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| 3GPP TR 23.700-03 V0.2.0 (2024-03) | |
| Technical Report | |
| 3rd Generation Partnership Project;  Technical Specification Group Services and System Aspects;  Study on system enhancement for Proximity based Services  (ProSe) in the 5G System (5GS);  Phase 3  (Release 19) | |
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# Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

In the present document, modal verbs have the following meanings:

**shall** indicates a mandatory requirement to do something

**shall not** indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

**should** indicates a recommendation to do something

**should not** indicates a recommendation not to do something

**may** indicates permission to do something

**need not** indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

**can** indicates that something is possible

**cannot** indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

**will** indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**will not** indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**might** indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

**might not** indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

**is** (or any other verb in the indicative mood) indicates a statement of fact

**is not** (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

# 1 Scope

The present document will study and identify potential enhancements to the 5G Proximity-based Services (5G ProSe) system defined in TS 23.304 [4] (beyond what has been specified in Rel-17 and Rel-18) considering the services requirements defined in TS 22.278 [5], TS 22.261 [6] and TS 22.115 [7].

The study will investigate potential 5GS enhancements in the following areas:

* Enhance ProSe to support multi-hop over NR PC5 reference point for UE-to-Network Relay for Layer-2 and Layer-3 Relays.
* Enhance ProSe to support multi-hop over NR PC5 reference point for UE-UE Relay for Layer-3 Relays.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TR 23.752: "Study on system enhancement for Proximity based Services (ProSe) in the 5G System (5GS)".

[3] 3GPP TR 23.700-33: "Study on system enhancement for Proximity based Services (ProSe) in the 5G System (5GS); Phase 2".

[4] 3GPP TS 23.304: "Proximity based Services (ProSe) in the 5G System (5GS)".

[5] 3GPP TS 22.278: "Service requirements for the Evolved Packet System (EPS); Stage 1".

[6] 3GPP TS 22.261: "Service requirements for next generation new services and markets; Stage 1".

[7] 3GPP TS 22.115: "Service aspects; Charging and billing; Stage 1".

[8] 3GPP TS 23.501: "System Architecture for the 5G System; Stage 2".

[9] IETF RFC 7181: "The Optimized Link State Routing Protocol Version 2".

[10] IETF RFC 6130: "Mobile Ad Hoc Network (MANET) Neighborhood Discovery Protocol (NHDP)".

[11] IETF RFC 5444: "Generalized Mobile Ad Hoc Network (MANET) Packet/Message Format".

# 3 Definitions of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the terms given in 3GPP TR 21.905 [1], TS 23.304 [4] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1] and TS 23.304 [4].

**5G ProSe Intermediate Relay:** A 5G ProSe-enabled UE that provides functionality to support connectivity to the network for 5G ProSe Remote UE(s) by using the PC5 reference point with other 5G ProSe-enabled UEs, The 5G ProSe Intermediate Relay is located on the path between 5G ProSe Remote UE and 5G ProSe UE-to-Network Relay.

NOTE 1: This term is defined for use during the study phase, so whether to define this term for normative work will be decided when concluding the study. There is no restriction that such 5G ProSe Intermediate Relay entity/function must be used for solutions.

Editor’s note: The definition of 5G ProSe Intermediate Relay may need to be further revised if this term is deemed necessary according to solution discussion. Whether and how to define intermediate relay for multi-hop UE-to-UE relay is FFS.

## 3.2 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1], TS 23.304 [4] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1] and TS 23.304 [4].

# 4 Architecture Requirements and Assumptions

## 4.1 Architecture Requirements

Solutions shall comply with and build on the 5G ProSe architecture principles as defined in TS 23.304 [4] and 5G System architectural principles as defined in TS 23.501 [8]. To satisfy the normative stage-1 requirements in TS 22.261 [6], the system shall:

* Support multi-hop over NR PC5 reference point for Layer-2 and Layer-3 UE-to-Network Relays.
* Support multi-hop over NR PC5 reference point for Layer-3 UE-to-UE Relays.

NOTE : This study requires coordination with RAN WGs.

## 4.2 Architecture Assumptions

- Architecture reference models defined in TS 23.304 [4] are used as baseline architecture for supporting 5G ProSe Ph3.

- NG-RAN for NR is used; non-3GPP access is not considered in this release.

- NR based PC5 and NR Uu are considered.- For multi-hop UE-to-Network Relay, all the relay entities on the path should be of the same type, either Layer-2 or Layer-3.

- Multi-path communication via Uu and via multi-hop UE-to-Network Relay is not supported.

# 5 Key Issues

## 5.1 Key Issue #1: Support of multi-hop UE-to-Network Relays

### 5.1.1 General description

This key issue focuses on architecture enhancements to support 5G ProSe multi-hop Layer-3 and Layer-2 UE-to-Network Relay over NR PC5 reference point. This key issue addresses scenarios where multi-hop UE-to-Network Relay(s) are in coverage and out of coverage.



Figure 5.1.1-1: Example scenario of multi-hop UE-to-Network Relay

Aspects such as support for single-hop relay discovery, selection, authorization, connection establishment and data transfer for ProSe UE-to-Network Relay have been addressed in previous releases and some of those aspects may need to be enhanced to support multi-hop extensions. In Release 19, at least the following aspects need to be studied in potential solutions:

- Whether and how to support the authorization of multi-hop UE-to-Network Relay and Remote UE authorization and policy and parameter provisioning.

- Whether and how to support the multi-hop UE-to-Network Relay discovery.

- Whether and how to perform multi-hop UE-to-Network Relay (re-)selection.

- Whether and how to enhance the existing mechanisms for IP address/prefix allocation to support Layer-3 multi-hop UE-to-Network Relay.

- Whether and how to control the maximum number of hops supported when using multi-hop Layer-3 UE-to-Network relays.

NOTE 1: For multi-hop Layer-2 UE-to-Network relays, the control of the maximum number of hops is in the scope of RAN WGs and alignment work (if any) will be made by SA2 based on RAN WGs conclusions.

- How to manage multi-hop PC5 links, at least including how to establish, modify and release Layer-2 link over PC5 reference point for multi-hop UE-to-Network Relays.

- Whether and how to support end-to-end QoS requirements between Remote UE and the network via multi-hop Layer-3 UE-to-Network Relay.

NOTE 2: For multi-hop Layer-2 UE-to-Network relays, the support of end-to-end requirements between Remote UE and the network is in the scope by RAN WGs and alignment work (if any) will be made by SA2 based on RAN WGs conclusions.

NOTE 3: Security and privacy aspects will be handled by SA WG3.

## 5.2 Key Issue #2: Support of Layer-3 multi-hop UE-to-UE Relays

### 5.2.1 General description

This key issue focuses on architecture enhancements to support ProSe multi-hop Layer-3 UE-to-UE Relay over NR PC5 reference point. This key issue intends to support multi-hop Layer-3 UE-to-UE Relays for in coverage and out of coverage operation.

Multi-Hop

UE-to-UE Relays



End UE

End UE

**Figure 5.2.1-1: Example scenario of support of Layer-3 multi-hop UE-to-UE Relay**

Aspects such as support for relay discovery, selection, authorization, connection establishment and data transfer for single hop ProSe UE-to-UE Relay have been addressed in previous releases and some of those aspects may need to be enhanced to support multi-hop extension. In Release 19, at least the following aspects need to be studied in potential solutions:

* Whether and how to enhance the existing mechanisms for multi-hop UE-to-UE Relay discovery.
* Whether and how to enhance the existing mechanisms for IP address/prefix allocation.
* Whether and how to control the maximum number of hops supported when using multi-hop UE-to-UE relays.
* Whether and how to support path changes or Relay (re)selections, e.g., in the case one or more UE-to-UE Relays become unavailable/suitable.
* Whether and how to support the network control 5G ProSe multi-hops UE-to-UE Relay operations, including at least, authorization, policy and parameters provisioning etc.
* How to manage multi-hop PC5 links, at least including how to establish, modify and release Layer-2 link over PC5 reference point for multi-hop UE-to-UE Relays.
* How to establish the connection between source UE and target UE via multiple 5G ProSe UE-to-UE Relays.
* How to satisfy end-to-end QoS requirements for the End UEs over the path via 5G ProSe multi-hop UE-to-UE Relays, if needed.

# 6 Solutions

## 6.0 Mapping of Solutions to Key Issues

Table 6.0-1: Mapping of Solutions to Key Issues

|  |  |  |
| --- | --- | --- |
|  | Key Issues | |
| Solutions | 1 | 2 |
| 1 | X |  |
| 2 | X |  |
| 3 |  | X |
| 4 | X | X |
| 5 |  | X |
| 6 |  | X |

## 6.1 Solution #1: Architecture enhancement to support 5G ProSe multi-hop UE-to-Network Relays

### 6.1.1 Description

The solution is illustrated with the architecture example as shown in Figure 6.1.1-1.



Figure 6.1.1-1: Example architecture of multi-hop UE-to-Network Relay

Following operation principles are applied to support the 5G ProSe multi-hop UE-to-Network Relay operations to provide services to a 5G ProSe Remote UE:

- Only 5G ProSe UE-to-Network Relay needs to be in coverage of NG-RAN and be able to establishes a connection with the NG-RAN.

- Other Intermediate UE-to-Network Relay(s) can be either in coverage or out of coverage. However, for a particular RSC, a relay UE can act as either a 5G ProSe UE-to-Network Relay or an Intermediate UE-to-Network Relay. To act as an Intermediate UE-to-Network Relay, e.g. forwarding the Model A discovery message or replying to the Model B Discovery Response message, the relay UE needs to have a valid connection towards the network via the 5G ProSe UE-to-Network Relay indicated by the Root Relay Info IE. If the Intermediate UE-to-Network Relay need to also operate as a Remote UE, e.g. it is also running some other applications, it should follow the behavior defined for Remote UE independent from the Intermediate UE-to-Network Relay logic.

- Relay Service Code (RSC), as defined in TS 23.304, is used for the indication of services offered by the 5G ProSe multi-hop UE-to-Network Relays. No special RSC is introduced for multi-hop operation, i.e. the 5G ProSe UE-to-Network Relay and the Intermediate UE-to-Network Relay use the same RSC.

- The 5G ProSe UE-to-Network Relay and the Intermediate UE-to-Network Relays can serve other Intermediate UE-to-Network Relays and 5G ProSe Remote UE at the same time.

