a key feature to support XR. The importance of each packet may be identified by SDAP or PDCP layer, and different treatment can be applied based on the identified importance. I-frame vs P-frame, TCP vs TCP ACK may be an example of traffic awareness.

17 – LG Uplus

From our view, the application awareness is an important aspect to support XR services efficiently. Like other companies said, the characteristics of the traffic and frames are depending on which kind of XR services are being provided so with this consideration, the awareness can be leveraged from NW side.

18 – Lenovo Information Technology

We support to have RAN awareness of XR application information and cross layer related enhancements, which may include RAN awareness of ADU/burst information, TCP ACK suppression, RAN assisted codec adaptation and etc.

19 – Beijing Xiaomi Mobile Software

If some application layer information is known by RAN, optimized lower layer operation can be performed to enhance system performance e.g. capacity, power consumption, etc. However, many enhancements in this area can be realized by NW implementation. We are supportive to consider enhancements in this area after the potential benefit and specification impact is clarified in the XR SI study.

20 – Intel K.K.

It is beneficial if network configuration, e.g., SPS, CG, DRX can match traffic pattern, e.g., periodicity. In our view, awareness of traffic information (e.g., traffic characteristics including periodicity, etc.) can be beneficial for at least enhancing the capacity. Methods for the gNB can be studied to be made aware that the UE has upper layer critical data within its buffers so that the gNB can take the information into account in UL scheduling decisions.

21 – Spreadtrum Communications

Application information is useful for data transmission in Uu interface. For downlink, some modification may be necessary to indicate this application related information to RAN.

22 – MediaTek Inc.

Cross-layer optimizations and **mutual awareness** between an **application** and the **system (incl. AS)** need investigating, in view of the need for frame-related QoS framework, real-time rendering (i.e. **zero buffer**), and for **end-to-end codec rate adaptation** according to experienced/expected system **conditions incl. radio conditions**.

23 – MediaTek Inc.

This work should be conducted in close coordination with SA2, SA4

24 – NEC Corporation

In general, the traffic information of an XR application (e.g., the periodicity, jitter, PDB, etc.) are quite useful for gNB/UE in the aspects of scheduling, power saving, mobility, etc. It is beneficial to allow gNB/UE to get and utilize these traffic information, especially in the lower layer (i.e., MAC and/or PHY). As a cross-layer issue, RAN1/RAN2/RAN3/SA2/SA4 may be all involved in this study.

25 – Sony Europe B.V.

Awareness of application traffic characteristics would be beneficial for the RAN network to optimize resource planning and scheduling.

Especially for demanding use cases like XR. Aspects like PDU vs DRB mapping, QCI/5QI, priority handling, GBR aspects and excessive TCP ACK handling should be considered.

26 – Ericsson LM

We support application awareness study since XR itsef is about applications with new traffic. It would be beneficial to understand which information of traffic characteristics are useful for RAN adatpation and what mechanisms in the different protocol layers to use the information are needed. Benefits and complexity should also be considered.

27 – Qualcomm Korea

As observed in our view for the previous question (or Section 1.1), the QoS parameters in 5G systems are specified for traffic in terms of "packets", which are typically IP packets. XR and Cloud Gaming application traffic, however, on the downlink typically consists of encoded video or scene information. Typically, the applications require a certain minimum granularity of application data to be available on the client side before the next level of processing can start. For example, in certain configurations, application client processing can start only if all bits, or a certain percentage of bits of a video frame is available. Although this information is packetized into IP payloads, the minimum granularity of traffic consumption on the application client side will require a certain minimum set of IP packets available before the next level of processing can start. We refer to this minimum granularity of information that a given application requires as "Application Data Unit" (ADU).

As noted in our comments for the previous question (or Section 1.1), it is beneficial to signal ADU based QoS parameters, ADB(ADU Delay Budget), AER(ADU Error Rate), ACP(Application Content Policy). However, these QoS parameters can be specified only if the 5G system is aware of the ADU itself. ADU awareness at the 5G system is required to take advantage of the specification of ADB, AER and ACP parameters.

In addition to ADU, 5G system can benefit from an awareness of the bursts that can constitute multiple ADUs. If the 5G system is aware of the end of the burst, then it can ensure that UE can be sent to sleep, without having to implement inactivity timers, resulting in additional power savings.

In addition to application awareness at RAN, there are potential benefits from an awareness at the Application of RAN related aspects. For example, XR traffic is periodic (often with jitter) and is often associated with a tight delay budget constraint, and in a scenario with multiple users in the same cell using XR applications, the XR capacity of the system may depend on whether the frame arrivals of these users are aligned with each other, or staggered relative to each other. Synchronized arrivals may increase the burden on the cell to deliver more bytes within the same delay budget. Mechanisms that enable staggering of user traffic patterns can improve capacity. While the RAN may be best placed to calculate the required offset in traffic, the staggering may need to be enforced at the source of the traffic. This may require mechanisms for the RAN to interface with the application server for this purpose. Further, during specific degradation events in RAN (e.g., due to handover), it will be useful to manage the overall user experience if RAN can communicate such degradation events, and Application can act (e.g., adapt traffic) that minimizes the user experience degradation.

28 – Nokia Corporation

Some of the enhancements related to capacity and power discussed in the Rel. 17 SI assumes the extra information about the XR traffic. From the preliminary results, we see that RAN awareness of pose information, 5QI PDB differentiation within a single stream, and other application related information can further improve the XR performance. New assistance information of e.g., current frame rate (frames per second, such as 30 fps, 60 fps, or 120 fps) helps gNB to improve UE power and satisfaction models. It is also important to coordinate the work with SA2.

29 – ZTE Corporation

First of all, as mentioned in Q1, the key point to implement traffic awareness transmission is that different data/streams are able to be identified in 5QI table.

Then, enhanced application awareness scheduling scheme can be considered. For example, for multi-stream traffic model, preemption or priority-based scheme is capable of scheduling more important stream when resource collision to ensure the performance of critical streams, which can improve the capacity performance in system.

On the other hand, we are also open to study delay-aware scheduler aiming to schedule the stream with stringent remaining PDB and file boundary-based scheduler aiming to schedule the stream with less remaining data in a file.

For the interaction service, UL assisted information can be one of the study topic ~~in study~~. The UL assisted information is used to report some information to assist scheduling in gNB. For example, in FoV and non-FoV stream transmission scenario, terminal device is capable of reporting the user's view point to gNB, then gNB can utilize this information to render a new FoV picture corresponding to users' view point and transmit the picture to the terminal device.

Last but not least, the RAN awareness of traffic information (e.g., traffic periodicity and jitter range) also has benefit to save power consumption.

30 – Guangdong OPPO Mobile Telecom.

Generally, application awareness makes RAN to be able to optimize radio process for XR characteristics, which is beneficial for improving capacity and power consumption. What information needs to be aware in RAN and how to achieve application awareness needs to be studied.

31 – Samsung Research America

We support studying mechanisms that enable application awareness at RAN. We consider such mechanisms to be a key enabler for successful XR deployments. Focus should be on the DL and coordination with SA4 and particularly SA2 is necessary.

1.3 Power Consumption

Please provide your views on work potentially needed on power consumptions ***specifically for XR*** using the feedback form below.

Feedback Form 3: XR-specific power consumption considerations

1 – VODAFONE Group Plc

This seems unnecessary. The data rates and application processing demands of XR are those of a "high end eMBB" device, so DRX-type optimisations focussed on "in game" power saving seem irrelevant.

2 – Futurewei

The related evaluation observation on power consumption are not yet available in R17 XR evaluation study. Some initial result shows that the C-DRX and e-DRX may provide little gains due to the mismatch of its parameters with periodic traffic of XR. Moreover, having the jitter may also mis align the e-DRX on duration. Further study is needed for feasible solution for power savings for XR.

3 – InterDigital

Some of the issues impacting power consumption identified during Rel-17 SI on XR include non-integer periodicities of XR traffic (e.g. 1/60Hz), high periodicity of UL pose/control traffic (e.g. 4ms), presence of jitter in DL traffic and misaligned handling of UL and DL traffic. When using semi-static CDRX configurations, a mismatch between traffic arrival and the start time of ON duration can result in packet losses and lower QoS. For improving power savings, a mechanism to dynamically adjust the parameters of CRX configuration (e.g. CDRX cycle, ON duration) for aligning with XR traffic pattern can be useful. Ad-

ditionally, to address issues related to non-integer periodicities and jitter, the UE can be configured with multiple CDRX configurations associated with different traffic types and/or traffic patterns associated with the supported XR application.

4 – AT&T

When considering potential power consumption enhancements for XR, it is important for the network to be made aware of any necessary information from the device relevant for determining the appropriate tradeoffs between network/application performance and power consumption at the device.

5 – Apple Europe Limited

As some design issues/solutions for UE power saving and system capacity are intertwined, we provide answers to them together. Note due to the multiple flow nature of XR traffic in many XR use cases, it is not enough to introduce optimization targeting a single data flow (e.g. the video stream), which may not deliver UE power saving benefit for multiple data flow traffic. The introduced enhancements should be applicable to broad XR use cases. More specifically we have the following proposals:

Rel-18 NR enhancements for XR should be motivated by XR services' traffic characteristics, especially the multiple data flow aspects

· Specify enhancements in SPS/configured grant/DRX configurations to adopt to non-integer periodicity of XR traffic. It should be noted for multiple flow traffic, DRX configuration enhancement alone may not deliver substantial UE power saving gain.

· Evaluate and specify control signaling enhancements to adapt to time-varying packet size for XR traffic and multiple flow traffic.

· Specify CSI enhancements for faithful CSI measurements

· Support CSI/HARQ feedback enhancements to achieve efficient transmission and satisfy stringent latency requirement, which can continue from the Rel-17 URLLC CSI enhancement

· Study, identify and specify if needed, suitable protocol enhancements to efficiently enable the support of XR traffic characteristics based on Rel-17 studies in RAN1 and SA4.

· Identify and specify enhancements for end-to-end scheduling adjustments (in interaction with SA4)

Besides the above items, we think that XR applications will require both low latency and high throughput. We expect that radio protocol enhancements to support sub bearer (DRB) differentiation as well as how they are handled at L2, will be needed. Some special packets will need to be transmitted faster and more reliably than others. Packets that are superfluous (I.e.., stale) should not require the high reliability (e.g., the use of RLC AM) granted to other packets in the same bearer. We expect these enhancements will mainly impact RAN2.

6 – Asia Pacific Telecom co. Ltd

Considering that some of the XR/CG devices are wearable, power saving should be one of the key topics in Rel-18. The issues specifically for XR are jitter and mis-match of the monitoring occasions or periodicity if there is no enhancement on legacy C-DRX. More dynamic methods to adapt the C-DRX configuration(s), e.g., dynamically change the C-DRX parameters, dynamically switch the C-DRX configurations, are practical. In addition, whether the mechanisms introduced in the previous releases of power saving WI can be reused are worth to be discussed at first. For instance, DCP, DCI-based PDCCH monitoring adaptation, SSG switching, etc.

7 – China Mobile Com. Corporation

We think power saving techniques are crucial to XR (especially AR which are more prone to operate outdoors) services.

In our opinion, those bulky "helmet like" device in nowadays are not going to help XR service success. Instead, something lighter and easier is much better but such devices do not have enough battery, which requires power consumption techniques.

The promising areas are:

1. Methods to fit XR service periodicity with DRX periodicity & SPS periodicity
2. Methods to dynamically align/re-sync XR traffic and DRX cycle
3. Methods to align UL transmission

8 – DOCOMO Communications Lab.

We support to study it in order to prolong UE battery life for XR applications. We think leading WG can be RAN1 or RAN2 depending on detailed enhancements scope that we would work on in Rel-18.

9 – vivo Mobile Communication Co.

We support to study and specify the following power saving enhancement features for XR.

- Specify features to support adaptive configured periodic monitoring to match XR traffic period for power saving purpose, including adaptive DRX configurations/parameters, SPS/CG configuration relative to DRX cycle.
- Study and specify features to support low power WUS or enhanced PDCCH monitoring adaptation (based on Rel-17 progress)

Current DRX configurations are not suitable for XR traffic, and enhancement of DRX configuration for XR traffic is needed. One possible method is to extend the value of DRX cycle to the field of non-integer, such as 8.33ms, 16.67ms. However, the non-integer DRX cycle is not efficient and does not work well with the jitter effect of DL transmission. To solve this problem, DRX start offset adaptation to XR traffic considering jitter effects can be considered for DRX enhancement. One potential method of DRX start-offset adaptation can be dynamically triggered by DCI, such as DCI indicates a certain start-offset applying for the next DRX cycle.

Another consideration is that both DL receptions and UL transmissions are quite frequent for XR devices, e.g. DL video data reception and UL pose uploading. If XR device needs to receive DL data and transmit UL data at a short interval, there is no much time for UE to go into sleep for reducing the power consumption. Therefore, UL and DL transmission time alignment to avoid transmitting/receiving during DRX off stage can be considered for power saving enhancement, e.g., SPS/CG configuration relative to DRX cycle.

Impact of jitter for UE receiving DL transmission should also be considered since jitter will result in either increased power consumption or scheduling latency. One possible method to deal with the jitter effect is to extend the length/duration of DRX on-duration or increase the density of PDCCH monitoring to cover the jitter range. However, the power consumption will be sacrificed for the sake of reducing the scheduling latency. To handle the jitter, a low power wake-up signal (WUS) can be monitored by UE. Another method could be to flexibly adapt the PDCCH monitoring behaviour, e.g. between dense monitoring and sparse monitoring based on the traffic characteristic.

10 – Facebook

Due to the compact form factors, we think power consumption remain the most one of the most important aspects which require significant improvements for successful XR services in 5G system.

11 – HuaWei Technologies Co.

R15/16 C-DRX can be used for XR UE power saving. However, there are some critical issues when using C-DRX for XR traffic. Firstly, XR traffic is quasi-periodic with non-integer periodicities. The current DRX cycle values only support integer multiples of 1ms, which will result in mismatch between XR traffic and DRX OnDuration over time. Secondly, due to different delay caused by encoding/rendering and network transmission, there may be some jitter at the gNB for DL XR traffic, e.g., [-4, 4] ms, which may degrade the performance of CDRX. CDRX enhancements can be considered to address the periodicity mismatch and jitter of XR traffic.

Proposal: CDRX enhancements can be considered to address the periodicity mismatch and jitter of XR traffic.

12 – LG Electronics Inc.

Multiple DRX configurations should be considered for XR. Different types of packets can be transmitted in one packet stream, and traffic pattern may also be different depending on the types of packets. Dynamic adjustment of multiple DRX configurations is essential for XR operation.

13 – Lenovo Information Technology

Power saving techniques addressing non-integer [slot] XR traffic periodicity, variable size of arrival bursts, jitter in DL traffic and misalignment between UL traffic and DL traffic can be considered, such as CDRX enhancements, concentrating transmissions and receptions (e.g., HARQ-ACK can be sent close to UL pose information or a subsequent DL transmission). It is imperative to compare such power saving techniques with existing mechanisms including Rel-17 power saving techniques and gNB implementation/scheduling.

14 – Beijing Xiaomi Mobile Software

Reducing power consumption is one of the most important requirements of XR enhancements. An important characteristic of XR traffic is on the delay jitter of XR traffic. Potential solutions to address the periodicity mismatch can be considered if the effectiveness can be confirmed in XR SI study. Other power saving techniques for UEs in RRC_connected state can also be considered.

15 – Intel K.K.

Agree with the observation from InterDigital. Periodicity of XR traffic is 1/fps with a jitter component that is quite significant and variable in both standard deviation and range.

