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Technical Report

3rd Generation Partnership Project;

Technical Specification Group Services and System Aspects;

Study on authentication and key management for applications;

based on 3GPP credential in 5G

(Release 16)

** 

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# Foreword

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

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# Introduction

This clause is optional. If it exists, it is always the second unnumbered clause.

# 1 Scope

The present document specifies key issues, derived requirements and potential solutions to support authentication and key management aspects for applications and 3GPP services based on 3GPP credentials in 5G, including the IoT use case. It analyzes issues and requirements for:

- providing authentication and key management procedures to applications and 3GPP services in 5G scenarios which allow the UE to securely exchange data with an application server

- decoupling these procedures from the the transport protocol, in order to allow for the adaption to differernt application layer protocols

The document takes into account new solutions as well as potential adaptations to existing ones such as GBA described in TS33.220 and BEST described in TS33.163, in order to support the above mentioned requirements with procedures and protocols defined in SBA.

# 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 33.220: "Generic Authentication Architecture (GAA); Generic Bootstrapping Architecture (GBA)".

[3] 3GPP TS 33.163: "Battery Efficient Security for very low Throughput Machine Type Communication (MTC) device (BEST)".

[4] IETF RFC 3748, Extensible Authentication Protocol (EAP)

[5] 3GPP TS 33.905:” Recommendations for trusted open platforms”

[6] ["ISO/IEC JTC 1/SC 17 Cards and security devices for personal identification"](https://www.iso.org/committee/45144.html).….

[7] 3GPP TS 27.007: "AT command set for User Equipment (UE) V15.3.0".

[8] IETF RFC 5191, Protocol for Carrying Authentication for Network Access (PANA)

[9] IEEE 802.1X, Port-Based Network Access Control

[10] 3GPP TS 33.501: "Security architecture and procedures for 5G system (Release 15)".

[x] <doctype> <#>[ ([up to and including]{yyyy[-mm]|V<a[.b[.c]]>}[onwards])]: "<Title>".

# 3 Definitions and abbreviations

## 3.1 Definitions

For the purposes of the present document, the terms and definitions 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].

**example:** text used to clarify abstract rules by applying them literally.

## 3.3 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].

<ACRONYM> <Explanation>

5GS 5G System

5GC 5G Core

AKA Authentication and Key Agreement

AKMA Authentication and Key Management for Applications

AKMA AF AKMA Application Function

AKRS AKMA Key Repository Service

EPS Evolved Packet System

GBA Generic Bootstrapping Architecture

GAA Generic Authentication Architecture

NAF Network Application Function

SBA Service Based Architecture

# 4 Scenario

## 4.1 Scenario #1: <Scenario name>

# 5 Key Issues

5.1 Key Issue #1: Security Anchor

5.1.1 Issue detail

The GBA/GAA features specified in TS 33.220 [2] leverage the EPS/UMTS authentication infrastructure (especially the HSS) to provide the security between the UE and an application function in the network with which the UE interacts on the User Plane. It should be noted that GBA uses UMTS AKA and that the HSS provides the CK/IK to the BSF instead of Kasme.

Figure 5.1.1-1 below shows the architecture of the features. GBA allows mutual authentication and the establishment of shared keys between the UE and BSF over the Ub interface. GAA, on the other hand, enables using such shared keys for protecting the access to a NAF. In principle GBA keys can be used to secure any protocol between a UE and a NAF over the Ua interface.



Figure 5.1.1-1: GBA and GAA reference architecture from TS 33.2020 [2]

Since the AKMA feature is intended to leverage the 5GS authentication infrastructure to provide similar services, it is understood that GBA/GAA would be one of the starting points for the architectural design of AKMA. However, due to differences between the 5GS and EPS/UMTS there is no direct equivalent of the BSF and HSS in the 5GC. These differences include, but are not limited to, the following:

- The subscription data including the AKA credentials are stored in the UDM. However, it is another function, the AUSF, that is directly involved in the Primary Authentication procedure towards the serving PLMN.

- The Primary Authentication procedure establishes a shared key (KAUSF) between the UE and the AUSF while no such key exits in the EPS key hierarchy.

- The Primary Authentication is terminated in the AUSF by comparison to EPS where it is terminated in the MME.

- All the internal interfaces in the 5GC are SBA-based by comparison to the DIAMETER-based Zh and Zn interfaces in GBA.

As shown in Figure 2, the AKMA architecture will naturally include an AKMA Application Function with which the UE communicates over the User Plane. The AKMA AF interacts with an anchor function, the BSF-equivalent, in the 5G Core. It is only logical to assume that such an anchor function is needed to authenticate the UE and potentially to provide key management services towards the AKMA AF.



Figure 5.1.1-2: Role of the anchor function in the AKMA architecture

Editor’s Note: Figure for non-standalone scenario is FFS.

Therefore, solutions to this key issue must address the following aspects.

- How the anchor function is realized.

- The interfaces involving the anchor function, the UE, the AKMA AF and other 5GS functions.

- The procedures flow for the UE authentication and the management of the resulting bootstrapped keys used to secure the communication between the UE and the AKMA AF.

5.1.2 Security Threat

Not applicable.

5.1.3 Potential architectural requirement

The AKMA architecture shall support an anchor function in the 5GC for UE authentication. This function can be realized by a standalone or an existing function.

5.2 Key Issue #2: Transport independent procedure definition

5.2.1 Issue details

In AKMA, application server needs to be able to securely exchange data with a UE based on the result of authentication and key derivation between mobile network and UE.

In AKMA, there are three different communication interfaces, namely, (1)the communication between UE and 3GPP network, (2) between UE and application server, and (3) between 3GPP network and application server. It is necessary to design the appropriate procedures Considering the stage-3 work, the protocol used for AKMA procedure can be divided into two categories:

1. Using an existing transport protocol

The existing protocols for carrying parameters and transferring data refer to the protocols well designed and widely used by 3GPP, IETF and/or other standard organizations, e.g. PDCP layer protocol, TCP/IP, etc. Using such protocols can bring benefit for the procedure design, as the work can concentrated on the signaling/message flows. There will not be a need to pay much attention on considering how to design message type, format, and any other details as they are well defined in the protocols.

However, using existed protocol may bring some issue. If the communication is through specific application layer protocol, it will bring requirement for transport layer protocol. For example, if the communication is based on HTTP, then TCP shall be applied between UE and mobile network.

However, for some kinds of UEs, especially UE used for IoT, the resource is limited. It will influence UE can only implement few protocols due to its memory and calculation limitation. If application server communicates with UE by using specific application protocol, it implies that UE may could not implement other protocols. It raises the requirement for the communication between UE and mobile network. If the communication is based on specific protocol, some kinds of UE that could not implement such protocol is not able to support AKMA feature. That may limit AKMA usage.

2. Designing specific protocol for AKMA

Compared to using existed protocol, designing a specific protocol for AKMA allows for as much freedom as possible to design protocol types, formats and content. So specific protocol can be designed more flexible to fit for various lower layer protocols.

However, designing such specific protocol is generally difficult and it is debatable whether the protocol will be sufficiently robust. What is more, as it is newly defined, there will not be existing implementations. If only a custom designed protocol will be used, adoption of AKMA may be hampered by the lack of these implementations and competition of existing protocols. Depending on the use case, therefore, it should be considered to reuse existing protocols and only design new ones if existing protocols do not meet the specific requirements of AKMA.

5.2.2 Security Threats

N/A

5.2.3 Potential architecture requirements

## 5.3 Key Issue #X: Mutual authenticationbetween UE and anchor function

5.3.1 Key Issue detailsTo allow UEs securely communicating and exchanging data with an application server using the authentication and key management procedures for applications in 5G scenarios, it is expected that the AKMA framework would be leveraged. Therefore, in order to establish secure communication between the UE and the application server, the UE and the anchor function need to be able to mutually authenticate each other based on the 5G authentication framework first before allowing the application server to leverage this authentication in order to establish secure communication between the UE and the application server.

### 5.3.2 Security Threats

Without authentication in the UE, an [illegal](https://www.baidu.com/link?url=PJJQkBVmLEbcqEKYabH97s-OGY3ATzQdh1SumlAqRs51SHO5Bs7thprksX_ZxYXrc_C850_glooX5nUSY-oq0Nt5MNBIwDNZJ9PtEqY9gkm&wd=&eqid=8d94fe2700072580000000045b644c0b) UE may communicate with the anchor function and access AKMA services.

A fake anchor function may communicate with the UE that could potentially lead to the loss and exposure of user privacy.

### 5.3.3 Potential security requirements

The UE and the anchor function shall be able to mutually authenticate each other based on 5G credentials using the 5G authentication framework.

5.4 Key Issue #4: Authentication framework

5.4.1 Issue details

The 5GS AKMA framework needs an authentication framework so that only legitimate UEs can use the AKMA services. For example, it needs to be studied whether the AKMA authentication framework can leverage the fact that the primary authentication in the 5GS produces a key called the KAUSF at the AUSF in the HPLMN and the UE. The primary authentication meaning the one used to allow 5GS access to that UE. If that KAUSF could be the root key for the AKMA authentication framework, there would be no need for yet another authentication and therefore beneficial for IoT devices both signalling and processing wise. Recall that - in GBA/GAA architecture, the UE authentication (called boostrapping) was separate and additional authentication than the primary/access authentication providing access to the 3GPP system.

A careful analysis is required on effects of potential security compromise of AKMA authentication on 3GPP primary authentication and vice-versa.

5.4.2 Security Threats

Without a proper security design, compromise on AKMA authentication can jeopardize security on 3GPP side.

5.4.3 Potential security requirements

The system shall support a secure authentication framework to allow only legitimate UEs to use AKMA services.

The system shall prevent a potential security compromise of AKMA authentication from propagating to the 3GPP primary authentication and NAS/AS security.

Editor's Note: The above requirements are non-exhaustive and could evolve during the study.

5.5 Key Issue #5: User privacy

5.5.1 Issue details

The Subscription Permanent Identifier (SUPI) is considered sensitive information, since attackers may identify an individual subscriber through his/her permanent ID. Combined with other kinds of information, such as geographic location, an attacker may be able to trace a subscriber, or obtain access to further sensitive information. Thus, the Subscription Permanent Identifier needs to be protected.

Meanwhile, the SUPI being the basis for providing any service in 5G a network, must be known to the operator. This means that the operator is obliged to ensure that the SUPI is not revealed to any other parties.

When an operator wants to provide authentication and key management to an application server, it must have the ability to exchange information about a subscriber to enable the application server to determine the identity of its user. Hence, there is a need for another kind of identifier (permanent and/or temporarily) to identify users between the 3GPP network and an application server. And the MNO should be able to map the other kind of identifier to the permanent identifier of the MNO domain.

5.5.2 Security Threats

The Subscription Permanent Identifier may be leaked to unauthorized parties.

The application server may be unable to identify the user.

The operator may be unable to identify the users SUPI based on the new identifier between 3GPP network and application server.

5.5.3 Potential security requirements

SUPI shall not be revealed to application servers.

The system shall allow privacy protection of the SUPI when exchanged between the UE and the network for the purposes of AKMA services.

The 3GPP network shall be able to recover the SUPI based on an alternative identifier used between 3GPP network and application server.