- A Hop-Count IE is introduced to reflect the nature of multi-hop operation, in both discovery and connection establishment, and is used to control the number of hops to be supported for multi-hop Relay operations. A separate Hop-Limit IE is used for controlling the maximum hops, and the value of the Hop-Limit is configured by the network. If the Hop-Limit is not included in the discovery messages, the Intermediate Relays will locally use a (pre-)configured value for the control.

Editor's Note: It is FFS if the value of the Hop-Limit is determined by 3GPP or left to operator to decide, e.g. configured based on the service type supported by the RSC.

Editor's Note: It is FFS if other metrics besides hop limit can be supported for the relay path selection, e.g. the accumulated delay over the hops.

NOTE: When the number of hops increases, the performance over the multi-hop relay link would be affected, e.g. the overall delay, and the stability of the link, mobility caused signaling overhead, etc. Therefore, the setting of the hop limit value, which determines the max number of hops, need to be selected properly taking these into consideration.

- Both Model A and Model B Discovery are supported for the 5G ProSe UE-to-Network Relay operation.

- The 5G ProSe Remote UE only selects the Intermediate UE-to-Network Relay directly serving it, i.e. it does not need to be aware of the identities of the other Intermediate UE-to-Network Relays.

- The 5G ProSe UE-to-Network Relay's identify is included in the UE-to-Network Relay Discovery message, to avoid message flooding and help 5G ProSe Remote UE's relay reselection.

### 6.1.2 Procedures

#### 6.1.2.1 Relay Discovery

##### 6.1.2.1.1 Support of Model A discovery

Figure 6.1.2.1.1-1 provides an example of how the Model A discovery is supported in the multi-hop relay environment.



Figure 6.1.2.1.1-1: Example Model A Discovery operation supporting multi-hop UE-to-Network Relay

For Model A discovery, the 5G ProSe UE-to-Network Relay reuses the 5G ProSe UE-to-Network Relay Discovery Announcement message as defined in TS 23.304 [4] clause 5.8.3, with the following additional IE:

* Hop-Count: This value should be set to 1. It serves as an indication that the 5G ProSe UE-to-Network Relay supports multi-hop operation. In order to be legacy compliant, i.e. serving prior release 5G ProSe Remote UEs, the encoding of this Hop-Count should allow the 5G ProSe Remote UE not support multi-hop operation to ignore it and follow the existing procedures defined in TS 23.304 [4].
* (optional) Hop-Limit: This indicates how many hops this 5G ProSe UE-to-Network Relay supports. Any Intermediate UE-to-Network Relay does not further forward the announcement message if the Hop-Count is equal or larger than the Hop-Limit. The value of the Hop-Limit is configured by the network. If the Hop-Limit is not included in the discovery messages, the Intermediate Relays will use a pre-configured value for the control.

For Model A discovery, the Intermediate UE-to-Network Relay(s) forwards the Announcement message with the following modifications:

- Source Layer-2 ID: this is set to the source Layer-2 ID of the Intermediate UE-to-Network Relay.

- Destination Layer-2 ID: the Destination Layer-2 ID for 5G ProSe UE-to-Network Relay Discovery is selected based on the configuration. It should be the same Destination Layer-2 ID of the Announcement message received by the Intermediate UE-to-Network Relay.

- Announcer Info: identify information (i.e. User Info ID) of the announcing Intermediate UE-to-Network Relay.

- Relay Service Code: no modification to the RSC of the received Announcement message.

- Hop-Count: The Intermediate UE-to-Network Relay increment the value of the received Announcement message by 1 before forwarding it. If this value is equal or bigger than the optional Hop-Limit value in the message, the message is not forwarded. Additionally, if the Hop-Count value is equal or larger than a locally configured threshold on the Intermediate UE-to-Network Relay, it will not forward the Announcement message.

- (optional) Hop-Limit: this should be kept unchanged from the value in the received message.

- Root Relay Info: this is the User Info ID contained in the Announcer Info from the original 5G ProSe UE-to-Network Relay Discovery Announcement message. If included, it is not modified by the Intermediate UE-to-Network Relays.

The rest of the information contained in the Announcement messages is kept without modification when the message is forwarded by the Intermediate UE-to-Network Relays.

The Intermediate UE-to-Network Relay(s) keeps a record of the RSC, Root Relay Info, Announcer Info, and the associated Hop-Count value. Optionally, the Hop-Limit value can be also stored. If it receives an Announcement message with the same RSC and Root Relay Info but different Announcer Info, it will only forward the Announcement message when the Hop-Count value is smaller than the stored value. In that case, the Intermediate UE-to-Network Relay updates it stored value, i.e. the Announcer Info and the Hop-Count value. These stored values should be timed out by the Intermediate UE-to-Network Relay based on a locally configured timer.

The Relay Discovery Additional Information message (using Model A) message as defined in TS 23.304 [4] clause 5.8.3 can be supported, similar to the additional handling for the Announcement message, i.e. by including the Hop-Count and (optional) Hop-Limit IE inside the message.

Editor's Note: It is FFS how Additional Information message for Model A discovery and related procedure are supported.

##### 6.1.2.1.2 Support of Model B discovery



Figure 6.1.2.1.2-1: Example Model B Discovery operation supporting multi-hop UE-to-Network Relay

For Model B discovery, the 5G ProSe Remote UE uses the 5G ProSe UE-to-Network Relay Discovery Solicitation message (Model B), with the following modified/additional IE:

- Discoverer Info: User Info ID of the 5G ProSe Remote UE.

- (optional) Target Info: User Info ID of a particular 5G ProSe UE-to-Network Relay. This may be used by a Remote UE to find a new/alternative path towards the UE-to-Network Relay that provides/provided service to it.

- Relay Service Code: the Relay Service Codes configured in the 5G ProSe Remote UEs for the service it interested in.

- Hop-Limit: This indicates the max hop count of the 5G ProSe Remote UEs accepts on the path. Therefore, if an Intermediate UE-to-Network Relay's stored information as described in 6.1.2.1.1 has a hop-count larger than the Hop-Limit, it does not respond to the Solicitation message. The 5G ProSe Remote UE can determine the value of the Hop-Limit based on the (pre-)configuration and ProSe Application requirements.

Additional information elements defined in the TS 23.304 [4] clause 5.8.3 are reused.

The Intermediate UE-to-Network Relay checks its valid (unexpired) stored information entries (as described in clause 6.1.2.1.1) against the received Solicitation message for the following criteria:

- RSC of the received Solicitation message matches the stored value;

- the optional Target Info match with the stored Root Relay Info; and

- the Hop-Limit of the received message is larger than the stored Hop-Count.

If all the criteria are met, the Intermediate UE-to-Network Relay may respond with a 5G ProSe UE-to-Network Relay Discovery Response message (Model B) as defined in TS 23.304 [4] clause 5.8.3 with the following modified/additional information:

- Source Layer-2 ID: the Source Layer-2 ID of the Intermediate UE-to-Network Relay.

- Destination Layer-2 ID: set to the Source Layer-2 ID of the received 5G ProSe UE-to-Network Relay Discovery Solicitation message.

- Relay Service Code: the RSC from the corresponding Discovery Solicitation message.

- Discoveree Info: User Info ID of the Intermediate UE-to-Network Relay.

- Hop-Count: this is the Hop-Count value of the stored entry incremented by 1. If the Hop-Count is bigger than the Hop-Limit, the message is dropped.

- (optional) Hop-Limit: this is from the matched stored entry if available.

- Root Relay Info: this is from the stored entry.

For any Intermediate UE-to-Network Relay received the 5G ProSe UE-to-Network Relay Discovery Response message (Model B), it updates/creates a new information entry as described in clause 6.1.2.1.1.

The Intermediate UE-to-Network Relay does not have a stored entry matching all the criteria, it may forward the 5G ProSe UE-to-Network Relay Discovery Solicitation message. When forwarding the message, the Intermediate UE-to-Network Relay modifies the following IEs in the message:

- Source Layer-2 ID: the Intermediate UE-to-Network Relay uses its own Source Layer-2 ID when forwarding the message.

- Discoverer Info: User Info ID of the Intermediate UE-to-Network Relay.

- (optional) Target Info: User Info ID of a particular 5G ProSe UE-to-Network Relay. This will be kept if it is present in the received message.

- Relay Service Code: the RSC of the received message is kept unchanged.

- Hop-Limit: the value in the received Solicitation message is decremented by 1 before it is forwarded . If the value reaches 1, the Intermediate UE-to-Network Relay does not forward the Solicitation message.

If a 5G ProSe UE-to-Network Relay received a Solicitation message, it checks the message against the following criteria:

- RSC of the received Solicitation message matches the stored value.

- The optional Target Info match its own User Info ID.

If all the criteria are met, the 5G ProSe UE-to-Network Relay may respond with a 5G ProSe UE-to-Network Relay Discovery Response message (Model B) as defined in TS 23.304 [4] clause 5.8.3 with the following modified/additional information:

- Hop-Count: this is set to 1.

- (optional) Hop-Limit: if there is a hop limit configured on the 5G ProSe UE-to-Network Relay.

For any Intermediate UE-to-Network Relay received the 5G ProSe UE-to-Network Relay Discovery Response message, it updates/creates a new information entry as described in clause 6.1.2.1.1, with the Discoveree Info stored as the Root Relay Info.

#### 6.1.2.2 Authentication and authorization for multi-hop relay operation

Existing service authorization configuration defined in TS 23.304 [4] clause 5.1.4 for 5G ProSe UE-to-Network Relay can be reused for the support of multi-hop relay operation, with the following enhancements:

- within the Authorization policy, for each PLMN, an indication of whether multi-hop relay operation is authorized and the related hop limit.

The Intermediate UE-to-Network Relay should be configured with the Policies for the 5G ProSe Remote UE, with the following enhancements:

- within the Authorization policy, for each PLMN, an indication of whether it can serve as an intermediate relay, and optionally a hop limit.

For the 5G ProSe Remote UE, the policies are enhanced as follows:

- within the 5G ProSe UE-to-Network Relay Discovery parameters, optionally a hop limit.

#### 6.1.2.3 Relay Selection/re-selection

For initial Relay selection, the 5G ProSe Remote UE select a Relay announcing the least Hop-Count value, either a 5G ProSe UE-to-Network Relay or an Intermediate UE-to-Network Relay, assuming that each of the hop will meet the AS layer quality criteria.

