**3GPP TSG-RAN WG2 Meeting #128 R2-24xxxxx**

**Orlando, Florida, 18th – 22nd November 2024**

**Agenda Item: 8.13.3**

**Source: InterDigital**

**Title: Report of [POST127][402][Relay] Multi-hop relay control plane**

**Document for: Discussion and Decision**

# 1 Introduction

This contribution gives the discussion summary of following post email discussion.

* [Post127][402][Relay] Multi-hop relay control plane (InterDigital)

Scope:

- Describe different solutions (from company contributions) for multihop U2N relay UE by at least describing:

* + Connection establishment procedures
  + Assumptions on RRC state(s) of intermediate UEs and last relay UE
  + Assumptions on controlling gNB/cell of each relay UE
  + How the remote and intermediate relay UEs obtain their configurations in each solution
  + How to meet QoS requirement e2e

- Evaluate the feasibility and pros/cons of the different solutions towards downscoping to a single solution

Intended outcome: Report to RAN2#128

Deadline: Very long (for RAN2#128)

## Phasing of the Email Discussion

The email discussion has been divided into two phases, where phase 1 will correspond to describing the different solutions in each of the areas identified (connection establishment procedure, RRC state assumptions, assumptions on the controlling gNB/cell, configuration procedure, and E2E QoS). This will ensure that companies have a common understanding of each of the solutions.

In the second phase, the solutions will be evaluated in terms of their feasibility and pros and cons.

## Contact information

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# 2 Phase 1 Discussion

Based on company contributions, there seem to be two main approaches for implementing multipath U2N relays. A first approach is a fully U2N based approach. The network directly controls each of the intermediate relay UEs using dedicated Uu RRC signalling. The second approach is still U2N-based but with some elements of U2U. Only the last relay UE needs to be controlled using dedicated RRC signalling.

For the email discussion, approach 1 and approach 2 will be used as follows:

* Approach 1: The network needs to directly control each of the intermediate relay UEs via Uu RRC.
* Approach 2: Only the last relay UE requires control by the network via Uu RRC.

In each subsection, the procedures and assumptions for each approach will be discussed to get a common understanding of both approach 1 and approach 2 in the context of the following aspects:

* Connection establishment procedures
* Assumptions on RRC state(s) of intermediate relay UEs and last relay UE
* Assumptions on controlling gNB/cell of each relay UE
* How the remote and intermediate relay UEs obtain their configurations in each solution
* How to meet QoS requirement e2e for remote UE

## 2.1 Connection Establishment Procedure

In each subsection, the purpose is to agree on a baseline procedure for connection establishment and RRC state assumptions for both approaches (to serve as the basis for further feasibility and pro/con evaluation.

2.1.1 Approach 1

Using connection establishment procedure for single-hop relays as a baseline, the figure below illustrates rapporteur’s assumptions of the establishment procedure for multiple-hop relays in approach 1.