## 5.6 Key Issue #6: secure communication between UE and application server

### 5.6.1 Issue details

In current BEST[3] and GBA[2] solutions, 3GPP network is responsible to derive Keys(e.g. KE2Menc,KE2Mint , Ks\_(int/ext)\_NAF) for UE and application server derived from the root subscriber authentication key K. However, the application server may not want to use this key, which is derived from the 3GPP network authentication key K. They may have a policy, which requires they use their own independently generated key (e.g. application specific key), but still require the use of features provided by the 3GPP network to distribute such a key. The mechanism can satisfy the demand of application providers who do not wish to establish the secure connection by using only a 3GPP credential.

In some scenarios, such as when the UE sends sensitive data to application server, the application security policy may require that the 3GPP network operator does not have accesses to that information. In addition, the services provided by the application server may be accessed by multiple applications. Therefore, it is desirable that a solution that addresses this key issue supports establishment of separate application specific keys for each application that are served by the application server.

### 5.6.2 Security threats

3GPP network may get access to sensitive data transferred between UE andapplications which is protected by the key derived from 3GPP network, or from 3GPP network and a pre-shared key (i.e., non-3GPP credential) if the pre-shared key gets compromised.

### 5.6.3 Potential security requirements

TBD

5.7 Key Issue #7: Protecting subscriber's personal information in control and data traffic

5.7.1 Issue details

This key issue is about potential personal information contained in various control and data traffic messages.

If AKMA architecture uses some form of content in control and or data traffic which is privacy sensitive, those content need to be protected against attacks.

By attacks, it is meant that unauthorized entities attempt to identify subscriptions by getting hold of the privacy sensitive content in one or more protocol messages.

5.7.2 Security Threats

Unprotected privacy sensitive content in control and or data traffic make it easier for attackers to potentially identify subscribers.

5.7.3 Potential security requirements

The system shall support protecting the privacy sensitive content in control and data traffic used in the AKMA architecture.

Editor's Note: It is FFS which AKMA interfaces are required to protected privacy sensitive content.

5.8 Key Issue #8: Protection of AKMA architecture interfaces

5.8.1 Issue details

The interfaces utilized by the AKMA architecture between the 5G system and the 3GPP services and application functions (commonly called AKMA AF) are supposed to transfer key material and and therefore needs to be properly evaluated.

5.8.2 Security Threats

In case the interfaces used by AKMA architecture lack confidentiality, integrity and replay protection between authenticated endpoints it will be possible for an attacker to eavesdrop, alter data unnoticed and replay packets.

5.8.3 Potential security requirements

The interfaces utilized by the AKMA architecture between the 5G system and the 3GPP services and application functions shall support confidentiality, integrity and replay protection between authenticated endpoints.

5.9 Key Issue #9: Key separation for AKMA AFs

5.9.1 Issue details

In a scenario where the 5G system provides cryptographic keys to AKMA Application Functions (either 3GPP services or third party applications), it is important to have key separation. In the sense that two separate AKMA AFs never utilize the same key.

5.9.2 Security Threats

If there is no key separation it can lead to a situation where one AKMA AF can decrypt traffic intended for another AKMA AF.

It would also allow the possibility for an actor to inject malicious packages which the UE would conclude as cryptographically correct.

5.9.3 Potential security requirements

The AKMA architecture shall support key separation for different AKMA AFs.

5.10 Key Issue #10: Compliance with local rules and regulations

5.10.1 Issue details

In different parts of the world, different rules and regulations apply with respect to the usage of cryptography. A service like AKMA that is intended to be deployed in many places around the globe should therefore be adaptable to the local situation.

In the case of AKMA, the operator is the facilitator of a service that can be used to agree a key between two parties which may not be under control of the operator. As such, operators in different parts of the world may be subject to some regulations with respect to providing key material to third parties.

Another potential use case of AKMA is that the operator facilitates end-to-end protection between a UE and a party outside of the operator domain. Also in such cases, restrictions may be enforced by the regulators.

In order to enhance adoption of the service, AKMA needs to be made regulations aware such that the service can be used irrespective of where the UE resides.

5.10.2 Security Threats

There are no threats.

5.10.3 Potential security requirements

AKMA service shall be made such that it can comply with rules and regulations of the serving network;

AKMA service shall be able to signal if services are not available under the regulations of the serving network

## 5.11 Key Issue #11: Generic battery efficient end-to-end security

### 5.11.1 Issue details

In case of a battery constrained UE that communicate to a 3rd party Application Server, it may be needed to enable end-to-end security (i.e. between UE and Application Server) that is battery efficient.

### 5.11.2 Security threats

Not applicable.

### 5.11.3 Potential security requirements

The solution shall support UEs that are battery constrained.

5.12 Key Issue #12: Key lifetimes

5.12.1 Issue details

For GBA, specified in [2], lifetimes are defined for the anchor key (Ks) and the derived sub-keys (Ks\_(ext/int) NAF). The maximum lifetime for a sub-key is equal to the lifetime of the anchor key.

Introducing a lifetime for anchor keys and derived sub-keys could be reasonable for AKMA as well.

5.12.2 Security Threats

If the anchor key and the derived sub-keys do not have a lifetime, an attacker may use compromised keys for a long time.

5.12.3 Potential security requirements

Both anchor keys and derived sub-keys shall be provided with a maximum lifetime.

The lifetime of the derived sub-keys shall not exceed the lifetime of the anchor key.

Either end on AKMA interfaces shall allow for renegotiation of keys when key lifetime is expired

5.13 Key Issue #13: API for AKMA keys in UE

Editors Note: This key issue needs to be revised to focus on the potential changes needed to the UICC – ME interface to support AKMA functions within the UE

5.13.1 Issue details

In GBA, the Network Application Function (NAF) has an interface, Zn, towards the Bootstrapping Server Function (BSF) as is shown in Key Issue 1. The NAF can request NAF specific keys from the BSF over the Zn. Similar interface is also expected to be defined between the AKMA application function (AF) and the AKMA security anchor. The benefit of having such standardized network interface is self-evident as it provides multivendor interoperability, i.e. it enables AFs from different vendors and application developers to request AKMA keys from the security anchor.

The ultimate purpose of the AKMA feature is to provide keys, which are used to secure application communication between an AF and an application running in the UE (called AKMA app). It is assumed that there will be a counterpart of the AKMA security anchor in the UE side (called AKMA bootstrapping client). See figure 5.13.1-1.



Figure 5.13.1-1: API within UE for fetching AKMA keys

While the AFs in the network side will have a standardised interface for fetching AKMA keys, as described above, such interface or API is missing in the UE side. This means that application developers would need to design, perhaps considerably, different versions of their AKMA apps depending on how AKMA keys are made available in different types of UEs. This could be an obstacle in adopting the use of AKMA keys for applications. Such API was not developed for GBA, but recommendations in this problem space were recorded in TR 33.905 [5]. Considerations in TR 33.905 could be useful to investigate in relation to this Key Issue.

Traditionally, 3GPP has not specified interfaces within the UE, except for the interface between the ME and UICC, which is a multivendor interface. Similarly, the interface between the AKMA bootstrapping client and AKMA apps could be seen as a multivendor interface as the developers of AKMA apps are assumed to be different from ME vendors.

Having such standardised API for requesting AKMA keys in the UE would mean less design effort for application developers as it would introduce multivendor interoperability also in the UE side. Thereby making AKMA more attractive for applications to use AKMA.

Solutions to this Key Issue should study the following aspects:

*-* How an API between an AKMA bootstrapping client and AKMA app could look like?

- What parameters are sent between the AKMA bootstrapping client and AKMA app?

- If and how does the AKMA bootstrapping client ensure that only authorized AKMA apps receive keys?

- If and how could considerations in TR 33.905 be useful in relation to this Key Issue?

5.13.2 Security Threats

Not applicable.

5.13.3 Potential security requirements

Not applicable.

5.14 Key Issue #14: Key revocation

5.14.1 Issue details

In key issue #12, lifetimes for the anchor key and derived sub-keys are discussed. A potential requirement is made that the lifetime of derived sub-keys (application keys) shall not exceed the lifetime of the anchor key.

To avoid re-negotiation of all sub-keys when the anchor key expires, one possibility is to continue to use these keys until their individual lifetime expires.

However, failure of the negotiation of a new anchor key implies that the UE is no longer authenticated. But according to the above, the derived sub-keys might still be in use.

Hence, a revocation procedure for application keys is needed in case there is no longer a valid anchor key.

5.14.2 Security Threats

If application keys cannot be revoked, there is a risk that a UE continues to use applications although the re-authentication of the UE fails or if the anchor key is compromised.

If an attacker can revoke application keys, there is a risk of DoS.

5.14.3 Potential security requirements

It shall be possible for the home network to revoke application keys securely.

Editor’s Note: It is FFS if the UE can revoke the application keys.

## 5.15 Key Issue #15: Synchronization of keys when using established keys.

### 5.15.1 Issue details

During authentication, the UE and the network will derive a number of keys, in order:

- KAUSF;

- KSEAF;

- KAMF;

Some of these established keys (or newly introduced keys specifically for AKMA) could be used as bootstrapping key for AKMA A likely candidate is KAUSF, which is what will be referred to in this key issue.

The KAUSF, however, is not part of the security context and a new KAUSF is derived at both the UE and the AUSF with any authentication, even if the resulting security context is never taken into use. As such, the AUSF and the UE may have a different view of which key is the current KAUSF. Similarly, if a specific key for AKMA was to be derived at the moment of authentication, the UE and the AKMA server may also get out of sync. As a consequence, the AKMA service may not be established because the UE and the AUSF / AKMA server are out of sync.

### 5.15.2 Security Threats

No service if the UE and AUSF / AKMA server are out of sync.

### 5.15.3 Potential security requirements

If established keys are used for AKMA, the keys shall be identifiable.

Potential AKMA use of established keys shall not lead to a denial of service.

## 5.16 Key Issue #16: Application Key freshness of AKMA

5.16.1 Issue details

AKMA as a key agreement scheme should guarantee of freshness of the application key KAF. That is if an AKMA AF that requests a key from the Anchor Function, that key might have already been used. In general key freshness is a desirable property of any method used to establish keys and should be included in AKMA.

5.16.2 Security Threats

If a KAF is used without freshness, then a weakness between UE and AKMA AF may allow an attacker to pretend to be a particular AKMA AF and obtain KAF. The attacker can masquerade as the UE towards the real AKMA AF.

5.16.3 Potential security requirements

It shall be possible to ensure the freshness of keys used between the UE and the AKMA application function.

# 6 Candidate Solutions

## 6.1 Solution #1: Introducing third party key to AKMA

### 6.1.1 Introduction

The secure transferring between the UE and the 3rd party not only requires secure connection, but to some extent protects data from leakage to untrusted parties even including MNOs, especially for some large CIoT corporations. Current GBA solution provides secure connection for the application providers based on 3GPP credentials, however, it lacks mechanism to ensure end to end security. Therefore, introducing a third party key to AKMA is an optional ability provided by 3GPP networks to protect data from UE all the way to the application server. The 3rd party key is defined as a secret key shared by the application server and the UE for application level communication. According to 3rd party service security requirements, whenever necessary to application providers, they can choose to use derived keys from 3GPP credentials and 3rd party keys to secure the end to end connection. In this way, application providers are able to control over the key material specifically.

