Security in Mobile Communications

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FRISC Winter school
FINSE, 24th April, 2013

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Background: Security basics

Information security

- System security
  - e.g. trying to ensure that the system does not contain any weak parts.
- Application security
  - e.g. Internet banking
- Protocol security
  - e.g. how to achieve security goals by executing well-defined communication steps.
- Platform security
  - e.g. system depends on correctness of OS in all elements.
- Security primitives
  - basic building blocks on top of which all protection mechanisms are built.
  - e.g. cryptographic algorithms, but also more concrete items like a protected memory.

Design of a secure system

- Threat analysis
  - list all possible threats against the system, regardless of difficulty or cost
- Risk analysis
  - weight of threats estimated
  - both probability of the attack and potential damage taken into account
- Requirements capture
  - based on risk analysis, decide what kind of protection is required for the system
- Design phase
  - build actual protection mechanisms to meet requirements
  - Existing building blocks, e.g. security protocols, are identified, possibly new mechanisms are created, and a security architecture is designed
- Security analysis
  - carrying out an evaluation of the results independently of the previous phase
  - automatic verification tools can be utilized only for parts of a security analysis
- Reaction phase
  - system management and operation taken into account in design phase
  - reaction to all future security breaches cannot be planned beforehand → original design should allow enhancements

Design of a secure system – our main emphasis

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Communication security

- *Authenticity*
  - Authentication is the process of verifying the identities of the communicating parties
- *Confidentiality*
  - Parties may want to limit the intelligibility of the communication just to themselves
- *Integrity*
  - If all messages sent by the party *A* are identical to the ones received by the party *B* and vice versa, then integrity of the communication has been preserved
  - Sometimes the property that the message is indeed sent by *A* is called 'proof-of-origin' while the term 'integrity' is restricted to the property that the message is not altered on the way
- *Non-repudiation*
  - For a message sent by *A,* this implies that *A* cannot later deny sending of it
- *Availability*
  - This is an underlying pre-requisite for communication: a channel must be available

Typical attacks

- Authentication: an *imposter* tries to masquerade as one of the communicating parties
- Confidentiality: an *eavesdropper* tries to get information about the communication
- Integrity: a *man-in-the-middle* tries to modify, insert or delete messages
- Non-repudiation: the sender of a certain message may want to later deny sending of a message that relates to a financial transaction
- Availability: a *Denial of Service* (DoS) –attack tries to prevent access to the communication channel

Communication security – our main emphasis

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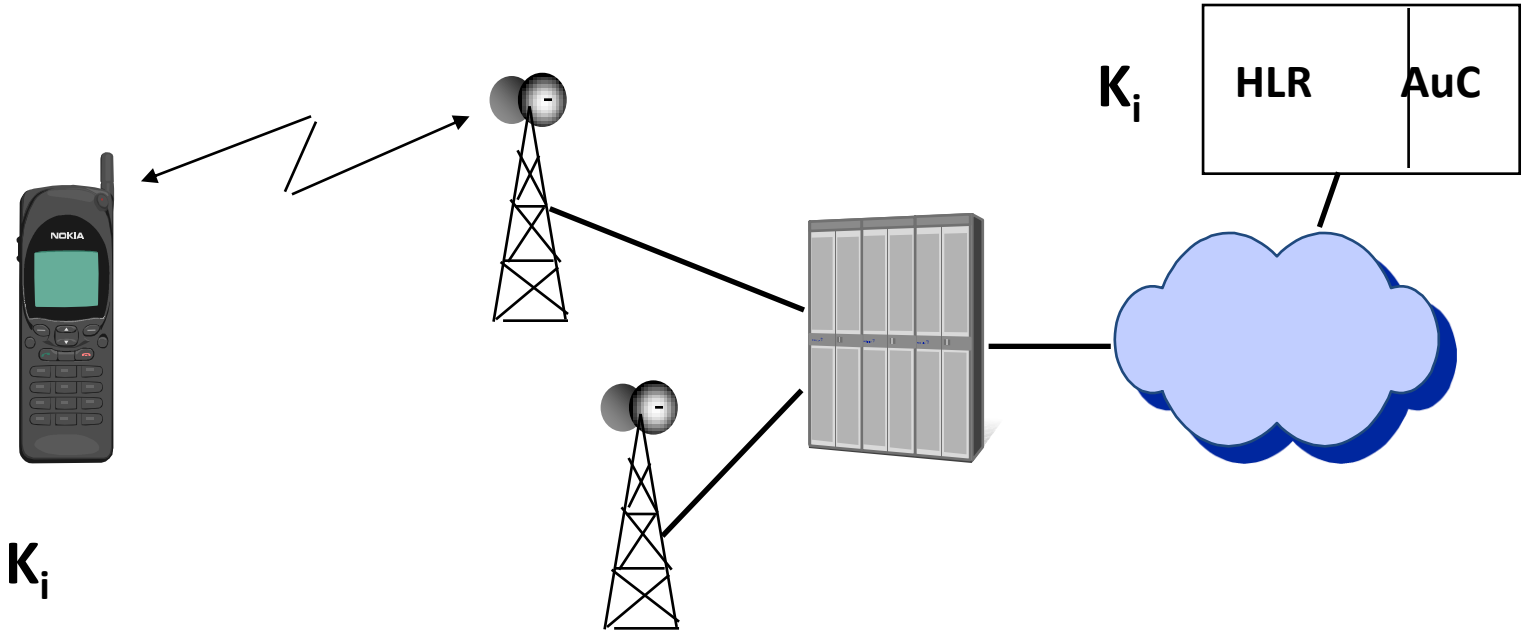
Security policies

- The usefulness of security methods depends on the defined policies
- For instance: ***if*** the policies allow to turn off all security mechanisms in case the peer communicating party informs it does not support them ***then*** the usefulness of these mechanisms is close to zero against active attackers
- Security mechanisms (protocols, encryption algorithms etc.) are useful tools; security policies define which tools to use in which situations
- Configuration of the system is orthogonal to the policies used
  - E.g. configuration can be perfect but policies undermine the security
- Policy management can be automated

GSM security

GSM access security



- The secret key of user i exists (and stays) only in two places:
  - in her own SIM card
  - in the Authentication Center

