**3GPP TSG-SA3 Meeting #115 *S3-240881***

Athens, Greece, 26th February - 1st March 2024

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| *CR-Form-v12.1* |
| **DRAFT CHANGE REQUEST** |
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|  | **1** | **CR** | **Draft CR** | **rev** |  | **Current version:** | **18.4.0** |  |
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| *For* [***HE******LP***](http://www.3gpp.org/3G_Specs/CRs.htm#_blank)*on using this form: comprehensive instructions can be found at* [*http://www.3gpp.org/Change-Requests*](http://www.3gpp.org/Change-Requests)*.* |
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| ***Proposed change affects:*** | UICC apps |  | ME |  | Radio Access Network |  | Core Network |  |

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|  |
| ***Title:***  | Draft CR CryptoSP for TS 33.501 |
|  |  |
| ***Source to WG:*** | Ericsson |
| ***Source to TSG:*** | S3 |
|  |  |
| ***Work item code:*** | CryptoSP |  | ***Date:*** | 2024-03-01 |
|  |  |  |  |  |
| ***Category:*** | B |  | ***Release:*** | Rel-19 |
|  | *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 canbe 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)* |
|  |  |
| ***Reason for change:*** | * RFC 2818 has been obsoleted by RFC 9110. Align the RFC changes between TS 33.501 and TS 33.310.
* Current example in Annex B only describes EAP-TLS 1.2. For clarity the example needs to be extended to cover also EAP-TLS 1.3.
* Added reference to RFC 9191, a companion document to RFC 9190 giving guidance on the use of certificates in EAP-TLS.
* - Removed EAP-TLS 1.2 specific fields from procedure and included example flow for EAP-TLS 1.3 (new figure).
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|  |  |
| ***Summary of change:*** | * RFC 2818 is replaced with RFC 9110
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|  |  |
| ***Consequences if not approved:*** | * Referencing obsolete RFCs is a security risk as obsolete RFCs often have obsolete security and privacy guidelines.
* Uncertanties about how EAP-TLS 1.3 fits into the primary authentication flow
 |
|  |  |
| ***Clauses affected:*** | 2, 13.1.0, Annex B.2 |
|  |  |
|  | **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:*** | SA3#115: S3-240672, S3-241678 |

#### \*\*\* Start of Change 1 \*\*\*

# 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 TS 23.501: "System Architecture for the 5G System".

[3] 3GPP TS 33.210: "3G security; Network Domain Security (NDS); IP network layer security".

[4] IETF RFC 4303: "IP Encapsulating Security Payload (ESP)".

[5] 3GPP TS 33.310: "Network Domain Security (NDS); Authentication Framework (AF)".

[6] IETF RFC 4301: "Security Architecture for the Internet Protocol".

[7] 3GPP TS 22.261: "Service requirements for next generation new services and markets".

[8] 3GPP TS 23.502: "Procedures for the 5G System".

[9] 3GPP TS 33.102: "3G security; Security architecture".

[10] 3GPP TS 33.401: "3GPP System Architecture Evolution (SAE); Security architecture".

[11] 3GPP TS 33.402: "3GPP System Architecture Evolution (SAE); Security aspects of non-3GPP accesses".

[12] IETF RFC 5448: " Improved Extensible Authentication Protocol Method for 3rd Generation Authentication and Key Agreement (EAP-AKA')".

[13] 3GPP TS 24.301: " Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3".

[14] 3GPP TS 35.215: " Specification of the 3GPP Confidentiality and Integrity Algorithms UEA2 & UIA2; Document 1: UEA2 and UIA2 specifications".

[15] NIST: "Advanced Encryption Standard (AES) (FIPS PUB 197)".

[16] NIST Special Publication 800-38A (2001): "Recommendation for Block Cipher Modes of Operation".

[17] NIST Special Publication 800-38B (2001): "Recommendation for Block Cipher Modes of Operation: The CMAC Mode for Authentication".

[18] 3GPP TS 35.221: " Specification of the 3GPP Confidentiality and Integrity Algorithms EEA3 & EIA3; Document 1: EEA3 and EIA3 specifications".

[19] 3GPP TS 23.003: "Numbering, addressing and identification".

[20] 3GPP TS 22.101: "Service aspects; Service principles".

[21] IETF RFC 4187: "Extensible Authentication Protocol Method for 3rd Generation Authentication and Key Agreement (EAP-AKA)".