### 6.1.2 Solution details

The proposed solution takes the current GBA procedure for example (Note: The related network elements and procedures in AKMA is FFS, the following figure only illustrates the 3rd party key involving procedure). During the procedure using bootstrapped security association, after NAF fetches Ks\_(ext/int)\_NAF from BSF, if necessary, the 3rd party executes end to end key derivation and sends to UE an e2e flag indicating the use of combination key scheme. According to the e2e flag, the UE derives the end to end key which is used for the following secure connection between UE and 3rd party.



Editor’s Note: It’s FFS that the 3rd party mentioned above could be key management service provider or application provider.

The e2e\_key is derived according to:

e2e \_key = KDF (Ks\_(ext/int)\_NAF, Ka);

where Ka is the 3rd party key defined in 6.X.1.

Editor’s Note: The derivation algorithm is FFS.

## 6.2 Solution #2: Access independent architecture solution for AKMA

### 6.2.1 Introduction

This solution addresses KI#1, KI#2 and KI#4.

### 6.2.2 Solution details

#### 6.2.2.1 Architecture and reference points

The AKMA architecture includes two new Network Functions:

* The AKMA Authentication Function (AAuF), and
* The AKMA Application Function (AApF).

The AAuF is the authentication anchor that provides UE authentication services using the AKA credentials. The AAUF is responsible for authenticating the UE, generating the key material to be used between the UE and the AAPF and maintaining a UE AKMA context to be used for subsequent bootstrapping requests and hence possibly avoiding a full re-authentication run. This solution does not currently take any stand on how the AAuF is realized, i.e. whether by a standalone NF or by the AUSF.

The AAuF interacts with the UE over the a1 reference point. The AAuF interacts with the AUSF and the AApF using Service-Based Interfaces.

The AApF is the function that benefits from the AAuF authentication services. The AApF interacts with the UE over the a2 reference point and whenever needed requests keying material from the AAuF via Service-Based Interfaces.

Figure 6.2.2.1-1 below illustrates the proposed architecture



Figure 6.2.2.1-1: AKMA reference architecture

#### 6.2.2.2 Procedures

##### 6.2.2.2.1 Initiation

In order to be able to secure the communication using AKMA, the UE and the AApF must first agree on its use. The procedure for negotiating the use of AKMA is given in Figure 6.2.2.2.1-1. The procedure is initiated by the UE sending a Request message not including any AKMA parameters and concluded by the AAuF sending an AKMA authentication required message. This is based on the GBA initiation procedure described in cl 4.5.1 of TS 33.220 [2].



Figure 6.2.2.2.1-1: Initiation procedure

##### 6.2.2.2.2 Authentication

Editor’s Note: The mechanisms for key revocation is FFS.

The authentication procedure assumes the support of the EAP framework as specified in RFC 3748 [4] such that:

* The UE takes the role of the peer,
* The AAuF takes the role of a pass-through authenticator, and
* The AUSF takes the role of the backend authentication server.

The authentication procedure is initiated by the UE sending a Request message to the AAuF. Following the UE request the AAuF triggers the EAP authentication procedure by sending an AKMA authentication request to the AUSF. The AUSF and the UE would then engage in an exchange of EAP messages that is concluded by the AUSF sending an AKMA authentication response message to the AAuF carrying either an EAP success or an EAP failure. In case of success, the message includes as well the AKMA anchor key KAKMA. The AAuF forwards the EAP result message to the UE and in case of success includes the necessary AKMA parameters such as a temporary identifier and a validity time. The temporary identifier is used by the UE for subsequent Requests towards AApFs as long as the validity period has not elapsed.

When the UE is registered to the 5G System, the transport protocol for the EAP message over the User Plane depends on the type of the PDU session. For PDU sessions of IP type, the EAP messages are carried over IP using the PANA protocol specified in RFC 5191 [8]. For PDU sessions of Ethernet type, the EAP messages are carried using the EAPol protocol specified in IEEE 802.1X [9].

When the UE is not registered to the 5G System, it is required that the UE has IP connectivity as in the GBA feature. In such case the EAP messages are carried using the PANA protocol as described above.



Figure 6.2.2.2.2-1: Authentication procedure

##### 6.2.2.2.3 Usage

Once the UE has been successfully authenticated by the AAuF, the UE has the necessary keying material to establish secure communication with any AApF. In order to do that, the UE derives the application key KAF using the AApF identifier (FQDN) and possibly other parameters and supplies its temporary identifier to the AApF. The AApF then retrieves the the application key from the AAuF.



Figure 6.2.2.2.3-1: Usage procedure

### 6.2.3 Evaluation

Editor’s note: The evaluation of the solution is FFS.

## 6.3 Solution #3: Architecture solution for AKMA with standalone anchor

### 6.3.1 Introduction

This solution addresses KI#1, KI#2 and KI#4.

### 6.3.2 Solution details

#### 6.3.2.1 Architecture and reference points

The AKMA architecture includes two new Network Functions:

* The AKMA Authentication Function (AAuF), and
* The AKMA Application Function (AApF).

The AAuF is the authentication anchor that provides UE authentication services. The AAuF is responsible for authenticating the UE, generating the key material to be used between the UE and the AApF and maintaining a UE AKMA context to be used for subsequent bootstrapping requests and hence possibly avoiding a full re-authentication run.

The AAuF interacts with the UE over the a1 reference point. The AAuF interacts with the UDM/ARPF and the AApF using Service-Based Interfaces.

The AApF is the function that benefits from the AAuF authentication services. The AApF interacts with the UE over the a2 reference point and whenever needed requests keying material from the AAuF via Service-Based Interfaces.

Figure 6.3.2.1-1 below illustrates the proposed architecture



Figure 6.3.2.1-1: AKMA reference architecture

#### 6.3.2.2 Procedures

##### 6.3.2.2.1 Initiation

In order to be able to secure the communication using AKMA, the UE and the AApF must first agree on its use. The procedure for negotiating the use of AKMA is given in Figure 6.3.2.2.1-1. The procedure is initiated by the UE sending a Request message not including any AKMA parameters and concluded by the AAuF sending an AKMA authentication required message. This is based on the GBA initiation procedure described in cl 4.5.1 of TS 33.220 [2].



Figure 6.3.2.2.1-1: Initiation procedure

##### 6.3.2.2.2 Authentication

The authentication procedure assumes the support of the EAP framework as specified in RFC 3748 [4] such that:

* The UE takes the role of the peer,
* The AAuF takes the role of EAP authentication server



Figure 6.3.2.2.2-1: Authentication procedure

The authentication procedure is initiated by the UE sending a Request message to the AAuF.

Following the UE request the AAuF requests AV from the UDM/ARPF.

AAuF triggers the EAP authentication procedure by sending an EAP request to the UE. The AAuF and the UE would then engage in an exchange of EAP messages that is concluded by the AAuF sending an AKMA authentication response message to the AAuF carrying either an EAP success or an EAP failure. In case of success, the AAuF derives the AKMA anchor key KAKMA.

The AAuF forwards the EAP result message to the UE and in case of success includes the necessary AKMA parameters such as a temporary identifier and a validity time. The temporary identifier is used by the UE for subsequent Requests towards AApFs as long as the validity period has not elapsed.

When the UE is registered to the 5G System, the transport protocol for the EAP message over the User Plane depends on the type of the PDU session. For PDU sessions of IP type, the EAP messages are carried over IP using the PANA protocol specified in RFC 5191 [8]. For PDU sessions of Ethernet type, the EAP messages are carried using the EAPol protocol specified in IEEE 802.1X [9].

When the UE is not registered to the 5G System, it is required that the UE has IP connectivity as in the GBA feature. In such case the EAP messages are carried using the PANA protocol as described above.

##### 6.3.2.2.3 Usage

Once the UE has been successefully authenticated by the AAuF, the UE has the necessary keying material to establish secure communication with any AApF. In order to do that, the UE derives the application key KAF using the AApF identifier (FQDN) and possibly other parameters and supplies its temporary identifier to the AApF. The AApF then retrieves the the application key from the AAuF.



Figure 6.3.2.2.3-1: Usage procedure

### 6.3.3 Evaluation

Editor’s note: The evaluation of the solution is FFS.

## 6.4 Solution #4: Bootstrapping authentication of AKMA

### 6.4.1 Introduction

This solution addresses key issue #3: Mutual authenticate between UE and anchor function.

The key issue proposes that the UE and the anchor function shall be able to mutually authenticate each other based on 5G credentials using the 5G authentication framework, i.e., 5G AKA and EAP-AKA'. In addition, during the authentication between UE and anchor function, a shared key Ks between UE and anchor function is derived. It is assumed that the anchor function is connected to the AUSF.

### 6.4.2 Solution details

When a UE wants to interact with an AKMA AF, and it knows that the bootstrapping procedure is needed, it shall first perform a bootstrapping authentication (see Figure 6.4.1). The authentication frameworks 5G AKA and EAP-AKA' in TS 33.501 are leveraged.

#### 6.4.2.1 Authentication procedure for 5G AKA



Figure 6.4.1: The bootstrapping authentication procedure for 5G AKA

The authentication procedure for 5G AKA works as follows, cf. also Figure 6.4.1:

1. The UE sends a request towards the Anchor Function.

2. The Anchor Function shall invoke the Nausf\_UEAuthentication service by sending a Nausf\_UEAuthentication\_Authenticate Request message to the AUSF, in which the user identity and Anchor Function identifier shall be included.

3. The AUSF shall send a Nudm\_UEAuthentication\_Get Request to the UDM.

4. The UDM/ARPF shall create a 5G HE AV from RAND, AUTN, XRES\*, and KAUSF. The UDM shall then return the 5G HE AV to the AUSF.

5. The AUSF shall store the XRES\* temporarily. The AUSF shall compute the HXRES\* from XRES\* and Anchor Function key KAKMA from KAUSF and Anchor Function identifier. The AUSF shall then generate the 5G AV from the 5G HE AV received from the UDM/ARPF by replacing the XRES\* with the HXRES\* and KAUSF with KAKMA in the 5G HE AV.

6. The AUSF shall return the 5G SE AV (RAND, AUTN, HXRES\*) to the Anchor Function.

7. The Anchor Function shall send RAND, AUTN to the UE.

8. At receipt of the RAND and AUTN, the USIM shall verify AUTN and compute a response RES. The ME then shall compute RES\* from RES. The ME shall calculate KAUSF from CK||IK and KAKMA from KAUSF and Anchor Function identifier.

9. The UE shall return RES\* to the Anchor Function.

10. The Anchor Function shall then compute HRES\* from RES\*, and the Anchor Function shall compare HRES\* and HXRES\*. If they coincide, the Anchor Function shall consider the authentication successful from the Anchor Function point of view.

11. The Anchor Function shall send RES\* as received from the UE to the AUSF.

12. When the AUSF receives the RES\*, it shall compare the received RES\* with the stored XRES\*. If the RES\* and XRES\* are equal, the AUSF shall consider the authentication as successful.

13. The AUSF shall indicate to the Anchor Function whether the authentication was successful or not from the home network point of view. If the authentication was successful, the KAKMA shall be sent to the Anchor Function in the Nausf\_UEAuthentication\_Authenticate Response.

14. The Anchor Function shall calculate a temporary identifier to bind the subscriber identity to the keying material. The temporary identifier value shall be generated in format of NAI by taking the base64 encoded and the Anchor Function identifier, i.e. base64encode(RAND)@ Anchor Function identifier. The Anchor Function shall send a response message to the UE to indicate the success of the authentication. This message shall also include the temporary identifier and the key lifetime of KAKMA.