Hence, we are open to study CDRX enhancements to better match XR traffic characteristics e.g, periodicity.

16 – SHARP Corporation

We think power consumption considerations for XR are beneficial to save battery life of XR devices. Power saving by considering XR traffic can be considered.

17 – Spreadtrum Communications

We think there are 3 main issues for power saving:

1 The mismatch between slots and the fps, for 60fps, the gap between two frames is 16.67ms.

2 The data jitter and the DRX onduration configuration.

3 UE shall be triggered to DRX-off state quickly after transmission a group of packets.

18 – MediaTek Inc.

We do not expect any *XR-specific* work (other than **C-DRX-related**). Energy efficiency is best handled as generic item. Power saving will also *result* from better QoS handling throughout the system (see 1.1 and 1.2).

19 – NEC Corporation

Power saving is very critical to improve user experience, especially for the wireless XR headset devices, e.g., the AR glasses. The following enhancements can be considered:

1. Enhancement of CDRX to better fit the non-integer periodicity of XR packet arrival time.

2. Enhancement of DCI based power saving, to better address the unpredictable packet arrival time due to the jitter issues.

3. Packet/transmission alignment to prolong the inactive time.

20 – Sony Europe B.V.

Power consumption enhancements would be needed to support XR scenarios, especially C-DRX scheme enhancements, for example. the alignment of Video Frame Rate and scheduled C-DRX periodicity. and potential SSSG switching enhancements.

Related to [RAN93e-R18Prep-14], including UE power save topic.

21 – Ericsson LM

We support DRX enhancements study specific to XR in order to ensure features not to create extra latency when XR traffic is present. For example, matching with the non-integer periodicity or XR and support of multiple flows in one device can be investigated. Benefits and complexity should also be considered.

22 – Qualcomm Korea

XR device power consumption is one of the most important aspects which require significant improvements for successful XR services in 5G system. To support XR traffic in current NR system with reduced power, R15/16/17 power saving schemes such as CDRX, BWP, enhanced PDCCH monitoring (a.k.a SSS switching or skipping), etc. could be useful. Some of those features could be confiugred and used togehter to achive low power consumption for XR. However, due to the nature of XR traffic such as high bit rates, low latency/PER, and frequent UL transmissions, it is still quite challenging to support XR services in current NR system, there is room for further optimization for XR UE power saving. We think following areas could be further improved to address XR power issue.

- **Enhancements for CDRX mechanism to better support XR traffic**: R15/16 CDRX cycle values mismatch with XR DL frame arrival periodicity. This tempo mismatch problem can cause increased packet latency and lower capacity. This mismatch leads to higher power consumption by waking up more often and staying longer in awake state. Optimized CDRX mechanim providing matching CDRX pattern with XR traffic pattern can address this issue.

- **Alignment between DL&UL activities**: Given that XR has periodic/intese DL and UL traffic, it is quite helpful to make an alignment between DL Rx and UL Tx and reduce unncessary UE wake ups for UE power saving. Such alignment can be faciliated by the following enhancements.
  - CG/SPS/SR transmission timing / periodicity could be alinged with XR traffic (or CDRX On duration in an enhanced CDRX scheme as addressed above) to reduce UE power consumption.
  - Frequent uplink traffic with XR and Cloud Gaming prevents the UE from going into sleep and taking advantage of any possible power savings from gaps between the less frequent downlink traffic. Power consumption could be reduced by introducing uplink-only state, e.g., decoupling uplink tx activity and downlink PDCCH monitroing or adapting DL PDCCH monitoring for UL tx. This could be realized by DCI based signaling or duty cycle deterimined by the cadence of DL traffic.
- **Better jitter handling**: The jitter in DL XR traffic could cause random traffic arrival and it could potentially increase UE power consumption. Enhanced dense/fast WUS or improved PDCCH moinotirng could mitigate negative impcat of jitter on power and capacity.
- **UE assitance informaiton**: Any XR application related information available at UE side (e.g., UL traffic pattern) could be usef to help gNB for UL resource allocation.

Power-state for frequent UL traffic: Frequent uplink traffic with XR and Cloud Gaming prevents the UE from going into sleep and taking advantage of any possible power savings from gaps between the less frequent downlink traffic. Power savings can be realized if we introduce a state to serve such traffic with transitions to and from the state based on DCI, or based on duty-cycles determined by the cadence of downlink traffic.

23 – Qualcomm Korea

Evaluation results following the methodology developed under Rel-17 XR SI, it turns out that, in UMa case, UL is the bottle neck for coverage. This is true for both VR/CG and AR. Thus, UL coverage for pose and other data such as scene needs to be improved.

24 – Qualcomm Korea

Please disregard the above Qualcomm's comment regarding coverage. I have no idea how to delete it.

25 – Nokia Corporation

Power consumption was identified as one of the limiting factors for XR operation. From the current Rel. 17 SI we see that the current DRX configurations do not fit well for (i) the non-integer XR traffic periodicity, (ii) variable XR data rate and (iii) quasi-periodic XR periodicity. It is important to define support for: (i) adaptive configuration of DRX parameters, (ii) dynamic on-the-fly change of aDRX configuration, (iii) resynchronization of DRX cycle and XR periodicity due to periodicity mismatch.

26 – ZTE Corporation

The power saving schemes should consider the features in XR traffic. For DL video traffic, non-integer periodicity, time-varying packet size and jitter are the characteristics.

- Non-integer periodicity

For periodicity traffic, DRX is a good choice. However, since the DRX cycle is always an integer value, there is a mismatch between the DRX cycle and traffic, which affects the capacity. So dynamic change of DRX parameters to match the traffic can be considered.

- Jitter handling

Jitter will increase the difficulty in applying UE power saving techniques because the packet arrival time fluctuates around the periodicity benchmarks. If DRX is used and a packet arrives later than the DRX On, the packet may not have enough chance to be scheduled. To solve the late arrival of packet, an enhancement on DRX as well as dynamic change of parameters should be discussed.

27 – Guangdong OPPO Mobile Telecom.

The evaluation observation on power consumption are not available. And power saving solutions developed in from R16 to R17 can be a baseline. Some straightforward solutions motivated by XR characteristic, e.g. non-integer periodicity, can be considered on top of existing mechanisms.

28 – CATT

UE power consumption is the critical factor of XR user experience. Rel-16/17 UE power saving techniques had been evaluated and shown some power saving gain. The power saving techniques customized for XR service in Rel-18 would provide additional power saving gain.

29 – Samsung Research America

UE power consumption is always important but it is unclear what additional gains are achievable on top of Rel-17. Traffic arrivals with jitter that is in the same order as a nominal periodicity are best handled by dynamic grants. Nevertheless, evaluation of possible, additional to Rel-17, gains from new power savings mechanisms can be considered for video traffic as part of a Rel-18 SI.

1.4 Coverage

Please provide your views on work potentially needed on coverage ***specifically for XR*** using the feedback form below.

Feedback Form 4: XR-specific coverage considerations

1 – VODAFONE Group Plc

The R17 studies are ongoing, so the need for this is not yet known. However, Dense Urban and Urban macro seem more valuable to 3GPP than Indoor Hotspot scenarios (as WiFi is likely to be used indoors).

2 – Futurewei

Evaluations are yet to be performed in Rel17 XR evaluation SI, however preliminary evaluations show the UL being the bottleneck. Coverage enhancements in the uplink may be studied to bridge the gap.

3 – InterDigital

It is unclear if any coverage related enhancements specific to XR are necessary at this stage. Given that the Rel-17 SI for XR is still ongoing, any additional enhancements may be identified based on the outcome of the SI discussions.

4 – AT&T

Areas for potential enhancement include application awareness regarding the specific radio conditions (e.g. coverage vs. congestion limitations). Also RAN awareness of critical application characteristics to ensure appropriate resource allocation (e.g. prioritization of certain packets/channels especially in the UL). Transitions between scenarios (e.g. outdoors to indoors) can be emphasized for optimization.

5 – AT&T

Areas for potential enhancement include application awareness regarding the specific radio conditions (e.g. coverage vs. congestion limitations). Also RAN awareness of critical application characteristics to ensure appropriate resource allocation (e.g. prioritization of certain packets/channels especially in the UL). Transitions between scenarios (e.g. outdoors to indoors) can be emphasized for optimization.

6 – Apple Europe Limited

XR traffic flows can pose stringent requirements on latency & reliability, and high throughput. Repeated transmissions (for PUCCH/PUSCH) is a major method for coverage enhancement. With latency requirement, the number of allowed repeated transmissions of PUCCH/PUSCH can be limited. It remains to be seen how the coverage enhancement goal can be reconciled with other already challenging design goals.

7 – Asia Pacific Telecom co. Ltd

We don't see the urgent need to enhance the coverage aspects specifically for XR at least at this stage since there is no obvious use cases. It's better to either wait for more progress on the R-17 SI evaluation or de-prioritize this topic.

8 – China Mobile Com. Corporation

Not sure if there's any XR specific coverage issue, since UL coverage issue may be common to all cases. Prefer to wait for more outcomes from R17 SI.

9 – DOCOMO Communications Lab.

We support to study it in order to improve capacity for XR applications. We think leading WG can be RAN1 and secondary WG can be RAN2.

10 – vivo Mobile Communication Co.

We are open for XR specific coverage enhancement depending on the output of XR SI study.

11 – DOCOMO Communications Lab.

We are sorry for our incorrect input above. We would like to correct our view for coverage enhancements as follows: Necessity for coverage enhancements is not clarified as evaluations have not been performed in Rel-17 XR SI. We are open to discuss whether it should be included in the WI or not.

12 – HuaWei Technologies Co.

There are some proposals related to coverage enhancement in Rel-18 workshop. We understand these aspects are rather generic enhancements and are not XR specific, therefore it can be discussed in the coverage area to avoid repeated studies.

13 – LG Electronics Inc.

We are skeptical about including the coverage enhancements in Rel-18 XR. No outstanding coverage issue specifically for XR has been found until now. We can still rely on the outcome of Rel-17 XR_eval study, but RAN1 has just agreed on the evaluation methodologies for XR coverage which is optional and plan to collect results starting from the next meeting in October. We are okay to come back to this topic later, but at the moment, there is no reason to include the XR-specific coverage in Rel-18 XR.

14 – Lenovo Information Technology

Coverage enhancement to provide better service experience at cell edge is beneficial for XR traffic but it is better to be handled in the uplink enhancement WI (covering coverage enhancement) to avoid any overlapping discussion.

15 – Beijing Xiaomi Mobile Software

The potential enhancement in this area may depend on the study results of XR SI.

16 – Intel K.K.

We are also not quite sure if any coverage related enhancements specific to XR are necessary at this stage.

17 – Spreadtrum Communications

Coverage is less important relatively than other topics. Since evaluation is ongoing in RAN1, so we think the coverage issue shall be postponed.

18 – MediaTek Inc.

We do not expect any *XR-specific* solution. Coverage should be treated in a generic manner – of particular importance are the outdoor-to-indoor coverage to ensure XR/CG will be available where consumed (Rel-17 should be sufficient), and **LLeMBB-capable Sidelink** to ensure efficient data communication in personal-area networks that are typical of XR/CG applications

19 – Ericsson LM

We do not see any critical motivation to study coverage enhancement specific to XR.

20 – Qualcomm Korea

Evaluation results following the methodology developed under Rel-17 XR SI, it turns out that, in UMa case, UL is the bottle neck for coverage. This is true for both VR/CG and AR. Thus, UL coverage for pose and other data such as scene needs to be improved.

21 – Nokia Corporation

We see this work to take place in the uplink enhancements WI. Current Rel 17. SI continues with the evaluation of coverage. However, from the preliminary evaluations we see the following could be relevant for XR: (i) coverage enhancements in power domain: and (ii) potential PUCCH enhancements (if there would not be coverage related work done in uplink enhancements)

22 – Guangdong OPPO Mobile Telecom.

The evaluation observation on coverage are not available. The need and potential solution are not clear.

23 – CATT

XR coverage has not been fully evaluated. The NR coverage enhancement techniques should be used for XR services before any further enhancement.

24 – Samsung Research America

It is unclear what about coverage enhancements is XR-specific (or specific to any particular application), or why the Rel-17 mechanisms are not sufficient.

1.5 Capacity

Please provide your views on work potentially needed on capacity ***specifically for XR*** using the feedback form below

Feedback Form 5: XR-specific capacity considerations

1 – VODAFONE Group Plc

The R17 studies are ongoing, so the improvements that might be achievable are not yet known. However, Dense Urban and Urban macro seem more valuable to 3GPP than Indoor Hotspot scenarios (as WiFi is likely to be used indoors).

2 – Futurewei

Capacity enhancements proposed from companies in ongoing Rel17 SI may need to be carefully evaluated as potential enhancements for XR. The standards impact should also be considered for any capacity enhancement.

3 – InterDigital

The existing CG and SPS approaches based on semi-static configuration of fixed periodicities and grant sizes are not adequate to support XR traffic with variable packet sizes, high data rate, and low latency requirements. As identified during Rel-17 SI, scheduling techniques which are agnostic to the remaining delay for delivering PDUs belonging to the same video frame, for example, can result in low user satisfaction and reduced capacity. In this regard, techniques which enable efficient and dynamic adaptation of SPS/CG configurations can be beneficial. For handling the transmission of variable PDU sizes associated with large video frames, mechanisms for combining CG and dynamic grants can be considered. Additionally, aligning CSI reporting with periodicities of XR traffic transmission may also be beneficial for capacity.

4 – AT&T

Areas for potential enhancement include application awareness regarding the specific radio conditions (e.g. coverage vs. congestion limitations). Also RAN awareness of critical application characteristics to ensure appropriate resource allocation (e.g. prioritization of certain packets/channels especially in the UL). Both outdoor and indoor scenarios should be considered.

5 – Apple Europe Limited

As some design issues/solutions for UE power saving and system capacity are intertwined, we provide answers to them together. Note due to the multiple flow nature of XR traffic in many XR use cases, it is

not enough to introduce optimization targeting a single data flow (e.g. the video stream), which may not deliver UE power saving benefit for multiple data flow traffic. The introduced enhancements should be applicable to broad XR use cases. More specifically we have the following proposals:

Rel-18 NR enhancements for XR should be motivated by XR services' traffic characteristics, especially the multiple data flow aspects

· Specify enhancements in SPS/configured grant/DRX configurations to adopt to non-integer periodicity of XR traffic. It should be noted for multiple flow traffic, DRX configuration enhancement alone may not deliver substantial UE power saving gain.

· Evaluate and specify control signaling enhancements to adapt to time-varying packet size for XR traffic and multiple flow traffic.

· Specify CSI enhancements for faithful CSI measurements

· Support CSI/HARQ feedback enhancements to achieve efficient transmission and satisfy stringent latency requirement, which can continue from the Rel-17 URLLC CSI enhancement

· Study, identify and specify if needed, suitable protocol enhancements to efficiently enable the support of XR traffic characteristics based on Rel-17 studies in RAN1 and SA4.

· Identify and specify enhancements for end-to-end scheduling adjustments (in interaction with SA4)

Besides the above items, we think that XR applications will require both low latency and high throughput. We expect that radio protocol enhancements to support sub bearer (DRB) differentiation as well as how they are handled at L2, will be needed. Some special packets will need to be transmitted faster and more reliably than others. Packets that are superfluous (I.e.., stale) should not require the high reliability (e.g., the use of RLC AM) granted to other packets in the same bearer. We expect these enhancements will mainly impact RAN2.