1. The U2N Remote UE, First Relay UE, Intermediate Relay UE, and Last Relay UE perform discovery procedure, and establish a PC5-RRC connection between each adjacent UE (U2N Remote UE<->First Relay UE, First Relay UE <-> Intermediate Relay UE, Intermediate Relay UE <-> Last Relay UE) using the NR sidelink PC5 unicast link establishment procedure.
2. The L2 U2N Remote UE sends the first RRC message (i.e., *RRCSetupRequest*) for its connection establishment with gNB via the First Relay UE, using a specified PC5 Relay RLC channel configuration. The first Relay UE sends the *SidelinkUEInformationNR* message to request for the dedicated configurations required to support the multi-hop relay operation for the U2N Remote UE. If the First Relay UE is not in RRC\_CONNECTED, it needs to do its own Uu RRC connection establishment via the Intermediate Relay UE (using similar actions as a U2N Remote UE) upon reception of a message from U2N Remote UE on the specified PC5 Relay RLC channel. The Intermediate Relay UE sends the *SidelinkUEInformationNR* message to request for the dedicated configurations required to support the multi-hop relay operation for the U2N Remote UE. If the Intermediate Relay UE is not in RRC\_CONNECTED, it needs to do its own Uu RRC connection establishment via the Last Relay UE (using similar actions as a U2N Remote UE) upon reception of a message from the First Relay UE on the specified PC5 Relay RLC channel. The Last Relay UE sends the *SidelinkUEInformationNR* message to request for the dedicated configurations required to support the multi-hop relay operation for the U2N Remote UE. If the Last Relay UE is not in RRC\_CONNECTED, it needs to do its own Uu RRC connection establishment upon reception of a message from the Intermediate Relay UE on the specified PC5 Relay RLC channel. The Last Relay UE receives SRB0 relaying Uu Relay RLC channel configuration for the Intermediate Relay UE from gNB. The Intermediate Relay UE receives SRB0 relaying Uu Relay RLC channel configuration for the First Relay UE from gNB. The gNB configures SRB0 (for U2N Remote UE) relaying Uu Relay RLC channel to the first Relay UE. The gNB responds with an *RRCSetup* message to U2N Remote UE. The *RRCSetup* message is sent to the U2N Remote UE using SRB0 relaying Last Relay RLC channel over Uu and the specified PC5 Relay RLC channels over each of the PC5 links.
3. The gNB, Last Relay UE, Intermediate Relay UE and First Relay UE perform relaying channel setup procedure over Uu. According to the configuration from the gNB, the First Relay/U2N Remote UE establishes a PC5 Relay RLC channel for relaying of SRB1 towards the U2N Remote UE/First Relay UE over PC5, the Intermediate Relay/First Relay UE establishes a PC5 Relay RLC channel for relaying of SRB1 towards the First Relay UE/Intermediate Relay UE over PC5 and the Last Relay UE/ Intermediate Relay UE establishes a PC5 Relay RLC channel for relaying of SRB1 towards the Intermediate Relay UE/Last Relay UE over PC5.
4. The *RRCSetupComplete* message is sent by the U2N Remote UE to the gNB via the First Relay UE, Intermediate Relay UE and the Last Relay UE using SRB1 relaying channels over PC5 and SRB1 relaying channel configured to the Last Relay UE over Uu. Then the U2N Remote UE is RRC\_CONNECTED with the gNB.
5. The L2 U2N Remote UE and gNB establish security following the Uu security mode procedure and the security messages are forwarded through the First Relay UE, Intermediate Relay UE, and Last Relay UE.
6. The gNB sends an *RRCReconfiguration* message to the U2N Remote UE via the Last Relay UE, Intermediate Relay UE, and First Relay UE to setup the end-to-end SRB2/DRBs of the U2N Remote UE. The U2N Remote UE sends an *RRCReconfigurationComplete* message to the gNB via the First Relay UE, Intermediate Relay UE, and Last Relay UE as a response. In addition, the gNB may configure additional Uu Relay RLC channels between the gNB and Last Relay UE, and PC5 Relay RLC channels between each of the Intermediate Relay UE, First Relay UE, and U2N Remote UE for the relaying traffic.

Based on the above procedure, for gNB to control each relay UE by RRC, each relay UE needs to be in RRC connected. As a result, for connection establishment of the remote UE, each relay UE should trigger its own connection establishment. For the last relay UE, Uu connection establishment is performed. However, for the other relay UEs, upon reception of a message on SL-SLB0, they perform connection establishment as though they are acting as a remote UE.

Question 1: Do you agree that for approach 1

* + the remote UE connection establishment always triggers connection establishment in each of the relay UEs (if they are in IDLE/INACTIVE)
  + for all relay UE’s except the last relay UE, upon reception of a message on SL-SRB0, it triggers a remote UE connection establishment?
  + For all relay UE’s except the last relay UE, they need to be configured with a remote UE Uu DRB configuration and SRAP configuration to act as a remote UE (without having any Uu traffic per se).

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| **Companies** | **Yes or No** | **Comments** |
| OPPO | See comments | We agree that all the relay UEs need to be in RRC connected state to serve a RRC connected remote UE, i.e., generally Yes for the first bullet.  While for the second and third bullet, we are confused on the intention:   * For the second bullet, what is the delta part compared to the first bullet? * For the third bullet, how to understand “configured with a remote UE Uu DRB configuration”? We understand the relay UE without having any Uu traffic doesn’t need to have DRB configuration (e.g., SDAP, PDCP configuration). |
| LG | Yes | We believe that reusing the legacy Rel-17 U2N scheme can be a straightforward way to implement a Rel-19 multi-hop U2N relay. The approach 1 can implement without big spec impact by reusing the legacy Rel-17 U2N procedure as much as possible. Therefore, we generally agree with the approach 1. But we have to clarify the details later. For example, the difference between 2nd and 3rd bullets. |
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Question 2: Do you agree that the above figure and steps can serve as the baseline connection establishment procedure of approach 1 that can serve for further discussion of pros/cons?