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



Figure 6.4.2: The bootstrapping authentication procedure for EAP-AKA'

The authentication procedure for EAP-AKA' works as follows, cf. also Figure 6.4.2:1. The UE sends a request towards the Anchor Function.

2. The Anchor Function shall invoke the Nausf\_UEAuthentication service by sending a Nausf\_UEAuthentication\_Authenticate Request message to the AUSF, in which the user identity and Anchor Function identifier shall be included.

3. The AUSF shall send a Nudm\_UEAuthentication\_Get Request to the UDM.

4. The UDM shall subsequently send this transformed authentication vector AV' (RAND, AUTN, XRES, CK', IK') to the AUSF. The UDM/ARPF shall compute CK' and IK' from Anchor Function identifier.

5. The AUSF shall send the EAP-Request/AKA'-Challenge message to the Anchor Function.

6. The Anchor Function shall transparently forward the EAP-Request/AKA'-Challenge message to the UE.

7. At receipt of the RAND and AUTN, the USIM shall verify AUTN and compute a response RES. The ME shall derive CK' and IK'.

8. The UE shall send the EAP-Response/AKA'-Challenge message to the Anchor Function.

9. The Anchor Function shall transparently forwards the EAP-Response/AKA'-Challenge message to the AUSF.

10. The AUSF shall verify the message, and if the AUSF has successfully verified this message it shall continue as follows, otherwise it shall return an error.

11. The AUSF derives EMSK from CK’ and IK’. The AUSF uses the first 256 bits of EMSK as the KAUSF and then calculates Anchor Function key KAKMA from KAUSF and Anchor Function identifier. The AUSF shall send an EAP Success message to the Anchor Function inside Nausf\_UEAuthentication\_Authenticate Response, which shall forward it transparently to the UE. Nausf\_UEAuthentication\_Authenticate Response message contains the KAKMA.

12. The Anchor Function shall calculate a temporary identifier to bind the subscriber identity to the keying material. The temporary identifier value shall be generated in format of NAI by taking the base64 encoded and the Anchor Function identifier, i.e. base64encode(RAND)@ Anchor Function identifier. The Anchor Function shall send the EAP Success message to the UE. This message shall also include the temporary identifier and the key lifetime of KAKMA.

### 6.4.3 Evaluation

TBA.

## 6.5 Solution #5: Transport independent procedure using existing protocols by applying OneM2M protocol binding mechanism

### 6.5.1 Introduction

OneM2M is a global standard organization aimed at developing the technical specification of global service platform for IoT. It develops technical specifications which address the need for a common M2M Service Layer that can be readily embedded within various hardware and software, and relied upon to connect the myriad of devices in the field with M2M application servers worldwide. OneM2M has defined the exchanging message protocol between the entities (oneM2M Primitive), oneM2M core protocol to handle errors and bindings between core protocol and application layer transport protocol (CoAP, HTTP, MQTT). The protocol binding is when one or more than one interfaces are combined with other protocols, which is focused on message translation between oneM2M's request/response and binding target protocol's message.

### 6.5.2 Solution details

With reference to oneM2M protocol specifications [2], primitives are common service layer messages exchanged over the reference points in oneM2M architecture. In case of using an IP-based Underlying Network as illustrated in Figure 6.X.1, the primitives are mapped to application layer communication protocols such as HTTP, CoAP or MQTT which use TCP or UDP on the transport layer. The specification of primitives is independent of underlying communication protocols and allows introduction of bindings to other communication protocols.



Figure 6.5.1: Communication model using OneM2M protocol binding

By applying protocol binding mechanism to AKMA, UE and AKMA functions interact with each other through OneM2M primitives. Each CRUD+N （CREATE, RETRIEVE, UPDATE, DELETE and NOTIFY ）operation defined in OneM2M protocol consisting of request and response primitives, is to be mapped to CoAP methods or MQTT payload. As illustrated in Figure 6.X.1 (UE and AKMA functions can be both originators or receivers depending on interaction direction, the figure depicts UE sending requests to AKMA functions as an example), while UE sends requests to AKMA functions, it implements the binding function to map request messages to specific MQTT or CoAP messages for transferring. Upon receiving MQTT or CoAP messages, AKMA functions unbind the messages from specific transport protocol and execute the subsequent actions.

Editor’s Note: It is FFS how these application layer protocols interwork with the proposed AKMA architecture, for e.g. to obtain keys, derive session specific keys etc.

### 6.5.3 Evaluation

This solution fulfils the requirement of transport independent procedure using existing protocols, thereby satisfying key issue #2.

## 6.6 Solution #6: Transport independent procedure using existing protocols by introducing a protocol transfer gateway

### 6.6.1 Introduction

To keep AKMA features applying for as many types of IoT devices as possible, a protocol transfer gateway/proxy can be introduced aiming at converting messages and communicating with terminals using different protocols. . In this solution, the AKMA architecture involving an AKMA transfer gateway (APTG) is introduced, corresponding procedures are proposed as well.

### 6.6.2 Solution details

Figure 6.6.1 Protocol Transfer Gateway Model

#### 6.6.2.1 Architecture reference model



Figure 6.6.2.1-1: AKMA architecture reference model

6.6.2.1.1 Entities

* AKMA Authentication Function (AAuF): the anchor function in AKMA is named as AAuF (AKMA Authentication Function). The AAuF interacts with the UE via the AKMA Protocol Transfer Gateway (APTG) over Service-Based interfaces.
* AKMA Application Function (AApF): interact with AAuF for AKMA application specific keys.
* AKMA Protocol Transfer Gateway (APTG): APTG translates messages between UE and AAuF. Since the UEs can be any of the devices running different application layer protocols of IoT (like MQTT，CoAP，etc.). APTG converts UE originated application messages to HTTP messages for AAuF processing. Similarly, APTG translates the messages sending from AAuF to UEs according to the UE types. In case of adding more IoT terminals based on different protocols, only the APTG is required to be upgraded.

Editor’s Note: Whether APTG is part of AAuF is FFS.

6.6.2.1.2 Service based interfaces

**Nausf:** Service-based interface exhibited by AUSF.

**Naauf:** Service-based interface exhibited byAAuF.

**Naapf:** Service-based interface exhibited by AApF.

**Naptg:** Service-based interface exhibited by APTG.

#### 6.6.2.2 Procedures



Figure 6.6.2.2-1: Authentication procedure

Step 1-2: UE and AApF agree on the use of AKMA with UE sending a request message including its application layer user ID to AApF, AApF then indicates the use of AKMA services by sending a response message, asking the UE to initiate the authentication request.

Step 3-8: The authentication procedure is initiated by the UE sending a Request message to the AAuF via APTG. APTG performs a “syntax” translation between the UE originated protocol and HTTP/HTTPS. Upon receiving the request from UE, APTG simply translates the message to HTTP/HTTPS message and forward it to AAuF. AUSF executes the authentication by checking the stored authentication result of requesting UE, where the result is obtained from the primary authentication. If the UE is legitimate, AUSF derives the intermediate key from KAUSF for AKMA use, which is KAKMA, and sends it to AAuF. Using KAKMA, AAuF derives the application specific key KAApF and keeps it in storage for subsequent use. AAuF generates a temporary identity named TID for the user, sends it to the UE via APTG along with the key lifetime of KAApF.

Step 9-12: UE derives the KAApF and initiates the AKMA use request message carrying TID to AApF. AApF asks AAuF for KAApF and its lifetime, indicating the UE of the use of KAApF by sending a response message.

Editor’s Note: It’s FFS how the procedure is implemented with at least one of the binding protocols.

### 6.6.3 Evaluation

## 6.7 Solution #7: UE implementation scheme- AKMA framework and application on modem

### 6.7.1 Introduction

To enable authentication and application key management using AKMA, 3GPP AKA protocol can be leveraged to bootstrap application security. 3GPP AKA is running on UICC with CK and IK generated to be provided for session key derivation. An AKMA logic module should be implemented on UE to achieve AKMA procedures with network functions. In this scheme, the AKMA logic module which is named as AKMA framework in the following details is implemented on modem, with applications utilizing AKMA capabilities running on modem as well.

### 6.7.2 Solution details

Figure 6.7.1 illustrates a UE implementation scheme that both AKMA framework and application are on modem. AKA module is running on UICC to receive AUTN and RAND as input from ME and return RES and CK/IK as output. AKMA framework is able to derive session keys and subsequent application keys based on CK and IK obtained from AKA module. Applications on modem interfaces with AKMA framework to obtain an application authentication identifier. AKMA framework requests for CK and IK via APDU (Application Protocol Data Unit) packets according to ISO7816 [6] protocols. Besides, there could be other instructions, parameters like request/response, keys, identifiers, etc., transferred between AKMA framework and UICC.



Figure 6.7.1: UE implementation scheme-AKMA framework and application on modem

### 6.7.3 Evaluation

This scheme is IoT applicable since it can be implemented without UE application processors, applications are running on modem to utilize AKMA capabilities directly.

## 6.8 Solution #8: UE implementation scheme- AKMA framework on UICC and application on modem

### 6.8.1 Introduction

To enable authentication and application key management using AKMA, 3GPP AKA protocol can be leveraged to bootstrap application security. 3GPP AKA is running on UICC with CK and IK generated to be provided for session key derivation. An AKMA logic module should be implemented on UE to achieve AKMA procedures with network functions. In this scheme, the AKMA framework is on UICC, with applications utilizing AKMA capabilities running on modem.

### 6.8.2 Solution details

Figure 6.8.1 illustrates a UE implementation scheme with AKMA framework on UICC and the applications on modem. Modem sends instructions and parameters to UICC via APDU (Application Protocol Data Unit) packets according to ISO7816 [6] protocols. In this case, the key derivations are UICC-based.



Figure 6.8.1: UE implementation scheme-AKMA framework on UICC and application on modem

### 6.8.3 Evaluation

Editor’s note: The evaluation of the solution is FFS.

## 6.9 Solution #9: UE implementation scheme- Application Processor (AP) scheme with AKMA framework on modem

### 6.9.1 Introduction

To enable authentication and application key management using AKMA, 3GPP AKA protocol can be leveraged to bootstrap application security. 3GPP AKA is running on UICC with CK and IK generated to be provided for session key derivation. An AKMA logic module should be implemented on UE to achieve AKMA procedures with network functions. In this scheme, AKMA framework is implemented on modem, with application processors (AP) implemented on UE to enable applications utilizing AKMA capabilities.

### 6.9.2 Solution details

This solution is similar to the solution in section 6.X in terms of the interaction between AKMA framework and AKA module, while applications on application processor (AP) interfaces AKMA framework through AT commands specified in TS 27.007[7].

* Open logical channel +CCHO
* Close logical channel +CCHC
* Generic UICC logical channel access +CGLA
* Restricted UICC logical channel access +CRLA

However, since the implementation of the above commands is optional in the specification, this kind of scheme is lack of mandatory command implementation.



Figure 6.9.1: AP scheme with AKMA framework on modem

### 6.9.3 Evaluation

Editor’s note: The evaluation of the solution is FFS.