6 – Asia Pacific Telecom co. Ltd

Given that the legacy CG/SPS mechanism/parameter may not fully meet the XR traffic characteristics, e.g., regarding the periodicities, TB size, repetition, etc. Some enhancments on top of the multuple CG/SPS configurations are useful. Furthermore, the UE couild provide assistance information of its preferred/expected traffic pattern to assist the network for better configurations of CG/SPS.

7 – China Mobile Com. Corporation

No XR specific issue is identified so far. If there is further capacity need, this can also be done in other WI, like MIMO enhancement. Prefer to wait for more outcomes from R17 SI.

8 – DOCOMO Communications Lab.

We support to study it in order to improve capacity for XR applications. We think leading WG can be RAN1 and secondary WG can be RAN2.

9 – vivo Mobile Communication Co.

We think following enhancements on capacity for XR can be considered.

- Study XR-specific SPS and CG to accommodate XR traffic.
    - Dynamic adaptive CG and SPS transmissions according to XR traffic characteristics
- Study CSI measurement/reporting enhancement for XR traffic.

- CSI reporting, beam management can be triggered by XR-specific UL transmission.

Since XR traffic is quasi-periodic, SPS and CG transmission for XR traffic is a particularly suitable method for data transmission, which can reduce the overhead of control signalling. However, the periodicity configuration of current SPS and CG does not support the non-integer period of XR traffic, it means that the SPS/CG period and real XR traffic period might mismatch over time. Secondly, due to the scheduling-related parameters (e.g. TDRA, FDRA, MCS) are configured semi-persistently, the amount of data that can be transmitted at one SPS or CG period is fixed and it cannot apply to XR traffic with the characteristic of varying packet size. Hence, dynamic adaptive CG and SPS transmissions according to XR traffic characteristics is needed.

In NR Rel-15/16/17, high data rate transmission with tight latency was not taken into account for eMBB or URLLC. To well support XR traffic in NR, or not, CSI measurement should be as accurate as possible, and CSI reporting should be done in time or even in advance, especially for retransmission. For XR service UE events like UL pose update may be triggered prior to DL video traffic. Hence, it could be beneficial that some channel measurement (e.g. CSI reporting, beam management) can be triggered by the UE event for XR specific UL transmission.

10 – HuaWei Technologies Co.

As identified in RAN1 XR study, there can be multiple data streams with different traffic characteristics and QoS requirements for a given XR application, for example, I-frame and P-frame, FOV stream and omnidirectional stream, video/depth and pose/control, video stream and audio stream. These data streams actually have different priorities, some of them directly dominate the end user experience, while some of them do not. Treating them equally in a single QoS flow may result in over-protection for non-important packets and potential waste of radio resources.

To accommodate the characteristic of multiple data streams in XR services, an E2E layered QoS mechanism is seen helpful. We propose the below with involvement of SA working groups.

Proposal: Specify E2E layered QoS mechanism to handle multiple data streams per XR application to enhance the capacity.

- Identify differentiation of priorities in a single QoS flow or the association between multiple QoS flows belonging to one XR service.

- specify efficient packet dropping and priority handling.

If companies think the above is relevant to application awareness at RAN, we are also open to discuss where to put it. In general we understand the purpose to discuss application awareness at RAN is to let RAN have more efficient radio resource management/scheduling, which results in capacity enhancements. This is why we think it is more appropriate to discuss here.

11 – LG Electronics Inc.

Together with power saving enhancements, we think the capacity enhancements is important to support XR in 3GPP. The application or traffic awareness can be leveraged to improve XR-specific capacity enhancements.

12 – LG Uplus

Capacity is also important factor for XR services where not many users can be served with limited cell capacity. AR/VR real time streaming need 50 60Mbps per a UE which is 1Gbps per 15 20 UEs simultaneously. Given this situation, like we emphasized, the application awareness and adjustable solution for each application with frame type is effective direction to serve XR services efficiently.

13 – Lenovo Information Technology

Capacity enhancing techniques addressing XR traffic characteristics (e.g., variable packet arrival rate: packets coming at 30-120 frames/second with some jitter, also packets having variable and large packet size, multiple traffics of different QoS requirements in a quasi-synchro nous manner) can enable more efficient (e.g., in terms of satisfying XR service requirements for a greater number of UEs) XR service delivery. In our view following can be considered:

· SPS/CG improvements including semi-static and dynamic mechanisms to accommodate variable packet arrival and size,

· dynamic scheduling improvements including UE assistance information (e.g., to help gNB decide whether to schedule retransmission of a TB with certain QoS/latency requirements)

· Some level of application awareness at RAN, such that gNB is able to distinguish and intentionally drop low importance data packet in case of QoS degradation.

It is imperative to compare such capacity enhancing techniques with existing mechanisms including gNB implementation/dynamic scheduling.

14 – Beijing Xiaomi Mobile Software

The potential enhancement in this area may depend on the study results of XR SI.

15 – Intel K.K.

Techniques to improve capacity is expected to be the primary focus for XR. Considering variable packet sizes, multiple streams, it seems beneficial to study techniques so that active SPS/CG configuration(s) could match XR traffic characteristics, such as periodicity. Multiple PDSCH/PUSCH scheduling framework being developed as part of Rel17 Above 52.6 GHz agenda can also be leveraged.

16 – SHARP Corporation

Enhancements on SPS and CG can be considered to improve to transmit different sized data while reducing latency and considering jitter.

17 – Spreadtrum Communications

We think the detail enhancement of capacity shall be discussed based on the evaluation of RAN1. From high layer point of view, some QoS related enhancements are useful to improve the the capacity of application.

18 – MediaTek Inc.

We do not expect any XR-specific solution. As indicated above, XR/CG will put a high pressure on system capacity. With XR/CG poised to be a “killer-app” it is vital the system be improved to meet the expected demand. To this end, spectrum resources in **FR2, unlicensed** are critical. Enhancements in terms of **DC and CA** should be sought. Capacity enhancement will also *result* from better QoS handling throughout the system (see 1.1 and 1.2).

19 – NEC Corporation

The traffic characteristics of XR services (e.g., the non-integer periodicity, jitter of packet arrival time, delay budget and the large and varying packet size) are quite different from traditional eMBB and URLLC, and should be considered in the enhancement for XR. To enhance the capacity of XR services, the following enhancements can be considered:

1. Enhancement of scheduling to better fit the characteristics of XR services, e.g., multi-PDSCH/PUSCH scheduled by single DCI, multi-TB transmission per SPS/CG periodicity to address the large and varying packet size issues.
2. Enhancement of SPS/CG to address the non-integer periodicity and jitter issues.
3. Enhancement of CBG based transmission, for both dynamic and semi-persistent scheduling.

20 – Sony Europe B.V.

Capacity may be a bottleneck with the combination of URLLC and eMBB traffic scenarios like XR This could potentially be solved with e.g.

- Improved robustness of transmissions, including CSI enhancements, minimization of re-transmissions
- Smaller cells, higher density of cells.
- Limited no of users
- Indoor coverage

But may be more related to network/ cell planning.

21 – Ericsson LM

We support capacity enhancement study as identified in many contributions in Rel-17 by considering the XR traffic characteristics, e.g. periodic and varying size of a large video frame with the mixture of small pose packets. Several important areas can be identified as examples: enhanced multi-TB scheduling for high bit rates, CG/SPS enhancement, enhanced buffer status report, link adaptation. Benefits and complexity should also be considered.

22 – Qualcomm Korea

- SPS/CG/prescheduled PUSCH enhancements to better support XR DL/UL traffic: SPS and CG are designed for low data rate application but not optimized for XR with high data rate with variable packet sizes. SPS/CG can be further improved to accomodate these aspect of XR traffic and be more flexible in adaption to link condition change to improve capacity.
- Delay-aware scheduling could increase XR capacity. Detailed scheduling policy and/or algorithm are up to implemention, but it can be faciliated by enhancements of specifications enabling application awareness, e.g., awareness of ADU and awareness of the burst that constitute multiple ADUs, as discussed in our comments above.
- With fluctuating inter-cell interference, the selection of appropriate MCS may be challenging. Approaches based on channel state feedback may be inadequate due to the processing delays involved, especially when the delay-budget is tight. Inter-cell interference coordination among different gNBs could increase XR capacity.
- As stated in Section 1.2, with multiple users in the same cell using XR applications, the capacity may depend on whether the frame arrivals of these users are aligned with each other, or staggered relative to each other. Synchronized arrivals may increase the burden on the cell to deliver more bytes within the same delay budget. Mechanisms that enable staggering of user traffic patterns can improve capacity. This may require mechanisms for the RAN to interface with the application server.
- As discussed in Section 1.2, in certain scenarios, the RAN may leverage XR traffic characteristics to improve XR performance. For example, the RAN may leverage XR application information such as XR viewport or pose information to predict the channel and UE/gNB beam changes so that the necessary beam management updates, measurement configurations or resource allocation may be triggered ahead of time.

- Application of Network Coding (NC) in RAN could be used to improve XR capacity. Controlled amount of redundancy added upfront in case of NC could help XR traffic to fulfil latency and reliability requirements without having to resort to HARQ/RLC retransmissions that would increase the delay of packet reception, especially in cases of blocking.

23 – Nokia Corporation

We support the capacity related enhancements. The following areas can further improve capacity by taking into account the XR specifics:

· RAN traffic awareness (Application Data Unit (ADU) for traffic differentiation

· Flexible SPS/CG to support variable frame rate/size and non-integer periodicity

· L2 Packet dropping and prioritization/aggregation

24 – ZTE Corporation

In our company's opinion, we consider the following aspects for capacity enhancement:

1. Support CSI enhancements for faithful CSI measurements e.g. the measurement and reporting of delta MCS

2.Support CSI/HARQ feedback enhancements to achieve efficient transmission and satisfy stringent latency requirement,e.g., enhancement of CBG-based re-transmission.-

3. Support considering XR -coexistence with other existing service, e.g., uRLLC, eMBB, to improve capacity by inter- UE multiplexing, including, e.g. finer granularity preemption. Intra-UE multiplexing under multiple streams can also be considered.

4. We also support UL can transmit triggering/assistance information to trigger/assist DL transmission to improve capacity performance by reducing radio resource, decreasing the PDSCH transmission times, etc. As we mentioned in Q2, UL assisted information, UL triggered DL transmission can be considered in this topic.

5. Due to the requirement of low latency and high reliability of XR traffic (and also URLLC traffic), the ARQ functionality in RLC layer needs to be closed or limited which leads to insufficient reliability. According to 5QI tables, there are many XR and URLLC traffic with high reliability, e.g. PER from 10-3 to 10-8. As a result, a possible alternative solution to improve the reliability is network/packet coding in PDCP layer or RLC layer or a sub-layer between PDCP layer and RLC layer. In the first example, a frame/P fame/I frame can be segmented into K source sub-packets with equal size, additional M redundancy sub-packets are generated by network coding (erasure coding), wherein all N=K+M sub-packets can be transmitted with a joint consideration of diversity and capacity, K sub-packets out of N sub-packets suffice to reproduce the original K sub-packets.

In the second example, the PDCP duplication has been specified in the scenario of dual-connection, selectivity diversity instead of combination diversity can be supported by the legacy PDCP duplication, which leads to insufficient usage of redundancy information and limited reliability performance. Thus we support the study of PDCP duplication enhancement based on network coding, which can obviously derive combination diversity gain and improve reliability. Note that capacity can be improved if the PER requirement is relaxed according to XR simulation results of same PDB and different PER requirements.

25 – Guangdong OPPO Mobile Telecom.

The evaluation observation on power consumption are not available. But from initial results, the capacity for XR is a critical issue. In addition, application awareness and capacity are intertwined. Capacity improvement depends on radio process enhancement tailored by XR characteristics significantly. To improve capacity, the following technics fit for XR can be considered:

SPS/CG enhancement, including non-integer periodicity, jitter, multi-PDSCH/PUSCH scheduling for large packet and adaptive SPS/CG for various packet transmission

PDCCH enhancement, including non-integer search space configuration and multi-PDSCH/PUSCH scheduling for large packet

Inter UE collision, including power control enhancement for configure grant.

26 – CATT

The potential NR enhancement in supporting periodic XR services with high data rate and lower latency requirements should be considered to increase the system capacity and improve the user experience. The delay jitter caused by XR packet transport through the network would make the design of periodic service even more challenged. The enhancement of DL SPS, UL CG, and dynamic grant should be considered in order to improve the resource utilization to satisfy the QoS requirements of XR service.

27 – Samsung Research America

Application awareness at RAN is expected to provide the vast majority of potential capacity enhancements. We consider dynamic grants to be a natural solution to address jitter and, considering the large data packets for XR and the small number of UEs to be scheduled per MO, control overhead is not an issue. Care should be taken to avoid a possible SI being consumed by questionable and corner-case optimizations that may not lead to meaningful outcomes.

1.6 Mobility

Please provide your views on work potentially needed on mobility ***specifically for XR*** using the feedback form below

Feedback Form 6: XR-specific mobility considerations

1 – VODAFONE Group Plc

Would mobility for XR be really any different to that for an eMBB device? At the moment, no XR specific mobility objectives seem obvious.

2 – Futurewei

It is not clear what are the XR specific mobility considerations in addition to the general mobility enhancements discussed in the other email thread. Furthermore, RAN2/3 involvements are needed for mobility aspects.

3 – InterDigital

XR applications such as AR may require supporting high data rate and low latency transmissions during mobility. In this regard, the enhancements for mobility should strive to minimize any interruptions that may result in degrading user experience. Possible mobility enhancements specific to XR, including in traditional HO and CHO, may consider awareness of the transmission status of PDUs associated with video frame for controlling the timing of HO execution.

4 – AT&T

Areas for potential enhancement include application awareness regarding the specific mobility conditions of XR users and L1/L2 inter-cell mobility enhancements. In addition, considerations of potential DL/UL imbalance during mobility scenarios could be of particular interest for XR users since both directions need to be optimized considering the overall end-to-end user experience.

5 – AT&T

Areas for potential enhancement include application awareness regarding the specific mobility conditions of XR users and L1/L2 inter-cell mobility enhancements. In addition, considerations of potential DL/UL imbalance during mobility scenarios could be of particular interest for XR users since both directions need to be optimized considering the overall end-to-end user experience.

6 – Asia Pacific Telecom co. Ltd

Extension of the multi-TRP/beam for L1/L2 inter cell mobility, CHO, and/or DAPS can be the baseline. However, we are wondering how to split the scope of the mobility enhancement between the R-18 XR WI and the R-18 Mobility WI.

7 – Apple Europe Limited

It is important to set a reasonable scope for XR enhancements. QoS enhancements, Application awareness at RAN, UE power saving and system capacity are already very substantial topics requiring many discussions. Similar to the situation for coverage enhancement, considering mobility enhancements for very high UE speed can complicate design due to other already challenging design goals. Not including mobility enhancements under the Rel-18 XR WI is preferred.

8 – China Mobile Com. Corporation

When considering the scenario, VR devices may not have stringent requirement on mobility because most of VR activities happen indoor. It is AR devices that may have mobility scenario. Consequently, the reason for further mobility enhancement needs more justification. Prefer to wait for more outcomes from R17 SI.

9 – DOCOMO Communications Lab.

It is not clear whether mobility enhancements are needed for XR in addition to the general mobility enhancements. It should be discussed in separate WI, i.e., Mobility enhancements WI

10 – vivo Mobile Communication Co.

We think XR specific mobility enhancement can be studied depending on the output of XR SI study. Other non XR specific mobility enhancement can be studied in a separate SI/WI.

11 – HuaWei Technologies Co.

Similar to coverage enhancements, in our view, the mobility enhancements for XR proposed by companies in Rel-18 workshop can be handled in the mobility area rather than in XR.

