**3GPP TSG-SA3 Meeting #103-e *S3-212103-r4***

**e-meeting, 17 - 28 May 2021**

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| **CHANGE REQUEST** | | | | | | | | |
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|  | **33.501** | **CR** | **1137** | **rev** | **1** | **Current version:** | **16.6.0** |  |
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| ***Proposed change affects:*** | UICC apps |  | ME | **X** | Radio Access Network |  | Core Network | **X** |

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| ***Title:*** | Handling of KAUSF upon successful primary authentication | | | | | | | | | |
|  |  | | | | | | | | | |
| ***Source to WG:*** | S3 | | | | | | | | | |
| ***Source to TSG:*** | Samsung, NEC, Nokia, Nokia Shanghai Bell, Intel | | | | | | | | | |
|  |  | | | | | | | | | |
| ***Work item code:*** | TEI16 | | | | |  | ***Date:*** | | | 2020-12-23 |
|  |  | | | |  | |  | | |  |
| ***Category:*** | **F** |  | | | | | ***Release:*** | | | Rel-16 |
|  | *Use one of the following categories:* ***F*** *(correction)* ***A*** *(mirror corresponding to a change in an earlier release)* ***B*** *(addition of feature),* ***C*** *(functional modification of feature)* ***D*** *(editorial modification)*  Detailed explanations of the above categories can be found in 3GPP [TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm). | | | | | | | | *Use one of the following releases: Rel-8 (Release 8) Rel-9 (Release 9) Rel-10 (Release 10) Rel-11 (Release 11) … Rel-15 (Release 15) Rel-16 (Release 16) Rel-17 (Release 17) Rel-18 (Release 18)* | |
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| ***Reason for change:*** | | SA3 clarified in its LS to CT4 (S3-201350):  - Only one KAUSF (latest one) is maintained in the AUSF and in the UE, as KAUSF is security association between the UE and the HPLMN.  - The AUSF in home PLMN never maintains two KAUSF, when a user is simultaneously registered in two Serving Networks via different access-types (3gpp and non-3gpp).  - SA3 does not see the need for maintaining multiple KAUSF in the UE and in the HPLMN. Further keeping the old keys laying around in the network is not a good security practice.  The above clarifications needs to be captured in the TS 33.501. | | | | | | | | |
|  | |  | | | | | | | | |
| ***Summary of change:*** | | * UDM stores the authEvents for both serving networks in multiple registrations. UDM selects the AUSF reporting the most recent successful authentication result. * When the UE having multiple registrations, while de-registers from the new serving network:   + AUSF and UE stores the latest KAUSF after UE deregistration;   + UDM, when deleting the authentication results for the new serving network, keeps the AUSF info in the authEvent. * UDM selects the latest AUSF that served the UE and maintains the latest KAUSF, for SoRProtection and/or UPUProtection services. * AUSF stores only the latest KAUSF upon successful authentication procedure and deletes any stored old KAUSF. * UE stores only the latest KAUSF upon successful authentication procedure and deletes any stored old KAUSF.   During the execution of e.g. SoR/UPU procedures, the UDM selects the AUSF that stores the latest KAUSF. | | | | | | | | |
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| ***Consequences if not approved:*** | | UE and HN may store and use different versions of KAUSF leading to failure of SoRProtection and UPUProtection services. | | | | | | | | |
|  | |  | | | | | | | | |
| ***Clauses affected:*** | | 6.1.1.1, 6.1.3.1, 6.1.4.1, 6.2.2.1, 6.2.2.2, 6.3.2.1, 6.4.2.1, 6.14.1, 6.14.2.1, 6.14.2.2, 6.14.2.3, 6.15.1, 6.15.2.1, 6.15.2.2, 14.1.Y | | | | | | | | |
|  | |  | | | | | | | | |
|  | | **Y** | **N** |  | | | |  | | |
| ***Other specs*** | |  | **X** | Other core specifications | | | | TS/TR ... CR ... | | |
| ***affected:*** | |  | **X** | Test specifications | | | | TS/TR ... CR ... | | |
| ***(show related CRs)*** | |  | **X** | O&M Specifications | | | | TS/TR ... CR ... | | |
|  | |  | | | | | | | | |
| ***Other comments:*** | |  | | | | | | | | |
|  | |  | | | | | | | | |
| ***This CR's revision history:*** | |  | | | | | | | | |

**\*\*\*\* Start of Changes \*\*\*\***

#### 6.1.1.1 General

The purpose of the primary authentication and key agreement procedures is to enable mutual authentication between the UE and the network and provide keying material that can be used between the UE and the serving network in subsequent security procedures. The keying material generated by the primary authentication and key agreement procedure results in an anchor key called the KSEAF provided by the AUSF of the home network to the SEAF of the serving network.

Keys for more than one security context can be derived from the KSEAF without the need of a new authentication run. A concrete example of this is that an authentication run over a 3GPP access network can also provide keys to establish security between the UE and a N3IWF used in untrusted non-3GPP access.

The anchor key KSEAF is derived from an intermediate key called the KAUSF. The KAUSF is an additional key established between the UE and HN resulting from the primary authentication procedure. The KAUSF may be securely stored in the AUSF based on the home operator's policy on using such key e.g. if the control plane solution for Steering of Roaming or UE Parameter Update procedures are supported by the HPLMN (see clauses 6.14 and 6.15).

NOTE A: For standalone non-public networks when an authentication method other than 5G AKA or EAP-AKA' is used, Annex I.2 applies.

NOTE 1: This feature is an optimization that might be useful, for example, when a UE registers to different serving networks for 3GPP-defined access and untrusted non-3GPP access (this is possible according to TS 23.501 [2]). The details of this feature are operator-specific and not in scope of this document.