## 6.10 Solution #10: UE implementation scheme- Application Processor (AP) scheme with AKMA framework on UICC

### 6.10.1 Introduction

To enable authentication and application key management using AKMA, 3GPP AKA protocol can be leveraged to bootstrap application security. 3GPP AKA is running on UICC with CK and IK generated to be provided for session key derivation. An AKMA logic module should be implemented on UE to achieve AKMA procedures with network functions. In this scheme, AKMA framework is implemented on UICC, with application processors (AP) implemented on UE to enable applications utilizing AKMA capabilities.

### 6.10.2 Solution details

This solution is similar to the solution in section 6.A in terms of the interaction between AKMA framework and AKA module, while application processor (AP) interfaces with AKMA framework through AT commands specified in TS 27.007[7]. As for AP interfacing AKMA framework via modem, there is the same issue due to AT command implementation introduced in section 6.9.



Figure 6.10.1: AP scheme with AKMA framework on UICC

### 6.10.3 Evaluation

Editor’s note: The evaluation of the solution is FFS.

## 6.11 Solution #11: UE implementation scheme- AKMA framework implemented on Secure Element (SE)

### 6.11.1 Introduction

To enable authentication and application key management using AKMA, 3GPP AKA protocol can be leveraged to bootstrap application security. 3GPP AKA is running on UICC with CK and IK generated to be provided for session key derivation. An AKMA logic module should be implemented on UE to achieve AKMA procedures with network functions, which is implemented on a secure element in this scheme, with application processors implemented on UE to enable applications utilizing AKMA capabilities.

### 6.11.2 Solution details

In this solution, it is assumed that some intelligent terminals are equipped with secure elements (SE). In this case illustrated in Figure 6.11.1, AKMA framework can be implemented on SE. The application processor inputs CK and IK obtained from UICC to AKMA framework, and afterwards gets application authentication identifier from SE.



Figure 6.11.1:UE implementation scheme-AKMA framework implemented on SE

### 6.11.3 Evaluation

Editor’s note: The evaluation of the solution is FFS.

## 6.12 Solution #12: UE implementation scheme- AKMA framework implemented on application processor’s OS

### 6.12.1 Introduction

To enable authentication and application key management using AKMA, 3GPP AKA protocol can be leveraged to bootstrap application security. 3GPP AKA is running on UICC with CK and IK generated to be provided for session key derivation. An AKMA logic module should be implemented on UE to achieve AKMA procedures with network functions. In this scheme, the AKMA framework is implemented on the application processor’s operating system (OS) within the UE.

### 6.12.2 Solution details

Figure 6.12.1 illustrates the UE implementation scheme where AKMA framework is implemented on the application processor’s operating system, the application authentication identifier is provided to upper layer applications via direct internal system calling.



Figure 6.12.1: AKMA framework implemented on application processor’s OS

### 6.12.3 Evaluation

Editor’s note: The evaluation of the solution is FFS.

## 6.13 Solution #13: AKMA authentication via the control plane

### 6.13.1 Introduction

This solution addresses KI#1, KI#2, KI#3 and KI#4.

In GBA [2], the bootstrapping (i.e. authentication to get a fresh master key Ks) requires only IP connectivity between the UE and BSF. While that means that GBA is access independent it also means that UEs need to support an additional authentication mechanism to run the AKMA bootstrapping compared to the access authentication mechanism. In case a UE has 5G connectivity, over 3GPP or non-3GPP access, it would be useful if the UE could re-use the access authentication mechanism to run AKMA bootstrapping via the control plane.

With re-use of access authentication mechanism it is ***not*** meant to run primary authentication for AKMA purposes as this would interfere with the serving network authentication policy and serving network keys. Instead, the intention is to re-use the access authentication mechanism (as much as possible) in order to perform an independent AKMA authentication run with the purpose to produce an AKMA anchor key in the UE and home network AKMA anchor function (AAuF). Therefore, this solution is also independent of the key hierarchy resulting from the primary authentication.

On high level this solution works in the following way:

- UE sends an AKMA authentication request over NAS to AMF/SEAF.

- The AMF/SEAF recognizes that the request is about AKMA authentication and finds the correct home network entity, AAuF, and sends an AKMA authentication request to AAuF.

- AAuF contacts the UDM to get authentication vector for AKMA purposes.

- UDM provides authentication vector for AAuF and indicates the authentication method.

- AAuF performs 5G AKA or EAP-AKA’ for AKMA purposes with the UE via the AMF/SEAF. Authentication messages between the UE and AMF/SEAF are sent over NAS.

- At the end of a successful AKMA authentication the UE and AAuF have a fresh AKMA anchor key KAKMA.

### 6.13.2 Solution details

#### 6.13.2.1 Architecture and reference points

The AKMA architecture includes two new Network Functions:

* The AKMA Authentication Function (AAuF), and
* The AKMA Application Function (AApF).

The AAuF is the authentication anchor that provides UE authentication services. The AAuF is responsible for authenticating the UE, generating the key material to be used between the UE and the AApF and maintaining a UE AKMA context to be used for subsequent requests from AApFs and hence possibly avoiding a full re-authentication run.

The AAuF interacts with the UE over the control plane via AMF/SEAF. The AAuF interacts with the UDM/ARPF, AMF/SEAF and the AApF using Service-Based Interfaces.

The AApF is the function that benefits from the AAuF authentication services. The AApF interacts with the UE over the a2 reference point and whenever needed requests keying material from the AAuF via Service-Based Interfaces.

Figure 6.x.2.1-1 below illustrates the proposed architecture

UDM

AUSF

SEAF

AAuF

UE

AApF

5GC

Figure 6.13.2.1-1: AKMA reference architecture

#### 6.13.2.2 Procedures

##### 6.13.2.2.1 Initiation

In order to be able to secure the communication using AKMA, the UE and the AApF must first agree on its use. The procedure for negotiating the use of AKMA is given in Figure 6.3.2.2.1-1. The procedure is initiated by the UE sending a Request message not including any AKMA parameters and concluded by the AAuF sending an AKMA authentication required message. This is based on the GBA initiation procedure described in clause 4.5.1 of TS 33.220 [2].



Figure 6.13.2.2.1-1: Initiation procedure

##### 6.13.2.2.2 AKMA authentication with EAP-AKA’

The authentication procedure assumes the support of the EAP framework as specified in RFC 3748 [4] such that:

* The UE takes the role of the peer,
* The AAuF takes the role of EAP authentication server

Since the UE will not be authenticated by the serving network the AAuF does not send any key material to the AMF/SEAF.

UDM

AMF/SEAF

AAuF

UE

Auth Request

Auth Request

Auth Request

Auth Resp (AV)

EAP-AKA’ chall

EAP-AKA’ chall

EAP-AKA’ resp

EAP-AKA’ resp

EAP success (LT, tid )

EAP success (LT, tid )

Figure 6.13.2.2.2-1: Authentication procedure

The AKMA authentication procedure is initiated by the UE sending an AKMA authentication request message to the AMF/SEAF over NAS.

The AMF/SEAF recognizes that the request is about AKMA authentication, determines the correct AAuF and sends an AKMA authentication request to the AAuF.

The AAuF requests AV for AKMA purposes from the UDM/ARPF.

UDM provides authentication vector to the AAuF and indicates the authentication method.

The AAuF triggers the EAP authentication procedure by sending an EAP request / AKA’ challenge to the AMF/SEAF.

The AMF/SEAF forwards the EAP request / AKA’ challenge to the UE over NAS.

The UE processes the EAP request / AKA’ challenge and, if successful, sends EAP response / AKA’ challenge over NAS to the AMF/SEAF.

The AMF/SEAF forwards the EAP response / AKA’ challenge to the AAuF.

The AAuF verifies EAP response / AKA’ challenge and, if successful, derives the AKMA anchor key KAKMA.

The AAuF sends an EAP success, temporary identifier pointing to KAKMA. and a validity time to the AMF/SEAF.

The AMF/SEAF forwards the EAP success, temporary identifier and validity time to the UE over NAS.

Upon receiving the message from the AMF/SEAF, the UE derives the AKMA anchor key KAKMA.

The temporary identifier is used by the UE for subsequent requests towards AApFs as long as the validity period has not elapsed.

##### 6.13.2.2.3 AKMA authentication with 5G AKA

The procedure for running 5G AKA for AKMA purposes is described below. The AAuF terminates the 5G AKA authentication in the network side. It should be noted that since the UE will not be authenticated by the serving network, the AAuF does not send the 5G SE AV to the AMF/SEAF, but instead the AAuF processes the 5G HE AV and 5G SE AV itself. Also, the AAuF does not send any key material to the AMF/SEAF.

UDM

AMF/SEAF

AAuF

UE

Auth Request

Auth Request

Auth Request

Auth Resp (AV)

Auth Resp(RAND,AUTN)

RAND, AUTN

RES\*

RES\*

Result (LT, tid )

Result (LT, tid )

Figure 6.13.2.2.3-1: Authentication procedure

The AKMA authentication procedure is initiated by the UE sending an AKMA authentication request message to the AMF/SEAF over NAS.

The AMF/SEAF recognizes that the request is about AKMA authentication, determines the correct AAuF and sends an AKMA authentication request to the AAuF.

The AAuF requests AV for AKMA purposes from the UDM/ARPF.

UDM provides authentication vector to the AAuF and indicates the authentication method.

The AAuF triggers the 5G AKA AKMA authentication procedure by sending the RAND and AUTN to the AMF/SEAF.

The AMF/SEAF forwards the RAND and AUTN to the UE over NAS.

The UE processes the RAND and AUTN and, if successful, sends RES\* over NAS to the AMF/SEAF.

The AMF/SEAF forwards the RES\* to the AAuF.

The AAuF verifies RES\* and, if successful, derives the AKMA anchor key KAKMA.

The AAuF sends a result indication, temporary identifier pointing to KAKMA. and a validity time to the AMF/SEAF.

The AMF/SEAF forwards the result indication, temporary identifier and validity time to the UE over NAS.

Upon receiving the message from the AMF/SEAF, the UE derives the AKMA anchor key KAKMA.

The temporary identifier is used by the UE for subsequent requests towards AApFs as long as the validity period has not elapsed.

##### 6.13.2.2.4 Usage

Once the UE has been successefully authenticated by the AAuF, the UE has the necessary keying material to establish secure communication with any AApF. In order to do that, the UE derives the application key KAF using the AApF identifier (FQDN) and possibly other parameters and supplies its temporary identifier to the AApF. The AApF then retrieves the the application key from the AAuF.



Figure 6.13.2.2.4-1: Usage procedure

### 6.13.3 Evaluation

Editor’s note: The evaluation of the solution is FFS.

## 6.14 Solution #14: Key revocation

### 6.14.1 Introduction

This solution addresses the key issue #14. According to the key issue, it shall be possible to revoke the application keys in a secure way.

### 6.14.2 Solution details

#### 6.14.2.1 Revocation in Application function

Between the anchor function and the application functions, there must be some secure interface in place providing confidentiality and authenticity, since this is used to transport the application keys. The revocation can be performed over that same interface and benefit from existing security procedures.

The anchor functions must keep a list of recipient AFs for each UE to keep track of which AFs to send a revocation to. the revocation request must at least include the application key identifier.



