**DT3GPP TSG-RAN Meeting #90e RP-20xxxx**

**Electronic Meeting, December 7-11, 2020**

**Agenda item:** xxx

**Source:** Moderator (Qualcomm)

**Title:** Summary of email discussions on NR Repeaters

**Document for:** Information

# Introduction

Coverage is a fundamental aspect of cellular network deployments. Mobile operators resort to different types of network nodes to offer blanket coverage in their deployments. While the deployment of regular full-stack cells is preferred, it may not be always a possible (e.g., not availability of backhaul) or economically viable option.

As a result, new types of network nodes have been considered to increase mobile operators’ flexibility for their network deployments. NR Rel-16 has introduced a new type of network node not requiring a wired backhaul through the specification of *Integrated Access and Backhaul* (**IAB**). The IAB node is a new type of relay node building over the front-haul architecture and constituting a node with a dual personality consisting of a Distributed Unit (DU) component making it possible to appear as a regular cell to the UEs it serves, and a Mobile Terminal (MT) component inheriting many properties of a regular UE which connects to its donor parent node(s). The IAB node is based on a Layer 2 architecture with end-to-end PDCP layer from the donor IAB node to the UE for Control Plane (CP) and User Plane (UP). IAB nodes can also be classified as re-generative relays, as every packet traversing the link between its donor and the MT component of the IAB node itself, i.e., backhaul-link, has to be properly decoded and re-encoded by the IAB node for transmission to the UE or subsequent IAB hop on the access link. While the first version of IAB in Rel-16 assumes half duplex operation between access and backhaul for transmission and reception, forward compatibility towards evolving IAB towards full duplex operation was put in place. One of the objectives of the Rel-17 IAB WI is to, indeed, enable full duplex implementations of IAB nodes.

Another type of network node is the *RF repeater*. **RF repeaters** have been used in 2G, 3G and 4G deployments to supplement the coverage provided by regular full-stack cells with various transmission power characteristics. They constitute the simplest and most cost-effective way to improve network coverage. The main advantages of RF repeaters are their low-cost, their ease of deployment and the fact that they do not increase latency. The main disadvantage is that they amplify signal and noise and, hence, may contribute to an increase of interference (pollution) in the system. Within RF repeaters, there are different categories depending on the power characteristics and the amount of spectrum that they are configured to amplify (e.g., single band, multi-band, etc.). RF repeaters are non-regenerative type of relay nodes and they simply amplify-and-forward everything that they receive. RF repeaters are typically full-duplex nodes and they do not differentiate between UL and DL from transmission or reception standpoint. Note that, to date, there is no definition of RF repeaters for NR. RF repeaters for LTE are specified in [36.106](https://www.3gpp.org/DynaReport/36106.htm) and are limited to FDD bands.

As NR moves to higher frequencies (around 4GHz for FR1 deployments and above 24GHz for FR2) propagation conditions degrade compared to lower frequencies exacerbating the coverage challenges. As a result, further densification of cells may be necessary. Multi-antenna techniques consisting of massive MIMO for FR1 and analog beamforming for FR2 assist in coping with the more challenging propagation conditions of these higher frequencies.

Note that all the frequency bands defined at this higher frequency regime are TDD. Another common property of these NR systems is the use of multi-beam operation with associated beam management.

The problem statement is two-fold (a) Many planned NR deployments are TDD and therefore simultaneous, bi-directional amplify-and-forward may not be necessary. This can reduce the pollution problem of regular RF repeaters; (b) Beamformed transmissions to individual users is fundamental to coverage esp. in FR2 bands. A simple RF repeater that the network is agnostic to may be unable to achieve the requisite beamforming gain.

With the above in mind, a type of network node*, somewhere in between RF repeaters and IAB nodes*, appears as a compelling proposition to try to leverage the main advantages of both. That network node, i.e., **smart repeater**, could, e.g., make use of some side control information to enable a more intelligent amplify-and-forward operation in a system with TDD access and multi-beam operation. It would still be non-regenerative and would only require a low capacity control backhaul between the donor cell(s) and itself. As a result, the low-complexity and low-cost properties of RF repeaters would be mostly preserved.

In preparation of the Rel-17 RAN4-led non-spectrum package discussion in RAN#89e an email discussion took place as submitted in [0] and captured, for completion, in the Annex of this contribution. A motivation paper was submitted to RAN#89-e in [1] and a draft WID in [2].

This document captures further companies’ views on NR repeaters as a candidate RAN4-led Rel-17 project.