NOTE 2: A subsequent authentication based on the KAUSF stored in the AUSF gives somewhat weaker guarantees than an authentication directly involving the ARPF and the USIM. It is rather comparable to fast re-authentication in EAP-AKA'.

NOTE 2a: Void.

UE and serving network shall support EAP-AKA' and 5G AKA authentication methods.

NOTE 2b: It is the home operator's decision which authentication method is selected.

The USIM shall reside on a UICC. The UICC may be removable or non-removable.

NOTE 3: For non-3GPP access networks USIM applies in case of terminal with 3GPP access capabilities.

If the terminal supports 3GPP access capabilities, the credentials used with EAP-AKA' and 5G AKA for non-3GPP access networks shall reside on the UICC.

NOTE 4: EAP-AKA' and 5G AKA are the only authentication methods that are supported in UE and serving network, hence only they are described in sub-clause 6.1.3 of the present document. For a private network using the 5G system as specified in [7] an example of how additional authentication methods can be used with the EAP framework is given in the informative Annex B.

NOTE 5: For non-public network (NPN) security the Annex I of the present document provides details.

**\*\*\*\* 2nd Change \*\*\*\***

#### 6.1.3.1 Authentication procedure for EAP-AKA'

EAP-AKA' is specified in RFC 5448 [12]. The 3GPP 5G profile for EAP-AKA' is specified in the normative Annex F.

Editor’s Note: The reference to RFC 5448 will be superseded by the internet draft referred to in [67] when it becomes an RFC.

The selection of using EAP-AKA' is described in sub-clause 6.1.2 of the present document.



Figure 6.1.3.1-1: Authentication procedure for EAP-AKA'

The authentication procedure for EAP-AKA' works as follows, cf. also Figure 6.1.3.1-1:

1. The UDM/ARPF shall first generate an authentication vector with Authentication Management Field (AMF) separation bit = 1 as defined in TS 33.102 [9]. The UDM/ARPF shall then compute CK' and IK' as per the normative Annex A and replace CK and IK by CK' and IK'.

2. The UDM shall subsequently send this transformed authentication vector AV' (RAND, AUTN, XRES, CK', IK') to the AUSF from which it received the Nudm\_UEAuthentication\_Get Request together with an indication that the AV' is to be used for EAP-AKA' using a Nudm\_UEAuthentication\_Get Response message.

NOTE: The exchange of a Nudm\_UEAuthentication\_Get Request message and an Nudm\_UEAuthentication\_Get Response message between the AUSF and the UDM/ARPF described in the preceding paragraph is the same as for trusted access using EAP-AKA' described in TS 33.402 [11], sub-clause 6.2, step 10, except for the input parameter to the key derivation, which is the value of <network name>. The "network name" is a concept from RFC 5448 [12]; it is carried in the AT\_KDF\_INPUT attribute in EAP-AKA'. The value of <network name> parameter is not defined in RFC 5448 [12], but rather in 3GPP specifications. For EPS, it is defined as " access network identity " in TS 24.302 [71], and for 5G, it is defined as "serving network name" in sub-clause 6.1.1.4 of the present document.

In case SUCI was included in the Nudm\_UEAuthentication\_Get Request, UDM will include the SUPI in the Nudm\_UEAuthentication\_Get Response.

If a subscriber has an AKMA subscription, the UDM shall include the AKMA indication in the Nudm\_UEAuthentication\_Get Response.

If a subscriber has an AKMA subscription, the UDM shall include the AKMA indication in the Nudm\_UEAuthentication\_Get Response.

3. The AUSF shall send the EAP-Request/AKA'-Challenge message to the SEAF in a Nausf\_UEAuthentication\_Authenticate Response message.

4. The SEAF shall transparently forward the EAP-Request/AKA'-Challenge message to the UE in a NAS message Authentication Request message. The ME shall forward the RAND and AUTN received in EAP-Request/AKA'-Challenge message to the USIM. This message shall include the ngKSI and ABBA parameter. In fact, SEAF shall include the ngKSI and ABBA parameter in all EAP-Authentication request message. ngKSI will be used by the UE and AMF to identify the partial native security context that is created if the authentication is successful. The SEAF shall set the ABBA parameter as defined in Annex A.7.1. During an EAP authentication, the value of the ngKSI and the ABBA parameter sent by the SEAF to the UE shall not be changed.

NOTE 1: The SEAF needs to understand that the authentication method used is an EAP method by evaluating the type of authentication method based on the Nausf\_UEAuthentication\_Authenticate Response message.

5. At receipt of the RAND and AUTN, the USIM shall verify the freshness of the AV' by checking whether AUTN can be accepted as described in TS 33.102 [9]. If so, the USIM computes a response RES. The USIM shall return RES, CK, IK to the ME. If the USIM computes a Kc (i.e. GPRS Kc) from CK and IK using conversion function c3 as described in TS 33.102 [9], and sends it to the ME, then the ME shall ignore such GPRS Kc and not store the GPRS Kc on USIM or in ME. The ME shall derive CK' and IK' according to Annex A.3.

If the verification of the AUTN fails on the USIM, then the USIM and ME shall proceed as described in sub-clause 6.1.3. 3.

6. The UE shall send the EAP-Response/AKA'-Challenge message to the SEAF in a NAS message Auth-Resp message.

7. The SEAF shall transparently forward the EAP-Response/AKA'-Challenge message to the AUSF in Nausf\_UEAuthentication\_Authenticate Request message.

8. The AUSF shall verify the message by comparing XRES and RES, and if the AUSF has successfully verified this message it shall continue as follows, otherwise it shall return an error to the SEAF. AUSF shall inform UDM about the authentication result (see sub-clause 6.1.4 of the present document for details on linking authentication confirmation).