#### 6.14.2.1 Revocation in UE

For revocation in the UE there are the following options

1. Send revocation request from Anchor function to UE bootstrapping client
2. Let the application function handle the revocation by not providing any service to the UE when the application key is revoked
3. Let the bootstrapping client in the UE handle revocation itself when authentication fails

For the revocation to be authenticated, option1 could use the old anchor key. This is not optimal since the key is expired.

Option 2 might not work if the application function is not functioning properly due to crash or similar.

Option 3 relies on the UE itself being responsible for the revocation. Since the UE bootstrapping client and anchor function shall perform mutual authentication, the bootstrapping client will know when the authentication fails. The bootstrapping client can then revoke the application keys in the respective application.

The bootstrapping client needs to save a list of identities of derived keys and their respective application, to be able to perform the revocation.

The interface between the bootstrapping client and the application must provide confidentiality and authenticity, since this is used to transport the application keys. The revocation can be performed over that same interface and benefit from existing security procedures.

Editor’s Note: Detailed description of the procedures and the steps after revocation are FFS.



## 6.15 Solution #15: Implicit Bootstrapping

### 6.15.1 Introduction

#### 6.15.1.1 Solution summary

EAP-AKA´ or 5G AKA can be used for primary authentication.

KAKMA is derived by AUSF as a sibling to KSEAF using a separate FC value and a counter as input.

KAKMA is transferred to AKAF together with the counter and an id for the user. This id shall fulfil the requirements in key issue #5.

KAKMA can be refreshed without a primary authentication in the UE and AKAF.

The AUSF and UE needs to be informed that the AKMA key shall be generated. This could be done by either

* pre-configuration of UE and AUSF
* signalling AUSF and UE in AMF field during primary authentication
* signalling between UDM and AUSF over service-based interfaces
* dynamic configuration of UE using parameter update from UDM using mechanisms in clause 6.15 of TS 33.501, [10]).

The requirements on each entity are listed below:

* UDM
  + New parameter keeping track of AKMA key is to be derived by AUSF
  + Potentially communicate AKMA usage to AUSF and UE (unless it is statically configured)
* AUSF
  + Store the KAUSF after the completion of the primary authentication
  + Derive KAKMA from KAUSF and parameters
  + Transfer KAKMA, sequence nr and ID to AKAF
  + Support key refresh procedure
* AKAF
  + Receive and store KAKMA, counter and ID
  + Support key refresh procedure using counter
  + Derive application keys on request from AFs
* UE
  + Derive AKMA key
  + Support key refresh procedure

#### 6.15.1.2 Background

This solution addresses the key issue #4 (mutual authentication).

To save roundtrips for the bootstrapping, the AKMA anchor key could be generated at the time of primary authentication. It could configurable whether the AKMA key is generated or not depending on operator settings.

Note that this solution requires that the same subscription, and therefore the same credentials, are used for 5G access and for AKMA.

The AKMA anchor could be either the AUSF or a separate entity, here named AKMA Anchor Function, AKAF. Or it could be two entities co-located for convenience.

The AKMA anchor key, KAKMA could be derived either as a sibling (Figure 6.15.1.2-1) or child key (Figure 6.15.1.2-2) in relation to KAUSF.

The different options above are analysed in this solution.



Figure 6.15.1.2-1 KAKMA sibling to KAUSF



Figure 6.15.1.2-2 KAKMA child to KAUSF

This solution only applies to the derivation of the anchor key KAKMA.

Application keys are derived as described in TS  33.220 [2].

The preferred option for deriving KAKMA is the child key option as it does not have any impact on the UDM.

### 6.15.3 Evaluation

Editor’s Note: This evaluation is preliminary.

Editor’s Note: The evaluation of on demand vs pre-generated anchor key derivation is FFS.

The solution addresses key issue KI#3 (Mutual authentication). The solution outlines two main options for the derivation of the AKMA anchor key with respect to the KAUSF, the sibling option and the child option.

Note that this solution requires that the same subscription, and therefore the same credentials, are used for 5G access and for AKMA. With this solution there is no need for a separate and specific AKMA authentication.

### 6.15.2 Solution details

#### 6.15.2.1 Authentication using EAP-AKA’

The procedure for EAP-AKA' defined in clause 6.1.3.1 of TS 33.501 [10] is the following. “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 proposed addition to the statement above for KAKMA is the following.

KAKMA is derived from EMSK.

Editor’s Note: How KAKMA is derived from EMSK is FFS.

This solution corresponds to the key hierarchy where the KAUSF and KAKMA are sibling keys.

However, this solution causes some problems if the AKMA key needs to be refreshed without performing a primary authentication, see 6.15.3.3.

Another option is to go for the hierarchy option where the KAKMA is a child key to KAUSF. In this case, KAKMA will be a sibling key to KSEAF and it can be derived similarly as KSEAF for example using another FC value and a counter value (to be used for re-fresh, see 6.15.3.3).

#### 6.15.2.2 Authentication using 5G AKA

For 5G AKA, the KAUSF is derived by the UDM (not by AUSF as in EAP-AKA´). Hence the UDM would be appropriate for derivation also of the KAKMA. Here there is no straight forward solution as for EAP-AKA´. One possible solution is to derive KAKMA similar to KAUSF but using another FC value.

This solution corresponds to the key hierarchy where the KAUSF and KAKMA are sibling keys.

However, this solution also causes some problems if the AKMA key needs to be refreshed without performing a primary authentication, see 6.15.3.3.

As for EAP-AKA´, we could instead derive KAKMA as a child key to KAUSF.

#### 6.15.2.3 AKMA key refresh

A new primary authentication also derives a new AKMA key, but application keys can continue to exist (see key issue #12 Key life-times).

If the new authentication fails, the AKMA key shall be revoked (see separate key issue #14).

The solutions with sibling keys do not support re-fresh of KAKMA without a primary authentication. To solve this, it could be possible to use the other key hierarchy option and derive KAKMA from KAUSF. This way, the refresh of KAKMA might be possible by a separate procedure creating some freshness parameters to the derivation of KAKMA. This could be a sequence number held by the AKAF and or AUSF.



Figure 6.15.2.3-1 AKMA key refresh

This refresh procedure is applicable regardless of which options is used for the primary authentication (EAP-AKA´ or 5G AKA).

The AKMA key also needs to be refreshed in the UE. This requires some synchronisation between the UE and the AKAF or between UE and AUSF. Alternatively, the synchronisation needs to be rely on both entities having synchronised time and that they choose to refresh the AKMA key when its lifetime approached its end. In Figure 6.15.3.3-2 an alternative where key refresh is signalled from AKAF to UE is shown. How this signalling is to be made is TBD.



Figure 6.15.2.3-2 Signal key refresh to UE

## 6.16 Solution #16: Use of KSEAF as root key for KAKMA

### 6.16.1 Introduction

This solution addresses key issue #10 by proposing an architecture that allows for using KSEAF as AKMA root key. In addition, it supports key issue #1 by proposing a logical connection between the SEAF and the anchor function introduced in solutions #2 and #3.

In order to fulfil key issue #10, this solution introduces to use KSEAF by introducing a generic architecture where the AAuF communicates with a key repository service (AKMA Key Repository Service – AKRS) that provides services to store a key together with an identifier and to retrieve (derivations) of the stored key upon request. In this solution, the AKRS is a service offered of the SEAF/AMF or the AUSF even though technically, the ARKS could also be a standalone function. This does not change the solution.

In order to enable using KSEAF for AKMA, this solution proposes to include an information element in the AKMA service request message that indicates which key the UE prefers to use and to include an information element in the AKMA service response message that indicates which key the network has selected to be used for this run of the AKMA service.

### 6.16.2 Solution details

#### 6.16.2.1 AKMA Key Repository Service

##### 6.16.2.1.1 AKMA Key Repository Service Serving Network Architecture Option

In order to support the functionality of established key usage, an AKMA Key Repository Service (AKRS) is included in the AKMA Architecture. In this version of the architecture, the AKRS connects to the SEAF. This architecture option is therefore called the 'Serving Network'-option. The AKRS has the following functionality:

- Offering an interface to the AAuF to retrieve a KAKMA derived from KSEAF for AKMA purposes;

- Storing the KSEAF

Note: Storage of the KSEAF is offered in the SEAF already, so colocation of this service with the SEAF would reduce duplicate storage.

The service can be collocated with the AMF/SEAF, but can also be run standalone. In this solution, collocation is assumed and the service is referred to as AKRS.

The figure 6.16.2.1-1 below illustrates the proposed architecture.

5GC

UDM

AUSF

SEAF  
AKRS

AAuF

SBI

UE

a1

AAuP

a2

Figure 6.16.2.1-1 Architecture showing collocated AKRS and connections to the AauF

##### 6.16.2.1.2 AKMA Key Repository Service Home Network Architecture Option

In order to support the functionality of established key usage, an AKMA Key Repository Service (AKRS) is included in the AKMA Architecture. This service has the following functionality:

- Offering an interface to the AAuF to retrieve a KAKMA derived from KSEAF for AKMA purposes;

- Storing the KAUSF or KSEAF

Note: Storage of the KAUSF is offered in the AUSF already, so colocation of this service with the AUSF would reduce duplicate storage.

Note: The KSEAF can be calculated from the KAUSF. As such, there is no need to store both the KSEAF and the KAUSF.

The service can be collocated with the AUSF, but can also be run standalone. In this solution, collocation is assumed and the service is referred to as AKRS.

The figure 6.16.2.1.x-1 below illustrates the proposed architecture.

5GC

UDM

AUSF  
AKRS

SEAF

AAuF

SBI

UE

a1

AAuP

a2

Figure 6.16.2.1.x-1 Architecture showing collocated AKRS and connections to the AAuF

#### 6.16.2.2 AKMA Established Key Use Procedure

##### 6.16.2.2.1 Procedure

This procedure takes the place of the "Authentication Procedure" in solution #2, clause 6.2.2.2.2 and takes place after an initiation procedure as detailed in 6.2.2.2.1.

The established key use procedure is initiated by the UE sending a request message to the AAuF including a key identifier (KI), and a flag indicating that the UE would like to use KSEAF for AKMA purposes. The AAuF verifies whether the use is allowed according to local policy and regulations and sends a "EstablishedKeyUseForAKMARequest" message to AKRS instance on the SEAF or AUSF.

Upon reception of the message, the SEAF or AUSF fetches the appropriate key from storage and calculates the AKMA Key as follows:

KAKMA = KDF (Input key, "AKMA", AKMA Counter),

Note: If the instance on the AUSF fetches the KAUSF, it first needs to calculate the KSEAF before KAKMA can be calculated.

Where the Input key is or KSEAF and the AKMA counter is kept to avoid key repetition in case of multiple requests. Subsequently, the SEAF forwards the KAKMA and the value of the AKMA Counter to the AAuF together with a RAND and an XRES calculated from KAKMA and the RAND.

After reception of the key, the AAuF will authenticate the UE as follows by sending a message to the UE containing a flag indicating which key was used for calculation of KAKMA, the AKMA Counter, the random value RAND, and a MAC calculated as follows:

MAC = KDF (KAKMA, "AKMA MAC", RAND)

Upon reception of this message, the UE will calculate the KAKMA according to the key that was used, verify the MAC and if successful respond with a RES calculated from KAKMA and the RAND to the AAuF. The AAuF verifies that the RES is the same as the XRES and if so replies with a service response including the temporary identifier and validity time.