When a 5G ProSe Remote UE discovers another Intermediate UE-to-Network Relay or 5G ProSe UE-to-Network Relay with the same RSC, but smaller Hop-Count, it may re-select the new Relay. It may trigger the mobility procedure as defined in clause 6.1.2.5.

For the Intermediate UE-to-Network Relay, if it sees another Intermediate UE-to-Network Relay or 5G ProSe UE-to-Network Relay with the same RSC, but smaller Hop-Count, it may re-select the new Relay. It may trigger the mobility procedure as defined in clause 6.1.2.5. This mobility may result in the move of all the Remote UEs connected via this Intermediate UE-to-Network Relay.

#### 6.1.2.4 PC5 Link establishment and management

##### 6.1.2.4.1 Layer-2 Link establishment and management

Each of the Intermediate UE-to-Network Relay needs to establish a Layer-2 Link with its parent Intermediate UE-to-Network Relay or the 5G ProSe UE-to-Network Relay, before it can serve the 5G ProSe Remote UE.

Existing Layer-2 link management procedure as defined in TS 23.304 [4] for UE-to-Network Relay operation can be re-used for that purpose. There can be RSC based configuration for the Intermediate UE-to-Network Relay on whether it should establish the Layer-2 Link with a parent Relay before it can participate in the discover operation.

When establishing the Layer-2 link with its parent Intermediate UE-to-Network Relay, the Intermediate UE-to-Network Relay takes the role of the 5G ProSe Remote UE, and its parent Intermediate UE-to-Network Relay takes the role of 5G ProSe UE-to-Network Relay as defined in TS 23.304 [4].

NOTE: in case of Layer-3 UE-to-Network Relay operation, only the root UE-to-Network Relay needs to establish the PDU session with the network.

Similarly, a 5G ProSe Remote UE can use the procedure defined in TS 23.304 [4] to establish a Layer-2 Link with the selected Intermediate UE-to-Network Relay. In this case, the Intermediate UE-to-Network Relay takes the role of of 5G ProSe UE-to-Network Relay as defined in TS 23.304 [4].

When an Intermediate UE-to-Network Relay has a child Intermediate UE-to-Network Relay or a 5G ProSe Remote UE connected, it needs to update the Layer-2 link with its parent relay, using the procedure defined in TS 23.304 clause 6.4.3.4, with the following enhancements:

- The link modification procedure may be enhanced to inform the parent relay, e.g. another Intermediate UE-to-Network Relay or the 5G ProSe UE-to-Network Relay, regarding the User Info of the child relay or the Remote UE. Therefore, the message is enhanced to provide a list of Remote UE (Remote User ID, Remote UE info), and the corresponding PC5 QoS Flow associated with each Remote UE.

- The Remote UE (Remote User ID, Remote UE Info) contains the information about the child Intermediate UE-to-Network Relay or the 5G ProSe Remote UE(s).

This Layer-2 Link modification procedure will propagate back towards the 5G system, until it reaches a 5G ProSe UE-to-Network Relay or Intermediate UE-to-Network Relay that also has the context of these new list of Remote UEs.

The 5G ProSe UE-to-Network Relay's Remote UE reporting procedure will report all the Remote UE information.

##### 6.1.2.4.2 IP address/prefix management for Layer-3 UE-to-Network Relay

When IP based PDU session types are used by the 5G ProSe UE-to-Network Relay, the Intermediate UE-to-Network Relay needs to act as an IP Router.

The actual IP address allocation is performed by the 5G ProSe UE-to-Network Relay, in the same way as that defined in TS 23.304 [4].

To support DHCP based IP address configuration, the Intermediate UE-to-Network Relay act as DHCPv4 o DHCPv6 proxy. To support IPv6 SLAAC, the Intermediate UE-to-Network Relay relays also the Router Solicitation and Router Announcement messages between the Remote UE and the 5G ProSe UE-to-Network Relay.

The Intermediate UE-to-Network Relay builds its local IP routing table based on the Remote UE info from the link modification procedures.

#### 6.1.2.5 Relay reselection and mobility support

There are two types of mobility scenarios, i.e. the mobility of a single 5G ProSe Remote UE, and the mobility of an Intermediate UE-to-Network Relay with multiple child relays and remote UEs.

For a single 5G ProSe Remote UE, when it lost the connection with its old relay (either an Intermediate UE-to-Network Relay or a 5G ProSe UE-to-Network Relay), it may select another relay offers the same service, identified by the same RSC.



Figure 6.1.2.5-1: Mobility of the 5G ProSe Remote UE with multi-hop UE-to-Network Relays

Figure 6.1.2.5-1 illustrates an example of such scenario. The 5G ProSe Remote UE has lost the connection or has an imminent connection loss/deteriorated connection with the Intermediate UE-to-Network Relay-1, and the Remote UE discovered an Intermediate UE-to-Network Relay -2 that offers the same RSC, and in this case even the connection to the same Root Relay, i.e. 5G ProSe UE-to-Network Relay.

5G ProSe Remote UE establishes the Layer-2 link with the Intermediate UE-to-Network Relay-2 as described in clause 6.1.2.4.1. After the connection establishment, the Intermediate UE-to-Network Relay-2 uses the Layer-2 Link Modification procedure to update the 5G ProSe UE-to-Network Relay regarding the new Remote UE joined the link. Since the 5G ProSe UE-to-Network Relay is aware of the 5G ProSe Remote UE, it can switch the connection/routing context from the Intermediate UE-to-Network Relay-1 link to that of the Intermediate UE-to-Network Relay-2.

At the same time, the 5G ProSe Remote UE may tear down the link with the Intermediate UE-to-Network Relay-1 (or the link failure is detected), which will trigger the Intermediate UE-to-Network Relay-1 to update the 5G ProSe UE-to-Network Relay to remove its association with 5G ProSe Remote UE.

In case the same 5G ProSe UE-to-Network Relay is used, the 5G ProSe Remote UE does not have to change its IP address/prefix (in case of Layer-3) or its RAN anchor point (in case of Layer-2).

If the Root Relay Info offered by the new Intermediate UE-to-Network Relay-2 is different than the original 5G ProSe UE-to-Network Relay, the same procedure as that described in clause 6.1.2.4 will be executed again. In this case, there may be IP address/prefix changes after the mobility.

In case the mobility is caused by the link change of an Intermediate UE-to-Network Relay (which is serving remote UEs), the similar consideration applies, i.e. it is preferrable to connect to a new relay that shares the same Root Relay. In that case, the Intermediate Relay needs to run the Layer-2 link modification procedure after the connection establishment to update the 5G ProSe UE-to-Network Relay of all the Remote UEs its serving.

#### 6.1.2.6 Support of End-to-end QoS management

For Layer-3 Relay operation, similar End-to-end QoS management as defined in TS 23.304 [4] can be reused, with the following enhancements:

- the end-to-end QoS flow is to be identified by both the Remote UE ID and the PC5 QoS flow IDs.

For Layer-2 Relay operation, the handling of End-to-end QoS management will be defined by RAN WGs.

Editor's Note: support of the end-to-end QoS management, e.g. QoS split among the multi-hops, is FFS.

#### 6.1.2.7 Support of Layer-2 multi-hop UE-to-Network Relay operation

Additional considerations for the support of Layer-2 multi-hop UE-to-Network Relay operation depends on RAN WG progress.

### 6.1.3 Impacts on services, entities and interfaces

**AMF**: No impact.

**PCF**: potential enhancement to provide multi-hop related policies.

**5G ProSe UE-to-Network Relay**: additional discovery message handling, new link management procedures.

**5G Intermediate UE-to-Network Relay**:

- handling new discovery messages, including managing new information entries.

- DHCPv4/v6 Proxy, IP Router,

- support new link management procedures support.

**5G ProSe Remote UE**:

- handling new discovery messages.

Note: Security aspects will be addressed by SA3.

Editor's Note: the maximum number of hops supported may be affected by the frequency of the relay discovery operations, as it has impacts on the delay in the link establishment and path switching. It is FFS any standards related work is needed.

## 6.2 Solution #2: Multi-hop 5G ProSe UE-to-Network Relay Discovery and Layer-3 Communication

### 6.2.1 Description

This solution provides a mechanism for enabling multi-hop 5G ProSe UE-to-Network Relay, where the Remote UE is connected to the UE-to-Network Relay via one or more 5G ProSe Intermediate Relay(s). It is assumed that the 5G ProSe UE-to-Network Relay, the Remote UE and the 5G ProSe Intermediate Relay(s) receive appropriate authorization and configuration to perform multi-hop 5G ProSe UE-to-Network Relay. In particular, the maximum number of hops is assumed to be a configurable parameter which can be set by the operator during the ProSe policy/parameter provisioning procedure for the 5G ProSe-enabled UEs supporting multi-hop Relay.

The solution addresses the following aspects:

* **5G ProSe UE-to-Network Relay Discovery:** To perform discovery, the Discovery message sent by the 5G ProSe UE-to-Network Relay in Model A or the Remote UE in Model B is propagated by the Intermediate Relays until the maximum number of hops is reached. The number of hops for each path is tracked by including a counter in the discovery message, which is updated by each 5G ProSe Intermediate Relay before forwarding. The discovery message is dropped if the maximum number of hops is reached. To avoid loops in the multi-hop paths, each 5G ProSe intermediate Relay includes its own ID when relaying the discovery message. The 5G ProSe Intermediate Relay does not transmit a discovery message that already includes its own ID.

As the Remote UE may receive a response from the same UE-to-Network Relay via different intermediate relays and paths, the Remote UE should select both the UE-to-Network Relay and the path to reach it including the set of Intermediate Relays. The Remote UE may select the UE-to-Network Relay and path based on parameters such as the number of hops, the end-to-end QoS, or additional information on the 5G ProSe Intermediate Relay(s) or links. To assist the Remote UE with UE-to-Network Relay and path selection, each Intermediate Relay also includes additional information on the relay and link.

* **5G ProSe Communication via multi-hop Layer-3 UE-to-Network Relay with and without N3IWF support:** Once the 5G ProSe UE-to-Network Relay and the multi-hop path have been selected by the Remote UE, the Remote UE sends a multi-hop Communication Request to the 5G ProSe UE-to-Network Relay, which includes information about the selected path (i.e. list of IDs of intermediate 5G ProSe Intermediate Relay(s)) and a path ID that can be used to reference the path in further communications. The multi-hop Communication Accept message includes the path ID. Then, the complete UE-to-Network multi-hop path is established, and 5G ProSe Direct Communication is established between the 5G ProSe-enabled UEs for each hop.