9. The AUSF and the UE may exchange EAP-Request/AKA'-Notification and EAP-Response /AKA'-Notification messages via the SEAF. The SEAF shall transparently forward these messages.

NOTE 2: EAP Notifications as described in RFC 3748 [27] and EAP-AKA Notifications as described in RFC 4187 [21] can be used at any time in the EAP-AKA exchange. These notifications can be used e.g. for protected result indications or when the EAP server detects an error in the received EAP-AKA response.

10. The AUSF derives EMSK from CK’ and IK’ as described in RFC 5448[12] and Annex F. The AUSF uses the most significant 256 bits of EMSK as the KAUSF and then calculates KSEAF from KAUSF as described in clause A.6. The AUSF shall send an EAP Success message to the SEAF inside Nausf\_UEAuthentication\_Authenticate Response, which shall forward it transparently to the UE. Nausf\_UEAuthentication\_Authenticate Response message contains the KSEAF. If the AUSF received a SUCI from the SEAF when the authentication was initiated (see sub-clause 6.1.2 of the present document), then the AUSF shall also include the SUPI in the Nausf\_UEAuthentication\_Authenticate Response message.

NOTE 3: For lawful interception, the AUSF sending SUPI to SEAF is necessary but not sufficient. By including the SUPI as input parameter to the key derivation of KAMF from KSEAF, additional assurance on the correctness of SUPI is achieved by the serving network from both, home network and UE side.

11. The SEAF shall send the EAP Success message to the UE in the N1 message. This message shall also include the ngKSI and the ABBA parameter. The SEAF shall set the ABBA parameter as defined in Annex A.7.1.

NOTE 4: Step 11 could be NAS Security Mode Command or Authentication Result.

NOTE 5: The ABBA parameter is included to enable the bidding down protection of security features that may be introduced later.

The key received in the Nausf\_UEAuthentication\_Authenticate Response message shall become the anchor key, KSEAF in the sense of the key hierarchy in sub-clause 6.2 of the present document. The SEAF shall then derive the KAMF from the KSEAF, the ABBA parameter and the SUPI according to Annex A.7 and send it to the AMF. On receiving the EAP-Success message, the UE derives EMSK from CK’ and IK’ as described in RFC 5448 and Annex F. The ME uses the most significant 256 bits of the EMSK as the KAUSF and then calculates KSEAF in the same way as the AUSF. The UE shall derive the KAMF from the KSEAF, the ABBA parameter and the SUPI according to Annex A.7.

NOTE 6: As an implementation option, the UE creates the temporary security context as described in step 11 after receiving the EAP message that allows EMSK to be calculated. The UE turns this temporary security context into a partial security context when it receives the EAP Success. The UE removes the temporary security context if the EAP authentication fails.

The further steps taken by the AUSF upon receiving a successfully verified EAP-Response/AKA'-Challenge message are described in sub-clause 6.1.4 of the present document.

If the EAP-Response/AKA'-Challenge message is not successfully verified, the subsequent AUSF behaviour is determined according to the home network's policy.

If AUSF and SEAF determine that the authentication was successful, then the SEAF provides the ngKSI and the KAMF to the AMF.

**\*\*\*\* 3rd Change \*\*\*\***

6.1.4.1 Introduction

The 5G authentication and key agreement protocols provide increased home control. Compared to EPS AKA in EPS, this provides better security useful in preventing certain types of fraud as explained in more detail below.

This increased home control comes in the following forms in 5GS:

- In the case of EAP-AKA', the AUSF in the home network obtains confirmation that the UE has been successfully authenticated when the EAP-Response/AKA'-Challenge received by the AUSF has been successfully verified, cf. sub-clause 6.1.3.1 of the present document.

- In the case of 5G AKA, the AUSF in the home network obtains confirmation that the UE has been successfully authenticated when the authentication confirmation received by the AUSF in Nausf\_UEAuthentication\_Authenticate Request message has been successfully verified, cf. sub-clause 6.1.3.2 of the present document.

When 3GPP credentials are used in above cases, the result is reported to the UDM. Details are described in clause 6.1.4.1a.

The feature of increased home control is useful in preventing certain types of fraud, e.g. fraudulent Nudm\_UECM\_Registration Request for registering the subscriber's serving AMF in UDM that are not actually present in the visited network. But an authentication protocol by itself cannot provide protection against such fraud. The authentication result needs to be linked to subsequent procedures, e.g. the Nudm\_UECM\_Registration procedure from the AMF in some way to achieve the desired protection.

The actions taken by the home network to link authentication confirmation (or the lack thereof) to subsequent procedures are subject to operator policy and are not standardized.

But informative guidance is given in sub-clause 6.1.4.2 as to what measures an operator could usefully take. Such guidance may help avoiding a proliferation of different solutions.

The feature of increased home control is also used to allow the UDM to keep track of the AUSF that stores the KAUSF to be used during e.g. the control plane solution for Steering of Roaming or UE Parameter Update procedures; i.e. the AUSF that stores the latest KAUSF generated after successful completion of the latest primary authentication reported to the UDM.

After the UDM is informed that the UE has been successfully (re-)authenticated, the UDM shall store the AUSF instance which reported the successful authentication. If the UDM has been previously informed that the UE was authenticated by a different AUSF instance, the UDM may request the old AUSF to clear the stale security parameters (KAUSF, SOR counter and UE parameter update counter). If the UDM determines to delete the security parameters in the old AUSF, then the UDM shall use the Nausf\_UEAuthentication\_deregister service operation (see clause 14.1.Y) to send the indication to the old AUSF to clear the old KAUSF.