# Discussion

Based on previous discussions [0] and in order to get a concrete project proposal, the following areas are identified for further discussion:

* Topic 0: Overall interest on NR repeaters RAN4 project in Rel-17
* Topic 1: Frequency range and duplexing of interest for NR repeaters (e.g., FR1 FDD/TDD, FR2)
* Topic 2: Objectives of candidate WID (e.g., RF/EMC requirements, assess benefits of smart repeaters, etc)
* Topic 3: Other WG involvement
* Topic 4: Other issues

## 1.1 Companies’ views

*Interested companies to provide comments on the sub-topics in the following sections*

### 1.1.0 Topic 0: Overall interest on NR repeaters project

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| **Company** | **Comments** |
| TIM | High Interest – this is an important feature to ensure outdoor to indoor coverage, especially (but not only) at FR2 |
| DT | We see the urgent need to specify first general requirement for “normal” repeaters as a baseline for “smart” repeaters. |
| Charter Communications | High Interest- this is an important feature to provide enhanced coverage. |
| Verizon | High Interest - this is an important feature to provide enhanced coverage, especially for our mmW network. We are interested in the “smartness”, if it is proven achievable. |
| CommScope | High Interest  Up to now there are standalone repeater standards for 2G/3G and 4G. There is a need for a 5G NR Repeater standards, core specification and conformance specification for FR1 and FR2 for both FDD and TDD modes of operation.  Repeaters have been used in 2G, 3G (Rel-4 WI RInImp-REP, Rel-10 WI RANimp-Repeaters1.28TDD) and 4G networks (Rel-18 WI LTE-Repeaters) as a cost-effective solution for extending coverage in sparsely populated areas or environments with particular propagation conditions such as buildings, tunnels, subways, stadiums, etc.  In GSM/UTRA/LTE repeaters have proven to be useful for coverage adjustments and interference mitigation.  These applications are expected to remain also in NR. However, NR may pose new or different requirements on the repeaters.  TDD operation will be used more frequently in NR, especially >3GHz, so it is important to consider TDD repeater operation as well.  We are seeing a growing market interest in Repeaters for NR and believe they are well suited for NR environments to overcome both penetration attenuation and free space attenuation. We think a standard for basic RF repeaters (including Over The Air Repeaters, Fiber Optic Repeaters, Distributed Antenna Systems) should be considered for 5GNR, and performance requirements must be defined.  We are interest in the smart repeater concept as a second priority and will be supporting this project. We propose to start working on the NR repeaters specification immediately and start an SI in parallel for the smart repeaters. |
| Telstra | High interest, in particular to help address FR2 coverage challenges. Important to understand how a ‘smart’ repeater performs relative to a ‘dumb’ repeater so baseline of the latter is necessary. Also important to understand how any proposed ‘smartness’ impacts possible forward compatibility of the repeater. |
| AT&T | We have high interest in this topic, including evaluating the potential benefits of “smart” repeaters especially for mmWave/FR2 bands and for Public Safety. The Public Safety use case should be considered from the start. |
| Qualcomm | High interest – NR repeaters (especially ‘smart repeaters’ as defined in the Introduction) are necessary to provide efficient and reliable coverage in various deployment scenarios, and different NR bands. |
| China Telecom | We are interested in smart repeater for NR TDD, which can be deployed in urban area with deep fading and in rural area. For the purpose of coverage extension in SA deployment, Rel-17 is a good time to do this work. |
| MediaTek | Technically and economically viable solutions to address known NR coverage issues are of course of interest. While repeaters may belong to such solutions, it is also important to understand their expected role and urgency in the ecosystem especially in view of other initiatives incl. at least IAB. It is important to characterize in sufficient details the different flavors of repeaters, their functionality in order to correctly assess what the scope of such a project would be, which WG(s) would be impacted, and what additional workload would be imposed onto these WGs. |

### 1.1.1 Topic 1: Frequency range and duplexing of interest

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| **Company** | **Comments** |
| TIM | Priority 1: FR2 TDD, priority 2: FR1 TDD, priority 3: FR1 FDD |
| DT | Priority 1: FR1 FDD, priority 2: FR1 TDD, priority 3: FR2 TDD |
| Charter Communications | Priority 1: FR! TDD, Priority 2: FR2 TDD, Priority 3 : FR1 FDD |
| Verizon | Priority 1: FR2 TDD, priority 2: FR1 TDD, priority 3: FR1 FDD |
| CommScope | For the RF Repeaters, we think it’s necessary to develop a core specification and a conformance specification for FDD/TDD NR repeaters for FR1 and FR2.  Our priority is as follows: FR1 TDD, FR1 FDD, FR2 TDD and FR2 FDD. |
| Telstra | Priority 1: FR2 TDD, priority 2: FR1 TDD, priority 3: FR1 FDD |
| AT&T | Priority 1: FR2 TDD, priority 2: FR1 TDD/FDD |
| Qualcomm | All FR1 (FDD and TDD) and FR2 (TDD) bands should be considered. However, we also agree with the prioritization proposed by TIM. |
| China Telecom | Suggest to give high and equal priority to FR1 TDD and FR2 TDD for smart repeater. |
| MediaTek | FR1 FDD – no real coverage problem identified.  FR1 TDD, FR2 TDD: unlike the above (FR1 FDD), TDD operation is not only a much more complex scenario, it is also one where coverage issues are critical. |