12 – LG Electronics Inc.

XR-specific enhancements are not clear yet. Whether and where to consider the mobility enhancements for XR can be discussed later once the XR mobility evaluation is performed in Rel-17 XR_eval SI and the corresponding observations are drawn from it. No consensus has been made until now on the evaluation methodologies for XR mobility.

13 – Lenovo Information Technology

Mobility enhancement to provide high throughput during mobility procedure is beneficial for XR traffic but it is better to be handled in the dedicated mobility WI to avoid any overlapping discussion.

14 – Beijing Xiaomi Mobile Software

The potential enhancement in this area may depend on the study results of XR SI and scope of mobility enhancement.

15 – Intel K.K.

HO enhancements to support consistent data rate during mobility can be considered. However, we think this can be handled in the RAN2 Mobility enhancement agenda.

16 – MediaTek Inc.

We do not expect any XR-specific solution. **FR2 mobility** needs **generic improvements** to guarantee seamless mobility with any service, but importantly XR/CG services as well.

17 – Spreadtrum Communications

The traffic pattern of XR session shall be considered in the enhancement of mobility procedure.

18 – Sony Europe B.V.

Mobility will surely have impact also on XR use cases, but can be captured in relation to Mobility enhancements discussion [RAN93e-R18-03], and maybe related to RAN93e-R18-16], others.

19 – Ericsson LM

We can study enhancements to mobility procedures taking XR-specific requirements into account, on, e.g., interrupt and sustainable data rates. **However, in our view mobility related enhancements should be addressed in a mobility specific WI, and not in XR.**

20 – Qualcomm Korea

Maintaining ”good” XR performance during mobile scenarios is important, therefore, mechanisms that faciliate continuity of services during handover would be beneficial. One of such mechanisms is the 3GPP Rel-16 5G NR Dual Access Protocol Stack (DAPS) handover (HO) feature which facilitates zero ms interruption during handover scenarios. This Release 16 feature maybe useful for XR mobility support, however, the feature was mostly developed for FR1 non-Carrier Aggregation (i.e. non-CA) scenarios, therefore, FR1 extensions to CA scenarios and support for FR2 would be required. Some of the FR2 extensions required to support XR include:

- Support for beam management and spatial division multiplexing during handover.

- Support for beam prioritization during collision between communication between the UE and the source and target cells.
- Support for Carrier Aggregation or Multi-TRP features at handover without explicit carrier activation/deactivation.

21 – Nokia Corporation

We are supportive for mobility related work for XR, but mobility discussion should be in a separate mobility work item. The following areas can be considered as potential enhancements for mobility and which are vital for XR type service:

· Robust L1/L2-centric inter-cell mobility to reduce handover interruption time close to 0 ms without DAPS (due to DAPS complexity).

· Solution(s) that reduce handover interruption time close to 0 ms in both DL and UL for intra-frequency FR2-FR2 scenario (for which DAPS is not specified), and improve the end-2-end UL latency in DAPS handover.

Enhancements for CHO handover.

22 – Guangdong OPPO Mobile Telecom.

Comparing with general mobility enhancement, XR specific enhancement is not clear

23 – CATT

The handover delay in the range of 50-100 ms would force several periodic XR packets to drop. However, the evaluation of the impact of UE mobility to the XR services had not been considered in XR study. We need to have the full evaluation of mobility impact to XR service before considering any enhancement.

2 Intermediate round - now closed

2.1 Potential areas of work on KPIs and QoS;

1. Enhanced granularity for QoS, frame level QoS and handling, ADU-based QoS;

2. XR-specific QoS parameters

3. Synchronization of QoS flow handling belonging to the same XR service association;

4. System level KPIs;

5. KPIs reflecting true end-user experience;

Note: Close cooperation is needed with SA2 and SA4

Feedback Form 7: Feedback on the 5 areas for KPIs and QoS described above

1 – Futurewei

The issues (1,2,5) raised are out of RAN expertise and it may mainly be SA2 and SA4 work. Therefore, it is not clear how it will impact RAN work. System level KPIs should follow the R17 study item outcomes. It is not clear what other system level KPI is proposed here. In addition to studying new KPI/QoS parameters for XR applications, mechanisms to support/enforce KPI/QoS on UL should also be looked into, e.g., active queue management of DRBs, N:M mapping from QoS flow to DRBs, and congestion condition exposure to rate-adaptive multimedia applications. On side note, a summary of the proposals was not provided by the moderator. It would be more beneficial if such summary is provided.

2 – Samsung Research America

We support further coordination with SA2/SA4.

3 – China Mobile Com. Corporation

All five areas can be further studied and specified if necessary. Coordination with SA WGs is needed after the completion of R17 XR SI, and in our opinion at least bullet 1 and 5 can be foreseen to be included for coordination.

4 – Verizon UK Ltd

Agree that all should be further studied and futher coordination with SA is needed. Some of the KPIs we like for XR include latency (consistence), jitter, and reliability.

5 – ZTE Corporation

We would like to reflect XR coexistence with other traffic given the consideration on commercial viability. It can either be a separate bullet or included as an example to any of the bullets listed

6 – Facebook

We agree the need to closely collaborate with SA2/SA4. On XR/Application-related KPIs/QoS should be under SA4. However, the mapping between Application layer QoS and RAN layer parameters and tradeoff probably need some joint discussion. We also agree the need on further discussion and enhancement on RAN adaptation to the XR-application. In particular, SDAP could be enhanced for the functions.

7 – CATT

XR QoS and KPI in RAN1 XR study had been based on the new 5GI values for XR specified by SA2/SA4.

8 – Apple Europe Limited

On Item 1 & Item 3, from companies' inputs, frame level QoS is about creating linkages among packets in the same media flow (e.g. the video stream), so the linked packets can be treated together; ADU-based QoS is about creating linkage among linked packets from different media flows (e.g. packets for a video frame and packets for the audio stream) so application can utilize them together assuming their timely delivery. Related work would span both RAN, SA and application also. SA's study is quite key here.

If some mechanism is provided so the 5G network can identify packets from different data flows belong to the same ADU, then core network and/or radio network can act on the provided information. Broadly, either core network or radio access network or both core network/radio access network can be enhanced to provide the needed improvements. Assume the enhancements are found useful & feasible, e.g. from SA's study, or joint SA/RAN study, what should be included under RAN and what should be included in SA, and the timeline should be discussed.

On item 3, XR-specific QoS parameters such as those for AR should be considered for the current QoS framework, note this does not depend on the discussion of item 1 or item 3.

On item 4, by KPIs, our understanding is the four KPIs mentioned in Rel-17 XR SID (UE power saving, system capacity, mobility and capacity). It may be good to first clarify the intended meaning for this item for companies to provide inputs.

On item 5, see our comment for item 4. We understand some companies propose XR quality index. Note such discussion is not within RAN1's expertise. It should be clarified where the KPIs reflecting true end-user experience should be studied in RAN or SA.

9 – InterDigital

On KPIs and QoS, we support areas (1), (2) and (3) identified by the moderator for Rel-18 work on XR. In particular, potential enhancements related to areas (1) and (2), including identifying and handling data transmission at different QoS granularities in UL/DL are beneficial for improving both capacity and power consumption. On area (3), ensuring synchronized delivery of data in different QoS flows (e.g. data in all associated QoS flows arrive within a relative latency window) is essential for meeting application layer QoS requirements. On area (4), while it is unclear which system level KPIs would be needed, the KPIs applied in the Rel-17 SI (e.g. percentage of satisfied UEs) can be considered as the starting point for further refinement. On area (5), it may be challenging to define and enforce a KPI which can precisely reflect user experience given the presence of multiple objective/subjective impacting variables (e.g. PDB/PER of video frames, tolerance of user when using 60fps instead of 120fps). We also support coordination with SA2 and SA4 for identifying the KPIs and QoS parameters (e.g. latency, reliability) which are expected to be enforced on E2E basis.

10 – vivo Mobile Communication Co.

We support 1, 2, and 3.

We think not only SA2 and SA4 work are needed for these issues, RAN is also involved. These enhanced KPIs and QoS information needs to be delivered to RAN. Hence, RAN can further study potential improvement based on the XR-specific QoS, e.g., adaptive scheduling

For system level KPIs, it is not clear and more clarifications are needed.

For KPIs reflecting end-user experience, in our point of view, we can leave it to SA4 at this stage.

11 – Intel K.K.

We agree in principle on the need for XR specific enhancements for at least items 1), 2). However, we think coordination with SA2/SA4 is needed, perhaps after completion of Rel17 XR SI, before we confirm the above proposals

12 – LG Electronics Inc.

We are generally ok with moderator's suggestion, and agree that the QoS and KPIs need close coordination with SA2/4.

But, bullet 3 is related to XR traffic identification, and propose to move it to 2.2.

13 – Lenovo Information Technology

In general, we are fine with the potential areas. It could be better to add 'RAN supports..' for each bullet to distinguish the work in SA group, e.g. RAN supports enhanced granularity for QoS, frame level QoS and handling, ADU-based QoS.

14 – HuaWei Technologies Co.

We think 1, 2, 3 and 5 are the major aspects we need to look into. In addition, as also some other companies commented, 1 and 3 are somehow related to application awareness and capacity enhancements, e.g., enhanced granularity for QoS, frame level QoS and handling, ADU-based QoS. Thus we see they are quite relevant and need to be discussed jointly.

15 – Asia Pacific Telecom co. Ltd

All the items listed by the moderator can be further studied in accordance with the cooperation with SA2, SA4 by involving RAN1 R-17 XR SI evaluation.

16 – DOCOMO Communications Lab.

We support to study the listed potential enhancements for KPIs and QoS and agree that coordination with SA2 and SA4 is needed.

17 – Nokia Corporation

In general, we support the potential areas of work on KPIs and QoS. We have a clarification question related to bullet 4 and 5. What is the difference between these two KPIs?

18 – Spreadtrum Communications

We support 1, 2 and 3. It is too complex to realize 4 and 5

we

19 – Spreadtrum Communications

We think 4 and 5 is complex, especially 5.

20 – Beijing Xiaomi Mobile Software

Many of the above working areas are out of scope of RAN. SA input is necessary to decide the final work scope.

21 – MediaTek Inc.

WE support 1, 2 and 3

22 – MediaTek Inc.

(and 4 :)

23 – Fujitsu Limited

We support 1, 3, 4. Some considerations are provided below.

2/ We are not sure if symbol-level periodicity is needed for XR-type traffic, since, according to our best knowledge, the time scale of application layer w.r.t the XR-type traffic processing is ms level.

24 – Fujitsu Limited

Sorry - please discard the comment above - here is the update

1/ Frame-level QoS seems to be challenging. If this is studied, this would be middle-term QoS metric e.g. tens of ms.

3/ The wording seems to be SA2/4-specific. What's important in RAN is DRB handling. The proposal can be updated like "Synchronization of QoS flow handling belonging to the same XR service association and corresponding DRB control"

25 – LG Uplus

We are fine with the proposed 5 areas of work

26 – VODAFONE Group Plc

we support work on this area, along with SA2/4 co-operation. If 3 is "between different UEs" then this is likely to be too complex.

27 – Guangdong OPPO Mobile Telecom.

Generally, this topic is closely related with SA2 and SA4, we support further coordination with SA2/SA4. Among these technical items, we support 2 and 4 due to they have been identified in R17 XR study item. For item 2, XR-specific 5QI values, e.g. {PDB=10ms, PER=1%}, can be added on top of existing 5QI list. For item 4, the number of UE satisfying traffic requirement, e.g. PDB and PER, can be a KPI for system performance. For item 1, enhanced granularity can be considered but one of frame level QoS and ADU-based QoS is enough, we do not think we need to support both solutions. For item 3, the related evaluation is not performed extensively, so the benefit from item 3 is not clear. We prefer to wait for more progress on the R17 SI. For item 5, KPI reflecting end-user experience is not clear for us.

28 – Qualcomm Korea

On #1, it is better to combine frame level QoS into the more generic ADU-based QoS. Also, it is better to separate out ADU-based QoS from "Enhanced granularity for QoS".

On #2, we agree that QoS parameters can be enhanced to take into account specific characteristics of XR flows.

On #3, the mapping of XR traffic of a single user to different flows needs to be studied before synchronization across flows. The requirement behind this item and any additional work required need to be studied further.

On #4 and #5, we agree that we should use KPIs that will better reflect the XR application and user experience. We are open to discussion on System level KPIs that would be beneficial in the study.

29 – Ericsson LM

We see all items listed are mainly handled by SA2, e.g., new 5QI values so that it would not be the main scope of RAN. As we proposed in 2.2 application awareness, it will be more efficient for RAN to focus on studying what specific information from applications or Core are needed and how to use it. Then, SA2 can study the impact of KPI/QoS based on the needs of RAN. For example, RAN can first investigate the benefit of ADU information for scheduling to justify ADU-based QoS or XR specific parameters.

2.2 Potential areas of work on Application Awareness

1. Identify the XR traffic characteristics and application layer attributes beneficial/feasible for the gNB to be aware of;

2. XR-specific network configuration: SRS, CG, DRX to adapt to e.g. non-integer periodicity;

3. UE assistance information (e.g. frame rate) to gNB to aid XR-specific handling;

4. RAN exchange of information with the Application Server to enforce traffic characteristics at the source;

Note: Close cooperation with SA2 is needed.

Feedback Form 8: Feedback form on the 4 areas for Application Awareness described above

1 – Futurewei The feasibility and merit of the proposal need further study. No conclusion was made in the R17 XR evaluation SI.
2 – Samsung Research America Identification of XR traffic characteristics is beneficial for link adaptation and we support further consideration. We do not see any need for ”XR-specific network configuration of SPS or CG” as it is further discussed below. DRX adaptation can be further considered/evaluated while also considering the Rel-17 mechanisms for UE power savings. RAN exchange of information with the Application Server is expected to be beneficial.
3 – China Mobile Com. Corporation We support at least bullet 1 and 3, which in our understanding will also bring RAN impacts to some extent. Bullet 4 seems like a sub bullet of Bullet 1, and Bullet 2 seems overlapping with the scope of power consumption and capacity.
4 – Verizon UK Ltd Agree wtih Samsung. Application awareness on both user plance and conrol plane.
5 – ZTE Corporation OK with bullet 1/2. Prefer to drop CG/SPS configuration pending further RAN1 conclusion.
6 – Facebook Right now the adaptation seems focus on video codec. However, in the actual deployment media layer protocols such as WebRTC, 3GPP MTSI are more critical in characterize the traffic pattern, media-layer adapation etc. The location of media processing units are also important in the end-to-end XR system.

7 – Convida Wireless

We are ok with the suggested potential areas of work on application awareness and are open for them.

8 – CATT

XR application awareness could be from UE feedback during the XR application establishment at UE. We are open to further discuss on how the gNB scheduler obtains the XR application information.

9 – Apple Europe Limited

We believe it is important to support non-integer periodicity for SPS and CG. For a single traffic flow, non-integer periodicity for DRX can be also useful. However, for multiple traffic flows, there may not be a feasible adaption of DRX periodicity to accommodate all the traffic flows, hence other enhancements are motivated also.

UE assistance information to gNB can be very useful, as the application on the UE is aware about high layer information which may be difficult for the gNB to acquire by itself.

10 – InterDigital

On application awareness at RAN, we support areas (1)(2) and (3) identified by the moderator for Rel-18 work, given that they are intended to address the issues related to what assistance information is provided to the gNB and how is the information provided. Regarding area (4), the interaction between RAN and application server may be possible for exchanging certain semi-static information (e.g. codec type, traffic statistics). This may require coordination with SA2. However, it may be challenging to exchange dynamic traffic information considering low motion-to-photon latency requirement (e.g. <20ms) of certain XR applications.