**\*\*\*\* 4th Change \*\*\*\***

6.2.2.1 Keys in network entities

***Keys in the ARPF***

The ARPF shall process the long-term key K and any other sensitive data only in its secure environment. The key K shall be 128 bits or 256 bits long.

During an authentication and key agreement procedure, the ARPF shall derive CK' and IK' from K in case EAP-AKA' is used and derive KAUSF from K in case 5G AKA is used. The ARPF shall forward the derived keys to the AUSF.

The ARPF holds the Home Network Private Key that is used by the SIDF to deconceal the SUCI and reconstruct the SUPI. The generation and storage of this key material is out of scope of the present document.

***Keys in the AUSF***

In case EAP-AKA' is used as authentication method, the AUSF shall derive a key KAUSF from CK' and IK' for EAP-AKA' as specified in clause 6.1.3.1. In case that 5G AKA is used as authentication method, the UDM/ARPF shall generate the KAUSF as specified in clause 6.1.3.2.

The KAUSF may be stored in the AUSF between two subsequent authentication and key agreement procedures.

When the AUSF stores the KAUSF, the AUSF shall store the latest KAUSF generated after successful completion of the latest primary authentication. The authentication is considered as successful and the AUSF shall store the latest KAUSF or replace the old KAUSF with the new KAUSF (if the SEAF(s) end up selecting the same AUSF instance for (re)authentication of the UE):

- in case 5G AKA is used as authentication method, when the RES\* and the XRES\* are equal (see clause 6.1.3.2.0, Step 11).

- in case EAP-AKA' is used as authentication method, when the AUSF sends an EAP-Success message to the SEAF (see clause 6.1.3.1, Step 10).

The AUSF shall generate the anchor key, also called KSEAF, from the authentication key material received from the ARPF during an authentication and key agreement procedure.

***Keys in the SEAF***

The SEAF receives the anchor key, KSEAF, from the AUSF upon a successful primary authentication procedure in each serving network.

The SEAF shall never transfer KSEAF to an entity outside the SEAF. Once KAMF is derived KSEAF shall be deleted.

The SEAF shall generate KAMF from KSEAF immediately following the authentication and key agreement procedure and hands it to the AMF.

NOTE 1: This implies that a new KAMF, along with a new KSEAF, is generated for each run of the authentication and key agreement procedure.

NOTE 2: The SEAF is co-located with the AMF.

***Keys in the AMF***

The AMF receives KAMF from the SEAF or from another AMF.

The AMF shall, based on policy, derive a key KAMF' from KAMF for transfer to another AMF in inter-AMF mobility. The receiving AMF shall use KAMF' as its key KAMF.

NOTE 3: The precise rules for key handling in inter-AMF mobility can be found in clause 6.9.3.

The AMF shall generate keys KNASint and KNASenc dedicated to protecting the NAS layer.

The AMF shall generate access network specific keys from KAMF. In particular,

- the AMF shall generate KgNB and transfer it to the gNB.

- the AMF shall generate NH and transfer it to the gNB, together with the corresponding NCC value.   
The AMF may also transfer an NH key, together with the corresponding NCC value, to another AMF, cf. clause 6.9.

- the AMF shall generate KN3IWF and transfer it to the N3IWF when KAMF is received from SEAF, or when KAMF' is received from another AMF.

***Keys in the NG-RAN***

The NG-RAN (i.e., gNB or ng-eNB) receives KgNB and NH from the AMF. The ng-eNB uses KgNB as KeNB.

The NG-RAN (i.e., gNB or ng-eNB) shall generate all further access stratum (AS) keys from KgNB and /or NH.

***Keys in the N3IWF***

The N3IWF receives KN3IWF from the AMF.

The N3IWF shall use KN3IWF as the key MSK for IKEv2 between UE and N3IWF in the procedures for untrusted non-3GPP access, cf. clause 11.

Figure 6.2.2-1 shows the dependencies between the different keys, and how they are derived from the network nodes point of view.



**Figure 6.2.2-1: Key distribution and key derivation scheme for 5G for network nodes**

NOTE 4: The key derivation and distribution scheme for standalone non-public networks, when an authentication method other than 5G AKA or EAP-AKA' is used, is given in Annex I.2.3.

**\*\*\*\* 5th Change \*\*\*\***

6.2.2.2 Keys in the UE

For every key in a network entity, there is a corresponding key in the UE.

Figure 6.2.2-2 shows the corresponding relations and derivations as performed in the UE.



**Figure 6.2.2-2: Key distribution and key derivation scheme for 5G for the UE**

***Keys in the USIM***

The USIM shall store the same long-term key K that is stored in the ARPF.

During an authentication and key agreement procedure, the USIM shall generate key material from K that it forwards to the ME.

If provisioned by the home operator, the USIM shall store the Home Network Public Key used for concealing the SUPI.

***Keys in the ME***

The ME shall generate the KAUSF from the CK, IK received from the USIM. The generation of this key material is specific to the authentication method and is specified in clause 6.1.3.

When 5G AKA is used, the generation of RES\* from RES shall be performed by the ME.

The UE shall store the latest KAUSF or replace the old KAUSF with the latest KAUSF, after successful completion of the latest primary authentication. If the USIM supports 5G parameters storage, KAUSF shall be stored in the USIM. Otherwise, KAUSF shall be stored in the non-volatile memory of the ME.

The ME shall perform the generation of KSEAF from the KAUSF. If the USIM supports 5G parameters storage, KSEAF shall be stored in the USIM. Otherwise, KSEAF shall be stored in the non-volatile memory of the ME.

The ME shall perform the generation of KAMF. If the USIM supports 5G parameters storage, KAMF shall be stored in the USIM. Otherwise, KAMF shall be stored in the non-volatile memory of the ME.

The ME shall perform the generation of all other subsequent keys that are derived from the KAMF.