The procedure is shown in figure 6.16.2.2.1-1

UE

AAuF

AUSF

Service request (SUCI/SUPI, Key Flag)

Established Key Use request (UE ID)

Decide whether key reusage is allowed

Fetch key from storage, derive KAKMA

Key Use response (KAKMA, RAND, XRES)

Service response (Key, Flag RAND, MAC)

Verify MAC, calculate RES

Response (RES)

Verify RES

Service response (Temp ID, validity timer)

Figure 6.16.2.2.1-1: Established Key Use procedure

As a result of the procedure the following has been achieved:

- A KAKMA has been derived from KSEAF;

- The UE and key anchor have authenticated each other using the newly derived KAKMA

### 6.16.3 Evaluation

This solution addresses key issue #10 by proposing a method for deriving a AKMA root key from KSEAF. In order to do so, this solution introduces an AKMA Key Repository Service which can be collocated with either the SEAF or the AUSF.

In order to derive the AKMA key, the solution proposes two routes:

- Deriving KAKMA directly from KSEAF;

- Deriving KAKMA from KAUSF with having KSEAF in between.

The solution works for both the case that the AKRS is present in the serving network, as well as the case that the AKRS resides the home network.

In the serving network option, the authentication is performed between the UE and the serving network without involving the home network. Consequently, the home network has no control over the authentication, which may pose problems with charging and liability. Therefore, this option is not preferred.

In the home network option, an authentication is performed between the UE and the home network based on KSEAF. Because KSEAF is known to the serving network, the serving network could pose as the AUSF which also leads to a situation of loss of home network control over the authentication. The solution lacks a mitigating measure for this attack. Therefore, this option is not preferred either.

## 6.17 Solution #17: Efficient key derivation for end-to-end security

### 6.17.1 Introduction

This solution addresses Key Issues #1, #3, #4. For key derivation for end-to-end security a solution is given that adds only a minimal amount of extra communication between the UE and the 3GPP network. The solution is based on the standard primary authentication and key agreement between UE and the 3GPP network as described in 3GPP TS 33.501 [xx]. In addition it uses an enterprise key KEnterprise that is pre-shared between UE and and Enterprise Application Server (EAS) in order to derive an end-to-end encryption key KE2Eenc and an end-to-end integrity key KE2Eint. These two end-to-end keys may be used to protect the communication between the UE and the EAS. This is similar to the use of such keys as described in 3GPP TS 33.163 [3].

### 6.17.2 Solution details

#### 6.17.2.1 Architecture

It is assumed that there is an AKMA Anchor Function capable of handling the Primary authentication and key agreement procedures similar to the SEAF according to 3GPP TS 33.501 [10] with extensions needed for handling AKMA functionality. The AKMA Anchor Function also will be able to communicate with the AKMA Enterprise Application Server (EAS).

#### 6.17.2.2 Procedures

##### 6.17.2.2.1 Information flow

The information flow describing the solution is split in two diagrams Figure 6.Y.2.2.1-1 and Figure 6.Y.2.2.1-2. The first part provides the primary authentication and key agreement procedure. The second part describes additions needed to complete the AKMA functionality (e.g. the calculation of the end-to-end encryption and integrity keys).



Figure 6.17.2.2.1-1: key deriviation for end-to-end security, part 1

The primary authentication and key agreement procedure (for 5G AKA) works as follows, cf. also Figure 6.Y.2.2.1-1:

Editor’s note: how key deriviation for end-to-end security works for EAP-AKA’ is FFS.

1. The UE sends a request towards the Anchor Function. This request may be one of the standard N1 messages between UE and SEAF that are the trigger for the subsequent authentication and key agreement procedure as described in 3GPP TS 33.501 [xx], clause 6.1.2. The request may optionally contain an enterprise id.

Editor’s note: how the user identity and other privacy sensitive information is protected is FFS.

2. The Anchor Function shall invoke the Nausf\_UEAuthentication service by sending a Nausf\_UEAuthentication\_Authenticate Request message to the AUSF, in which the user identity and Anchor Function identifier shall be included.

3. The AUSF shall send a Nudm\_UEAuthentication\_Get Request to the UDM.

4. The UDM/ARPF shall create a 5G HE AV from RAND, AUTN, XRES\*, and KAUSF. The UDM shall then return the 5G HE AV to the AUSF.

5. The AUSF shall store the XRES\* temporarily. The AUSF shall compute the HXRES\* from XRES\* and KAnchor Function from KAUSF. The AUSF shall then generate the 5G AV from the 5G HE AV received from the UDM/ARPF by replacing the XRES\* with the HXRES\* and KAUSF with KAnchor Function in the 5G HE AV.

6. The AUSF shall return the 5G SE AV (RAND, AUTN, HXRES\*) to the Anchor Function.

7. The Anchor Function shall send RAND, AUTN to the UE.

8. At receipt of the RAND and AUTN, the USIM shall verify AUTN and compute a response RES. The ME then shall compute RES\* from RES. The ME shall calculate KAUSF from CK||IK and KAnchor Function from KAUSF. The ME shall also calculate the KEAS from the KAnchor Function.

9. The UE shall return RES\* to the Anchor Function.

10. The Anchor Function shall then compute HRES\* from RES\*, and the Anchor Function shall compare HRES\* and HXRES\*. If they coincide, the Anchor Function shall consider the authentication successful from the Anchor Function point of view.

11. The Anchor Function shall send RES\* as received from the UE to the AUSF.

12. When the AUSF receives the RES\*, it shall compare the received RES\* with the stored XRES\*. If the RES\* and XRES\* are equal, the AUSF shall consider the authentication as successful.

13. The AUSF shall indicate to the Anchor Function whether the authentication was successful or not from the home network point of view. If the authentication was successful, the KAnchor Function shall be sent to the Anchor Function in the Nausf\_UEAuthentication\_Authenticate Response.

14. The Anchor Function generates key material KEAS from KAnchor Function according to the key hierarchy described in clause 6.Y.2.2.2.

NOTE: the primary authentication and key agreement procedure above is similar to the primary authentication and key agreement procedure described in 3GPP TS 33.501 [xx], with the following differences:

* The Anchor Function takes the role of the SEAF.
* The UE may optionally include a enterprise id in the initial request (in 1.). The enterprise id may be used to select the appropriate Enterprise Application Server (see below).
* The UE shall derives a KEAS from the previously derived KAnchor Function (in 8.).
* The Anchor Function derives a KEAS from the previously received KAnchor Function (in 14.).

Editor’s note: the relationship between the Anchor Function and the SEAF is FFS.



Figure 6.Y.2.2.1-2: key deriviation for end-to-end security, part 2

The second part of the procedure for key deriviation for end-to-end security works as follows cf. also Figure 6.Y.2.2.1-2:

14. The Anchor Function generates key material KEAS from KAnchor Function according to the key hierarchy described in clause 6.Y.2.2.2.

15. The Anchor Function sends an EAS Session Request message to the Enterprise Application Server (EAS). It includes the KEAS.

16. The EAS calculates KE2Eenc and KE2Eint keys from the received KEAS and a pre-shared KEnterprise according to the key hierarchy described in clause 6.Y.2.2.2.

17. The EAS sends an EAS Session Start message to the Anchor Function.

18. The Anchor Function sends a Response to the UE. This response may be one of the standard N1 messages occurring after authentication and key agreement.

19. The UE calculates KE2Eenc and KE2Eint keys from the previously derived KEAS and a pre-shared KEnterprise according to the key hierarchy described in clause 6.Y.2.2.2.

##### 6.17.2.2.2 Key hierarchy

The key hierarchy explaining the dependency of the various keyss is depicted in diagram Figure 6.Y.2.2.2-1.



Figure 6.17.2.2.2-1: key hierarchy for battery efficient AKMA

The above key hierarchy is similar to the one described in 3GPP TS 33.163 [3].

Editor’s note: the exact derivation of the keys KAnchor Function, KEAS, KE2Eenc, and KE2Eint is FFS.

Editor’s note: what are the benefits of this solution when compared to other solutions is FFS.

### 6.17.3 Evaluation

Editor’s note: the evaluation of this solution is FFS.

## 6.18 Solution #18: Key separation for AKMA AFs using Counters

### 6.18.1 Introduction

This solution addresses KI#9. The assumption is that the UE has been successfully authenticated by the AAuF as described in the solution 3 or by the AUSF itself.

### 6.18.2 Solution details

Editor’s Note: Whether the key has to be crypographically separated per protocol at the application level and if so, how is FFS.

Once the UE has been successfully authenticated, the UE has necessary keying material to establish secure communication with any AKMA application function. The key separation for a UE between any AKMA application function is supported using a 16-bit AKMA Application Function Counter (AF Counter). The UE and the AKMA authentication fuction (either AAuF or AUSF) initializes the AF Counter to ‘0’ whenever an AKMA anchor key (KAKMA) is generated for a UE based on a 3GPP credential in 5G. The AF counter can be monotonically incremented for every new application key (KAF) generation and used as an input during KAF generation from the same KAKMA. To derive the application key the UE increments the locally stored AF counter and verify if it matches with the AF counter received from the AKMA application function. If the verification is successful, the UE generates the application key using the received AF Counter and the other AKMA parameters. The AF counter specific to the UE is managed by both the UE and the AKMA authentication function. The AKMA application key is derived as follows.

KAF = KDF (KAKMA, AApF ID, AF Counter)

where AApF ID is the AKMA Application Function Identifier.

Editor’s Note: The derivation of KAKMA, the derivation algorithm to use and other required inputs to derive the KAF are FFS.

Figure 6.18.2-1illustrates the proposed key separation mechanism.



Figure 6.18.2-1: Key separation procedure

### 6.18.3 Evaluation

TBD

## 6.19 Solution #19: Reusing KAUSF for AKMA

### 6.19.1 Introduction

This solution addresses KI#1, KI#2, KI#3, KI#4 and KI#5.

### 6.19.2 Solution details

This solution introduces two new functions to 5GC:

* AKMA Authentication Function (AAuF)
* AKMA Application Function (AApF)



Figure 6.19.2-1: AKMA Architecture that reuses KAUSF

In this solution, no separate authentication is performed to support AKMA functionality. Instead, it reuses the 5G primary authentication for AKMA purposes. Therefore, it is assumed that the UE had successfully registered to the 5G core before invoking AKMA services. A successful 5G primary authentication results in KAUSF being stored at the AUSF and the UE.

The KAUSF is used for the following AKMA purposes:

1. Deriving a KAUSF key identifier from KAUSF at the UE and the AUSF. The KAUSF key identifier is stored by the AUSF along with the KAUSF. The derived key identifier is transported from the UE in NAI format to the AApF where the “username” part of the NAI includes the UE’s KAUSF key identifier and the “realm” part is set to home network identifier identifying the AUSF in the home network that holds KAUSF. If the AApF does not have context associated with the key identifier, then the AApF sends a request to AAuF with the key identifier to request AKMA keys for the UE. The KAUSF key identifier is equivalent to the B-TID in GBA and identifies the KAUSF key of the UE from which other AKMA keys are derived.
2. Deriving a key KAKMA at the UE and the AUSF. The AUSF sends KAKMA to the AAuF. KAKMA is equivalent to key Ks for GBA in TS 33.220)

Both the AAuF and the UE use KAKMA to derive application specific keys needed for AKMA Application Functions (AApFs) in similar manner as for NAFs in GBA. This implies that existing GBA based Ua protocols can be mostly reused (with any necessary adaptations) by the UE and the AApF with AKMA and is denoted as Ua\* interface.