Trust model

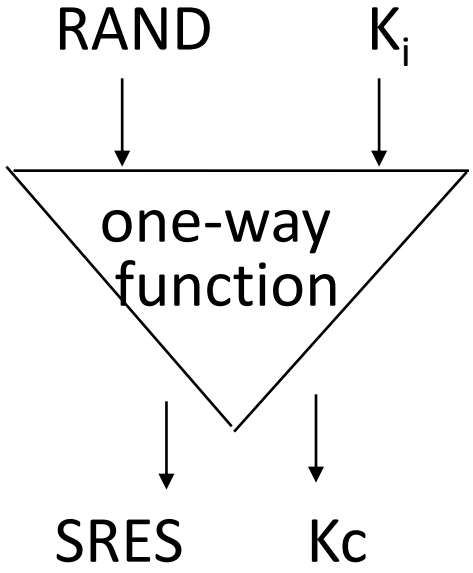
- Each operator shares long term security association with its subscriber
  - Security association credentials stored in tamper-resistant identity module issued to subscriber (called the SIM or UICC)
- Operators may enter roaming agreements with other operators → a certain level of trust exists between the respective domains

Original design decisions for GSM security

- GSM aimed to be *as secure as the fixed networks* to which it would be connected
- *Active attacks* which involve impersonating a network element were intentionally not addressed

Authentication of user i

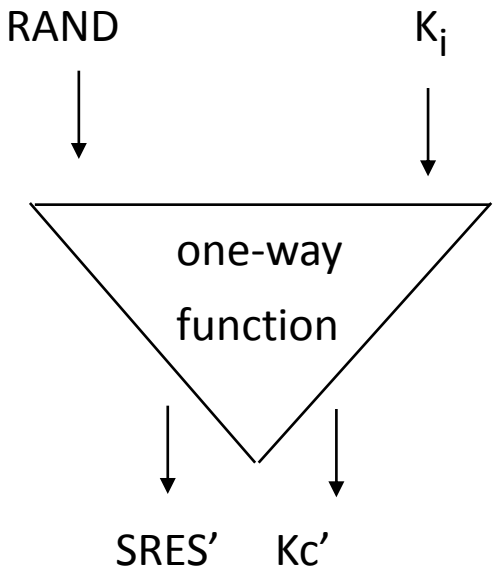
- Authentication Center chooses a random number RAND and computes



- The triple (RAND, SRES, Kc) is sent to the MSC/VLR.
- MSC/VLR sends RAND to the phone.
- The one-way function of computing SRES/Kc is called A3/A8. These are *operator-specific*.

Authentication cont'd

- The SIM card computes



and sends the output SRES' to the MSC/VLR.

- If SRES = SRES', then the call is accepted.

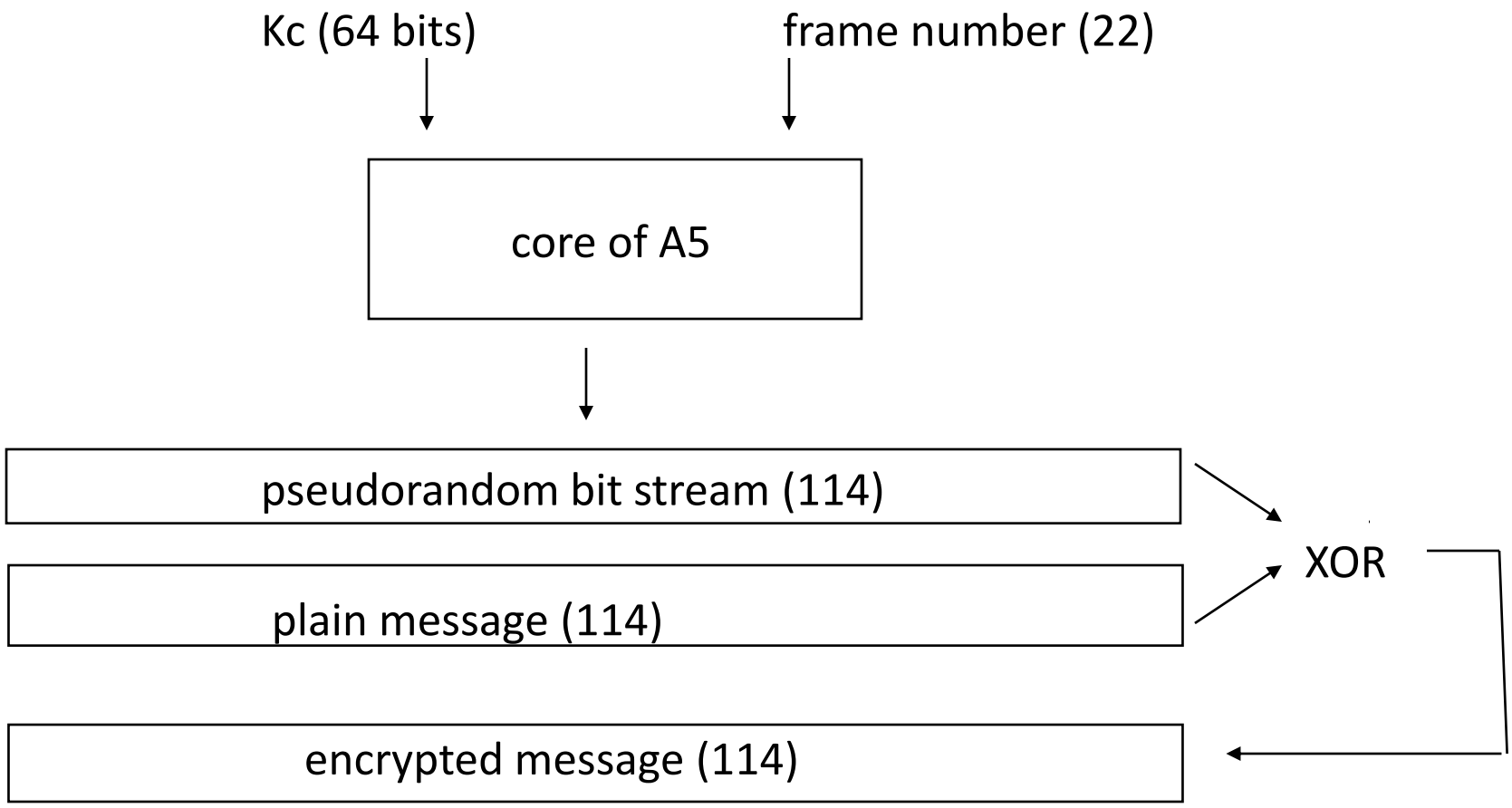
Encryption of the call

- During the authentication a secret key is exchanged:

  $$Kc = Kc'$$

  by which all calls/signalling are encrypted between the phone and the base station until the next authentication occurs.
- The encryption algorithm is called A5. The first two versions A5/1 and A5/2 were standardized but the specs are confidential and managed by GSM Association. The third version A5/3 is publicly available. All make use of 64-bit keys Kc.
- As a Rel-9 addition, there is also a 128-bit key algorithm A5/4.
  - Deployment of this is more difficult than in A5/3 case because longer keys require changes in many parts of the system

Structure of A5 stream cipher

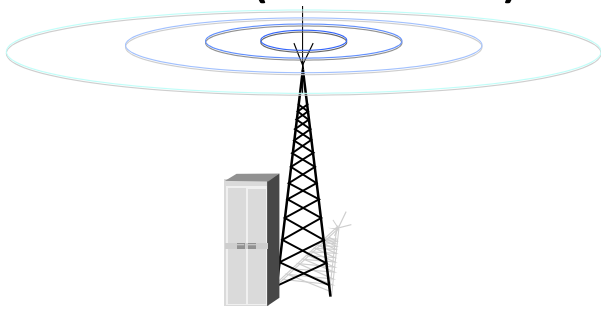


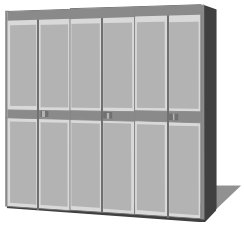
GSM security protocol

MS (SIM)
IMSI, **Ki**

MSC/VLR
(and BTS)

HLR
{{IMSI,**Ki**}}





IMSI / TMSI

IMSI

RAND

RAND, XRES, **Kc**

Kc

SRES

SRES=XRES ?

encrypted TMSI

Barkan–Biham A5/2 Attack (from 2003)

Exploited weaknesses in cryptographic algorithms:

- A5/2 can be broken very fast

… and exploited also other legacy features in the GSM security system:

- A5/2 was a mandatory feature in terminals
- Call integrity based only on encryption
- Same Kc is used in different algorithms
- Attacker can force the victim MS to use the same Kc by RAND replay

An example attack: Decryption of strongly encrypted call

- Catch a RAND and record a call encrypted with Kc and A5/3
- Replay the RAND and tell the MS to use A5/2
- Analyse Kc from the received encrypted uplink signal
- Decrypt the recorded call with Kc

Countermeasure

- Withdrawal of A5/2 from all 3GPP terminals (starting from release 6)

GPRS security

- Similar to GSM security
- SGSN takes the role of MSC/VLR for authentication
- Encryption terminates also in SGSN
  - Embedded in Logical Link Layer (LLC)
  - Counter: frame number (22 bits) replaced by LLC counter (32 bits)
  - Algorithms:
    - GEA1 (confidential, weakest)
    - GEA2 (confidential)
    - GEA3 (publicly available)
    - GEA4 (Rel-9 addition; first to use 128-bit keys instead of 64-bit keys)

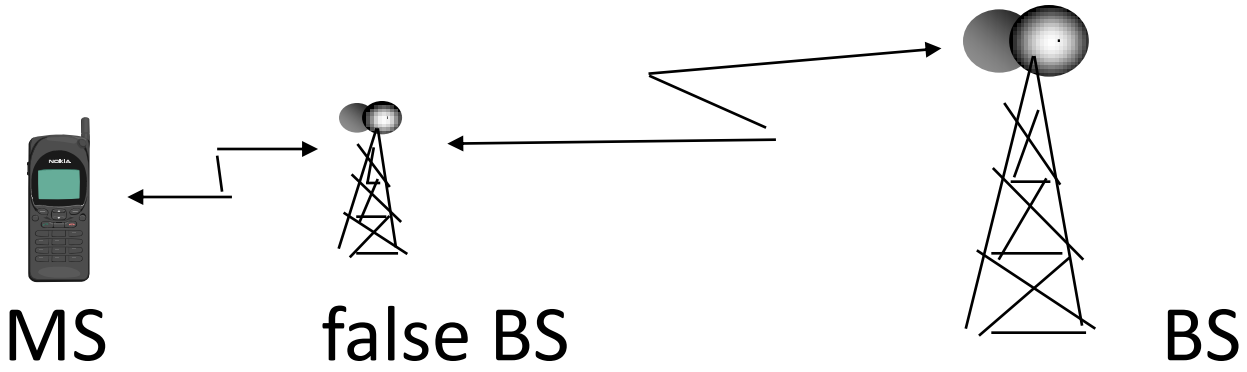
3G security

3G security background

- Leading *design principles* were:
  - Move useful 2G security features to 3G
  - Add countermeasures against real weaknesses in 2G
- Main *security characteristics* in GSM (= 2G) :
  - User authentication & radio interface encryption
  - SIM used as security module
  - Operates without user assistance
  - Requires minimal trust in serving network
- Main *weaknesses* in GSM:
  - Active attacks are possible (false BS etc.)
  - Authentication data (e.g. cipher keys) sent in clear inside one network and between networks
  - Cipher keys too short (if 64 bits)
  - Secret algorithms do not create trust