Any 5G security context, KAUSF and KSEAF that are stored at the ME shall be deleted from the ME if:

a) the USIM is removed from the ME when the ME is in power on state;

b) the ME is powered up and the ME discovers that the USIM is different from the one which was used to create the 5G security context;

c) the ME is powered up and the ME discovers that there is no USIM is present at the ME.

NOTE 1: The key derivation and distribution scheme for standalone non-public networks, when an authentication method other than 5G AKA or EAP-AKA' is used, is given in Annex I.2.3.

**\*\*\*\* 6th Change \*\*\*\***

6.3.2.1 Multiple registrations in different PLMNs

The UE shall independently maintain and use two different 5G security contexts, one per PLMN's serving network. Each security context shall be established separately via a successful primary authentication procedure with the Home PLMN.

The ME shall store the two different 5G security contexts on the USIM if the USIM supports the 5G parameters storage. If the USIM does not support the 5G parameters storage, then the ME shall store the two different 5G security contexts in the ME non-volatile memory. Both of the two different 5G security contexts are current 5G security context.

The latest KAUSF result of the successful completion of the latest primary authentication shall be used by the UE and the HN regardless over which access network type (3GPP or non-3GPP) it was generated.

The HN shall keep the latest KAUSF generated during successful authentication over a given access even if the UE is deregistered from that access, but the UE is registered via another access.

**\*\*\*\* 7th Change \*\*\*\***

6.4.2.1 Multiple active NAS connections with different PLMNs

TS 23.501 [2] has a scenario when the UE is registered to a VPLMN's serving network via 3GPP access and to another VPLMN's or HPLMN's serving network via non-3GPP access at the same time. When the UE is registered in one PLMN's serving network over a certain type of access (e.g. 3GPP) and is registered to another PLMN's serving network over another type of access (e.g. non-3GPP), then the UE has two active NAS connections with different AMF's in different PLMNs. As described in clause 6.3.2.1, the UE shall independently maintain and use two different 5G security contexts, one per PLMN serving network. The 5G security context maintained by the UE shall contain the full set of 5G parameters, including NAS context parameters for 3GPP and non-3GPP access types per PLMN. In case of connection to two different PLMNs, it is necessary to maintain a complete 5G NAS security context for each PLMN independently, each with all associated parameters (such as two pairs of NAS COUNTs, i.e. one pair for 3GPP access and one pair for non-3GPP access).

Each security context shall be established separately via a successful primary authentication procedure with the Home PLMN.

If UE receives more than one authentication requests via different access types simultaneously (e.g. initial registration after UE powers on, UE initiate the service request procedures simultaneously via both NAS connections), the UE should process the authentication challenges in sequence. The UE should respond to the second authentication challenge after completion of the first authentication procedure. In case if the first authentication procedure is 5G-AKA, then after sending the Authentication Response message to the network the UE should respond to the second authentication challenge and in case if the first authentication procedure is EAP-AKA', then after receiving EAP Success/Failure from the network the UE should respond to the second authentication challenge.

All the NAS and AS security mechanisms defined for single registration mode are applicable independently on each access using the corresponding 5G security context.

NOTE: The UE belongs to a single HPLMN.

**\*\*\*\* 8th Change \*\*\*\***

6.14.1 General

This clause describes the security functions necessary to support steering of the UE in the VPLMN during registration procedure and also after registration as described in TS 23.122 [53] Annex C. The security functions are described in the context of the functions supporting the control plane solution for steering of roaming in 5GS.

If the control plane solution for Steering of Roaming is supported by the HPLMN, the AUSF shall store the latest KAUSF after the completion of the latest primary authentication.

The content of the Steering List as well as the conditions for sending it to the UE are described in TS 23.122 [53] Annex C. The Steering List includes either a list of preferred PLMN/access technology combinations, a secured packet or the HPLMN indication that 'no change of the "Operator Controlled PLMN Selector with Access Technology" list stored in the UE is needed and thus no list of preferred PLMN/access technology combinations is provided'.

NOTE: The Steering of Roaming Information is defined in clause 1.2 of TS 23.122 [53]. It contains thus the ACK indication, the Steering List and the integrity protection information.

**\*\*\*\* 9th Change \*\*\*\***

6.14.2.1 Procedure for steering of UE in VPLMN during registration

The security procedure for the case where the UE registers with VPLMN AMF is described below in figure 6.14.2.1-1:



**Figure 6.14.2.1-1: Procedure for providing list of preferred PLMN/access technology combinations** **during registration in VPLMN**

1) The UE initiates registration by sending Registration Request message to the VPLMN AMF.

2-3) The VPLMN AMF executes the registration procedure as defined in sub-clause 4.2.2.2.2 of 3GPP TS 23.502 [8]. As part of the registration procedure, the VPLMN AMF executes primary authentication of the UE and then initiates the NAS SMC procedure, after the authentication is successful.

4-5) The VPLMN AMF invokes the Nudm\_UECM\_Registration message to the UDM and registers access with the UDM as per step 14a in sub-clause 4.2.2.2.2 of 3GPP TS 23.502[8].

6) The VPLMN AMF invokes Nudm\_SDM\_Get service operation message to the UDM to get amongst other information the Access and Mobility Subscription data for the UE (see step 14b in sub-clause 4.2.2.2.2 of 3GPP TS 23.502 [8]).

7) The UDM decides to send the Steering of Roaming Information, and obtains a list of preferred PLMN/access technology combinations or a secured packet list as described in TS 23.122 [53].

If the UDM determines that the UE is configured to not expect to receive Steering of Roaming Information at initial registration and if the UDM determines that no change of the "Operator Controlled PLMN Selector with Access Technology" list stored in the UE is needed, then the UDM may not piggyback Steering of Roaming Information at all in the Nudm\_SDM\_Get response and hence the following steps are omitted.

