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| 3GPP TR 33.740 V18.1.0 (2023-09) | |
| Technical Report | |
| 3rd Generation Partnership Project;  Technical Specification Group Services and System Aspects;  Study on security aspects of Proximity Based Services (ProSe) in 5G System (5GS) phase 2  (Release 18) | |
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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 studies the security and privacy aspects of proximity based services in 5G system phase 2. It ensures that the security solutions are aligned with the work in SA2 (i.e. TR 23.700-33 [2]), RANs, SA1 (i.e. TS 22.278 [3], TS 22.261 [4], and TS 22.115 [5]) and SA3 (i.e. TS 33.503 [6] and TR 33.870 [7]). The present document covers the following issues:

- Security and privacy key issues, threats and potential requirements of proximity based services in 5G system phase 2.

- Potential security solutions to cover these potential requirements.

Both roaming and non-roaming scenarios are considered.

# 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 23.700-33: "Study on System enhancement for Proximity based Services (ProSe) in the 5G System (5GS); Phase 2".

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

[4] 3GPP TS 22.261: "Service requirements for the 5G system; Stage 1".

[5] 3GPP TS 22.115: " Service aspects; Charging and billing".

[6] 3GPP TS 33.503: "Security Aspects of Proximity based Services (ProSe) in the 5G System (5GS)".

[7] 3GPP TR 33.870: "Study of privacy of identifiers over radio access".

[8] 3GPP TS 23.304: "Proximity based Services (ProSe) in the 5G System (5GS)".

[9] 3GPP TS 33.536: "Security aspects of 3GPP support for advanced Vehicle-to-Everything (V2X) services".

[10] IRTF "CPace, a balanced composable PAKE" available online at <https://datatracker.ietf.org/doc/draft-irtf-cfrg-cpace/>

[11] IRTF "The OPAQUE Asymmetric PAKE Protocol" available online at <https://datatracker.ietf.org/doc/draft-irtf-cfrg-opaque/>

[12] IRTF "SPAKE2, a PAKE" available online at <https://datatracker.ietf.org/doc/draft-irtf-cfrg-spake2/>

[13] IRTF "SPAKE2+, an Augmented PAKE" available online at <https://datatracker.ietf.org/doc/draft-bar-cfrg-spake2plus/>

[14] 3GPP TS 33.220: "Generic Authentication Architecture (GAA); Generic Bootstrapping Architecture (GBA)".

[15] 3GPP TS 33.535: "Authentication and Key Management for Applications (AKMA) based on 3GPP credentials in the 5G System (5GS)".

[16] 3GPP TS 22.101: "Service aspects; Service principles".

[17] Hao, Feng, and Paul C. van Oorschot. "SoK: Password-Authenticated Key Exchange--Theory, Practice, Standardization and Real-World Lessons." Proceedings of the 2022 ACM on Asia Conference on Computer and Communications Security. 2022.

[18] Joern-Marc Schmidt, RFC 8125: "Requirements for Password-Authenticated Key Agreement (PAKE) Schemes", April 2017, available online at <https://datatracker.ietf.org/doc/rfc8125/>

# 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] 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].

**5G ProSe U2U UE:** A 5G ProSe-enabled UE that discovers or is discovered by a 5G ProSe-enabled UE(s) via a 5G ProSe UE-to-UE Relay; or a 5G ProSe-enabled UE that communicates with other 5G ProSe-enabled UE(s) via a 5G ProSe UE-to-UE Relay.

**5G ProSe UE-to-UE Relay:** A 5G ProSe-enabled UE that provides functionality to support connectivity between 5G ProSe U2U UEs.

## 3.2 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] 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].

5G DDNMF 5G Direct Discovery Name Management Function

CP Control Plane

DCA Direct Communication Accept

DCR Direct Communication Request

E2E End-to-End

PAKE Password-based key establishment

PKMF ProSe Key Management Function

PRUK Prose Remote User Key

RSC Relay Service Code

U2U UE-to-UE

UP User Plane

# 4 Security Aspects of 5G ProSe

## 4.1 General

Security solutions should build on the 5G ProSe architecture principles as defined in TS 23.304 [8] and 5G ProSe security architecture principles as defined in TS 33.503 [6], including flexibility and modularity for newly introduced functionalities.

## 4.2 Architecture assumption

- Security architecture defined in TS 33.503 [6] is used as basis security architecture for supporting 5G ProSe Security phase 2.

- The security architecture needs to enable secure UE-to-UE relay discovery and communication when the Source UE, Target UE as well as the UE-to-UE relay can be out of coverage.

- The 5G ProSe UE-to-UE Relay is specified in TS 23.304 [8].

- It is assumed that the 5G ProSe UE-to-UE Relay is a trusted entity.

# 5 Key issues

## 5.1 Key Issue #1: Security for UE-to-UE Relay discovery

### 5.1.1 Key issue details

In case of UE-to-UE Relay communication, a source UE discovers a target UE via a UE-to-UE Relay in proximity. The discovery messages to discover either a UE-to-UE Relay or a target UE via UE-to-UE Relays in proximity need to be security protected. Failure to protect the security of these discovery messages for UE-to-UE Relay communication may lead to various attacks by unauthorized UEs, e.g. discovery message manipulation, or potential leakage of privacy sensitive information. Therefore, the security aspects of the discovery messages broadcasted in UE-to-UE Relay discovery should be studied.

### 5.1.2 Security threats

If the discovery messages are not integrity protected and replay protected, the parameters included in the discovery messages (e.g. Relay Service Code and ProSe Restricted Code) can be modified, or replayed by an attacker. Consequently, a source UE may fail to find a relay UE or a target UE for an intended service.

If the discovery messages are not confidentiality protected, the privacy sensitive parameters (e.g. Relay Service Code and ProSe Restricted Code) can be eavesdropped by an attacker.

### 5.1.3 Potential security requirements

The 5G System shall provide a means for confidentiality protection, integrity protection and replay protection of discovery messages for UE-to-UE Relay discovery.

The 5G System shall provide a means to protect the privacy sensitive information of source UE and target UE during UE-to-UE Relay discovery procedure.

The 5G System shall provide a means to securely provision the security materials for UE-to-UE Relay discovery.

## 5.2 Key Issue #2: Security of UE-to-UE Relay

### 5.2.1 Key issue details

3GPP system has to be able to protect security (i.e. the integrity and confidentiality) of information between the peer UEs over the UE-to-UE Relay. Failure to protect integrity and confidentiality of information exchanged between the peer UEs over the UE-to-UE Relay will open vulnerability in 5GS and allow various attacks such as unauthorized disclosure and modification of information. Protection of communications between the peer UEs should take into consideration that the UE-to-UE Relay is a trusted node.

TR 23.700-33 [2], key Issue #1: Support of UE-to-UE Relay, has the following key issue:

*- How to enhance the system architecture to provide security/privacy protection for a relayed connection.*

*NOTE 3: For security/privacy protection aspects, coordination with SA WG3 is needed."*

### 5.2.2 Security threats

Failure to protect integrity and confidentiality of information exchanged between the peer UEs over the UE-to-UE Relay will open vulnerability in 5GS and allow various attacks such as unauthorized disclosure and modification of information.

A malicious Relay UE that can establish a unicast link with the source UE, as well as the target UE may conduct an MITM attack.

Failure to protect integrity and confidentiality of information during path change will open vulnerability in 5GS and allow various attacks resulting in unauthorized disclosure and modification of information.

### 5.2.3 Potential security requirements

The 3GPP system shall support a means to provide confidentiality, integrity and replay protection of end-to-end information exchanged between the peer UEs over the UE-to-UE Relay.

The 3GPP system shall support a means to protect security (i.e. the integrity, confidentiality, and replay protection) of user-plane and control-plane messages, including during UE-to-UE Relay path switch.

The 3GPP system shall support a means to establish a secure connection between the source UE and the target UE in the UE-to-UE relay scenario.

## 5.3 Key issue #3: Authorization in the UE-to-UE Relay Scenario

### 5.3.1 Key issue details

TR 23.700-33 [2], key issue #1 describes its key Issue regarding support of UE-to-UE Relay:

*"- Whether and how the network can control UE-to-UE Relay operation, at least including how to:*

*- Authorize the UE-to-UE Relay, e.g. authorize a UE as UE-to-UE Relay.*

*- Authorize Source/Target UEs to use a UE-to-UE Relay.*

*…*

*NOTE 3: For security/privacy protection aspects, coordination with SA WG3 is needed."*

From a security point of view, whether the UE can act as a UE-to-UE Relay should be assured by the Source UE or Target UE. Similarly, whether the UE can act as a Source UE or Target UE should be assured by the UE-to-UE relay.

3GPP system should be able to authorize a UE to perform as UE-to-UE Relay and a UE to communicate with another UE via a UE-to-UE Relay.

### 5.3.2 Security threats

An attacker may impersonate the UE-to-UE Relay. If the Source/Target UE cannot verify if the UE acting as UE-to-UE relay is authorized, the attacker UE may impersonate the UE-to-UE relay. The attacker may then deny the UE services between the two UEs (e.g. arbitrary discard messages).

Similarly, an attacker may impersonate the Source UE or the Target UE.

### 5.3.3 Potential security requirements

The 5GS shall support authorization of the UE as a UE-to-UE relay in the UE-to-UE relay scenario.

The 5GS shall support authorization of the UE as a Source UE or a Target UE in the UE-to-UE relay scenario.

## 5.4 Key Issue #4: Privacy of information over the UE-to-UE Relay

### 5.4.1 Key issue details

3GPP system has to be able to protect the privacy of identities exchanged in the communications between peer UEs over a UE-to-UE Relay. Failure to protect the privacy of identities of peer UEs communicating over the UE-to-UE Relay will open vulnerability in 5GS and allow various privacy attacks including tracing and tracking of identities.

TR 23.700-33 [2] Key Issue #1: Support of UE-to-UE Relay, has the following key issue:

*'- How to enhance the system architecture to provide security/privacy protection for relayed connections.*

*...*

*NOTE 3: For security/privacy protection aspects, coordination with SA WG3 is needed.'*

### 5.4.2 Security threats

Failure to protect the privacy of identities exchanged in the communications between the peer UEs over the UE-to-UE Relay will open vulnerability in 5GS and allow various privacy attacks including tracing and tracking of identities.

The existing Link identifier update procedure specified in TS 33.536 [9] provides privacy of the identities on a per unicast link basis (e.g. the link between a UE and the UE-to-UE Relay). Therefore an attacker may be able to link identities exchanged over the link between a UE and the UE-to-UE Relay to those exchanged over the corresponding link between the peer UE and the UE-to-UE Relay

Path switch between UE-to-UE Relay UEs is a new feature aiming to preserve user experience. Such preservation may be achieved by making certain elements (e.g. IP addresses) of user experience persistent across sessions and UE-to-UE Relays. Persistent parameters may leak unique attributes associated with UEs and other ProSe entities and allow privacy attacks on these entities (e.g. UEs). Failure to protect the privacy of entities and identities during UE to UE Relay path change will open vulnerability in 5GS and allow various privacy attacks including tracing and tracking of entities and identities.

### 5.4.3 Potential security requirements

The 5G System should provide means for mitigating trackability attacks on peer UEs during communications over a UE-to-UE Relay including during the UE-to-UE Relay path switch.

The 5G System should provide means for mitigating linkability attacks on peer UEs during communications over a UE-to-UE Relay including during the UE-to-UE Relay path switch.

## 5.5 Key Issue #5: Security of source and target UE communication via U2U relay

### 5.5.1 Key issue details

3GPP system has to be able to protect security (i.e. the integrity and confidentiality) of information transmitted between the source and target UEs over the UE-to-UE Relay. With the U2U relay being trusted, the protection of security between source and target UEs connected via the U2U relay can be realized either hop-by-hop or end-to-end or both. However, from an efficiency point of view, it does not make sense to do both hop-by-hop and end-to-end at the same time, especially since the U2U relay scenario most likely focuses on the case where the UEs are out of network coverage and therefore out of power source.

This key issue addresses the need for the U2U relay and the source and target UEs to negotiate and agree on a protection scheme, whether it is hop-by-hop or end-to-end. It is independent of the need to apply integrity-, confidentiality-, and replay-protection once the protection scheme is negotiated. Key issue is for L3 relay.

### 5.5.2 Security threats

If source and target UEs communicating with each other via U2U relay are not using the same protection scheme (i.e. hop-by-hop or end-to-end), the source and target UEs will not be able to communicate with each other or the traffic between the source and target UEs may not be protected at all.

### 5.5.3 Potential security requirements

The 3GPP system shall support a means for the source UE, target UE and U2U relay to use the same security protection method in protecting source UE to target UE traffic via the U2U relay.

## 5.6 Key Issue #6: Support for Emergency service over UE-to-Network Relaying

### 5.6.1 Key issue details

In TR 23.700-33 [1], key issue #7 is about support of Emergency for UE-to-Network Relaying. According to TS 22.101 [16], emergency service is defined as citizen to authority services, and it is left to the national authorities to decide whether the network accepts emergency calls e.g. for valid UE only, or for UEs without the SIM/USIM/ISIM.

In the 5G ProSe UE-to-Network relaying, for both layer 2 UE-to-network relay and layer 3 UE-to-network relay, if there is an emergency request from the remote UE, it implies that the Relay UE needs to be responsible for remote UE's emergency service.

A Remote UE which has no USIM inserted may need to initiate an emergency service with a network over PC5 interface via a Layer 3 UE-to-network relay. This Remote UE can only discover UE-to-network relays which indicates a RSC for emergency in clear text. Also, this Remote UE is not able to establish a secure PC5 link with a UE-to-network relay.

Based on the operator policy, the Relay UE needs to support to establish PC5 communication for emergency service with or without PC5 security.

### 5.6.2 Security threats

Emergency service cannot be fulfilled if a Remote UE cannot be properly identified and establish the PC5 security with the relay UE (if required).

### 5.6.3 Potential security requirements

The 5G system shall support the establishment of PC5 communication for emergency service over UE-to-network relay with or without PC5 security.

## 5.X Key Issue #X: <Key Issue Name>

### 5.X.1 Key issue details

### 5.X.2 Security threats

### 5.X.3 Potential security requirements

# 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 | 3 | 4 | 5 | 6 |  |  |
| 1 | X |  | X | X |  |  |  |  |
| 2 |  |  |  | X |  |  |  |  |
| 3 |  | X | X |  |  |  |  |  |
| 4 |  | X | X |  |  |  |  |  |
| 5 |  | X | X |  |  |  |  |  |
| 6 |  | X |  |  |  |  |  |  |
| 7 |  | X |  |  |  |  |  |  |
| 8 | X |  |  |  |  |  |  |  |
| 9 | X |  |  |  |  |  |  |  |
| 10 |  | X | X |  |  |  |  |  |
| 11 | X |  |  |  |  |  |  |  |
| 12 |  | X |  | X |  |  |  |  |
| 13 | X |  | X | X |  |  |  |  |
| 14 |  | X |  | X |  |  |  |  |
| 15 |  | X | X |  |  |  |  |  |
| 16 | X |  | X |  |  |  |  |  |
| 17 | X |  | X |  |  |  |  |  |
| 18 |  | X |  |  |  |  |  |  |
| 19 |  | X | X |  | X |  |  |  |
| 20 |  | X |  |  |  |  |  |  |
| 21 |  | X |  |  |  |  |  |  |
| 22 |  |  |  |  | X |  |  |  |
| 23 | X |  |  |  |  |  |  |  |
| 24 | X |  |  |  |  |  |  |  |
| 25 |  | X |  |  |  |  |  |  |
| 26 |  | X | X |  |  |  |  |  |
| 27 |  |  |  |  |  | X |  |  |
| 28 | X |  |  |  |  |  |  |  |
| 29 |  | X | X |  | X |  |  |  |
| 30 | X | X |  |  |  |  |  |  |
| 31 | X | X |  |  |  |  |  |  |
| 32 |  | X |  |  |  |  |  |  |
| 33 |  |  |  |  | X |  |  |  |
| 34 |  | X |  |  |  |  |  |  |
| 35 |  |  |  | X |  |  |  |  |
| 36 | X |  |  |  |  |  |  |  |
| 37 | X | X |  |  |  |  |  |  |

## 6.1 Solution #1: Restricted Peer UE IP Discovery with Layer-3 UE-to-UE Relay

### 6.1.1 Introduction

This solution is for the 5G ProSe Layer-3 UE-to-UE Relay case. It addresses Key Issue #4: Privacy of information over the UE-to-UE Relay, Key Issue #3: Authorization in the UE-to-UE Relay Scenario, and 2nd requirement of Key Issue #1: Security for UE-to-UE Relay discovery (protection of privacy sensitive information of source and target UEs).

TR 23.700-33 [2] describes several solutions for Layer-3 based which are all based on IP routing functionality at the UE-to-UE Relay. As part of the PC5 unicast link establishment procedure, the ProSe 5G UE-to-UE Relay allocates an IP address/prefix to the UE or is informed of the UE's IP address/prefix. The Relay stores the association of the UE's Application layer ID (also called User Info) and UE's IP address/prefix (e.g. into its DNS entries). When a source UE needs to communicate with a target UE via the ProSe 5G UE-to-UE Relay, it sends a request (e.g. DNS query) to the ProSe 5G UE-to-UE Relay, over the unicast link, to obtain the target UE's IP address/prefix (based on Target User Info). The Relay returns the IP address/prefix of the target UE. The source UE sends IP data to the target UE via the PC5 unicast link to UE-to-UE Relay. The UE-to-UE Relay acts as an IP router and forwards the packets to the corresponding PC5 unicast link towards the target UE.

When using the IP based routing, a UE connected to a UE-to-UE Relay may wish to restrict the discovery of its IP address/prefix for privacy reasons, such as only authorized peer UEs can discover the UE. This is similar to the restricted discovery mechanism where only an authorized Discoverer UE may discover a Discoveree UE. Besides IP address/prefix privacy aspect, the UE-to-UE Relay also needs to ensure that only authorized peer UEs can communicate with the UE.

To enable the support of Restricted IP address/prefix discovery, a UE indicates to the UE-to-UE Relay during the PC5 link establishment procedure if its IP address/prefix may be discovered/shared with peer UEs without seeking the UE authorization or if a prior authorization from the UE is required. In addition, to minimize the PC5 signaling needed to support Restricted IP address/prefix discovery, the UE may provide a token to the UE-to-UE Relay to delegate IP address/prefix sharing authorization to the UE-to-UE Relay using this token.

### 6.1.2 Solution details

This procedure enables a UE (UE1) to indicate to the UE-to-UE Relay if its IP address/prefix may be shared with a peer UE (UE2) without seeking its authorization or if its authorization is required. It also enables UE1 to provide information to the UE-to-UE Relay to verify directly if UE2 is authorized to receive IP address/prefix information of UE1.



Figure 6.1.2-1: "Restricted" IP discovery procedure for 5G ProSe Layer-3 UE-to-UE Relay

1. UE1 provides an indication (*IP discovery* *authorization required*) and may provide an authorization token during the PC5 Link Establishment procedure with the UE-to-UE Relay. UE-to-UE Relay stores this indication and token (if received) along with other UE1 and PC5 link information. UE1 may be pre-provisioned with the IP discovery authorization token. The token may be generated by UE1 to allow UE2 to discover its IP address. The validity of the token can be associated with the current PC5 unicast link, particular target UE(s), for a particular period, etc. The token is sent protected over the secure PC5 link using the security keys established with the relay.

2. UE-to-UE Relay receives a DNS query from UE2 including UE1's User Info and possibly a token. UE-to-UE Relay retrieves UE1's info and if the *IP discovery* *authorization required* indication is set, UE-to-UE Relay validates the token received from UE2 with UE1's saved token, if a token is received on Query and if a token from UE1 is saved on the UE-to-UE Relay.

The distribution of such token to the UE2 may be performed out of band or in band, e.g. by UE-to-UE Relay after/during a successful DNS query (as specified at step 5).

3. If no token is received from UE2 and/or no token has been provided by UE1 during the link establishment procedure, UE-to-UE Relay sends a PC5-S IP Discovery Authorization Request message with UE2's User Info, UE2's IP address, and the token from UE2 (if received on the Query) to UE1, requesting authorization to share UE1's IP address with UE2.

4. UE1 receives the PC5-S IP Discovery Authorization Request message and replies with a PC5-S IP Discovery Authorization Accept or Reject message, specifying UE2's User Info. UE1 may provide a token at this point for future DNS query messages to be authorized directly at the UE-to-UE Relay using this token. UE1's decision to authorize IP disclosure via the UE-to-UE Relay or provide an authorization token to the UE-to-UE Relay may be based on policies, Application's layer authorization, etc.

5. UE-to-UE Relay sends a DNS response to UE2 with UE1's IP address (if token matches at the UE-to-UE Relay or if a PC5-S IP Discovery Authorization Accept message is received from UE1) or does not reply to the Query message (if no match with token or if a PC5-S IP Discovery Authorization Reject message is received from UE1). UE-to-UE Relay stores the token, if provided by UE1, and may send it to the UE2 with the response. UE2 may use this token the next time it needs to send a DNS query message to discover UE1's IP address.

### 6.1.3 Evaluation

This solution proposes to use an authorization request with optional token exchanged with a L3 UE-to-UE Relay prior to allowing the discovery of UE's IP address/prefix information. This solution ensures that private UE's IP address/prefix information is only exposed to authorized peer UEs.

The U2U Relay and UE need to support a PC5-S Authorization Request/Accept, with optional authorization token, prior to providing UE's IP address/prefix information to a requesting UE. The DNS server logic at the U2U Relay needs to check for IP sharing authorization before returning IP address/prefix information.

This solution addresses:

- Key Issue #3 (2nd requirement): Authorization in the UE-to-UE Relay Scenario

- Key issue #4 (all requirements): Privacy of information over the UE-to-UE Relay

NOTE: Further evaluation is not addressed in the present document.

## 6.2 Solution #2: Privacy handling for Layer-3 UE-to-UE Relay based on IP routing

### 6.2.1 Introduction

This solution addresses Key Issue #4: Privacy of information over the UE-to-UE Relay and in the case of the 5G ProSe Layer-3 UE-to-UE Relay.

A Source UE (UE1) communicating with a Target UE (UE2) over PC5 unicast links, via a UE-to-UE Relay, may need to change its Layer-ID, MSB of Knrp-sess ID and potentially IP address/prefix and other identifiers, e.g. for privacy reasons.

When a Source UE changes its identifiers, the UE-to-UE Relay also needs to update its identifiers at the same time (as per the Link Identifier Update (LIU) procedure defined in TS 23.304 [8] and TS 33.536 [9]) since the PC5 link is established between UE1 and the UE-to-UE Relay. In the case where UE1 changes its IP address/prefix, its Target UE needs to be informed of UE1's new IP address/prefix since communication between UE1 and UE2 is IP-based. Note that the UE IP address is protected over PC5, however existing LIU procedure mandates the change of IP address for IP communications, as per TS 24.554, clause 7.3.2.4. Furthermore, the UE-to-UE Relay needs to be informed as well of UE1's new IP address/prefix since the UE-to-UE Relay handles the IP routing of messages exchanged between the UE1 and UE2. In other words, when used in the UE-to-UE Relay scenario, current LIU procedure would lead to breaking the communication between Source UE and Target UE without proper IP change handling. Therefore, LIU procedure needs enhancements for the UE-to-UE Relay scenario to correctly handle the Source UE IP address change (or Target UE IP address change if LIU procedure is run between Target UE and the UE-to-UE Relay) to avoid this issue.

Likewise, UE1 may be communicating with more than one Target UE over the PC5 unicast link via the UE-to-UE Relay. In that case, all Target UEs need to be informed of UE1's new IP address/prefix.

### 6.2.2 Solution details

Figure 6.2.2-1 illustrates the procedure between the Source UE (UE1), the UE-to-UE Relay, and the Target UE (UE2) handling the change of identifiers at the Source UE. The Link Identifier Update procedure defined in TS 23.304 [8] is reused between UE1 and the UE-to-UE Relay complemented with additional messages between the UE-to-UE Relay and UE2 (i.e. Target UE(s)).

The new procedure between the Relay and the Target UE(s) is needed to inform the Target UE(s) about UE1's new IP address/prefix. The Target UE(s) do not need to change their IDs at this point since they are using a distinct PC5 link with the UE-to-UE Relay. The UE-to-UE Relay however needs to inform UE2 of UE1's new IP address/prefix during the Link Identifier Update procedure between UE1 and UE-to-UE Relay to avoid disruption and loss of communication between UE1 and UE2.

This solution applies to Layer-3 based Solutions #2, #3, #11, #12 and #34 described in TR 23.700-33[2]. These solutions are all based on IP routing functionality at the UE-to-UE Relay with a difference related to the proposed method for IP address/prefix allocation. With some solutions, the UE-to-UE Relay allocates the IP address/prefix to the UE, while for other solutions, a link-local IP address that is assigned by the UE itself is used and sent to the UE-to-UE Relay. Differences in the procedure detailed below are explained when needed.



Figure 6.2.2-1: Privacy handling procedure for 5G ProSe Layer-3 UE-to-UE Relay

0) A PC5 unicast link is established between UE1 and the UE-to-UE Relay. A distinct PC5 unicast link is established between the UE-to-UE Relay and UE2. Both Source/Target UEs learn their peer UE's IP addresses/prefixes via the Relay UE using e.g. DNS. IP data is exchanged between UE1 and UE2 via the UE-to-UE Relay over the PC5 unicast links. The UE-to-UE Relay handles the routing of IP packets to another PC5 unicast link based on the destination IP address/prefix.

1) UE1 is informed (e.g. via the application layer, privacy timer expiration) that its Layer-2 ID, Knrp-sess ID, and IP address/prefix, needs to be changed. UE1 sends a Link Identifier Update Request message to the UE-to-UE Relay, which includes the usual parameters sent on the Link Identifier Update Request message, e.g. new Layer-2 ID and new MSB of Knrp-sess ID. In addition, information related to the change of IP address/prefix may also be included e.g. "new IP address needed" and "inform peer UE" indications as well as UE2's specific information needed at step 2, i.e. UE2's IP address/prefix, UE2's user info.

a) The "new IP address needed" indication is included to request a new IP address/prefix for UE1 from the UE-to-UE Relay.

b) If UE1 uses a link-local IP address, a new link-local IP address is self-allocated on UE1, sent to the UE-to-UE Relay using the Link Identifier Update Request message and, in this case, the "new IP address needed" indication is not included.

2) If the "new IP address needed" indication is included, UE-to-UE Relay assigns a new IP address/prefix to UE1, otherwise, the UE-to-UE Relay saves the new IP address/prefix provided by UE1. If the "inform peer UE" indication is included, the UE-to-UE Relay uses UE2's specific information received at steps 1 to retrieve the PC5 link established with UE2 and sends a new PC5 Relay Update Request message to UE2 over the PC5 link including UE1's new IP address/prefix.

3) UE2 saves UE1's new IP address/prefix. UE2 sends a new PC5 Relay Update Response message to the UE-to-UE Relay including all parameters received on the PC5 Relay Update Request message to ACK them.

4) UE-to-UE Relay sends a Link Identifier Update Response message to UE1 including the usual parameters sent on the Link Identifier Update Response message, e.g. new Layer-2 ID and new LSB of Knrp-sess ID and including UE1's new IP address/prefix.

5) UE1 completes the Link Identifier Update procedure by sending a Link Identifier Update ACK message to the UE-to-UE Relay. UE1 starts using its new IP address/prefix. The new Layer-2 IDs and Knrp-sess ID associated with the PC5 unicast link are also used at that point.

### 6.2.3 Evaluation

This solution proposes to enhance the existing per-hop Link Identifier Update (LIU) procedure to support the L3 UE-to-UE Relay scenario. A UE is informed by the L3 UE-to-UE Relay about the IP address/prefix change of its peer UE when a per-hop LIU procedure is performed between the peer UE and the L3 UE-to-UE Relay. This mechanism allows to avoid disruption to IP communications between the peer UEs that would result otherwise from a conventional per-hop LIU run.

This solution fully addresses Key issue #4: Privacy of information over the UE-to-UE Relay.

## 6.3 Solution #3: PC5 security establishment when L3 UE-to-UE relay is in coverage

### 6.3.1 Introduction

This solution addresses Key issue #2: Security of UE-to-UE Relay and Key issue #3: Authorization in the UE-to-UE Relay Scenario. This solution addresses a L3 UE-to-UE relay.

For L3 UE-to-UE relay use cases, the L3 UE-to-UE relay may be in or out of 3GPP coverage. This solution provides a mechanism for PC5 security setup procedure between a source UE or target UE and a L3 UE-to-UE relay when the L3 UE-to-UE relay is in 3GPP coverage.

This solution assumes 5GC NFs e.g. 5GDDNMF and PKMF are deployed in the network.

### 6.3.2 Solution details

#### 6.3.2.1 Procedure for PC5 security establishment between the 5G ProSe Source UE and 5G ProSe UE-to-UE Relay

Figure 6.3.2.1-1 illustrates the high-level procedure of the proposed solution.



Figure 6.3.2.1-1: High-level procedure of PC5 security between Source/Target UE and UE-to-UE relay

0. The 5G ProSe Source/Target UE and UE-to-UE relay are provisioned with the discovery security materials, PC5 security policies and/or PRUK when they are in coverage.

NOTE 1: 5GC NF(s) that provision PC5 security policies are to be determined during normative work.

1. The discovery procedure for UE-to-UE Relay is performed by the 5G ProSe Source UE using the discovery parameters and discovery security material, based on the Relay Service Code for UE-to-UE Relay. If the UE-to-UE Relay is in 3GPP coverage, it also indicates whether network-based Relay service authentication and authorization is supported for UE-to-UE relay in the discovery announcement message.

Note 1a: How to verify the service authorization information if relay UE uses the same security materials for both in-coverage and out-of-coverage mode is not addressed in the present document.

NOTE 2: In case the Relay UE is capable to support more security methods (e.g. as described in Solution #4) when the Relay UE is in 3GPP coverage, it is preferrable to use the security method described in this solution.

2. If the discovered UE-to-UE Relay supports network-based Relay service authentication and authorization, the 5G ProSe Source UE sends a Direct Communication Request (DCR) that contains PRUK ID or SUCI, Relay Service Code (RSC) of the 5G ProSe UE-to-UE Relay service and KNRP freshness parameter 1 to the 5G ProSe UE-to-UE Relay. Protection of PRUK ID and RSC in DCR can be done same as described in TS 33.503 [6].

3. The 5G ProSe UE-to-UE Relay sends a Key Request message that contains PRUK ID or SUCI, RSC and KNRP freshness parameter 1 to the 5GC.

NOTE 3: 5GC NFs and internal signalling are not described in detail. Here for brevity. The similar security procedure as Security for 5G ProSe Communication via 5G ProSe Layer-3 UE to-Network Relay as defined in TS 33.503 [6] can be reused.

4. The 5GC sends the Key Response message to the 5G ProSe UE-to-UE Relay, which includes KNRP, KNRP freshness parameter 2. The message may also contain GPI, EAP message exchange depending on the selected security methods (UP or CP) as defined in TS 33.503 [6]

5a. The 5G ProSe UE-to-UE Relay derives the session key (KNRP-SESS) from KNRP and then derive the confidentiality key (NRPEK) (if applicable) and integrity key (NRPIK) based on the PC5 security policies as specified in TS 33.536 [9]. The 5G ProSe UE-to-UE Relay sends a Direct Security Mode Command message to the 5G ProSe Source UE and include KNRP Freshness Parameter 2 in the message.

5b. The 5G ProSe Source UE derives KNRP from its PRUK, RSC, KNRP Freshness Parameter 1 and the received KNRP Freshness Parameter 2 and then derive the session key (KNRP-SESS) and the confidentiality key (NRPEK) (if applicable) and integrity key (NRPIK) based on the PC5 security policies in the same manner as the 5G ProSe UE-to-UE Relay and process the Direct Security Mode Command. Successful verification of the Direct Security Mode Command assures the 5G ProSe Source UE that the 5G ProSe UE-to-UE Relay is authorized to provide the UE-to-UE relay service.

5c. The 5G ProSe Source UE responds with a Direct Security Mode Complete message to the 5G ProSe UE‑to-UE Relay.

5d. On receiving the Direct Security Mode Complete message, the 5G ProSe UE-to-UE Relay verifies the Direct Security Mode Complete message. Successful verification of the Direct Security Mode Complete message assures the 5G ProSe UE-to-UE Relay that the 5G ProSe Source UE is authorized to get the UE-to-UE relay service.

6. After successful verification, the 5G ProSe UE-to-UE Relay responds a Direct Communication Accept message to the 5G ProSe Source UE to complete the PC5 connection establishment procedure.

7. PC5 security establishment between the 5G ProSe Target UE and 5G ProSe UE-to-UE Relay is performed according to the procedure described in clause 6.3.2.2.

#### 6.3.2.2 Procedure for PC5 security establishment between the 5G ProSe Target UE and 5G ProSe UE-to-UE Relay



Figure 6.3.2.2-1 PC5 security establishment between the 5G ProSe Target UE and 5G ProSe UE-to-UE Relay

1. If the target UE is not discovered by the 5G ProSe UE-to-UE Relay yet, the discovery procedure is performed.

2. The 5G ProSe UE-to-UE Relay sends a Direct Communication Invite that contains Relay Service Code to the 5G ProSe Target UE. It is assumed the PRUK of Target UE is used as root for the PC5 security thus the Target UE needs to send another DCR in step 3 with PRUK ID or SUCI of Target UE to establish PC5 security as described in TS 33.503 [6].

Note: The need for the new Direct Communication Invite message is not addressed in the present document.

3-7. Steps 3-7 are same as steps 2-6 of clause 6.3.2.1, where the 5G ProSe Target UE acts the role of the 5G ProSe Source UE.

### 6.3.3 Evaluation

This solution resolves Key issue #2: Security of UE-to-UE Relay and Key issue #3: Authorization in the UE-to-UE Relay Scenario when L3 UE-to-UE relay is within 3GPP coverage.

This solution is for commercial services and public safety and supports the PC5 communication with a UE-to-UE Relay capable with network-based Relay service authentication and authorization similar to the UE-to-network relay as described in clauses 6.3.3.2.2 and 6.3.3.3.2 in TS 33.503 for the PC5 security establishment when in 3GPP coverage.

This solution only works when the UE-to-UE relay is located within network's coverage area. The 5G ProSe Source/Target and UE-to-UE relay need to store security materials dedicated to the In-Coverage scenario. Apart from the PC5 signalling, additional user plane/signalling interactions with the network are required in this mechanism.

In the case the UEs (Source/Target/Relay) support multiple security methods (i.e. for In-Coverage and Out-of-Coverage), the 5G ProSe Source/Target and UE-to-UE relay are required to have the logic to choose between the In-Coverage dedicated mechanism and the Out-of-Coverage dedicated mechanism before starting the direct communication establishment.