### 1.1.2 Topic 2: Objectives of candidate WID

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| **Company** | **Comments** |
| Charter Communications | We agree on the current objectives but will like to point out that we believe the side information provided by the repeater with beam/timing information may have some RAN1 impact. We believe some RAN1 work needs to be added to the wid |
| CommScope | Develop a core specification and a conformance specification for NR repeaters for FR1 and FR2 for both FDD and TDD modes of operation.  Add repeater to the NR EMC specification.  The new NR repeater requirements can be developed based on the existing LTE repeater standards (36.113, 36.106, 36.143). And in addition, as with UMTS and LTE, the base station transmitter requirements (for NR 38.104 and 38.141) can be considered, which are suitable for repeater as well.  3GPP 36.106 and 36.143 LTE Repeater requirements  Output power  Frequency stability  Out of band gain  Operating band unwanted emissions  Spurious emissions  Error Vector Magnitude (EVM)  Input intermodulation  Output intermodulation  Adjacent Channel Rejection Ratio (ACRR) |
| Qualcomm | RAN4 should specify RF and EMC requirements for NR repeaters, that can primarily be based on re-using the gNB/UE and IAB (mostly IAB-MT) specifications.  RAN4 should also assess the performance gains over the RF repeaters that can be achieved by having side control information (i.e. TDD configuration, and beamforming information). Some very simple system simulations like what is used for co-existence studies (e.g. SINR improvement) can be considered for this purpose. Repeaters are generally used for coverage extension, the potential improvement for such scenarios coming from use of side information should be to straight forward to assess.  Based on the outcome of the above assessment, RAN4 should later decide whether to ask other WGs (RAN1 and RAN2) for the specification support of side control information required for the operation of smart repeaters. |
| Nokia, Nokia Shanghai Bell | A study is needed before starting a WI in case anything else than a conventional analog RF repeater is considered.  If smart functions are in scope, study needs to aim at converging on a set of deployment scenarios and use cases in which the performance difference to IAB and potential gains to traditional repeaters, which also are not specified for NR, are quantified. Study shall also establish the target for how the side information is provided to the repeater and how beamforming behaves. Study also needs to identify the scope of work required in other WGs for proposed solutions.  Based on the study, the objectives and the level of “smartness” to be specified can be then discussed for the potential WI. |
| MediaTek | As per our answer to 1.1.1 we would recommend this work, if moving forward, be handled across two separate work items that could be worked on in parallel:   * WID(Feature): FR1 FDD * SID(Study): FR1 TDD, FR2 TDD   FR1 FDD WID:   * Using LTE repeaters specification as a baseline, this work is a low-hanging fruit that we do not expect would be subject to much controversy, if any * Requirement: the Repeater operation shall be transparent to UEs i.e. no UE impact   FR1 TDD, FR2 TDD SID: *Explicit, close-ended, list of issues to be studied, along with the responsible WG(s) to handle them.*   * Requirement: the Repeater operation shall be transparent to UEs i.e. no UE impact * Definition of Repeater architecture incl. interfaces and functionalities * The following aspects need to be studied, in particular to ensure UE transparency   + Initial access (synchronization, measurement, RACH)   + Beam management (P1, P2, P3 procedures for UL and DL, repeater panel/beam selection)   + MIMO (PDSCH demodulation and CSI report when the # of antenna at the repeater is not as large as BS)   + UL power control   + UL timing advance   + RRM (SCell activation/deactivation, handover, … ) * We also suggest to study the functions needed for this smart repeater, e.g.,   + Minimum existing “UE” functions that are needed for the repeater in order to maintain the link to BS,   + Existing “UE” functions that are not needed for the repeater to operate (e.g. mobility?)   + New functions for BS to control the repeater.   Definition of RAN4 RF requirements |

### 1.1.3 Topic 3: Other WG involvement

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| **Company** | **Comments** |
| TIM | Due to the current overload situation, we should aim to keep the scope restricted to RAN4 as much as possible. |
| Charter Communications | As highlighted above, we believe some RAN1 impact should be considered regarding some of the side information required from repeater with beam and timing information |
| Verizon | Agree with both TIM and Charters Communications. We would very much like to limit the impact outside of RAN4, but we also acknowledge that limited involvement form other WG(s), such as RAN1 is likely needed. We are interested in the side information in e.g., beamforming and timing information, and we like its potential in performance enhancement if it turns out to be achievable. Also, needless to say, we expect no company shall be forced to implement such “smartness” in their repeaters, if 3gpp indeed chooses to specify such “smartness”. |
| CommScope | Agree with TIM, Charter and VZ on keeping the workload within RAN4.  Smart Repeater could have potential impact on other WG. This should be evaluated in the SI. |
| AT&T | OK to start with keeping the workload initially in RAN4, but are open to involvement of other WGs, if necessary, based on the progress in the SI. |
| Qualcomm | As mentioned above (Section 1.1.2), RAN4 should decide later (e.g. by RAN#93) whether to ask RAN1 and RAN2 to assess the specification impact of the smart repeaters.  In that case, we anticipate RAN1 (and possibly RAN2) should get involved in the design of the required control signaling to provide the necessary information (i.e. TDD configuration, and beamforming information) to the smart repeaters.  However, it is desirable to limit the impact to these groups to a minimal level while trying to leverage existing NR frameworks and signaling (especially those defined for IAB) as much as possible. |
| Nokia, Nokia Shanghai Bell | Study item should be contained within RAN4.  The level of other WG involvement in potential WI should be minimal based on the current workload. The achievable performance based on the study should be weighed against the effort level in other WG. |
| China Telecom | Other WG impact is expected based on the current objectives. We agree that other WG impact should be minimized with a clear and concise scope for this RAN4-led work. |
| MediaTek | As we mentioned in a previous question, we need to first identify the area to be studied and then assign the correct WG(s) to handle it. Therefore, we suggest to first work on Topic 2 before discussing Topic 3.  The TU budgets not only for RAN4 but also for RAN1 and RAN2 need to be considered altogether. |