11 – vivo Mobile Communication Co.

We support proposal 1, 2, and 3.

We think not only SA2 and SA4 work are needed for these issues, RAN is also involved. These enhanced KPIs and QoS information needs to be delivered to RAN. Hence, RAN can further study potential improvement based on the XR-specific QoS, e.g., adaptive scheduling

For system level KPIs, it is not clear and more clarifications are needed.

For KPIs reflecting end-user experience, in our point of view, we can leave it to SA2/SA4 at this stage.

12 – vivo Mobile Communication Co.

(sorry for misplacing our last comment)

For application awareness areas, we support proposal 1, 2, 3 and 4.

For 1, some XR traffic characteristics and application layer attributes have shown benefit for the gNB, e.g. frame boundary identification, identifier of IP packets belonging to a same frame, identifier of multiple flows with different importance, synchronization information among packets or flows, packets latency, etc. We think such XR service-related information should be included. We are open to further study other XR traffic characteristics and application layer attributes.

For 2, besides XR-specific network configuration for SRS, CG, DRX to adapt to XR traffic, we would like to add XR-specific network scheduling e.g. QoS management, adaptive scheduling, adaptively packets dropping and delay aware scheduling for XR.

For 3, we would like to add more examples for the UE assistance information, e.g. UL traffic related information, special pose/control information, packet delay information etc.

13 – Intel K.K.

Item 1), 2) seem to be the most relevant areas to focus on/prioritize for initial study for considering XR traffic awareness, although the benefit of the example on non-integer SRS periodicity needs more discussion/clarification. Whether and how UE assistance information in item 3) can be leveraged can be discussed at a later stage. More discussion is needed for item 4)

14 – LG Electronics Inc.

We think the key feature is "XR traffic identification and XR-specific handling based on identification".

However, the XR-specific handling is not limited to SRS, CG, DRX.

Thus, we propose to modify the bullet 2 with general sentence "2. XR-specific handling (e.g. radio bearer handling, scheduling) based on identification".

Note that SRS and CG could be discussed in 2.5, and DRX could be discussed in 2.3.

For bullet 4, we don't see the need to explicitly sort out because it could be a part of bullet 1.

15 – Lenovo Information Technology

- The need for SRS and CG adaptation to non-integer XR periodicity needs to be justified e.g., given the possibility of using multiple active CG configurations from Rel-16, and considering PDB of larger than 7ms for XR traffic.
- We are not convinced by the bullet 4). More evaluation is needed to identify what kind of RAN information should be exchanged.

16 – HuaWei Technologies Co.

We support 1 and 3, we think 4 is overlapping with 1 and not sure what the difference is. For the first item, we think it is a high-level description and we would like to confirm whether this includes the awareness for both QoS flow association and frame-level QoS. For instance, identification/correlation of the packets belonging to the same frame/ADU or frame/ADU boundary, differentiation packets type/importance (e.g. critical vs non-critical, I-frame vs P-frame, etc), and traffic information of an XR application (e.g., the periodicity, jitter, PDB, etc).

Therefore, we suggested the following changes for the first bullet:

1. Identify the XR traffic characteristics and application layer attributes beneficial/feasible for the gNB to be aware of, including the QoS flow association, frame-level QoS etc. that was concluded from KPI and QoS.

For the second item, SRS should be SPS? SPS and CG have been proposed in capacity part and DRX has been proposed in power part, not sure whether this requires another explicit bullet here. If the intention is to ensure the E2E mechanism, we think bullet 1 and 3 should also be mentioned in the capacity as well to facilitate the RAN radio resource management and scheduling enhancements.

17 – Asia Pacific Telecom co. Ltd

Support bullets 1 to 3. Bullet 2 should be SPS instead of SRS. XR-specific configurations/parameters for SPS,CG, C-DRX by taking XR traffic characteristics into account is needed to increase the scheduling and power efficiency for XR. To have a more accurate configurations for a UE, RAN awareness should be

considered. Both the information provided by UE side (e.g., by UE assistance information) or obtained by gNB itself are open for discussion.

18 – DOCOMO Communications Lab.

We generally support to study the listed potential enhancements for application awareness. However, on the 3rd bullet, we propose some modification as follows to generalize the UE assistance information and include other potential enhancements at both UE/gNB sides. » 3. ~~UE assistance information~~ Application layer information (e.g. frame rate, delay, packet importance, etc.) ~~to gNB~~ to aid XR-specific handling, e.g. scheduling, packet discarding, etc;

19 – Sony Europe B.V.

For application awareness in gNB, we think UE feedback/report some assistance information (e.g. traffic model parameters) is necessary and helpful.

20 – Nokia Corporation

We support bullets 1-3. We have one minor clarification related to bullet 2: is SRS in bullet 2 supposed to be SPS, like commented by some other companies as well above?

About bullet 3: we can also consider frame size as an example of UE assistance information.

We have a concern related to the bullet 4: RAN exchanging information with Application Server. What is the extension to current capability of application to adapt to the channel quality? How can RAN enforce anything to the application running in the Application server? Could you please elaborate a bit here?

21 – Spreadtrum Communications

We think all the bullets is benefit for the scheduling in RAN. However, if the exchanging information between RAN and application server is applied, some SA2 modification is necessary.

22 – NEC Corporation

Thanks for the summary, we support the listed potential areas.

23 – Beijing Xiaomi Mobile Software

Further study on these areas is needed. The feasibility and benefit of theses enhancement needs further study.

24 – MediaTek Inc.

We support 1, 2, 3 and 4

25 – Fujitsu Limited

We support 1, 3, 4. Some considerations are provided below.

2/ We are not sure if symbol-level periodicity is needed for XR-type traffic, since, according to our best knowledge, the time scale of application layer w.r.t the XR-type traffic processing is ms level.

26 – VODAFONE Group Plc

Support for all 4 would be ideal.

Agree with DoCoMo's clarification.

On 2, non-integer periodicity seems important to deal with.

27 – Guangdong OPPO Mobile Telecom.

In our understanding, item 1 is the first step, i.e. identify XR characteristics and application layer attributes beneficial for gNB. If some important XR characteristics and application layer attributes are identified, then we could consider related spec work. According to study in R17 XR SI, periodicity information for XR is important for RAN due to it impacts many semi-static resource configurations, e.g. SPS, CG, Search space, DRX. Moreover, non-integer periodicity requires some spec effort in RAN. For other characteristics or attributes, we prefer to wait for more progress on R17 SI and open to solutions with significant gain.

For another, in current protocol framework, application information is exchanged between RAN and CN. We prefer to reuse current protocol, rather than a new exchange between UE and gNB due to benefit from the latter is not clear but spec work is very enormous.

The last but not the least, application awareness is expected to be studied in a SA2 SID "Study on architecture enhancement for XR and media services". So in our understanding, parallel SI other than WI in RAN maybe more suitable.

28 – LG Uplus

Thanks for summarizing and we are fine with the bullet 1 and 3 where 4 may be merged into 1 as some companies mentioned.

29 – Ericsson LM

We support Item 1, 2, 3. However, it is unclear if 2 fits well enough to application awareness since DRX is mentioned in 2.3 while CG/SPS is also proposed in 2.5. We would like to propose to remove at least "CG, DRX to adapt to e.g. non-integer periodicity".

Regarding Item 4, it is a bit unclear if it is intended to study signaling between RAN and application server and how this differs from Item 1. In general, signaling between RAN and application server would involve Core and application layers so that it would be better to clarify further the exact scope of RAN.

30 – Rakuten Mobile

We support all 4 objectives, however 1) is the key objective and need to be discussed in detail.

2.3 XR-specific power consumption considerations

1. XR-optimized C-DRX, aligning C-DRX with XR service periodicity and jitter

Feedback Form 9: Feedback form on XR-specific power consumption aspects

1 – Futurewei

The feasibility and merit of the proposal need further study. No conclusion was made in the R17 XR evaluation SI.

2 – Samsung Research America

The feasibility and possible additional power savings benefit of ”aligning C-DRX with XR service periodicity and jitter” can be evaluated for video applications on top of the mechanisms that are available in Rel-17. It may be part of a Rel-18 SI.

3 – Verizon UK Ltd

Support XR optimized CDRX, not just aligning the periodicty but the adaptation schemes as well to fit changing traffic pattern and radio environment

4 – ZTE Corporation

OK

5 – Facebook

OK with the proposal. Also fine with Samsung’s suggestion.

6 – CATT

We don’t agree to limit the power saving proposal to optimize C-DRX to align the XR source generation and delay jitter. C-DRX would be used for XR service and other service. We should allow other power saving technique, such as enhancement of DL SPS/UL CG, and enhancement of dynamic grant for power saving.

7 – Apple Europe Limited

UE power saving is of paramount importance for XR. Because of XR’s traffic characteristics, e.g. multiple flows, quasi-periodical, etc. they offer opportunities for power saving which are not available to generic eMBB/URLLC traffic.

As commented in Item 2 under 2.2, for a single traffic flow, non-integer periodicity for DRX can be also useful. However, for multiple traffic flows, there may not be a feasible adaption of DRX periodicity to accommodate all the traffic flows, hence other enhancements are motivated also.

Essentially two major sources for UE power consumption are data channel processing and control channel processing.

On the data channel processing part: SPS and CG have been identified as suitable solutions to carry XR traffic. With packet size fluctuation, using a fixed SPS and CG resource allocation may not be desirable from both UE power consumption and system capacity point of view. Nimble and light-weighted signaling schemes can be considered so the UE does not burn power for non-existent SPS PDSCH transmissions. Note it may be possible to use the same solution for jitter handling.

On the control channel processing part: as DRX periodicity (even if enhanced to support non-integer periodicity) may not be able to accommodate multiple data flows at different periodicities, dynamic signaling to reduce UE power consumption should be considered.

Hence we suggest that the adaption to packet size, and control channel monitoring enhancements for multiple traffic flows be included for UE power saving enhancements.

8 – InterDigital

The techniques identified for power consumption considerations are generally in-line with the current Rel-17 XR evaluation discussions. From the initial evaluation results available it is unclear whether techniques

based on semi-static CRDX configuration are able to balance the tradeoffs with respect to capacity performance and provide sufficient power saving gains. In this regard, it may be useful to consider dynamic and low complexity techniques such as adaptive CDRX and pre-configuration of multiple CDRX configurations associated with different traffic types for Rel-18 work.

9 – vivo Mobile Communication Co.

We support to enhance power saving for XR.

For proposal 1, we share the similar view as Verizon that it does not just for align with XR service periodicity. We think that adaptive DRX configurations/parameters(e.g. DRX timer) for variable packet size of XR traffic should also be included.

Besides, we would like to add a proposal for studying the features to handle jitter impact. As we commented earlier, handling the jitter by extending the length/duration of DRX on-duration or increasing the density of PDCCH monitoring is not efficient. To handle the jitter, lower power WUS than PDCCH monitoring or enhanced PDCCH monitoring adaptation (based on Rel-17 progress) can be included.

10 – Intel K.K.

We are open to study C-DRX adaptation based on XR characteristics such as periodicity, however it is unclear how to align C-DRX with jitter.

11 – LG Electronics Inc.

We are supportive to study XR-optimized DRX.

But, not just aligning periodicity and jitter, we think dynamic adaptation of DRX configuration should also be studied.

12 – China Mobile Com. Corporation

Aligning DRX periodicity to XR service is good, and SPS periodicity should also be handled.

Agree on Apple's comment: when multiple activities (flows) are ongoing, DRX may not be very helpful on power saving. A power-friendly dynamic signalling mechanism can be helpful.

Also Aligning DL and UL traffic is promising, to further extend the sleep time on UE.

13 – Lenovo Information Technology

Agree to have a manageable workload. We suggest rewording to: "XR-optimized C-DRX, aligning C-DRX with XR traffic considering XR service periodicity and jitter" to potentially better capturing the intent.

14 – Asia Pacific Telecom co. Ltd

Power saving is necessary for XR device. The enhancements on C-DRX to handle at least the issues of periodicy and jitter could be studied according to RAN1 evaluation results in R-17 SI.

15 – DOCOMO Communications Lab.

We support to study the listed potential enhancements for power saving enhancements.

16 – HuaWei Technologies Co.

We agree with the moderator's proposal. Some companies mentioned some other PDCCH enhancements, if time allows, we could be a bit open but not seen as high priority.

17 – Sony Europe B.V.

We agree with CATT, Apple Europe Limited and InterDigital that, bullet 1 [aligning C-DRX with XR service periodicity and jitter] may not be enough for XR power saving. With XR traffic characteristics (variable packet size, multi flows, etc.), more power saving technics including DG enhancement (both control channel processing design and data scheduling design, etc.) should be considered.

18 – Nokia Corporation

We support the optimization of C-DRX to capture the XR specifics.

19 – Spreadtrum Communications

Considering the haptic information, current DRX process shall be enhanced furtherly.

20 – NEC Corporation

Thanks for the summary, we support to study and enhance the XR specific CDRX. Besides, we think the enhancement of DCI based power saving should also be considered to better support XR.

21 – Beijing Xiaomi Mobile Software

The proposed enhancement can be included in XR Rel-18 work scope if the benefit is confirmed in Rel-17 XR evaluation.

22 – MediaTek Inc.

We support

23 – Fujitsu Limited

We are open to this proposal. If going for this proposal, the benefit should be well clarified.

24 – VODAFONE Group Plc

We do NOT see the benefit of this complexity for power saving.

25 – Guangdong OPPO Mobile Telecom.

We support C-DRX configuration optimization to match non-integer periodicity of XR. However, considering jitter and multiple-streams, we are not sure that other C-DRX mechanism enhancement is still helpful. So we prefer to wait more progress in R17 SI and open to solutions with significant gain.

26 – Qualcomm Korea

We would like to clarify that “aligning C-DRX with XR service periodicity” cannot effectively resolve the jitter issue. Please note that random traffic arrivals due to jitter prevents UE from staying longer in a sleep mode, and this cannot be effectively addressed by enhancements of C-DRX configuration. Thus, enhancements for better jitter handling need to be separately discussed from C-DRX enhancements. From the 1st round email discussion, we observe that 13 companies are addressing the jitter issue, but there are diverse views on possible solutions, e.g., R16 WUS based solution, 17 DCI based solution enhancement, CDRX enhancement, and some solutions without details, etc. It should be noted that Rel-17 XR study item is focused on evaluation of XR performance over NR, and discussion on potential enhancement solutions are very limited. Given that many companies agree that the jitter issue is not trivial, it is desirable to

carefully study possible solutions. We can have a study phase in the Rel-18 WI, or Rel-18 can start with a study item (followed by a work item in Rel-18) rather than directly jumping into a work item, especially given the limited study in Rel-17 on enhancements. Again, all other enhancements, not only power related solutions, have not been much discussed in Re-17.

27 – Ericsson LM

We support XR-optimized C-DRX. However, as Apple, CATT, LG, InterDigital commented already, limiting C-DRX to only XR periodicity and jitter is a very narrow scope considering identified XR traffic characteristics. For example, studying how CDRX can work with multiple flows is one of important aspects. We propose to update the proposed study area to ensure multi-flow aspects which are XR specific, are covered.

2.4 XR-specific coverage considerations

No immediate urgent need identified for any further XR-specific work on coverage enhancements.