8-9) The UDM shall invoke Nausf\_SoRProtection service operation message to the AUSF to get SoR-MAC-IAUSF and CounterSoR as specified in sub-clause 14.1.3 of this document. The UDM shall select the AUSF that holds the latest KAUSF of the UE.

If the HPLMN decides that the UE is to acknowledge the successful security check of the received Steering of Roaming Information, then the UDM shall set accordingly the ACK Indication included in the Nausf\_SoRProtection service operation message to signal that it also needs the expected SoR-XMAC-IUE, as specified in sub-clause 14.1.3 of this document.

NOTE: At reception of Nausf\_SoRProtection\_Protect request from the UDM, the AUSF constructs the SOR header, as described in clause 9.11.3.51 of TS 24.501 [35], based on the information received from the UDM, i.e. ACK Indication and list of preferred PLMN/access technology combinations or secured packet (if provided).

The details of the CounterSoR are specified in sub-clause 6.14.2.3 of this document. The inclusion of the Steering List and the SoR header in the calculation of SoR-MAC-IAUSF allows the UE to verify that the received Steering of Roaming Information is not tampered with or removed by the VPLMN. The expected SoR-XMAC-IUE allows the UDM to verify that the UE received the Steering of Roaming Information.

10) The UDM responds to the Nudm\_SDM\_Get service operation to the VPLMN AMF, which shall include the ACK Indication, the list of preferred PLMN/access technology combinations or secured packet (if provided), SoR-MAC-IAUSF and CounterSoR within the Access and Mobility Subscription data. If the UDM requests an acknowledgement, it shall temporarily store the expected SoR-XMAC-IUE.

11) The VPLMN AMF shall construct the SOR header based on the ACK Indication and the list of preferred PLMN/access technology combinations or secured packet (if provided) received from the UDM and include it in the SOR transparent container as specified in clause 9.11.3.51 of TS 24.501 [35]. The resulting Steering of Roaming Information, also including SoR-MAC-IAUSFand CounterSoR(both also received from the UDM), is conveyed to the UE in the Registration Accept message;

12) On receiving the Registration Accept message with Steeringof Roaming Information the UE shall calculate the SoR-MAC-IAUSF in the same way as the AUSF (as specified in Annex A.17) on the received Steering of Roaming Information, including the CounterSoR and the SoR header, and verifies whether it matches the SoR-MAC-IAUSF value received in the Registration Accept message. Based on the SoR-MAC-IAUSF verification outcome, the behaviour of the UE is specified in TS 23.122 [53].

13) If the UDM has requested an acknowledgement from the UE and the UE verified that the Steering of Roaming Information received in step 11 has been provided by the HPLMN, then the UE shall send the Registration Complete message to the serving AMF. The UE shall generate the SoR-MAC-IUE as specified in Annex A.18 and includes the generated SoR-MAC-IUE in a SOR transparent container in the Registration Complete message.

14) The AMF sends a Nudm\_SDM\_Info request message to the UDM. If a transparent container with the SoR-MAC-IUE was received in the Registration Complete message, the AMF shall include the SoR-MAC-IUEin the Nudm\_SDM\_Info request message.

15) If the HPLMN indicated that the UE is to acknowledge the successful security check of the received Steering of Roaming Information in step 10, then the UDM shall compare the received SoR-MAC-IUE with the expected SoR-XMAC-IUE that the UDM stored temporarily in step 10.

**\*\*\*\* 10th Change \*\*\*\***

6.14.2.2 Procedure for steering of UE in VPLMN or HPLMN after registration

The security procedure for the steering of UE in VPLMN after registration is described below in figure 6.14.2.2-1:



**Figure 6.14.2.2-1: Procedure for providing list of preferred PLMN/access technology combinations** **after registration**

1) The UDM decides to notify the UE of the changes to the Steering of Roaming Information by the means of invoking Nudm\_SDM\_Notification service operation.

2-3) The UDM shall invoke Nausf\_SoRProtection service operation message by including the ACK Indication and optionally the list of preferred PLMN/access technology combinations or secured packetto the AUSF to get SoR-MAC-IAUSF and CounterSoR as specified in sub-clause 14.1.3 of this document. The UDM shall select the AUSF that holds the latest KAUSF of the UE.

If the HPLMN decided that the UE is to acknowledge the successful security check of the received Steering of Roaming Information, then the UDM shall set accordingly the ACK Indication included in the Nausf\_SoRProtection service operation message to signal that it also needs the expected SoR-XMAC-IUE, as specified in sub-clause 14.1.3 of this document.

NOTE: At reception of Nausf\_SoRProtection\_Protect request from the UDM, the AUSF constructs the SOR header, as described in clause 9.11.3.51 of TS 24.501 [35], based on the information received from the UDM, i.e. ACK Indication and optionally the list of preferred PLMN/access technology combinations or secured packet.

The details of the CounterSoR are specified in sub-clause 6.14.2.3 of this document. The inclusion of the Steering List and the SOR header in the calculation of SoR-MAC-IAUSF allows the UE to verify that the Steering of Roaming Information received is not tampered with or removed by the VPLMN. The inclusion of these information in the calculation of the expected SoR-XMAC-IUE allows the UDM to verify that the UE received the Steering of Roaming Information.

4) The UDM shall invoke Nudm\_SDM\_Notification service operation, which contains optionally the list of preferred PLMN/access technology combinations or secured packet,the ACK Indication, SoR-MAC-IAUSF, and CounterSoR within the Access and Mobility Subscription data. If the UDM requests an acknowledgement, it shall temporarily store the expected SoR-XMAC-IUE.