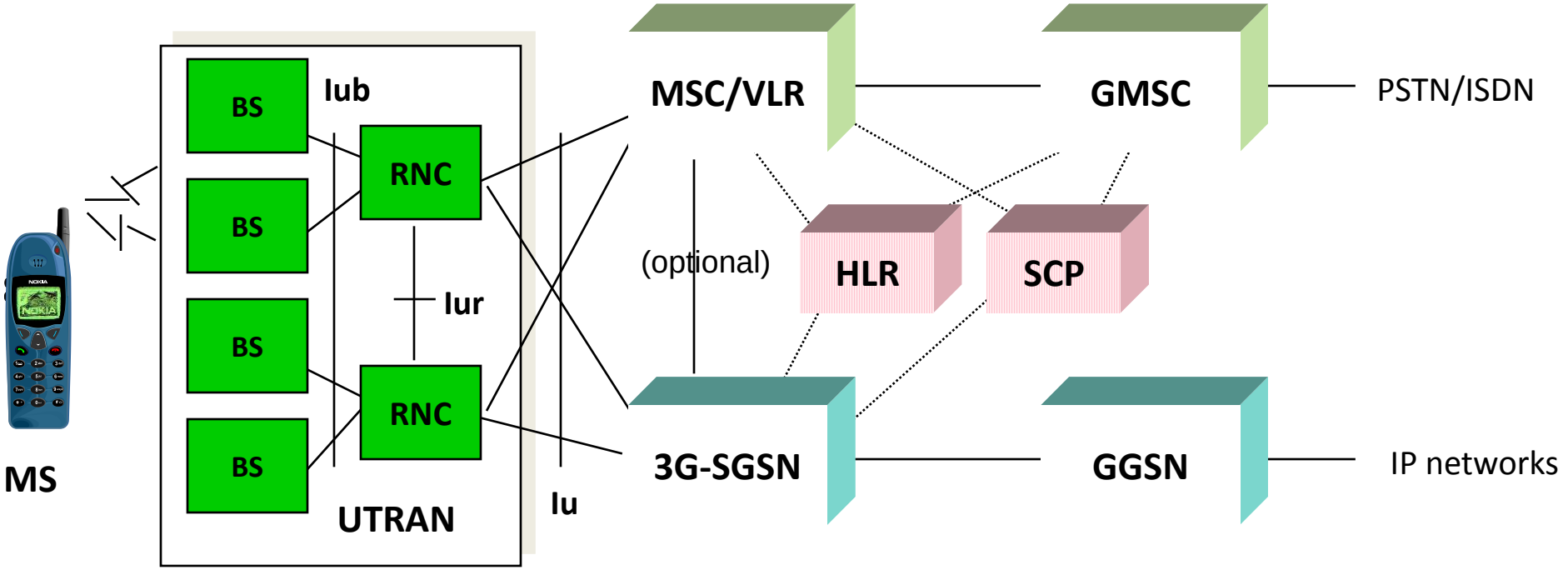
Active attack

- A false element masquerades
  - as a base station towards terminal
  - as a terminal towards network
- Objectives of the attacker:
  - eavesdropping
  - stealing of connection
  - manipulating data



3G system architecture

based on GSM/GPRS architecture



Encryption & integrity

Transport of auth data

Execution of authentication

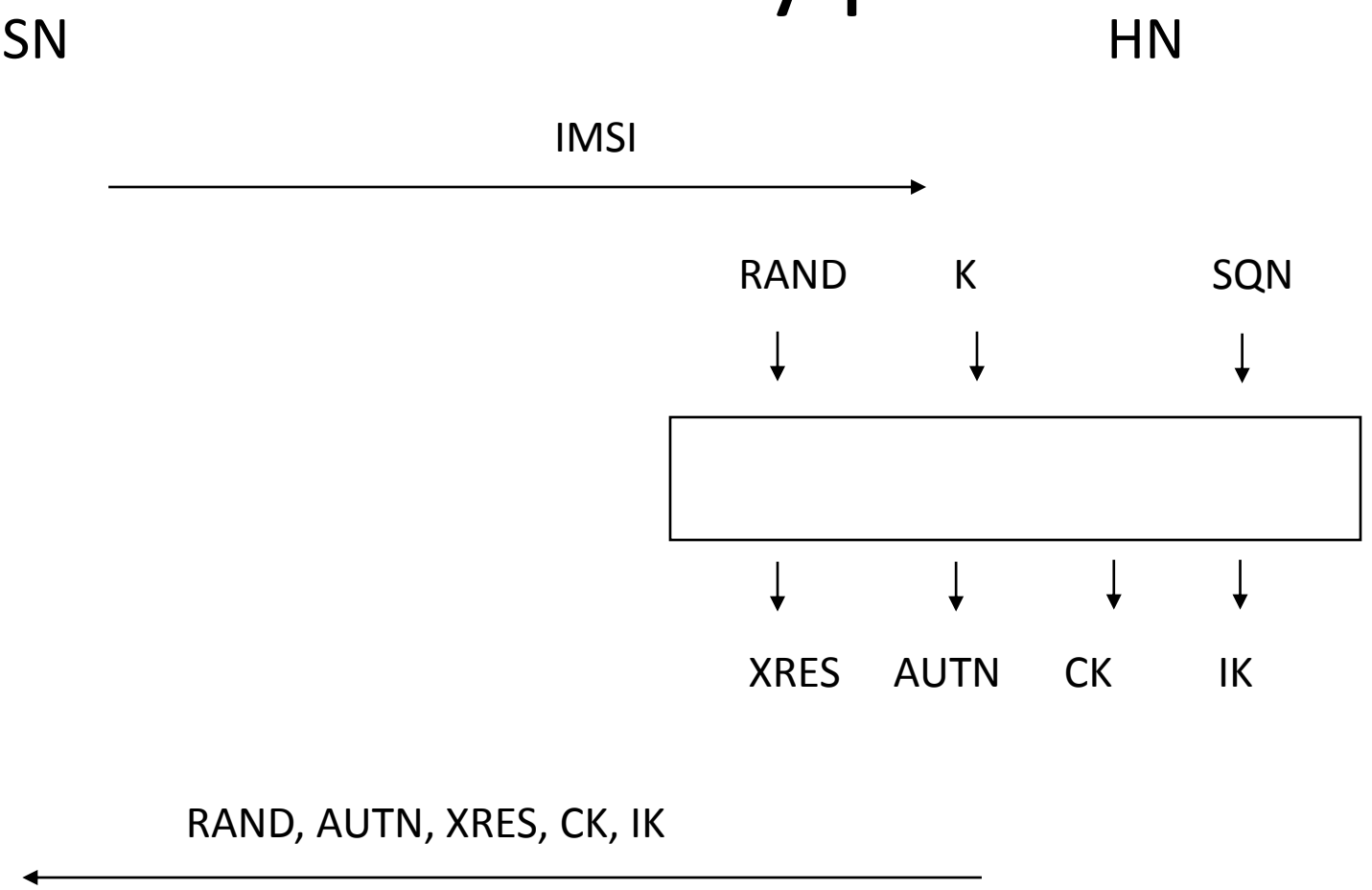
Mutual authentication

- There are three entities involved:
  - Home network HN (AuC)
  - Serving network SN (VLR/SGSN)
  - Mobile station MS (USIM)
- Executed whenever SN decides