2.5 XR-specific capacity considerations

1. Dynamic XR-specific SPS and CG

2. XR-specific CSI measurement/reporting

Feedback Form 10: Feedback on the 2 areas for XR-specific capacity enhancements outlined above

1 – Futurewei

The feasibility and merit of the proposal need further study. No conclusion was made in the R17 XR evaluation SI. Though it is a bit early to list the potential enhancements, we'd like to add a proposal on cooperative MIMO to improve XR capacity. Our evaluation for R17 XR SI shows that it can significantly boost XR capacity.

2 – Samsung Research America

XR is a rather "text book" scenario for dynamic scheduling (varying arrival times, large TBs requiring relatively low BLER for which scheduling flexibility and link adaptation offset any overhead penalty due to DCI) and there is no apparent need to complicate operation with "Dynamic XR-specific SPS and CG".

It is also unclear what "XR-specific" the extremely flexible Rel-17 CSI configurations need to account for.

3 – CATT

We support the proposal. In addition, XR-specific dynamic grant and UE feedbacks on extending delay budget would be areas for capacity enhancement.

4 – Apple Europe Limited

We have the following proposals:

- Specify enhancements in SPS/configured grant to adopt to non-integer periodicity of XR traffic.

- Evaluate and specify control signaling enhancements to adapt to time-varying packet size for XR traffic and multiple flow traffic.
- Specify CSI enhancements for faithful CSI measurements
- Support CSI/HARQ feedback enhancements to achieve efficient transmission and satisfy stringent latency requirement, which can continue from the Rel-17 URLLC CSI enhancement

5 – InterDigital

We support the areas identified by moderator given the potential benefits for capacity, including when supporting multi-stream XR applications. The other areas which can also be applicable for improving capacity are described under the 'potential areas for application awareness' topic.

6 – vivo Mobile Communication Co.

We support the proposal 1 and 2.

To well support XR traffic in NR, CSI measurement should be as accurate as possible, and CSI reporting should be done in time or even in advance, especially for retransmission. For XR service, CSI measurement and reporting to adapt to XR traffic can be beneficial, e.g., CSI measurement/reporting can be triggered by the UE event for XR specific UL transmission.

7 – ZTE Corporation

Prefer to drop XR specific SPS and CG pending sufficient RAN1 evaluation results and conclusion.

According to the characteristic of XR traffic, HARQ feedback enhancements to achieve efficient transmission and satisfying stringent latency requirement should also be considered.

Potential techniques to address XR coexistence with other service, e.g. uRLLC and eMBB are mentioned. Evolved preemption scheme would be candidate to handle different service collision. The initial evaluation results as captured in our contribution R1-2106529 imply that enhanced preemption indication is capable of obtaining decent capacity performance gain. We prefer to capture a bullet reflecting techniques to handle XR coexistence with other service.

8 – Intel K.K.

We are open to study item 1). We are not quite clear of the need for item 2), why may the existing CSI reporting framework not suffice?

9 – LG Electronics Inc.

We are supportive to study XR-specific CG/SPS.

But, the CSI measurement/reporting can be discussed in a separate topic (e.g., in URLLC/IIoT).

The timely CSI measurement/reporting was already triggered in the context of URLLC/IIoT, and can be applied to XR once it is agreed.

We are not sure if any further XR-specific optimizations are needed.

10 – Lenovo Information Technology

- For item 1: We suggest updating to: XR-specific SPS and CG enhancements. There could be semi-static enhancements for SPS/CG, and at this stage, seems premature to eliminate that possibility.

- For item 2: We are not sure if “XR-specific” CSI enhancements needed. If pursued, it should be justified how it is envisioned we would not end up with a similar situation as Rel-17 CSI enhancements for URLLC, especially if similar schemes as discussed in Rel-17 are to be further discussed.

11 – China Mobile Com. Corporation

1. Dynamic XR-specific SPS and CG

This can be addressed in power consumption? And to our understanding, the bullet points in ”KPI and QoS” and ”Application Awareness” are serving the purpose of capacity (and latency) already.

BTW, ”Power Consumption”, ”Coverage”, ”Capacity”, ”Mobility” are all requirements but for the first two (”KPI and QoS” and ”Application Awareness”), it is not very clear on the purpose.

2. XR-specific CSI measurement/reporting

Open to discuss more on details, or what is special about a ”XR CSI report”.

12 – Asia Pacific Telecom co. Ltd

Suport at least bullet 1. Dynamic and finer configuratoin on top of the current multuple CG/SPS configurations scheme are useful. Not clear whether bullet 2 is needed. Probably some evaluation is required before including XR-specific CSI measurement/reporting.

13 – DOCOMO Communications Lab.

We generally support to study the listed potential enhancements for capacity enhancements. However, we prefer some modification on the 1st bullet to include other potential enhancements as follows:

–1. ~~Dynamic~~ XR-specific SPS and CG enhancements, including dynamic SPS/CG parameter update, multi-TB SPS/CG, etc.

14 – HuaWei Technologies Co.

We are OK for SPS/CG. We have similar view as LGE, think CSI measurement/reporting enhancements are generic enhancements and not specific to XR. It is more suitable to discuss this in MIMO.

In addition, as we also commented in application awareness and QoS, we think these two aspects are quite relevant on potential capacity enhancements. RAN can have capacity enhancements like packet dropping, timely transmission of data according to the awareness of information discussed in example area 1 and 2. So we believe this is worth mentioning in capacity enhancements.

15 – Nokia Corporation

We support 1st bullet. But we do a question related to the 2nd bullet. What are the XR specific in enhancements related to CSI measurement and reporting?

16 – Sony Europe B.V.

We generally support the proposal. However, we think it is still too early to discuss the scope as RAN1 study item is still on-going and the conclusion has not been made. We should not preclude other potential items at this stage, e.g. reliability improvements, HARQ enhancements, uplink enhancements for XR.

17 – Spreadtrum Communications

We think CSI measurement enhancement is benefit to improve the XR capacity.

18 – NEC Corporation

Thanks for the summary. For bullet 1, we think both the dynamic scheduling and SPS/CG should be considered at this stage.

19 – Beijing Xiaomi Mobile Software

The proposed enhancement can be included in XR Rel-18 work scope if the benefit is confirmed in Rel-17 XR evaluation.

20 – MediaTek Inc.

What does ”dynamic” imply?
What does the first objective target? We understand PDCCH is not really a bottleneck, unlike PUSCH

What does the 2nd item target? Traffic Pattern consideration?

21 – Fujitsu Limited

We are open to this proposal. If going for this proposal, the benefit should be well clarified.

22 – VODAFONE Group Plc

We need to support non-integer periodicity for these services.

23 – Guangdong OPPO Mobile Telecom.

We support item 1 but confused on item 2.

XR-specific SPS and CG tailors SPS and CG procedure for XR characteristics, including non-integer periodicity, multi-PDSCH/PUSCH for large packet transmission, adaptive configuration for various packet transmission and SPS HARQ-ACK enhancement for jitter. In addition, in our understanding, the intention to add “Dynamic” is to express that SPS and CG resource are adaptive to match various packet of XR. However, “Dynamic” seems inconsistent with “SPS and CG” literally, so we slightly suggest to delete “dynamic” in item 1. “XR-specific” can cover any XR-orient design, e.g. various packet size.

In addition, considering XR characteristics, e.g. jitter and various packet size, dynamic scheduling is also beneficial for XR. So PDCCH enhancement, including non-integer search space configuration and multi-PDSCH/PUSCH scheduling for large packet, should be considered.

For item 2, the benefit and solution are not clear for us. Especially considering multiple traffics supported by UE, we do not know why CSI configuration, a common procedure for all kinds of traffic, should be aligned with XR.

24 – LG Uplus

We prefer to have the bullet 1 only where 2 is somewhat general enhancement which can be discussed in other items.

25 – Qualcomm Korea

Regarding #1, we agree that SPS/CG need to be enhanced to better support XR services. Since current SPS/CG mechanisms were designed with traffics with small volume (e.g., VoIP) in mind, XR traffic with high bit rate, variable packet size, jitter, etc may not be easily supported with current mechanisms. Thus, we expect further enhancements are required for CG and SPS, especially in the area of adaptability to link conditions, compatibility with XR traffic characteristics (e.g., frame rates), reduced overhead while supporting variable packet sizes, jitter etc.

Regarding #2, in certain cases, XR application information such as XR viewport or pose information may be used to predict channel and beam changes at the gNB/UE. The channel and beam changes may require measurement configuration (e.g., CSI measurement/reporting) parameter updates such as periodicity, number of CSI measurements, etc. The changes in the measurement configurations could be triggered by UE request or gNB's decision. In general, adaptation of measurement configurations such as CSI measurement/reporting parameters could be triggered by XR application changes.

Together with those two areas, we think network coding could be further considered for capacity enhancement.

26 – Ericsson LM

We support Item 1 and 2 with the following additions. The motivation is as previously commented, XR specific SPS and CG enhancement is better handled in capacity considerations since it is one of important potential mechanisms to address periodic traffic. At the same time, considering SPS/CG and CSI enhancement only is very limited since it may miss important XR specific traffic characteristics. For example, as Apple commented, studying control signaling enhancements for time-varying large video frames can be beneficial by enhancing existing multi-TB scheduling and BSR. Therefore, we have the following proposal:

- Study SPS/CG enhancements considering XR specific non-integer periodicity
- Study control signaling enhancements for resource allocation considering a time-varying and large video frame size
- Study XR specific CSI measurement/reporting

2.6 XR-specific Mobility considerations

1. DAPS extension to FR1 CA and FR2, improved e2e latency for DAPS;

2. 0ms interruption without DAPS;

Feedback Form 11: Feedback on the 2 areas above on XR-specific mobility aspects

1 – Futurewei

These 2 proposals may be discussed under the general mobility thread (03). On XR-specific mobility considerations, study is yet to be conducted in R17 XR SI.

2 – Samsung Research America

In general, potential mobility enhancements can be considered in a separate SI/WI, if any.

We do not identify anything that is XR-specific to mobility events, even considering the PDB KPI. For typical AR scenarios, mobility events will not degrade performance at an order of magnitude that is comparable to events during ”regular operation” (and there is no issue for VR), especially considering availability of Rel-16 DAPS and of Rel-17 MIMO enhancements for inter-cell mobility.

DAPS extension to FR1 CA and FR2 was considered in Rel-16 but was not pursued due to the very substantial UE complexity requirements - things have not changed since then and, if anything, typical XR-specific devices are even less tolerant than smartphones to such complexity requirements. Also, an overall benefit to extend CA support for DAPS is questionable on its own.

3 – China Mobile Com. Corporation

The two bullets listed above seems more like a general issue than a XR specific issue, so we would prefer to treat them in a more generic WI.

4 – CATT

We need further analysis and evaluation to justify the 0ms interruption time.

5 – Apple Europe Limited

Both 1) and 2) are for quite general mobility enhancements, they are best studied under a mobility enhancement item. It should be noted so far mobility evaluation methodology has not been agreed in RAN1. The evaluation methodology for mobility evaluation should be consistent with that for UE power saving, system capacity, etc.

6 – InterDigital

The areas (1)(2) identified by moderator can be useful for addressing issues related to supporting high data rate and low latency requirements of some services during mobility. Additionally, certain aspects specific to XR such as ensuring the timing of HO execution based on awareness of transmission status of video frame data can be an area for further consideration. Such consideration for mobility may be applicable for conventional HO, CHO and DAPS. Since the identified areas are generic, we are also ok to consider them in a separate SI/WI on mobility enhancements.

7 – vivo Mobile Communication Co.

We share the same view as CMCC that these two proposals are general issues for mobility and they can be discussed in mobility WI. XR specific mobility enhancement can be studied depending on the output of XR SI study.

8 – Intel K.K.

We are open to discuss these topics as part of RAN2 led Mobility enhancements.

9 – LG Electronics Inc.

We think mobility issue is not XR-specific. Thus, we prefer to study mobility enhancement in a separate WI/SI.

10 – Lenovo Information Technology

We are wondering how to achieve 0ms interruption without DAPS. The DAPS is the solution what have been defined to achieve 0 ms. The bullet 2 needs further clarifications. In general, we think the mobility for XR should be covered by the dedicated mobility WI.

11 – Asia Pacific Telecom co. Ltd

We agree both bullets 1 and 2 are worth to be discussed in Rel-18. However, we are wondering how to split the scope of the mobility enhancement between the R-18 XR WI and the R-18 Mobility WI.

12 – DOCOMO Communications Lab.

It seems these are also proposed and being discussed in the mobility enhancements thread. It should be discussed in Mobility enhancements WI

13 – HuaWei Technologies Co.

These proposals are generic enhancements and not specific to XR. Both are covered in the mobility discussion and we do not see need to duplicate the discussion here.

14 – Nokia Corporation

We are supportive of the proposed areas. We also propose that XR-specific Mobility is considered as a part of Mobility WI, so then we don't need to address these as part of the XR work (other applications benefit also from improvements like shorter (or 0 ms) interruption time than XR.

15 – Spreadtrum Communications

For the video frame, it is not necessary to consider the 0ms interruption. However, whether the 0ms interruption is useful for haptic data transmission? This all be studied furtherly.

16 – Beijing Xiaomi Mobile Software

These two bullets can be covered by mobility enhancement. We don't see the need to duplicate discussion, unless there is specific requirement from XR.

17 – MediaTek Inc.

To be covered in Mobility enhancements as generic item

18 – Fujitsu Limited

We share the views above. This can be discussed in RAN2 led Mobility enhancements.

19 – VODAFONE Group Plc

0ms interruption without DAPS seems useful for XR, but, might be better handled under Thread #03 - mobility enhancements

20 – Guangdong OPPO Mobile Telecom.

It is preferred to discuss these two items under general mobility enhancement.

21 – LG Uplus

Also we do not see need to have this area.

22 – Qualcomm Korea Mobility enhancements are generic enhancements which can benefit other applications as well. Therefore, we think that mobility study for XR can be done separately in Mobility WI. We think we should focus on capacity and power enhancements tailored for XR applications instead.
23 – Ericsson LM Identified issues are relevant but it would be better to be discussed under a mobility agenda.
24 – Rakuten Mobile Agree with other's; although relevant but need to be discussed with Mobility enhancements

3 Final round - now closed.

3.1 Potential areas of work on KPIs and QoS

Wide support was expressed for the following items:

1. RAN support for enhanced granularity for QoS;

2. RAN support for ADU-based QoS;

3. RAN support for XR-specific QoS parameters.

4. Synchronization of QoS flow handling belonging to the same XR service association and corresponding DRB control

Note: Close coordination is required with SA2 and SA4 work for all the above aspects

Potential further work on KPIs heavily depends on the outcome of the Rel-17 work on XR. Hence, potential enhancements on KPIs can be better identified over the next few months and are left open at this point.

Feedback Form 12: Final comments on KPIs/QoS

1 – CATT We are OK with the proposed scope in KPIs/QoS
2 – Samsung Research America We support the list with potential areas of work on KPIs and QoS.
3 – Futurewei - Potential further work on KPIs heavily depends on the outcome of the Rel-17 work on XR. Hence, potential enhancements on KPIs can be better identified over the next few months and are left open at this point.

- The proposal as formulated here may be a bit misleading as the wide support from the companies is to *study* the items listed rather than directly *adopt* the listed techniques
- SA2 and SA4 involvement is needed and there should be clear split to what and how certain aspects are handled in RAN. At this point the proposal by the moderator does not clarify that aspect. By explicitly mentioning *RAN support* for all of items would mean that RAN should handle all aspects which may not be the case.

4 – China Mobile Com. Corporation

We support all four areas as potential further work. And we agree that above work can be better identified within a few months and can be left open at this point.

5 – Asia Pacific Telecom co. Ltd

6 – HuaWei Technologies Co.