Editor’s Note: Derivation of AKMA specific keys and the key identifier are FFS.

In this solution, the AKMA keys can only be refreshed by running a fresh primary authentication. This means that the AKMA key lifetime(s) cannot be shorter than the time interval between primary authentications.

Editor’s Note: It is FFS whether there is a need to refresh AKMA keys more often than the 5G primary authentication.

### 6.19.3 Evaluation

This solution reuses primary authentication and the key KAUSF for AKMA, thus avoiding the need to perform a separate authentication for AKMA.

This solution supports user privacy as SUPI is never sent by the UE to the network. The derived KAUSF key identifier is also used by the AApF to identify the UE.

## 6.20 Solution #20: Key Identification when Implicit Bootstrapping is used

### 6.20.1 Introduction

This solution addresses key issue #3 (Authentication) and key issue #18 (Established Key Synchronization).

This solution introduces a key identifier in order to identify the key used for implicit bootstrapping. The key to be identified depends on the solution and can be an established key from the 5G key hierarchy or a key derived from this key hierarchy such as the KAKMA. This solution refers to the KAUSF and the AUSF, however, it can easily be generalized to also work for other keys and other network functions.

The solution has two options:

1) The key identifier is calculated from the keys;

2) The ngKSI is reused.

### 6.20.2 Solution details

#### 6.20.2.1 Option 1 – Key Identifier calculated from the keys

In this option, an AKMA KAUSF identifier (A-KI) is calculated from the KAUSF as follows:

A-KI = KDF (KAKMA, "AKMA").

The UE and the AUSF will store the KAUSF together with this identifier. The UE and AUSF may store more than one A-KI and KAUSF pair in order to combat desynchronization errors.

In order to use the key, the procedure is as follows:

1) Whenever the UE starts an initiation procedure for AKMA, the UE will retrieve the A-KI corresponding to the latest KAUSF from memory. The UE will then send a service request according to solution 2 to the AKMA server including the A-KI of the KAUSF.

2) The AKMA server / AUSF looks up the key based on the A-KI received (and UE identity if included) and if found uses this key for further procedures with the UE. If no key was found, the AUSF will either:

- Fall back to solution #2 and run an authentication; or

- Return an error message with another A-KI that the AUSF has in memory for the UE.

3) Upon reception of the response the UE will either:

- Perform the authentication according to solution #2; or

- Retrieve the KAUSF that corresponds to the A-KI received or if not found, return an error message.

#### 6.20.2.2 Option 2 – Reuse of ngKSI

Editor’s Note: The impacts of using ngKSI for key identification is FFS.

In this option, the existing ngKSI is reused. In order to do so the AUSF has to receive the ngKSI that is communicated to the UE. This can be achieved as follows:

**EAP AKA'**

After the SEAF has received the RES from the UE, the SEAF forwards the RES in a Nausf\_Authentication Authenticate Request message. In this message, the SEAF also includes the ngKSI

The AUSF then stores the ngKSI together with the KAUSF.

**5G AKA**

After the SEAF has received the RES\* from the UE, the SEAF forwards the RES\* in a Nausf\_Authentication Authenticate Request message. In this message, the SEAF also includes the ngKSI

The AUSF then stores the ngKSI together with the KAUSF.

**Binding of the ngKSI to KSEAF**

In order to make sure that both the UE and the AUSF have the same ngKSI, the calculation of the KSEAF is changed as follows to also include the ngKSI.:

KSEAF = KDF (KAUSF, Serving network name, ngKSI)

**Using the key**

In order to use the key, the procedure is as follows:

1) Whenever the UE starts an initiation procedure for AKMA, the UE will retrieve the ngKSI corresponding to the latest KAUSF from memory. The UE will then send a service request according to solution 2 to the AKMA server including the ngKIS of the KAUSF.

2) The AKMA server / AUSF looks up the key based on the ngKSI received (and UE identity if included) and if found uses this key for further procedures with the UE. If no key was found, the AUSF will either:

- Fall back to solution #2 and run an authentication; or

- Return an error message with another ngKSI that the AUSF has in memory for the UE.

3) Upon reception of the response the UE will either:

- Perform the authentication according to solution #2; or

- Retrieve the KAUSF that corresponds to the ngKSI received or if not found, return an error message.

### 6.20.3 Evaluation

Editor’s note: The evaluation is FFS.

Editor’s Note: The evaluation should make statements of how and whether backwards compatibility is achieved if existing network nodes are touched.

## 6.21 Solution #21: Combining Implicit bootstrapping solutions for usage of KAUSF or KSEAF as AKMA root key

### 6.21.1 Introduction

This solution addresses key issue #10 by introducing a procedure for deciding which key to use for AKMA root key depending on the deployment and local configuration.

This solution combines parts of solutions #15 and #16. With respect to the presence of an AAuF it has three options:

1) Home Network Option: In this option, there is no AAuF in the serving network that plays a role in this solution;

2) Serving Network Option: In this option, there is only an AAuF in the serving network;

3) Combined option: In this option, there is an AAuF in both the serving network and the home network.

Solution #15 and solution #16 are similar in that they introduce a new element AKAF and AKRS respectively that functions roughly similar between the two solutions. In this solution, the term AKRS is used.

### 6.21.2 Solution details

#### 6.21.2.1 Generic procedure

This generic procedure for solution works as follows:

1) The UE initiates an initiation procedure by contacting an AAuP according to clause 6.2.2.2.1. The AAuP reponds signalling AKMA compatibility. Upon reception of the trigger, the UE initiates an AKMA Established Key Use Procedure by sending a service request to the AAuF including the UE Identity and the UE’s preference for which key to use.

2) Upon reception of the service request, the AAuF decides whether the KAKMA should be derived from KSEAF or KAUSF and sends a request for a KAKMA based on a particular key to the AKRS.

3) The AKRS generates the KAKMA, and sends the key together with a random and an XRES to the AAuF.

4) The AAuF authenticates the UE, and if successful sends the UE the necessary information for AKMA (which key was used as a base for KAKMA, the temporary identity, and the validity timer).

The procedure is shown in the figure below:

UE

AAuF

AKRS

Service request (SUCI/SUPI, Key Flag)

Established Key Use request (UE ID, Key Flag)

Decide whether key reusage is allowed

Fetch key from storage, derive KAKMA

Key Use response (KAKMA, RAND, XRES)

Authentication  
Temporary ID and validity timer exchange

Each of the options differs in how the decision on which key to use is taken. Depending on the decisions and access to keys, KAKMA will be derived in one of the following ways:

1) KAKMA = KDF(KAUSF, …)

2) KAKMA = KDF( KDF( KAUSF, Serving Network Name) , …)

3) KAKMA = KDF(KSEAF, …)

#### 6.21.2.2 Home Network Option

In this option, it is assumed that the AAuF is connected to the AKRS in the home network and that this AKRS has access to (the relevant keys derived from) KAUSF. For this solution it is not relevant whether this is implemented using a push mechanism according to solution #15 or a pull mechanism according to solution #16.

In this case, the AAuF can choose between using a KAKMA based on KAUSF directly or based on KSEAF. The AAuF can decide based on criteria like:

1) Whether the UE is roaming and where;

2) Whether the service is located in the country where the UE is roaming / serving network;

3) Whether there is a network element in the serving network that can receive the derived key;

4) Local configuration.

#### 6.21.2.3 Serving Network Option

In this option, it is assumed that the AAuF is connected to the AKRS in the serving network and that this AKRS has access to (the relevant keys derived from) KSEAF. For this solution it is not relevant whether this is implemented using a push mechanism according to solution #15 or a pull mechanism according to solution #16.

In this case, the AAuF cannot choose and will instruct the AKRS to derive a key from KSEAF.

#### 6.21.2.4 Combined Option

In this option, it is assumed that there is an AAuF is connected to the AKRS in the home network and one connected to the AKRS in the serving network. For this solution it is not relevant whether this is implemented using a push mechanism according to solution #15 or a pull mechanism according to solution #16. It is assumed that the AAuF in the serving network can take the rol of a proxy for the AAuF in the home network.

In this case, the Home AAuF can choose between using a KAKMA based on KAUSF directly or based on KSEAF. The AAuF can decide based on criteria like:

1) Whether the UE is roaming and where;

2) Whether the service is located in the country where the UE is roaming / serving network;

3) Whether there is a network element in the serving network that can receive the derived key;

4) Local configuration.

### 6.21.3 Evaluation

In the serving network option, the authentication is performed between the UE and the serving network without involving the home network. Consequently, the home network has no control over the authentication, which may pose problems with charging and liability. Therefore, this option is not preferred.

In the home network option, an authentication is performed between the UE and the home network based on KSEAF or KAUSF. If the KSEAF is used, the serving network could pose as the AUSF because the serving network knows the KSEAF. Also this situation leads to a situation of loss of home network control over the authentication. The solution lacks a mitigating measure for this attack. Therefore, this option is not preferred either.

Editors Note: Further evaluation is for further study

## 6.22 Solution #22: Key freshness in AKMA

6.22.1 Introduction

This solution addresses key issue #16 Key freshness in AKMA.

It is assumed that the derived sub-keys (i.e., application key KAF) is not exceed the lifetime of the anchor key KAKMA. When the key lifetime of KAF is expired, the application key KAF shall be renegotiated.

### 6.22.2 Solution details

Once the UE has been successfully authenticated by the Anchor Function, the UE has the necessary keying material to establish secure communication with any AKMA AF. Once the UE and the NAF have established that they want to use AKMA then every time the UE wants to interact with an NAF the following steps are executed as depicted in Figure 6.22.2-1.



Figure 6.22.2-1: Usage procedure

Editor’s Note: How application keys are generated for different applications is FFS.

1. The UE starts communication with AKMA AF. The UE supplies the temporary identifier to the AKMA AF. The temporary identifier is generated in the procedure of bootstrapping authentication of AKMA and used to bind the subscriber identity to the keying material.

2. The AKMA AF checks if the KAF lifetime is expired, if so the AKMA AF requests key material corresponding to the temporary identifier supplied by the UE. The AKMA AF supplies the temporary identifier and AKMA AF identifier to the Anchor Function.

3. The Anchor Function checks the lifetime of KAKMA. If the KAKMA is expired or the remaining lifetime of KAKMA shorter than the lifetime of KAF going to generated, the Anchor Function shall trigger to renegotiate a new KAKMA. Otherwise, Anchor Function derives the key KAF from the key KAKMA.

Editor’s Note: the way to derive the new KAF is FFS.

4. The Anchor Function supplies to AKMA AF the requested key KAF, as well as the lifetime of KAF.

5. The Anchor Function stores the key KAF and lifetime of KAF.

6. The AKMA AF supplies the lifetime of KAF to the UE. The AKMA AF calculates a MAC using KAF to protect the integrity of the message.

7. The UE derives the key KAF from the key KAKMA. Then the UE checks the MAC using KAF.

### 6.X.3 Evaluation

TBD.

## 6.X Solution <X>: <Solution Name>

### 6.x.1 Introduction

### 6.x.2 Solution details

### 6.x.3 Evaluation

# 7. Evaluation and conclusion

Annex <A>:  
<Annex title>

# A.1 <Subtitle>

Annex <X>:  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
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