This solution supports per-hop links setup. The Source UE initiates the PC5 security link setup with UE-to-UE Relay (first hop) similar to the UE-to-network relay as defined in TS 33.503. And the UE-to-UE Relay initiates the PC5 security link setup with the target UE (second hop) after the Security Establishment procedure is completed at the first hop. In order to trigger the Target UE to initiate a DCR message, the UE-to-UE Relay could send a new Direct Communication Invite message that contains Relay Service Code to the 5G ProSe Target UE. The need for this new message can be decided during normative work.

## 6.4 Solution #4: PC5 security establishment when L3 UE-to-UE relay is out of coverage

### 6.4.1 Introduction

This solution addresses Key issue #2: Security of UE-to-UE Relay and Key issue #3: Authorization in the UE-to-UE Relay Scenario. This solution addresses a L3 UE-to-UE relay.

For UE-to-UE relay use cases, the L3 UE-to-UE relay may be in or out of 3GPP coverage. This solution provides a mechanism for PC5 security setup procedure between a source UE or target UE and a L3 UE-to-UE relay when the L3 UE-to-UE relay is out of 3GPP coverage.

This solution assumes long term credentials are provisioned into the UE(s) and form the root of the security of the PC5 unicast link as specified in TS 33.536 [9].

This solution proposes to use authorization tokens as in OAuth 2.0 to indicate that a source UE or a target UE or a L3 UE-to-UE relay is authorized to use a specific UE-to-UE service or to serve a specific UE-to-UE service. When the source UE or the target UE or the L3 UE-to-UE relay registers in the 3GPP network and is authorized to use the UE-to-UE service, the network provides a token stating what kind of UE-to-UE service it can use or serve. The token has an expiration time and is signed with a private key. The network also provides the public key to the UEs to be used for verifying the token from other parties.

This solution assumes the peer UEs retrieve authorization token and public key for token verifying from the Prose Application server. The method how the UEs retrieve tokens and public keys is application specific and not described in 3GPP specification.

### 6.4.2 Solution details

Figure 6.4.2-1 illustrates the high-level procedure of the proposed solution.



Figure 6.4.2-1: High-level procedure of PC5 security between Source/Target UE and UE-to-UE relay

0. The 5G ProSe Source/Target UE and UE-to-UE relay are provisioned with the discovery security materials and PC5 security policies, and request authorization tokens when they are in coverage.

1. The discovery procedure for UE-to-UE Relay is performed by the 5G ProSe Source UE using the discovery parameters and discovery security material, based on the Relay Service Code for UE-to-UE Relay.

2. If discovery result indicates the UE-to-UE Relay supports Direct Relay service authentication and authorization, the 5G ProSe Source UE sends a Direct Communication Request (DCR) that contains Relay Service Code (RSC) of the 5G ProSe UE-to-UE Relay service and Authorization token of 5G ProSe Source UE which is retrieved from step 0, and also the Key\_Est\_Info used for direct authentication and key establishment. Protection of Authorization token and RSC in DCR can be done in a similar way as described in TS 33.503 [6].

NOTE 1: The details regarding the ciphering algorithm for the token are not addressed in the present document.NOTE 2: The need for authorization token is not addressed in the present document.3. Direct Auth and Key Establish procedure as specified in TS 33.536 [9] is performed.

4. The 5G ProSe UE-to-UE Relay uses the public key provided by the network to verify the token of the 5G ProSe Source UE that the 5G ProSe Source UE is authorized to get the UE-to-UE relay service.

5. The 5G ProSe UE-to-UE Relay derives KNRP and other security material as specified in TS 33.536 [9]. The 5G ProSe UE-to-UE Relay sends a Direct Security Mode Command message to the 5G ProSe Source UE including the Authorization token of 5G ProSe UE-to-UE Relay which is retrieved from step 0. The protection of the Authorization token is applied in the same way as step 2.

6. The 5G ProSe Source UE uses the public key provided by the network to verify the token of the 5G ProSe UE-to-UE Relay that the 5G ProSe UE-to-UE Relay is authorized to provide the UE-to-UE relay service. The 5G ProSe Source UE derives KNRP and other security material similar as the 5G ProSe UE-to-UE Relay in step5.

7. The 5G ProSe Source UE sends the Direct Security Mode Complete message to the 5G ProSe UE-to-UE.

8. The 5G ProSe UE-to-UE Relay responds a Direct Communication Accept message to the 5G ProSe Source UE to complete the PC5 connection establishment procedure.

9. Steps 1-8 are repeated for PC5 security establishment between the 5G ProSe Target UE and 5G ProSe UE-to-UE Relay.

### 6.4.3 Evaluation

This solution resolves Key issue #2: Security of UE-to-UE Relay and Key issue #3: Authorization in the UE-to-UE Relay Scenario when L3 UE-to-UE relay is out of 3GPP coverage.

This solution is for commercial services and public safety and assumes that the long term credentials are provisioned into the UE(s) and form the root of the security of the PC5 unicast link as specified in TS 33.536 [9].

This solution proposes that Authorization tokens are used by the UE's during PC5 connection establishment in order for the UE's being able to authorize each other as the involved Source/Target UE and UE-to-UE Relay are out of 3GPP coverage and the network cannot perform the authorization of the Source/Target UE and UE-to-UE Relay. The Authorization tokens are provisioned by the AF to the Source UE, Target UE and UE-to-UE Relay when the UE's are in 3GPP coverage.

This solution supports per-hop links setup. The UEs are then using the security procedures as defined in V2X in TS 33.536 [9] to establish a secure PC5 link and exchange and use the tokens for authorization.

NOTE 1: It is not addressed in the present document about how the token is bound to the authentication based on the configured long term credential.The Authorization token included in the DCR message can be protected in a similar way as described in TS 33.503 [6].

The Authorization token's are exchanged during PC5 security establishment between the Target UE and the 5G ProSe UE-to-UE Relay in a similar way as for the Source UE and UE-to-UE Relay.

Note 2: Further evaluation is needed.

## 6.5 Solution #5: PC5 link security establishment for Layer-3 U2U Relay

### 6.5.1 Introduction

This solution addresses Key Issue #2 and Key Issue #3. This solution provides a means to establish the secure PC5 link between the source UE/target UE and the UE-to-UE Relay. When UE-to-UE Relay is in coverage, the source UE/target UE may establish the secure PC5 link with the UE-to-UE Relay by using the same security procedure as 5G ProSe UE-to-Network Relay communication.

NOTE: How to select the PC5 link security procedure proposed by this solution for the source UE/target UE and the UE-to-UE Relay is not addressed in the present document.

### 6.5.2 Solution details

#### 6.5.2.0 General

Both user-plane (UP) based and control-plane (CP) based procedures of 5G ProSe UE-to-Network Relay can be reused for 5G ProSe UE-to-UE Relay authorization and PC5 link security establishment. 5G ProSe UE-to-UE Relay service and 5G ProSe UE-to-Network Relay service can be distinguished by Relay Service Code.

#### 6.5.2.1 PC5 link security establishment procedure over User Plane

The PC5 link security establishment procedure over User Plane for 5G ProSe UE-to-UE Relay is as follows:



Figure 6.5.2.1-1: PC5 link security establishment procedure over User Plane for 5G ProSe UE-to-UE Relay

NOTE 1: Figure 6.5.2.1-1 shows the security procedure of the non-roaming for 5G ProSe UE-to-UE Relay services. In this figure, the source UE and the target UE and UE-to-UE Relay use a subscription of the same PLMN.

0. The source UE and the target UE is provisioned with the discovery security materials and Prose Remote User Key (PRUK) when it is in coverage. The UE-to-UE Relay is provisioned with the discovery security materials when it is in coverage. These security materials are associated with an expiration time, after which they become invalid. If the UE does not have valid discovery security materials, it needs to connect to the 5G PKMF and obtain fresh ones to use the 5G ProSe UE-to-UE Relay services. The UE gets the 5G PKMF address from the 5G DDNMF.

NOTE 2: The detail of discovery procedure is not addressed in the present document.

1. The source UE performs the discovery procedure and discover the target UE via UE-to-UE Relay.

NOTE 2a: UE-to-UE Relay discovery and communication establish is not addressed in the present document.2a. The source UE sends a Direct Communication Request (DCR) that contains the PRUK ID or a SUCI if the source UE does not have a valid PRUK, Relay Service Code (RSC) of the 5G ProSe UE-to-UE Relay service and KNRP freshness parameter 1 to the 5G ProSe UE-to-UE Relay.

NOTE 3: The PRUK ID and RSC in DCR message can be protected by the same security mechanism as described in clause 6.3.5 of TS 33.503 [6].

2b. The source UE and the UE-to-UE Relay perform the same authorization and key establishment procedure over User Plane as 5G ProSe UE-to-Network Relay. According the PC5 key hierarchy over user plane as defined in clause 6.3.3.2.3 of TS 33.503 [6], the PRUK of source UE (Remote UE) will be shared by 5G ProSe UE-to-Network Relay service and 5G ProSe UE-to-UE Relay service. And the PKMF of source UE use the PRUK identified by PRUK ID, KNRP freshness parameter 1, KNRP freshness parameter 2 and the RSC indicating the UE-to-UE Relay service to derive the KNRP different from the 5G ProSe UE-to-Network service.

2c. The UE-to-UE Relay derive the session key (KNRP-SESS) from KNRP and then derive the confidentiality key (NRPEK) (if applicable) and integrity key (NRPIK) based on PC5 policies. The UE-to-UE Relay sends a Direct Security Mode Command message to the source UE. This message also include the KNRP freshness parameter 2 and be protected as specified in TS 33.536 [9].

2d. If the source UE receives the message containing the GPI, it processes the GPI and derive the PRUK and obtain the PRUK ID from the GPI.

The source UE derives KNRP from its PRUK, RSC, KNRP Freshness Parameter 1 and the received KNRP Freshness Parameter 2. It then derive the session key (KNRP-SESS) and the confidentiality key (NRPEK) (if applicable) and integrity key (NRPIK) based on the PC5 security policies in the same manner as the UE-to-UE Relay and process the Direct Security Mode Command. Successful verification of the Direct Security Mode Command assures the source UE that the UE-to-UE Relay is authorized to provide the relay service.

The source UE responds with a Direct Security Mode Complete message to the UE-to-UE Relay as specified in TS 33.536 [9].

3. On receiving the Direct Security Mode Complete message, the UE-to-UE Relay verifies the Direct Security Mode Complete message. Successful verification of the Direct Security Mode Complete message assures the UE-to-UE Relay that the source UE is authorized to get the relay service. After successful verification, the UE-to-UE Relay sends a Direct Communication Request message that contains Relay Service Code to the target UE to trigger the second hop PC5 link establishment.

4a. The target UE responds a Direct Communication Response message to the 5G ProSe UE-to-UE Relay to perform the second hop PC5 security procedure. The Direct Communication Response message contains the PRUK ID or a SUCI if the target UE does not have a valid PRUK, Relay Service Code (RSC) and KNRP freshness parameter 1.

4b-4d. Step 4b-4d are same as step 2b-2d, where the target UE acts the role of the source UE.

5. On receiving the Direct Security Mode Complete message from the target UE, the 5G ProSe UE-to-UE Relay verifies the Direct Security Mode Complete message. Successful verification of the Direct Security Mode Complete message assures the UE-to-UE Relay that the target UE is authorized to get the relay service. After successful verification, the 5G ProSe UE-to-UE Relay sends a Direct Communication Ack message to the target UE.

6. The target UE sends the Direct Communication Accept message to the 5G ProSe UE-to-UE Relay after received Direct Communication Ack message.

7. The 5G ProSe UE-to-UE Relay sends the Direct Communication Accept message to source UE after received Direct Communication Accept message from Target UE.

NOTE 3a: The need for the new Direct Communication Response and Direct Communication Ack message is not addressed in the present document.

8. The source UE and the target UE establish a secure connection between them.

NOTE 4: How to establish a secure connection between the source UE and the target UE is not addressed in the present document.

#### 6.5.2.2 PC5 link security establishment procedure over Control Plane

The PC5 link security establishment procedure over Control Plane for 5G ProSe UE-to-UE Relay, as follows:



Figure 6.5.2.2-1: PC5 link security establishment procedure over Control Plane for 5G ProSe UE-to-UE Relay

NOTE 1: Figure 6.5.2.2-1 shows the security procedure of the non-roaming for 5G ProSe UE-to-UE Relay services. In this figure, the source UE and the target UE and UE-to-UE Relay use a subscription of the same PLMN.

0. The source UE and the target UE and the UE-to-UE Relay are registered with the network. The UE-to-UE Relay is authenticated and authorized by the network to provide UE-to-UE Relay service. The source UE and the target UE are authenticated and authorized by the network to receive UE-to-UE Relay service. Discovery security material and PC5 security policies are provisioned to the source UE and the target UE and the UE-to-UE Relay respectively during this authorization and information provisioning procedure.

NOTE 2: The detail of discovery procedure is not addressed in the present document.

1. The source UE performs the discovery procedure and discover the target UE via UE-to-UE Relay.

NOTE 2a: UE-to-UE discovery and communication establish is not addressed in the present document.2a. The source UE sends a Direct Communication Request (DCR) that contains its security capabilities and PC5 signalling security policy, the PRUK ID or a SUCI if the source UE does not have a valid PRUK, RSC of the 5G ProSe UE-to-UE Relay service and Nonce\_1.

NOTE 3: The PRUK ID and RSC in DCR message can be protected by the same security mechanism as described in clause 6.3.5 of TS 33.503 [6].

2b. The source UE and the UE-to-UE Relay perform the same authorization and key establishment procedure over Control Plane as 5G ProSe UE-to-Network Relay. According the PC5 key hierarchy over control plane as defined in clause 6.3.3.3.3 of TS 33.503 [6], the PRUK of source UE (Remote UE) will not be shared by 5G ProSe UE-to-Network Relay service and 5G ProSe UE-to-UE Relay service. The source UE performs an 5G ProSe Remote UE specific authentication independent of 5G ProSe UE-to-Network Relay service and derive the PRUK from KAUSF-P by using the RSC of 5G ProSe UE-to-UE Relay service.

2c. When receiving a KNR\_ProSe from the AUSF of the source UE via the AMF of UE-to-UE Relay, the UE-to-UE Relay derive the PC5 session key (Krelay-SESS) from KNR\_ProSe and then derive the confidentiality key (Krelay-enc) (if applicable) and integrity key (Krelay-int) based on PC5 policies. The UE-to-UE Relay sends a Direct Security mode command message to the source UE. This message also include the received Nonce\_2 and source UE's PC5 signalling security policy and be integrity protected using Krelay-int. EAP Success message also be included if received from the AMF.

2d. The source UE generate the KNR\_ProSe key in the same way as its AUSF, and derive the PC5 session key Krelay-sess and confidentiality and integrity keys from KNR\_ProSe and process the Direct Security Mode Command. Successful verification of the Direct Security Mode Command assures the source UE that the UE-to-UE Relay is authorized to provide the relay service.

The source UE send the Direct Security Mode Complete message containing its PC5 user plane security policies to the UE-to-UE relay, which is protected by Krelay-int or/and Krelay-enc according to the negotiated PC5 signalling policies between the source UE and the UE-to-UE Relay.

3. After the successful verification of the Direct Security Mode complete message, the 5G ProSe UE-to-UE Relay store the 5GPRUK ID in the security context associated to the PC5 link with the source UE and sends a Direct Communication Request message that contains Relay Service Code to the target UE to trigger the second hop PC5 link establishment.

4a. The target UE responds a Direct Communication Response message to the 5G ProSe UE-to-UE Relay to perform the second hop PC5 security procedure. The Direct Communication Response message contains the security capabilities and PC5 signalling security policy of the target UE, the PRUK ID or a SUCI if the target UE does not have a valid PRUK, RSC of the 5G ProSe UE-to-UE Relay service and Nonce\_1.

4b-4d. Step 4b-4d are same as step 2b-2d, where the target UE acts the role of the source UE.

5. After the successful verification of the Direct Security Mode complete message, the 5G ProSe UE-to-UE Relay store the 5GPRUK ID in the security context associated to the PC5 link with the target UE and sends a Direct Communication Ack message to the target UE.

6. The target UE sends the Direct Communication Accept message to the 5G ProSe UE-to-UE Relay after received Direct Communication Ack message.

7. The 5G ProSe UE-to-UE Relay sends the Direct Communication Accept message to source UE after received Direct Communication Accept message from Target UE.

NOTE 3a: The need for the new Direct Communication Response and Direct Communication Ack message is not addressed in the present document.

8. The source UE and the target UE establish a secure connection between them.

NOTE 4: How to establish a secure connection between the source UE and the target UE is not addressed in the present document.

### 6.5.3 Evaluation

This solution only works when the UE-to-UE relay is located within network's coverage area. The 5G ProSe Source/Target and UE-to-UE relay need to store security materials dedicated to the In-Coverage scenario. Apart from the PC5 signalling (i.e. step 2b), additional user plane/signalling interactions with the network are required in this mechanism.

In the case the UEs (Source/Target/Relay) support multiple security methods (i.e. for In-Coverage and Out-of-Coverage), the 5G ProSe Source/Target and UE-to-UE relay are required to have the logic to choose between the In-Coverage dedicated mechanism and the Out-of-Coverage dedicated mechanism before starting the direct communication establishment.

## 6.6 Solution #6: End-to-end security establishment for Layer-2 UE-to-UE relay

### 6.6.1 Introduction

This solution addresses security requirement for providing confidentiality, integrity protection of end-to-end information exchanged between the peer UEs over the L2 UE-to-UE Relay in key issue #2.

### 6.6.2 Solution details

#### 6.6.2.1 End-to-end security establishment for Layer-2 UE-to-UE relay



Figure 6.6.2.1: End to end security establishment for Layer-2 UE-to-UE relay

1. Service authorisation and policy provisioning is performed for the Source UE, Target UE and UE-to-UE Relay, the security policy can be provisioned by PCF as defined in TS 33.536 [9].

2. Source UE has selected a suitable UE-to-UE Relay and received the Layer-2 ID of the target UE after Model A or Model B discovery, and the discovery procedure described here is standalone. Source UE decides to connect with target UE via the selected UE-to-UE Relay.

3a. If there is no PC5 link between source UE and UE-to-UE Relay existing for the required RSC, the source UE sends a Direct Communication Request to UE-to-UE Relay.

3b. If there is an existing PC5 link between the source UE and UE-to-UE relay for the required RSC, the source UE sends a Link Modification Request to UE-to-UE relay. The security for this existing PC5 link may have been established, then the step 4 can be skipped.

4. The security establishment for PC5 link between the source UE and UE-to-UE relay is as specified in clause 5.3.3 of TS 33.536 [9].

5a. If there is no PC5 link between UE-to-UE Relay and the target UE exist for the required RSC, UE-to-UE Relay sends a Direct Communication Request to the target UE.

5b. If there is an existing PC5 link between the target UE and UE-to-UE relay for the required RSC, UE-to-UE relay sends a Link Modification Request to the target UE. The security for this existing PC5 link may have been established, then the step 6 can be skipped.

6. The security establishment for PC5 link between the target UE and UE-to-UE relay is as specified in clause 5.3.3 of TS 33.536 [9].

NOTE a: Which entity (e.g., U2U relay or target UE) initiates the DSMC procedure in step 6 is not addressed in the present document.7a. After step 6, the target UE sends the Direct Communication Accept to the UE-to-UE relay.

7b. After step 5b, the target UE sends the Link Modification Accept to the UE-to-UE relay.

8a. If step 3a is performed, the UE-to-UE relay sends the Direct Communication Accept to the source UE.

8b. If step 3b is performed, the UE-to-UE Relay sends the Link Modification Accept to the source UE.

9. After PC5 link between source UE and UE-to-UE relay, UE-to-UE relay and target UE sets up, the E2E PC5 link establishment performs. The source UE sends a Direct Communication Request message to initiate the E2E PC5 link establishment procedure with the target UE.

To establish the End-to-End security between source UE and target UE, the message includes RSC, source UE's security capability and source UE's security policy. This message may include shared security credential ID between source UE and target UE to generate KD, or if there exists a shared key KD between source UE and target UE, the message may include KD ID, Nonce\_1 (for session key KD-sess generation), and the most significant 8-bits of the KD-sess ID (for uniquely identifying KD-sess at source UE).

Note 1: The provisioning of security credentials and security credential ID in the Source UE and Target UE is out of 3GPP scope.

The privacy information of source UE such as source UE's security capability and security policy, Nonce\_1 can be protected by these security per-hop links between source UE and UE-to-UE relay, UE-to-UE relay and target UE.

10. During the Direct Auth and Key Establishment, several authentication signallings are exchanged between the peer UEs to derive the shared key KD based on the shared credential between source UE and target UE.

Note 2: How the source UE and the target UE generate the shared key KD is not addressed in this solution.

11a. In case the target UE decides to active the End-to-End security protection, based on source UE's security policy, target UE choose Nonce\_2 and generates the session key KD-sess as specified in clause 6.6.2.3.1, selects integrity and encryption algorithms from Source UE's capability, generates integrity and encryption keys as specified in clause 6.6.2.3.2. The target UE may choose LSB of KD-sess ID, forms KD-sess ID, and stores KD-sess ID with KD-sess. The target UE may choose the MSB of KD ID to uniquely identify KD at target UE if a new KD is generated.

11b. The target UE activates the integrity protection before sending the Direct Security Mode message if the U2U relay integrity key KD-int has been derived.

12. The target UE sends the Direct Security Mode message to source UE through UE-to-UE relay, including Source UE's security capabilities, Source UE's security policy to protect from bidding down attack. The message also includes Nonce\_2, LSB of KD-sess ID, chosen\_algs, and MAC for integrity protection, or the message may include MSB of KD ID.

13a. Upon reception of the Direct Security Mode message from the UE-to-UE Relay, the source UE generates the session key KD-sess as specified in clause 6.6.2.3.1. According to the chosen\_algs from target UE, source UE generates integrity and encryption keys as specified in clause 6.6.2.3.2. The source UE forms KD-sess ID from the received LSB of KD-sess ID and chosen MSB of KD-sess ID, and stores KD-sess ID with KD-sess. Or, if a new KD is generated, the source UE forms KD ID from the received MSB of KD ID and chosen LSB of KD ID, and stores the complete KD ID with KD.

13b. The source UE verifies the integrity protection using the indicated integrity algorithm in chosen\_algs and the generated integrity key. After the successful verification, source UE starts integrity and encryption protection before sending the Direct Security Mode Complete message.

14. The source UE sends the Direct Security Mode Complete message to target UE through the UE-to-UE Relay, which may contain the LSB of KD ID if a new KD is generated.

15. Upon reception of the Direct Security Mode Complete message from the UE-to-UE Relay, the target UE deciphers and checks the integrity protection on the Direct Security Mode Complete message. The target UE may form the KD ID and store it with KD.

16. The Target UE sends a Direct Communication Accept message to the Source UE.

Note 3: How the PC5-S messages in steps 4, 5, 7, 9, 11 are forwarded by the UE-to-UE Relay is to be determined by RAN2, such as based on an Adaptation layer.

#### 6.6.2.2 Key Hierarchy for UE-to-UE relay

There are 4 different layers of keying material as shown in figure 6.6.2.2-1.



Figure 6.6.2.2-1: Key Hierarchy for UE-to-UE relay

- Security Credentials: Upon successful configuration procedure, each UE will be configured with the credentials which include a public/private key pair. Authentication signallings are exchanged between source UE and target UE via UE-to-UE relay to derive the KD.

- KD: This is a root key that is shared between source UE and target UE that communicating using UE-to-UE relay link. It may be refreshed by re-running the authentication signallings using the security credentials. Nonces are exchanged between the UEs and used with the KD to generate a KD-sess (the next layer of keys). The KD ID is used to identify KD.

- KD-sess: This key is derived by source UE and target UE from KD and is used derive keys that to protect the transfer of data between the peer UEs. The actual keys (see next bullet) that are used in the confidentiality and integrity algorithms are derived directly from KD-sess. The KD-sess ID identifies the KD-sess ID.

- KD-enc, KD-int: The U2U relay Encryption Key (KD-enc) and Integrity Key (KD-int) are used in the chosen confidentiality and integrity algorithms respectively for protecting control plane data and user plane data between source UE and target UE.

#### 6.6.2.3 Key derivation functions

##### 6.6.2.3.1 KD-sess derivation function

The KD-sess derivation function is specified in clause A.3 of TS 33.536 [9], and the input key is KD.

##### 6.6.2.3.2 Integrity and encryption keys derivation function

The integrity key KD-int and encryption key KD-enc derivation function are specified in clause A.2 of TS 33.536 [9], and the input key is KD-sess.

### 6.6.3 Evaluation

The solution fulfils the security requirement of Key Issue #2: Security of UE-to-UE Relay.

The solution supports security per hop links (i.e. PC5 link between Source UE and UE-to-UE Relay, as well as between UE-to-UE Relay and Target UE) and security E2E PC5 link between source UE and target UE setup.

The solution supports security method (i.e. Out-of-Coverage). With the provisioned/pre-configured security materials, the security keys can be generated without the assistance of the network.

This solution is suitable for the standalone discovery.

This solution proposes that the security credential and security credential ID could be pre-configured in the ProSe enabled UE (i.e. Source UE, Target UE and UE-to-UE Relay), and provisioning of the security credential and the security ID in the ProSe enabled UE is out of the 3GPP scope.

## 6.7 Solution #7: Non-network-assisted Security Establishment Procedure for 5G ProSe Layer-3 UE-to-UE Relay

### 6.7.1 Introduction

The solution addresses Key Issue #2: Security of UE-to-UE Relay. It largely reuses the mechanism of Direct Security Establishment procedure defined in TS 33.503 [6] to ensure the security of UE-to-UE Relay Communication.

For Layer-3 UE-to-UE Relay, the full security of a UE-to-UE PC5 link depends on the security of two separate PC5 links, i.e. the link between the Source UE and UE-to-UE Relay and the link between UE-to-UE Relay and Target UE. The security of these two separate PC5 link relies on the security materials (i.e. the long term credential), which can be pre-configured on the 5G ProSe UE (incl. Source UE, Target UE and UE-to-UE Relay) or provisioned by the network during the service authorization procedure. In other words, all the ProSe UEs can obtain the security materials without the assistance of network. Therefore, the Source UE and the Target UE can establish the UE-to-UE PC5 link via Layer-3 UE-to-UE Relay regardless of whether they are within or out of network coverage.

### 6.7.2 Solution details

 Figure 6.7.2-1: Non-network-assisted PC5 link security establishment procedure for 5G ProSe Layer-3 UE-to-UE Relay

0. The long term credential and long term credential ID are associated with RSC, which could be pre-configured on the 5G ProSe UE (incl. Source UE, Target UE and UE-to-UE Relay) or provisioned by the network e.g. during Service Authorization and Provisioning procedure before the U2U discovery procedure.

Note 1: How to pre-configure the long term credential to UE is out of the 3GPP scope.

1. The Discovery & Relay Selection procedure is performed between the peer UEs and the UE-to-UE Relay.

Note 2: It is assumed that after the Discovery & Relay Selection procedure, the Source UE (UE1) and the Target UE (UE2) can discover each other by selecting the same UE-to-UE Relay.

2. The Source UE sends a Direct Communication Request that contains the long term credential ID, Source UE's security capabilities, RSC and nonce 1 to the UE-to-UE Relay as specified in the TS 33.503 [6]. The message may also include a Knrp ID if the Source UE has an existing Knrp with this UE-to-UE Relay for the same RSC.

3. The UE-to-UE Relay may initiate a Direct Auth and Key Establish procedure with Source UE to generate the Knrp. If the Knrp ID is included in the Direct Communication Request, this step is skipped.

4. The UE-to-UE Relay derives the session key (KNRP-SESS) from KNRP and then derives the confidentiality key (NRPEK) (if applicable) and integrity key (NRPIK) based on the PC5 security policies as specified in TS 33.503 [6]. The UE-to-UE Relay sends a Direct Security Mode Command message to the Source UE. This message also includes the chosen security algorithm and nonce 2.

5. The Source UE responds with a Direct Security Mode Complete message to the UE-to-UE Relay.

6. The UE-to-UE Relay sends a Direct Communication Request that contains the long term credential ID, the chosen security algorithm, RSC and nonce 1' to the Target UE as specified in the TS 33.503 [6]. The message may also include a Knrp ID' if the UE-to-UE Relay has an existing Knrp' with this Target UE under the same RSC.

Note 3: How the U2U relay determines to send DCR to UE2 is determined by SA2.

7. The Target UE may initiate a Direct Auth and Key Establish procedure with UE-to-UE Relay to generate the Knrp'. If the Knrp ID' is included in the Direct Communication Request, this step is skipped.

8. The Target UE derives the session key (KNRP-SESS') from KNRP' and then derives the confidentiality key (NRPEK') (if applicable) and integrity key (NRPIK') based on the PC5 security policies. The Target UE sends a Direct Security Mode Command message to the UE-to-UE Relay. This message also includes the nonce 2'.

9. The UE-to-UE Relay responds with a Direct Security Mode Complete message to the Target UE.

10. The Target UE sends the Direct Communication Accept message to the UE-to-UE Relay.

11. Only receiving the Direct Communication Accept message from the Target UE, the UE-to-UE Relay then responds with the Direct Communication Accept message to the Source UE.

12. The secure Layer-3 PC5 link between the Source UE and the Target UE via the UE-to-UE Relay is established. The UE-to-UE Relay can forward the traffic between the peer Prose UEs.

### 6.7.3 Evaluation

This solution is based on the Direct Security Establishment procedure defined in TS 33.503 [6]. This solution fulfils all the security requirements of KI#2. Once the security has been established, the user-plane/control-plane messages exchanged between the Source End UE and Target End UE via UE-to-UE Relay are integrity protected and confidentiality protected.

This solution is aligned with the SA2's procedure defined in TS 23.304 [8].

This solution can ensure that the Source End UE and the Target End UE can establish the UE-to-UE PC5 link via Layer-3 UE-to-UE Relay regardless of whether they are within or out of network coverage.

In this solution, the long term credential is used as the root key for UE-to-UE Relay link establishment. The long term credential can be pre-configured on the 5G ProSe UE (incl. Source End UE, Target End UE and UE-to-UE Relay).

Using the V2X solution with a long term key between an End UE and UE-to-UE relay, when UE-to-UE relay is in 3GPP coverage and UE-to-UE relay is able to establish a secure PC5 link with network assistant, will provide lower security as V2X solution does not support authorization. UE-to-UE relay in 3GPP coverage should therefore always establish a secure PC5 link with network assistant with End UE.

## 6.8 Solution #8: Restricted 5G ProSe UE-to-UE Relay Discovery Model A

### 6.8.1 Introduction

The solution addresses Key Issue #1: Security for UE-to-UE Relay discovery and Key Issue #3: Authorization in the UE-to-UE Relay Scenario. It largely reuses the mechanism of Prose Discovery defined in TS 33.503 [6] to ensure the security of UE-to-UE Relay Discovery.

If the Source UE cannot reach the Target UE directly, it will try to discover a UE-to-UE Relay, which is responsible for providing relay service in connecting two Remote UEs over PC5. In the Model A method of the ProSe discovery, the UE-to-UE Relay plays the role of the Announcing UE and broadcasts the announcement message to all the UEs in proximity. To protect the announcement message, the UE-to-UE relay needs to request the security parameters from the DDNMF in the control plane or the PKMF in the user plane.

The solution meets all the security requirements in Key issue #1 by achieving privacy protection, protection of messages and security materials provisioning.

### 6.8.2 Solution details

Figure 6.8.2-1: Security procedure for restricted 5G ProSe U2U Discovery Model A

The ProSe Application Server allocates a User Info ID for each ProSe UE and returns the User Info ID to the application client in the UE.

As defined in the TS 23.304 [8], the UE-to-UE Relay can discover other UEs in proximity via the previous U2U discovery or U2U communication procedures, the UE-to-UE Relay may buffer their User Info ID as Discovered UE ID. The Discovered UE ID will be removed by UE-to-UE Relay in case the buffer timer expired.

When the user-plane based security procedure for the UE-to-UE Relay discovery is used, the 5G PKMF takes the role of the 5G DDNMF. Steps 1-3 refer to the Relay Discovery Key Request procedure of UE-to-UE Relay. For the 5G ProSe UE-to-UE Relay Discovery, the UE-to-UE Relay plays the role of the Announcing UE.

1. UE-to-UE Relay sends a Relay Discovery Key Request message containing its User Info ID and Relay Service Code (RSC) to its 5G DDNMF in order to get the associated security material. In addition, the UE-to-UE Relay includes its PC5 UE security capability that contains the list of supported ciphering algorithms by the UE-to-UE Relay in the Relay Discovery Key Request message.

Note 1: The RSC may either be pre-configured on the UE or provisioned by the network during the service authorization and provisioning procedure.

2. The 5G DDNMF of the UE-to-UE Relay may check for the announcement authorization with the PCF/UDM of the UE-to-UE relay or the ProSe App Server.

Note 2: If the UE-to-UE relay is roaming, the 5G DDNMFs in the HPLMN and VPLMN of the UE-to-UE Relay may exchange Announcement Auth, which is omitted in the above figure.

3. The 5G DDNMF of the UE-to-UE Relay returns the corresponding Code-Sending Security Parameters, along with the CURRENT\_TIME and MAX\_OFFSET parameters. The Code-Sending Security Parameters are stored with the RSC, which provide the necessary information for the UE-to-UE Relay. The 5G DDNMF of the UE-to-UE Relay includes the chosen PC5 ciphering algorithm in the Relay Discovery Key Response message, which is determined by the RSC and the received PC5 UE security capability in step 1.

Steps 4-9 refer to the Relay Discovery Key Request procedure of Source UE/Target UE. For the 5G ProSe UE-to-UE Relay Discovery, the Source UE and Target UE play the role of the Monitoring UE.

4. The Source UE/Target UE sends a Relay Discovery Key Request message containing its User Info ID, RSC and its PC5 UE security capability and optionally the Relay User Info ID(s) to its 5G DDNMF in order to be allowed to monitor for one or more UE-to-UE Relay.

Note 3: The application client provides the Source UE/Target UE with the list of potential UE-to-UE Relay containing the Relay User Info ID(s). The Relay User Info ID(s) of Source UE/Target UE to be monitored are passed in an Application Lever Container.

5. The 5G DDNMF of the Source UE/Target UE sends an authorization request to the PCF/UDM of the Source UE/Target UE or the ProSe App Server. If, based on the permission settings, the Source UE/Target UE is allowed to monitor the announcement message under this specific U2U relay service and allowed to discover at least one of the Relay User Info(s) contained in the Application Level Container, the PCF/UDM of the Source UE/Target UE or the ProSe App Server returns an authorization response.