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| **Companies** | **Yes or No** | **Comments** |
| OPPO | See comments | We generally agree with the figure, and the detail wording in the steps can be further checked/discussed, e.g.:  In step-2, “*The Last Relay UE receives SRB0 relaying Uu Relay RLC channel configuration for the Intermediate Relay UE from gNB. The Intermediate Relay UE receives SRB0 relaying Uu Relay RLC channel configuration for the First Relay UE from gNB. The gNB configures SRB0 (for U2N Remote UE) relaying Uu Relay RLC channel to the first Relay UE.*” We understand gNB provides SRB0 configuration to each UE via RRC message, there is no need to say xx Relay UE relaying Uu relay RLC channel configuration for xx Relay. |
| LG | Yes | We agree the procedure as the basic procedure for the further pros/cons discussion. |
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2.1.2 Approach 2

Using connection establishment procedure for single-hop relays as a baseline, the figure below illustrates rapporteur’s assumptions of the establishment procedure for multiple-hop relays in approach 2.



1. The U2N Remote UE, First Relay UE, Intermediate Relay UE, and Last Relay UE perform discovery procedure, and establish a PC5-RRC connection between each adjacent UE (U2N Remote UE<->First Relay UE, First Relay UE <-> Intermediate Relay UE, Intermediate Relay UE <-> Last Relay UE) using the NR sidelink PC5 unicast link establishment procedure.
2. The L2 U2N Remote UE sends the first RRC message (i.e., *RRCSetupRequest*) for its connection establishment with gNB via the First Relay UE, using a specified PC5 Relay RLC channel configuration. If the First Relay UE is in RRC\_CONNECTED, it sends the *SidelinkUEInformationNR* message to request for the dedicated configurations required to support the multi-hop relay operation for the U2N Remote UE. Otherwise, it obtains the configuration from SIB or preconfiguration. If the Intermediate Relay UE is in RRC\_CONNECTED, it sends the *SidelinkUEInformationNR* message to request for the dedicated configurations required to support the multi-hop relay operation for the U2N Remote UE. Otherwise, it obtains the configuration from SIB or preconfiguration. The Last Relay UE sends the *SidelinkUEInformationNR* message to request for the dedicated configurations required to support the relay operation for the U2N Remote UE. If the Last Relay UE is not in RRC\_CONNECTED, it needs to do its own Uu RRC connection establishment upon reception of a message on the specified PC5 Relay RLC channel. After the Last Relay UE's RRC connection establishment procedure and sending the *SidelinkUEInformationNR* message, gNB configures SRB0 relaying Uu Relay RLC channel to the Last Relay UE. The gNB responds with an *RRCSetup* message to U2N Remote UE. The *RRCSetup* message is sent to the U2N Remote UE using SRB0 relaying Last Relay RLC channel over Uu and the specified/preconfigured PC5 Relay RLC channels over each of the PC5 links.
3. According to (pre)configuration, the First Relay/U2N Remote UE establishes a PC5 Relay RLC channel for relaying of SRB1 towards the U2N Remote UE/First Relay UE over PC5, the Intermediate Relay/First Relay UE establishes a PC5 Relay RLC channel for relaying of SRB1 towards the First Relay UE/Intermediate Relay UE over PC5 and the Last Relay UE/ Intermediate Relay UE establishes a PC5 Relay RLC channel for relaying of SRB1 towards the Intermediate Relay UE/Last Relay UE over PC5.
4. The *RRCSetupComplete* message is sent by the U2N Remote UE to the gNB via the First Relay UE, Intermediate Relay UE and the Last Relay UE using SRB1 relaying channels over PC5 and SRB1 relaying channel configured to the Last Relay UE over Uu. Then the U2N Remote UE is RRC\_CONNECTED with the gNB.
5. The L2 U2N Remote UE and gNB establish security following the Uu security mode procedure and the security messages are forwarded through the First Relay UE, Intermediate Relay UE, and Last Relay UE.
6. The gNB sends an *RRCReconfiguration* message to the U2N Remote UE via the Last Relay UE, Intermediate Relay UE, and First Relay UE to setup the end-to-end SRB2/DRBs of the U2N Remote UE. The U2N Remote UE sends an *RRCReconfigurationComplete* message to the gNB via the First Relay UE, Intermediate Relay UE, and Last Relay UE as a response. In addition, the gNB may configure additional Uu Relay RLC channels between the gNB and Last Relay UE, and PC5 Relay RLC channels between each of the Intermediate Relay UE, First Relay UE, and U2N Remote UE for the relaying traffic.