We agree to the moderator's proposal 1-4. Regarding potential KPI definition, we understand RAN1 would not spend more time to discuss KPI in the remaining study, we are fine to keep it open but we think this is more dependent on SA4 discussion and QoE discussion.

7 – Facebook

We are fine with the moderator proposal. However, most of the XR-related QoS/KPI are application specific. So the definition of use cases and application/media layer abstraction are particularly important. Both have to be in close collaboration SA2/SA4. We should take into account of existing media layer protocols both within and outside 3GPP.

8 – InterDigital

We support moderator's summary of potential areas of work on KPIs and QoS. RAN2 should lead on the areas listed above

9 – LG Electronics Inc.

We are fine with bullets 1-3. For bullet 4, we think it is one specific mechanism to achieve bullets 1-3, and it does not need to be explicitly listed.

10 – DOCOMO Communications Lab.

We support the listed potential areas on KPIs/QoS.

11 – Intel K.K.

We agree with moderator's view to revisit the aforementioned items based on outcome of Rel-17 work. We are ok with the suggested items however the topics seems to overlap with one of the objectives addressed in next section 3.2 (i.e. "Identify the XR traffic characteristics and application layer attributes beneficial/feasible for the gNB to be aware of, including the QoS flow association, frame-level QoS etc. that was concluded from KPI and QoS"). We suggest consolidating them and add any missing aspect there. In addition, "ADU based QoS" may be a solution to use but would require further discussion to understand it. Therefore we suggest adding it as an example mechanism to discuss instead than an actual objective. In conclusion, our suggestion is to update the objective in 3.2 as follows: "Identify the XR traffic characteristics and application layer attributes beneficial/feasible for the gNB to be aware of, e.g. the QoS flow association, frame-level QoS, ADU-based QoS, XR specific QoS etc. that was concluded from KPI and QoS"

12 – Nokia Corporation

We also support the current list

13 – RadiSys

We support Moderator's proposal and agree close co ordination with SA2 and SA4 is needed for the proposed items.

14 – LG Uplus

We are supportive for this list

15 – Guangdong OPPO Mobile Telecom.

We support moderator's intention. To be specific, we support 2 and 3 at least. Item 1 and 2 are duplicated to some extent, so it's better to leave one item. If we misunderstand, we'd like to hear more clarification on item 1, especially for difference between item1 and item2.

Meanwhile, we agree with Futurewei. SA2 and SA4 should be involved and the formulated proposals are study items.

16 – Fujitsu Limited

We support the proposed scope.

17 – vivo Mobile Communication Co.

We support the proposals for potential areas of work on KPIs and QoS.

18 – Beijing Xiaomi Mobile Software

We are fine with the moderator proposals.

19 – Spreadtrum Communications

We support all the potential areas of work on KPIs and QoS in the summary.

20 – NEC Corporation

We support the listed potential areas.

21 – Apple Europe Limited

We support close coordination with SA2 and SA4 to study the listed aspects.

22 – Lenovo Information Technology

In general, we support QoS related enhancements. For 2), the definition of ADU (e.g. the difference between frames and ADU) needs to be clarified. It seems there is no clear definition of ADU in both RAN and SA.

We think the KPIs or new metric for evaluate XR performance is important for XR application which can be triggered by SA4. It is not related with RAN1's Rel-17 work.

23 – MediaTek Inc.

We support the moderator proposal, resulting from sound justifications

24 – Qualcomm Korea

On #1, we agree that XR applications can have different QoS requirements. However, it's not clear if further specification work is required to capture the granularity of requirements. Instead, existing XR 5QIs can be adapted to suit the requirements of a given XR application.

On #2, we agree with the need for ADU-based QoS.

On #3, we agree that QoS parameters can be enhanced to take into account specific characteristics of XR flows.

On #4, the mapping of XR traffic of a single user to different flows needs to be studied before synchronization across flows. The requirement behind this item and any additional work required need to be studied further.

Beyond these, we think that it's important to look at KPIs that will better reflect the XR application and user experience. We are open to discussion on KPIs that reflect end-to-end user experience and system level KPIs that would be beneficial in the study.

25 – Ericsson LM

In general, we understand the intention behind Item 1, 2, 3 which we are fine in principle. Also we agree that we need very close collaboration especially with SA2. However, we need further clarification on "RAN support" with respect to 3.3 and 3.4 which also discuss potential RAN support for identified XR specific QoS and KPI in a broad sense.

For Item 4, it is still questionable if that is the scope of RAN while SA2 defines a mapping rule between QoS and DRB in general.

3.2 Potential areas of work on Application Awareness

Wide support was expressed for the following areas:

1. Identify the XR traffic characteristics and application layer attributes beneficial/feasible for the gNB to be aware of, including the QoS flow association, frame-level QoS etc. that was concluded from KPI and QoS.

2. Application layer information (e.g. frame rate, delay, packet importance, etc.) to aid XR-specific handling, e.g. scheduling, packet discarding, etc; One potential mechanism for this is to introduce UE assistance information;

Feedback Form 13: Final comments on Application Awareness

1 – CATT

We are supportive of this proposal.

2 – T-Mobile USA Inc.

This objective needs to take security and the impact of end to end encryption on application identification.

3 – Samsung Research America

We support the list with potential areas for study on application awareness.

4 – Futurewei

- Further study is needed for both areas. These may be considered/evaluated in SI first before and making conclusions on its merit
- The proposals formulated here may be a bit misleading as the wide support from the companies is to *study* the items listed rather than directly *adopt* the listed techniques

5 – China Mobile Com. Corporation

We are fine with above two proposals.

6 – Asia Pacific Telecom co. Ltd

7 – HuaWei Technologies Co.

We support the proposal.

8 – Facebook

Similar to our previous comments. The definition of applications and application/media layer abstraction are particularly important. Both have to be in close collaboration SA2/SA4. We should take into account of existing media layer protocols both within and outside 3GPP such WebRTC, MTSI.

9 – InterDigital

We support moderator's summary of potential areas of work on application awareness. RAN2 should lead on the areas listed above

10 – LG Electronics Inc.

We are fine with moderator's proposals.

One suggestion is to change "packet discarding" to "radio bearer handling" because packet discarding is one specific method of XR-specific radio bearer handling.

11 – DOCOMO Communications Lab.

We support the listed potential areas on application awareness.

12 – Intel K.K.

We are fine in principle with the potential work scope. In addition, please check the related inputs provided in previous section.

13 – Nokia Corporation

We are fine with the current proposals

14 – LG Uplus

We are supportive for the proposed area

15 – RadiSys

We are fine with the Moderator's proposals.

16 – ZTE Corporation

We agree with the moderator's proposals. And we think more power saving technics including enhancement of PDCCH monitoring reduction(e.g., PDCCH skipping, search space set group switching) can also be considered.

17 – Fujitsu Limited

We support the proposed scope.

18 – Guangdong OPPO Mobile Telecom.

We are fine in principle with potential scope. However, Application awareness is also expected to be studied in a SA2 SID "Study on architecture enhancement for XR and media services". So parallel SI other than WI in RAN maybe more suitable. In addition, this topic is closely related with SA2, so SA2 should be involved too.

19 – vivo Mobile Communication Co.

We support the proposals for potential areas of work on application awareness.

20 – Beijing Xiaomi Mobile Software

We are fine with the proposals.

21 – Spreadtrum Communications

We support these 2 proposals.

22 – Apple Europe Limited

As we commented previously, because of XR's traffic characteristics, e.g. multiple flows, quasi-periodical, etc. they offer opportunities for power saving which are not available to generic eMBB/URLLC traffic. The opportunities are not limited to PDCCH monitoring, but it can also include data channel processing, e.g. SPS PDSCH skipping. Essentially a traffic-centric design should be pursued to reduce power consumption as much as possible, this does not need to be achieved by imposing restriction on the network side, just not to waste power.

As already clear in the KPs & QoS enhancement part, two proposals for the final round are motivated by multiple data flows traffic characteristics for XR (copied below for easy reference). With all enhanced QoS support from core network/radio access network, in the end the UE needs to handle multiple data flows with XR. As C-DRX enhancement alone does not help much in that (note we also agree C-DRX enhancement may be helpful for the single flow case), other power saving enhancements should be considered so in the end the potential of XR is unlocked.

Below are two proposals from KPIs & QoS final round:

2. RAN support for ADU-based QoS;

4. Synchronization of QoS flow handling belonging to the same XR service association and corresponding DRB control

23 – Apple Europe Limited

It looks we entered the comments for UE power saving under this Application awareness – sorry for the confusion.

We support moderator's proposal. Close work with SA2/SA4 should help determine what application awareness can be achieved. Also T-mobile USA raised an important point.

24 – NEC Corporation

We support the listed potential areas.

25 – Lenovo Information Technology

The first bullet seems overlapping with the objectives with QoS. The second bullet is fine.

26 – MediaTek Inc.

We support the moderator proposal, resulting from sound justifications. Coordination with SA2 (possibly SA4) is also required.

27 – Qualcomm Korea

On #1 and #2, we agree that by having the application awareness (e.g., Application Data Unit – ADU) at the gNB, the gNB can better optimize for the XR traffic such that the overall quality of experience for the user is improved. We agree with many observations that each bit/packet that is transmitted does not have equal importance. By leveraging the application awareness, the gNB may be able to better schedule or prioritize to allow for better overall experiences for multiple users.

Further, we think that it's important for RAN to look into mechanisms of shifting the behaviour of the application server, and realize benefits beyond what is possible by optimizing the RAN alone.

28 – Sony Europe B.V.

We support the moderator's proposals.

29 – Ericsson LM

We support the list in general. However, we have some suggestion to avoid the overlap between two items in this list as well as an area stated in 3.4.

It is our understanding that 3.2 focuses on identifying and understanding application information useful for RAN while 3.1 studies general RAN mechanisms to use those when a Core network is involved. However, we need further clarification on a difference between Item 1 and Item 2. In principle, both items focus on the identification of XR traffic and application information to make a RAN better. Our proposal is merging both Items into on as:

- Identify the XR traffic characteristics and application layer information beneficial/feasible for the gNB to be aware of for XR specific handling, including the QoS flow association, frame-level QoS, scheduling, packet discarding, etc.

Mechanisms for UE assistance information can be also moved to 3.4 since it is not about identified information itself but solutions to identify information.

3.3 XR-specific power consumption aspects

There was wide support for the following areas:

1. XR-optimized C-DRX: aligning C-DRX with XR service periodicity and jitter, XR-specific multi-flow aspects.

2. Dynamic adaptation of DRX

Feedback Form 14: Final comments on XR-specific power consumption aspects

1 – CATT

During RAN1 study of XR power saving, the optimized C-DRX and aligning C-DRX does not show significant power saving gain. In particular, the delay jitter assumed in the XR evaluation is quite small and there is no out-of-order XR packet arrival. Thus, the power saving gain with optimized C-DRX with out-of-order XR packet arrival would have further reduced. In addition, the C-DRX configuration would be not only used by XR services but also other data/voice/video service in all cells for the UE since it is from the same MAC control. The optimized C-DRX could provide insignificant power saving for XR services but potential detrimental to the power consumption of other data services. We should have more open with study of the UE power saving techniques in general. We have the suggestion of wording as follows,

- XR specific power saving techniques with C-DRX configuration, e.g., optimized C-DRX, dynamic adaptation of C-DRX.

2 – Samsung Research America

Agree with CATT - we also expect the (incremental to Rel-17) power saving gains from C-DRX adaptation to be marginal. We support a general study for UE power savings related to XR - C-DRX adaptation can only be an example.

3 – Futurewei

One general comment, the discussion here in [RAN93-e-R18Prep-05] seems not aligned with the conclusions and agreements made in the RAN1 meetings from Rel-17 SI. In particular, there is no conclusion yet on the gains provided by such enhancement. It would be better if the outcome of the SI drives the proposals on power consumption and capacity instead of leading a separate discussion

It is not clear what the difference between 1 and 2 are. Moreover, the conclusions from DRX enhancements have not been finalized from Rel 17 XR SI. Some companies observed little gains from alignment especially when jitter is present. It may be better to finalize the SI before deciding on this point.

4 – China Mobile Com. Corporation

People all agree that power consumption is very important but just not sure if DRX enhancement can help much.

We support a study for power consumption techs in R17 XR SI. We can also study these cases:

1. SPS periodicity aligned with XR
2. DL/UL are aligned
3. A flexible yet power saving dynamic signaling, like WUS

These are the aspects that people mentioned as well.

5 – Asia Pacific Telecom co. Ltd

6 – HuaWei Technologies Co.

We support the proposal.

7 – InterDigital

We support moderator's summary of the potential areas of work on power consumption

8 – LG Electronics Inc.

We are fine with moderator's proposals.

9 – DOCOMO Communications Lab.

We support the proposal by moderator, and we are also fine with the wording suggested by CATT. The detailed solution can be based on the outcome of the study, but XR-optimized C-DRX enhancements which are supported by many companies should be included at least as an example area.

10 – Intel K.K.

We are open to study XR specific power saving techniques, including C-DRX optimization based on XR traffic characteristics.

11 – Nokia Corporation

We support proposal by the moderator, and also the discussions during the study has shown that existing C-DRX solutions are not optimal for XR. Alternatively we are also fine with the wording from CATT, considering the study is in relatively early stage regarding actual enhancements.

12 – LG Uplus

We are fine with the proposed area where also agree with many companies' opinion for waiting the outcome of the Rel-17 XR SI.

13 – RadiSys

Agree with Moderator's proposal

14 – ZTE Corporation

We agree with the moderator's proposals. And we think more power saving technics including enhancement of PDCCH monitoring reduction(e.g., PDCCH skipping, search space set group switching) can also be considered.

15 – Fujitsu Limited

We are open to this topic and we have slight preference to CATT's suggestion.

16 – Guangdong OPPO Mobile Telecom.

Agree with CATT. We support a general study for UE power saving, e.g. PDCCH based enhancement and non-integer periodicity C-DRX.

17 – vivo Mobile Communication Co.

Generally, we are fine with the proposals. However, for jitter handling, C-DRX is not efficient to solve the jitter. Other solutions such as low power WUS and enhanced PDCCH monitoring adaptation could be more efficient. Therefore, we would like to update the proposal as following:

- XR-optimized C-DRX: aligning C-DRX with XR service periodicity, XR-specific multi-flow aspects.
- Dynamic adaptation of DRX
- Jitter handling e.g. low power WUS or enhanced PDCCH monitoring adaptation

18 – SHARP Corporation

We are fine with the moderator's proposal.

19 – Beijing Xiaomi Mobile Software

We are fine with the proposal.

20 – Spreadtrum Communications

We think DRX may be enhanced to transmit more types of traffic, for example, the haptic data.

21 – Apple Europe Limited

As we commented previously, because of XR's traffic characteristics, e.g. multiple flows, quasi-periodical, etc. they offer opportunities for power saving which are not available to generic eMBB/URLLC traffic. The opportunities are not limited to PDCCH monitoring, but it can also include data channel processing, e.g. SPS PDSCH skipping. Essentially a traffic-centric design should be pursued to reduce power consumption as much as possible, this does not need to be achieved by imposing restriction on the network side, just not to waste power.

As already clear in the KPs & QoS enhancement part, two proposals for the final round are motivated by multiple data flows traffic characteristics for XR (copied below for easy reference). With all enhanced QoS support from core network/radio access network, in the end the UE needs to handle multiple data flows with XR. As C-DRX enhancement alone does not help much in that (note we also agree C-DRX enhancement may be helpful for the single flow case), other power saving enhancements should be considered so in the end the potential of XR is unlocked.