### 6.2.2 Procedures

#### 6.2.2.1 5G ProSe multi-hop UE-to-Network Relay Discovery

##### 6.2.2.1.1 5G ProSe multi-hop UE-to-Network Relay Discovery with Model A

Figure 6.2.2.1.1-1 illustrates the procedure for 5G ProSe muti-hop UE-to-Network Discovery with Model A.



Figure 6.2.2.1.1-1: 5G ProSe multi-hop UE-to-Network Relay Discovery with Model A

1. The 5G ProSe UE-to-Network Relay sends a UE-to-Network Relay Discovery Announcement message. Additional to the parameters described in clause 6.3.2.3.2 from TS 23.304 [4], the UE-to-Network Relay Discovery Announcement message includes an indication that multi-hop relay is supported, and an initialized multi-hop counter.

2. The 5G ProSe Intermediate Relays with (pre)configured RSC(s) matching the RSC in the Relay Discovery Announcement message propagate the Announcement message while updating the multi-hop counter until the maximum number of hops is reached, in which case the message is dropped. Additional information related to the intermediate relays and links of the path from which the Announcement message transits is added at each hop to facilitate path selection by the Remote UE and avoid loops.

Editor’s Note: How to minimize the number of propagated Announcement messages is FFS.

The 5G ProSe Remote UEs monitor the announcement messages corresponding to the desired services, and select the 5G ProSe UE-to-Network Relay and multi-hop path based on the information received.

##### 6.2.2.1.2 5G ProSe multi-hop UE-to-Network Relay Discovery with Model B

Figure 6.2.2.1.2-1 illustrates the procedure for 5G ProSe muti-hop UE-to-Network Discovery with Model B.



Figure 6.2.2.1.2-1: 5G ProSe multi-hop UE-to-Network Relay Discovery with Model B

1. The 5G ProSe Remote UE sends a 5G ProSe UE-to-Network Relay Discovery Solicitation message which includes, additional to the parameters described in clause 6.3.2.3.3 from TS 23.304 [4], an indication that multi-hop relay is supported, and an initialized multi-hop number counter.

2. The Solicitation message is propagated by the 5G ProSe Intermediate Relay(s) with (pre)configured RSC(s) matching the RSC in the message while updating the multi-hop counter until the maximum number of hops is reached, in which case the message is dropped. To avoid loops and allow the routing of the Discovery Response, each Intermediate Relay includes its ID in the message.

3. If the information contained in the Solicitation message matches the 5G ProSe UE-to-Network Relay configuration, the 5G ProSe UE-to-Network Relay(s) that receives the Solicitation message send a Response which is relayed back to the Remote UE by the Intermediate Relays. Additional information related to the Intermediate Relays and links of the path from which the Response message transits is added at each hop to facilitate path selection by the Remote UE.

Editor’s Note: How to minimize the number of transmitted Response messages is FFS.

4. If one or more discovery responses are received, the 5G ProSe Remote UE selects the 5G ProSe UE-to-Network Relay and multi-hop path to reach it based on the information received.

#### 6.2.2.2 5G ProSe Communication via multi-hop Layer-3 UE-to-Network Relay

##### 6.2.2.2.1 5G ProSe Communication via multi-hop Layer-3 UE-to-Network Relay without N3IWF support

Figure 6.2.2.2.1-1 depicts the procedure for 5G ProSe Communication via multi-hop Layer-3 UE-to-Network Relay without N3IWF support.



Figure 6.2.2.2.1-1: 5G ProSe Communication via multi-hop 5G ProSe Layer-3 UE-to-Network Relay without N3IWF

1. Service authorization and parameter provisioning are performed for the 5G ProSe Layer-3 UE-to-Network Relay (step 1a), the 5G ProSe Intermediate Relay(s) (step 1b), and the 5G ProSe Layer-3 Remote UE (step 1c).

2. Similar to Step 2 in clause 6.5.1.1 from TS 23.304[4], the 5G ProSe Layer-3 UE-to-Network Relay may establish a PDU Session for relaying.

3. The 5G ProSe Layer-3 Remote UE performs the (re-)discovery of a 5G ProSe Layer-3 UE-to-Network Relay and multi-hop path as described in clause 6.2.2.1. If no multi-hop path is discovered, the 5G ProSe Communication cannot be established, and the other steps are skipped.

4. Once the 5G ProSe UE-to-Network Relay and the multi-hop path have been selected by the Remote UE, the Remote UE sends a multi-hop Communication Request to the 5G ProSe UE-to-Network Relay, which includes information about the selected path (i.e. ordered list of IDs of 5G ProSe Intermediate Relay(s)) and a path ID. The 5G ProSe UE-to-Network Relay responds with a multi-hop Communication Accept message which includes the path ID.

Editor’s note: It is FFS how the multi-hop path ID is provided and managed.

5. The complete UE-to-Network multi-hop path is established, and 5G ProSe Direct Communication is established between the 5G ProSe-enabled UEs for each hop. If there is no PDU Session associated with the Relay Service Code or a new PDU Session for relaying is needed, the 5G ProSe Layer-3 UE-to-Network Relay may establish a new PDU Session for relaying.

6. Steps 5 to 7 as described in clause 6.5.1.1 from TS 23.304[4].

If the PDU Session for relaying is released by the UE-to-Network Relay or the network as described in clause 4.3.4 of TS 23.502, the UE-to-Network Relay and 5G ProSe Intermediate Relay(s) should initiate the release of the layer-2 links associated with the released PDU Session using the procedure defined in clause 6.4.3.3 of TS 23.304.

The PDU Session(s) used for relaying should be released as described in clause 4.3.4 of TS 23.502 (e.g. by 5G ProSe Layer-3 UE-to-Network Relay), if the service authorization for acting as a 5G ProSe Layer-3 UE-to-Network Relay in the serving PLMN is revoked.

The 5G ProSe Layer-3 UE-to-Network Relay may send the Remote UE Report message when the 5G ProSe Layer-3 Remote UE or any 5G ProSe Intermediate Relay disconnects from the multi-hop 5G ProSe Layer-3 UE-to-Network Relay chain, to inform the SMF that the 5G ProSe Layer-3 Remote UE(s) have left.

NOTE: The security aspects of multi-hop UE-to-Network path establishment will be addressed by SA3.

Editor’s Note: When the Remote UE needs to switch to a new Intermediate Relay (e.g. due to link failure), if there are multiple UE-to-Network Relays associated with the same RSC, it is FFS whether and how the Remote UE needs to retrieve the same UE-to-Network Relay with which the original connection was established.

##### 6.2.2.2.2 5G ProSe Communication via multi-hop Layer-3 UE-to-Network Relay with N3IWF support

Intermediate Relay UE can connect to N3IWF as per clause 6.5.1.2 in TS 23.304 and provides the relay function to Remote UE.

**Figure 6.2.2.2.2-1 Control plane protocol stacks between 5G ProSe Layer-3 Remote UE and N3IWF over 5G ProSe Layer-3 Intermediate Relay and Layer-3 UE-to-Network Relay after the signalling IPSec SA is established**

Following diagram shows the Connection (re-)establishment over 5G ProSe Layer-3 Intermediate Relay and UE-to-Network Relay with N3IWF support:



Figure 6.2.2.2.2-2: 5G ProSe Communication via multi-hop 5G ProSe Layer-3 UE-to-Network Relay with N3IWF support

1. The 5G ProSe Layer-3 UE-to-Network Relay, the Remote UE and the 5G ProSe Layer-3 Intermediate Relay UE perform service authorization and parameter provisioning.

2. The 5G ProSe Layer-3 Remote UE performs the (re-)discovery of a 5G ProSe Layer-3 UE-to-Network Relay and multi-hop path as described in clause 6.2.2.1 using the RSC configured for making the 5G ProSe Layer-3 Remote UE access to 5GC via N3IWF.

3. A 5G ProSe Layer-3 UE-to-Network Relay and 5G ProSe Layer-3 Remote UE follow the procedures described in steps 4-5 in clause 6.2.2.2.1 for communication establishment using the RSC configured for making the 5G ProSe Layer-3 Remote UE access to 5GC via N3IWF.

4. Steps 4-7 in clause 6.5.1.2 of TS 23.304 are performed by the Remote UE.

Editor’s Note: Whether and how the Intermediate Relay(s) perform N3IWF selection and IPSec tunnel establishment is FFS.

### 6.2.3 Impacts on services, entities and interfaces

The solution has impacts on the following entities:

**UE:**

- Needs to support 5G ProSe Intermediate Relay functionality, as well as the discovery and communication establishment procedures for multi-hop 5G ProSe UE-to-Network Relay for the 5G ProSe Remote UE, 5G ProSe Layer-3 UE-to-Network Relay, and 5G ProSe Intermediate Relay.

## 6.3 Solution #3: Architecture enhancement to support Layer-3 multi-hop UE-to-UE Relays

### 6.3.1 Description

The solution is illustrated with the architecture example as shown in Figure 6.3.1-1.



Figure 6.3.1-1: Example architecture of Layer-3 multi-hop UE-to-UE Relay

Following operation principles are applied to support the 5G ProSe Layer-3 multi-hop UE-to-UE Relay operations to provide services to a 5G ProSe End UEs:

- 5G ProSe UE-to-UE Relays and the 5G ProSe End UEs can be in or out of coverage of NG-RAN.

- Relay Service Code (RSC), as defined in TS 23.304 [4], is used for the indication of services offered by the 5G ProSe UE-to-UE Relays.

- All the 5G ProSe UE-to-UE Relays supporting the same RSC can form a 5G ProSe UE-to-UE Relay cloud to provide connectivity for 5G ProSe End UEs configured to use the same RSC.

NOTE 1: if a 5G ProSe UE-to-UE Relay support multiple RSCs, different Layer-2 links will be established with each associated with a specific RSC. The 5G ProSe UE-to-UE Relay operates as separate logical entities in the separate RSC clouds, i.e. no routing table sharing, and no traffic forwarding across different RSC clouds.

- One 5G ProSe End UE may establish multiple Layer-2 Links with different 5G ProSe UE-to-UE Relays supporting the same RSC, in order to maximize the reachability (e.g. in some cases, different 5G ProSe UE-to-UE Relays may serve different disjointed MANET sub-networks).