### 1.1.4 Topic 4: Other issues

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| **Company** | **Comments** |
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# Summary

*To be filled upon completion of comapnies’ views.*

# Annex: Email Discussion prior to RAN#89e

## A.1 Relevant documents submitted to RAN#88e

A motivation paper was submitted in [1] and a draft SID in [2].

## A.2 Issues related to Smart Repeaters for discussion

* Sub-topic 1-0: General interest on exploring the benefits of this type of network node
* Sub-topic 1-1: SI vs. WI
* Sub-topic 1-2: Potential project objectives
* Sub-topic 1-3: Other WG involvement
* Sub-topic 1-4: Any other issue

## A.3 Companies’ views

*Interested companies to provide comments on the sub-topics in the following sections*

### A.3.1 Sub-topic 1-0: General interest on exploring the benefits of smart repeaters

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| **Company** | **Comments** |
| Qualcomm | We believe smart repeaters, with a knowledge of TDD configuration (DL/UL split) and proper spatial RX/TX information, will offer significant system performance gains, at a lower cost and complexity compared with a full stack gNB or an IAB-node. The expected gains, compared to traditional RF repeaters, are achieved via higher array gains in the direction of the communication, as well as lower system interference. |
| Ericsson | The SID describes a new node with its performance aiming between the conventional RF repeater and a IAB node. However, as there is no NR repeater specification mentioned in SID, the baseline performance of the conventional repeater is unknown in the context of NR including AAS BS network. We believe the first step before making the conventional NR repeater “smarter” is to study and understand the baseline of conventional NR RF repeater. With understanding the drawback of deploying such conventional NR repeater in network, then we could start to think what will be new functionality to be added in the repeater and mitigate the possible shortcomings in a conventional RF repeater for NR where AAS BS network deployments are considered.  As the SID aims to improve the drawback of the pollution of the network of conventional repeater and suggest adding new functionality to mitigate it, it is important to understand the drawbacks and possible gain with smart repeaters. The objective mentions the potential such functionality like TDD time slot configuration and TX/RX beam spatial information. Using the spatial information as proposed in the smart repeater, it implies that at least the beamforming functionality similar to IAB-DU and corresponding interfaces will be needed. In addition, According to current BS architecture, the description of smart repeater resemble a case where the e.g. CPRI/e-CPRI interfaces to the radio unit of a BS. If moving the CPRI to the wireless is a goal then the burden/complexity will reside in the network side as well and the “smart repeater” is not transparent/agnostic to the network anymore and thus complexity and cost will be split between network and repeater side. The benefit on cost and complexity of this new smart repeater is not clear when it has AAS capability considering lack of studies compared to a baseline conventional repeater.  It is currently not entirely clear how the overall system concept looks and what the gains can be like. |
| China Telecom | We are interested in smart repeater. For 3G/4G, we deployed repeater in urban area with deep fading as well as in rural area, which is based on FDD band. Now for NR with TDD as major band, we see the benefit of the concept of smart repeater. |
| Deutsche Telekom | Unlike previous 3GPP RATs, there is currently no NR repeater (RF) specification available.  We think that is needs to be addressed directly with an appropriate WI in Rel-17 as there is clearly growing demand of operators for such solutions. This general requirement refers to “normal” repeaters and will be baseline for “smart” repeaters as well. Both FR FDD and TDD should be covered with equal priority.  In a 2nd step we support studying the “smart” repeater solution. |
| CMCC | Though lacking of RF repeater corresponding 3GPP specification, low cost RF repeaters have been deployed in 2G, 3G and 4G (FDD/TDD) networks with the simple amplify-and-forward operation to supplement network coverage. The main drawback of this cost-efficient RF repeater is that it could simultaneously amplify noise from other directions except for the wanted signal, deteriorating the received SINR. Therefore, it is necessary to study the potential gain achieved by the smart repeater with the knowledge of feasible UL/DL configuration and the beamforming information.  To achieve the large-scale deployment, the smart repeater should be designed and specified based on the low-cost principal and avoid complex functions as much as possible. |
| Verizon | There are RF repeaters for NR, even without 3gpp repeater specification. Together with IABs, they are part of the integreated coverage solution. However, we feel that RF repeater and IAB alone, do not offer us sufficient options to cover the spectrum of cost/complexity and performance tradeoff. We are looking for something that can be moderately more complex than the RF repeater but a lot simpler than IAB but can offer significant performance gain over conventional RF repeaters by e.g., leveraging beamforming. Therefore we have high expectation for this smart repeater.  And of coruse, we support a thorough evaluation. |
| Telstra | We are very interested in the Smart Repeater concept. Adding side control capability to a conventional RF repeater may significantly improve its performance while maintaining a low-cost price point.  FR2 TDD should be given highest priority |
| ZTE | RF requirements for NR smarter repeater and IAB with full duplex mode in Rel-17 should be further clarified, in addition, whether RAN1/RAN2 should be got involved as smarter repeaters mentioned should reply on some side control information transferred from parent DU to RF repeater to achieve the requisite beamforming gain. In addition, whether different scenarios, like outdoor repeater, indoor repeater and trunwall repeater should also been considered. |