5) Upon receiving the Nudm\_SDM\_Notification message, the AMF shall send a DL NAS Transport message to the served UE. The AMF shall include in the DL NAS Transport message the SOR transparent container (including the SOR header) constructed as specified in clause 9.11.3.51 of 3GPP TS 24.501 [35] based on the ACK Indication, the Steering List, SoR-MAC-IAUSF and CounterSoR received from the UDM.

6) On receiving the DL NAS Transport message, the UE shall calculate the SoR-MAC-IAUSF in the same way as the AUSF (as specified in Annex A.17) on the received Steering of Roaming Information, including the CounterSoR and the SoR header and verify whether it matches the SoR-MAC-IAUSF value received in the DL NAS Transport message.

7) If the UDM has requested an acknowledgement from the UE and the UE verified that the Steering Information has been provided by the HPLMN, then the UE shall send the UL NAS Transport message to the serving AMF. The UE shall generate the SoR-MAC-IUE as specified in Annex A.18 and includes the generated SoR-MAC-IUE in a SOR transparent container in the UL NAS Transport message.

8) The AMF shall send a Nudm\_SDM\_Info request message to the UDM. If a SOR transparent container with the SoR-MAC-IUE was received in the UL NAS Transport message, the AMF shall include the SoR-MAC-IUE in the Nudm\_SDM\_Info request message.

9) If the HPLMN indicated that the UE is to acknowledge the successful security check of the received Steering of Roaming Information, then the UDM shall compare the received SoR-MAC-IUE with the expected SoR-XMAC-IUE that the UDM stored temporarily in step 4.

**\*\*\*\* 11th Change \*\*\*\***

6.14.2.3 SoR Counter

The AUSF and the UE shall associate a 16-bit counter, CounterSoR, with the key KAUSF.

The UE shall initialize the CounterSoR to 0x00 0x00 when the newly derived KAUSF is stored (see clause 6.2.2.2). The UE shall store the SoR counter. If the USIM supports both 5G parameters storage and 5G parameters extended storage, then CounterSoR shall be stored in the USIM. Otherwise, CounterSoR shall be stored in the non-volatile memory of the ME.

To generate the SoR-MAC-IAUSF, the AUSF shall use the CounterSoR. The CounterSoR shall be incremented by the AUSF for every new computation of the SoR-MAC-IAUSF. The CounterSoR is used as freshness input into SoR-MAC-IAUSF and SoR-MAC-IUE derivations as described in the Annex A.17 and Annex A.18 respectively, to mitigate the replay attack. The AUSF shall send the value of the CounterSoR (used to generate the SoR-MAC-IAUSF) along with the SoR-MAC-IAUSF to the UE. The UE shall only accept CounterSoR value that is greater than stored CounterSoR value. The UE shall store the received CounterSoR, onlyif the verification of the received SoR-MAC-IAUSF is successful. The UE shall use the stored CounterSoR received from the HPLMN, when deriving the SoR-MAC-IUE for the SoR acknowledgement.

The AUSF and the UE shall maintain the CounterSoR for lifetime of the KAUSF.

The AUSF that supports the control plane solution for steering of roaming shall initialize the CounterSoR to 0x00 0x01 when the newly derived KAUSF is stored (see clause 6.2.2.1). The AUSF shall set the CounterSoR to 0x00 0x02 after the first calculated SoR-MAC-IAUSF, and monotonically increment it for each additional calculated SoR-MAC-IAUSF. The SoR Counter value of 0x00 0x00 shall not be used to calculate the SoR-MAC-IAUSF and SoR-MAC-IUE.

The AUSF shall suspend the SoR protection service for the UE, if the CounterSoR associated with the KAUSF of the UE, is about to wrap around. When a fresh KAUSF is generated for the UE, the CounterSoR at the AUSF is reset to 0x00 0x01 as defined above and the AUSF shall resume the SoR protection service for the UE.

**\*\*\*\* 12th Change \*\*\*\***

6.15.1 General

This clause describes the security functions necessary to update the UE parameters using the UDM control plane procedure specified in TS 23.502 [8]. The security functions are described in the context of the functions supporting the delivery of UE Parameters Update Data from the UDM to the UE after the UE has successfully registered to the 5G network.

If the control plane procedure for UE parameters update is supported by the UDM, the AUSF shall store the latest KAUSF after the completion of the latest primary authentication.

The content of UE Parameters Update Data and the conditions for sending it to the UE as well as how it is handled at the UE are specified in TS 24.501 [35].

NOTE : The home network relies on the serving network to deliver the UE parameters update.

**\*\*\*\* 13th Change \*\*\*\***

6.15.2.1 Procedure for UE Parameters Update

The UDM may decide to perform UE parameters update anytime after the UE has been successfully authenticated and registered to the 5G system. The security procedure for the UE parameters update is described below in figure 6.15.2.1-1:

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**Figure 6.15.2.1-1: Procedure for UE Parameters Update**

1) The UDM decides to perform the UE Parameters Update (UPU) using the control plane procedure while the UE is registered to the 5G system. If the final consumer of any of the UE parameters to be updated (e.g., the updated Routing ID Data) is the USIM, the UDM shall protect these parameters using a secured packet mechanism (see 3GPP TS 31.115 [65]) to update the parameters stored on the USIM. The UDM shall then prepare the UE Parameters Update Data (UPU Data) by including the parameters protected by the secured packet, if any, as well as any UE parameters for which final consumer is the ME (see TS 24.501 [35]).

2-3) The UDM shall invoke Nausf\_UPUProtection service operation message by including the UPU Data to the AUSF to get UPU-MAC-IAUSF and CounterUPU as specified in sub-clause 14.1.4 of this document. The UDM shall select the AUSF that holds the latest KAUSF of the UE.