6. If the Relay Discovery Key Request is authorized, and the PLMN ID in the Relay User Info ID(s) indicates a different PLMN, the 5G DDNMF of the Source UE/Target UE contacts the indicated PLMN's 5G DDNMF (i.e. the 5G DDNMF of the UE-to-UE Relay) by sending a Monitor Request message including the PC5 UE security capability received in step 4.

7. The 5G DDNMF of the UE-to-UE Relay may exchange authorization messages with the ProSe App Server. The ProSe Application Server may check whether the Source UE/Target UE and the UE-to-UE Relay are authorized to perform the U2U discovery under the specific U2U relay service.

8. If the Monitor Request is authorized and the PC5 UE security capability in step 4 includes the chosen PC5 ciphering algorithm, the 5G DDNMF of the UE-to-UE Relay responds to the 5G DDNMF of the Source UE/Target UE with a Monitor Response message including the corresponding Code-Receiving Security Parameters and the chosen PC5 ciphering algorithm. The Code-Receiving Security Parameters provide the information needed by the Source UE/Target UE to undo the protection applied by the UE-to-UE relay. The 5G DDNMF of the Source UE/Target UE stores the RSC and the Code-Receiving Security Parameters.

9. The 5G DDNMF of the Source UE/Target UE returns the Code-Receiving Security Parameters, along with the CURRENT\_TIME and MAX\_OFFSET parameters and the chosen PC5 ciphering algorithm. The Source UE/Target UE stores Code-Receiving Security Parameters, and the chosen PC5 ciphering algorithm together with the RSC.

Steps 10 and 11 occur over PC5:

10. The UE-to-UE relay broadcasts the U2U Relay announcement message and protects it by using the corresponding Code-sending security parameters. The U2U announcement message may contain the Type of Discovery (i.e. U2U relay), RSC, User Info ID of U2U Relay and Discovered UE ID (i.e. User Info ID of discovered UEs in proximity via the previous U2U Discovery or U2U Communication), etc..

11. The Source UE/Target UE listens to the announcement message that satisfies its RSC if the UTC-based counter associated with that discovery slot is within the MAX\_OFFSET of the Source UE/Target UE's ProSe clock. In order to find such a matching message, it processes the message. Only if the integrity check is passed, the UE can decide if it can use this UE-to-UE relay according to RSC and Discovered UE ID(s). If the UE wants to communicate with other UEs via this relay, the UE may initiate the U2U relay link establishment procedure.

Note 4: The Source UE/Target UE may check the integrity of the announcement message on its own or check the integrity by sending a Match Report as defined in TS 33.503 [6].

### NOTE 5: Solution details are not addressed in the present document.NOTE 6: It is not addressed in the present document about whether both CP and UP based procedures are needed for security materials provisioning.6.8.3 Evaluation

This solution is aligned with the procedure defined in TS 23.304 [8].

By using the security materials, the 5G Prose End UEs can securely discover each other via UE-to-UE Relay and the Announcement message can be protected.

This solution fulfils the security requirements of KI#3 based on the DDNMF/PKMF's authorization by reusing the Discovery procedure defined in clause 6.1.3.2 of TS 33.503 [6]. Once the authorization is passed, the 5G Prose End UEs and UE-to-UE Relay can perform UE-to-UE relay discovery.

This solution uses one set of discovery security material to protect the Announcement message by reusing the Discovery procedure defined in clause 6.1.3.2 of TS 33.503 [6].

## 6.9 Solution #9: Restricted 5G ProSe UE-to-UE Relay Discovery Model B

### 6.9.1 Introduction

The solution addresses Key Issue #1: Security for UE-to-UE Relay discovery and Key Issue #3: Authorization in the UE-to-UE Relay Scenario. It largely reuses the mechanism of Prose Discovery defined in TS 33.503 [6] to ensure the security of UE-to-UE Relay Discovery.

If the Source UE cannot reach the Target UE directly, it will try to discover a UE-to-UE Relay, which is responsible for providing relay service in connecting two Remote UEs over PC5. In the Model B method of the ProSe discovery, the Source UE plays the role of the Discoverer UE, the Target UE plays the role of the Discoveree UE and the UE-to-UE Relay forwards all the messages between the Source UE and the Target UE. To achieve the security of UE-to-UE Relay Discovery, the UEs need to request the security parameters from the DDNMF in the control plane or the PKMF in the user plane.

The solution meets all the security requirements in Key issue #1 by achieving privacy protection, protection of messages and security materials provisioning.

### 6.9.2 Solution details

Figure 6.9.2-1: Security procedure for restricted 5G ProSe U2U Discovery Model B

The ProSe Application Server allocates a User Info ID for each Prose UE and returns the User Info ID to the application client in the UE.

When the user-plane based security procedure for the UE-to-UE Relay discovery is used, the 5G PKMF takes the role of the 5G DDNMF. Steps 1-3 refer to the Discovery Key Request procedure of UE-to-UE Relay.

1. UE-to-UE Relay sends a Relay Discovery Key Request message containing its User Info ID and Relay Service Code (RSC) to its 5G DDNMF in order to get associated security materials. In addition, the UE-to-UE Relay includes its PC5 UE security capability that contains the list of supported ciphering algorithms by the UE in the Relay Discovery Key Request message.

Note 1: The RSC may either be pre-configured on the UE or provisioned by the network during the service authorization and provisioning procedure.

2. The 5G DDNMF of the UE-to-UE Relay may check for the announcement authorization with the PCF/UDM of the UE-to-UE Relay or the ProSe App Server depending on the local configuration.

Note 2: If the UE-to-UE relay is roaming, the 5G DDNMFs in the HPLMN and VPLMN of the UE-to-UE Relay may exchange Announcement Auth message, which is omitted in the above figure.

3. The 5G DDNMF of the UE-to-UE Relay returns the Code Security Parameters along with the CURRENT\_TIME and MAX\_OFFSET parameters and the chosen PC5 ciphering algorithm. The Code Security Parameters are stored with the RSC, which provides the necessary information for the UE-to-UE relay. The 5G DDNMF of the UE-to-UE Relay includes the chosen PC5 ciphering algorithm in the Relay Discovery Key Response message, which is determined by the RSC and the received PC5 UE security capability in step 1.

Steps 4-9 refer to the Relay Discovery Key Request procedure of Discoveree UE/Discoverer UE. For the 5G ProSe UE-to-UE Relay Discovery, the Source UE plays the role of the Discoverer UE and the Target UE plays the role of the Discoveree UE.

4. The Source UE/Target UE sends a Relay Discovery Key Request message containing the User Info ID, RSC, its PC5 UE security capability and optionally the Relay User Info ID(s) to its 5G DDNMF in order to be allowed to discover one or more UE-to-UE Relay.

Note 3: The application client provides the Source UE/Target UE with the list of potential UE-to-UE Relay containing the Relay User Info ID(s). The Relay User Info ID(s) of Source UE/Target UE to be monitored are passed in an Application Lever Container.

5. The 5G DDNMF of the Source UE/Target UE sends an authorization request to the PCF/UDM of the Source UE/Target UE or the ProSe App Server. If, based on the permission setting, the Source UE/Target UE is allowed to perform UE-to-UE Relay Discovery procedure under this specific U2U relay service and allowed to discover at least one of the Relay User Info(s) contained in the Application Level Container,, the PCF/UDM of the Source UE/Target UE or the Prose App Server returns an authorization response.

6. If the Relay Discovery Key Request is authorized, and the PLMN ID in the Relay User Info ID indicates a different PLMN, the 5G DDNMF of the Source UE/Target UE contacts the indicated PLMN's 5G DDNMF (i.e. the 5G DDNMF of the UE-to-UE Relay) by sending a Discovery Request message including the PC5 UE security capability in step 4.

7. The 5G DDNMF of the UE-to-UE Relay may exchange authorization messages with the ProSe Application Server. The ProSe Application Server may check whether the Source UE/Target UE and the UE-to-UE relay are authorized to perform the UE-to-UE Relay Discovery under the specific U2U relay service.

8. If the Discovery Request is authorized and the PC5 UE security capability in step 4 includes the chosen PC5 ciphering algorithm, the 5G DDNMF of the UE-to-UE Relay responds to the 5G DDNMF of the Source UE/Target UE with a Discovery Response message including the Code Security Parameters and a chosen PC5 ciphering algorithm. The Code Security Parameters provide the information needed by the Source UE/Target UE to protect/unprotect all discovery messages under the specific U2U relay service. The 5G DDNMF of the Source UE/Target UE stores the RSC and Code Security Parameters.

9. The 5G DDNMF of the Source UE/Target UE returns the Code Security Parameters along with the CURRENT\_TIME, MAX\_OFFSET parameters and the chosen PC5 ciphering algorithm. The Source UE/Target UE stores the Code Security Parameters together with the RSC.

Steps 10 and 13 occur over PC5:

10. The Source UE broadcasts the Solicitation Message and protects it by using the corresponding code security parameters. The Solicitation Message may contain the Type of Discovery (i.e. U2U relay), RSC, source UE info (i.e. User Info ID of the Source UE) and target UE info (i.e. User Info ID of Target UE), etc..

11. The UE-to-UE Relay listens to a solicitation Message that satisfies the RSC if the UTC-based counter associated with that discovery slot is within the MAX\_OFFSET of the UE-to-UE Relay's ProSe clock. On receiving the solicitation message including the supported RSC, UE-to-UE Relay(s) process it by using the corresponding code security parameters. If the integrity check/confidentiality check is passed, the UE-to-UE Relay adds the relay information in the solicitation message and broadcasts the new solicitation message, which is protected by the corresponding code security parameters. The new solicitation message may contain the Type of Discovery, Relay Info (i.e. User Info ID of UE-to-UE Relay), RSC, Relay indication (to indicate ProSe direct discovery forwarding), original Discoverer Info (i.e. User Info ID of Source UE) and target discoveree info (i.e. User Info ID of Target UE).

12. The Target UE listens to the solicitation Message that satisfies its RSC if the UTC-based counter associated with that discovery slot is within the MAX\_OFFSET of the Target UE's ProSe clock. If the integrity check/ confidentiality check is passed, the Target UE responds to the solicitation message via a response message.

Note 4: The Source UE/Target UE may check the integrity of the discovery message on its own or check the integrity by sending a Match Report as defined in TS 33.503 [6].

13. On receiving the response message, UE-to-UE Relay(s) checks its integrity and confidentiality based on the security policies. If the check is passed, UE-to-UE relay forwards response message containing the Type of Discovery, Relay Info (i.e. User Info ID of Relay), RSC, Relay indication (to indicate ProSe direct discovery forwarding), original Discoveree Info (i.e. User Info ID of Target UE) and Discoverer Info (i.e. User Info ID of Source UE).

On receiving the response message from UE-to-UE relay, Source UE checks its integrity and confidentiality based on the security policies and determines if it can use this relay. If the Source UE wants to communicate with the Target UE via this Relay, the Source UE may initiate the U2U relay link establishment procedure.

Note 5: The UE-to-UE relay selection may be performed on the Target UE or Source UE.

### NOTE 6: Solution details based on the conclusion of TR 23.700-33 [2] are not addressed in the present document.NOTE 7: It is not addressed in the present document about whether both CP and UP based procedures are needed for security materials provisioning.6.9.3 Evaluation

This solution is aligned with the procedure defined in TS 23.304 [8].

By using the security materials, the 5G Prose End UEs can securely discover each other via UE-to-UE Relay and the Solicitation/Response messages can be protected.

This solution fulfils the security requirements of KI#3 based on the DDNMF/PKMF's authorization by reusing the Discovery procedure defined in clause 6.1.3.2 of TS 33.503 [6]. Once the authorization is passed, the 5G Prose End UEs and UE-to-UE Relay can perform UE-to-UE relay discovery.

This solution uses one set of discovery security material to protect the Solicitation/Response message by reusing the Discovery procedure defined in clause 6.1.3.2 of TS 33.503 [6].

## 6.10 Solution #10: PAKE-based security for UE-to-UE relay

### 6.10.1 Introduction

This solution addresses Key Issue #2 and Key Issue #3.

This solution proposes the usage of a password-based key establishment (PAKE) for UE-to-UE relay security and authorization. A PAKE allows establishing a secure channel while authenticating the peers based on a password. The PAKE is used to setup the security between:

- the source UE (S-UE) and the UE-to-UE Relay (UE2UE),

- the target UE (T-UE) and the UE2UE and

- the S-UE and the T-UE.

The password(s) may be configured in an initial authorisation and parameter provisioning phase when the UEs are in coverage. When this is done, it is ensured that the network remains in control of the UE-to-UE relay secure communication. However, the password(s) may also be entered by a user or generated by the involved devices, e.g. when one or more of the devices are out-of-coverage. This option ensures that the security requirements can be fulfilled even in challenging operational cases.

Furthermore, the usage of a PAKE provides a reasonable approach for the authentication/authorization of the communicating parties:

- using a balanced PAKE authenticates two peers in a similar role, e.g. source and target UE;

- using an augmented PAKE can be used to differentiate roles, e.g. the role of a UE-to-UE relay and the role of a source/target UE preventing impersonation.

For cases in which these authorisation capabilities are not enough, this solution proposes the optional use of authorization tokens and policies -- deployed in the initial authorisation and parameter provisioning phase – for enhanced authorization capabilities.

### 6.10.2 Solution details

#### 6.10.2.0 General

Figure 6.10.2-1 depicts the steps of this solution.

Text

Description automatically generated

Figure 6.10.2-1

The required steps are as follows:

- Step 0 is the initial authorization and parameter provisioning of S-UE, UE2UE and T-UE.

- Steps 1 and 2 involve the exchange of an initial Direct Communication Request (DCR) message.

- Step 3 involves the setup of a secure authenticated channel between UE2UE and T-UE based on a PAKE.

- Step 4 involves an optional authorization phase.

- Step 5 involves the exchange of Direct Communication Accept (DCA) from T-UE to UE2UE.

- Step 6 involves the setup of a secure authenticated channel between S-UE and UE2UE based on a PAKE.

- Step 7 involves an optional authorization phase.

- Step 8 involves the exchange of DCA from UE2UE to S-UE.

- Step 9 involves the setup of a secure authenticated channel between S-UE and T-UE based on a PAKE.

- Step 10 involves an optional authorization phase.

- Step 11 involves the exchange of DCA from T-UE to S-UE.

The PAKE in Steps 3, 6, and 9 may rely on a password shared amongst both UEs (in case of balanced PAKE), or a password and a password derived value (in case of augmented PAKE) that might be, e.g. pre-configured in Step 0. This password may also be entered in the involved devices by the users or generated by the devices and exchanged out-of-band.

The PAKE in Steps 3 and 6 may be an augmented PAKE in which, e.g. the Target UE (or Source UE) does not have access to the password itself, but a password-derived value used in the augmented PAKE and from which the actual password can only be retrieved by means of an offline dictionary attack. This prevents the target UE (or Source UE) from impersonating the UE2UE.

The PAKE in Steps 3, 6, and 9 allow the communicating parties to authenticate to each other and establishing symmetric-cryptographic keys used to protect the communication link. This process provides a certain level of authorization, e.g. if two UEs share a same password (-derived) value, the authentication will be successful fulfilling authorization requirements in many scenarios.

Note 1: The PAKE choice is left to application layer. This solution only provides the means to support an application layer defined PAKE in ProSe.

The message flow in Figure 6.10.2-1 can be adapted to other message flows, e.g. relying on discovery messages. For instance, the S-UE can send a Discovery Solicitation message towards the T-UE through the UE2UE. The T-UE replies with a Discovery Response message towards the S-UE through the UE2UE. Next, S-UE and UE2UE can establish a secure PC5 interface relying on a PAKE. Next, UE2UE and T-UE can establish a secure PC5 interface relying on a PAKE. And finally, S-UE and T-UE can establish a secure PC5 interface (assuming an L2 UE2UE) based on a PAKE.

This PAKE based solution can be either fully in ProSe scope or partial ProSe scope.

- In partial ProSe scope, it is required the ProSe definition of at least (1) parameters to be provisioned, (2) parameters exchanged prior to the PAKE itself, and (3) method to provision a password in out-of-coverage situations.

- In full ProSe scope, it is required the choice of at least a PAKE protocol. Full ProSe scope provides increased interoperability.

#### 6.10.2.1 Parameter provisioning in-coverage and out-of coverage

The provisioning of passwords can be done either in coverage or out-of-coverage in Step 0.

When the provisioning is done when a UE is in coverage, the UE is configured with one or multiple passwords "raw-passwords" or "password-derived tokens".

Each "raw-password" or "password-derived token" is associated to "metadata". The "metadata" includes "password hint", "expiration date", and "access rights". The field "password hint" indicates which password to use; the field "expiration date" indicates how long a password is valid; the field "access rights" indicates which authorization provides a password. The bitstring used as "password" in a PAKE is computed as the KDF of the "raw-password" and the associated metadata fields. In the case of an augmented PAKE, the "password-derived token" is derived from the "password" itself.

As in other solutions, the parameters can be received from the 5G PKMF and 5G DDNMF when the UE is in coverage.

During provisioning in-coverage, a UE is also provisioned with an "out-of-coverage policy" determining whether a UE may use a temporary password entered or provisioned by the user when the UE is out-of-coverage. When the UE is then out-of-coverage, a UE can be provisioned with a temporary password entered by the user if "out-of-coverage policy" allows for it.

Note: Details on how a UE can be provisioned with a temporary password in an out-of-coverage situation (out of band, keyboard, QR code,…) are left to normative phase.

#### 6.10.2.2 PAKE protocols

There are many PAKE protocols in the literature. Specific PAKE protocols that are of special interest are IETF PAKE protocols in discussion and/or standardization at IRTF CFRG, e.g. CPAKE[10], OPAQUE[11], SPAKE2[12] or SPAKE2+[13]. CPAKE and SPAKE2 are balanced PAKE protocols. OPAQUE and SPAKE2+ are augmented PAKE protocols. While CPAKE and OPAQUE have been formally endorsed in the PAKE selection process by IRTF CFRG as balanced and augmented options, the choice of SPAKE2 and SPAKE2+ as balanced and augmented PAKE protocols, respectively, is also meaningful due to the similarity between them.

#### 6.10.2.3 Parameters exchanged prior to the PAKE execution

Several parameters need to be exchanged prior to the PAKE execution in Steps 3, 6, and 9. These parameters include:

- The Relay Service Code,

- A "password hint" used to identify the "raw password". In the absence of an explicit password hint, then it is the RSC that serves as a password hint, i.e. the password is linked to the RSC.

In particular,

- The DCR message in Step 1 includes the RSC and password-hints for the PAKEs in Steps 6 and 9.

- The DCR message in Step 2 includes the RSC and password-hints for the PAKEs in Steps 3 and 9.

When the UE2UE relay receives message of Step 1, the UE2UE relay may remove the password hint for the PAKE in Step 6. Furthermore, the UE2UE relay adds its password hint for the PAKE to the DCR message in Step 2.

When the target UE receives message in Step 2, the target UE starts the PAKE in Step 3 based on the received password hint.

#### 6.10.2.4 PAKE execution

This subclause explains how a PAKE can be executed in the context of SPAKE2 and SPAKE2+ that involve the exchange of four messages as explained in Clause 3.1 in [12] and [13].

The first and second PAKE messages are exchanged in a *Direct Auth and Key Establish Request* and a *Direct Auth and Key Establish Response* messages, respectively.

The third and fourth messages are exchanged in the *Direct Security Mode Command* and the *Direct Security Mode Complete*, respectively.

#### 6.10.2.5 Secure exchange of data

The secure exchange of data relies on a shared key Ks between two UEs result of the PAKE. This key Ks is K\_shared as defined in Clause 3.4 in [13] or TT as defined in Clause 4 in [12].

For a L2 UE2UE relay, Ks is used as shared secret to derive PC5 keys for user/control planes and encryption/integrity by means of a key derivation function according to TS 33.220.

For a L3 UE2UE relay, Ks is used to derive a PSK hint and a PSK. PSK and PSK hint are used in IKE-PSK to secure the L3 communication by means of a key derivation function according to TS 33.220.

Note: Details related to the inputs to the KDF such FC value or other identifiers are left to normative phase.

#### 6.10.2.6 PAKE-based authorization

As described in Clause 6.10.2.1, the bitstring used as "password" in a PAKE is computed as the KDF of the "raw-password" and the associated metadata fields. Thus, a successful PAKE authentication procedure allows verifying the associated metadata fields, including, access rights. This allows the peers of the PAKE to perform PAKE-based authorization.

The optional authorization phase in Steps 4, 7, and 9 might be required when one of the devices requires further authorisation assurances. This phase relies on the exchange of authorization tokens and policies configured in Step 0. For instance, in Step 4, the target UE can send an authorization token so that the UE2UE can verify that the target UE is indeed entitled to use the UE2UE relay.

Note: Details on the optional authorization phase in Steps 4, 7, and 9 are left to normative phase.

### 6.10.3 Evaluation

This solution addresses Key Issue #2 and Key Issue #3 by describing how ProSe can support the usage of PAKEs. This allows setting up a secure/authenticated link and authorizing it based on the usage of passwords.

Impact on ProSe is limited to the exchange of information/messages required to support a PAKE:

- The configuration of Source-UE, Target-UE, UE-to-UE relay with PAKE parameters as in Clause 6.10.2.1.

- The derivation of the PAKE parameters and password from the "raw-password" and the associated metadata fields as in Clause 6.10.2.1.

- The exchange of PAKE related parameters required for the PAKE execution as in Clause 6.10.2.3.

- The usage of PAKE derived keys as in Clause 6.10.2.5.

- The configuration of a policy determining whether a user is allowed to enter a password when Source-UE/Target-UE/UE-to-UE relay is/are out-of-coverage.

This solution allows authorizing the Source-UE, Target-UE, UE-to-UE relay based on the configured password information. This provides a simple approach to ensure that the involved UEs are authenticated and authorized to communicate with each other regardless of their coverage situation.

TS 33.536 [9] defines long-term credentials as "the credentials that are provisioned into the UE(s) and form the root of the security of the PC5 unicast link. The credentials may include symmetric key(s) or public/private key pair depending on the particular use case". This definition in TS 33.536 [9] enables multiple protocols for key establishment and authentication based on symmetric keys or public key cryptography; but it leaves out PAKEs. However, PAKE-based schemes are very useful and have been adopted in real-world commercial systems for various use cases such as credential recovery (e.g. SRP-6a in iCloud), device pairing (e.g. third-generation e-passports and readers' mutual authentication with Machine Readable Zone (MRZ) data used as a shared secret), or end-to-end security (e.g. J-PAKE in Thread) [17]. IRTF has also performed extensive research and standardisation in this area [18]. PAKEs are a type of protocol for authentication and key establishment that are based on passwords. Passwords as such are a type of credentials that may be valid for a variable (e.g. short or long) time period.

There are multiple features that make PAKEs interesting:

- passwords may be short, and still, PAKEs allow for secure communication links;

- authentication is based on passwords hence allowing for authentication/authorization without the need for a public key infrastructure;

- passwords may be short, thus, passwords may be entered in a device by a user, e.g. to provide authentication in out-of-coverage scenarios or in emergency situations when no other credentials are available;

- in augmented PAKEs, the password is not stored in the clear, thus providing protection against impersonation.

## 6.11 Solution #11: Security for UE-to-UE Relay (Model A) discovery

### 6.11.1 Introduction

This solution addresses Key Issue #1 (as defined in clause 5.1). This solution is based on the solutions in TR23.700-33[2], the UE-to-UE Relay may perform Direct Discovery Model A or Model B to discover Target UE in advance.

In this solution, during UE-to-UE Relay model A discovery, the announcement discovery message sent and received between the source/target UE and the UE-to-UE Relay can be protected by using the discovery key associated with the RSC, which is obtained from the DDNMF of the HPLMN of the UE-to-UE Relay pointed by Relay's RPAUID, and the RSC can carry one or more the ProSe Application information or associate with the ProSe Application information.

### 6.11.2 Solution details

#### 6.11.2.1 Restricted 5G ProSe UE-to-UE Relay discovery Model A



Figure 6.11.1: Security procedure for UE-to-UE Relay discovery with Model A

NOTE 1: Figure shows the security procedure of the non-roaming for 5G ProSe UE-to-UE Relay discovery. In this figure, the source UE and the target UE and UE-to-UE Relay are in HPLMN.

NOTE 1a: Details parameters for relay discovery are not addressed in the present document.NOTE 1b: Details network function involved in relay discovery are not addressed in the present document.Steps 1-4 refer to the Security procedure of UE-to-UE Relay

1. UE-to-UE Relay sends Relay Discovery Key Request message containing the Restricted ProSe Application User ID(RPAUID) and RSC to the 5G DDNMF in order to get the associated security material. In addition, the UE-to-UE Relay includes its PC5 UE security capability that contains the list of supported ciphering algorithms by the UE-to-UE Relay in the Relay Discovery Key Request message.

2. The 5G DDNMF may check for the UE-to-UE Relay authorization with the ProSe Application Server.

3. The 5G DDNMF of the UE-to-UE Relay returns the corresponding Code-Sending Security Parameter and Code-Receiving Security Parameter, along with the CURRENT\_TIME and MAX\_OFFSET parameters. The UE-to-UE Relay takes the same actions with CURRENT\_TIME and MAX\_OFFSET as described for the Announcing UE in step 4 of clause 6.1.3.1 of the TS 33.503 specification. The 5G DDNMF of the UE-to-UE Relay includes the chosen PC5 ciphering algorithm in the Relay Discovery Key Response message. The 5G DDNMF determines the chosen PC5 ciphering algorithm based on the received PC5 UE security capability in step 1. The UE stores the chosen PC5 ciphering algorithm, Code-Sending Security Parameter and Code-Receiving Security Parameter together with the RSC.

Steps 4a-9a refer to Security procedure for Source UE

4a. The Source UE sends a Relay Discovery Key Request message containing the RPAUID, RSC and its PC5 UE security capability to the 5G DDNMF in order to be allowed to monitor for one or more RPAUIDs of UE-to-UE Relay UEs.

5a. The 5G DDNMF of the Source UE sends an authorization request to the ProSe Application Server. If, based on the RPAUID and RSC of Source UE, the RPAUID is allowed to discover at least one of the UE-to-UE Relay RPAUIDs contained in the Application Level Container, the ProSe Application Server returns an authorization response.

6a. If the Authorization Request is authorized in Step5a, and the PLMN ID in the UE-to-UE Relay RPAUID indicates a different PLMN, the 5G DDNMF of the Source UE contacts the indicated PLMN's 5G DDNMF of UE-to-UE Relay by sending a Discovery Request message including the PC5 UE security capability and RSC received in step 4a.

7a. The 5G DDNMF of the UE-to-UE Relay may exchange authorization messages with the ProSe Application Server. ProSe Application Server may check whether the Source UE is authorised to implement UE-to-UE Relay Discovery under specific UE-to-UE Relay Service.

8a. If the PC5 UE security capability in step 4a includes the chosen PC5 ciphering algorithm, the 5G DDNMF of the UE-to-UE Relay responds to the 5G DDNMF of the Source UE with a Discovery Response message including the corresponding Code-Receiving Security Parameters, an optional Discovery User Integrity Key (DUIK), and the chosen PC5 ciphering algorithm. The Code-Receiving Security Parameters provide the information needed by the Source UE to undo the protection applied by the UE-to-UE Relay. The 5G DDNMF of the Source UE stores the RSC and the Code-Receiving Security Parameters.

9a. The 5G DDNMF of the Source UE returns the Code-Receiving Security Parameters, along with the CURRENT\_TIME and MAX\_OFFSET parameters and the chosen PC5 ciphering algorithm. The Source UE takes the same actions with CURRENT\_TIME and MAX\_OFFSET as described for the Monitoring UE in step 9 of clause 6.1.3.1 of the TS 33.503 specification. The Source UE stores Code-Receiving Security Parameters and the chosen PC5 ciphering algorithm together with the RSC.

Steps 4b-9b refer to Security procedure for Target UE

NOTE 2: UE-to-UE Relay may perform Direct Discovery Model A or Model B to add UEs in Target UE list based on previous discovery.

4b. The Target UE sends a Relay Discovery Key Request message containing the RPAUID, RSC and its PC5 UE security capability to the 5G DDNMF in order to be allowed to monitor/discover for one or more RPAUIDs of UE-to-UE Relay UEs.

5b. The 5G DDNMF of the Target UE sends an authorization request to the ProSe Application Server. If, based on the RPAUID and RSC of Target UE, the RPAUID is allowed to monitor/discover at least one of the UE-to-UE Relay RPAUIDs contained in the Application Level Container, the ProSe Application Server returns an authorization response.

6b. If the Authorization Request is authorized in Step5b, and the PLMN ID in the UE-to-UE Relay RPAUID indicates a different PLMN, the 5G DDNMF of the Target UE contacts the indicated PLMN's 5G DDNMF of UE-to-UE Relay by sending a Discovery Request message including the PC5 UE security capability and RSC received in step 4b.

7b. The 5G DDNMF of the UE-to-UE Relay may exchange authorization messages with the ProSe Application Server. ProSe Application Server may check whether the Target UE is authorised to implement UE-to-UE Relay Discovery under specific UE-to-UE Relay Service.

8b. If the PC5 UE security capability in step 4b includes the chosen PC5 ciphering algorithm, the 5G DDNMF of the UE-to-UE Relay responds to the 5G DDNMF of the Target UE with a Discovery Response message including the corresponding Code-Sending Security Parameters, Code-Receiving Security Parameters, an optional Discovery User Integrity Key (DUIK), and the chosen PC5 ciphering algorithm. The Code-Receiving Security Parameters provide the information needed by the Target UE to undo the protection applied by the UE-to-UE Relay. The 5G DDNMF of the Target UE stores the RSC, Code-Sending Security Parameters and the Code-Receiving Security Parameters.

9b. The 5G DDNMF of the Target UE returns Code-Sending Security Parameters, the Code-Receiving Security Parameters, along with the CURRENT\_TIME and MAX\_OFFSET parameters and the chosen PC5 ciphering algorithm. The Target UE takes the same actions with CURRENT\_TIME and MAX\_OFFSET as described for the Monitoring UE in step 9 of clause 6.1.3.1 of the TS 33.503 specification. The Target UE stores Code-Sending Security Parameters, Code-Receiving Security Parameters, and the chosen PC5 ciphering algorithm together with the RSC.

10. UE-to-UE Relay broadcasts Relay Announcement message with a Target UE list and protect it.

11a. The UE-to-UE Relay may perform Discovery procedure with the RSC it supports to discover target UEs it can announce.

In this procedure, Target UE monitors Relay Announcement message, after receiving Relay Announcement message, if Target UE wants to use the relay to be discovered by other UEs, the Target UE will send a Response message and use Code-Sending Security Parameters to protect it.

NOTE 3: There are two methods for Target UE adding into UE lists. 1. When Target UE adds into UE list by previous discovery. The UE-to-UE Relay may perform Direct Discovery procedure (either Model A or Model B) with the RSC it supports to discover target UEs it can announce. Previous discovery is not shown in this solution. 2. When Target UE adds into UE list after receiving Relay announcement message, the step 11a will be implemented

11b. Source UE receives Announcement message, if the Source UE wants to communicate with the UEs in Target UE list, the UE will implement UE-to-UE relay link establishment procedure.

### 6.11.3 Evaluation

None.

## 6.12 Solution #12: Security of Layer-2 UE-to-UE Relay and Adaptation Layer

### 6.12.1 Introduction

This contribution proposes a solution to address KI #2: Security of UE-to-UE Relay and Key Issue #4: Privacy of information over the UE-to-UE Relay. Most specifically, this contribution provides a solution for E2E security establishment during E2E PC5 unicast link establishment via a Layer-2 UE-to-UE Relay and privacy when using such E2E PC5 unicast link. The solution uses the new Adaptation Layer on the Control Plane and User Plane protocol stacks as specified in TR 23.700-33 [2], Annex A2 as a baseline.

A PC5 unicast link (also called per-hop link or management link), is established with the UE-to-UE Relay by source/target UEs to send E2E messages such as DSMC messages via the Relay. The management link is secured between the source/target UEs and the UE-to-UE Relay using existing procedures and does not use an adaptation layer.

### 6.12.2 Solution details

#### 6.12.2.1 End-to-End PC5 unicast link establishment and data forwarding



Figure 6.12.1.1-1: End-to-End PC5 unicast link establishment and data forwarding using Relay-specific identifiers.

0. UE-to-UE Relay registers with the network and specifies its relay capabilities. UE-to-UE Relay is provisioned with relay security policy parameters from the network based on existing procedures as described in TS 23.304 [8], TS 33.503 [6].

1. UE1 establishes a secure per-hop PC5 unicast link with the UE-to-UE Relay using existing procedures.

2. UE1 sends a DCR message which includes security parameters (i.e. UE1 MSB of KNRP-sess ID, KNRP ID, nonce1, etc.) as specified in TS 33.536 [9], clause 5.3.3.1.4 to establish an E2E PC5 unicast link via the UE-to-UE Relay.

3. The UE-to-UE Relay retransmits the DCR message if it is authorized to relay for this application based on provisioned relay policy/parameters. The UE-to-UE Relay adds an adaptation header containing info identifying UE1 and includes its unique Relay ID and relay-specific MSB of KNRP-sess ID in the DCR. The UE-to-UE Relay keeps the association of its relay-specific MSB of KNRP-sess ID and MSB of KNRP-sess ID received from UE1. Any subsequent E2E messages (i.e. PC5-S and data) are forwarded based on UE identifier info specified in the adaptation header.

NOTE: The details of handling of messaging via L2 UE-to-UE Relay (i.e., with adaptation layer) are not addressed in the present document.4. Interested Target UE (i.e. UE3) receives the DCR message via the UE-to-UE Relay, establishes a PC5 unicast link establishment with the UE-to-UE Relay, if such link does not already exist.

5. Authentication between UE1 and UE3 via the Relay is performed to establish KNRP/KNRP ID pair if UE3 does not have a KNRP and KNRP ID pair as indicated in DCR from UE1. Authentication and KNRP/KNRP ID establishment via the relay is done according to the same principles as described in TS 33.536 [9], clause 5.3.3.1.3 (i.e. using E2E exchange of Key\_Est\_Info).

6. UE3 sends a Direct Security Mode Command message to UE1 via the Relay (i.e. over the direct PC5 unicast link to the UE-to-UE Relay). UE3 generates and includes its LSB of KNRP-sess ID. UE3 forms the KNRP-sess ID from the MSB of KNRP-sess ID received from the Relay in step 4, and its LSB of KNRP-sess ID. UE3 derives KNRP-sess fromKNRP to create the e2e security context used with UE1 and NRPEK/ NRPIK as described in TS 33.536 [9]. UE3 adds an adaptation header including its LSB of KNRP-sess ID, and the info identifying UE1 as received with the DCR message. UE3 includes the Relay ID in the adaptation header when sending the first message to UE1 (i.e. Direct Link Authentication Request or Direct Security Mode Command).