| CATT | We also think a traditional repeater baseline is needed for smarter repeater. Actually for the TDD mode, there’re already some implementation based solutions to solve the problem of synchronization and separate UL and DL transmissions. Some study may be needed to know the gain of the smart repeater considering the implementation cost and complexity. |
| MTK | We are interested in the study of smart repeater, but we think there are many aspects needs to be further clarified.  From our understanding, this smart repeater could be more like a L1 relay. It is not possible to be transparent to the BS and UE. For an example, when network is requesting TCI-state switch, it should be this L1 relay to response network’s request rather than the UE. Also, this L1 relay should maintain a separate beamforming function to the UEs it serves in order to setup reliable link to UEs. This means some L1 functions are needed, such transmitting its own SSB or CSI-RS for L1-RSRP measurement, DCI indication for TCI-state switch to UE, PRACH channel for BFR handling. Furthermore, since the channel quality of BS-to-Relay and Relay-to-UE are different, even some dedicated CSI-RS for CQI/PMI/RI reporting and TRS need to be considered. Other aspects like timing advance, power control or even [handover] between relays should also be clarified. In summary, we are not sure if this L1 relay can be purely non-regenerative. |
| vivo | Based on input from operators, our understanding is that it is a low-cost network node which is similar to current IAB nodes. For FR2, we see the deployment scenario may be different from that of FR1 legacy repeaters.  Anyway, RAN4 can perform evaluation on the potential system level gain regarding to the utilization of this smart repeater, and in our view FR2 can be prioritized. |
| Intel | So far, no RF Repeater is defined in NR and the basic RF repeater performance is unclear. The reference RF repeater design should be clarified before enhancements can be investigated.  We agree that RF repeater in FR2 may benefit from availability of side information. However, many of the technical issues can be potentially resolved in implementation-specific manner (e.g. via detection of selected parameters or via vendor-specific signalling/configuration of required parameters). The studies shall aim to identify if the network assistance is required or it can be left up to UE implementation.  For instance, for beam management, to ensure proper operation FR2 repeater shall be capable to adjust its Tx/Rx beams towards the gNB in order to guarantee high antenna gains. One way is to perform Tx/Rx beam selection manually (e.g. during repeater installation). Alternatively, a repeater can implement SSB searcher and perform Tx/Rx beams selection to match the best SSB. Both approaches are viable, and no side information assistance required.  For DL/UL configuration thorough studies are required to identify the possible performance benefits. NR supports dynamic UL/DL configurations and basic repeater design should ensure robust performance even under dynamic UL/DL configuration conditions. |
| Samsung | Operators input on the interesting of repeater like network node can be one of strong justifications of introducing repeater in the 3GPP specifications.  The functionality of configuration TDD configuration and spatial RX/TX information is other WG scope instead of RAN4.  Also, as explained by motivation paper, the repeaters can be considered as other type of IAB with additional low-cost, easy deployment benefit. Therefore, we can further discuss whether introducing such repeaters under a RAN4 led WI/SI or existing Rel-17 IAB WI once the necessity of introducing repeaters in 3GPP spec is concluded |
| Nokia. Nokia Shanghai Bell | In order to be able to study which solutions would potentially be needed and evaluate possible gain there need to be a common understanding of the baseline. It needs to be clarified whether such baseline is understood to be Rel-16 IAB, traditional repeater defined for LTE or something else. Additionally, there would be a need to first have a clear system concept and a set of use cases based on which the impact to other WGs and therefore the organization of the potential SI could be defined. |
| Vodafone | Defining basic repeater requirements seems fine with low bands in mind, we assume this has no Base Station impact.  When we consider a smart repeater then this seems a much larger work with Layer 1 decisions to be made regarding the functionality required (which requires RAN1 effort), and closer in terms of functionality to an IAB node (something which we are still progressing in parallel). This seems to require a broader discussion about the benefits and impacts before we define another type of node with a different type of Base Station impact. |
| KDDI | We are interested in this proposal. Repeater is generally a very important component in current 3G/4G network. However, traditional repeaters that are without beam capability are not suitable for NR network especially for middle and high frequency range. This smart repeater has the potential to fill the need in this regard. |
| Sony | We are interested in study such a smart repeater. A thorough study is needed to understand how the smart repeater can offer the promised performance at reduced cost/complexity, for example, compared to IAB. A topic of particular important is beam management in FR2 bands, i.e., how high gain beams can be directed to the gNB and UEs with reasonable system complexity/hardware cost reduction. |
| Huawei | We would like to have more study for this smart repeater. Some performance evaluation would be needed to see what the impacts on the macro network when repeater coexists with normal BS and what the achievable performance gain is.  And before running simulation, we would like to know how the smart repeater utilizes those side information and how the side information could be achieved at the smart repeater. The study of those mechanism needs involve RAN1. |
| AT&T | As commented by other companies, we see the potential for NR repeater solutions as a scalable solution to extend coverage and increase reliability, especially for FR2 bands and outdoor-to-indoor scenarios. One key aspect should be to ensure that the introduction of repeaters does not negatively impact regular network deployments. |