The main difference in the procedure with approach 1 is that a relay UE (other than the Last Relay) in RRC\_IDLE/RRC\_INACTIVE is not required to trigger an RRC connection as a result of the remote UE’s RRC connection. Also, rapporteur has assumed (as was done for SL in Rel16, as well as for U2U relays in Rel18) that for a relay UE that is already in RRC\_CONNECTED, the relay UE obtains its configuration using dedicated RRC signaling. For the case of the relay UE in RRC\_IDLE/RRC\_INACTIVE, how the relay UE obtains its configuration is further discussed in section 2.2.

Question 3: Do you agree that for approach 2

* + a relay UE in RRC\_IDLE/RRC\_INACTIVE (other than the Last Relay UE) is not required to trigger its own RRC Connection upon RRC connection establishment of the U2N Remote UE.
  + similar to legacy (Rel16 SL, and Rel18 U2U), if a relay UE is in RRC\_CONNECTED, it obtains its relaying RLC channel configuration in dedicated signaling.

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| **Companies** | **Yes or No** | **Comments** |
| OPPO | Yes |  |
| LG | Yes | Approach 2 introduces new concepts compared to the legacy Rel-17 U2N; however, the benefits are not understood when the intermediate Relay UE is in RRC\_IDLE/INACTIVE. The intermediate Relay UE has to serve relay functionality while communication is ongoing between the remote UE and gNB regardless of its RRC state. We believe that management by the gNB can be performed efficiently when the intermediate Relay UE is in RRC\_CONNECTED.  In step 4, it’s not clear how to deliver the *RRCSetup* message to the remote UE without local ID assignment. The intermediate Relay UE which doesn’t have the local ID of the Remote UE may not deliver the message to the correct Remote UE among multiple other Remote UEs.  The local ID assignment scheme may be different from the scheme used in the Rel-18 U2U. In the case of Rel-18 U2U, the relay UE easily assigns the local ID to the source Remote UE and target Remote UE because there are only two hops. When discussing multi-hop extension in Rel-19, a new local ID assignment mechanism should be considered for when the intermediate Relay UE assigns the local ID of the Remote UE. In terms of local ID assignment or QoS split, we may not be able to inherit the legacy Rel-18 U2U relay. |
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Question 4: Do you agree that the above figure and steps can serve as the baseline connection establishment procedure of approach 2 that can serve as further discussion of pros/cons?

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| **Companies** | **Yes or No** | **Comments** |
| OPPO | Yes |  |
| LG | Yes |  |
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## 2.2 Assumptions on the Controlling cell/gNB

The controlling cell/gNB of the remote UE and associated relay UEs may depend on the RRC state of the remote UE and the coverage situation of the relay UE.

For a remote UE in RRC\_IDLE/RRC\_INACTIVE, the U2N remote UE acquires SIB of a cell that may eventually provide network connectivity. As with the single-hop case, it’s assumed this is the SIB read by Last Relay UE that would eventually be the cell controlling the U2N Remote UE.

Question 5: Do you agree (for both approach 1 and approach 2) that the U2N Remote UE in RRC\_IDLE/RRC\_INACTIVE gets its SI from the Last Relay UE?