[22] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification".

[23] 3GPP TS 38.323: "NR; Packet Data Convergence Protocol (PDCP) specification".

[24] 3GPP TS 33.117: "Catalogue of general security assurance requirements".

[25] IETF RFC 7296: "Internet Key Exchange Protocol Version 2 (IKEv2)"

[26] Void

[27] IETF RFC 3748: "Extensible Authentication Protocol (EAP)".

[28] 3GPP TS 33.220: "Generic Authentication Architecture (GAA); Generic Bootstrapping Architecture (GBA)".

[29] SECG SEC 1: Recommended Elliptic Curve Cryptography, Version 2.0, 2009. Available <http://www.secg.org/sec1-v2.pdf>

[30] SECG SEC 2: Recommended Elliptic Curve Domain Parameters, Version 2.0, 2010. Available at <http://www.secg.org/sec2-v2.pdf>

[31] 3GPP TS 38.470: "NG-RAN; F1 General aspects and principles".

[32] 3GPP TS 38.472: "NG-RAN; F1 signalling transport".

[33] 3GPP TS 38.474: "NG-RAN; F1 data transport".

[34] 3GPP TS 38.413: "NG-RAN; NG Application Protocol (NGAP)"

[35] 3GPP TS 24.501: "Non-Access-Stratum (NAS) protocol for 5G System (5GS); Stage 3".

[36] 3GPP TS 35.217: "Specification of the 3GPP Confidentiality and Integrity Algorithms UEA2 & UIA2; Document 3: Implementors' test data".

[37] 3GPP TS 35.223: "Specification of the 3GPP Confidentiality and Integrity Algorithms EEA3 & EIA3; Document 3: Implementors' test data".

[38] IETF RFC 5216: "The EAP-TLS Authentication Protocol".

[39] IETF RFC 4346: "The Transport Layer Security (TLS) Protocol Version 1.1".

[40] IETF RFC 5246: "The Transport Layer Security (TLS) Protocol Version 1.2".

[41] 3GPP TS 38.460: "NG-RAN; E1 general aspects and principles".

[42] Void.

[43] IETF RFC 6749: "OAuth2.0 Authorization Framework".

[44] IETF RFC 7519: "JSON Web Token (JWT)".

[45] IETF RFC 7515: "JSON Web Signature (JWS)".

[46] IETF RFC 7748: "Elliptic Curves for Security".

[47] IETF RFC 9113: "HTTP/2".

[48] IETF RFC 5280: "Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile".

[49] IETF RFC 6960: "X.509 Internet Public Key Infrastructure Online Certificate Status Protocol - OCSP".

[50] IETF RFC 6066: "Transport Layer Security (TLS) Extensions: Extension Definitions".

[51] 3GPP TS 37.340: "Evolved Universal Terrestrial Radio Access (E-UTRA) and NR; Multi-connectivity; Stage 2".

[52] 3GPP TS 38.300: "NR; NR and NG-RAN Overall Description; Stage 2".

[53] 3GPP TS 33.122: "Security Aspects of Common API Framework for 3GPP Northbound APIs".

[54] 3GPP TS28.533: " Management and orchestration; Architecture framework".

[55] 3GPP TS28.531: "Management and orchestration of networks and network slicing; Provisioning".

[56] Void

[57] IETF RFC 7542: "The Network Access Identifier".

[58] IETF RFC 6083: " Datagram Transport Layer Security (DTLS) for Stream Control Transmission Protocol (SCTP)".

[59] IETF RFC 7516: "JSON Web Encryption (JWE)".

[60] IETF RFC 8446: "The Transport Layer Security (TLS) Protocol Version 1.3".

[61] IETF RFC 5705,"Keying Material Exporters for Transport Layer Security (TLS)".

[62] IETF RFC 5869 "HMAC-based Extract-and-Expand Key Derivation Function (HKDF)".

[63] NIST Special Publication 800-38D: "Recommendation for Block Cipher Modes of Operation: Galois Counter Mode (GCM) and GMAC".

[64] IETF RFC 6902: "JavaScript Object Notation (JSON) Patch".

[65] 3GPP TS 31.115: "Secured packet structure for (Universal) Subscriber Identity Module (U)SIM Toolkit applications.

[66] 3GPP TS 31.111: "Universal Subscriber Identity Module (USIM), Application Toolkit (USAT)".