### A.3.2 Sub-topic 1-1: SI vs. WI

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| **Company** | **Comments** |
| Qualcomm | We think that just an SI would push the availability of specifications to Rel.18 and this could be too late and jeopardize the timely availability of smart repeaters ; It seems there is a need for these devices that were widely used in previous generations and are beneficialfor reliable and economical deployment of NR networks  The benefits of smart repeaters, mainly achieved via higher beamforming gains and lower system interference (compared to traditional RF repeaters) are very straightforward. Moreover, the specification efforts of smart repeaters are anticipated to be manageable.  Hence, we believe that a WI or short SI+WI for smart repeaters is possible in order to be able to complete the normative work as soon as possible. |
| Ericsson | We think it is pre-mature to have a WI as we commented there is missing baseline of NR repeater.  We think a Study would be needed to clarify what the system concept is and what the likely benefits are, answering questions such as:   * How is the beamforming managed for the gNB to repeated link ? * How is the beamforming managed for the repeater to UE link ? * How is transmitter power managed at the repeater ? * How is transmitter power managed at the UE ? * Timing aspects and impact on TDD synchronocity * Co-existence with neighbor operators * Gains in capacity and/or coverage that may be expected * … |
| China Telecom | Ok with short SI+WI. Generally we can understand the motivation of introducing some side control information for TDD repeater, and the exact information needed can be identified in the SI phase. |
| Deutsche Telekom | We see urgent need to start with a NR repeater specification Work Item covering FR1 FDD and TDD as part of Rel-17.  In a dedicated SI the potential of “smart” repeaters could be elaborated. |
| CMCC | Start with a SI is OK. At the beginning of this study, we suggest focusing on the evaluation of the performance gain and the potential impact to the other work group. Whether to kick off the WI relies on the output of this SI. Once the SI shows the gain and request to involve other WGs, a subsequent WI can be kicked off. At the current stage, we should focus on the SI scope first. |
| Verizon | We see the urgent need for a better than converentional RF repeater – though whether or not it is easily definable is unclear. So we can start with a SI and then based on the outcome decide if we want to start a WI. It is better not to limit the effort to a SI only at this moment, |
| Telstra | We also see an urgent need for this work in Rel-17. Our preference is for a Work Item with a short study phase to assess the feasibility & performance gains for FR2 TDD as a priority |
| ZTE | Given that lots of coexistence simulation scenarios and different frequency ranges could be expected in this SID;  In addition, assess the performance gains for smarter repeater should not be RAN4 work, we think this might be part of RAN1 work. From RAN4 perspective, we only need to conduct the coexistence study and feasibility study based on RAN1’s design, however here the logic has been reversed we think.  Assess the performance advantages of having side control information to intelligently apply amplify-and-forward relay operation assuming availability of the following [RAN4]:   * Timing information, i.e., slot and symbol UL/DL configuration * Transmitter and receiver spatial information, i.e., beam information |
| CATT | We think SI is needed to study the gain compared with the traditional repeater. |
| MTK | Definitely a study phase is needed to identify the required functionality for this smart repeater. Whether to have a SI first or to have a SI+WI can be further discussed. In our view, RAN1 seems a better WG to start this study because there are many L1 functions involved |
| vivo | This should be SI first if the use case scenarios can be justified clearly. |
| Intel | SI is preferred |
| Samsung | We also observed that no RF requirements defined for NR repeaters. Specifying RF requirements for repeaters is in RAN4 scope. RAN4 WI can start WI of specifying the RF requirements once the necessity of introducing repeaters in 3GPP spec is concluded. However, as commented in pervious issue, the functionality of beamforming and DL/UL configuration configurations is in other WG scope. Study the feasibility of introducing such functionality in RAN4 is not proper. |
| Nokia, Nokia Shanghai Bell | If there is consensus to start this work, SI is needed to enable analyzing the use cases, requirements and potential benefits. |
| KDDI | OK with short SI+WI considering the operators’ urgent need for NR coverage improvement but this item needs to start with the study on the scope. It may be realistic to start with small objectives in Rel-17 and enhance in Rel-18. |
| Sony | SI is needed. |
| Huawei | We prefer to have SI first to clearly understand how it can work and what the impacts on RAN1, RAN2, and RAN4 are. |
| AT&T | Agree with KDDI, it may not be possible to cover all potential scenarios/use cases in Rel-17 and a study phase to assess benefits/spec impact would be useful to assist in prioritization. Rel-17 WI could be considered if the findings of the SI are concluded in a timely fashion and do not negatively impact other key Rel-17 features. |