- Only IP based connections are supported over the Layer-3 multi-hop UE-to-UE Relays.

- Each of the UE-to-UE Relay acts as a Mobile Ad-hoc Network (MANET) router, and attempts to establish connections with all other UE-to-UE suitable Relays in proximity.

- The exact MANET routing protocols to be supported, e.g. OLSRv2 [9], are associated with the RSCs based on configuration.

NOTE 2: If 5G ProSe UE-to-UE Relay has traffic for its own, it can use any IP address it owns for the transmission.

Editor's Note: it is FFS if the MANET caused route change requires any additional security or QoS management enhancements.

- For a 5G ProSe End UE that connects with more than one UE-to-UE Relays, it also needs to support establishing the routing table for itself to determine which Relay to use for a particular destination IP address. This can be achieved by either support MANET TC messages, or some other IP information exchange with the Relays.

- The 5G ProSe End UE only needs to discover the UE-to-UE Relay in proximity, if it cannot establish a direct connection with a target End UE. Once connected to the UE-to-UE Relay(s), the 5G ProSe End UE discovery other 5G ProSe End UEs at IP layer, e.g. using DNS queries.

Editor's Note: it is FFS if any DNS operation enhancements need to be specified by 3GPP.

- Based on configuration associated with the RSC, the 5G ProSe End UE IP address allocation can operation in two options:

- Each of the 5G ProSe End UE will use a configured routable IP address/prefix associated with an RSC when connected to the 5G ProSe UE-to-UE Relay cloud. This IP address/prefix does not change when the End UE changes the UE-to-UE Relay connections.

- If the 5G ProSe End UE does not have a pre-configured IP address/prefix for the RSC, it will obtain an IP address/prefix from the 5G ProSe UE-to-UE Relay it connects to. In this case, the 5G ProSe End UE may need to change IP address/prefix when it changes 5G ProSe UE-to-UE Relay.

### 6.3.2 Procedures

#### 6.3.2.1 Relay Discovery

Both Model A and Model B discovery can be used to discover a Layer-3 multi-hop UE-to-UE Relay. This discovery does not include information about the End UEs connected via the UE-to-UE Relay. Therefore, the information included in the discovery message only contains the UE-to-UE Relay Discovery set as defined in TS 23.304 [4].

For Model A discovery, the Multi-hop UE-to-UE Relay Announcement message is sent by the relay and includes the following:

- Source Layer-2 ID: the 5G ProSe Layer-3 multi-hop UE-to-UE Relay self-selects a Source Layer-2 ID.

- Destination Layer-2 ID: the Destination Layer-2 ID for 5G ProSe UE-to-UE Relay Discovery Announcement message is selected based on the configuration (associated with the RSC).

- User Info ID of 5G ProSe UE-to-UE Relay: provides information about the 5G ProSe Layer-3 multi-hop UE-to-UE Relay.

- Relay Service Code: information to indicate the connectivity service the 5G ProSe Layer-3 multi-hop UE-to-UE Relay provides to 5G ProSe End UEs.

For Model B discovery, the 5G ProSe UE-to-UE Relay Discovery Solicitation message (Model B) is sent by the source 5G ProSe End UE, and includes the following:

- Source Layer-2 ID: the discoverer 5G ProSe End UE self-selects a Source Layer-2 ID.

- Destination Layer-2 ID: the Destination Layer-2 ID for 5G ProSe UE-to-UE Relay Discovery Solicitation message is selected based on the configuration (associated with the RSC).

- User Info ID of discoverer 5G ProSe End UE: this may be used for authorization of the End UE.

- Relay Service Code: information about connectivity service offered by the 5G ProSe Layer-3 UE-to-UE Relay(s).

The 5G ProSe UE-to-UE Relay Discovery Response message (Model B) sent by the 5G ProSe Layer-3 UE-to-UE Relay(s) matching the RSC includes the following:

- Source Layer-2 ID: the 5G ProSe Layer-3 UE-to-UE Relay self-selects a Source Layer-2 ID.

- Destination Layer-2 ID: set to the Source Layer-2 ID of the received 5G ProSe UE-to-UE Relay Discovery Solicitation message.

- User Info ID of discoverer 5G ProSe End UE: the User Info ID from the received Solicitation message, to ensure the Response can be matched at the receiver.

- User Info ID of 5G ProSe UE-to-UE Relay: provides information about the 5G ProSe UE-to-UE Relay.

- Relay Service Code: information about connectivity service offered by the 5G ProSe Layer-3 multi-hop UE-to-UE Relay.

#### 6.3.2.2 Layer-2 Link establishment and management

5G ProSe End UE establishes one or more Layer-2 link with the 5G ProSe Layer-3 multi-hop UE-to-UE Relay discovered, that meets the AS layer criteria. The link establishment procedure as defined in TS 23.304 [4] clause 6.4.3.1 can be used.

The Layer-2 link can be of the type of IP (v4 or v6).

The 5G ProSe End UE provides its configured IP address/prefix to the 5G ProSe Layer-3 multi-hop UE-to-UE Relay, which will propagate further to other 5G ProSe Layer-3 multi-hop UE-to-UE Relay(s) via the MANET routing protocol messages, e.g. the TC message as defined in OLSRv2 [9].

The 5G ProSe Layer-3 multi-hop UE-to-UE Relay also runs a DNS protocol, to populate the 5G ProSe End UE's User Info ID to other 5G ProSe Layer-3 multi-hop UE-to-UE Relay, if needed.

To locate a target 5G ProSe End UE, the source 5G ProSe End UE uses DNS query for the known User Info ID via the Layer-2 Link(s) it has with the 5G ProSe Layer-3 multi-hop UE-to-UE Relay(s). This returns the IP address/prefix of the target 5G ProSe End UE.

The source 5G ProSe End UE can then initiate IP sessions with the target 5G ProSe End UE via the 5G ProSe Layer-3 multi-hop UE-to-UE Relay. If the source 5G ProSe End UE has multiple connections to 5G ProSe Layer-3 multi-hop UE-to-UE Relays, it uses the IP routing table it established to decide which link to use for the IP session.

### 6.1.3 Impacts on services, entities and interfaces

**5GC:** No impact.

**5G ProSe End UE**:

- understand the new discovery message,

- support IP routing (either MANET or other IP information exchange with the relays)

- support configuration for a fixed IP address for an RSC.

**5G ProSe Layer-3 multi-hop UE-to-UE Relay**: Support MANET routing protocols, support DNS protocols.

Editor's Note: the number of hops supported may be affected by the frequency of the relay discovery operations, as it has impacts on the delay in the link establishment and path switching. It is FFS any standards related work is needed.

## 6.4 Solution #4: Layer-3 Multi-hop Relay based on MANET

### 6.4.1 Key Issue mapping

This solution primarily addresses Key Issue #2 (Support of Layer-3 multi-hop UE-to-UE Relays).

Some considerations are also provided for addressing Key Issue #1 (Support of multi-hop UE-to-Network Relays).

### 6.4.2 Description

The solution assumes that the Multi-hop ProSe UE-to-UE Relays have a collocated MANET router functionality (IETF RFC 7181 [9]) that connect with neighbouring MANET routers and establish a mobile ad-hoc network as defined in MANET (IETF RFC 7181 [9]). The Multi-hop ProSe UE-to-UE Relay relies on a new MANET messages (formatted according to IETF RFC 5444 [11]) to exchange information about discovered ProSe End UEs. ProSe UE-to-UE Relays also exchange point-to-point signalling messages (related to ProSe Direct Communication establishment and release) with each other over the MANET. The links between each pair of U2U Relays acting as MANET routers are based on Rel-18 PC5 and all MANET messages exchanged between a pair of U2U Relays acting as MANET routers is data traffic (from PC5 perspective).

Depicted in Figure 6.4.2-1 is a simple MANET network consisting of five routers (A, B, C, D and E). The participating routers establish links with neighbouring routers and perform the MANET Neighborhood Discovery Protocol (NHDP) by exchanging Hello messages with each adjacent MANET router as defined in IETF RFC 6130 [10]. The Hello messages are enhanced as defined in the Optimized Link State Routing Protocol Version 2 specification (IETF RFC 7181 [9]).



Figure 6.4.2-1: MANET network

Based on the information exchanged in the Hello messages, the participating routers may select a set of “flooding multi-point relays” (flooding MPRs) and a set of “routing multi-point relays” (routing MPRs) in order to achieve flooding reduction and topology reduction, respectively.

- Only flooding MPRs forward control messages flooded through the MANET, thus effecting a flooding reduction, an optimization of the flooding mechanism, known as *MPR flooding*.

- Routing MPRs are used to effect a topology reduction in the MANET. If no such reduction is required, then a router can select all of its relevant neighbours as routing MPRs.

IETF RFC 7181 [9] defines a second type of MANET message referred to as Topology Control (TC) message that carries selected topology (link state) information. Contrary to the Hello messages that are exchanged locally between two adjacent MANET routers, the TC messages are diffused throughout the MANET, preferably by using MPR flooding.

As an example, Figure 6.4.2-1 illustrates the diffusion of TC message generated by Router E using MPR flooding. In this example Router E has selected Router D and Router A as MPRs (but not Router C). Please note that the MPR flooding is an optional feature and is not essential for the solution.

Depicted in Figure 6.4.2-2 is a MANET network where the MANET routers also have a collocated ProSe UE-to-UE Relay functionality, as defined in TS 23.304 [4].



Figure 6.4.2-2: MANET routers with ProSe UE-to-UE Relay functionality

As illustrated in Figure 6.4.2-2, every router (except Router D) is in proximity of a set of End UEs. By performing ProSe Discovery (Model A or Model B) as defined in TS 23.304 [4], each of the U2U Relays discovers the UEs in proximity and obtains a list of locally discovered User Info IDs, as follows:

- U2U Relay A obtains a list of (User Info A1, User Info A2, User Info A3)

- U2U Relay B obtains a list of (User Info B1, User Info B2)

- U2U Relay C obtains a list of (User Info C1, User Info C2)

- U2U Relay D obtains an empty list

- U2U Relay E obtains a list of (User Info E1)

Suppose that End UE A1 wishes to discover End UE E1 and establish a point-to-point communication. Although End UE E1 is reachable via the MANET by U2U Relay A, End UE A1 will not attempt a connection with U2U Relay A, unless U2U Relay A advertises the availability of User Info E1.