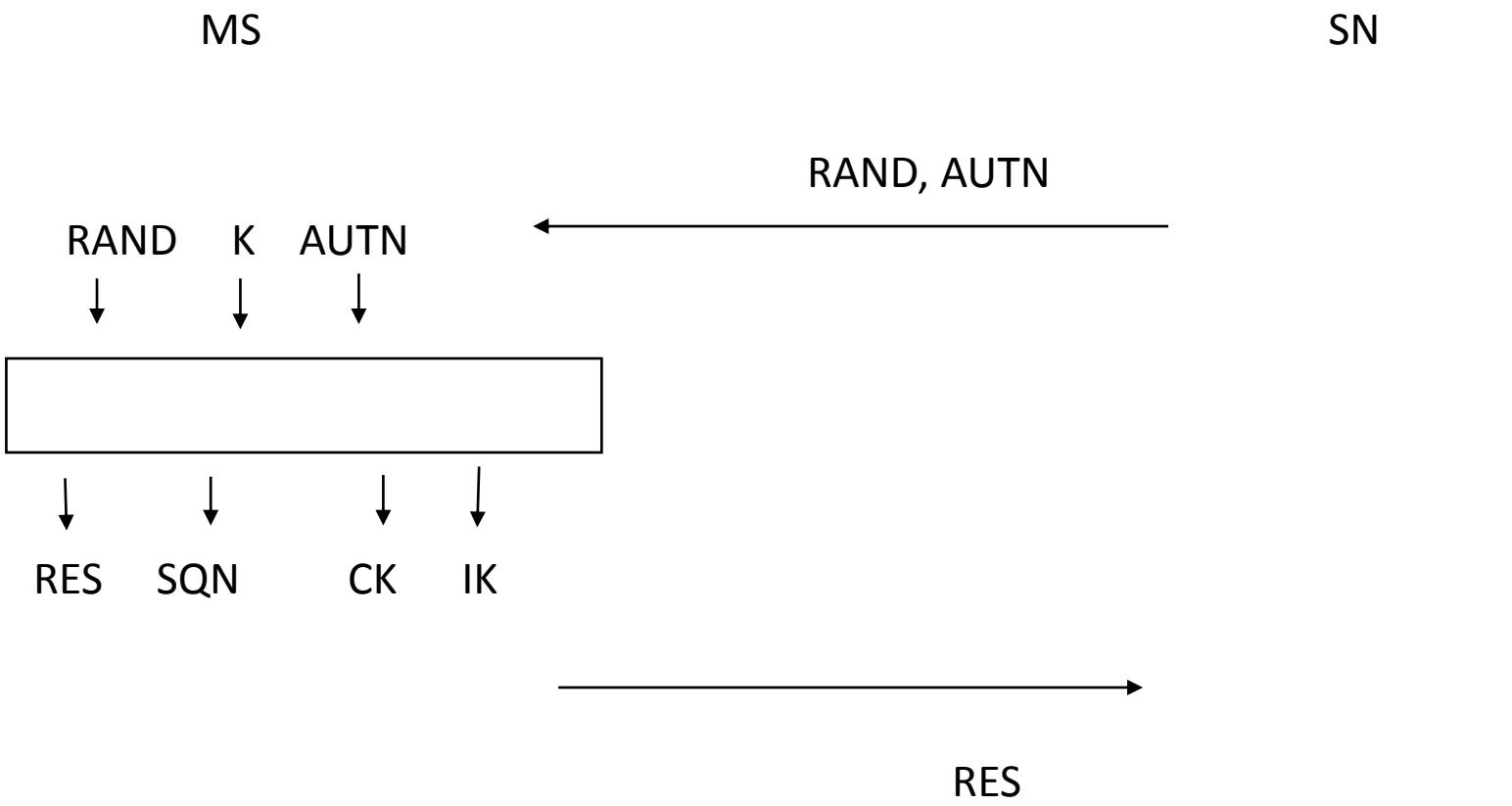
- The idea: SN checks MS's identity (as in GSM) and MS checks that SN has *authorization* from HN
- A *master key K* is shared between MS and HN
- GSM-like *challenge-response* in *user-to-network* authentication
- Network proves its authorization by giving a token AUTN which is protected by K and contains a sequence number SQN

- Each operator may use its *own algorithms* for authentication
- At the same time keys for ciphering and integrity checking are derived
- Ciphering and integrity checking are performed in MS and in RNC and these are independent of the authentication mechanism