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| **Companies** | **Yes or No** | **Comments** |
| OPPO | See comments | We agree that the U2N Remote UE should use the SI of the cell that the Last Relay camps, while it is a little confusing to say “gets its SI from the Last Relay UE” since it relates to SI forwarding mechanism. |
| LG | See comments | If the intermediate Relay UE is connected, the serving cell of the intermediate Relay UE is the same as the last Relay UE’s cell. We believe that the U2N Remote UE in RRC\_IDLE/INACTIVE can receive its SI from the directly connected intermediate Relay UE. |
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In single-hop relaying, the U2N Relay is in coverage and connected via Uu. The remote UE is assumed to be out of coverage, and therefore, the control is assumed to come from the same cell as the cell to which the U2N Relay is connected. In approach 1, a relay UE (other than the Last Relay UE) acts as a remote UE. As a result, if a relay UE (other than the Last Relay UE) is out of coverage, its control should come from the same cell to which a parent relay UE is connected to. This is illustrated below and should also apply for approach 2.



Question 6: Do you agree (for both approach 1 and approach 2) that the control/configuration of an out of coverage relay UE connected to only one parent, when it is RRC\_CONNECTED and the U2N Remote UE is in RRC\_CONNECTED, comes from the same cell controlling/configuring the remote UE and the Last Relay UE?

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| **Companies** | **Yes or No** | **Comments** |
| OPPO | Yes |  |
| LG | Yes |  |
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In the previous case, a relay UE (other than the Last Relay UE) could potentially be RRC connected to a different cell. This would be the case, for example, if the relay UE is in coverage, or if it has two PC5 links with two different parent relays (connected to two different cells). In this case, it could obtain its relaying configuration from a cell which is different than the cell from which the remote UE is obtaining its end-to-end configuration. This is shown in the figure below. The same situation would arise for a relay UE connected to two different parent relays, and also applies to both approach 1 and approach 2.



Question 7: Should we support the case (for both approach 1 and approach 2) the relay UE (other than the last relay UE) is RRC connected to (and obtains its configuration from) a different cell than the remote UE and parent relay UE for that remote UE?

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| **Companies** | **Yes or No** | **Comments** |
| OPPO | No | Firstly, this is out of R19 multi-hop U2N relay scope since for the relay UE it has two legs towards different NWs (i.e., multipath topology).  And we are wondering what the use case of this scenario is, i.e., a relay UE has direct connection to the network (can support single hop U2N Relay) but chose to act a multi-hop U2N intermediate relay. |
| LG | No | In this case, the intermediate Relay UE has two paths. One is a direct path and the other is an indirect path. It looks out of the scope in Rel-19. |
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One remaining case for an RRC\_CONNECTED remote UE that is specific to approach 2 is when one or more of the relay UE’s are in RRC\_IDLE/RRC\_INACTIVE/OOC during active relaying for the U2N Remote UE. If we use rules which are consistent with previous releases of SL and relays, the relay UE may obtain its configuration from SIB/preconfiguration. The remaining question would then be to determine which SIB to use in the case where there are multiple cells involved. Alternatively (and deviating from previous release assumptions), it could obtain its configuration from a parent relay UE (e.g., the Last Relay UE) that obtains its configuration via dedicated RRC signaling.

Question 8: In approach 2, when the remote UE is RRC\_CONNECTED and the relay UE (other than the Last Relay UE) is in RRC\_IDLE/RRC\_INACTIVE/OOC, where does this relay UE get its configuration?

1. From its camping cell, when IDLE/INACTIVE, or from preconfiguration, when OOC.
2. From SIB of the cell of a parent relay UE that receives it on Uu
3. From a parent relay UE (e.g., the Last Relay UE) that obtains it via dedicated signaling.

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| **Companies** | **Response** | **Comments** |
| OPPO | Do not see the need to support approach-2 | We understand each option has some further issues to resolve:   * How to configure UE ID to avoid collision in the multi-hop link. * For Option A and Option B, how for the relay UE to derive the bearer configuration from SIB/Pre-configuration based on per-QoS flow or per-bearer Uu QoS information. * For Option C, how for the Last Relay UE to report sidelink UE information for the whole link   Therefore, the complexity by supporting this approach is not justified by the gain if any. |
| LG | See the comments | It can be different depending on the topology scenario. If the intermediate Relay UE is allowed to have two different parent Relay UEs, the way in which the intermediate Relay UE receives its configuration will be different depending on whether the parent Relay UE belongs to the same cell or not. So, we think it is better to discuss this issue after deciding on the topology scenario. |
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## 2.3 E2E QoS

End-to-end QoS is guaranteed in relaying by splitting the QoS requirements (i.e., latency) between the different hops. In approach 1, each relay UE is in RRC\_CONNECTED when the U2N Remote UE is RRC\_CONNECTED. It is therefore natural that the gNB performs the QoS splitting for each hop, considering this was done for single hop U2N relays where the L2 U2N relay also needed to be RRC\_CONNECTED.