The UE-to-UE Relay retransmits the DSMC message to UE1 (over PC5 unicast link with UE1) including info identifying UE3 in the adaptation header. The UE-to-UE Relay also includes in the adaptation header a relay-specific LSB of KNRP-sess ID associated with the E2E link between UE3 and UE1 (i.e. associated to MSB of KNRP-sess ID as received in step 3). UE-to-UE Relay puts its Layer-2 ID as the source and UE1 Layer-2 ID as the destination. The UE-to-UE Relay keeps the association of UE3 LSB of KNRP-sess ID and its relay-specific LSB of KNRP-sess ID associated with UE3. When receiving a DSMC message from the Relay, UE1 extracts the Relay ID. UE1 forms KNRP-sess ID using LSB of KNRP-sess ID specified in the adaptation header and its MSB of KNRP-sess ID sent in step 2. UE1 derives KNRP-sess fromKNRP to create the e2e security context used with UE3 and NRPEK/ NRPIK as described in TS 33.536 [9].

7. UE1 sends a Direct Security Mode Complete message to UE3 via the Relay (i.e. over the direct PC5 unicast link to the UE-to-UE Relay) protected using the established e2e security context. UE3 processes the security of the DSM Complete message which completes the E2E link security establishment procedure between UE1 and UE3.

8. UE3 sends a DCA message to UE1 via the Relay to complete the secure e2e link establishment between UE1 and UE3.

9. UE1 and UE3 exchange E2E data via the UE-to-UE Relay. UE-to-UE Relay replaces the fields specified in the PDCP header with relay-specific identifiers, based on the mapping established in steps 2 and 5, before forwarding the E2E messages.

#### 6.12.2.2 Privacy of identifiers for End-to-End PC5 unicast link

As described in clause 6.12.2.1, an end-to-end (E2E) PC5 unicast link is established with an E2E peer UE via the 2 per-hop links, i.e. between source UE and the Relay and between the Relay and target UE. The E2E PC5 packets are using an adaptation header containing information identifying the source UE and/or destination UE, enabling the forwarding of packets E2E between peer UEs. PC5 packets also carry E2E session key identifiers, as for regular non-relayed PC5 communication, in the headers (e.g. PDCP header).

Considering the new adaptation layer and that all identifiers sent as cleartext needs to be updated at the same time, the Link Identifier Update procedure, designed in the context of direct communication only, is enhanced to support the periodic change of the source/destination UEs identity information carried into the adaptation header, at the same time as the per-hop identifiers (i.e. L2 IDs) and the end-to-end session key identifiers. In other words, all identifiers carried together, in cleartext, and that may be associated needs to be changed at the same time.

Furthermore, multiple end-to-end unicast links may be used via a shared single per-hop link which means that source/destination UEs identity information carried in the adaptation header, of all end-to-end unicast links, may be associated (i.e. bound) to the same per-hop identifiers since they are sent in the clear when end-to-end peer UEs exchange messages via the UE-to-UE Relay. This implies that the source UE and all its peer UEs communicating over the same per-hop link/ UE-to-UE Relay would need to change their identifiers (i.e. per-hop identifiers, end-to-end identifiers in the adaptation layer and session key identifiers for related to per-hop and end-to-end communication) at the same time. Using conventional per-hop LIU procedure could therefore lead to a signalling storm of PC5-S message exchanges.

To overcome this problem, the UE-to-UE Relay replaces the received source UE identifiers with mapped relay-specific identifiers (as defined in 6.12.2.1) before forwarding a message to a peer UE via another per-hop link. This limits the scope of identifiers sent in cleartext (i.e. in the headers) to the per-hop link, allowing reuse of per-hop LIU procedure while preserving the privacy of the E2E identifiers and without the need the change the latter at the same time.



Figure 6.12.2.2-1: Privacy of Identifiers for End-to-End PC5 unicast link

0. UE1 and UE2 establish and end-to-end PC5 unicast link via the UE-to-UE Relay. Security is established E2E between UE1 and UE2. Both UEs have a PC5 unicast link (also called per-hop link or management link) established with the UE-to-UE Relay. The PC5 unicast link established with the UE-to-UE Relay is used for the transport of E2E messages, and also for the management of these E2E links when the UE-to-UE Relay needs to be involved.

1. UE1 receives a trigger to change its identifiers e.g. privacy timer expiry. UE1 sends a Link Identifier Update (LIU) Request message to the UE-to-UE Relay via the management link. The LIU Request message includes a new L2 ID and new security parameters (i.e. UE1 MSB of KNRP-sess ID) for the management link. In addition, new E2E security parameters (i.e. UE1 E2E MSB of KNRP-sess ID) for the E2E link with UE2 and a new E2E identifier used in the adaptation header are included.

2. The UE-to-UE Relay receives the message and generates a new L2 ID and new security parameter (i.e. LSB of KNRP-sess ID) for the management link. In addition, a new relay-specific E2E security parameter (i.e. E2E LSB of KNRP-sess ID) and a new relay-specific E2E identifier associated with UE2 and used in the adaptation header are included. The UE-to-UE Relay sends a LIU Response message to UE1 which includes its new L2 ID and security parameter for the management link, the new relay-specific E2E identifier, and the new relay-specific E2E security parameter.

3. [optional] If UE1 has triggered the LIU procedure because a new Application layer ID and/or a new IP address/prefix has been received from the upper layer, UE1 sends a Link Modification Request to UE2 including its new Application layer ID and new IP address/prefix.

4. [optional] UE2 sends a Link Modification Accept to acknowledge the new IDs from UE1.

5. UE1 completes the LIU procedure by sending a LIU Ack message to the Relay.

### 6.12.3 Evaluation

For security, this solution proposes that a PC5 unicast link (also called per-hop link or management link), is established with the L2 UE-to-UE Relay by source/target UEs using unicast mode security mechanism defined in clause 5.3 of TS 33.503 [6] before establishing E2E security via the L2 UE-to-UE Relay.

NOTE: Further evaluation on end-to-end link establishment is needed.During E2E link security establishment, the L2 UE-to-UE Relay creates a mapping between its Relay specific MSB and LSB of KNRP-sess ID respectively with Source UE's MSB of KNRP-sess ID, and Target UE's LSB of KNRP-sess ID. The Relay forwards messages and data between Source and Target UE by replacing the security context E2E identifiers (i.e. MSB or LSB of KNRP-sess ID) in the PDCP header with relay specific identifiers according to the above mapping.

For privacy, this solution proposes a mechanism so that the LIU procedure between a UE and the L2 UE-to-UE Relay does not impact the E2E peer UEs, using TR 23.700-33 [2], sol#32 as baseline.

This solution fully addresses the following KI for the L2 UE-to-UE Relay scenario:

- Key Issue #2: Security of UE-to-UE Relay.

- Key issue #4: Privacy of information over the UE-to-UE Relay.

## 6.13 Solution #13: E2E authentication with Layer-3 UE-to-UE Relay

### 6.13.1 Introduction

This solution is for the 5G ProSe Layer-3 UE-to-UE Relay case. It addresses Key Issue #4: Privacy of information over the UE-to-UE Relay, Key Issue #3: Authorization in the UE-to-UE Relay Scenario, and 2nd requirement of Key Issue #1: Security for UE-to-UE Relay discovery (protection of privacy sensitive information of source and target UEs).

TR 23.700-33[2] describes several solutions for Layer-3 based UE-to-UE Relay which are all based on IP routing functionality at the UE-to-UE Relay. As part of the PC5 unicast link establishment procedure, the ProSe 5G UE-to-UE Relay allocates an IP address/prefix to the UE or is informed of the UE's IP address/prefix. The Relay stores the association of the UE's Application layer ID (also called User Info) and UE's IP address/prefix (e.g. into its DNS entries). When a source UE needs to communicate with a target UE via the ProSe 5G UE-to-UE Relay, it sends a request (e.g. DNS query) to the ProSe 5G UE-to-UE Relay, over the unicast link, to obtain the target UE's IP address/prefix (based on Target User Info). The Relay returns the IP address/prefix of the target UE. The source UE sends IP data to the target UE via the PC5 unicast link to UE-to-UE Relay. The UE-to-UE Relay acts as an IP router and forwards the packets to the corresponding PC5 unicast link towards the target UE.

When using the IP based routing, the UE and UE-to-UE Relay may wish to allow E2E communication only with a peer UE that is authenticated and authorized by the UE for both privacy reasons and to prevent unauthorized usage of UE-to-UE Relay resources (e.g. due to unauthorized IP traffic). To enable this, a UE informs the UE-to-UE Relay during the PC5 link establishment procedure whether E2E authentication/authorization with peer UEs is required before allowing communications via the UE-to-UE Relay. The Relay enforces the E2E authentication/authorization between peer UEs accordingly.

### 6.13.2 Solution details

This solution describes how E2E authentication and authorization is enforced prior to allowing user data traffic. Key\_Est\_Info used in the procedure below is a generic authentication container as defined in TS 33.536 [9]. This container is transparent to the PC5 interface and used to transport different data required for key establishment depending on the authentication method used by the application.



Figure 6.13.2-1: End-to-end authentication via Layer-3 UE-to-UE Relay

1. PC5 unicast links are established between UE1 and the Relay, UE2 and the Relay. During PC5 link establishment, UE1 and/or UE2 informs the Relay that E2E authentication and authorization is required prior to E2E communication, i.e. DNS resolution/E2E IP communication is not allowed before E2E authentication and authorization is successfully run. The Relay stores the E2E authentication and authorization requirement information along with UE1 and/or UE2 user info.

NOTE: Privacy of IP address/prefix requirement can be configured on a per RSC and/or 5G ProSe service basis.

2. UE1 sends IP Discovery Authorization Request to Relay including target UE2 user info, UE1 user info, and Key\_Est\_Info.

3. Relay determines that E2E authentication and authorization is required based on stored UE1 and UE2 user info and triggers E2E authentication and authorization.

The following steps 4 and 5 may be run multiple times depending on the authentication method used.

4. (a) Relay sends a Relayed Auth and Key Establishment Request message to UE2 including UE1 user info, UE2 user info, and Key\_Est\_Info. (b) UE2 sends a Relayed Auth and Key Establishment Response message to Relay including UE1 user info, UE2 user info, and Key\_Est\_Info. The final response indicates to the relay the authentication is complete with the corresponding result.

5. (a) Relay sends a Relayed Auth and Key Establishment Request message to UE1 including UE2 user info, UE1 user info, and Key\_Est\_Info. (b) UE1 sends a Relayed Auth and Key Establishment Response message to Relay including UE1 user info, UE2 user info, and Key\_Est\_Info. The final response indicates to the relay the authentication is complete with the corresponding result.

6. The relay stores the authorization result with UE1 and UE2 user info.

7. Once a final successful authentication result is received by the Relay from UE1 and UE2, Relay replies with an IP Discovery Authorization Response message including the successful authorization result. If the E2E authentication and authorization fails, the Relay sends a Response indicating failure.

8. If UE1 is authorized, it sends a DNS Query to obtain UE2's IP address/prefix. Relay verifies that UE1 is authorized to obtain UE2's IP address/prefix based on stored UE1 and UE2 user info and sends UE2's IP address/prefix in a DNS Response message.

### 6.13.3 Evaluation

This solution proposes a new PC5-S messaging to initiate E2E authentication and authorization via a L3 UE-to-UE Relay prior to allowing the discovery of peer UE's IP address/prefix information. This solution ensures that private UE's IP address/prefix information is only exposed to authorized peer UEs.

The peer UEs need to support exchange of E2E PC5-S Authentication and Authorization Request messaging. The U2U Relay needs to support handling of exchange of mutual authentication messages between the peer UEs and store the authorization result. The Relay provides IP Discovery authorization result to the requesting UE. The Relay replies to DNS Query with peer UE's IP address/prefix information to the requesting UE if authorization is successful.

This solution addresses:

- Key Issue #3 (2nd requirement): Authorization in the UE-to-UE Relay Scenario

- Key issue #4 (all requirements): Privacy of information over the UE-to-UE Relay.

## 6.14 Solution #14: path switching with Layer-2 UE-to-UE Relay

### 6.14.1 Introduction

This contribution proposes a solution to address KI #2: Security of UE-to-UE Relay and Key Issue #4: Privacy of information over the UE-to-UE Relay. Most specifically, this contribution provides a solution for path switching between two Layer-2 UE-to-UE Relays (i.e. relay re-selection).

This solution proposes to enable the preparation of the new security keys between the Source UE and Target UE using the existing PC5 unicast link via the first Relay and associated existing security association. The new security keys are then used for the security of a new PC5 unicast link that the UEs establish for path switching via a second relay. New security keys are necessary since the KNRP-sess is derived per unicast link as per TS 33.536, clause 5.3.3.1.2.1.

As in the UE-to-Network Relay scenario, it is assumed that PC5 signalling integrity security policy is set to "REQUIRED".

Details related to the establishment of the new security keys for the new PC5 unicast link using the existing security association from the existing PC5 unicast link are specified in the following clause.

### 6.14.2 Solution details

Figure 6.14.2-1 illustrates the high-level procedure of the proposed solution.



Figure 6.14.2-1: Layer-2 based UE-to-UE Relay Path Switching

1. A PC5 unicast link is established between Source UE and Target UE via Relay\_1. Traffic is exchanged between the Source UE and the Target UE over the PC5 unicast link, via Relay\_1.
2. Source UE triggers path switching, i.e. change of UE-to-UE Relay. The Source UE has obtained a list of candidate UE-to-UE Relay IDs (i.e. RIDs).
3. Source UE sends a Link Modification Request message to Target UE (via Relay\_1) including a list of candidate RIDs and a source UE link ID, which is used on the Source UE to associate the existing PC5 unicast link via Relay\_1 to the new PC5 unicast link with the selected Relay (e.g. Relay\_2). Security parameters (i.e. nonce\_1, MSB of KNRP-sess ID) to enable the establishment of new KNRP-sess and its ID and security keys are included as well.

The Source UE link ID is a locally generated random number by the Source UE. To avoid replay and linkability/trackability attacks across path switching procedures, a new Source UE link ID is generated and used each time a new path switch is initiated, i.e. each time a Link Modification message for path switching is sent. To preserve the privacy of the transmitted ids (Source UE link ID, MSB of KNRP-sess ID) the Link Modification Request message is protected for confidentiality, using current PC5 link security context.

4. Target UE selects a Relay from the received list of candidate RIDs (e.g. Relay\_2). Target UE uses the security parameters received from Source UE in the Link Modification Request message and its own security parameters to generate a new KNRP-sess (from current KNRP) and KNRP-sess ID and new security keys for the link to be established via the selected Relay. The new keys are stored to be later located when a DCR message for new link establishment is received (at step 8).

5. Target UE sends a Link Modification Accept message to Source UE (via Relay\_1) including its selected RID and a Target UE link ID, which is used on the Target UE to associate the existing PC5 unicast link via Relay\_1 to the new PC5 unicast link with the selected Relay (i.e. Relay\_2). Target UE's security parameters (i.e. nonce\_2, LSB of KNRP-sess ID) used to establish a new KNRP-sess and KNRP-sess ID and new security keys for the link to be established via the selected Relay are also included. The Target UE link ID is generated as described for the Source UE link ID in step 3. To preserve the privacy of the transmitted ids (Target UE link ID, LSB of KNRP-sess ID) the Link Modification Accept message is protected for confidentiality, using current PC5 link security context.

6. Source UE uses the security parameters received from the Target UE on the Link Modification Accept message and its own security parameters to generate a new KNRP-sess (from current KNRP) and KNRP-sess ID and new security keys for the link to be established via the selected Relay. Source UE protects for integrity the Target UE link ID using the new security keys.

7. Source UE sends a broadcast Direct Communication Request (DCR) message including the selected RID (i.e. Relay\_2), Target UE link ID received from Target UE at step 5. Relay\_2 receives the DCR message and forwards it to Target UE.

8. Target UE receives the DCR message and uses the Target UE link ID to locate the new security keys derived in step 4. Target UE uses the new security keys to verify the integrity of the received Target UE link ID parameter. A successful verification by the Target UE validates the new PC5 unicast link establishment request used for path switching. Target UE associates the new security context with the new PC5 unicast link.

9. Target UE sends a Direct Communication Accept message protected using the new security context. Target UE includes the Source UE link ID from Source UE as received at step 3 in the message. Relay\_2 receives the DCA message and forwards it to Source UE.

10. Source UE verifies the security of the DCA message using the new security keys. A successful verification by source UE completes the establishment of the new PC5 unicast link used for path switching. Source UE associates the new security context with the new PC5 unicast link.

11. Source UE and Target UE use the newly established PC5 unicast link via the Relay\_2 for path switching.

### 6.14.3 Evaluation

This solution is based on the concluded negotiated L2 UE-to-UE Relay reselection (see TS 23.700-33, clause 8.1).

This solution proposes to include security parameters in the E2E signalling over the current relay, to derive security keys that are used for a fast setup of the E2E security and switch over to the new UE-to-UE Relay.

Impact for the source and target UEs:

- support preparation via current UE-to-UE Relay of the new security keys between the Source UE and Target UE.

- support skipping the Direct Authentication and Key Establish procedures via the new UE-to-UE Relay by retrieving the new security key using Link ID.

There are no impact for the L2 UE-to-UE Relay as it only needs to perform regular forwarding of the E2E LMR/LMA and DCR/DCA messages between peer UEs.

This solution addresses requirements of KI #2: Security of UE-to-UE Relay requirements, including during UE-to-UE Relay re-selection (path switch).

This solution addresses requirements of KI #4: Privacy of information over the UE-to-UE Relay, including during UE-to-UE Relay re-selection (path switch).

## 6.15 Solution #15: Selection and authorization of in-coverage and out-of-coverage authentication and key establishment

### 6.15.1 Introduction

This solution addresses Key Issue #2 and Key Issue #3.

Different types of solutions and configurations may be available to establish a secure and authorized PC5 communication link. For instance, Solution #3 and #5 address in-coverage scenarios while Solution #4, #6 and #7 address out-of-coverage scenarios, and Solution #10 may be used in both in-coverage and out-of-coverage.

Since more than a single solution might be needed to address different scenarios, it is required to determine which solution is allowed to be used when. For instance, an out-of-coverage source UE might attempt to use a solution for out-of-coverage when the UE-to-UE relay is in-coverage. In this exemplary situation, the UE-to-UE relay should be able to determine, based on a policy, that an in-coverage solution is (not) required and indicate this to the source UE.

This solution describes the configuration of a policy that allows source/target Ues and UE-to-UE relay to agree on the type of solution and parameters that is preferred and/or authorized to be used.

### 6.15.2 Solution details



Figure 6.15.2-1

The message flow and steps of this solution are as outlined in Figure 6.15.2-1.

- In Step 0, the Ues perform an initial authorization and parameter provisioning for in-coverage and out-of-coverage situations. This step includes the configuration of parameters for different solutions for in-coverage and out-of-coverage security establishment and authorization.

Note 1: The configured parameters for in-coverage and out-of-coverage solution depend on the configured solution.

- In Step 1, the source UE and UE-to-UE relay perform a discovery phase.

- In Step 2, the source UE determines its out-of-coverage (in-coverage) situation, and choses a security solution and/or security parameters for its out-of-coverage (in-coverage) situation. This choice can be based on multiple reasons, e.g. application requirements such as performance or an in-coverage (out-of-coverage) indication received from the UE-to-UE relay during discovery, etc. The source UE builds correspondingly a Direct Communication Request based on the chosen out-of-coverage (in-coverage) solution and security parameters.

- In Step 3, the UE-to-UE relay receives the DCR message and determines whether the DCR message either implicitly or explicitly contains parameters for an out-of-coverage (in-coverage) solution. The UE-to-UE relay then checks that the requested solution and security parameters fit its out-of-coverage (in-coverage) situation and whether a policy deployed in Step 0 together with any authorization information received in Step 2 allow the usage of said solution and security parameters. Once this policy is evaluated and if the result is positive, the UE-to-UE relay will proceed executing the requested out-of-coverage (in-coverage) solution. Alternatively, if the result is negative, the UE-to-UE relay may – based on configuration – indicate the source UE policy mismatch, and potentially request a different DCR message including a requested solution and security parameters.

- In Step 4, the UE-to-UE relay may take one of the following alternative steps:

- Step 4-A, send a message to the Source UE to go on with an in-coverage solution.

- Step 4-B, send a message to the core network to go on with an out-coverage solution.

- Step 4-C, send a message to the Source UE indicating that the security establishment based on the exchanged parameters is not feasible and requesting alternative parameters.

Note 2: The above steps can be repeated for the security establishment process and authorization between Target UE and UE-to-UE relay.

Note 3: The above process illustrates how Ues signal and agree on solution and security parameters to use by means of the DCR message. This signalling and agreement phase might also be carried out in the discovery phase.

This solution requires a policy to choose the In-Coverage or Out-of-Coverage solution to use. This policy might include:

- Which of the supported solutions or solution parameters are preferred when in-coverage and/or when out-of-coverage.

- Whether/how security parameters (e.g. a password, or a key, etc) of an out-of-coverage solution may be entered when devices are out-of-coverage.

### 6.15.3 Evaluation

This solution coordinates the selection and authorization of in-coverage and out-of-coverage authentication and key establishment procedures, and thus, supports Key Issue #2 and Key Issue #3.

This solution allows the UEs (Source/Target/Relay) to support multiple security methods (i.e. for In-Coverage and Out-of-Coverage). UEs are required to support both In-Coverage and Out-of-Coverage mechanisms if they intend to work under both scenarios. The 5G ProSe Source/Target and UE-to-UE relay need to have the logic and a new policy to choose between the In-Coverage dedicated mechanism and the Out-of-Coverage dedicated mechanism before/during the direct communication establishment procedures.

## 6.16 Solution #16: Centralized discovery key management and U2U relay authorization

### 6.16.1 Introduction

This solution addresses Key Issue #1: Security for UE-to-UE Relay discovery and Key issue #3: Authorization in the UE-to-UE Relay Scenario. For Key Issue #1, this solution specifically addresses the security requirement:

*The 5G System shall provide a means to securely provision the security materials for UE-to-UE Relay discovery.*

This solution assumes that the discovery security materials used for direct discovery and U2U relay discovery are different. Therefore, U2U relay authorization can be executed during the U2U relay discovery key provision process. Otherwise this solution does not address the Key Issue #3.

This solution needs to extend the existing specification as follows:

- Permit multiple roles in the restricted discovery request. (Currently, there is only one role (Announce, Monitor, Query or Response) in the restricted discovery request.)

U2U relay communication is carried out without the participation of the operators' networks, and the UEs involved can come from different PLMNs. If the discovery security materials are provisioned by different PLMNs, such as 5G DDNMF or PCF, the key management may be too complex. This solution assumes that only one ProSe Key Management Function (PKMF) is responsible for provisioning discovery security materials for direct discovery, U2U relay discovery or both. This solution does not prevent multiple PKMFs in a U2U relay communication system. For example, one or more PKMs are used for direct discovery, and one or more PKMFs are used for RSC specific U2U relay discovery. However, there is no interaction between PKMFs. Any interaction between PKMFs needs to be implemented in the application layer.

The PKMF in this solution is also called 5G U2U Relay PKMF to distinguish it from other kinds of PKMFs. A 5G U2U Relay PKMF can provision various discovery security materials based on a 5G ProSe UE's roles in U2U relay discovery procedures.

### 6.16.2 Solution details

 Figure 6.16.2-1: Centralized discovery key management and U2U relay authorization procedure

Note 1: This solution only covers the parameters related to security material retrieval.

Note 2: The U2U relay discovery security materials are used to protect U2U discovery messages. The direct discovery security materials are used to protect the direct discovery set in the U2U discovery messages.

0. The 5G ProSe UE (Source UE/Target UE/Relay UE) gets the address of the 5G U2U Relay PKMF from the PCF of its HPLMN, which is responsible for provisioning discovery security materials related to direct discovery and U2U relay discovery. The direct discovery security materials can also be provisioned to the Source UE and Target UE using the approaches specified in clause 6.1.3.2 of TS 33.503 [5].

1. The 5G ProSe UE establishes a secure connection with the 5G U2U Relay PKMF and sends a U2U Relay Discovery Key Request to the 5G U2U Relay PKMF. The request includes User Info ID, RSC, Security capability, and UE's roles in RSC-specified relay service.

Security for the interface between the 5G ProSe UE and the 5G U2U Relay PKMF relies on Ua security if GBA specified in TS 33.220 [14] is used (see clause 5.2.3.4) or Ua\* security if AKMA specified in TS 33.535 [15] is used (see clause 5.2.5.4).

In U2U relay discovery, a UE can be the role of Announcing UE or Monitoring UE in Model A, or the role of Discoveree UE or Discoverer UE in Model B.

2. 5G U2U Relay PKMF checks whether the 5G ProSe UE is authorized to play these roles in RSC-specified relay service.

3. The 5G U2U Relay PKMF provides a set of discovery security materials corresponding to the authorized roles to the 5G ProSe UE through U2U Relay Discovery Key Response. The discovery security materials related to U2U relay discovery are associated with the RSC. The 5G U2U Relay PKMF may include relay discovery security policies specifying how the provided security material is used in the U2U relay discovery procedure in the response. For example, a security policy can specify whether end-to-end protection needs to be enabled in relay discovery messages.

### 6.16.3 Evaluation

Solution #16 addresses the third security requirement of key issue #1 and Key issue #3.

This solution allows the UE to provide multiple roles that it can play in U2U relay communication in the security material request; so that all discovered security materials can be obtained at one time.

This solution assumes that there is only one PKMF involved in a security material provision process for direct discovery, U2U relay discovery or both. Therefore, there is no interaction between PKMFs if there are more PKMFs involved in a U2U relay communication system. If interaction between PKMFs is required, it needs be implemented in the application layer. The address of the PKMF is provided to UE by its HPLMN.

The U2U relay authorization check is done by the PKMF during discovery security materials provision process. The PKMF checks whether a UE can play its claimed roles, and then provisions corresponding discovery security materials to the UE. This solution assumes that the discovery security materials provisioned for direct discovery and U2U relay discovery are different.

The U2U relay authorization check method is not applicable if the discovery security materials are not used in the procedure of discovery is integrated into the PC5 unicast link establishment.

## 6.17 Solution #17: U2U relay discovery security material retrieval and authorization across PLMNs

### 6.17.1 Introduction

This solution addresses Key Issue #1: Security for UE-to-UE Relay discovery and Key issue #3: Authorization in the UE-to-UE Relay Scenario. For Key Issue #1, this solution specifically addresses the security requirement:

*The 5G System shall provide a means to securely provision the security materials for UE-to-UE Relay discovery.*

This solution assumes that the discovery security materials used for direct discovery and U2U relay discovery are different. Therefore, U2U relay authorization can be executed during the U2U relay discovery key provision process. Otherwise this solution does not address the Key Issue #3.

This solution needs to extend the existing specification as follows:

- Permit multiple roles in the restricted discovery request. (Currently, there is only one role (Announce, Monitor, Query or Response) in the restricted discovery request.)

- Permit to return more than two sets security materials in the restricted discovery response. (Currently, the restricted discovery response can return code-sending-security-parameter, code-receiving-security-parameter or both.

This solution assumes that multiple ProSe Key Management Functions (PKMFs) are used to generate and provision discovery security materials for direct discovery and U2U relay discovery. The PKMF in this solution is also called 5G U2U Relay PKMF to distinguish it from other kinds of PKMFs. A 5G U2U Relay PKMF can provision various discovery security materials based on a 5G ProSe UE's roles in U2U relay discovery procedures. 5G ProSe UEs will always retrieve discovery security materials from one 5G U2U Relay PKMF which address is provided by the PCF or 5G DDNMF. It is possible for a 5G U2U Relay PKMF to retrieve discovery security materials from other 5G U2U Relay PKMFs.

### 6.17.2 Solution details

 Figure 6.17.2-1: U2U relay discovery security material retrieval and authorization procedure across PLMNs

Note 0: This solution only covers the parameters related to security material retrieval.

0. The 5G ProSe UE (Source UE/Target UE/Relay UE) gets the address of 5G DDNMF/5G U2U Relay PKMF from the PCF of its HPLMN, which is responsible for provisioning discovery security materials related to direct discovery and U2U relay discovery.

NOTE 1: U2U relay discovery materials are provisioned by the 5G DDNMF or 5G U2U Relay PKMF can be determined in the conclusion phase or the normative work phase.

1. The 5G ProSe UE establishes a secure connection with the 5G DDNMF/5G U2U Relay PKMF in its HPLMN and sends a U2U Relay Discovery Key Request to the 5G DDNMF/5G U2U Relay PKMF. The request includes User Info ID, Security capability, and UE's roles in RSC-specified relay service. The request should include RSC if discovery security materials for U2U relay discovery are required.

Security for the interface between the 5G ProSe UE and the 5G DDNMF/5G U2U Relay PKMF relies on Ua security if GBA specified in TS 33.220 [14] is used (see clause 5.2.3.4) or Ua\* security if AKMA specified in TS 33.535 [15] is used (see clause 5.2.5.4).

In U2U relay discovery, a UE can be the role of Announcing UE or Monitoring UE in Model A, or the role of Discoveree UE or Discoverer UE in Model B.

2. The 5G DDNMF/5G U2U Relay PKMF in the HPLMN may need to send an Authorization Check Request to the UDM/ProSe App Server to check whether the UE is allowed to play its declared roles. The request includes User Info ID and the role list. The request should include RSC if discovery security materials for U2U relay discovery are required.

NOTE 2: Authorization check of U2U relay discovery is performed by the UDM or ProSe App Server can be determined in the conclusion phase or the normative work phase.

3. The UDM/ProSe App Server checks whether the UE is allowed to play the roles it claims, and returns the allowed roles through Authorization Check Request

4. If the security materials for the roles are not available locally, the 5G DDNMF/5G U2U Relay PKMF in the HPLMN may need to send an U2U Relay Discovery Key Request to another 5G DDNMF/5G U2U Relay PKMF in a VPLMN to obtain the security materials. The request includes User Info ID and role list. The request should include RSC if discovery security materials for U2U relay discovery are required.

5-6. The 5G DDNMF/5G U2U Relay PKMF in the VPLMN may need to send an Authorization Check Request to the UDM/ProSe App Server to check whether the UE is allowed to play its declared roles.

7. The 5G DDNMF/5G U2U Relay PKMF in the VPLMN gets the discovery security materials for the allowed roles in the RSC-specific U2U relay service, and returns them through U2U Relay Discovery Security Material Response. The discovery security materials related to U2U relay discovery are associated with the RSC. The 5G DDNMF/5G U2U Relay PKMF may include relay discovery security policies specifying how the provided security material is used in the U2U relay discovery procedure in the response. For example, a security policy can specify whether end-to-end protection needs to be enabled in relay discovery messages.

8. The 5G DDNMF/5G U2U Relay PKMF in the HPLMN returns the discovery security materials obtained from the local and other PLMNs to the UE through U2U Relay Discovery Key Response. The discovery security materials related to U2U relay discovery are associated with the RSC. If there are Relay Discovery Security Policies for the RSC-specific U2U relay service, the 5G DDNMF/5G U2U Relay PKMF includes these policies in the response.

### 6.17.3 Evaluation

Solution #17 addresses the third security requirement of key issue #1 and Key issue #3.

This solution allows the UE to provide multiple roles that it can play in U2U relay communication in the security material request; so that all discovered security materials can be obtained at one time.

This solution assumes that there may be multiple PKMFs/5G DDNMFs involved in a security material provision process for direct discovery, U2U relay discovery or both. This solution supports interaction between multiple PKMFs/5G DDNMFs. The address of the PKMF is provided to UE by its HPLMN.

The U2U relay authorization check is done by the PKMF/5G DDNMF during discovery security materials provision process. The PKMF/5G DDNMF checks whether a UE can play its claimed roles, and then provisions corresponding discovery security materials to the UE. This solution assumes that the discovery security materials provisioned for direct discovery and U2U relay discovery are different.

The U2U relay authorization check method is not applicable if the discovery security materials are not used in the procedure of discovery is integrated into the PC5 unicast link establishment.

## 6.18 Solution #18: UE-to-UE Relay security

### 6.18.1 Introduction

This solution addresses Key Issue #2: Security of UE-to-UE Relay.

This solution uses PC5 security mechanism defined in in TS 33.536 [9] for the security between Remote UE and Relay UE.

This solution uses IPsec for the security between Remote UEs in Layer-3 UE-to-UE Relay scenario.

This solution uses PC5 security mechanism defined in TS 33.536 [9] for the security between Remote UEs in Layer-2 UE-to-UE Relay scenario.

### 6.18.2 Solution details

 Figure 6.18.2-1: UE-to-UE relay security procedure

0. The Source UE, Relay UE and Target UE discover each other, and then establish connections between them. This solution does not address the key issue of U2U relay discovery security.

1. According to the PC5 security policies provisioned by the PCFs of the Source/Target/Relay UEs or the application layer, the Source UE and Target UE may use the unicast mode security mechanism defined in clause 5.3 of TS 33.536 [9] to establish secure connections with the Relay UE respectively.

NOTE 1: Whether the hop-by-hop link security is implemented between the source UE and the relay UE and between the target UE and the relay UE is controlled by the PC5 security policies provisioned to the Source, Target and Relay UEs. This process is independent of E2E security between the source UE and the target UE. In order to avoid unnecessary excessive security, appropriate PC5 security policies should be designed for source, target and relay UEs.

2. For the Layer-3 UE-to-UE relay scenario, establishing a secure connection between the Source UE and the Target UE is out of the scope of 3GPP.

For the Layer-2 UE-to-UE relay scenario, the Source UE and the Target UE can reuse the unicast mode security mechanism defined in clause 5.3 of TS 33.536 [9] to establish a secure connection via the Relay UE.

NOTE 2: How the Layer-2 link is established between the Source UE and the Target UE via a Relay UE can align with the decision of RAN WGs during normative work.

### 6.18.3 Evaluation

Solution #18 addresses the key issue #2.

This solution proposes that the Source UE and Target UE reuse the security mechanism defined in clause 5.3 of TS 33.536 [9] to establish secure connections with the Relay UE respectively.

For the Layer-3 UE-to-UE relay scenario, this solution proposes that establishing a secure connection between the Source UE and the Target UE is out of the scope of 3GPP.

For the Layer-2 UE-to-UE relay scenario, this solution proposes that the Source UE and Target UE reuse the security mechanism defined in clause 5.3 of TS 33.536 [9] to establish a secure connection via the Relay UE.