Generation of security parameters



3G Authentication & key agreement

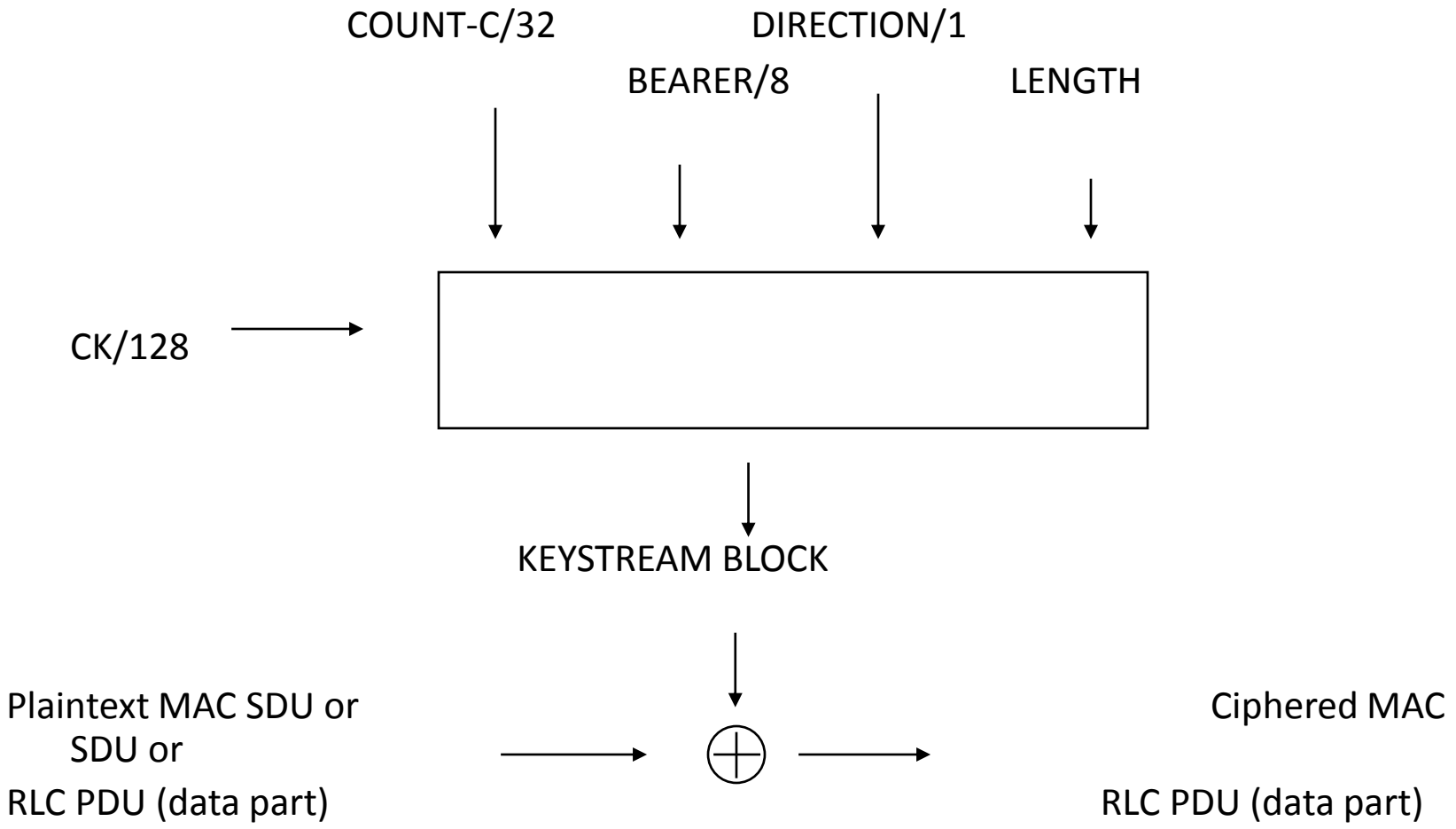


3G ciphering mechanism

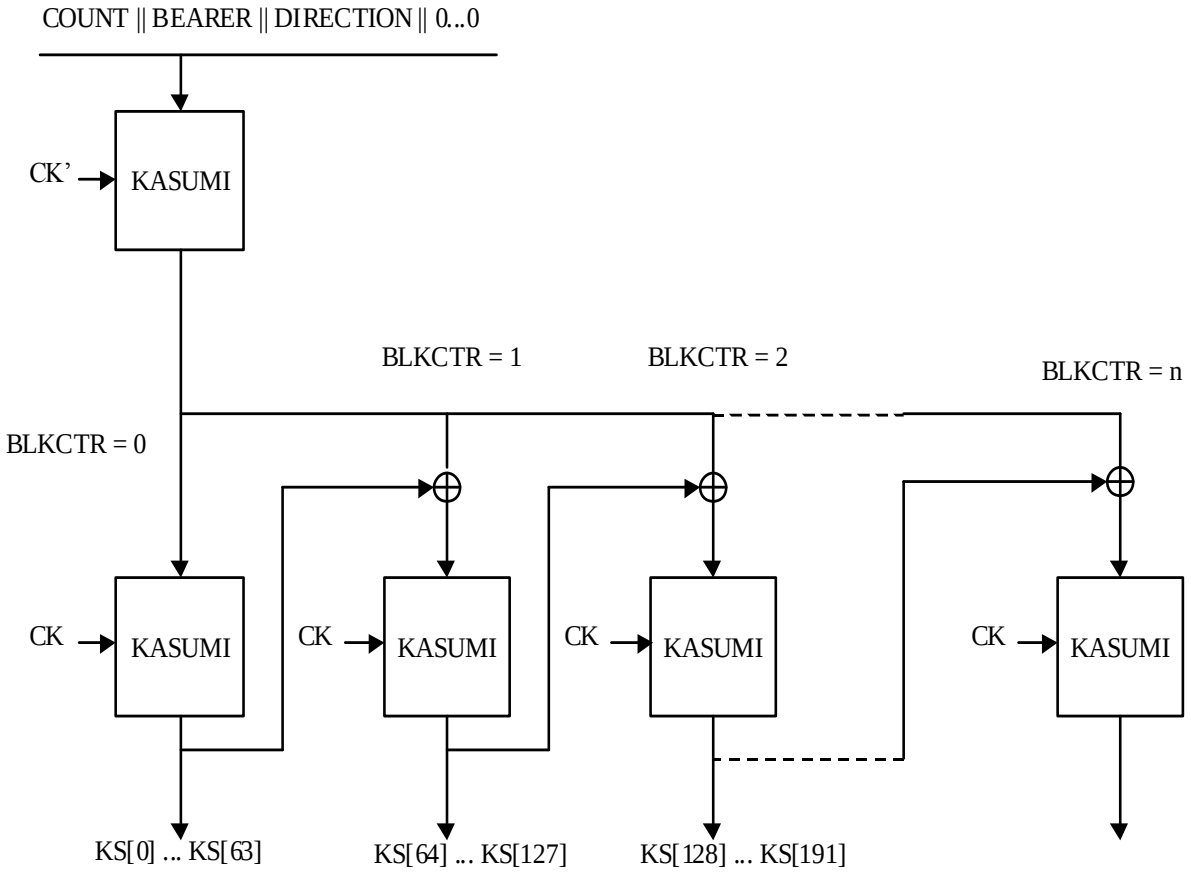
- Between UE and RNC
- Stream cipher like in GSM and GPRS
- Key length 128 bits
- Key lifetime could be limited.