### A.3.3 Sub-topic 1-2: Potential project objectives

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| **Company** | **Comments** |
| Qualcomm | For RAN4, the study part would include assessing the performance gains by looking at possible implementations of the active antenna systems that the repeater would use(e.g. beamforming gain, number of beams, etc). Some very simple system simulation similar to what is used for co-existence studies(e.g. SINR improvement) can also be considered. This would also relate to how much side information is needed.  The actual specification work would consist of defining RF core requirements, these would be based on re-using the gNB/UE and IAB(mostly IAB-MT) specifications. Depending on the definition of side information, there could be some performance work related to it(e.g defining performance requirements for the demodulation of the control information).  Scope/objectives for other groups are discussed below. |
| China Telecom | For the system level simulation, we agree that simple/ideal beamforming model used for co-existence simulation can be considered; otherwise it would be time consuming to agree on new simulation parameters and align results from different companies. |
| Deutsche Telekom | WI Rel-17: Define NR repeater (RF) specification as for previous generations of 3GPP RATs for FR1 FDD and TDD.  SI Rel-17: Defined deployment scenarios for smart repeater deployment, incl. frequency bands, antenna design, RF parameters etc.; evaluate performance enhancement depending on the “level of smartness”. Assess the benefits of reusing existing solutions, ie. From IAB work. Define control framework for smart repeaters (if necessary) |
| CMCC | The potential project should include   1. The performance gain of smart repeater with a knowledge of the UL/DL TDD configuration and beamforming information 2. RF core requirement, the start point of this is to reuse IAB RF requirements 3. Performance requirements based on the necessary control signaling 4. The impact to other WGs |
| Verizon | The RAN4 issues are clear.  We also think we need to define what side info is needed by e.g., identifying scenarios, performaning SLS and identifing the parameters needed by the repeaters, and then how to signal these parameters. These can be covered by the SI. |
| Telstra | Agree with CMCC |
| CATT | Besides the RAN4 traditional work for repeaters, we think the followings are needed for SI,   1. The aspects needs to be enhanced compared with traditional repeaters. 2. The potential solutions of the enhancement from standard point of view.  * The performance gain, the impact to other WGs and the cost should be considered.   Decide if smart repeater is valuable and if smart repeater WI should established. |
| MTK | Study first. And then the WI (or work phase) should be based on the study outcome. |
| vivo | If study phase is needed in R17, we would like to understand what would be the performance metrics for the evaluation. |
| Samsung | If we go for RAN4 led WI, the scope is to specify the RF requirements for repeaters. Existing IAB RF requirements can be used as starting points. If other features, e.g., functionality of beamforming and DL/UL configurations is specified by other WG, RAN4 will also define the corresponding requirements. |
| Nokia, Nokia Shanghai Bell | The targeted use cases for smart repeaters need to be set as starting point for the study as the beam interface requirements and the control mechanisms vary significantly e.g. between only FWA-type operation and connecting to moving UEs.  Performance gap to IAB would need to be studied as that is the closest reference we have currently for NR. |
| Sony | The use cases, the advantages of the smart repeater, and operation mechanism (e.g., beam management in FR2,) need to be understood during the SI stage. |
| Huawei | In our view the potential objectives should include   * Identify the scenario where repeater and smart repeater will be utilized. * Investigate the performance gain and/or impact on performance by introduction of NR repeater and smart repeater in terms of coverage and throughput. * Study the mechanism/scheme for acquiring the side information about the beam forming and UL/DL configuration and how to use this.   + How the BS control the beam direction of smart repeater.   + What kind of improvement compared to pure RF repeater is needed for smart repeater.   + FFS beam management * Study the architecture of smart repeater. * Identify the necessary RAN4 RF and RRM core requirements. * Identify the necessary RAN4 performance requirements. |
| AT&T | QC proposal sounds reasonable. Reusing existing specifications/requirements as much as possible (i.e. IAB) would be very desirable. |