## 6.19 Solution #19: End-to-end security establishment over the UE-to-UE Relay

### 6.19.1 Introduction

This solution addresses Key Issue #2, #3, and #5. When Source/Target UEs and a Relay UE are in the network coverage, they are authorized and provisioned with the required information for security establishments during the registration procedure that includes the primary authentication (i.e. 5G-AKA or EAP-AKA').

The Source UE sends a Direct Communication Request to the Target UE over the UE-to-UE Relay, so that the direct authentication takes place and the end-to-end protection key is established regardless of whether the UEs (the Source UE, Target UE and/or UE-to-UE Relay) are within or outside the network coverage. This solution applies to both Layer-2 UE-to-UE Relay and Layer-3 UE-to-UE Relay.

### NOTE: The need of end-to-end security in Layer-3 solution is not addressed in the present document.6.19.2 Solution details

#### 6.19.2.1 End-to-end security establishment procedure over the L3 UE-to-UE Relay

Figure 6.19.2.1-1 illustrates the end-to-end security establishment procedure between the Source UE and the Target UE over the UE-to-UE Relay.



Figure 6.19.2.1-1: End-to-end security establishment procedure over the UE-to-UE Relay

1. The Source UE, Target UE, and UE-to-UE Relay are authorized and provisioned with the security materials for the hop-by-hop and/or end-to-end security establishment (refer to clause 6.19.2.3).
2. The discovery and selection procedure may be performed between the Source UE, Target UE, and UE-to-UE Relay using Model A or Model B mode as specified in TS 23.304 [2]. If discovery integrated into PC5 unicast link establishment procedure concluded by SA2 in TR 23.700-33 [3] is to be performed in the following steps, this step is skipped.
3. There are various authentication and key establishment methods to be used between the Source UE and the Target UE over a UE-to-UE Relay. Hence, all the authentication is specified to be carried in a generic container called Auth\_Key\_Info in the following steps.

The Source UE generates ephemeral public key (UE1.ePK) and private key (UE1.eSK), and a digital signature (UE1.Sig). The digital signature is signed over the source UE's identity (UE1.ID) and UE1.ePK using the security materials provisioned in step 0. Then, the Source UE generates UE1.Auth\_Key\_Info which includes UE1.ID, UE1.ePK, and UE1.Sig.

1. The Source UE wants to establish a secure unicast link with the Target UE via the UE-to-UE Relay. The Source UE sends the UE-to-UE Relay a Direct Communication Request message including Relay Service Code (RSC), its Auth\_Key\_Info, and relay\_indication which is enabled if discovery integrated into PC5 unicast link establishment procedure is used. The message also includes the security capabilities and PC5 signalling security policy.

NOTE 1: The relay\_indication is a newly proposed field in Sol#1 for KI#1 from TR 23.700-33 [3], which is concluded to be used as basis for normative phase in SA2, to indicate whether a relay can be used in the communication and to integrate the relay discovery/selection into the unicast link establishment procedure.

1. The UE-to-UE Relay receives the Direct Communication Request and forwards the message to the Target UE with the relay\_indication disabled.
2. Upon reception of the Direct Communication Request message, the Target UE verifies the Source UE with UE1.Sig included in UE1.Auth\_Key\_Info using the security materials provisioned in step 0. If the verification is successful and the Target UE decides to accept the request, the Target UE generates ephemeral public key (UE2.ePK) and private key (UE2.eSK), and a digital signature (UE2.Sig). The digital signature is signed over the Target UE's identity (UE2.ID) and UE2.ePK using the security materials provisioned in step 0. Then, the Target UE generates UE2.Auth\_Key\_Info which includes UE2.ID, UE2.ePK, and UE2.Sig.

In this step, the Target UE derives a symmetric key that is used to protect the end-to-end link (i.e. end-to-end protection key), using the Source UE's ephemeral public key (UE1.ePK) and its own ephemeral private key (UE2.eSK).

1. In this step, the PC5 unicast link security can be established between the Target UE and the UE-to-UE Relay as defined in clause 5.3 of TS 33.536 [3].

NOTE 2: This solution focuses on the end-to-end security establishment between the Source UE and the Target UE, as the hop-by-hop security between the Source/Target UE and the UE-to-UE Relay can be established by Solution #29 in this specification.

1. The Target UE sends the UE-to-UE Relay a Direct Communication Accept message including RSC and its Auth\_Key\_Info.
2. In this step, the PC5 unicast link security can be established between the Source UE and the UE-to-UE Relay as defined in clause 5.3 of TS 33.536 [3].
3. The UE-to-UE Relay receives the Direct Communication Accept and forwards the message to the Source UE.
4. Upon reception of the Direct Communication Accept message, the Source UE verifies the Target UE with UE2.Sig included in UE2.Auth\_Key\_Info using the security materials provisioned in step 0. If the verification is successful, the Source UE derives a symmetric key that is used to protect the end-to-end link (i.e. end-to-end protection key), using the Target UE's ephemeral public key (UE2.ePK) and its own ephemeral private key (UE1.eSK).
5. The Source UE and the Target UE finish setting up the secure communication link over the UE-to-UE Relay with the shared end-to-end protection key. To suffice the security policies, the IPsec Security Association (SA) can be established between the Source UE and the Target UE by using the end-to-end protection key. With IPsec operating on the IP layer, the IP packets are end-to-end protected between the Source UE and the Target UE over the Layer-3 UE-to-UE Relay.

#### 6.19.2.2 End-to-end security establishment procedure over the L2 UE-to-UE Relay

The Source UE and the Target UE establish end-to-end security for PC5 connection with the end-to-end protection key shared using the same mechanism (from step 0 to step 10) specified in clause 6.19.2.1. The encryption key and integrity key are derived from the end-to-end protection key and used in the chosen confidentiality and integrity algorithms, respectively. Then, at the PDCP layer, the signalling and user plane data are end-to-end protected between the Source UE and the Target UE over the Layer-2 UE-to-UE Relay.

#### 6.19.2.3 Authorization and Parameter Provisioning to the UEs

The Source/Target UE and the UE-to-UE Relay are authenticated and authorized to receive or provide UE-to-UE Relay service by the network during the primary authentication procedure (i.e. 5G AKA or EAP-AKA'). A UE initiates the procedure by sending a Registration Request message to the network. In the meanwhile, the UDM checks the subscription information, called UE-to-UE indication, related to the UE-to-UE Relay service. The UE-to-UE indication of the Source/Target UE indicates:

- Whether the Source/Target UE is authorized to receive the UE-to-UE Relay service;

And the UE-to-UE indication of the UE-to-UE Relay indicates:

- Whether the UE-to-UE Relay is authorized to provide the UE-to-UE Relay service.

The UE-to-UE indication is transferred from the UDM to the AUSF, and is forwarded to the UE along with the AKA challenge. Upon reception of the UE-to-UE indication, which allows the UE to receive or provide the UE-to-UE Relay service, the UE provides UE-to-UE\_Auth\_Info, which can be used by the AUSF to generate security materials for the end-to-end security establishment, to the network along with the AKA challenge response. In the Certificate-based approach, the UE generates a public and private key pair, and generate UE-to-UE\_Auth\_Info including the UE's ID and the generated public key. In the Identity-based approach, the UE generates UE-to-UE\_Auth\_Info including the UE's ID.

NOTE 1: Which identifier is to be used as a UE’s ID is not addressed in the present document.

Note 2: How and which entity associates UE’s ID with the U2U relay service is not addressed in the present document.

Note 3: AUSF impact for generating and provisioning security materials to UEs is not addressed in the present document.

Note 4: How to support U2U relay services across multiple PLMNs is not addressed in the present document.

If UE-to-UE indication allows the UE to receive or provide the UE-to-UE Relay service, the AUSF generates the security materials using the UE-to-UE\_Auth\_Info and provisions them to the UE. The provisioned security materials are used as long term credentials of the UE. The authorized UE is provisioned with the security materials when it has not been provisioned with the security materials before or when the validity of the security materials has been expired.

Note 5: The security materials provisioned to the UE by the network are associated with an expiration time after which they become invalid. If the UE does not have valid security materials, the UE needs to obtain fresh ones to receive or provide the UE-to-UE Relay service.

In the Certificate-based approach, the security materials include the UE's certificate and the root CA certificate(s), which allows the UE to verify the certificates of other UEs. In the Identity-based approach, the security materials include the UE's identity, secret signing key (SSK), public validation token (PVT), and KMS public authentication key(s) (KPAK), which allows the UE to verify the signatures of other UEs.

If the UE is authorized to receive or provide UE-to-UE service based on UE-to-UE indication, PCF provides the security policy/parameters to the UE. The security policy/parameters of the Source/Target UE related to the UE-to-UE Relay service includes Hop-by-hop Security Indicator per RSC and End-to-end Security Indicator per RSC. The security policy/parameters of the UE-to-UE Relay related to the UE-to-UE Relay service includes Hop-by-hop Security Indicator per RSC:

- The Hop-by-hop Security Indicator indicates whether the Source/Target UE requires the hop-by-hop security (signalling integrity, signalling confidentiality, user plane integrity, and user plane confidentiality) establishment with the UE-to-UE Relay, or not;

- The End-to-end Security Indicator indicates whether the Source/Target UE requires the end-to-end security (signalling integrity, signalling confidentiality, user plane integrity, and user plane confidentiality) establishment, or not.

The same hop-by-hop and/or end-to-end protection schemes are supported for the Source UE, Target UE and UE-to-UE Relay provisioned with the same Hop-by-hop Security Indicator and/or End-to-end Security Indicator by a service level to protect the UE-to-UE relay traffic.

### 6.19.3 Evaluation

This solution supports authorization and provisioning of the Source/Target UE and UE-to-UE Relay for the UE-to-UE Relay Communication service when the UEs are in the network coverage.

This solution proposes the end-to-end security establishment procedure between the Source UE and the Target UE over the Layer-2 or Layer-3 UE-to-UE Relay using the provisioned security materials, both within and outside the network coverage.

This solution employs a generic container, which allows different authentication and key establishment mechanisms such as certificate-based one and identity-based one to be applied, for the end-to-end security establishment. For example, the "Elliptic Curve-based Certificateless Signatures for Identity-based Encryption" (ECCSI) can be used for the identity-based direct authentication and key establishment as described in clause 6.5.7 of TS 33.303 [5].

This solution supports a means for the UEs to agree on the same end-to-end security protection schemes in UE-to-UE Relay service.

The solution requires 5GC to support means of managing security materials, such as certificates and UEs' identities, and this may introduce additional complexities on AUSF, AMF, etc.

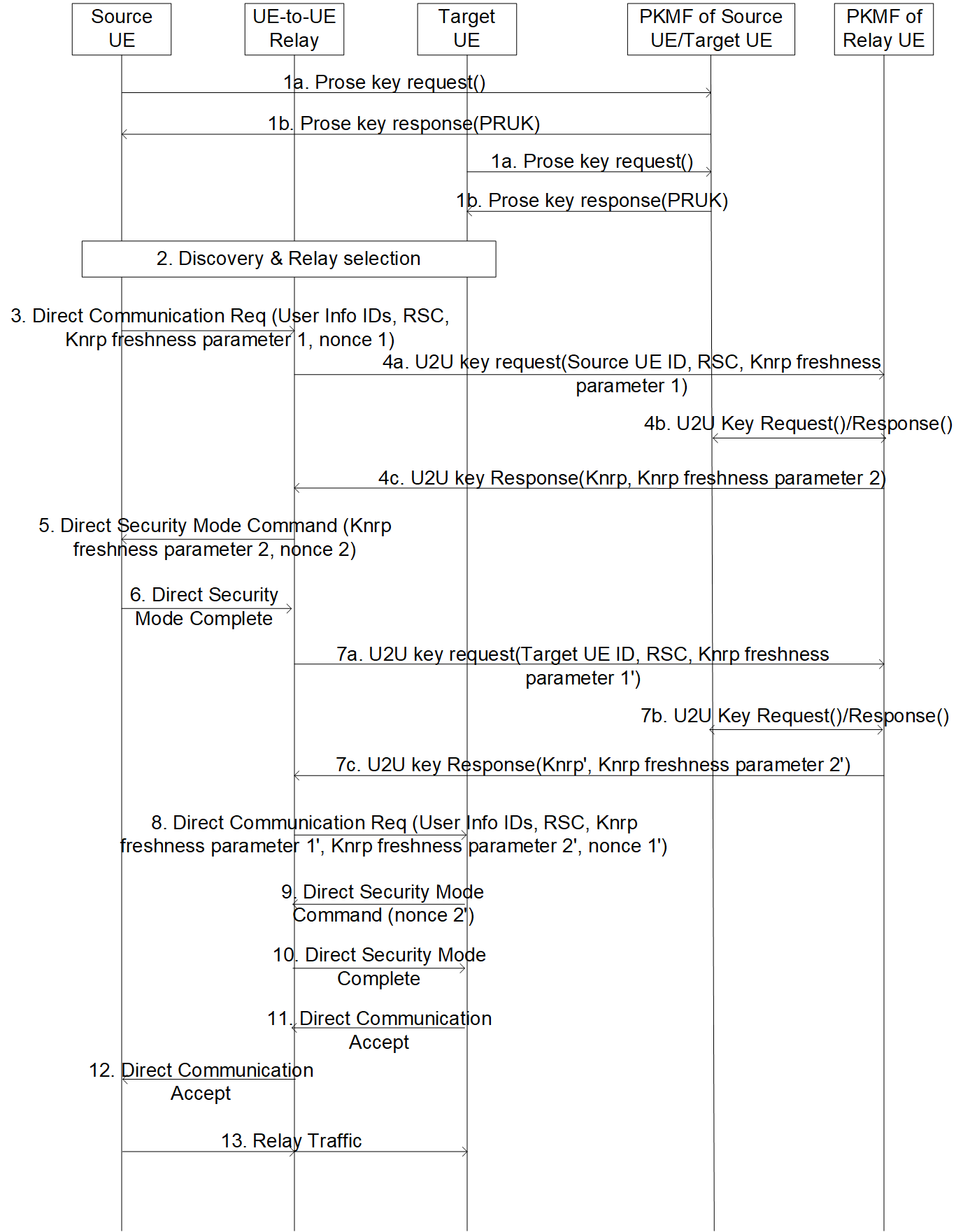
## NOTE: Further evaluation is needed.6.20 Solution #20: Network-assisted security establishment procedure for 5G ProSe Layer-3 UE-to-UE Relay

### 6.20.1 Introduction

The solution addresses Key Issue #2: Security of UE-to-UE Relay. It largely reuses the mechanism of UE-to-Network Relay Security Establishment procedure defined in TS 33.503 [6] to ensure the security of UE-to-UE Relay Communication.

In the UE-to-UE relay scenario, two options (Layer-2 UE-to-UE Relay and Layer-3 UE-to-UE Relay) are under consideration. For Layer-3 UE-to-UE Relay, the full security of a UE-to-UE PC5 link depends on the security of two separate PC5 links, i.e. the link between the Source UE and UE-to-UE Relay and the link between UE-to-UE Relay and Target UE. The security of these two separate PC5 link relies on the UE-to-UE Relay's security materials, which are provided by the network after passing the authorization check. With the assistance of network, the UE-to-UE PC5 link via 5G ProSe Layer-3 UE-to-UE Relay can be securely established.

### 6.20.2 Solution details

Figure 6.20.2-1: Network-assisted PC5 link security establishment procedure for 5G ProSe Layer-3 UE-to-UE Relay

1a. The Source UE/Target UE sends a Prose Key Request message to its 5G PKMF. The message indicates that the Source UE/Target UE is requesting a PRUK from the 5G PKMF.

1b. The 5G PKMF checks (or checks with the ProSe Server) that the Source UE/Target UE is authorized to receive U2U relay services. If the Source UE/Target UE is authorized to receive the service, the 5G PKMF sends a PRUK to the Source UE/Target UE and stores the UE identity associated with PRUK. If a PRUK is included, the Source UE/Target UE stores the new one and deletes any previously stored ones for this 5G PKMF.

NOTE a: It is not addressed in the present document about how the interface between PKMF and Prose Server is achieved.2. The Discovery & Relay Selection procedure is performed between the peer UEs and the UE-to-UE Relay.

NOTE 1: It is assumed that after the Discovery & Relay Selection procedure, the Source UE and the Target UE can discover each other by selecting the same UE-to-UE Relay.

3. The Source UE sends a Direct Communication Request that contains the User Info ID of Source UE, User Info ID of U2U Relay, User Info ID of Target UE, Source UE's security capabilities, RSC and nonce 1 to the UE-to-UE Relay.

Note 2: Whether the protection of User info ID is needed is not addressed in the present document.

Note 3: Which identifier is used as a source UE/target UE ID is not addressed in the present document.

Note 4: How a U2N relay knows Target UE ID is not addressed in the present document.

4a.The U2U Relay sends a U2U Key Request message that contains Source UE ID, RSC, Knrp freshness parameter 1 to its 5G PKMF, indicating that the U2U Rely is requesting the Knrp between the Source UE and U2U Relay.

4b. Once receiving the U2U Key Request message, the 5G PKMF of U2U Relay checks if the U2U Relay is authorized to provide U2U Relay service. If the U2U Relay is authorized, the 5G PKMF of U2U Relay sends the U2U Key Request to the 5G PKMF of the Source UE, which may contain the Source UE ID, RSC and the Knrp freshness parameter 1.

Once receiving the U2U Key Request message, the 5G PKMF of Source UE identifies the PRUK of Source UE based on the received Source UE ID, then generates Knrp freshness parameter 2 and derives Knrp as specified in TS 33.503 [6]. The 5G PKMF of Source UE sends a U2U Key Response message that contains Knrp and Knrp freshness parameter 2.

Note 5: It is not addressed in the present document about how PKMF discovers each other based the Application layer UE IDs.

4c. The 5G PKMF of U2U Relay forwards the Knrp and the Knrp freshness parameter 2 to the U2U Relay, by sending the U2U Key Response message.

Note 6: How to provide credential in the CP based security procedure is not addressed in the present document.

NOTE 7: In this solution, the U2U relay is in the network coverage.

5. The UE-to-UE Relay derives the session key (KNRP-SESS) from KNRP and then derives the confidentiality key (NRPEK) (if applicable) and integrity key (NRPIK) based on the PC5 security policies as specified in TS 33.503 [6]. The UE-to-UE Relay sends a Direct Security Mode Command message to the Source UE. This message also includes the chosen security algorithm and nonce 2.

6. The Source UE responds with a Direct Security Mode Complete message to the 5G ProSe UE-to-UE Relay.

Steps 7a-7c are performed to generate the Knrp between the Target UE and U2U Relay. The details of steps 7a-7c are the same as the details of steps 4a-4c.

8. Based on the User Info ID or Layer-2 ID of Target UE obtained after the UE-to-UE Relay discovery, the UE-to-UE Relay sends a Direct Communication Request that contains the User Info ID of Source UE, User Info ID of U2U Relay, User Info ID of Target UE , the Chosen security algorithm, RSC, Knrp freshness parameter 1', Knrp freshness parameter 2' and nonce 1*'* to the Target UE.

Note 9: Security risk of U2U generating Knrp freshness parameter 1’ on behave of target UE (step 7a, 8) is not addressed in the present document.

9. The Target UE derives the session key (KNRP-SESS*'*) from KNRP*'* and derives the confidentiality key (NRPEK*'*) (if applicable) and integrity key (NRPIK') based on the PC5 security policies as specified in TS 33.503 [6]. The Target UE sends a Direct Security Mode Command message to the UE-to-UE relay. This message also includes the nonce 2*'*.

10. The UE-to-UE Relay responds with a Direct Security Mode Complete message to the Target UE.

11. The Target UE sends the Direct Communication Accept message to the UE-to-UE Relay.

12. Only after receiving the Direct Communication Accept message from the Target UE, the UE-to-UE Relay then responds the Direct Communication Accept message to the Source UE.

13. The secure L3 PC5 link between the Source UE and the Target UE via the UE-to-UE Relay is established. The UE-to-UE Relay can forward the traffic between the peer Prose UEs.

### 6.20.3 Evaluation

This solution only works when the UE-to-UE relay is located within network's coverage area. This solution requires user plane message interactions with the network.

Note: Further evaluation is needed.

## 6.21 Solution #21: E2E security establishment procedure for 5G ProSe Layer-3 UE-to-UE Relay

### 6.21.1 Introduction

The solution addresses Key Issue #2: Security of UE-to-UE Relay. It largely reuses the IKEv2 protocol and the mechanism of Direct Security Establishment procedure defined in TS 33.503 [6] to ensure the end-to-end security between the Source UE and Target UE.

After the per-hop links (i.e. the PC5 link between Source UE and UE-to-UE Relay, as well as the PC5 link between UE-to-UE Relay and Target UE) are established, the peer UEs may exchange their security materials and associate the end-to-end security keys to establish E2E security. The Source UE and Target UE perform the IKEv2 protocol, which enables the end-to-end security in the UE-to-UE relay communication.

### 6.21.2 Solution details

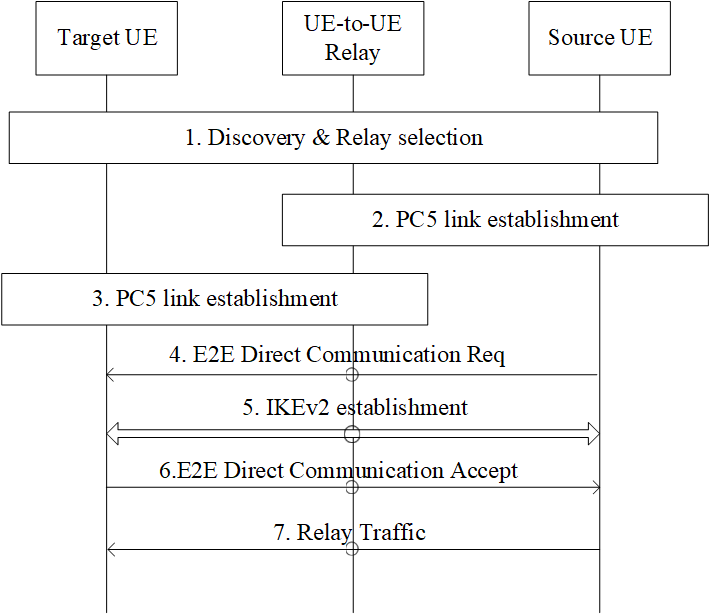


Figure 6.21.2-1: PC5 link security establishment procedure for 5G ProSe Layer-3 UE-to-UE Relay

1. The Discovery & Relay Selection procedure is performed between the peer UEs and the UE-to-UE Relay.

2. The Source UE initiates the PC5 link setup with UE-to-UE Relay by performing the Direct Communication procedures specified in TS 33.503 [6].

3. After the PC5 link between the Source UE and UE-to-UE Relay is established, the UE-to-UE Relay initiates the PC5 link setup with the Target UE based on the Direct Communication procedure specified in TS 33.503 [6].

4. The Source UE sends E2E Direct Communication Request to the Target UE, which is forwarded by the Layer-3 U2U relay. The E2E Direct Communication Request is protected by the NRPIK/NRPEK of each hop (i.e. the link between Source UE and Layer-3 U2U Relay and the link between Layer-3 U2U Relay and Target UE).

5. [Optional]The Target UE initiates the security negotiation procedure with the Source UE to establish an end-to-end IPSec connection by performing IKEv2 authentication procedure. After the IKEv2 authentication, the Source UE and the Target UE generate the E2E security keys. The details of IKEv2 protocol is out of the scope of 3GPP.

NOTE: The detail of IKEv2 protocol is out of the scope of 3GPP.

6. The Target UE responds with the E2E Direct Communication Accept forwarded by the Layer-3 U2U Relay. The E2E Direct Communication Accept is protected by the E2E security keys generated in step 5.

7. The End-to-End PC5 link between the Source UE and the Target UE via the UE-to-UE Relay is established. The UE-to-UE Relay can forward the traffic between the peer UEs.

### 6.21.3 Evaluation

This solution ensures that the Source End UE can establish the E2E security with Target End UE via Layer-3 UE-to-UE relay.

If the E2E PC5 link is needed, the E2E security is established after the hop-by-hop security. The IKEv2 protocol is performed between Source End UE and Target End UE to establish the E2E security. The detail of IKEv2 protocol is out of the 3GPP scope.

## 6.22 Solution #22: Common security protection setup via UE-to-UE Relay

### 6.22.1 Introduction

This solution addresses security requirement for the U2U relay and the remote UEs to use a common security protection scheme in key issue #5.

The solution reuses existing provisioning, discovery, authentication, authorization, and PC5 establishment procedures as much as possible. Once Source and Target UEs and U2U relay have been authenticated and authorized, a common protection scheme is applied among Source UE, Target UE, and U2U relay so that the communication between Source UE and Target is protected either using hop-by-hop via the U2U relay or end-to-end between the source and target UEs.

### 6.22.2 Solution details

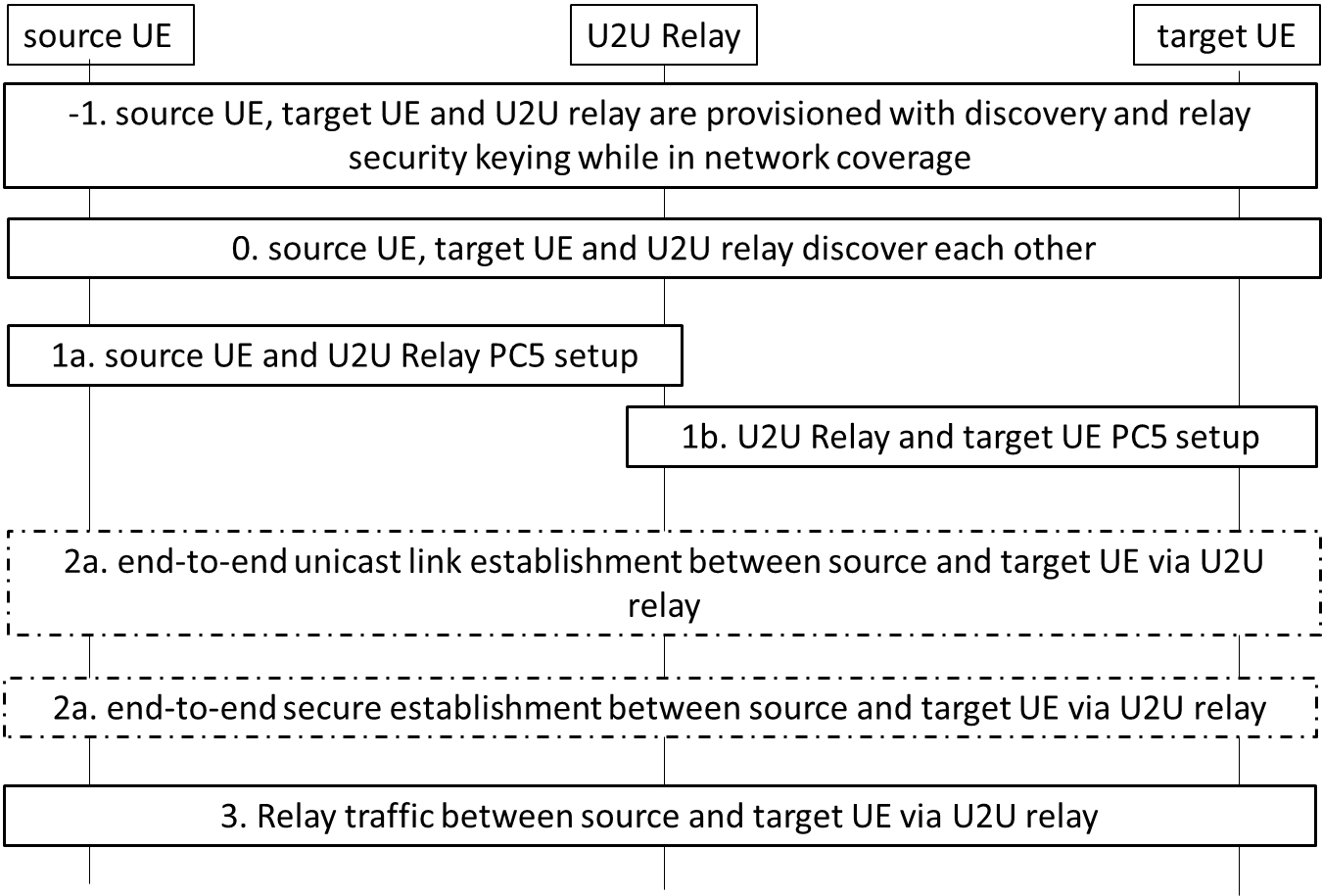


Figure 6.22.2.1: Security establishment for UE-to-UE relay

1. While still in network coverage, the source UE, target UE and the U2U relay get the discovery parameters. The source and target UEs can be provisioned with the security materials for PC5 security setup or end-to-end security setup. Additionally, source UE, target UE and U2U relay can be provisioned with security policy for the protection scheme to be used for communication between source UE and target UE.

0. The Source UE, Relay UE and Target UE discover each other. This solution does not address the key issue of U2U relay discovery security.

1a. During PC5 link setup procedure between source UE and U2U relay, based on security policy of either the source UE or U2U relay, the PC5 link setup may include security establishment between the source UE and U2U relay. The PC5 link establishment procedure may need to be enhanced to indicate that which security is to be applied. If the security policy (e.g. flag or indicator to use hop-by-hop) of the source UE is to use hop-by-hop security protection, source UE indicates to the U2U relay by a Direct Communication Request followed by a Direct Authorization and Key procedure.

If the security policy of the U2U relay is the same as the source UE, the U2U relay continues with and completes the PC5 link setup procedure, including the Direct Security Mode procedure. This means that the PC5 link setup includes security establishment, and that hop-by-hop security is intended. Otherwise, the source UE and U2U relay only set up the PC5 without security protection. Since both source UE and U2U relay are aware of the security protection to be used (e.g. hop-by-hop), the U2U relay repeats the process with target UE.

NOTE: U2U relay may override the security policy of the source UE, for example, if U2U relay is unable to support hop-by-hop security due to capacity reasons such as being low in power.

1b. During PC5 link setup procedure between target UE and U2U relay, U2U relay is aware of the security protection scheme to be used between source UE and U2U relay. U2U relay proceeds to setup PC5 link with target UE with the same protection scheme as the one between source UE and U2U relay. If hop-by-hop security protection is already established between source UE and U2U relay, the PC5 link setup includes security establishment between the target UE and U2U relay. If the security policy of the target UE is to use end-to-end security, target UE may reject the PC5 link setup by including an appropriate reason for rejecting the setup. Otherwise, target UE and U2U relay completes the PC5 link setup procedure including security establishment.

2a. Source UE, target UE and U2U relay are aware PC5 security has been activated, and that end-to-end security is not needed. End-to-end link is established between source UE and target UE via U2U relay. Step 2b is skipped.

2b. If Step 2a is skipped, it means that Steps 1a and 1b do not contain security establishment during PC5 link setup. Source UE, target UE and U2U relay are aware that PC5 security has not been activated and that end-to-end security is needed. End-to-end security establishment proceeds between source UE and target UE.

3. Traffic between source UE and target UE continues. Depending on the previous steps taken, the traffic between source UE and target UE is either protected hop-by-hop or end-to-end.

### 6.22.3 Evaluation

This solution addresses the requirements in KI#5 by applying a common security protection scheme between Source UE, Target UE, and U2U relay. Existing solutions for provisioning, discovery, authentication and authorization, PC5 link establishment are reused as much as possible.

## 6.23 Solution #23: Security mechanism for UE-to-UE Relay Model A discovery

### 6.23.1 Introduction

This solution addresses the Key Issue #1.

An Announcement message by the U2U relay includes two sets of elements, i.e. direct discovery set(s) (e.g. the User Info ID of source UE and target UE) and a U2U discovery set (e.g. Type of Discovery Message, RSC, User Info ID of the relay). The 5G ProSe U2U Relay only modifies the elements of the U2U discovery set. The direct discovery set is constructed by the target UE and is only interpreted by the source UE. The U2U Relay can use a single RSC (and the associated security materials) to relay direct discovery sets associated with the multiple ProSe services. This means that the 5G ProSe U2U Relay uses the same security materials to protect the Announcement messages that contain the direct discovery sets associated with different ProSe services. Unless each direct discovery set is protected using the security materials of the corresponding ProSe service, a source UE (or a target UE) that is authorized to use the RSC for U2U discovery can decrypt (and manipulate) any direct discovery sets that are delivered using the same RSC. This poses security threats.

To prevent such security threats, this solution proposes a U2U discovery security mechanism that protects the Announcement message using two sets of security materials (i.e. the Announcement message and the direct discovery set(s) are protected using the respective set of security materials).

### 6.23.2 Solution details



Figure 6.23.2-1: Model A discovery

0. This solution consists of two protection mechanisms using two sets of security materials: one for the direct discovery set(s) protection and the other one for the Announcement message protection.

1. Direct discovery set(s) protection by the target UE:

The target UE is provisioned with the ProSe restricted code, RSC, and the respective discovery security materials as specified in clause 6.1.3.2.2 of TS 33.503 [6].

The target UE protects the direct discovery set(s) using the discovery security materials associated with the ProSe restricted code as specified in clause 6.1.3.2.3 of TS 33.503 [6].

The target UE protects the direct discovery set(s) using the discovery security materials associated with the RSC as specified in clause 6.1.3.2.3 of TS 33.503 [6].

The target UE provides the protected direct discovery set(s) to the U2U Relay.

NOTE 1: the protection mechanisms specified in clause 6.1.3.2.3 of TS 33.503 [6] are reused for the direct discovery set and U2U discovery set protection. The details of how the protection mechanisms in clause 6.1.3.2.3 of TS 33.503 [6] is applied to the U2U discovery message protection will be specified during the normative work.

NOTE 2: The direct discovery set contains all information (e.g. UTC-based time counter and MIC) needed to process (decrypt/integrity check) it.

2. Announcement message protection by U2U Relay:

The U2U Relay and source UE are provisioned with the RSC for a U2U relay service and the discovery security materials associated with the RSC as specified in clause 6.1.3.2.2 of TS 33.503 [6].

The U2U Relay constructs an Announcement message that contains RSC, user info ID of itself, and the direct discovery set(s) received from the target UE, as specified in TS 23.304 [8].

NOTE 3: The direct discovery set, if its protection is enabled, is protected by the Target UE. The Relay UE includes them in the Announcement message without modification.

The U2U Relay protects an Announcement message using the provisioned discovery security materials associated with the RSC as specified in clause 6.1.3.2.3 of TS 33.503 [6].

3. Announcement message processing by Source UE:

The source UE that is provisioned with the ProSe restricted code, RSC, and the respective discovery security materials as in the target UE, processes the Announce message as follows.

The source UE decrypts and/or verifies the received Announcement message using the discovery security materials associated with the RSC. Then, the source UE extracts the direct discovery set(s) from the Announcement message and decrypts and/or verifies the direct discovery set(s) using the discovery security materials associated with the ProSe restricted code as specified in clause 6.1.3.2.3 of TS 33.503 [6].