[67] IETF RFC 9048: "Improved Extensible Authentication Protocol Method for 3GPP Mobile Network Authentication and Key Agreement (EAP-AKA')".

[68] 3GPP TS 29.510: "5G System; Network function repository services".

[69] 3GPP TS 36.331: "Radio Resource Control (RRC); Protocol specification".

[70] 3GPP TS 29.505: "5G System; Usage of the Unified Data Repository services for Subscription Data; Stage 3".

[71] 3GPP TS 24.302: "Access to the 3GPP Evolved Packet Core (EPC) via non-3GPP access networks; Stage 3".

[72] 3GPP TS 23.216: "Single Radio Voice Call Continuity (SRVCC)".

[73] 3GPP TS 29.573: " Public Land Mobile Network (PLMN) Interconnection; Stage 3".

[74] 3GP TS 29.500: "5G System; Technical Realization of Service Based Architecture; Stage 3".

[75] IEEE TSN network aspects: see 3GPP TS 23.501 [2] references [95], [96], [97], [98], [104], and [107].

[76] IETF RFC 9190: "EAP-TLS 1.3: Using the Extensible Authentication Protocol with TLS 1.3".

[77] IETF RFC 8446: "The Transport Layer Security (TLS) Protocol Version 1.3".

[78] 3GPP TS 38.401: "NG-RAN; Architecture description".

[79] 3GPP TS 23.316: "Wireless and wireline convergence access support for the 5G System (5GS)"

[80] IEEE Std 802.11-2016 (Revision of IEEE Std 802.11-2012) - IEEE Standard for Information technology—Telecommunications and information exchange between systems Local and metropolitan area networks—Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.

[81] IETF RFC 2410 "The NULL Encryption Algorithm and Its Use With IPsec".

[82] Void

[83] RFC 7858: "Specification for DNS over Transport Layer Security (TLS)".

[84] RFC 8310: "Usage Profiles for DNS over TLS and DNS over DTLS".

[85] RFC 4890: "Recommendations for Filtering ICMPv6 Messages in Firewalls".

[86] 3GPP TS 23.273: "5G System (5GS) Location Services (LCS); Stage 2".

[87] 3GPP TS 38.305: "Stage 2 functional specification of User Equipment (UE) positioning in NG-RAN".

[88] 3GPP TS 36.300: "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access (E-UTRAN); Overall description; Stage 2".

[89] IANA: "Transport Layer Security (TLS) Parameters".

[90] Void

[91] 3GPP TS 33.535: "Authentication and key management for applications based on 3GPP credentials in the 5G System (5GS)".

[92] 3GP TS 29.573: "5G System; Public Land Mobile Network (PLMN) Interconnection".

[93] 3GPP TS 29.503: "5G System; Unified Data Management Services".

[94] 3GPP TS 29.501: "5G System; Principles and Guidelines for Services Definition".

[95] 3GPP TS 29.502: "5G System; Session Management Services".

[96] 3GPP TS 29.526: "5G System; Network Slice-Specific Authentication and Authorization (NSSAA) services".

[97] 3GPP TS 23.402: "Authentication enhancements for non-3GPP accesses".

[98] 3GPP TS 23.548: "5G System Enhancements for Edge Computing; Stage 2".

[99] RFC 5281: "Extensible Authentication Protocol Tunneled Transport Layer Security Authenticated Protocol Version 0 (EAP-TTLSv0)".

[100] RFC 6678: "Requirements for a Tunnel-Based Extensible Authentication Protocol (EAP) Method".

[101] General Data Protection Regulation, <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:02016R0679-20160504&from=EN>.

[102] 3GPP TS 33.246: "Security of Multimedia Broadcast/Multicast Service (MBMS)".

[103] 3GPP TS 23.247: "Architectural enhancements for 5G multicast-broadcast services".

[104] 3GPP TS 33.535: "Authentication and Key Management for Applications (AKMA) based on 3GPP credentials in the 5G System (5GS)".

[105] 3GPP TS 23.288: "Architecture enhancements for 5G System(5GS) to support network data analytics services".

[106] 3GPP TS 23.554 Application architecture for MSGin5G Service; Stage 2.

[107] 3GPP TS 22.262 Message service with the 5G System (5GS); Stage 1.

[108] 3GPP TS 26.502: "5G multicast–broadcast services; User Service architecture".