To allow U2U Relay A to advertise the availability of User Info E1, there is a need for the lists of discoverable UEs to be shared by all participating routers in the MANET. This can be done by defining a new MANET message called [MANET] Discovery Info, as illustrated in Figure 6.4.2-2. Upon reception of a [MANET] Discovery Info message, the MANET router forwards a copy to the collocated U2U Relay. The U2U Relay updates the list of discovered User Info ID and advertises the updated list to End UEs in proximity.

Editor’s note: It is FFS if the dissemination of [MANET] Discovery Info can be made compatible with Rel-18 security mechanisms for UE-to-UE Relay defined in TS 33.304[4].



Figure 6.4.2-3: Signalling for connection establishment

Once End UE A1 has determined that it can reach End UE E1 via U2U Relay A, it can send a Direct Communication Request to U2U Relay A, as illustrated with step 1 in Figure 6.4.2-3. The Direct Communication Request needs to be propagated to U2U Relay E (step 2 in Figure 6.4.2-3) and delivered to End UE E1 (step 3 in Figure 6.4.2-3). Similar logic applies to the Direct Communication Accept message in the reverse direction (i.e. from End UE E1 via U2U Relay E via U2U Relay A to End UE A1).

To allow the propagation of Direct Communication messages over the MANET network (i.e. step 2 in Figure 6.4.2-3), there is a need for a point-to-point transport for signalling messages between a pair of U2U Relays.

As a result of the enhancements described above, the entire MANET (with collocated U2U Relays) behaves as a single ProSe UE-to-UE Relay, with no impact on the End UEs.

### 6.4.3 Procedures

This solution relies on a new MANET message, referred to as [MANET] Discovery Info, that carries:

- Identity of the Relay that is originator of the [MANET] Discovery Info message.

- List of locally discovered User Info IDs (per RSC).

- Signalling Endpoint Address (IP address and port number) that can be used for establishment of point-to-point signalling connection between a pair of U2U Relays over the MANET.

- (optional) Security information related to establishment of point-to-point signalling connection between a pair of U2U Relays over the MANET.

The [MANET] Discovery Info message is diffused throughout the MANET using MPR flooding (as defined in IETF RFC 7181 [9]), if available. As an example, in reference to Figure 6.4.2-2, by relying on MPR flooding, the [MANET] Discovery Info is transmitted only on a subset of the network interfaces. If MPR is not available, then the [MANET] Discovery Info message is diffused using simple flooding i.e. by transmitting a copy of the [MANET] Discovery Info message on all interfaces (except the one on which the message has been received).

The [MANET] Discovery Info message is formatted according to IETF RFC 5444 [11]. Specifically, the message originator address (<msg-orig-addr> in IETF RFC 5444 [11]) and the message sequence number (<msg-seq-num> in IETF RFC 5444 [11]) are used to enable the MPR flooding mechanism, as defined in IETF RFC 7181 [9].

Upon reception of a [MANET] Discovery Info message, the MANET router forwards a copy to the collocated U2U Relay. The U2U Relay updates the list of User Info IDs that are reachable via the MANET network. For each stored User Info ID the U2U Relay keeps information of the U2U Relay that originated the information. It is noted that the same User Info ID can be associated with more than one U2U Relays (e.g. in case the UE was discovered by more than one U2U Relays).

NOTE 1: Instead of defining a new MANET message, the content of the [MANET] Discovery Info message described above could be carried as new information element in the existing MANET Topology Control (TC) message. The drawback of this approach is that the frequency of topology updates is different and unrelated from the frequency of End UE discovery events. Another possibility would be to diffuse the content of the [MANET] Discovery Info message described above using a flooding-based signalling protocol that is defined on its own. The drawback of this approach is that it cannot readily re-use the MPR flooding mechanisms that are built-in features in MANET.

The signalling protocol carrying the Direct Communication messages (as defined in 3GPP TS 23.304 [4]) between a pair of U2U Relays can be defined by 3GPP. The only thing needed from the new MANET message (i.e. [MANET] Discovery Info) is to be able to carry the Signalling Endpoint Address (IP address and port number) that uniquely identifies the signalling endpoint of the U2U Relay functionality collocated with the MANET router.

When the local U2U Relay (e.g. U2U Relay A) receives a Direct Communication Request from the source End UE and the target End UE has been discovered by more than one remote U2U Relays (e.g. U2U Relay B and U2U Relay C), the local U2U Relay chooses to which remote U2U Relay to forward the Direct Communication Request based on implementation.

Upon reception of the Direct Communication Accept generated by the target End UE, the remote U2U Relay reserves an IP address/prefix for the target End UE and forwards the Direct Communication Accept towards the local U2U Relay, including the reserved IP address/prefix of the target End UE. The local U2U Relay forwards the Direct Communication Accept message to the source End UE.

Source End UE obtains the IP address/prefix of the target End UE using existing mechanisms described in TS 25.303 [9].

The IP subnet address/prefix that is used by the U2U Relay to assign IP addresses to End UEs, as well as the Signalling Endpoint Address of the U2U Relay functionality, need to be advertised by the collocated MANET router via MANET Topology Control (TC) messages ahead of time. This is needed to ensure the existence of stable routes prior to the establishment of a signalling connection between a pair of U2U Relays, or prior to the exchange of user plane packets between a pair of distant End UEs.

NOTE 2: The End UE might need to establish a communication link with two (or more) U2U Relays in case the two U2U Relays belong to two disjoint MANET networks. For example, this could be the case where End UE A needs to reach End UE B and End UE C, whereby End UE B is advertised by U2U Relay X only, while End UE C is advertised by U2U Relay Y only. In this case End UE A chooses the link on which to route the outgoing IP packet based on the target End UE address.

If a MANET router happens to include a ProSe UE-to-Network functionality, the [MANET] Discovery Info message indicates that the Relay that is originator of the [MANET] Discovery Info message has UE-to-Network functionality and includes the Relay Service Code (RSC) of the collocated ProSe UE-to-Network Relay. The RSC indicates the connectivity service that the ProSe UE-to-Network Relay provides to the Remote UE.

Editor’s note: When End UE needs to switch to a new U2U Relay (e.g. due to link failure), if there are multiple UE-to-Network Relays associated with the same RSC, it is FFS whether and how the End UE needs to retrieve the same UE-to-Network Relay with which the original connection was established.

### 6.4.4 Impacts on services, entities and interfaces

ProSe UE-to-UE Relay impact:

- Has a collocated MANET router functionality and is able to initiate or join a mobile ad hoc network as defined in MANET (IETF RFC 7181 [9]).

- Supports a new MANET message called [MANET] Discovery Info that is used to diffuse information about discovered End UEs to other U2U Relays over the MANET.

- Advertises User Info IDs that have been discovered by any U2U Relay that is part of the MANET.

- Establishes p2p signalling connection with a remote U2U Relay and tunnels Direct Communication messages (for establishment, release, etc.).

End UE impact:

- None.

## 6.5 Solution #5: Support of Multi-hop UE-to-UE Relay Discovery

### 6.5.1 Description

This solution addressed Key Issue #2 “Support of Layer-3 Multi-hop UE-to-UE Relays”.

In this solution, the ProSe 5G UE-to-UE Relay operations is supported with the following principles:

- 5G ProSe multi-hop UE-to-UE Relay discovery with Model B:

* The Source End UE decides the maximum number of hops for discovery based on QoS requirement and (pre-)configuration. E.g., according to some mapping to the service or RSC.

NOTE: the maximum number of hops decided by the Source End UE may also be used in Model A discovery.

* The Source End UE sends a 5G ProSe UE-to-UE Relay Discovery Solicitation message containing the maximum number of hops for discovery in the UE-to-UE Discovery set.
* The User Info IDs of UE-to-UE Relays are used for (1) avoiding loop: if the Relay’s own User Info ID is already contained in the message, the Relay may drop the message; (2) counting the number of hops in the path, a UE-to-UE Relay decides whether to forward the Solicitation message according to the maximum number of hops and the number of User Info IDs of UE-to-UE Relays.
* When a UE-to-UE Relay forwards the Solicitation message, it additionally includes its own User Info ID in the message. The principles of assigning Source Layer-2 ID of the Solicitation message reuse the current Rel-18 methods.
* The Target End UE responds to a UE-to-UE Relay with a Response message, including the User Info IDs of Relays in the path. If the Target End UE may choose the path based on e.g., the PC5 signal strength of each message received, the number of hops to the Source End UE.

### 6.5.2 Procedures



Figure 6.5.2-1: 5G ProSe multi-hop UE-to-UE Relay Discovery with Model B

The procedure of 5G ProSe multi-hop UE-to-UE Relay Discovery with Model B is extended based on the Rel-18 UE-to-UE Relay Discovery with Model B.

1. The Source End UE decides the maximum number of hops for discovery based on e.g., according to QoS requirement or configuration.

Then the Source End UE can decide the maximum number of hops based on this End-to-End QoS parameters and PQI parameters. For example, the E2E Packet Delay Budget is 100ms while the PDB of a PQI is 30ms, then the max number of hops can be decided as floor[100/30]=3.

2a. The Source End UE sends a Solicitation message. The Solicitation message additionally contains the maximum number of hops.

The maximum number of hops can be a constant value or a variable similar to TTL which will be decreased by 1 per hop. They are equivalent if the User Info IDs of Relays in the path are also included in the message. i.e., can be calculated out of each other.

3a. A 5G ProSe UE-to-UE Relay may forward the Solicitation message when its own User Info ID is not contained in the received Solicitation message. If the number of User Info IDs of Relays included in the message has reached the maximum number of hops (or the TTL is 0), the Relay should drop the message.

NOTE 1: If the Source End UE does not receive any response after a timeout, based on application requirement, it may increase the maximum number of hops and send the discovery message again.

NOTE 2: Based on implementation, Relay UEs can decide to forward the discovery message with the same direct discovery set at most once in order to control the total number of discovery messages transferred among relays. To determine the identical direct discovery set, the relay UE can compare the direct discovery set bit by bit if it is encrypted, or check the source End UE and target End UE User info if the direct discovery set is not encrypted.

4a. A 5G ProSe UE-to-UE Relay sends a Solicitation message, it additionally includes its own User Info ID in the message. i.e., the message contains the User Info IDs of all Relays in the path.

The UE-to-UE Relay may assign unique Layer-2 ID for sending Solicitation message as described in the current Rel-18 single-hop U2U Relay discovery procedure.

2b.-6b. Another discovery path.