### 6.23.3 Evaluation

This solution addresses the Key Issue #1.

This solution fulfils all security requirements of the Key Issue #1.

This solution requires to support provisioning of:

- two sets of discovery security materials at source UE and target UE.

NOTE: How the freshness of protected direct discovery set is maintained with Model A with this solution is not addressed in the present document.

## 6.24 Solution #24: Security mechanism for UE-to-UE Relay Model B discovery

### 6.24.1 Introduction

This solution addresses the Key Issue #1.

A (relayed) Solicitation message and (relayed) Response message by the U2U relay includes two sets of elements, i.e. direct discovery set(s) (e.g. the User Info ID of source UE and target UE) and a U2U discovery set (e.g. Type of Discovery Message, RSC, User Info ID of the relay). The 5G ProSe U2U Relay only modifies the elements of the U2U discovery set. The direct discovery set that is constructed by the source UE can only be interpreted by the target UE, and vice versa. The U2U Relay can use a single RSC (and the associated security materials) to relay direct discovery sets associated with the multiple ProSe services. This means that the 5G ProSe U2U Relay uses the same security materials to protect the discovery messages that contain the direct discovery sets associated with different ProSe service. Unless each direct discovery set is protected using the security materials of the corresponding ProSe service, a source UE (or a target UE) that is authorized to use the RSC for U2U discovery can decrypt (and manipulate) any direct discovery sets that are delivered using the same RSC. This poses security threats.

To prevent such security threats, this solution proposes a U2U discovery security mechanism that protects the discovery messages using two sets of security materials (i.e. the discovery messages and the direct discovery set(s) are protected using the respective set of security materials).

### 6.24.2 Solution details



Figure 6.24.2-1: Model B discovery

This solution consists of two protection mechanisms using two sets of security materials: one for the Solicitation and Response message protection and the other one for the direct discovery set(s) protection.

The security procedure is described as follows:

NOTE 1: the procedures for discovery security materials provisioning and protection mechanisms specified in clause 6.1.3.2 of TS 33.503 [6] are reused for the U2U Relay Model B discovery. The details of how the protection mechanisms in clause 6.1.3.2.3 of TS 33.503 [6] is applied to the U2U discovery message protection will be specified during the normative work.

NOTE 2: The direct discovery set contains all information (e.g. UTC-based time counter and MIC) needed to process (decrypt/integrity check) it.

NOTE 3: How to retrieve the corresponding direct security material associated with Prose Code to verify the direct discovery set(s) is not addressed in the present document.0. The source UE, target UE, and U2U Relay are provisioned with the following discovery security materials based on the procedure specified in clause 6.1.3.2.2 of TS 33.503 [6].

0a. The source UE and target UE are provisioned with the discovery security materials associated with the ProSe code (i.e. query and response code) for a ProSe service.

0b. The source UE, target UE, and U2U Relay are provisioned with discovery security materials associated with an RSC.

1. The source UE protects a direct discovery set(s) (e.g. user info ID of target UE) using the discovery security materials associated with the ProSe code. Then, the source UE provides the protected direct discovery set(s) to the U2U Relay via a Solicitation message. The Solicitation message is protected as specified in clause 6.1.3.2.3 of TS 33.503 [6].

2. On receiving the Solicitation message from the source UE, the U2U Relay decrypts and/or verifies the received Solicitation message using the discovery security materials associated with the RSC. If the verification is successful, the U2U Relay constructs a (relayed) Solicitation message that contains U2U discovery set and the direct discovery set(s). Then, the U2U Relay protects the (relayed) Solicitation message using the same security materials and forwards (relays) the message to the target UE.

3. The target UE decrypts and/or verifies the received Solicitation message using the discovery security materials associated with the RSC. The target UE further extracts the protected direct discovery set(s) from the message and decrypts and/or verifies the direct discovery set(s) using the discovery security materials associated with the ProSe code.

4. The target UE protects direct discovery set(s) (e.g. user info ID of source UE) using the discovery security materials associated with the ProSe code and includes it in a Response message. Then, the target UE protects the Response message using the discovery security materials associated with the RSC and sends the message to the U2U Relay.

5. The U2U Relay decrypts and/or verifies the received Response message using the discovery security materials associated with the RSC. If the verification is successful, the U2U Relay constructs a (relayed) Response message that contains (modified) U2U discovery set and the direct discovery set(s) and protects the message using the same security materials. Then, the U2U Relay forwards (relays) the message to the source UE.

6. The source UE decrypts and/or verifies the received Response message using the discovery security materials associated with the RSC. If the verification is successful, the source UE further extracts the protected direct discovery set(s) from the message and decrypts and/or verifies the direct discovery set(s) using the discovery security materials associated with the ProSe code as specified in clause 6.1.3.2.3 of TS 33.503 [6].

### 6.24.3 Evaluation

This solution addresses the Key Issue #1.

This solution fulfils all security requirements of the Key Issue #1.

This solution requires to support provisioning of:

- Two sets of discovery security materials at source UE and target UE.

- This solution reuses the security material provisioning mechanism for Restricted 5G ProSe Direct Discovery as specified in TS 33.503 for the provisioning of discovery security materials for the direct discovery set.

- This solution reuses the security material provisioning mechanism for 5G ProSe UE-to-Network Relay discovery as specified in TS 33.503 for the provisioning of discovery security materials for the U2U relay discovery message.

## 6.25 Solution #25: PC5 link setup for Layer-3 UE-to-UE Relay

### 6.25.1 Introduction

This solution addresses the KI #2. This solution provides a mechanism to setup a connection between source and target UEs via the UE-to-UE (U2U) Relay. This solution is a Layer-3 (L3) U2U Relay solution when the U2U Relay is in coverage and is based on the L3 user-plane UE-to-Network Relay architecture specified in TS 33.503 [6]. This solution only describes the PC5 link setup procedure between the source/target UE and the U2U Relay and end-to-end security setup between source and target UEs. The end-to-end security is an optional feature and is only established when configured by the service (i.e. 5G ProSe Key Management Function).

### 6.25.2 Solution details



Figure 6.25.2-1:. Secure PC5 link establishment procedure for UE-to-UE Relay

NOTE 1: In this solution, the source and target UEs, and U2U Relay are assumed to be provisioned with the discovery security materials when they are in coverage. Also, those security materials are associated with an expiration time, after which they become invalid. When the security materials become invalid the source/target UE needs to be in coverage to obtain fresh ones to be able to connect via U2U Relay.

Note 2: The details of discovery security materials are addressed in other solutions addressing KI#1 in the present document.

0. The source UE, target UE and the U2U Relay get the discovery parameters and 5G Prose Key management function (PKMF) address from the 5G DDNMF and the discovery security materials from the 5G PKMF respectively. Furthermore, the source and target UEs are provisioned with the security materials for end-to-end security setup by the PKMF if the U2U Relay service requires end-to-end security.

1a. The source UE performs the discovery procedure.

NOTE 3: The discovery procedure is based on the solution of Key Issue #1.

1b. The source UE performs a PC5 unicast link setup procedure with the U2U Relay. The PC5 unicast link setup procedure is based on the procedure specified in clause 6.3.3.2.2 of TS 33.503 [6].

2. The target UE performs the discovery procedure and PC5 unicast link setup procedure with the U2U Relay in the same manner as source UE.

3. The source UE and target UE establish an end-to-end IPsec connection via U2U Relay if security materials for end-to-end security are provisioned by the 5G PKMF. To establish an end-to-end IPsec connection, the source UE and target UE may perform IKEv2 authentication using the keying materials provisioned in step 0.

NOTE 4: Whether the end-to-end IPsec is needed is configured at the source UE and target UE by the 5G PKMF.

### NOTE 5: The needs of E2E security in L3 solution is not addressed in the present document.6.25.3 Evaluation

This solution provides end-to-end confidentiality and integrity protection of communication between the peer UEs over the U2U Relay at the IP layer.

This solution provides confidentiality and integrity protection of user-plane data and control-plane signalling between the source UE/target UE and the U2U Relay based on the PC5 security establishment procedure over User Plane as specified in clause 6.3.3.2.2 of TS 33.503 [6] when the U2U Relay is in coverage.

## 6.26 Solution #26: UE-to-UE relay PC5 connection security establishment

### 6.26.1 Introduction

This solution addresses Key issue #2 (Security of UE-to-UE Relay) and Key issue #3 (Authorization in the UE-to-UE Relay Scenario). This solution reuses the mechanism of unicast mode 5G ProSe Direct Communication security defined in TS 33.503 [6] to setup the security of UE-to-UE Relay Communication. This solution covers both In-Coverage and Out-of-Coverage under both L2 and L3 UE-to-UE relay scenarios.

### 6.26.2 Solution details

This solution reuses the mechanism of unicast mode 5G ProSe Direct Communication security defined in TS 33.503 [6] to setup the security of UE-to-UE Relay Communication. The security between UEs based on the provisioned/pre-configured Long-term credentials in the UEs (i.e. source End UE, target End UE and UE-to-UE Relay) involved in the UE-to-UE relay communication. The Long-term credentials are used to form the root of the security of the PC5 unicast link by exchanging the key\_est\_info during Direct Authentication and Key Establishment procedures as specified in TS 33.503 [6].

The PC5 connection security establishment procedures between the End UE (source End UE or target End UE) and UE-to-UE Relay, or between the End UEs (only for L2 case) follow the procedures below:

0. ProSe UE-to-UE relay communication security-related parameter pre-configuration and provisioning, the security-related parameter includes the Long-term credential and signalling/user plane security policies. The Long-term credentials are provisioned as specified in clause 5.3.3.1.2.1 of TS 33.536 [9].

NOTE a: How Long-term credential is provisioned is not addressed in the present document.

NOTE 1: Step 0 may happen under network coverage (e.g. provisioned by PCF).

NOTE 2: This solution assumes the UE always has valid Long-term credentials.

1. UE-to-UE discovery procedures to find a peer UE. The peer UE can be source End UE, target End UE and UE-to-UE Relay.

2. In the case, initiating UE determines it needs to establish a PC5 connection with another UE (i.e. the peer UE), the initiating UE sends the Direct Communication Request (DCR) message and this message is received by the peer UE. Under the condition of initiating UE's signalling integrity security policy is not 'NOT NEEDED', the DCR includes the Key\_Est\_Info. The message may also include a KNRP ID if the initiating UE has an existing KNRP for the peer UE.

3. The initiating UE and the peer UE exchanges Direct Auth and Key Establishment messages including Key\_Est\_Info. This is mandatory if the peer UE does not have the KNRP and KNRP ID pair indicated in step 1, and signalling integrity protection is needed.

NOTE 3: It is not addressed in the present document about how the two UE’s authorise each other for direct communication.

4. In case the signalling integrity protection is needed, peer UE calculates KNRP and send a Direct Security Mode Command message to initiating UE, including MSB of KNRP ID.

5. On receiving the Direct Security Mode Command, the initiating UE calculates KNRP and choose the LSB of KNRP ID if signalling integrity protection is needed. Initiating UE shall send a Direct Security Mode Complete message to UE\_2 which contains the LSB of KNRP ID.

### 6.26.3 Evaluation

The security of the PC5 link relies on the provisioned/pre-configured security materials. Security keys for each PC5 connection can be generated without the assistance from the network. Therefore, the Source UE and the Target UE can establish the UE-to-UE connection via UE-to-UE Relay regardless of whether they are within or out of network coverage.

Note: Further evaluation is needed.

## 6.27 Solution #27: Support Emergency Service over L3 and L2 UE-to-Network Relay

### 6.27.1 Introduction

This solution addresses KI#6: Support Emergency Service over UE-to-Network Relay. This solution addresses a L3 UE-to-Network relay.

The PC5 link establishment procedure can be applied to both L3 and L2 Relay.

In the 5G ProSe UE-to-Network relaying, if there is an emergency request from the remote UE, the Relay UE is responsible for remote UE's emergency service. It is assumed the Relay UE gets the regulation and the associated operator policy about emergency service from the Relay UE's serving PLMN.

Based on the regulation and the operator policy, the Relay UE supports to establish PC5 communication for emergency service, for either an authenticated Remote UE (e.g. Remote UE with USIM and properly being authenticated by UP or CP based security procedure) or an unauthenticated Remote UE (e.g. Remote UE without USIM or authentication cannot complete for any reason).

Based on the regulation and the operator policy, the announcement and discovery of Emergency RSC and the PC5 link establishment may be performed without security protection, e.g. for a Remote UE without USIM nor pre-configured discovery security materials.

Based on the regulation, the operator policy and UP security policies of the remote UE and the Relay UE for the emergency RSC, the UP traffic may be transmitted via PC5 link without security protection for an unauthenticated Remote UE e.g. Remote UE without USIM or authentication cannot complete for any reason.

In Remote UE Report for emergency service, Remote User ID i.e. (UP-/CP-) PRUK ID is used as UE ID for the authenticated Remote UE. In case of unauthenticated Remote UE, PEI is used to identify the UE in Remote UE Report.

It is assumed that the 5G ProSe enabled UE acting as Relay has a USIM and is registered to a PLMN in case of emergency service.

### 6.27.2 Solution details

Figure 6.27.2-1 illustrates the high-level procedure of the proposed solution. 5GC NFs and internal signalling are not described in detail here for brevity.



Figure 6.27.2-1: High-level procedure of PC5 link establishment for Emergency Service over UE-to-Network relay

0a. The 5G ProSe UE-to-Network relay is provisioned with the discovery security materials as described in TS 33.503 [6]. Based on the regulation and the operator policy, there may or may not be discovery security materials provisioned for Emergency RSC.

0a. The 5G ProSe Remote UE is provisioned with the discovery security materials and retrieves the UP-PRUK and UP-PRUK ID for UP based security method from the network as described in TS 33.503 [6]. Based on the regulation and the operator policy, there may be or may be no discovery security materials provisioned for Emergency RSC.

If the 5G ProSe Remote UE is USIM-less, this step is skipped. The Emergency RSC and the discovery security materials if exist are locally configured in the 5G ProSe Remote UE.

1. The discovery procedure for the Emergency RSC is performed between the 5G ProSe Remote UE and the 5G ProSe UE-to-Network Relay using the discovery parameters and discovery security material as described in TS 33.503 [6].

Based on the regulation and the operator policy, the announcement and discovery of Emergency RSC may be performed without security protection.

2. If the 5G ProSe Remote UE has USIM, the 5G ProSe Remote UE sends a Direct Communication Request (DCR) that contains (UP-/CP-) PRUK ID or SUCI, Emergency RSC and KNRP freshness parameter 1 to the 5G ProSe UE-to-Network Relay. The message may additionally include the PEI of the 5G ProSe Remote UE.

If the 5G ProSe Remote UE is USIM-less, the 5G ProSe Remote UE sends a Direct Communication Request that contains PEI, Emergency RSC to the 5G ProSe UE-to-Network Relay.

3. If (UP-/CP-) PRUK ID or SUCI is received, the 5G ProSe UE-to-Network Relay performs UP or CP based security procedure as described in TS 33.503 [6].

If only PEI and Emergency RSC are received, the 5G ProSe UE-to-Network Relay skips this step if the regulation and the operator policy allow.

4. If step 3 is successfully performed, the 5G ProSe UE-to-Network Relay performs Direct Security Mode Command procedure towards the 5G ProSe Remote UE as described in TS 33.503 [6].

If step 3 is failed or skipped, e.g. the 5G ProSe Remote UE is USIM-less, the 5G ProSe UE-to-Network Relay performs Direct Security Mode Command procedure with Null ciphering and integrity protection if the regulation and the operator policy allow. In this case, the 5G ProSe Remote UE treats UP integrity protection as not activated for this connection and includes the UP integrity protection policy as NOT NEEDED in the Direct Security Mode Complete. The 5G ProSe UE-to-Network Relay sets UP integrity protection to OFF.

The 5G ProSe Remote UE accepts Null ciphering and integrity algorithms if, and only if, the Remote UE has sent an Emergency RSC in step 2.

UP confidentiality protection policy is handled as specified in TS 33.536 [9].

5. If the 5G ProSe Remote UE is not authenticated successfully via UP or CP based security procedure and PEI is not received from Direct Communication Request, the 5G ProSe UE-to-Network Relay sends Remote Identity Request to the 5G ProSe Remote UE to retrieve the PEI based on the regulation and the operator policy.

6. The 5G ProSe UE-to-Network Relay sends a Direct Communication Accept message to the 5G ProSe Remote UE to finish the PC5 connection establishment procedures for the emergency service.

The 5G ProSe UE-to-Network Relay includes the configuration of UP integrity and confidentiality protection based on the agreed UP security policy in the Direct Communication Accept message as specified in TS 33.536 [9].

7. When the 5G ProSe Layer-3 UE-to-Network Relay sends a Remote UE Report to the SMF for the Emergency RSC, the 5G ProSe Layer-3 UE-to-Network Relay includes Remote User ID i.e. (UP-/CP-) PRUK ID if UP or CP based security procedure is successfully performed. Otherwise, the 5G ProSe Layer-3 UE-to-Network Relay includes the PEI of the 5G ProSe Remote UE in the Remote UE Report.

If UP confidentiality protection is not activated for this connection, the UP confidentiality protection algorithm is the same as the selected signalling confidentiality algorithm as specified in TS 33.536 [9].

If UP integrity protection is not activated for this connection, the 5G ProSe Remote UE and the 5G ProSe Layer-3 UE-to-Network Relay do not put MAC-I into PDCP packet

NOTE: It is assumed that the SMF is able to resolve a PRUK ID into a SUPI.

### 6.27.3 Evaluation

This solution resolves KI#6: Support Emergency Service over UE-to-Network Relay.

This solution can be applied to both Layer 2 Relay and Layer 3 Relay.

In this solution it is assumed that the 5G ProSe enabled UE acting as a UE-to-Network Relay has a USIM and is registered to a PLMN in case of emergency service.

This solution assumes that if there is an emergency request from the Remote UE in the 5G ProSe UE-to-Network relaying, the UE-to-network relay is responsible for Remote UE's emergency service. It is assumed the UE-to-network relay gets the regulation and the associated operator policy about emergency service from the UE-to-network relay's serving PLMN. Based on the regulation and the operator policy, the UE-to-network relay supports to establish PC5 communication for emergency service, for either an authenticated Remote UE (e.g. Remote UE with USIM and properly being authenticated by UP or CP based security procedure) or an unauthenticated Remote UE (e.g. Remote UE without USIM or authentication cannot complete for any reason).

This solution assumes that a specific Emergency RSC has been defined. The announcement and discovery of Emergency RSC and the PC5 link establishment may be performed without security protection, e.g. for a Remote UE without USIM nor pre-configured discovery security materials.

For a Remote UE without a USIM, the Remote UE can provide its PEI via the UE-to-network relay to the network, which is used to identify the Remote UE in the network.

In Remote UE Report for emergency service, Remote User ID i.e. (UP-/CP-) PRUK ID is used as UE ID for the authenticated Remote UE. In case of unauthenticated Remote UE, PEI is used to identify the Remote UE in Remote UE Report.

If the Remote UE is USIM-less or authentication cannot complete for any reason, then the 5G ProSe UE-to-Network Relay performs Direct Security Mode Command procedure with Null ciphering and integrity protection if the regulation and the operator policy allow. In this case, the 5G ProSe Remote UE treats UP integrity protection as not activated for this connection and includes the UP integrity protection policy as NOT NEEDED in the Direct Security Mode Complete. The 5G ProSe UE-to-Network Relay sets UP integrity protection to OFF in this case.

The UP confidentiality protection policy is handled as specified in TS 33.536 [9].

This solution allows a Remote UE without a USIM to initiate emergency services with the network via a 5G ProSe UE-to-Network.

## 6.28 Solution #28: UE-to-UE relay discovery security

### 6.28.1 Introduction

This solution addresses Key Issue #1: Security for UE-to-UE Relay discovery and Key issue #3: Authorization in the UE-to-UE Relay Scenario. For Key Issue #1, this solution specifically addresses the security requirement:

The 5G System provides a means for confidentiality protection, integrity protection and replay protection of discovery messages for UE-to-UE Relay discovery.

In clause of 8.1 of TR 23.700-33 [2], there are the following conclusions about 5G ProSe UE-to-UE Relay discovery:

*- The 5G ProSe UE-to-UE Relay discovery message contains two sets of elements, i.e. direct discovery set(s) and a U2U discovery set.*

*- The direct discovery set of elements can be part of the contents of 5G ProSe Direct Discovery message as defined in Rel-17. This includes for example the User Info ID of Source UE and Target UE.*

*- The U2U discovery set contains the information to support the discovery of the UE-to-UE relay and extensions of the direct discovery. This includes for example Type of Discovery Message, RSC, User Info ID of the relay, etc.*

*- 5G ProSe UE-to-UE relay only modifies the U2U set of the elements, and forwards the end-to-end elements during the discovery procedures.*

In clause 5.1.3 of the present document, there are the following security requirements for 5G ProSe UE-to-UE Relay discovery:

*The 5G System shall provide a means for confidentiality protection, integrity protection and replay protection of discovery messages for UE-to-UE Relay discovery.*

*The 5G System shall provide a means to protect the privacy sensitive information of source UE and target UE during UE-to-UE Relay discovery procedure.*

This solution proposes reusing the existing security mechanism specified in TS 33.503 [6] to protect the direct discovery set and U2U discovery set in U2U relay discovery messages.

The security requirements for U2U relay discovery messages may vary, such as in a U2U relay application, all the UEs can be the role of Source, Target or Relay UE, and all of them have the same security parameters used to protect discovery messages. In this case, no additional security protection may be required for the direct discovery message. In other cases, only confidentiality or integrity protection may be required. In addition, when the UE is in a low power situation, it may want to disable some security functions, such as direct discovery message security, because in this case, communication capability is more important than security. Therefore, the flexibility of controlling the message security of U2U relay discovery should be considered to meet the requirements of various application scenarios. A security policy indicator is introduced into the U2U relay discovery message to control how to handle the security of the direct discovery set to avoid unnecessary security protection in some scenarios.

This solution introduces two sets of security parameters, one for protecting the direct discovery set and the other for protecting U2U discovery set. In this way, the Source/Target UE and the Relay UE can be authorized in the UE-to-UE relay scenario.

### 6.28.2 Solution details

#### 6.28.2.1 UE-to-UE relay discovery security of Model A

 Figure 6.28.2-1: Security procedure of UE-to-UE relay discovery of Model A

0. Key management function (PCF/5G DDNMF/PKMF) is responsible for provisioning discovery security parameters to the UEs involved in direct discovery and U2U relay discovery. The key management functions used to provision direct discovery security parameters and U2U relay discovery security parameters can be different. Direct discovery security parameters are provisioned to the Source UE (Monitoring UE) and Target UE (Announcing UE). U2U relay discovery security parameters are provisioned to the Source UE, Target UE and Relay UE, and are associated with a RSC. The security related parameters used in U2U relay discovery are the same as those used in direct discovery specified in TS 33.503 [6].

For U2U relay discovery Model A, there are:

- Code-Sending Security Parameters and other security related parameters used in direct discovery are provisioned to the Target UE (Announcing UE).

- Code-Receiving Security Parameters and other security related parameters used in direct discovery are provisioned to the Source UE (Monitoring UE).

- Code-Sending Security Parameters and other security related parameters used in U2U relay discovery are provisioned to the Target UE (Announcing UE) and Relay UE. These parameters are associated with a RSC.

- Code-Receiving Security Parameters and other security related parameters used in U2U relay discovery are provisioned to the Source UE (Monitoring UE) and Relay UE. These parameters are associated with a RSC.

NOTE 1: More details about how to provision discovery security parameters to the Source UE, Target UE, and Relay UE are not addressed in this solution.

U2U relay discovery security policy can be provisioned or preconfigured in the Source UE. U2U relay discovery security policy specifies what security protection should be applied to the direct discovery message carried in the relay discovery message. Security protection can be confidentiality protection, integrity protection, scrambling protection, or none. The U2U relay discovery security policy can also indicate that a preconfigured security policy will be used to protect U2U relay discovery message. The method of including security policies in U2U relay discovery messages can provide maximum security control flexibility for ProSe relay discovery scenarios.

NOTE 1a: Need for discovery security policy is not addressed in the present document.1. The Target UE (Announcing UE) generates U2U relay discovery message as follows:

- Generate direct discovery set (see clause 8.1 of TR 23.700-33 [2]) , and then protect it with the direct discovery security parameters by using the procedures defined in clause 6.1.3.2.3 of TS 33.503 [6] according to the U2U relay discovery security policy.

- Generate the plaintext of relay discovery message sent to the Relay UE as specified in clause 8.1 of TR 23.700-33 [2], and then protect it with the relay discovery security parameters associated with the RSC by using the procedures defined in clause 6.1.3.2.3 of TS 33.503 [6] with the following extensions:

- RSC indicates which relay discovery security parameters are used to protect the relay discovery message.

- Message sender indicator indicates this message is generated by the Target UE.

- U2U Relay discovery security policy indicator indicates how the direct discovery message is protected.

- Direct discovery set.

- U2U relay control parameter indicates how the Relay UE handles discovery message it receives. The U2U relay control parameter can specify:

- Message validity period: It specifies the validity time of this message. During this validity period, the Relay UE will continue to include the announcement information of the message in its announcement messages, even if the connection to the Announcing UE has been established.

- Maximum forwarding delay: It specifies the maximum delay time for the Relay UE to send the announcement information in the message in its announcement message for the first time. If its value is set to zero, it means that the Relay UE should immediately process the message.

- Message forwarding frequency: It specifies at which frequency (such as once per minute) the Relay UE should announce the announcement information in this message.

- Stop forwarding messages: It allows Announcing UE can actively request Relay UEs to stop forwarding its messages. This option does not affect any existing connections.

Note 1b: How Model A using protected discovery set is supported for the case of End UE discovered via prior communication procedure is not addressed in the present document.

Note 1c: Usage of maximum forwarding delay parameter is not addressed in the present document.

Note 1d: Usage forwarding frequency and stop forwarding parameter is not addressed in the present document.

Note 1e: How the U2U relay control parameter is configured in the End UE is not addressed in the present document.

NOTE 2: How the direct discovery set and U2U discovery set are protected by the direct discovery security parameters and U2U relay discovery security parameters is left to the normative phase.

2. The Target UE sends the relay discovery message to the Relay UE.

3. The Relay UE receives the relay discovery message, and knows that the relay discovery message is targeted at it by checking the Message sender indicator which shows the generator is a Target UE, and then perform the following operations:

- The Relay UE undoes the received U2U relay discovery message with relay discovery security parameters associated with RSC by using the procedures defined in 6.1.3.2.3 of TS 33.503 [6].

- According to the U2U relay control parameter carried in the message, the Relay UE generates a new plaintext of relay discovery message sent to the Source UE as specified in clause 8.1 of TR 23.700-33 [2], and then protect it with the relay discovery security parameters associated with the RSC by using the procedures defined in 6.1.3.2.3 of TS 33.503 [6] with the following extensions:

- RSC indicates which relay discovery security parameters are used to protect the relay discovery message.

- Message sender indicator indicates this message is generated by the Relay UE.

- U2U Relay discovery security policy indicator obtained from the received relay discovery message.

- Direct discovery set obtained from the received U2U relay discovery message.

4. The Relay UE sends the new generated relay discovery message to the Source UE.

5. The Source UE receives the relay discovery message and knows that the relay discovery message is targeted at it by checking the Message sender indicator, which shows the generator is a Relay UE, and then perform the following operations:

- Undo the received relay discovery message with the relay discovery security parameters associated with the RSC.

- If the U2U relay discovery security policy indicator shows that the direct discovery message is protected, undo the direct discovery message or the direct discovery set with the direct discovery security parameters.

#### 6.28.2.2 UE-to-UE relay discovery security of Model B

 Figure 6.28.2-2: Security procedure of UE-to-UE relay discovery of Model B

0. Key management function (PCF/5G DDNMF/PKMF) is responsible for provisioning discovery security parameters to the UEs involved in direct discovery and U2U relay discovery. The key management functions used to provision direct discovery security parameters and U2U relay discovery security parameters can be different. Direct discovery security parameters are provisioned to the Source UE and Target UE. U2U relay discovery security parameters are provisioned to the Source UE, Target UE and Relay UE, and are associated with a RSC. The security related parameters used in U2U relay discovery are the same as those used in direct discovery specified in TS 33.503 [6].

For U2U relay discovery Model B, there are:

- Code-Sending Security Parameters, Code-Receiving Security Parameters and other security related parameters used in direct discovery are provisioned to the Source UE (Discoverer UE) and Target UE (Discoveree UE).

- Code-Sending Security Parameters, Code-Receiving Security Parameters and other security related parameters used in U2U relay discovery are provisioned to the Source UE (Discoverer UE), Target UE (Discoveree UE) and Relay UE. These parameters are associated with a RSC.

NOTE 1: More details about how to provision discovery security parameters to the Source UE, Target UE, and Relay UE are not addressed in this solution.

U2U relay discovery security policy can be provisioned or preconfigured in the Source UE and Target UE. U2U relay discovery security policy specifies what security protection should be applied to the direct discovery message carried in the relay discovery message. Security protection can be confidentiality protection, integrity protection, scrambling protection, or none. The U2U relay discovery security policy can also indicate that a preconfigured security policy will be used to protect U2U relay discovery message. The method of including security policies in U2U relay discovery messages can provide maximum security control flexibility for ProSe relay discovery scenarios.

Note 1a: Need for discovery security policy is not addressed in the present document.

1. The Source UE (Discoverer UE) generates relay discovery message as follows:

- Generate direct discovery set (see clause 8.1 of TR 23.700-33 [2]) , and then protect it with the direct discovery security parameters by using the procedures defined in 6.1.3.2.3 of TS 33.503 [6] according to the U2U relay discovery security policy.

- Generate the plaintext of relay discovery message sent to the Relay UE as specified in clause 8.1 of TR 23.700-33 [2], and then protect it with the relay discovery security parameters associated with the RSC by using the procedures defined in 6.1.3.2.3 of TS 33.503 [6] with the following extensions:

- RSC indicates which relay discovery security parameters are used to protect the relay discovery message.

- Message sender indicator indicates this message is generated by the Source UE.

- U2U Relay discovery security policy indicator indicates how the direct discovery message is protected.

- Direct discovery set.

- U2U relay control parameter indicates how the Relay UE handles discovery message it receives. The U2U relay control parameter can specify:

- Message validity period: It specifies the validity time of this message. During this validity period, the Relay UE will continue to forward the solicitation information in its new solicitation message, even if the connection to a Discoveree UE has been established.

- Maximum forwarding delay: It specifies the maximum delay time for the Relay UE to send the solicitation information in the message in its solicitation message for the first time. If its value is set to zero, it means that the Relay UE should immediately process the message.

- Message forwarding frequency: It specifies at which frequency (such as once per minute) the Relay UE should forward the announcement information in this message.

- Stop forwarding messages: It allows Discoverer UE can actively request Relay UEs to stop forwarding its messages. This option does not affect any existing connections.

NOTE 1b: Whether Model B needs these parameters is not addressed in the present document.NOTE 2: How the direct discovery set and U2U discovery set are protected by the direct discovery security parameters and U2U relay discovery security parameters is left to the normative phase.

2. The Source UE sends the relay discovery message to the Relay UE.

3. The Relay UE receives the relay discovery message, and knows that the relay discovery message is targeted at it by checking the Message sender indicator which shows the generator is a Target UE, and then perform the following operations:

- The Relay UE undoes the received U2U relay discovery message with relay discovery security parameters associated with RSC by using the procedures defined in 6.1.3.2.3 of TS 33.503 [6].

- According to the U2U relay control parameter carried in the message, the Relay UE generates a new plaintext of relay discovery message sent to the Source UE as specified in clause 8.1 of TR 23.700-33 [2], and then protect it with the relay discovery security parameters associated with the RSC by using the procedures defined in 6.1.3.2.3 of TS 33.503 [6] with the following extensions:

- RSC indicates which relay discovery security parameters are used to protect the relay discovery message.

- Message sender indicator indicates this message is generated by the Relay UE.

- U2U Relay discovery security policy indicator obtained from the received relay discovery message.

- Direct discovery set obtained from the received U2U relay discovery message.

4. The Relay UE sends the new generated relay discovery message to the Target UE.

5. The Target UE receives the relay discovery message and knows that the relay discovery message is targeted at it by checking the Message sender indicator, which shows the generator is a Relay UE, and then perform the following operations:

- Undo the received relay discovery message with the relay discovery security parameters associated with the RSC.

- If the U2U relay discovery security policy indicator shows that the direct discovery message is protected, undo the direct discovery message with the direct discovery security parameters.

6-10.The Target UE sends discovery response message to the Source UE via the Relay UE. The security process is similar to the steps 1-5.

### 6.28.3 Evaluation

Solution #28 addresses the first security requirement of key issue #1 and Key issue #3.

This solution uses two sets of security parameters to protect the direct discovery set and U2U discovery set. The security parameters used to protect the direct discovery set are not newly defined. They are the security parameters used in the direct discovery scenario. The security parameters used to protect the U2U discovery set are newly defined. The details of which parameters in the direct discovery set and U2U discovery set need to be protected and how to protect them will be determined in the normative phase.

This solution introduces a security policy, which can flexibly control how to protect the direct discovery set in U2U discovery message according to the security requirements in various situations. For example, all UEs can play the roles of Source, Target and Relay UEs, or the Source/Target UEs are in a low power situation and Source/Target turn off some security functions in order to save some power, etc.

Because the direct discovery security parameters are used to protect the data exchanged between the Source UE and the Target UE, while the U2U discovery security parameters are used to protect the data exchanged between the Source/Target UE and the Relay UE, the authorization requirements described in KI#3 can be met through the key provision process (not addressed in this solution) and the cryptographic technology applied to U2U discovery messages.

This solution does not support Source/Target UE and Relay UE authorization during communication establishment. This authorization may depend on the application layer or other specific solutions.

## 6.29 Solution #29: Hop-by-hop security establishment for the UE-to-UE Relay

### 6.29.1 Introduction

This solution addresses Key Issue #2, #3, and #5. When Source/Target UEs and a Relay UE are in the network coverage, they are authorized and provisioned with the required information for security establishments during the registration procedure that includes the primary authentication (i.e. 5G-AKA or EAP-AKA').

The Source UE sends a Direct Communication Request to the UE-to-UE Relay, so that the direct authentication takes place and the hop-by-hop protection key is established regardless of whether the UEs (the Source UE, Target UE and/or UE-to-UE Relay) are within or outside the network coverage. This solution applies to both Layer-2 UE-to-UE Relay and Layer-3 UE-to-UE Relay.