### A.3.4 Sub-topic 1-3: Other WG involvement

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| **Company** | **Comments** |
| Qualcomm | RAN1 and possibly RAN2 should get involved in the design of the required control signaling to provide the necessary information to the repeater (e.g. time domain scheduling and beam related controls)  RAN3 may get involved, in case additional signaling is considered on the backhaul interfaces for differential treatment of the repeater.  It is desirable to limit the impact to these groups to a minimal level while trying to leverage existing NR frameworks and signaling as much as possible. |
| Ericsson | Some parts of the system concept (e.g. beam management, power control, other control aspects) may have impacts to other WGs.  What is the link between the gNB and the repeater? Is this a new kind of interface? In that case, the impact to other WGs could be significant. |
| Deutsche Telekom | Agree with Qualcomm  It should also be studied how the configuration of the smart repeater should be handled. This seems to go also into the direction of Ericsson’s comment. |
| CMCC | Since other WGs are already fully occupied, before involving RAN1~3, RAN4 should focus on the performance evaluation of the potential gain and then analyze the impact to other WGs.  We also agree with limiting the impact to other WGs to a minimal level. More complex functions and more cost will have negative impact on the large-scale economical deployment. Hence, we should carefully evaluate the impact on RAN1~3. |
| Verizon | We agree that other WGs need to get involved at some point. So in the SI phase, we should set a goal to miniumize the impact to other WGs. |
| Telstra | Agree with CMCC |
| ZTE | RAN1/RAN2/RAN3 should be get involved as some signalling information should be added and interferace information exchange if needed. |
| CATT | We think the impact to other WGs should be minimized and the impact to current gNB should be very small or no impact at all. |
| MTK | We think at least RAN1 and RAN2 needs to be involved even in the study phase. |
| vivo | For R17, RAN1/2/3 capacity is full and there is no TU. Maybe we can perform system level evaluation in a RAN4-only SI. If the performance gain and necessary enhancement can be justified then we can include RAN1/2/3 in future release. |
| Intel | Basic RF repeaters typically do not have L1/L2 implementations. Conveying the information using L1/L2 may have a substantial impact on RF repeater complexity and cost (e.g. comparable to IAB nodes). Prefer to minimize RAN1/2 impacts. |
| Samsung | To enable the functionality of smart part of repeaters, other WG shall be definitely involved and even as primary WG. |
| Nokia, Nokia Shanghai Bell | RAN1 and RAN2 work depend on the solutions and possible need for signaling, but impact to RAN1 and RAN2 should be minimized as much as possible taking into account their current workload. Preferably SI shall focus on RAN4 aspects only. |
| KDDI | As mentioned above, small objective would be realistic to meet the urgent demand which implies involving other WGs as less as possible. This approach would also bring the benefit on the cost side as well. |
| Huawei | RAN1 and RAN2 should be involved for studying the mechanism from the beginning.  Regarding how the work can be organized, we prefer to start from RAN1 if possible. |
| AT&T | Too early to tell at this stage what WGs would be involved, but it seems at least RAN1 would be involved and depending on the complexity of the “smart” repeaters RAN2/RAN3 would also potentially need to be involved. |

### A.3.5 Sub-topic 1-4: Any other issue

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| **Company** | **Comments** |
| ZTE | EMC study for NR repeater is also necessary if approved. |

## A.4 Summary of discussion

A total of 16 unique responses were provided to the email discussion.

In this section we summarize the main observations from the replies received:

**Sub-topic 1-0**: General interest on exploring the benefits of this type of network node

The majority of companies have shown interest in the area. Operators have recognized the importance of the repeaters in 2G, 3G, and 4G deployments and the fact that 3GPP does not have requirements for repeaters in NR.

A number of companies expressed the urgent desire to specify RF repeaters for NR as they have already been specified for LTE. The RF repeaters would constitute the baseline for enhancements offered by the availability of side control information on TDD configuration and spatial information (smart repeaters).

**Sub-topic 1-1**: SI vs. WI

Specification of RF repeaters for NR could go straight to WI (leveraging, as possible, IAB RF requirements). At the same time, RF repeaters would constitute the baseline for smart repeaters to compare against while sharing RF requirements.

Advantages and specification impact of smart repeaters would need to be studied so that the performance advantages are established while enabling low-cost and low-complexity implementations compared to IAB. This could be done as an objective of a potential WI on NR repeaters.

**Sub-topic 1-2**: Potential project objectives

Requirements for RF repeaters.

Assessment of advantages offered by smart repeaters (over RF repeaters) and the corresponding specification impact.

**Sub-topic 1-3**: Other WG involvement

In addition to RAN4, involvement of RAN1 and RAN2 has been broadly recognized for the specification impact of Smart repeaters. RAN3 involvement can be avoided limiting the scope of smart repeaters.

**Sub-topic 1-4**: Any other issue

EMC study for smart repeaters have been mentioned as necessary if this project gets approved.

As a result, the following is proposed:

**Proposal**: Approve a WI on NR repeaters for Rel-17. This WI would specify requirements for RF repeaters and would study the advantages of smart repeaters and their specification impact. A check-point at the end of the study objective of the WI could be done to decide whether and when to move to normative phase. A draft WID proposal is available at [2].

# References

[0] RP-201830, “Summary of Email discussions on Smart Repeaters”, Moderator (Qualcomm).

[1] RP-201831, “Motivation paper for NR Repeaters”, Qualcomm.

[2] RP-201832, “New WID proposal for NR Repeaters”, Qualcomm.