If the UDM decided that the UE is to acknowledge the successful security check of the received UE Parameters Update Data, then the UDM shall set the corresponding indication in the UE Parameters Update Data (see TS 24.501 [35]) and include the ACK Indication in the Nausf\_UPUProtection service operation message to signal that it also needs the expected UPU-XMAC-IUE, as specified in sub-clause 14.1.4 of this document.

The details of the CounterUPU is specified in sub-clause 6.15.2.2 of this document. The inclusion of UE Parameters Update Data in the calculation of UPU-MAC-IAUSF allows the UE to verify that it has not been tampered by any intermediary. The expected UPU-XMAC-IUE allows the UDM to verify that the UE received the UE Parameters Update Data correctly.

4) The UDM shall invoke Nudm\_SDM\_Notification service operation, which contains UE Parameters Update Data, UPU-MAC-IAUSF, CounterUPU within the Access and Mobility Subscription data. If the UDM requests an acknowledgement, it shall temporarily store the expected UPU-XMAC-IUE.

5) Upon receiving the Nudm\_SDM\_Notification message, the AMF shall send a DL NAS Transport message to the served UE. The AMF shall include in the DL NAS Transport message the transparent container received from the UDM.

6) On receiving the DL NAS Transport message, the UE shall calculate the UPU-MAC-IAUSF in the same way as the AUSF (as specified in Annex A.19) on the received UE Parameters Update Data and the CounterUPU and verify whether it matches the UPU-MAC-IAUSF value received in the DL NAS Transport message. If the verification of UPU-MAC-IAUSF is successful and the UPU Data contains any parameters that is protected by secured packet (see 3GPP TS 31.115 [65]), the ME shall forward the secured packet to the USIM using procedures in 3GPP TS 31.111 [66]. If the verification of UPU-MAC-IAUSF is successful and the UPU Data contains any parameters that is not protected by secure packet, the ME shall update its stored parameters with the received parameters in UDM Updata Data.

7) If the UDM has requested an acknowledgement from the UE and the UE has successfully verified and updated the UE Parameters Update Data provided by the UDM, then the UE shall send the UL NAS Transport message to the serving AMF. The UE shall generate the UPU-MAC-IUE as specified in Annex A.20 and include the generated UPU-MAC-IUE in a transparent container in the UL NAS Transport message.

8) If a transparent container with the UPU-MAC-IUE was received in the UL NAS Transport message, the AMF shall send a Nudm\_SDM\_Info request message with the transparent container to the UDM.

9) If the UDM indicated that the UE is to acknowledge the successful security check of the received UE Parameters Update Data, then the UDM shall compare the received UPU-MAC-IUE with the expected UPU-XMAC-IUE that the UDM stored temporarily in step 4.

**\*\*\*\* 14th Change \*\*\*\***

6.15.2.2 UE Parameters Update Counter

The AUSF and the UE shall associate a 16-bit counter, CounterUPU, with the key KAUSF.

The UE shall initialize the CounterUPU to 0x00 0x00 when the newly derived KAUSF is stored (see clause 6.2.2.2). The UE shall store the UPU counter . If the USIM supports both 5G parameters storage and 5G parameters extended storage, then CounterUPU shall be stored in the USIM. Otherwise, CounterUPU shall be stored in the non-volatile memory of the ME.

To generate the UPU-MAC-IAUSF, the AUSF shall use the CounterUPU. The CounterUPU shall be incremented by the AUSF for every new computation of the UPU-MAC-IAUSF. The CounterUPU is used as freshness input into UPU-MAC-IAUSF and UPU-MAC-IUE derivations as described in the Annex A.19 and Annex A.20 respectively, to mitigate the replay attack. The AUSF shall send the value of the CounterUPU (used to generate the UPU-MAC-IAUSF) along with the UPU-MAC-IAUSF to the UE. The UE shall only accept CounterUPU value that is greater than stored CounterUPU value. The UE shall update the stored CounterUPU with the received CounterUPU, onlyif the verification of the received UPU-MAC-IAUSF is successful. The UE shall use the CounterUPU received from the UDM, when deriving the UPU-MAC-IUE for the UE Parameters Upadate Data acknowledgement.

The AUSF and the UE shall maintain the CounterUPU for lifetime of the KAUSF.

The AUSF that supports the UE parameters update using control plane procedure shall initialize the CounterUPU to 0x00 0x01 when the newly derived KAUSF is stored (see clause 6.2.2.1). The AUSF shall set the CounterUPU to 0x00 0x02 after the first calculated UPU-MAC-IAUSF, and monotonically increment it for each additional calculated UPU-MAC-IAUSF. The UPU Counter value of 0x00 0x00 shall not be used to calculate the UPU-MAC-IAUSF and UPU-MAC-IUE.

The AUSF shall suspend the UE Parameters Update protection service for the UE, if the CounterUPU associated with the KAUSF of the UE, is about to wrap around. When a fresh KAUSF is generated for the UE, the CounterUPU at the AUSF is reset to 0x00 0x01 as defined above and the AUSF shall resume theUE Parameters Update protection service for the UE.

**\*\*\*\* 15th Change \*\*\*\***

14.1.Y Nausf\_UEAuthentication\_deregister service operation

**Service operation name:** Nausf\_UEAuthentication\_deregister

**Description:** Deletion of stale security parameters (KAUSF, SOR counter and UE parameter update counter) in AUSF. UDM uses this service operation to request the AUSF to clear the stale security parameters, after the UE has been successfully (re)authenticated in different AUSF Instance.

**Input, Required:** SUPI

**Input, Optional:** None

**Output, Required:** None

**Output, Optional:** None

**\*\*\*\* End of Changes \*\*\*\***