[109] 3GPP TS 33.503: "Security Aspects of Proximity based Services (ProSe) in the 5G System (5GS)".

[110] NIST Special Publication 800-90A (2015): "Recommendation for Random Number Generation Using Deterministic Random Bit Generators".

[111] IETF RFC 4555 (2006-06): "RFC IKEv2 Mobility and Multihoming Protocol (MOBIKE)".

[XX] IETF RFC 9110: " HTTP Semantics".

[XY] IETF RFC 9191: "Handling Large Certificates and Long Certificate Chains in TLS-Based EAP Methods".

#### \*\*\* End of Change 1 \*\*\*

#### \*\*\* Start of Change 2 \*\*\*

# 13 Service Based Interfaces (SBI)

## 13.1 Protection at the network or transport layer

### 13.1.0 General

All network functions shall support mutually authenticated TLS and HTTPS as specified in RFC 9113 [47] and RFC 9110 [XX]. The identities in the end entity certificates shall be used for authentication and policy checks. Network functions shall support both server-side and client-side certificates. TLS client and server certificates shall be compliant with the SBA certificate profile specified in clause 6.1.3c of TS 33.310 [5].

The TLS profile shall follow the profile given in clause 6.2 of TS 33.210 [3] with the restriction that it shall be compliant with the profile given by HTTP/2 as defined in RFC 9113 [47]. TLS clients shall include the SNI extension as specified in RFC 9113 [47].

TLS shall be used for transport protection within a PLMN unless network security is provided by other means.

NOTE 1: Regardless of whether TLS is used or not, NDS/IP as specified in TS 33.210 [3] and TS 33.310 [5] can be used for network layer protection.

NOTE 2: If interfaces are trusted (e.g. physically protected), it is for the PLMN-operator to decide whether to use cryptographic protection.

NOTE 3: It is a vendor implementation decision how the SNI extension is being used in TLS servers.

\*\*\* End of Change 2 \*\*\*

## \*\*\*\*\*\* NEXT CHANGE **\*\*\*\***

# B.2 Primary authentication and key agreement

## B.2.1 EAP TLS

### B.2.1.1 Security procedures

EAP-TLS is a mutual authentication EAP method that can be used by the EAP peer and the EAP server to authenticate each other. It is specified in RFC 5216 [38] and RFC 9190 [76]. The 3GPP TLS protocol profile related to supported TLS versions and supported TLS cipher suites in 3GPP networks is specified in clause 6.2 of TS 33.210 [3]. The 3GPP profile of TLS certificates is specified in clause 6.1.3a of TS 33.310 [5]. Guidance on the use of certificates in EAP-TLS is specified in RFC 9191 [XY].

EAP-TLS supports several TLS versions, and the negotiation of the TLS version is part of EAP-TLS. The main principle of negotiation goes as follows. The EAP server indicates the support for EAP-TLS in the EAP-Request. If the peer chooses EAP-TLS, it responds with an EAP-Response indicating in the ClientHello message which TLS versions the peer supports. The EAP server chooses the TLS version, and indicates the chosen version in the ServerHello message.

The EAP-TLS procedure described in the RFC 5216 [38] is applicable to TLS 1.2 defined in RFC 5246 [40]. The EAP-TLS procedure described in the RFC 9190 [76] is applicable to TLS 1.3 defined in RFC 8446 [77].

The procedure below is based on the unified authentication framework from the present document, procedures from TS 23.502 [8] and RFC 5216 [38]. The procedure for EAP-TLS 1.2 and EAP-TLS 1.3 are presented here as examples, and other potential procedures are possible, e.g. if TLS resumption is used, or if EAP-TLS 1.2 is used with privacy.



Figure B.2.1.1-1: Using EAP-TLS 1.2 Authentication Procedures over 5G Networks for initial authentication



Figure B.2.1.1-X: Using EAP-TLS 1.3 Authentication Procedures over 5G Networks for initial authentication

1. The UE sends the Registration Request message to the SEAF, containing SUCI. If the SUPI is in NAI format, only the username part of the NAI is encrypted using the selected protection scheme and included in the SUCI, together with the realm part in the NAI needed for UDM routing.

Privacy considerations are described in Clause B.2.1.2.

2. The SEAF sends Nausf\_UEAuthentication\_Authenticate Request message to the AUSF. The SUCI and the serving network name (as described in clause 6.1.1.4) are included in the message.