7-8. The Target End UE responds to the 5G ProSe UE-to-UE Relay with a Response message.

The Response message additionally contains the User Info IDs of Relays in the path.

If the Target End UE may choose the path based on e.g., the PC5 signal strength of each message received, hops to the Source End UE, the User Info IDs of UE-to-UE Relays in the path, etc.

9-10. A UE-to-UE Relay sends a Response message. The Response message additionally contains the User Info IDs of Relays in the path.

A UE-to-UE Relay can associate the User Info ID and Layer-2 ID of neighbour UE-to-UE Relays according to the Response message. The association can be used in the subsequent Link Management procedure.

11. The Source End UE may perform the UE-to-UE Relay(s)/path selection based on e.g., the PC5 signal strength and the number of hops of the received Response messages. The number of hops corresponds to the number of User Info IDs of Relays in the path.

### 6.5.3 Impacts on services, entities and interfaces

There is no impact to NG-RAN, as the solution is using the existing features supported in Rel-18 NR ProSe design.

There are impacts to 5G ProSe End UE, UE-to-UE Relay, maybe to ProSe Policy.

## 6.6 Solution #6: Multi-hop extension of 5G ProSe UE-to-UE Relay

### 6.6.1 Description

In this solution, 5G ProSe multi-hop Layer-3 UE-to-UE Relay over NR PC5 is supported with the following principles:

* Authorization and configuration
* For supporting multi-hop extension, a UE-to-UE Relay shall be authorized and configured as a UE-to-UE Relay with multi-hop extension.
* Multi-hop UE-to-UE Relay Discovery
* Model A and Model B discovery can be used for multi-hop UE-to-UE Relay discovery. When supporting multi-hop discovery, Announcement message for model A discovery and Solicitation and Response messages for model B discovery include multi-hop extension indication and hop\_count to indicate the number of hops from announcing UE (in model A) or the number of hops from discoverer UE (in model B).
* When UE-to-UE Relay sends a Relay discovery message including direct discovery set received from End UE or from another UE-to-UE Relay, each direct discovery set is appended with hop count and user info of UE-to-UE relays in the path. The list of UE-to-UE Relays in the path is called “Route information”.
* Each UE-to-UE Relay may include link quality information in the Relay discovery message (e.g. per hop delay or cumulative delay, etc.)
* When an End UE selects a multi-hop UE-to-UE Relay path to another End UE, it selects a multi-hop path based on several criteria (e.g. number of hops, channel quality, end to end delay, etc) and saves the Route information from the End UE to another End UE using UE-to-UE relays involved in the path.
* Multi-hop UE-to-UE Relay Connection setup
* After discovery procedure, End UE sends a DCR or a LMR to the first UE-to-UE Relay in the selected Route information to another End UE, including the Route information using UE-to-UE relays user info [list] in the path.
* When a UE-to-UE Relay receives a DCR or a LMR for end to end connection between source End UE and target End UE with Route information, the UE-to-UE Relay sends a DCR or LMR (when reusing existing PC5 connection) to another UE-to-UE Relay or target End UE at next hop based on the Route information.
* Support of multi-hop UE-to-UE Relay Connection setup with integrated discovery
* For integrated discovery, source End UE sends a DCR with relay\_indication. When a UE-to-UE Relay receives a DCR with relay\_indication, it sends a DCR for integrated discovery to another UE-to-UE Relay with appending user info ID of UE-to-UE Relay and hop\_count (new hop\_count set to 1 if no hop\_count at the received message or increasing hop\_count by 1 when hop\_count exists). Each UE-to-UE Relay may include link quality information in the DCR for integrated discovery to another UE-to-UE Relay (e.g. per hop delay or cumulative delay, etc.).
* For integrated discovery, when target End UE receives DCRs or LMRs for end to end connection setup with source End UE via multi-hop UE-to-UE Relays, it may select a proper multi-hop path to the source End UE based on several criteria (e.g. number of hops, channel quality, end to end delay, etc).
* Multi-hop UE-to-UE Relay Reselection or path change
* Negotiated 5G ProSe UE-to-UE Relay reselection procedure is extended to multi-hop UE-to-UE Relay connection.
* When there is no UE-to-UE Relay available in single hop for relay reselection, source End UE sends a link modification request including a list of UE-to-UE relays available in multi-hop with indication of multi-hop extension.
* Target End UE may trigger Candidate Relay discovery procedure with multi-hop extension for the UE-to-UE Relay in the list of UE-to-UE relay from source End UE.
* Candidate Relay discovery procedures are extended to multi-hop by including indication of multi-hop connection and Route information of the path to the candidate Relay (i.e. list of UE-to-UE relays in the path).
* Target End UE selects new multi-hop UE-to-UE Relay path and sends the new multi-hop path to the source End UE.
* Supporting IP address/prefix allocation
* For multi-hop UE-to-UE Relay extension, each UE-to-UE Relay works as DHCP server.
* When UE is authorized as U2U relay UE and supporting DHCP server mechanism, the IP address pool is configured by NW to avoid collision between U2U relay UEs which behave as DHCP servers.
* For multi-hop UE-to-UE Relay extension with IP communication, an End UE is assigned an IP address from the UE-to-UE Relay after setting up a unicast PC5 link. UE-to-UE Relay stores an association of the User info of the UE of the unicast link and IP address/prefix allocated to the UE into its DNS entries. Each UE-to-UE Relay works as a DNS server for the UEs having PC5 connection with it.
* For IP routing between U2U relay UEs for multi-hop connection, during PC5 connection setup or during discovery, U2U relay UEs may share their range of IP address with other U2U relay UE.
* When a (source) UE needs to communicate with another (target) UE, it sends a DNS query for the target UE (based on Target User Info) and receives a DNS Response with the IP address/prefix of the target UE. UE-to-UE Relay may communicate with other UE-to-UE Relays to retrieve the IP address of the target UE.

### 6.6.2 Procedures

#### 6.6.2.1 5G ProSe multi-hop UE-to-UE Relay Discovery

##### 6.6.2.1.1 Multi-hop U2U Relay discovery using model A



Figure 6.6.2.1.1-1: Multi-hop U2U Relay Discovery with model A

Precondition: End UEs and U2U Relays are authorized and provisioned with multi-hop specific configurations such as multi-hop indication to indicate multi-hop is enabled, multi-hop authorization based on the capabilities/subscription, RSC supporting multi-hop U2U connection, and allowed max #hops per RSC.

1a. U2U Relay\_1 sends a U2U relay discovery announcement message including multi-hop indication, list of direct discovery set with assistance information (e.g, hop count for number of hops and cumulative delay information to the End UE in the discovery set, User info Relay\_1).

1b. U2U Relay\_2 sends a U2U relay discovery announcement message including direct discovery set received from U2U Relay\_1 with assistance information (e.g. hop count increased by 1 and updated cumulative delay, User info Relay\_1, and User Info Relay\_2).

2. U2U Relay\_3 sends a U2U relay discovery announcement message including direct discovery set of the End UEs in the proximity and direct discovery set received from other U2U relays. When including direct discovery set received from other U2U Relay, it updates its assistance information (e.g. hop count increased by 1 and updated cumulative delay, list of User Info of U2U Relays, User info of Relay\_3). For the direct discovery set of the End UEs in the proximity, the assistance information includes hop count set to zero.

When same direct discovery sets are received from different U2U Relays, U2U Relay\_3 selects a direct discovery set based on various criteria (e.g., minimum hop counter value, minimum cumulative delay, or channel quality of received message.)

##### 6.6.2.1.2 Multi-hop U2U Relay discovery using model B



Figure 6.6.2.1.2-1: Multi-hop U2U Relay Discovery with model B

Precondition: End UEs and U2U Relays are authorized and provisioned with multi-hop specific configurations such as multi-hop indication to indicate multi-hop is enabled, multi-hop authorization based on the capabilities/subscription, RSC supporting multi-hop U2U connection, and allowed max #hops per RSC.

1a. End UE\_1 sends a U2U relay discovery solicitation message including multi-hop indication, direct discovery set (user info of discoverer end UE, user info of discoveree end UE), RSC supporting multi-hop U2U connection, hop count value set to zero, maximum number of hops allowed, maximum delay allowed.

1b. U2U Relay\_1 sends an U2U relay discovery solicitation message including multi-hop indication, direct discovery set (user info of discoverer end UE, user info of discoveree end UE), RSC supporting multi-hop U2U connection, Routing information (i.e., user info of U2U relay\_1), hop count value increased by 1, maximum number of hops allowed, maximum delay allowed, and delay information between End UE\_1 and U2U Relay\_1.

2. U2U Relay\_2 sends an U2U relay discovery solicitation message including multi-hop indication, direct discovery set (user info of discoverer end UE, user info of discoveree end UE), RSC supporting multi-hop U2U connection, Routing information (i.e., user info of U2U relay\_1, user info of U2U relay\_2), hop count value increased by 1, maximum number of hops allowed, maximum delay allowed, and cumulative delay information between End UE\_1 and U2U Relay\_2.

When hop count exceeds maximum number of hops allowed, or cumulative delay exceeds maximum delay allowed, the received discovery solicitation message is discarded.

If the same Direct Discovery Set is received from different U2U relays, U2U Relay\_2 may select a Direct Discovery Set to be sent to next hop based on various criteria (e.g., minimum hop counter value, minimum delay, or channel quality of received message).

3. Discoveree End UE (here End UE-2) sends an U2U Relay Discovery Response message when RSC matches the authorized information and Discoveree UE’s user info matches its user info. U2U Relay Discovery Response message incudes RSC, direct discovery set (user info of discoverer end UE, user info of discoveree end UE), Route information of selected multi-hop path (i.e. list of U2U relays in the path), number of hops, and cumulative delays.

4. U2U Relay-2 sends a U2U Relay Discovery Response message to End UE-1 when receiving U2U Relay Discovery Response message from End UE-2. U2U Relay Discovery Response message includes RSC, direct discovery set (user info of discoverer end UE, user info of discoveree end UE), Route information of selected multi-hop path (i.e. list of U2U relays in the path), number of hops, and cumulative delays.

End UE-1 selects a multi-hop path to End UE-2 based on the information received in step 4.

#### 6.6.2.2 5G ProSe Communication via 5G ProSe multi-hop Layer-3 UE-to-UE Relay



Figure 6.6.2.2-1. IP address assignment procedure based on configured IP address pool for multi-hop relay

0. UE1 and UE2 are authorized for multi-hop UE-to-UE Relay service as End UE and are provisioned with parameters for discovery and connection setup with other UEs via multi-hop UE-to-UE Relay services.