- Begins with RNC sending *"Security mode command"*
- Layer:
  - RLC for non-transparent RLC mode
  - MAC for transparent RLC mode
- Both MSC/VLR and SGSN may give cipher keys to RNC. One key is used for each CN domain user data. The key for signaling data is changed whenever a new key is generated (which means key changes during active connections).

3G Ciphering algorithm



UEA1 (based on KASUMI block cipher)



CT[i] = PT[i] XOR KS[i]

KASUMI block cipher

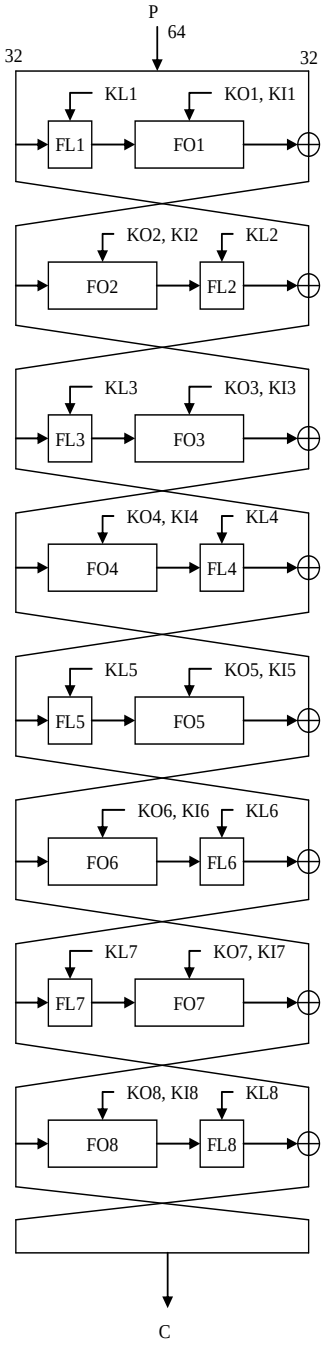


Fig. 1: KASUMI

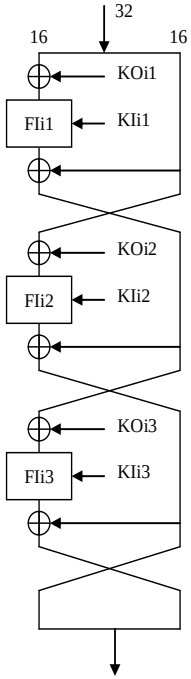


Fig.2: FO Function

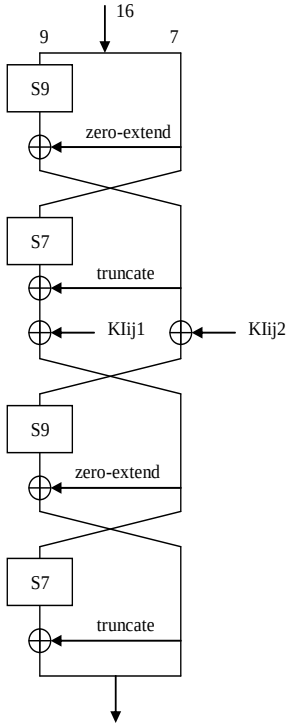
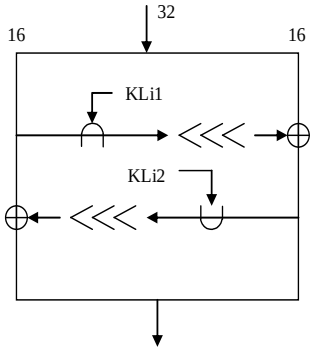