3. AUSF sends the the Nudm\_UEAuthentication\_Get Request, containing SUCI and the serving network name, to UDM. The general rules for UDM selection apply.

4. The SIDF located within the UDM de-conceals the SUCI to SUPI if SUCI is received in the message. The UDM then selects the primary authentication method.

5. If the UDM chooses to use EAP-TLS, it sends the SUPI and an indicator to choose EAP-TLS to AUSF in the Nudm\_UEAuthentication\_Get Response.

6. With the received SUPI and the indicator, the AUSF chooses EAP-TLS as the authentication method. The AUSF sends thea Nausf\_UEAuthentication\_Authenticate Response message containing EAP-Request/EAP-TLS [TLS start] message to the SEAF.

7. The SEAF forwards the EAP-Request/EAP-TLS [TLS start] in the Authentication Request message to the UE. This message also includes the ngKSI and the ABBA parameter. In fact, the SEAF shall always 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.

8. After receiving the EAP-TLS [TLS-start] message from SEAF, the UE replies with an EAP-Response/EAP-TLS [client\_hello] to the SEAF in the Authentication Response message. The contents of TLS client\_hello are defined in the TLS specification of the TLS version in use.

NOTE1: The EAP framework supports negotiation of EAP methods. If the UE does not support EAP-TLS, it should follow the rule described in RFC 3748 [27] to negotiate another EAP method. In 5G system, UDM typically knows which EAP method and credentials are supported by the subscriber, and consequently EAP based negotiation may never be used.

9. The SEAF forwards the EAP-Response/EAP-TLS [client hello] message to AUSF in the Nausf\_UEAuthentication\_Authenticate Request.

10. The AUSF replies to the SEAF with EAP-Request/EAP-TLS in the Nausf\_UEAuthentication\_Authenticate Response, which further includes information elements such as server\_hello, server\_certificate, certificate\_request etc. depending on the TLS version. These information elements are defined in the RFCs for the corresponding TLS version in use.

11. The SEAF forwards the EAP-Request/EAP-TLS message with server\_hello and other information elements to the UE through Authentication Request message. This message also includes the ngKSI and the ABBA parameter. The SEAF shall set the ABBA parameter as defined in Annex A.7.1.

12. The UE authenticates the server with the received message from step 11.

NOTE 2: The UE is required to be pre-configured with a UE certificate and also certificates that can be used to verify server certificates.

13. If the TLS server authentication is successful, then the UE replies with EAP-Response/EAP-TLS in Authentication Response message, which further contains information element such as client\_certificate, client\_certificate\_verify, client\_finished etc. depending on the TLS version. Privacy considerations are described in Clause B.2.1.2.

14. The SEAF forwards the message with EAP-Response/EAP-TLS message with client\_certificate and other information elements to the AUSF in the Nausf\_UEAuthentication\_Authenticate Request.

15. The AUSF authenticates the UE based on the message received. The AUSF verifies that the client certificate provided by the UE belongs to the subscriber identified by the SUPI. If there is a miss-match in the subscriber identifiers in the SUPI, the AUSF does not accept the client certificate. If the AUSF has successfully verified this message, the AUSF continues to step 16, otherwise it returns an EAP-failure.

NOTE 2: The AUSF is required to be pre-configured with the root or any intermediary CA certificates that can be used to verify UE certificates. Deployment of certificate revocation lists (CRLs) and online certificate status protocol (OCSP) are described in clause B.2.2.

16. The AUSF sends EAP-Request/EAP-TLS message with information elements that depend on the TLS version to the SEAF in the Nausf\_UEAuthentication\_Authenticate Response.

17. The SEAF forwards EAP-Request/EAP-TLS message from step 16 to the UE with Authentication Request message. This message also includes the ngKSI and the ABBA parameter. The SEAF shall set the ABBA parameter as defined in Annex A.7.1.

18. The UE sends an empty EAP-TLS message to the SEAF in Authentication Response message.

19. The SEAF further forwards the EAP-Response/EAP-TLS message to the AUSF in the Nausf\_UEAuthentication\_Authenticate Request.

20. The AUSF uses the most significant 256 bits of EMSK as the KAUSF and then calculates KSEAF from KAUSF as described in Annex A.6. The AUSF sends an EAP-Success message to the SEAF together with the SUPI and the derived anchor key in the Nausf\_UEAuthentication\_Authenticate Response.