U2U Relay\_1, and U2U Relay\_2 are authorized for multi-hop UE-to-UE Relay service as Relay UE and are provisioned with parameters for discovery and connection setup with other UEs and relay UEs via multi-hop UE-to-UE Relay services. The provisioned parameter may include parameters such as RSC (Relay service Code)(s), list of PLMN, User Info ID of UE for application which are allowed at multi-hop relay connection.

When U2U Relay\_1, and U2U Relay\_2 are authorized for multi-hop UE-to-UE Relay service as Relay UE, they are provisioned with IP address pool which can be used when relay UEs, as DHCP servers, assign IP address to the end UEs which have PC5 connection with relay UEs. It is to avoid the conflict of IP address at End UEs in multi-hop relay connection.

1. UE1 may perform multi-hop U2U relay discovery procedure to find end to end route to UE2 via multi-hop relay service as specified in 6.6.2.1 in this solution.

2. UE1 selects a proper multi-hop path with Route information (i.e. list of U2U Relay in the path) to UE2 based on the discovery result of step 1.

UE1 initiates a PC5 connection setup or modification procedure to the closest U2U relay in the selected path as specified in step 3 clause 6.7.1.1 of TS23.304. Additionally, DCR or LMR includes Route information to indicate the selected multi-hop path. UE1 may send DCR to U2U Relay\_1 if UE1 has no PC5 connection with U2U Relay\_1 or UE1 may send Link modification request including selected e2e route to U2U Relay\_1 if UE1 has existing PC5 connection with U2U Relay\_1.

3. After sending DCR, security association procedure may be performed between UE1 and U2U Relay\_1.

4. After receiving DCR or LMR from UE1, U2U Relay 1 may trigger a new PC5 connection setup or modification of existing PC5 connection with entity at next hop in the selected multi-hop path. In DCR or LMR, Route information is included as received in step 3.

5. After sending DCR, security association procedure is performed between U2U Relay 1 and U2U Relay 2.

6. After receiving DCR or LMR from U2U Relay 1, U2U Relay 2 may trigger a new PC5 connection setup or modification of existing PC5 connection with entity at next hop in the selected multi-hop path (here UE2). In DCR or LMR, Route information included as received in step 4.

7. After sending DCR, security association procedure is performed between U2U Relay 2 and UE2.

8. UE2 sends DC Accept or LM accept to U2U Relay 2 when accepting the requested PC5 link setup or link modification for communication to UE1 via the selected multi-hop path.

9. For IP traffic, IPv6 prefix or IPv4 address is allocated for UE2 as defined in clause 5.5.1.4 TS23.304. When an IP address is assigned to UE2, the IP address value shall be within the IP address pool configured at U2U Relay 2 during step 0. U2U Relay2 stores an association of User Info ID and assigned IP address of UE2 for use DNS lookup and IP traffic routing. U2U Relay 2 may act as a DNS server to End UEs and Relay UEs having PC5 connection with Relay 2.

10. U2U Relay 2 sends DC Accept or LM accept to U2U Relay 1 after receiving DC accept or LM accept from UE2.

During PC5 connection setup or link modification procedure between U2U Relay 1 and U2U Relay 2, each Relay UE’s assigned IP address pool may be shared to each other so that U2U relay 1 and U2U relay 2 are aware of other relay UE’s IP address pool. Other U2U relay UE’s IP address pool information may be used for IP traffic forwarding to correct relay UE when receiving IP data from End UE to forward other end UE in multi-hop relay connection.

11. U2U Relay 1 sends DC Accept or LM Accept to UE1 after receiving DC Accept or LM Accept from Relay 2.

U2U Relay1 saves mapping information between User Info of UE2 and U2U Relay2 which have a PC5 link with UE2.

12. For IP traffic, IPv6 prefix or IPv4 address is allocated for UE1 as defined in clause 5.5.1.4 TS23.304. When an IP address is assigned to UE1, the IP address value shall be within the IP address pool configured at U2U Relay 1 during step 0. U2U Relay1 stores an association of User Info ID and assigned IP address of UE1 for use DNS lookup and IP traffic routing. U2U Relay 1 may act as a DNS server to End UEs and Relay UEs having PC5 connection with Relay 1.

13. UE1 may send a DNS query including user info ID of UE2 to U2U Relay 1 to request IP address of UE2.

14. U2U Relay 1 decides to send DNS query to relay 2 based on the mapping between user info of UE2 and relay2. And U2U Relay 1 may communicate with U2U Relay 2 to retrieve an IP address of UE2 using User Info ID of UE2.

15. U2U Relay 1 sends a DNS response including IP address of UE2 to UE1.

16. Based on received IP address of UE2, UE1 may exchange IP traffic with UE2 via multi-hop path. When receiving IP packet between UE1 and UE2, U2U relay 1 and U2U relay2 forward IP packet to U2U relay 2 and U2U relay 1 based on information of IP address pool handled by relay UE.

#### 6.6.2.3 5G ProSe multi-hop Layer-3 UE-to-UE Relay Reselection with negotiated U2U relay reselection procedure.

This solution is about negotiated layer-3 UE-to-UE relay reselection procedure with multihop relay discovery support and with list of candidates U2U relays which are directly reachable by Initiating End UE(UE1).

Based on the list of U2U relays, Responding End UE(UE2) tries to find new end to end route to UE1. UE2 may consider multi-hop routes to UE1 if there is no relay in the provided list reachable directly by UE2.

Once UE2 determines that multi-hop connection is needed (e.g. because no candidate relays are directly reachable), UE2 initiates multi-hop U2U relay discovery for UE1 or multi-hop candidate U2U relay discovery for relay UEs in the list, if needed.

UE2 selects an end-to-end route to reach UE1 based on received information from the discovery procedure, initiates PC5 connection setup procedure via this selected route and informs UE1 about the selected e2e route.

During this negotiated U2U Relay reselection procedure, UE1 and UE2 exchange their new IP address to be used at the newly selected end to end route.



Figure 6.6.2.3-1. Layer3 based Negotiated UE-to-UE Relay reselection procedure.

0. UE1, UE2 are authorized for multi-hop U2U Relay service as End UE and are provisioned with parameters for discovery and connection setup with other UEs via multi-hop UE-to-UE Relay services.

Relay1, Relay2, Relay3, and Relay4 are authorized for multi-hop U2U Relay service as Relay UE and are provisioned with parameters for discovery and connection setup with other UEs and relay UEs via multi-hop UE-to-UE Relay services.

1. UE1 and UE2 setup PC5 connection with Relay1 for communication between UE1 and UE2.

2. UE1 and UE2 exchange data traffic e.g., IP traffic, via Relay1.

3. UE1 (initiating End UE) determines, e.g. based on PC5 signal strength, to perform U2U Relay reselection.

UE1 obtains a list of U2U Relays which are accessible by UE1 in direct PC5 connection and support multi-hop connection (e.g. via U2U Relay Discovery Procedure). The list of UE-to-UE Relays may include the U2U Relays which have PC5 connection with UE1.

4. UE1 sends a Link Modification Request message to relay1. Link Modification Request includes a Relay re-selection indication, information of candidate UE-to-UE Relay(s), IP addresses of the responding End UEs (here UE2), IP address of UE1, and indication of multi-hop connection supported.

5. Based on received End UEs IP address in step 4, Relay1 determines the responding End UEs (here UE2) and sends a Link Modification Request message to the responding End UEs (here UE2).

The Link Modification Request message includes a Relay re-selection indication, User Info ID(s) of the candidate UE-to-UE Relay(s), IP address of UE1, and indication of multi-hop connection supported.

6. After receiving Link Modification Request for Relay reselection with list of U2U Relays, for each U2U relay, UE2 may perform multi-hop candidate Relay discovery procedure to find available multi-hop path to each candidate U2U Relay with number of hop and delay.

7. UE2 may select a proper multi-hop path to UE1 based on discovery results at step 6 (e.g., link quality, number of hops of e2e route, end to end delay of e2e route, etc.)

8. UE2 may initiate PC5 connection setup or modification procedure for communication with UE1 with Routing information for the selected multi-hop path as shown in 6.6.2.2 in this solution.

9. UE2 sends a Link Modification Accept message to Relay1. Link Modification Accept message includes Route information for the new multi-hop path, IP address of UE1, IP address of UE2, new IP address of UE2 at newly selected multi-hop path, and Relay re-selection indication.

10. Relay1 sends Link Modification Accept message to UE1. The Link Modification Accept message includes Route information for the new multi-hop path, IP address of UE1, IP address of UE2, new IP address of UE2 at newly selected multi-hop path, and Relay re-selection indication.

11. UE1 sends Link Modification Ack to relay1. Link Modification Ack includes the IP address of UE1 at newly selected multi-hop path, IP address of UE2 and Relay reselection indication.

12. Relay1 sends Link Modification Ack to UE2. Link Modification Ack includes the IP address of UE1 at newly selected multi-hop path, IP address of UE1, IP address of UE2 and Relay reselection indication.

13. UE1 and UE2 transfer traffic via the newly selected multi-hop path.

### 6.6.3 Impacts on services, entities and interfaces

5GC:

* Authorization and provisioning parameters for multi-hop Layer-3 UE-to-UE Relay

End UE, U2U Relay:

* Support Multi-hop Layer-3 UE-to-UE Relay functionality

# 7 Overall Evaluation

Editor's note: This clause will provide evaluation of different solutions.

# 8 Conclusions

Editor's note: This clause will list conclusions that have been agreed during the course of the study item activities.

Annex A (informative):  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2024-01 | SA2#160-Ah Hoc-e |  | - | - | - | Proposed skeleton for FS\_5G\_ProSe\_Ph3 | 0.0.0 |
| 2024-01 | SA2#160-Ah Hoc-e |  |  |  |  | Implemented approved pCRs S2-2401641 (Scope), S2-2401808 (Terms and abbreviations), S2-2401809 (Architecture requirements and assumptions), S2-2401810 (KI#1), S2-2401811 (KI#2) | 0.1.0 |
| 2024-03 | SA2#161 |  |  |  |  | Implemented approved pCRs:S2-2403687, S2-2403838, S2-2403397, S2-2403689, S2-2403399, S2-2402855 | 0.2.0 |