### 6.29.2 Solution details

#### 6.29.2.1 Hop-by-hop security establishment procedure for the UE-to-UE Relay

Figure 6.29.2.1-1 illustrates the hop-by-hop security establishment procedure between the Source/Target UE and the UE-to-UE Relay.



Figure 6.29.2.1-1: Hop-by-hop security establishment procedure for the UE-to-UE Relay

1) The Source UE, Target UE, and UE-to-UE Relay are authorized and provisioned with the security materials for the hop-by-hop security establishment (refer to clause 6.29.2.2).

2) The discovery and selection procedure may be performed between the Source UE, Target UE, and UE-to-UE Relay using Model A or Model B mode as specified in TS 23.304 [2]. If discovery integrated into PC5 unicast link establishment procedure concluded by SA2 in TR 23.700-33 [3] is to be performed in the following steps, this step is skipped.

3) There are various authentication and key establishment methods to be used between the Source UE and the UE-to-UE Relay. Hence, all the authentication is specified to be carried in a generic container called Auth\_Key\_Info in the following steps.

4) The Source UE generates ephemeral public key (UE1.ePK) and private key (UE1.eSK), and a digital signature (UE1.Sig). The digital signature is signed over the source UE's identity (UE1.ID) and UE1.ePK using the security materials provisioned in step 0. Then, the Source UE generates UE1.Auth\_Key\_Info which includes UE1.ID, UE1.ePK, and UE1.Sig.

5) The Source UE wants to establish a secure PC5 unicast link with the UE-to-UE Relay. The Source UE sends the UE-to-UE Relay a Direct Communication Request message including Relay Service Code (RSC) and its Auth\_Key\_Info. The message also includes the security capabilities and PC5 signalling security policy.

6) Upon reception of the Direct Communication Request message, the UE-to-UE Relay verifies the Source UE with UE1.Sig included in UE1.Auth\_Key\_Info using the security materials provisioned in step 0. If the verification is successful and the UE-to-UE Relay decides to accept the request, the UE-to-UE Relay generates ephemeral public key (UE2.ePK) and private key (UE2.eSK), and a digital signature (UE2.Sig). The digital signature is signed over the UE-to-UE Relay's identity (UE2.ID) and UE2.ePK using the security materials provisioned in step 0. Then, the UE-to-UE Relay generates UE2.Auth\_Key\_Info which includes UE2.ID, UE2.ePK, and UE2.Sig.

7) In this step, the UE-to-UE Relay derives a symmetric key that is used to protect the hop-by-hop link (i.e. hop-by-hop protection key), using the Source UE's ephemeral public key (UE1.ePK) and its own ephemeral private key (UE2.eSK).

8) The UE-to-UE Relay sends the Source UE a Direct Security Mode Command message including RSC and its Auth\_Key\_Info.

9) Upon reception of the Direct Security Mode Command message, the Source UE verifies the UE-to-UE Relay with UE2.Sig included in UE2.Auth\_Key\_Info using the security materials provisioned in step 0. If the verification is successful, the Source UE derives a symmetric key that is used to protect the hop-by-hop link (i.e. hop-by-hop protection key), using the UE-to-UE Relay's ephemeral public key (UE2.ePK) and its own ephemeral private key (UE1.eSK).

10) The Source UE sends the UE-to-UE Relay a Direct Security Mode Complete message.

11) The Source UE and the UE-to-UE Relay finish setting up the secure PC5 communication link with the shared hop-by-hop protection key. The encryption key and integrity key are derived from the hop-by-hop protection key and used in the chosen confidentiality and integrity algorithms, respectively.

12) The hop-by-hop security between the UE-to-UE Relay and the Target UE is established by repeating the step 2-8, where the UE-to-UE Relay initiates the procedure by sending the Direct Communication Request message.

NOTE: This solution applies to the hop-by-hop security establishment of both Layer-2 UE-to-UE Relay and Layer-3 UE-to-UE Relay with the Source/Target UE. The end-to-end security between the Source UE and the Target UE over the UE-to-UE Relay can be established by Solution #19 in this specification.

#### 6.29.2.2 Authorization and Parameter Provisioning to the UEs

The Source/Target UE and the UE-to-UE Relay are authenticated and authorized to receive or provide UE-to-UE Relay service by the network during the primary authentication procedure (i.e. 5G AKA or EAP-AKA'). A UE initiates the procedure by sending a Registration Request message to the network. In the meanwhile, the UDM checks the subscription information, called UE-to-UE indication, related to the UE-to-UE Relay service. The UE-to-UE indication of the Source/Target UE indicates:

- Whether the Source/Target UE is authorized to receive the UE-to-UE Relay service;

And the UE-to-UE indication of the UE-to-UE Relay indicates:

- Whether the UE-to-UE Relay is authorized to provide the UE-to-UE Relay service.

The UE-to-UE indication is transferred from the UDM to the AUSF, and is forwarded to the UE along with the AKA challenge. Upon reception of the UE-to-UE indication, which allows the UE to receive or provide the UE-to-UE Relay service, the UE provides UE-to-UE\_Auth\_Info, which can be used by the AUSF to generate security materials for the hop-by-hop security establishment, to the network along with the AKA challenge response. In the Certificate-based approach, the UE generates a public and private key pair, and generate UE-to-UE\_Auth\_Info including the UE's ID and the generated public key. In the Identity-based approach, the UE generates UE-to-UE\_Auth\_Info including the UE's ID.

Note 1: Which identifier is to be used as a UE’s ID is not addressed in the present document.

Note 2: How and which entity associates UE’s ID with the U2U relay service is not addressed in the present document.

Note 3: AUSF impact for generating and provisioning security materials to UEs is not addressed in the present document.

Note 4: How to support U2U relay services across multiple PLMNs is not addressed in the present document.

If UE-to-UE indication allows the UE to receive or provide the UE-to-UE Relay service, the AUSF generates the security materials using the UE-to-UE\_Auth\_Info and provisions them to the UE. The provisioned security materials are used as long term credentials of the UE. The authorized UE shall be provisioned with the security materials when it has not been provisioned with the security materials before or when the validity of the security materials has been expired.

Note 5: The security materials provisioned to the UE by the network are associated with an expiration time after which they become invalid. If the UE does not have valid security materials, the UE needs to obtain fresh ones to receive or provide the UE-to-UE Relay service.

In the Certificate-based approach, the security materials include the UE's certificate and the root CA certificate(s), which allows the UE to verify the certificates of other UEs. In the Identity-based approach, the security materials include the UE's identity, secret signing key (SSK), public validation token (PVT), and KMS public authentication key(s) (KPAK), which allows the UE to verify the signatures of other UEs.

If the UE is authorized to receive or provide UE-to-UE service based on UE-to-UE indication, PCF provides the security policy/parameters to the UE. The security policy/parameters of the Source/Target UE related to the UE-to-UE Relay service includes Hop-by-hop Security Indicator per RSC and End-to-end Security Indicator per RSC. The security policy/parameters of the UE-to-UE Relay related to the UE-to-UE Relay service includes Hop-by-hop Security Indicator per RSC:

- The Hop-by-hop Security Indicator indicates whether the Source/Target UE requires the hop-by-hop security (signalling integrity, signalling confidentiality, user plane integrity, and user plane confidentiality) establishment with the UE-to-UE Relay, or not.

- The End-to-end Security Indicator indicates whether the Source/Target UE requires the end-to-end security (signalling integrity, signalling confidentiality, user plane integrity, and user plane confidentiality) establishment, or not.

The same hop-by-hop and/or end-to-end protection schemes are supported for the Source UE, Target UE and UE-to-UE Relay provisioned with the same Hop-by-hop Security Indicator and/or End-to-end Security Indicator by a service level to protect the UE-to-UE relay traffic.

### 6.29.3 Evaluation

This solution supports authorization and provisioning of the Source/Target UE and UE-to-UE Relay for the UE-to-UE Relay Communication service when the UEs are in the network coverage.

This solution proposes the hop-by-hop security establishment procedure between the Source/Target UE and the Layer-2 or Layer-3 UE-to-UE Relay using the provisioned security materials, both within and outside the network coverage.

This solution employs a generic container, which allows different authentication and key establishment mechanisms such as certificate-based one and identity-based one to be applied, for the hop-by-hop security establishment. For example, the "Elliptic Curve-based Certificateless Signatures for Identity-based Encryption" (ECCSI) can be used for the identity-based direct authentication and key establishment as described in clause 6.5.7 of TS 33.303 [4].

This solution supports a means for the UEs to agree on the same hop-by-hop security protection schemes in UE-to-UE Relay service.

The solution requires 5GC to support means of managing security materials, such as certificates and UEs' identities, and this may introduce additional complexities on AUSF, AMF, etc.

## 6.30 Solution #30: Security for discovery integrated into PC5 link establishment

### 6.30.1 Introduction

The solution addresses Key Issue #1: Security for UE-to-UE Relay discovery and Key Issue #2: Security of UE-to-UE Relay. It largely reuses the mechanism of Restricted Discovery procedure and Direct Security Establishment procedure defined in TS 33.503 [6]

In addition to the Model A discovery and Model B discovery, discovery integrated into PC5 unicast link establishment procedure is supported in the U2U Relay scenario, which is concluded by SA2. By broadcasting the DCR message, the Source UE and Target UE can discover and select one U2U Relay to establish the PC5 link. However, the broadcast UE identity (i.e. User Info ID) may compromise the user's privacy information and the missing of discovery procedure may introduce additional security threats, e.g. the unauthorized UE-to-UE Relay can arbitrarily initiate to establish the PC5 link with peer UE.

This solution uses the code security parameters to protect the privacy-sensitive information in the DCR message and uses the security materials (i.e. the long term credential) to secure the link establishment. To obtain the code security parameters, the peer UE and UE-to-UE Relay need to send the Discovery Request. Once receiving the Discovery Request, the network can check the authorization of peer UE and U2U Relay, which reuses the Restricted Discovery procedure specified in TS 33.503 [6]. By authorization checking and direct authentication, the hop-by-hop security can be provided between the Source UE and Target UE via 5G ProSe Layer-3 UE-to-UE Relay.

### 6.30.2 Solution details

#### 6.30.2.1 Security for discovery integrated into PC5 link establishment

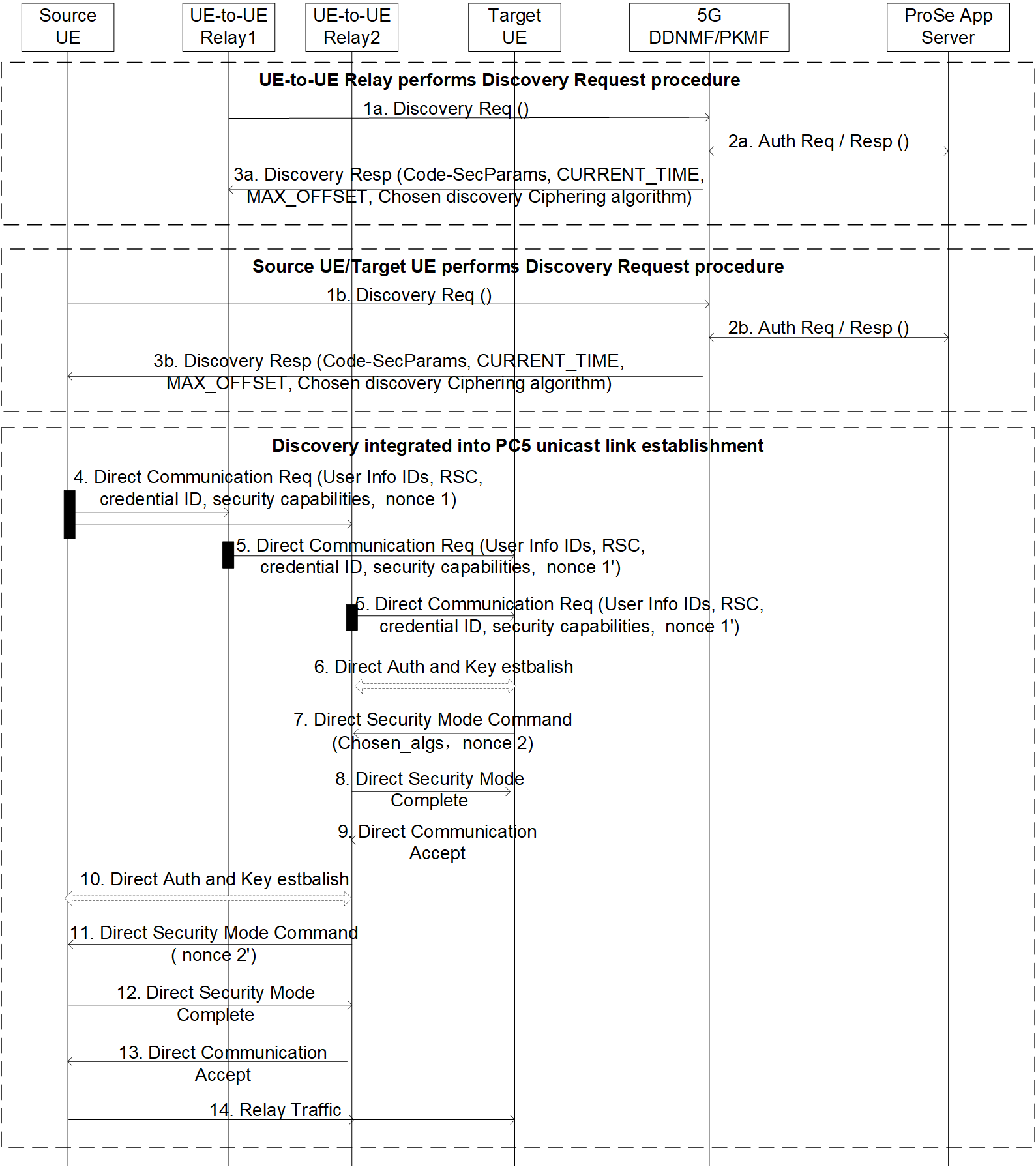


Figure 6.30.2-1: Security for discovery integrated into PC5 link establishment

Note 1: When the user-plane based security procedure for the UE-to-UE Relay is used, the 5G PKMF takes the role of the 5G DDNMF.

Steps 1a-3a refer to the Discovery Key Request procedure of UE-to-UE Relay.

1a. UE-to-UE Relay sends a Discovery Request message containing its User Info ID, the Relay Service Code (RSC) to the 5G DDNMF in order to get the associated security parameters. In addition, the U2U Relay includes its PC5 UE security capability that contains the list of supported ciphering algorithms by the UE in the Discovery Request message.

2a. The 5G DDNMF may check for the authorization with the ProSe Application Server based on the User Info ID and RSC.

3a. The 5G DDNMF of the U2U Relay returns the corresponding code security parameters, along with the CURRENT\_TIME and MAX\_OFFSET parameters. The code security parameters provide the necessary information for the UE-to-UE Relay to protect the information in the DCR message and are stored with the RSC. The 5G DDNMF of the U2U Relay may include the chosen discovery ciphering algorithm in the Discovery Response message. The 5G DDNMF determines the chosen discovery ciphering algorithm based on the RSC and the received security capability in step 1a. The UE-to-UE Relay stores the chosen discovery ciphering algorithm together with the RSC.

Steps 1b-3b refer to the Discovery Key Request procedure of Source UE/Target UE.

1b. The Source UE/Target UE sends a Discovery Request message containing the User Info ID and its PC5 UE security capability to the 5G DDNMF in order to get the associated security parameters.

2b. The 5G DDNMF of Source UE/Target UE sends an authorization request to the ProSe Application Server. If, based on the permission settings, the user Info ID is allowed to access U2U relay service, the ProSe Application Server returns an authorization response.

3b. If the Discovery Request is authorized and the PC5 UE security capability in step 1b includes the chosen discovery ciphering algorithm, the 5G DDNMF responds with the Discovery Response message including the corresponding Code Security Parameters and the chosen discovery ciphering algorithm (based on the information/keys stored in step 3a).Steps 4-14 refer to the discovery integrated into PC5 unicast link establishment procedure.

4. The Source UE wants to establish unicast communication with the Target UE via a UE-to-UE relay. Then the Source UE broadcasts Direct Communication Request containing User Info ID of Source UE and User Info ID of Target UE, RSC, long term credential ID, nonce 1 and its security capabilities. The message will be received by U2U relay-1, U2U relay-2. The User Info ID of Source UE/Target UE are protected by using the method defined in Clause 6.30.2.2.

Note 2: The long term credential and long term credential ID could be pre-configured on the 5G ProSe UE (incl. Source UE, Target UE and UE-to-UE Relay).

Note 3: How to pre-configure the long term credential and the long term credential ID to the UE is out of the 3GPP scope.

5. The U2U Relay-1 and U2U Relay-2 receive the DCR message and check the RSC. If they are authorized to provide the Relay service associated with RSC, then broadcast a new Direct Communication Request message. When a U2U Relay broadcasts the Direct Communication Request message, it includes User info ID of Source UE, User info ID of Target UE and User info ID of U2U Relay, long term credential ID, its nonce 1' and its security capabilities in the message.

6. The Target UE receives the Direct Communication Requests from U2U Relay-1 and U2U Relay-2. The Target UE verifies the DCR message by using the code security parameters and chooses one U2U relay (e.g. U2U Relay-2). The Target UE may initiate a Direct Auth and Key Establish procedure with U2U Relay-2 to generate the KNRP.

7. The Target UE derives the session key (KNRP-SESS) from KNRP and then derive the confidentiality key (NRPEK) (if applicable) and integrity key (NRPIK) based on the PC5 security policies. The Target UE sends a Direct Security Mode Command message to the U2U Relay-2. This message includes the chosen PC5 security algorithm, nonce 2', and is protected as specified in TS 33.536 [9].

8. The U2U Relay-2 responds with a Direct Security Mode Complete message to the Target UE.

9. Once receiving the Direct Security Mode Complete message from the U2U relay-2, the Target UE sends the Direct Communication Accept message to the U2U Relay-2.

10. The U2U Relay-2 may initiate a Direct Auth and Key Establish procedure with Source UE to generate the KNRP'.

11. The U2U Relay-2 derives the session key (KNRP-SESS') from KNRP' and then derives the confidentiality key (NRPEK') (if applicable) and integrity key (NRPIK') based on the PC5 security policies. The U2U Relay-2 sends a Direct Security Mode Command message to the Source UE. This message includes the chosen PC5 security algorithm, the nonce 2.

12. The Source UE responds with a Direct Security Mode Complete message to the U2U Relay-2.

13. The U2U Relay-2 sends the Direct Communication Accept message to the Source UE.

14. The secure L3 PC5 link between the Source UE and the Target UE via the U2U Relay-2 is established. The U2U Relay-2 can relay the traffic between the peer UEs.

#### 6.30.2.2 Privacy protection of User Info ID and RSC in DCR

The 5G Prose Source UE encrypts the Source User Info ID, Target User Info ID and RSC, and the 5G Prose UE-to-UE Relay encrypts the Source User Info ID, Relay User Info, Target User Info ID and RSC as follows:

1) If the UE is configured with Discovery User Confidentiality Key (DUCK)/Discovery User Scrambling Key (DUSK), the DCR ciphering key KDCR is set to DUCK/DUSK. If the UE is configured with both DUCK and DUSK, the KDCR is set to DUCK. If the UE is not configured with DUCK/DUSK, the DCR message is not protected, and Steps 2-3 are skipped.

2) Set Keystream to DCR confidentiality keystream calculated using KDCR, UTC-based counter, Bearer, Direction, and Length as described in Annex A.7 in TS 33.503 [6].

3) The KEYSTREAM is XORed with RSC+Source User Info ID+Relay User Info ID+Target User Info ID for privacy protection.

NOTE 1: If the UE is configured with DUIK, the DCR message is integrity protected as specified in TS 33.503 [6].

NOTE 2: Which other fields of the DCR message (e.g. relay\_indication, etc.) require protection will be decided in the normative phase.

Note 3: How the security mechanism specified in clause A.7 of TS 33.503 [6] is applied to DCR protection is not addressed in the present document.

### 6.30.3 Evaluation

This solution addresses KI#1 and KI#2 by largely reusing the mechanisms defined for Restricted Discovery in TS 33.503 [6].

This solution addresses how the 5G Prose UEs retrieve their discovery materials associated with RSC to protect its privacy sensitive information in the case that UE-to-UE Relay Discovery is integrated into PC5 link establishment.

This solution also addresses how the 5G Prose UEs securely establish the ProSe Communication via UE-to-UE Relay with Discovery integrated into PC5 unicast link establishment procedure.

This solution is aligned with the procedure defined in TS 23.304 [8].

For discovery integrated into PC5 link establishment, 5G Prose UEs use the discovery materials associated with RSC to protect the information in DCR messages. The provisioning of discovery materials reuses the discovery request procedure defined in clause 6.1.3.2 of TS 33.503 [6].The discovery request in sol can be seen as the relay discovery key request in the U2N discovery.

This solution proposes in the solution details that the long term credential and long term credential ID could be pre-configured on the 5G ProSe UE (incl. Source UE, Target UE and UE-to-UE Relay). But how to pre-configure the long term credential and the long term key ID to the UE's (incl. Source UE, Target UE and UE-to-UE Relay) is out of the 3GPP scope.

The long term credential ID is used for peer UE to retrieve the same long term credential for authentication and key derivation, which has the same functionality as long term ID in clause 6.5.5.2 of TS 33.303 [4].

## 6.31 Solution #31: Security for discovery integrated into PC5 link establishment when L3 UE-to-UE relay is in coverage

### 6.31.1 Introduction

The solution addresses Key Issue #1: Security for UE-to-UE Relay discovery and Key Issue #2: Security of UE-to-UE Relay.

SA2 has concluded to support discovery integrated into PC5 unicast link establishment procedure in the UE-to-UE Relay scenario. It largely reuses the mechanism of Restricted Discovery procedure and Direct Security Establishment procedure defined in TS 33.503 [6].

This solution addresses a L3 UE-to-UE relay. For L3 UE-to-UE relay use cases, the L3 UE-to-UE relay may be in or out of 3GPP coverage. This solution provides a mechanism for PC5 security setup procedure between a source UE or target UE and a L3 UE-to-UE relay when the L3 UE-to-UE relay is in 3GPP coverage. The solution is based on Solution #1 Alternative 1 of TR 23.700-33 [1].

This solution assumes 5GC NFs e.g. 5GDDNMF and PKMF are deployed in the network.

### 6.31.2 Solution details

#### 6.31.2.1 Procedure for PC5 security establishment between the 5G ProSe Source UE and 5G ProSe UE-to-UE Relay and between the 5G ProSe Target UE and 5G ProSe UE-to-UE Relay

Figure 6.31.2.1-1 illustrates the high-level procedure of the proposed solution.



Figure 6.31.2.1-1: High-level procedure of PC5 security between Source/Target UE and UE-to-UE relay

1. The 5G ProSe Source/Target UE and UE-to-UE relay1/UE-to-UE relay2 are provisioned with the discovery security materials, PC5 security policies and/or PRUK when they are in coverage.

2. The 5G ProSe Source UE wants to establish unicast communication with the 5G ProSe Target UE via a UE-to-UE relay. The Source UE broadcasts Direct Communication Request message. The 5G ProSe Source UE includes source UE info, target UE info, Application ID, as well as Relay Service Code. It is assumed the PRUK of the 5G ProSe Source UE is used as root for the PC5 security with the UE-to-UE relay selected by the 5G ProSe Target UE. The 5G ProSe Source UE includes also PRUK ID or SUCI of the 5G ProSe Source UE, key freshness parameter to establish PC5 security as described in TS 33.503 [6]. The message will be received by UE-to-UE relay-1, UE-to-UE relay-2. The User Info ID of 5G ProSe Source UE/5G ProSe Target UE are protected by the code security parameters as defined in the TS 33.503 [6].Editor's Note: The details of Direct Communication Request message (e.g. Application ID) is FFS.

3. The UE-to-UE relay-1 and the UE-to-UE relay-2 decide to participate in the procedure. They broadcast a new Direct Communication Invite message in their proximity to the 5G ProSe Target UE. The Relay UE includes source UE info, target UE info and Relay UE info (e.g. Relay UE ID) in the message and use Relay's L2 address as the source Layer-2 ID.

NOTE: The need for the new Direct Communication Invite message is not addressed in the present document.

4. The 5G ProSe Target UE receives the Direct Communication Invite messages from UE-to-UE relay1 and UE-to-UE relay2 and selects UE-to-UE relay-2. It is assumed the PRUK of 5G ProSe Target UE is used as root for the PC5 security established with the UE-to-UE relay-2 thus the 5G ProSe Target UE sends another Direct Communication Request to the UE-to-UE relay-2 with PRUK ID or SUCI of Target UE, key freshness parameter and RSC to establish PC5 security as described in TS 33.503 [6].

5. The 5G ProSe UE-to-UE relay-2 sends a Key Request message that contains PRUK ID or SUCI of the 5G ProSe Target UE, key freshness parameter and RSC received in step 4 to the 5GC.

6. The 5GC sends the Key Response message to the 5G ProSe UE-to-UE relay-2, which includes a key derived from PRUK i.e. KNRP.

7a. The 5G ProSe UE-to-UE relay-2 derives the session key from KNRP and then derive the confidentiality key and integrity key. The 5G ProSe UE-to-UE relay-2 sends a Direct Security Mode Command message to the 5G ProSe Target UE.

7b. The 5G ProSe Target UE shall derive the KNRP from its PRUK and then derive the session key from KNRP and the confidentiality key and integrity key in the same manner as the 5G ProSe UE-to-UE Relay and process the Direct Security Mode Command. Successful verification of the Direct Security Mode Command assures the 5G ProSe Target UE that the 5G ProSe UE-to-UE relay-2 is authorized to provide the UE-to-UE relay service.

7c. The 5G ProSe Target UE responds with a Direct Security Mode Complete message to the 5G ProSe UE‑to-UE relay-2.

7d. On receiving the Direct Security Mode Complete message, the 5G ProSe UE-to-UE relay-2 verifies the Direct Security Mode Complete message. Successful verification of the Direct Security Mode Complete message assures the 5G ProSe UE-to-UE relay-2 that the 5G ProSe Target UE is authorized to get the UE-to-UE relay service.

8. After successful verification, the 5G ProSe UE-to-UE relay-2 UE responds with a Direct Communication Accept message to the 5G ProSe Target UE to complete the PC5 connection establishment procedure.

9. The 5G ProSe UE-to-UE relay-2 sends another Key Request message that contains PRUK ID or SUCI of the 5G ProSe Source UE, key freshness parameter and RSC received in step 2, to the 5GC.

10. The 5GC sends the Key Response message to the 5G ProSe UE-to-UE relay-2, which includes a key derived from PRUK i.e. KNRP.

11a. The 5G ProSe UE-to-UE relay-2 derives the session key from KNRP and then derive the confidentiality key and integrity key. The 5G ProSe UE-to-UE relay-2 sends a Direct Security Mode Command message to the 5G ProSe Source UE.

11b. The 5G ProSe Source UE derives the KNRP from its PRUK and then derive the session key from KNRP and the confidentiality key and integrity key in the same manner as the 5G ProSe UE-to-UE relay-2 and process the Direct Security Mode Command. Successful verification of the Direct Security Mode Command assures the 5G ProSe Source UE that the 5G ProSe UE-to-UE relay-2 is authorized to provide the UE-to-UE relay service.

11c. The 5G ProSe Source UE responds with a Direct Security Mode Complete message to the 5G ProSe UE‑to-UE relay-2.

11d. On receiving the Direct Security Mode Complete message, the 5G ProSe UE-to-UE relay-2 verifies the Direct Security Mode Complete message. Successful verification of the Direct Security Mode Complete message assures the 5G ProSe UE-to-UE relay-2 that the 5G ProSe Source UE is authorized to get the UE-to-UE relay service.

12. After successful verification, the 5G ProSe UE-to-UE relay-2 responds with a Direct Communication Accept message to the 5G ProSe Source UE to complete the PC5 connection establishment procedure.

The authorization between UEs is described in steps 7b/7d and steps 11b/11d, which are following the same practice of UE-to-network relay in R17 as described in TS 33.503.

### 6.31.3 Evaluation

This solution is for commercial services and public safety and supports the PC5 communication with a UE-to-UE Relay capable with network-based Relay service authentication and authorization similar to the UE-to-network relay as described in clauses 6.3.3.2.2 and 6.3.3.3.2 in TS 33.503 for the PC5 security establishment when in 3GPP coverage.

This solution only works when the UE-to-UE relay is located within network's coverage area. The 5G ProSe Source/Target and UE-to-UE relay need to store security materials dedicated to the In-Coverage scenario. Apart from the PC5 signalling, additional user plane/signalling interactions with the network are required in this mechanism.

This solution supports per-hop links setup. The Source UE initiates the PC5 security link setup with UE-to-UE Relay (first hop) similar to the UE-to-network relay as defined in TS 33.503. And the UE-to-UE Relay initiates the PC5 security link setup with the Target UE (second hop). After the Security Establishment procedure is completed between the UE-to-UE Relay and the Target UE, the UE-to-UE Relay continues the PC5 security link setup with the Source UE.

In order to trigger the Target UE to initiate a DCR message, the UE-to-UE Relay could send a new Direct Communication Invite message that contains Relay Service Code to the 5G ProSe Target UE. The need for this new message can be decided during normative work.

This solution is not aligned with TR 23.700-33 [2]. More specifically, the DCR message sent by Target UE and the DCA sent by U2U Relay is not aligned with TR 23.700-33 [2].

Note: Further evaluation is needed.

## 6.32 Solution #32: Security for discovery integrated into PC5 link establishment procedure

### 6.32.1 Introduction

The solution addresses Key Issue #1: Security for UE-to-UE Relay discovery and Key Issue #2: Security of UE-to-UE Relay.

This solution reuses the Direct Security Establishment procedure defined in TS 33.503 [6] with the following extensions:

- Extend the Direct Communication Request (DCR) by adding a new parameter (named U2U\_Dis\_Info) to carry the U2U discovery message.

- The format of the U2U discovery message put into the DCR is the same as the normal U2U discovery message.

### 6.32.2 Solution details



Figure 6.32.2-1: Security for discovery integrated into PC5 link establishment procedure

1. The Source UE, Target UE and Relay UE are provisioned with U2U discovery security materials that are used to protect the U2U discovery messages.

2. The Source UE generates a U2U discovery message that is protected by the security mechanism specified in KI#1. The format of the U2U discovery message generated here is the same as the normal U2U discovery message.

3. The Source UE sends Direct Discovery Request (DCR) with U2U\_Dis\_Info parameter to the Relay UE. The U2U\_Dis\_Info parameter carries the U2U discovery message.

4. The Relay UE verifies the received U2U discovery message carried in the DCR message using U2U discovery security materials, and then generates a new U2U discovery message for discovering the Target UE. The U2U discovery message is protected by the security mechanism specified in KI#1.

5. The Relay UE sends Direct Discovery Request (DCR) with U2U\_Dis\_Info parameter to the Target UE. The U2U\_Dis\_Info parameter carries the new generated U2U discovery message.

6. The Relay UE and the Target UE establish a secure connection using the security mechanism specified in clause 6.2 of TS 33.503 [6]

7. The Target UE replies with Direct Communication Accept message to complete the PC5 link establishment with the Relay UE.

8. The Relay UE and the Source UE establish a secure connection using the mechanism specified in clause 6.2 of TS 33.503 [6]

9. The Relay UE replies with Direct Communication Accept message to complete the PC5 link establishment with the Source UE.

10. The Source UE and the Target UE establish a secure connection using the security mechanism specified in KI#2.

Note 1: Alignment with stage 2 integrated discovery is not addressed in the present document.

Note 2: Justification and content of discovery message in DCR is not addressed in the present document.

### 6.32.3 Evaluation

This solution addresses the first security requirement of key issue #1 and the first security requirement of Key issue #2 in the scenario where the discovery is integrated into PC5 link establishment procedure.

This solution realizes the discovery security through extending the Direct Communication Request (DCR) by adding a new parameter to carry the U2U discovery message. The format of the U2U discovery message put into the DCR is the same as the normal U2U discovery message.

The solution does not address the End-to-End security requirement between the Source UE and the Target UE.

## 6.33 Solution #33: Security policy negotiation for Layer-3 UE-to-UE Relay Communication

### 6.33.1 Introduction

This solution addresses Key Issue #5. The Source UE, Target UE and UE-to-UE Relay are provisioned with the hop-by-hop and end-to-end security policies for 5G ProSe UE-to-UE Relay Communication.

The Source UE, Target UE, and UE-to-UE Relay negotiates and decides whether to activate or deactivate the hop-by-hop and end-to-end security based on the provisioned security policies during the security establishment. The solution largely reuses the security policy handling mechanism of security establishment procedure defined in TS 33.503 [6].

### 6.33.2 Solution details

Figure 6.33.2-1 illustrates the hop-by-hop and end-to-end security policy negotiation procedure between the Source UE, Target UE, and UE-to-UE Relay.



Figure 6.33.2-1: Security policy negotiation procedure for the Layer-3 UE-to-UE Relay Communications

1. The Source UE, Target UE, and UE-to-UE Relay respectively are provisioned with the hop-by-hop and end-to-end security policies per UE-to-UE Relay service (i.e. RSC: Relay Service Code) by the PCF during the service authorization and provisioning procedure as defined in TS 23.304 [8].

NOTE 1: The Source UE, Target UE, and UE-to-UE Relay may get the security policies in a different way (e.g. from PKMF, from DDNMF, from ProSe Application Server, or based on operator configuration).

The hop-by-hop security policies indicate whether the signalling integrity protection, signalling confidentiality protection, user plane integrity protection, and user plane confidentiality protection for the hop-by-hop links are required, preferred, or not needed.

The end-to-end security policies indicate whether the signalling integrity protection, signalling confidentiality protection, user plane integrity protection, and user plane confidentiality protection for the end-to-end link are required, preferred, or not needed.

NOTE 2: The security policies can be configured based on UE-to-UE Relay service, UE resource constraints, operator policy, etc.

1. The discovery procedure may be performed between the Source UE, Target UE, and UE-to-UE Relay using Model A or Model B mode as specified in TS 23.304 [8]. If discovery integrated into PC5 unicast link establishment procedure concluded in TR 23.700-33 [2] is to be performed in the following steps, this step is skipped.
2. The Source UE sends the UE-to-UE Relay a Direct Communication Request message. The message includes the RSC, Source UE's hop-by-hop security policies, Source UE's end-to-end security policies, and Source UE's security capabilities (the list of supported algorithms).

Note 3: Whether to include end-to-end security policies in DCR message to/from the Relay UE is not addressed in the present document.

Note 4: Whether this solution aligns with TR 23.700-33 [2] is not addressed in the present document.

3-5. The hop-by-hop security establishment between the Source UE and the UE-to-UE Relay including security policy negotiation and protection of messages follows the unicast security mechanism defined in TS 33.503 [6], using the hop-by-hop security policies.