Question 9: Do you agree that for approach 1, the QoS split is performed by the network?

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| **Companies** | **Yes or no** | **Comments** |
| OPPO | Yes |  |
| LG | Yes |  |
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In approach 2, only the Last Relay UE needs to be in RRC\_CONNECTED. Since the Uu hop is managed by the network, it should be the network to determine the QoS split (i.e., the portion of the latency) associated with the Uu hop.

Question 10: Do you agree that for approach 2, the QoS split on the Uu hop is determined by the network?

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| **Companies** | **Yes or no** | **Comments** |
| OPPO | Yes |  |
| LG | Yes |  |
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The remaining question is how to perform the splitting over the path between the Last Relay UE and the U2N Remote UE. If the relays are all in RRC\_CONNECTED, the situation is the same as the assumption for approach 1, and the network can perform the splitting. On the other hand, if the relays are in RRC\_IDLE/RRC\_INACTIVE/OOC, it would be possible to use the U2U mechanism in Rel18 and leave the splitting to the relay UE implementation.

Question 11: For approach 2, which entity should perform the QoS split of each link of the path between the Last Relay UE and the U2N Remote UE?

1. Network.
2. Relay UE serving that link

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| **Companies** | **Response** | **Comments** |
| OPPO | See comments | We understand for Option-B, the further clarification is needed on which relay UE to do the splitting when there are 2 relays serving the same link (i.e., the link between 2 relays). |
| LG | See comment | We need to discuss this issue further. In the case of Rel-18 U2U, it was easy for the relay UE to split the QoS, because there were only two links on both sides of the relay UE. However, as the multi-hop count increases, a single relay UE cannot know the quality of the entire link between hops. Before determining how the intermediate Relay UE knows the overall link quality, we cannot make any decisions.  For Approach 2, both option A and option B have the same problem. That is, how the network or Relay UE serving that link can know the overall hop link quality. |
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3 Phase 2 Discussion

Following discussion in Phase 1 to agree on the high level details of the different solutions, Phase 2 will discuss feasibility and pros/cons of the different solutions.

TBD

4 Conclusion

This contribution makes the following proposals:

TBD

# 5 References

1. R2-2406366 Control plane procedures of multi-hop U2N relay OPPO
2. R2-2406494 Discussion on control plane procedures for multi-hop relays MediaTek Inc.
3. R2-2406506 Considerations on Control Plane of Multi-hop Relay NEC discussion
4. R2-2406529 Discussions on the L2 Intermediate U2N Relay in multi-hop L2 U2N Relay ASUSTeK
5. R2-2406563 E2E Connection Setup and QoS Split for Multi-hop Relay CATT
6. R2-2406612 Initial considerations on CP and UP aspects for R19 multi-hop relay Samsung
7. R2-2406633 Control plane procedure for multi-hop U2N relay Sony
8. R2-2406684 Control Plane Design for Multi-hop UE-to-NW Relay Apple
9. R2-2406696 Discussion on architecture and control plane procedures for support of multi-hop SL relay ZTE Corporation, Sanechips
10. R2-2406713 Scenarios, QoS Handling, and Control Plane Procedures for Multi-hop InterDigital France R&D, SAS
11. R2-2406755 Discussion on QoS handling for NR sidelink multi-hop relay Spreadtrum Communications
12. R2-2406888 Control plane in Multi-hop relay Lenovo
13. R2-2407008 Discussion on multi-hop U2N Relay Control Plane Procedures vivo
14. R2-2407034 discussion on control plane procedure Ericsson, FirstNet, AT&T
15. R2-2407058 Discussion on Control Plane Procedure LG Electronics France
16. R2-2407102 Control procedure for multi-hop L2 based U2N relay Qualcomm Incorporated
17. R2-2407206 Control Plane under multihop L2 U2N relaying Kyocera
18. R2-2407295 Control plane procedures for multi-hop relay Huawei, HiSilicon
19. R2-2407318 Control plane procedure for multi-hop relay Nokia
20. R2-2407403 discussion on C-plane procedure for multi-hop relay Sharp