21. The SEAF forwards the EAP-Success message to the UE and the authentication procedure is finished. This message also includes the ngKSI and the ABBA parameter. The SEAF shall set the ABBA parameter as defined in Annex A.7.1. Then the SEAF derives the KAMF from the KSEAF, the ABBA parameter and the SUPI according to Annex A.7, and provides the ngKSI and the KAMF to the AMF.

On receiving the EAP-Success message, the UE derives EMSK and 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 derives the KAMF from the KSEAF, the ABBA parameter and the SUPI according to Annex A.7.

NOTE 3: Step 21 could be NAS Security Mode Command or Authentication Result.

NOTE 4: The ABBA parameter is included to enable the bidding down protection of security features that may be introduced later.

NOTE 5: As an implementation option, the UE creates the temporary security context as described in step 21 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.

### B.2.1.2 Privacy considerations

#### B.2.1.2.1 EAP TLS without subscription identifier privacy

For EAP TLS, if the operator determines to not provide subscription identifier privacy for the UE in TLS layer (e.g., in TLS 1.2 without privacy option), the subscription identifier protection in NAS layer, i.e., in Step 1 of Figure B.2.1-1, becomes ineffective privacy-wise. Therefore, the operator may just choose that UE uses "null-scheme" for calculation of SUCI which is sent in NAS layer. However, the operator may anyway use other than null-schemes (e.g., one of ECIES schemes) for simplification of having single scheme for all UEs in NAS layer even though privacy is not enhanced in this particular case.

The operator could also determine not to provide subscription identifier privacy for the UE in NAS layer even though the TLS layer inherently provides subscription identifier privacy (e.g., in TLS 1.3). In such case, the operator may just choose that UE uses "null-scheme" for calculation of SUCI which is sent in NAS layer.

#### B.2.1.2.2 EAP TLS with subscription identifier privacy

For EAP TLS, if the operator determines to provide subscription identifier privacy for the UE in TLS layer, the the EAP TLS server needs to support privacy either inherently (e.g., in TLS 1.3) or via separate privacy option (e.g., in TLS 1.2). If privacy is an option in TLS layer, then the operator needs to configure UE with the information that privacy-on-TLS layer is enabled. Further, following considerations need to be taken.

In Step 1 of Figure B.2.1-1, it is important that calculation of SUCI, which is sent in NAS layer, is done using schemes other than "null-scheme". Otherwise, the subscription identifier protection provided by TLS layer becomes ineffective privacy-wise. Nevertheless, the "null-scheme" could be used in NAS layer while still preserving subscription identifier privacy, by omitting the username part from NAI as described in RFC 4282 clause 2.3 [y]. It would be analogous to using anonymous identifier in EAP, meaning that only realm part from NAI is included in SUCI which is sent in NAS layer. Thus formed SUCI can still be used to route the authentication request to AUSF.

In Step 13 and 14 of Figure B.2.1-1, when TLS 1.2 is used, the UE would need to behave as described in "Section 2.1.4. Privacy" of RFC 5216 [38] where instead of sending the client certificate in cleartext over the air, the UE first sends TLS certificate (no cert) and only later sends TLS certificate after a TLS is setup.

### B.2.2 Revocation of subscriber certificates

Subscriber certificates that are used with EAP-TLS typically include static validity times. A certificate revocation list (CRL) as specified in RFC 5280 [48] and online certificate status protocol (OCSP) as specified in RFC 6960 [49] are means for the issuing certificate authority (CA) to revoke the certificates before their scheduled expiration date. In 5G security architecture, the UDM/ARPF is responsible for such subscriber status information. EAP-TLS peers and servers may also support Certificate Status Requests (OCSP stapling) as specified in RFC6066 [50] which allows peers to request the server's copy of the current status of certificates.

The deployment of CRLs is demonstrated in figure B.2.2-1. When the UDM/ARPF maintains the CRLs, the lists may be periodically updated to AUSFs, and stored locally in AUSF.



Figure B.2.2-1: AUSF requests CRL from UDM/ARPF

The deployment of OSCP is demonstrated in figure B.2.2-2. When the UDM/ARPF supports OCSP, the AUSF may check the certificate status online.



Figure B.2.2-2: AUSF requests the status of TLS certificate from UDM/ARPF

\*\*\*\*\*\* END OF CHANGES **\*\*\*\***