1. The UE-to-UE Relay sends the Target UE a Direct Communication Request message. The message includes the RSC, UE-to-UE Relay's hop-by-hop security policies, UE-to-UE Relay's security capabilities, Source UE's end-to-end security policies, and Source UE's security capabilities.

7-9. The hop-by-hop security establishment between the UE-to-UE Relay and the Target UE including security policy negotiation and protection of messages follows the unicast security mechanism defined in TS 33.503 [6], using the hop-by-hop security policies.

1. The Target UE may accept the Direct Communication Request and respond with the Direct Communication Accept message which indicates the activation/deactivation of user plane security protection.
2. The UE-to-UE Relay may accept the Direct Communication Request and respond with the Direct Communication Accept message which indicates the activation/deactivation of user plane security protection.

12-14. The end-to-end security establishment between the Source UE and the Target UE over the Layer-2 UE-to-UE Relay including security policy negotiation and protection of messages follows the unicast security mechanism defined in TS 33.536 [2], using the end-to-end security policies.

NOTE 3: The end-to-end security establishment procedure between the Source UE and the Target UE over the Layer-3 UE-to-UE Relay including security policy negotiation and protection of messages is implemented in the application layer, using the end-to-end security policies.

1. The Target UE may accept the Direct Communication Request and respond with the Direct Communication Accept message.

### 6.33.3 Evaluation

This solution provides a means for the UEs in UE-to-UE Relay Communications to negotiate the hop-by-hop and end-to-end security policies so that the UEs agree on common protection schemes.

The solution requires separate security policies for hop-by-hop and end-to-end links.

Note: Further evaluation is needed.

## 6.34 Solution #34: L2 U2U Relay reselection using Re-Keying

### 6.34.1 Introduction

This solution addresses KI #2: Security of UE-to-UE Relay in the Layer-2 UE-to-UE Relay reselection scenario.

This solution proposes to use the exchange of security parameters during the UE-to-UE Relay reselection procedure to trigger the establishment of new E2E security keys used for the security over the second L2 UE-to-UE Relay. The new E2E keys are established by reusing the re-keying procedure enhanced for the UE-to-UE Relay reselection scenario. The new security keys are then used for the security of a new PC5 unicast link between the End UEs via the second relay. New security keys are necessary since the KNRP-sess is derived per PC5 unicast link, as per TS 33.536, clause 5.3.3.1.2.1. As in the UE-to-Network Relay scenario, it is assumed that PC5 signalling integrity security policy is set to "REQUIRED".

This solution proposes to use the exchange of security parameters during the UE-to-UE Relay reselection procedure to trigger the establishment of new E2E security keys used for the security over the second L2 UE-to-UE Relay. The new E2E keys are established by reusing the re-keying procedure enhanced for the UE-to-UE Relay reselection scenario. The new security keys are then used for the security of a new PC5 unicast link between the End UEs via the second relay. New security keys are necessary since the KNRP-sess is derived per PC5 unicast link, as per TS 33.536, clause 5.3.3.1.2.1. As in the UE-to-Network Relay scenario, it is assumed that PC5 signalling integrity security policy is set to "REQUIRED".

### 6.34.2 Solution details

Figure 6.34.2-1 illustrates the high-level procedure of the proposed solution.



Figure 6.34.2-1: Layer-2 based UE-to-UE Relay reselection using (p)Re-keying procedure

1. End UEs have set up per hop PC5 unicast links with Relay#1 using the procedure defined in TS 23.304, clause 6.7.2. A connection for unicast communication between the End UEs is established via Relay#1.
2. End UE#1 decides to perform U2U Relay reselection with End UE#2 with pre-keying of the new connection via current connection based on current connection security policy/configuration (e.g. signalling integrity is turned ON). End UE#1 allocates new MSB of a link reselection correlation (LRC) ID.
3. End UE#1 sends to End UE#2 a Link Modification Request message which includes MSB of LRC ID, new connection pre-keying indication and other reselection related parameters, as per TS 23.304 [8], clause 6.7.4.2 (e.g. reselection indication, identifiers of Relay candidates including Relay#2).
4. End UE#2 allocates LSB of LRC ID and combines MSB and LSB of LRC ID to form a new LRC ID and store LRC ID in a new connection context associated with Relay#2, along End UE#1 info (e.g. User Info ID, KNRP/KNRP ID) and Relay#2 info (e.g. Relay User Info ID, L2 ID).

End UE#2 sends to End UE#1 a Link Modification Accept message which includes ack of new connection pre-keying, LSB of LRC ID and other parameters (e.g. identifier of selected Relay#2).

1. End UE#1 combines MSB and LSB to form a new LRC ID and store the LRC ID in a new connection context associated with Relay#2, along End UE#2 info, Relay#2 info.

End UE#1 sends to End UE#2 via first Relay a Re-keying request message including an indication for generating new keys for the new connection and the LRC ID. End UE#1 also includes security parameters as per existing Re-keying procedure as described in TS 33.536 [6], clause 5.3.3.1.4.4 (e.g. security capabilities, nonce, MSB of new KNRP-sess ID).

Note: Whether Re-keying request and DSM command procedure are performed via an existing E2E link is not addressed in the present document.

1. End UE#2 generates a new session (KNRP-sess) and security keys (NRPEK and NRPIK) and store the keys in the new connection context.

End UE#2 sends to End UE#1 via Relay#1 a DSM Command message including LRC ID and security parameters, as per existing Re-keying procedure. The message is protected using the already established security context for current connection (e.g. no indication is sent to the lower layer to activate new security using new keys).

1. End UE#1 generates and stores the new security keys in the new connection context. End UE#1 sends to End UE#2 via first Relay a DSM Complete message.
2. End UE#2 sends to End UE#1 a Re-keying response message confirming that End UE#2 is ready to use new keys in a connection via second relay.
3. End UEs set up per-hop PC5 unicast links, if not already set up, with Relay#2, by using the procedure defined in TS 23.304, clause 6.7.2. End UE#1 sends to End UE#2 via Relay#2 an integrity protected DCR message including the LRC ID. The message is protected using the new keys associated from the new connection context.

End UE#2 locates the new connection security keys based on LRC ID and verify integrity protection of the DCR message. The authentication and security establishment procedures are skipped over the new connection. End UE#2 activates a security context for the new connection using the new connection stored security keys.

UE#2 sends a DCA to End UE#1 fully protected using the security context. End UE#1 activates a security context for the new connection using the new connection stored security keys located with LRC ID.

### 6.34.3 Evaluation

This solution addresses requirements of KI #2: Security of UE-to-UE Relay requirements, including during UE-to-UE Relay re-selection.

Impact for the End UEs:

- support preparation via current UE-to-UE Relay of the new security keys between the Source UE and Target UE using a modified Re-keying procedure to generate keys for a new connection (i.e. other than the ongoing connection).

- support skipping the Direct Authentication and Security Establishment procedures via the new UE-to-UE Relay by using the new security key located using LRC ID established during Relay reselection procedure.

There is no impact for the L2 UE-to-UE Relay, as it only needs to perform regular forwarding of the E2E LMR/LMA, Re-Keying Req/Resp and DCR/DCA messages between End UEs.

Note 1: Whether this solution enables a fast E2E security setup compared to existing unicast security setup procedure defined in TS 33.503 is not addressed in the present document.

Note 2: Further evaluation is needed.

## 6.35 Solution #35: KNRP ID privacy in L2 U2U Relay reselection

### 6.35.1 Introduction

This solution addresses Key Issue #4: Privacy of information over the UE-to-UE Relay, in the Layer-2 UE-to-UE Relay reselection scenario.

This solution proposes to protect the privacy of KNRP ID shared between the End UEs. The privacy threat allows to link the connection via the original Relay to the connection via the new Relay, caused by either the same KNRP ID or same partial KNRP ID value being sent in the Direct Communication Request message for the connection via the new Relay. A similar privacy threat and resolution mechanism are specified in TS 33.536 [6], clause 5.3.3.2.

Two scenarios are supported:

- Scenario#1: The End UEs maintain the connection via original Relay prior to the setup of the new connection via the new Relay. New KNRP ID is established during LMR/LMA procedure.

- Scenario#2: The End UEs release the connection via original Relay prior to the setup of the new connection via the new Relay. New KNRP ID is established during coordinated Link Release procedure for the old connection.

### 6.35.2 Solution details

#### 6.35.2.1 New KNRP ID establishment using LMR/LMA

Figure 6.35.2.1-1 illustrates the high-level procedure of the proposed solution considering Scenario#1.



Figure 6.35.2.1-1: Layer-2 based UE-to-UE Relay reselection with KNRP ID change in LMR/LMA

1. A connection for unicast communication between the End UEs is established via Relay#1.
2. End UE#1 decides to perform U2U Relay reselection with End UE#2 and to generate a new KNRP ID with End UE#2 based on decision to maintain the current connection via Relay#1.
3. End UE#1 sends to End UE#2 a Link Modification Request message which includes an indication for the maintenance of the initial connection prior to setup of connection via second Relay, an MSB of KNRP ID and other reselection related parameters, as per TS 23.304 [8], clause 6.7.4.2 (e.g. reselection indication, identifiers of Relay candidates including Relay#2). Newly allocated MSB of KNRP ID, associated with End UE#2, uniquely identifies KNRP in End UE#1.
4. End UE#2 selects Relay#2 from the list of Relay candidates. End UE#2 allocates LSB of KNRP ID, associated with End UE#1, that uniquely identifies KNRP in End UE#2. End UE#2 combines MSB and LSB of KNRP ID to form a new KNRP ID to be used when reconnecting with End UE#1. End UE#2 replaces old KNRP ID with new KNRP. End UE#2 sends to End UE#1 a Link Modification Accept message which includes LSB of KNRP ID and other parameters (e.g. identifier of selected Relay#2).
5. End UE#1 combines MSB and LSB of KNRP ID to form a new KNRP ID to be used when reconnecting with End UE#2. End UE#1 replaces old KNRP ID with new KNRP. End UE#1 sends to End UE#2 via Relay#2 a DCR message including the new KNRP ID (a direct PC5 link with Relay#2 may be setup or modified before).
6. End UE#1 and End UE#2 establish the security for the connection between End UEs via Relay#2. The KNRP ID is used to locate the corresponding KRNP used to derive the session and security keys to secure the connection.
7. End UE#1 receives from End UE#2 a DCA completing the connection establishment.

#### 6.35.2.2 New KNRP ID establishment using coordinated Link Release

Figure 6.35.2.2-1 illustrates the high-level procedure of the proposed solution considering Scenario#2.



Figure 6.35.2.2-1: Layer-2 based UE-to-UE Relay reselection with KNRP ID change in coordinated Link Release

1. A connection for unicast communication between the End UEs is established via Relay#1.
2. End UE#1 decides to perform U2U Relay reselection with End UE#2 with coordinated release of the initial connection (prior to new connection setup).
3. End UE#1 sends to End UE#2 a Link Modification Request message which includes an indication to request a coordinated release of the initial connection via Relay#1 and other reselection related parameters, as per TS 23.304 [8], clause 6.7.4.2.
4. End UE#2 sends to End UE#1 a Link Modification Accept message which includes an acceptance of the coordinated release of the initial connection via Relay#1 and other reselection related parameters.
5. End UE#1 sends to End UE#2 a Link Release Request message which includes new MSB of KNRP ID.
6. End UE#2 sends to End UE#1 a Link Release Response message which includes new LSB of KNRP ID. End UE#2 allocates new LSB of KNRP ID and establishes a new KNRP ID combining received MSB of KNRP ID with new LSB of KNRP ID.
7. End UE#2 establishes a new KNRP ID combining MSB of KNRP ID with received LSB of KNRP ID. End UE#1 setup a new connection with End UE#2 using the newly established KNRP ID.

### 6.35.3 Evaluation

This solution addresses requirements of Key Issue #4: Privacy of information over the UE-to-UE Relay requirements, including during UE-to-UE Relay re-selection.

Impact for the End UEs:

- Exchange of MSB/LSB of KNRP ID in LMR/LMA procedure or Link Release procedure (resp. if original connection is maintained or release).

- Exchange of indication to maintain or release original connection in LMR/LMA procedure.

There is no impact for the L2 UE-to-UE Relay, as it only needs to perform regular forwarding of the E2E LMR/LMA, Link Release Req/Resp and DCR/DCA messages between End UEs.

Note: Further evaluation is needed.

## 6.36 Solution #36: Model A Relay discovery using multiple key sets

### 6.36.1 Introduction

This solution addresses Key Issue #1: Security for UE-to-UE Relay discovery and Key Issue #3: Authorization in the UE-to-UE Relay Scenario.

This solution proposes to ensure the timely transmission of Relay discovery announcements by the Relay when transporting protected direct discovery sets. The solution also proposes a mechanism to support the co-existence of both approaches (i.e. using single key set and multiple key sets).

Two scenarios are supported:

- Scenario#1: The End UE is discoverable by actively sending announcement messages. The Relay provide End UEs with timing about its next announcements to ensure close to real time transmission of protected direct discovery sets inside the Relay announcement message.

- Scenario#2: The End UE is discoverable while being already connected (and not necessarily announcing) to the Relay. The Relay obtains the protected direct discovery set from the connected End UE on-demand to ensure close to real time transmission of the protected direct discovery set inside the Relay announcement message.

### 6.36.2 Solution details

#### 6.36.2.1 UE-to-UE Relay Scheduling of Direct Discovery Set Announcements

Figure 6.36.2.1-1 illustrates the high-level procedure of the proposed solution considering Scenario#1.



Figure 6.36.2.1-1: 5G ProSe UE-to-UE Relay Model A Discovery using U2U Relay announcement scheduling assistance to End UEs

1. The End UEs are provisioned with direct discovery security parameters (including MAX\_OFFSET, CURRENT\_TIME) using existing mechanisms defined in TS 33.503 [6], clause 6.1.3.2. The End UEs use the security material for E2E protection of the direct discovery set. The End UEs are also provisioned with relay discovery security parameters for Relay discovery message protection.
2. Relay decides to advertise Relay announcement timing info based on an indication that RSC supports per direct discovery set protection. An example of timing info is a time window for when the Relay expects to receive the End UE's announcement for the End UE to be announced via the next Relay announcement.

NOTE 1: other examples of timing info (e.g. deadline, announcing cycle) can be considered during normative phase

Note 1a: Whether announcement timing info is needed is not addressed in the present document.

Note 1b: How a timing info is configured and provisioned to End UEs and U2U relay is not addressed in the present document.

Note 1c: Whether a timing info (i.e., time window) is related to a UTC-based time counter is not addressed in the present document.

1. U2U Relay sends a U2U Relay protected discovery message including RSC, U2U Relay User info ID and announcement timing info.
2. End UE#1 (Announcing) schedules its next announcement message including a protected direct discovery set based on the received advertised Relay announcement timing info (e.g. ensures a timely transmission within advertised time window). End UE#2 (Monitoring) aligns its listening for Relay Announcement messages based on the received advertised Relay announcement timing info.

NOTE 2: How the End UE handle announcement with timing info from multiple eligible Relays is left to normative phase.

1. End UE#1 sends a protected U2U Relay discovery message including RSC, and a protected direct discovery set from End UE#1.

Note 6: The new procedure (step 2 and 4) needs to be aligned with stage 2 procedure is not addressed in the present document.

1. U2U Relay verifies that Announcement message from End UE#1 is received within the acceptable time based on advertised Relay announcement timing info. U2U Relay discards the Announcement message from End UE#1 if not compliant with advertised Relay announcement timing info (e.g. outside time window).
2. U2U Relay sends a protected U2U Relay protected discovery message including RSC, U2U Relay User info ID the protected direct discovery set received from End UE#1 according to advertised announcement timing info. End UE#2 (Monitoring) receives the Relay Announcement at a time aligned with Relay advertised announcement timing info and discovers End UE#1 presence following the successful processing of the Relay discovery message and included protected direct discovery set of End UE#1.

#### 6.36.2.2 U2U Relay on-demand direct discovery set protection

Figure 6.36.2.2-1 illustrates the high-level procedure of the proposed solution considering Scenario#2.



Figure 6.36.2.2-1: 5G ProSe UE-to-UE Relay Model A Discovery using U2U Relay using on-demand direct discovery set protection

1. The End UEs are provisioned with discovery security parameters (including MAX\_OFFSET, CURRENT\_TIME) for the direct discovery set using existing mechanisms defined in TS 33.503 [6], clause 6.1.3.2. The End UEs use the security material for E2E protection of the direct discovery set. The End UEs are also provisioned with relay discovery security parameters for Relay discovery message protection.
2. A prior connection for unicast communication between the End UE#1 with another End UE (i.e. not shown, other End UE#3) is established via Relay#1 for a given Prose Service. This prior communication is established following a prior discovery procedure (e.g. using mechanism as in scenario#1 or other standalone discovery method) or using direct communication with integrated discovery (see TS 23.304, clause 6.7.3). The End UE sends with the RSC a ProSe Restricted code associated with the Prose Service in the DCR message to the U2U Relay, if the RSC is configured with an indicator for per direct discovery set protection. Alternatively, the End UE sends the ProSe Restricted code after the DCR (e.g. using LMR/LMA). The Relay verifies that the RSC supports per direct discovery set protection and stores the ProSe Restricted code in the PC5 unicast link context.
3. U2U Relay decides to announce connected UEs.
4. For each of the connected End UE with a stored ProSe Restricted Code, the U2U Relay sends a secure PC5-S request message including the ProSe Restricted Code for the Prose Service previously received from End UE#1 to request a corresponding protected direct discovery set. The PC5-S request messages is protected using the per hop PC5 link security context between the Relay and End UE.

Note a: Whether PC5-S Request and PC5-S Response message is needed is not addressed in the present document.

1. End UE#1 generates a secure PC5-S response message including RSC and a direct discovery set protected using the provisioned direct discovery security material. The End UE#1 protects the PC5-S message using the per hop PC5 link security context and sends it to U2U Relay.
2. U2U Relay processes the PC5-S response message security and extracts the included protected direct discovery set(s). U2U Relay sends a U2U Relay protected discovery message including RSC, U2U Relay User info ID the protected direct discovery set received from End UE#1. U2U Relay protects the U2U Relay discovery message using the security material associate with the RSC. End UE#2 processes the security of the Relay discovery message security and of the included protected direct discovery set to discover End UE#1.

NOTE: How the Relay ensures the included protected direct discovery set(s) are not stale is left to normative phase

### 6.36.3 Evaluation

This solution addresses Key Issue #1: Security for UE-to-UE Relay discovery and Key Issue #3: Authorization in the UE-to-UE Relay Scenario.

The solution also proposes a mechanism to support the co-existence of both approaches (i.e. using single key set and multiple key sets) using a configuration parameter for the RSC indicating support for protected direct discovery sets.

Impact for the End UEs and Relay:

- Support for on demand delivery of protected direct discovery to Relay (Connected).

- Support for RSC indicator for protected direct discovery sets.

Note: Further evaluation is needed.

## 6.37 Solution #37: PC5 link establishment with secure integrated discovery

### 6.37.1 Introduction

This solution addresses KI#1 Security for UE-to-UE Relay discovery and KI#2 Security of UE-to-UE Relay.

The solution describes means to protect a Direct Communication Request message with Integrated Discovery, proposes a new field (i.e. "integrated\_discovery\_indication"), and describes the security establishment procedures that Target-UE could perform, to establish a secure link with a UE-to-UE relay and Source-UE, based on its evaluation of the DCR messages received and its path selection preferences.

### 6.37.2 Solution details

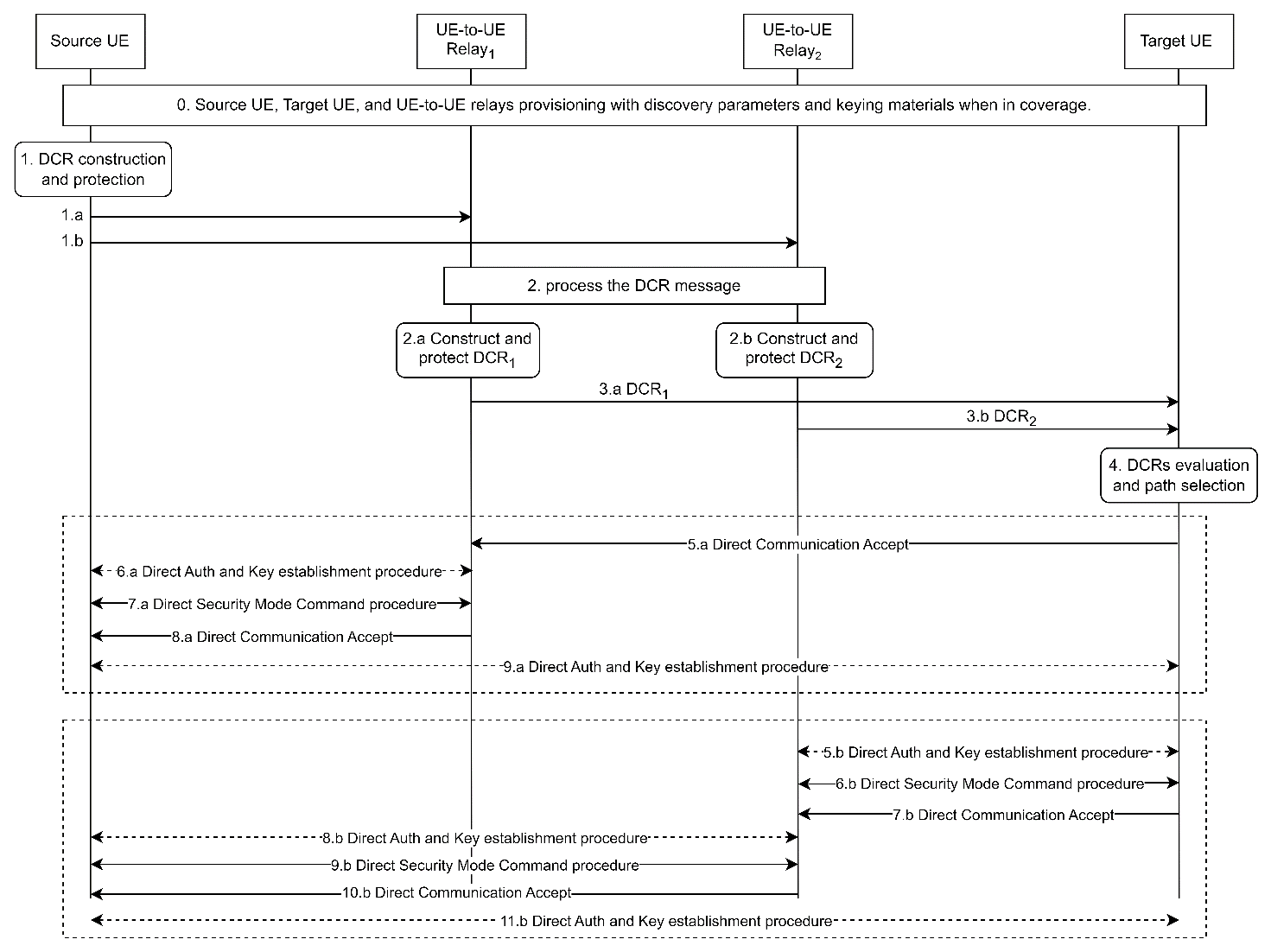


Figure 6.37.2-1 PC5 link establishment with secure integrated discovery

0. Source, Target, and UE-to-UE Relays are provisioned with security policies, discovery security materials and parameters to enable the establishment of secure PC5 links with a UE-to-UE relay and Source-UE.

NOTE 1: the security parameters and corresponding provisioning procedure will be decided in normative phase.

1. Source UE constructs the DCR message including a Direct Discovery set, a UE-to-UE Discovery set, and fields specific to the DCR message e.g. Security Information, relay indication, and an integrated\_discovery\_indication. Source-UE protects the Direct Discovery set and the integrated\_discovery\_indication using the Direct Code-sending security parameters, and the whole DCR message is protected with the UE-to-UE relay Code-sending security parameters, whereby the Direct Discovery set and integrated\_discovery\_indication are not confidentiality protected.

Note 1a: Whether E2E protection in integrated discovery is required to maintain consistency with UE-to-UE discovery procedures and/or 5G ProSe Direct communication is not addressed in the present document.

NOTE 2: The field integrated\_discovery\_indication indicates to Target-UE whether the discovery message is integrated into a DCR.

2.  When a UE-to-UE Relay receives the DCR message, it descrambles/decrypts, and integrity verifies it. If integrity verification succeeds, the UE-to-UE relay removes the relay indication, and constructs another DCR message (e.g. DCR1 or DCR2) as in step 1.

2.a If the relay e.g. UE-to-UE Relay1, identifies Target-UE and a secure link is already established with Target-UE, UE-to-UE Relay1 uses the security keys corresponding to the already established security context with Target-UE to protect DCR1.

Note 2a: How a UE-to-UE Relay identifies the Target-UE is not addressed in the present document.

2.b If the relay, e.g. UE-to-UE Relay2, cannot identify Target-UE or does not have a security context established with it, UE-to-UE Relay2 uses the UE-2-UE Code-sending security parameters to protect DCR2.

NOTE 3: UE-to-UE Relay2 could protect DCR2 by re-using the same UE-2-UE Code-sending security parameters used to protect the DCR message.

3.a/b UE-to-UE Relay1 and UE-to-UE Relay2 transmit DCR1 and DCR2 to Target-UE.

4. As Target-UE may receive several DCR messages (e.g. from one or multiple UE-to-UE relays). When applicable, Target-UE unscrambles/decrypts, and verifies the integrity of the received DCR message with the corresponding keys (either corresponding to an existing security context or UE-2-UE Code-receiving security parameters). Then, the target-UE uses the Direct Code-receiving security parameters to decrypt, and integrity verify the Direct discovery set including integrated\_discovery\_indication.

Based on the received the DCR messages and Target-UE's path selection preferences in step 4, a secure link is established with Source-UE in either one of the following ways:

**Case 1: Target-UE selects a communication path going through UE-to-UE Relay1:**

5.a Since a security context is already established, the Direct auth and Key Establishing, and Direct Security Mode Command procedures are skipped, instead, Target-UE sends a Direct Communication Accept to UE-to-UE Relay2.

6.a/7.a/8.a correspond to the establishment of a secure link between Source-UE and UE-to-UE Relay1.

9.a Source-UE and Target-UE establish an end-to-end secure link through UE-to-UERelay1.

Case 2: Target-UE selects a communication path going through UE-to-UE Relay2:

5.b/6.b/7.b correspond to the establishment of a secure link between UE-to-UE Relay2 and Target-UE.

8.b/9.b/10.b correspond to the establishment of a secure link between UE-to-UE Relay2 and Source-UE.

11.b. Source-UE and Target-UE establish an end-to-end secure link through UE-to-UERelay2.

NOTE 4: This solution is applicable to both L2 and L3 UE-to-UE relay scenarios.

NOTE 5: Secure hop-by-hop or end-to-end links between UE-to-UE Relays and End-UEs, and between Ends UEs are established as described in clause 5.3 of TS 33.536 [1], based on Security Information in the DCR message.

### 6.37.3 Evaluation

None.

# 7 Conclusions

## 7.1 Key Issue #1: Security for UE-to-UE Relay discovery

The following text is taken as a conclusion for the UE-to-UE Relay discovery:

The two sets of discovery security materials are used for UE-to-UE Relay discovery message protection. One is used for protecting direct discovery set. The other one is used for protecting the U2U relay discovery message.

Provisioning of discovery security materials for the direct discovery set reuses the security material provisioning mechanism for Restricted 5G ProSe Direct Discovery as specified in TS 33.503 [6].

Provisioning of discovery security materials for the U2U relay discovery message reuses the security material provisioning mechanism for 5G ProSe UE-to-Network Relay discovery as specified in TS 33.503 [6].

## 7.2 Key Issue #2: Security of UE-to-UE Relay

For Key Issue #2, the following statements are agreed:

NOTE: The choice and co-existence of the security mechanisms in different use cases (i.e. U2U Relay in and out of coverage) will be decided in normative phase.

Regarding End-to-End security:

For L2 relay, the End UEs (Source UE and/or Target UE) reuse the unicast mode security mechanism defined in clause 5.3.3.1 of TS 33.536 [6] to establish a secure connection via the Relay UE.

For L3 relay, End-to-End security can be supported in the application layer which is out of 3GPP scope.

Regarding hop-by-hop security during PC5 link establishment in Layer 3/Layer 2 UE-to-UE Relay Communication:

- When the Layer 3/Layer 2 UE-to-UE Relay is in 3GPP coverage, the End UE and the UE-to-UE Relay can establish a secure PC5 link with network assistance. The similar security procedure as PC5 security for 5G ProSe Communication via 5G ProSe Layer-3 UE to-Network Relay as defined in clause 6.3 in TS 33.503 [6] can be reused.

- The solutions for UE-to-UE Relay authorisation and security can be classified as user-plane (UP) or controlled-plane (CP) based solutions. It is concluded that both control plane and user plane solutions are supported for 5G ProSe Layer 2 UE-to-UE Relay and 5G ProSe Layer 3 UE-to-UE relay.

- When the Layer 3/Layer 2 UE-to-UE Relay is out of 3GPP coverage, the End UE and the UE-to-UE Relay can establish a secure PC5 link without network assistance. The similar security procedure as PC5 security for unicast mode 5G ProSe Direct Communication as defined in clause 6.2.3 in TS 33.503 [6] can be reused.

## 7.3 Key issue #3: Authorization in the UE-to-UE Relay Scenario

For Key Issue #3, the following statement is agreed:

The PCF based service authorisation as defined in TS 23.304 [3] is reused as the basis for normative work of service authorisation for UE-to-UE Relay operation.

Authorization in the UE-to-UE Relay Scenario is performed during discovery security material provision procedure and U2U relay discovery procedure.

During hop-by-hop PC5 link establishment in Layer 3 and Layer 2 UE-to-UE Relay Communication, when the Layer 3 and Layer 2 UE-to-UE Relay is in 3GPP coverage, the existing procedures specified in clause 6.3 in TS 33.503 [6] can be re-used between the Ends UE (Source UE and/or Target UE) and (Layer 3 and Layer 2) the UE-to-UE Relay for authorization.

## 7.4 Key Issue #4: Privacy of information over the UE-to-UE Relay

For Key Issue #4, the following is agreed:

- For Layer 3 UE-to-UE relay communication privacy, enhanced Link Identifier Update (LIU) procedure, Sol#2 is used as basis for normative work.

## 7.5 Key Issue #5: Security of source and target UE communication via U2U relay

## 7.6 Key Issue #6: Support for Emergency service over UE-to-Network Relaying

For Key Issue #6, the following is agreed:

Solution #27 is selected for the normative work for emergency call via Layer 2 UE-to-Network Relay and Layer 3 UE-to-Network Relay.

NOTE: The SMF of the 5G ProSe UE-to-Network Relay is able to resolve a CP-PRUK ID or UP-PRUK ID of the 5G ProSe Remote UE into a SUPI of the 5G ProSe Remote UE as specified in clause 6.3 of TS 33.503 [6].

Annex A:  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2022-05 | SA3#107e | S3-221021 |  |  |  | Skeleton | 0.0.0 |
| 2022-07 | SA3#107 Adhoc-e | S3-221643 |  |  |  | S3-221489, S3-221640, S3-221693, S3-221609, S3-221608, S3-221677 implemented | 0.1.0 |
| 2022-08 | SA3#108-e | S3-222344 |  |  |  | S3-222364, S3-222365, S3-222354, S3-222355, S3-222402, S3-221927, S3-222341, S3-222371, S3-222372, S3-222373, S3-222296, S3-222306 implemented | 0.2.0 |
| 2022-10 | SA3#108Adhoc-e | S3-223054 |  |  |  | S3-222969, S3-223116, S3-222592, S3-222943, S3-222944, S3-222945, S3-222946, S3-222993, S3-222628, S3-222665, S3-222666, S3-222947, S3-222948, S3-223051, S3-223052, S3-223053, S3-222791, S3-222794, S3-222986, S3-222796, S3-222987, S3-222798, S3-222799, S3-222989, S3-223060, S3-223109, S3-223110, S3-223111 | 0.3.0 |
| 2022-11 | SA3#109 | S3-223971 |  |  |  | S3-223996, S3-223963, S3-224029, S3-223997, S3-223998, S3-223999, S3-223964, S3-224005, S3-223965, S3-223966, S3-223967, S3-224006, S3-223278, S3-223279, S3-223969, S3-223311, S3-224000, S3-224001, S3-224007, S3-223970, S3-223401, S3-223972, S3-223452, S3-224009, S3-223968, S3-223973, S3-223628, S3-224002, S3-223974, S3-224003, S3-223975, S3-224004, S3-223723, S3-223976, S3-223977, S3-224095, S3-223995, S3-223661 | 0.4.0 |
| 2022-11 | SA3#109 |  |  |  |  | New version created due to wrong file uploaded in the Portal | 0.4.1 |
| 2023-01 | SA3#109 Adhoc-e | S3-230567 |  |  |  | S3-230031, S3-230435, S3-230436, S3-230437, S3-230438, S3-230485, S3-230492, S3-230478, S3-230479, S3-230548, S3-230549, S3-230586, S3-230497, S3-230498, S3-230499, S3-230500, S3-230501, S3-230454, S3-230267, S3-230455, S3-230292, S3-230293, S3-230528, S3-230536, S3-230537, S3-230550, S3-230551, S3-230552, S3-230553, S3-230554, S3-230556, S3-230557, S3-230558 | 0.5.0 |
| 2023-02 | SA3#110 | S3-231439 |  |  |  | S3-231438, S3-231076, S3-231579, S3-231580, S3-231443, S3-231444, S3-231445, S3-231616, S3-231582, S3-231611, S3-231253, S3-231446, S3-231566, S3-231553, S3-231552, S3-230979, S3-231180, S3 231252, S3-231554, S3-231265, S3-230940, S3-231630, S3-231631, S3-231313, S3-231314 | 0.6.0 |
| 2023-04 | SA3#110 Adhoc-e | S3-232146 |  |  |  | S3-232203, S3-232204, S3-232221, S3-232140, S3-232141, S3-232191, S3-232192, S3-232111, S3-232112, S3-232113, S3-232125, S3-232202, S3-232167, S3-231869, S3-231870, S3-231847, S3-231871 | 0.7.0 |
| 2023-05 | SA#100 | SP-230567 |  |  |  | Presented for information and approval | 1.0.0 |
| 2023-06 | SA#100 |  |  |  |  | Upgrade to change control version | 18.0.0 |
| 2023-06 | SA#100 |  |  |  |  | EditHelp and MCC review | 18.0.1 |
| 2023-09 | SA#101 | SP-230889 | 0001 | - | F | Clean Up for TR 33.740 | 18.1.0 |