Below are two proposals from KPIs & QoS final round:

2. RAN support for ADU-based QoS;

4. Synchronization of QoS flow handling belonging to the same XR service association and corresponding DRB control

22 – NEC Corporation

We support the listed potential areas.

23 – Lenovo Information Technology

We think item 1 can cover item 2, and hence, the intention/additional value of having the 2nd item (dynamic adaptation) is not clear.

24 – VODAFONE Group Plc

We still think that this is a waste of 3GPP time.

25 – MediaTek Inc.

We support the moderator proposal, resulting from sound justifications

26 – Ericsson LM

We support the list. Nevertheless, Item 2 can be a subset of Item 1 since it includes one possible way of CDRX optimization specific to XR. We propose one general Item and leave possible solutions to be identified during the study item phase:

- XR-optimized C-DRX **for** aligning C-DRX with XR service periodicity and jitter, XR-specific multi-flow aspects.

27 – Sony Europe B.V.

We consider C-DRX optimization is one of the keys of UE power saving for XR. We prefer the updated proposal from CATT. We are also open to study other power saving techniques based on XR characteristics.

28 – Qualcomm Korea

We think the scope and solution space is still too narrow to solve power issues for XR. C-DRX is a useful technique, but is not sufficient to address the jitter issue. Given that Rel-17 XR SI is evaluating the performance of enhancements techniques, it is not desired to limit the work scope of Rel-18 XR WI w.r.t. UE power consumption to C-DRX related enhancements. It should be allowed to discuss other solutions potentially with more results from Rel-17 XR SI.

#1: For proper handling of jitter issue, we think the scope of enhancing CDRX for XR should be broader enough to include related schemes and operations such as WUS monitoring for CDRX wake up, or PDCCH monitoring operation during DRX On duration, etc. All these related schemes can be considered as an enhancement of CDRX for XR.

Alternatively, we can also handle jitter separately in separate bullet to keep solution space open. We see diverse approaches for jitter handling.

#2: Dynamic adaptation of DRX could be considered.

Together with the above two, we think it is important to consider the enhancements of SPS and CG for power saving. The SPS/CG enhancement is mentioned in capacity part, but it is limited to dynamic parameter update. Given that SPS and CG are important mechanism for power saving for periodic traffic, the enhancements of SPS/CG should be considered in XR power.

3.4 XR-specific capacity considerations

Support was expressed for the following item, but it is also understood that Rel-17 XR study needs to be progressed further before finetuning the potential scope for this work in Rel-18:

1. XR-specific SPS and CG enhancements including dynamic SPS/CG parameter update, multi-TB SPS/CG, etc; to address XR-specific non-integer periodicity.

Feedback Form 15: Final comments on XR-specific capacity considerations

1 – CATT

We are OK with the enhancement of DL SPS and UL CG. However, other techniques of NR capacity enhancements in support of XR services should be considered. The enhancement of dynamic grant customized for XR service had shown the increasing the system capacity in the XR study. The UE feedback of XR playout buffer to extend the time budget of gNB scheduling also provide the system capacity gain. Thus, we have a suggestion modification of the bullet to cover more general term

XR-specific *resource allocation and scheduling enhancement, which include UE assistance,* SPS and CG enhancements including dynamic SPS/CG parameter update, multi-TB SPS/CG, etc; to address XR-specific non-integer periodicity.

2 – Samsung Research America

CG and particularly SPS are inappropriate for the XR traffic characteristics, including the TBS and the non-integer periodicity with jitter. We support study for general scheduling enhancements but do not support the above specific limitation to SPS and CG.

3 – Futurewei

- One general comment, the discussion here in [RAN93-e-R18Prep-05] seems not aligned with the conclusions and agreements made in the RAN1 meetings from Rel-17 SI. In particular, the different capacity enhancement techniques (not limited to those mentioned in the proposal) are being evaluated and it is FFS how to capture those in the TR.
- Only a selective capacity enhancement schemes are proposed here. There are other capacity enhancing schemes that need to be considered and are evaluated extensively in Rel-17 XR SI. Such as the cooperative MIMO schemes for interference management. We propose to add this to the potential enhancements
- Since the SI has not concluded yet on the capacity enhancement schemes, this proposal may not be appropriate as it does not capture all enhancement techniques

4 – China Mobile Com. Corporation

We are ok to wait for Rel-17 XR SI further. Plus, some of ideas listed here are coincident with power saving techs. Maybe we can call them ”power-saving / capacity” techs.

5 – Asia Pacific Telecom co. Ltd

6 – HuaWei Technologies Co.

We are fine with the proposal.

7 – InterDigital

We support moderator’s summary of the potential areas of work on capacity

8 – LG Electronics Inc.

We are fine with moderator's proposals.

But, we would like to suggest the following changes as jitter is also considered as one of the main motivations of XR-specific SPS and CG enhancements.

1. XR-specific SPS and CG enhancements including dynamic SPS/CG parameter update, multi-TB SPS/CG, etc; to address XR-specific non-integer periodicity **and jitter.**

9 – DOCOMO Communications Lab.

We support the proposal but are also fine with the update from CATT to more generalize the study scope.

10 – Intel K.K.

We are open to study SPS and CG enhancements based on XR traffic characteristics, including dynamic adaptation of SPS/CG configuration, multi TB scheduling etc. We suggest to replace "SPS/CG parameter" by "SPS/CG configuration".

11 – Nokia Corporation

We are fine with the proposal from the moderator, however the addition from CATT is also acceptable

12 – LG Uplus

Also supportive where we are fine with the CATT's general expression.

13 – RadiSys

We agree with Moderator's proposal.

14 – ZTE Corporation

The benefit of XR-specific SPS and CG enhancements is not clear.Prefer to drop XR specific SPS and CG pending sufficient RAN1 evaluation results and conclusion.

We have the following proposals on capacity:

1. Support CSI enhancements for faithful CSI measurements e.g. the measurement and reporting of delta MCS

2. Support CSI/HARQ feedback enhancements to achieve efficient transmission and satisfy stringent latency requirement,e.g., enhancement of CBG-based re-transmission.

3. Support potential techniques to address XR coexistence with other service, e.g. uRLLC and eMBB since a large number of XR service access has a great impact on current network.Evolved preemption scheme would be candidate to handle different service collision. The initial evaluation results as captured in our contribution R1-2106529 imply that enhanced preemption indication is capable of obtaining decent capacity performance gain. Therefore, we prefer to capture a bullet reflecting techniques to handle XR coexistence with other service.

4. Support enhancement for UL signalling to assist/trigger DL transmission , e.g., finer granularity BSR with some UL specific information which is needed by DL.

5. Network coding can be studied in XR.

15 – Fujitsu Limited

We support the understanding of the moderator. Probably, it is good to add "...depending on the progress of Rel-17 XR study" in the Scope 1.

16 – Guangdong OPPO Mobile Telecom.

We support XR-specific SPS and CG, but jitter issue maybe missed in the proposal. So we have suggestion of wording as follows:

XR-specific SPS and CG enhancements including dynamic SPS/CG parameter update, multi-TB SPS/CG, **HARQ-ACK enhancement** etc; to address XR-specific non-integer periodicity **and jitter**.

In addition, considering XR characteristics, e.g. jitter and various packet size, dynamic scheduling is also beneficial for XR. So PDCCH enhancement, including non-integer search space configuration and multi-PDSCH/PUSCH scheduling for large packet, should be considered.

17 – vivo Mobile Communication Co.

We are fine with the proposal for XR-specific SPS and CG enhancements. But we don't think it should be restricted to XR-specific SPS and CG enhancements to address XR-specific non-integer periodicity. Enhancement for dynamic scheduling e.g. delay aware scheduling and packet discarding, and CSI enhancement can also be considered.

In addition, XR capacity is still under evaluation in Rel-17 XR SI and not concluded yet. At this stage, we suggest to be more open for the other capacity enhancement schemes.

- Study XR specific capacity enhancement techniques, e.g. XR-specific SPS and CG enhancements including dynamic SPS/CG parameter update, multi-TB SPS/CG, delay aware scheduling and packet discarding, etc.
- Study CSI measurement/reporting enhancement for XR traffic.

18 – SHARP Corporation

We support the moderator's proposal. SPS/CG enhancement is beneficial in terms of both capacity and power consumption.

19 – Spreadtrum Communications

We support the SPS/CG enhancement, however, the dynamic scheduling shall also be studied further.

20 – Apple Europe Limited

For capacity enhancements, we propose to consider two additional points:

To specify CSI enhancements for faithful CSI measurements can be also important. With staggered transmission (proposed by some companies to alleviate system capacity issue), the interference pattern can change within a period of the data flow's . Similar to the need to update SPS/CG with non-integer periodicity, the CSI measurement also needs that.

Another enhancement can be

• Support CSI/HARQ feedback enhancements to achieve efficient transmission and satisfy stringent latency requirement. Some kind of soft HARQ-ACK feedback can be helpful.

21 – NEC Corporation

We support the listed potential areas.

22 – Lenovo Information Technology

We suggest

1. updating to: "to address XR-specific ***traffic characteristics such as*** non-integer periodicity".
2. adding a note such as: It is imperative to compare XR-specific SPS and CG enhancements with existing mechanisms including gNB implementation/dynamic scheduling.

23 – MediaTek Inc.

We support the proposal, with the understanding "to address XR-specific non-integer periodicity"

24 – VODAFONE Group Plc

Broadly agree with the moderator's proposal and many of the above comments on generalising it a bit.

25 – Qualcomm Korea

#1 : We support SPS and CG enhancement. We think the SPS/CG enhancements should be considered not only from capacity perspective but also from power perspective since there are techniques which can benefit both capacity and power. Thus, we suggest to include SPS/CG enhancements in power section as well.

26 – Sony Europe B.V.

We propose to add CSI measurement enhancements and HARQ feedback enhancements. It is very important to ensure the transmitted packet is within the packet delay budget (PDB).

It is a bit premature on agreeing a topic only. We can wait until Rel-17 XR study item is concluded / matured.

3.5 XR-specific mobility considerations

The following areas were widely supported, albeit understood that these are not strictly XR-specific, hence are better handled in the generic Mobility discussions from now on:

1. DAPS extension to FR1 CA and FR2, improved e2e latency for DAPS;

2. 0ms interruption without DAPS;

Feedback Form 16: Final comments on XR-specific mobility considerations

1 – CATT

We are OK that the mobility issue will be handled by "mobility enhancement" WI.

2 – Samsung Research America

We do not support inclusion of mobility aspects in a possible XR SI. Topics for a possible mobility WI should be discussed in the corresponding agenda and may or may not include the above two aspects.

3 – Futurewei

We agree with most companies' previous comments, these two points should be handled in separate WI or SI.

4 – China Mobile Com. Corporation

Share view that above two bullets could be treated in Mobility WI, and whether to include these two bullets can be handled there.

5 – Asia Pacific Telecom co. Ltd

It's OK to be handled by Mobility WI.

6 – HuaWei Technologies Co.

Yes we also agree these can be handled by mobility.

7 – InterDigital

We support moderator's summary

8 – LG Electronics Inc.

As moderator indicated, this topic should be discussed in Mobility Enhancement item.

9 – DOCOMO Communications Lab.

We are OK with the proposed direction that mobility enhancements will not be handled in the XR WI. Mobility enhancements will be handled by the separated mobility enhancements WI.

10 – Intel K.K.

Agree with CATT and Samsung comments that those can be discussed in WI dedicated to mobility enhancements.

11 – Nokia Corporation

We are fine that these are handled by the mobility discussions (then just need to make sure these elements are indeed going to be part of discussion there)

12 – LG Uplus

Fine with the moderator's proposal to move this to Mobility discussion.

13 – Apple Europe Limited

We don't see the reason to handle these two points under XR, second whether they are motivated or not in the mobility item can be investigated over there.

14 – Fujitsu Limited We are fine with the suggestion by moderator.
15 – Guangdong OPPO Mobile Telecom. We support proposal
16 – vivo Mobile Communication Co. We support the mobility enhancement to be discussed in general WI.
17 – Beijing Xiaomi Mobile Software We support moderator proposal.
18 – Spreadtrum Communications We support moderator's summary, but the 0ms interruption may not be always needed.
19 – NEC Corporation We support the listed potential areas.
20 – Lenovo Information Technology We have some doubts on the bullet 2). Anyway, we can discuss the detailed objectives on Mobility WI.
21 – MediaTek Inc. We support addressing these in a generic manner
22 – VODAFONE Group Plc We are OK to handle this under 'mobility' **BUT** then we need to ensure that mobility covers the inter-CU case properly and e.g. includes "2. 0ms interruption without DAPS" -> so some update of the mobility thread's conclusion will be needed.
23 – Ericsson LM We agree that these are studied in the mobility discussion.
24 – Qualcomm Korea This should be discussed in mobility WI session since they are not XR-specific.

4 Conclusions

This section presents the conclusions from the pre-RAN#93E NWM round.

Note-i: Rel-17 XR study work is still very much ongoing, hence these conclusions should be understood as a snapshot based on the current status. Further finetuning is expected over the coming months.

Note-ii: Some of the identified areas overlap with each other, consolidation of these may be necessary in the next iteration.

Note-iii: It is understood that many of the areas outlined below have a strong correlation with related SA2 and SA4 work. Hence, close cooperation with these groups is needed both for Objective setting, as well as during the actual work.

4.1 KPIs and QoS

The following areas were widely supported:

1. Study and potentially specify RAN support for enhanced granularity for QoS;

2. Study and potentially specify RAN support for ADU-based QoS;

3. Study and potentially specify RAN support for XR-specific QoS parameters.

4. Study and potentially specify synchronization of QoS flow handling belonging to the same XR service association and corresponding DRB control (in coordination with SA2).

Potential further work on KPIs (both system-level KPIs and KPIs for end-user experience) heavily depends on the outcome of the Rel-17 work on XR and on SA4 work around QoE. Hence, potential enhancements on KPIs can be better identified over the next few months and are left open at this point.

4.2 Potential areas of work on Application Awareness

The following areas were widely supported for further study and potential normative work:

1. Identify the XR traffic characteristics and application layer attributes beneficial/feasible for the gNB to be aware of, e.g. the QoS flow association, frame-level QoS, ADU-based QoS, XR specific QoS etc. that was concluded from KPI and QoS

2. Application layer information (e.g. frame rate, delay, packet importance, etc.) to aid XR-specific handling, e.g. scheduling, radio bearer handling, etc; One potential mechanism for this is to introduce UE assistance information;

4.3 XR-specific power consumption aspects

There was wide support to study (and potentially specify) XR-specific power saving techniques, e.g: XR-optimized C-DRX for aligning C-DRX with XR service periodicity and jitter, XR-specific multi-flow aspects. Enhancements to PDCCH monitoring and WUS can also be considered.

4.4 XR-specific capacity considerations

It is understood that the ongoing Rel-17 XR study is addressing many of the capacity aspects, and we should wait for the further progress of that study before finalizing the Rel-18 scope. Currently the following potential areas were identified for Rel18:

1. XR-specific resource allocation and scheduling enhancement, SPS and CG enhancements including dynamic SPS/CG parameter update, multi-TB SPS/CG, HARQ-ACK enhancement etc... to address XR-specific non-integer periodicity and jitter.

4.5 XR-specific mobility considerations

The following areas were widely supported, albeit understood that these are not strictly XR-specific, hence are better handled in the generic Mobility discussions from now on:

1. DAPS extension to FR1 CA and FR2, improved e2e latency for DAPS;

2. 0ms interruption without DAPS;

Note: mobility aspects will not be considered within the planning of the Rel-18 XR work in the future. All XR-relevant mobility aspects will be handled in the generic Mobility area.