Fig.3: FI Function



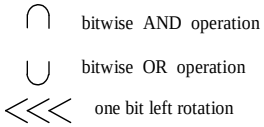


Fig.4: FL Function

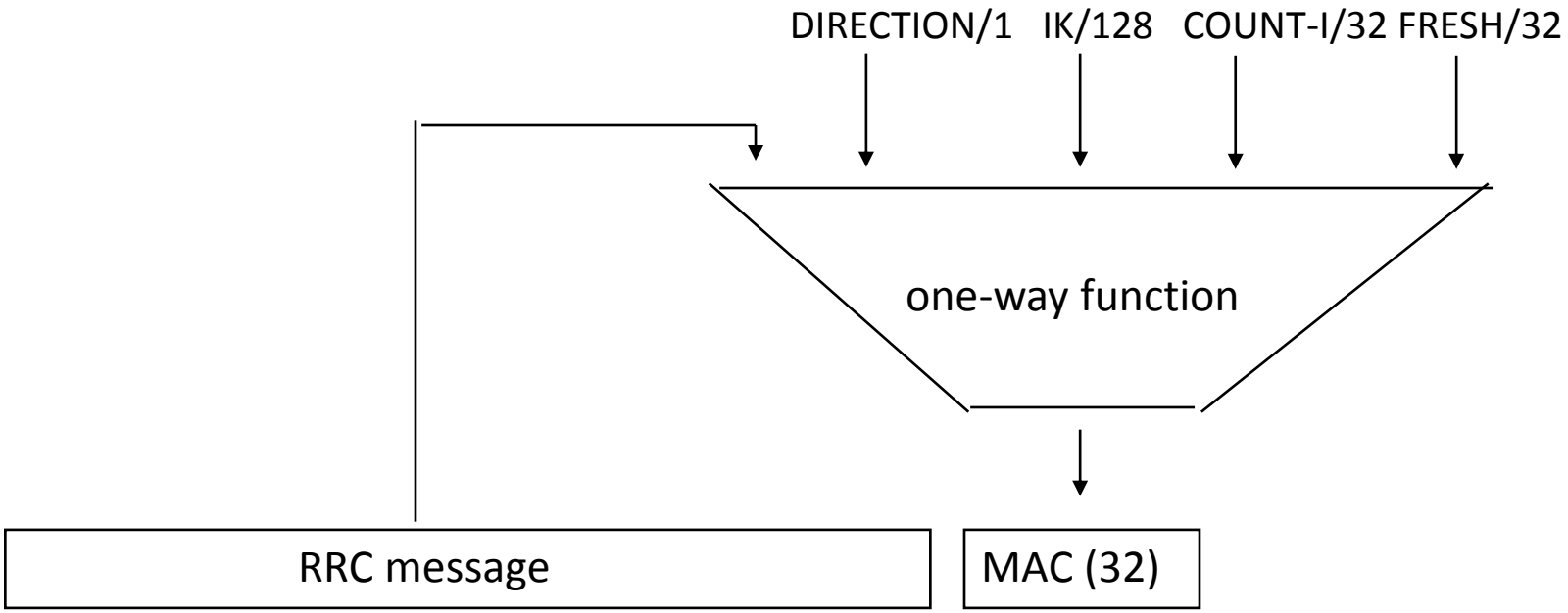
S7 substitution box

```
int S7[128] = {
     54, 50, 62, 56, 22, 34, 94, 96, 38,  6, 63, 93,  2, 18,123, 33,
     55,113, 39,114, 21, 67, 65, 12, 47, 73, 46, 27, 25,111,124, 81,
     53,  9,121, 79, 52, 60, 58, 48,101,127, 40,120,104, 70, 71, 43,
     20,122, 72, 61, 23,109, 13,100, 77, 1, 16,  7, 82, 10,105, 98,
    117,116, 76, 11, 89,106, 0,125,118, 99, 86, 69, 30, 57,126, 87,
    112, 51, 17,  5, 95, 14, 90, 84, 91,  8, 35,103, 32, 97, 28, 66,
    102, 31, 26, 45, 75,  4, 85, 92, 37, 74, 80, 49, 68, 29,115, 44,
     64,107,108, 24,110, 83, 36, 78, 42, 19, 15, 41, 88,119, 59, 3
 };
```

Integrity protection

- Purpose: to authenticate *individual* RRC signaling messages
- Examples of critical messages:
  - from MS to RNC:
    - MS capabilities, including authentication, ciphering and integrity algorithm capabilities
    - Security control accept/reject message
    - Called party number in a mobile originated call
    - Periodic message authentication messages
    - Cell and URA updates
  - from RNC to MS:
    - Security mode command, including whether ciphering is enabled or not and the ciphering and integrity algorithms that are used
    - Periodic message authentication messages.
- Almost all RRC messages are integrity protected

Integrity mechanism

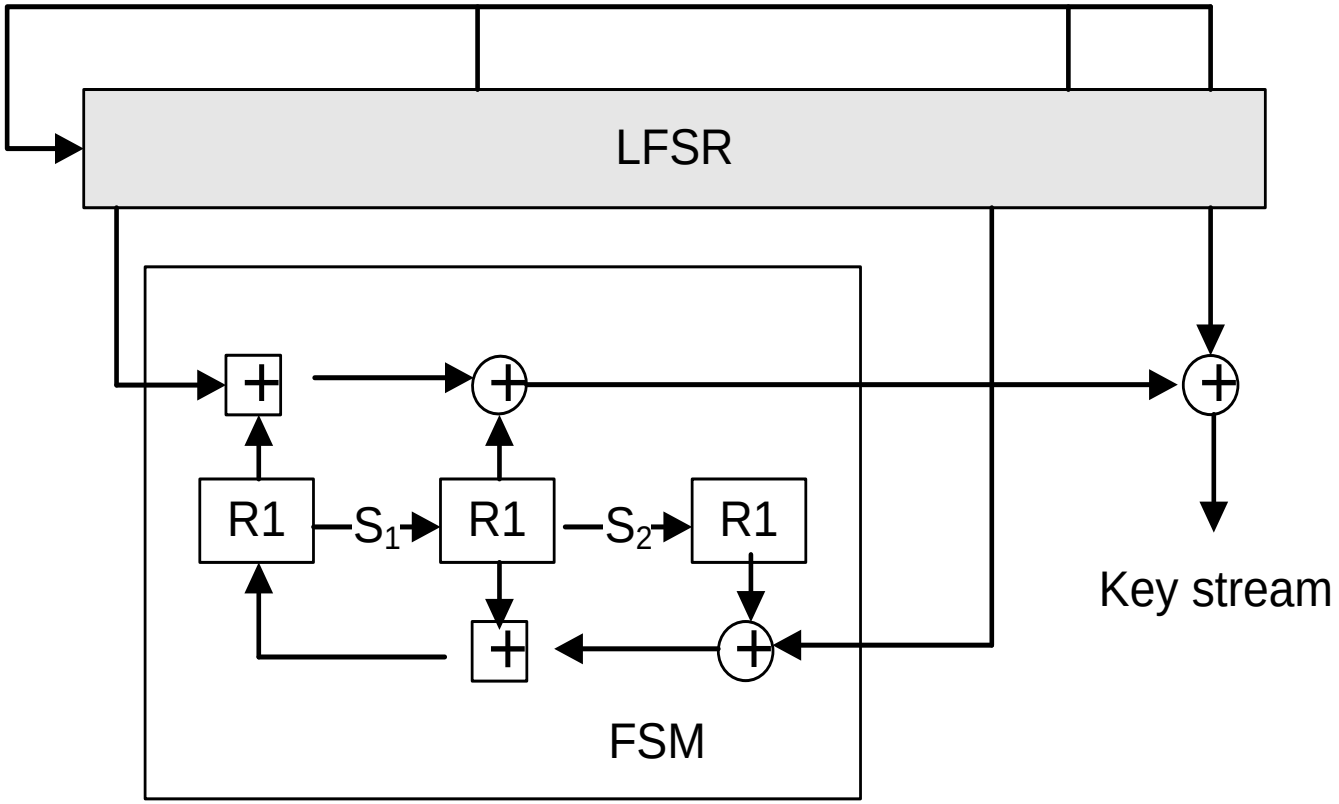


For UIA1: the one-way function is based on KASUMI block cipher

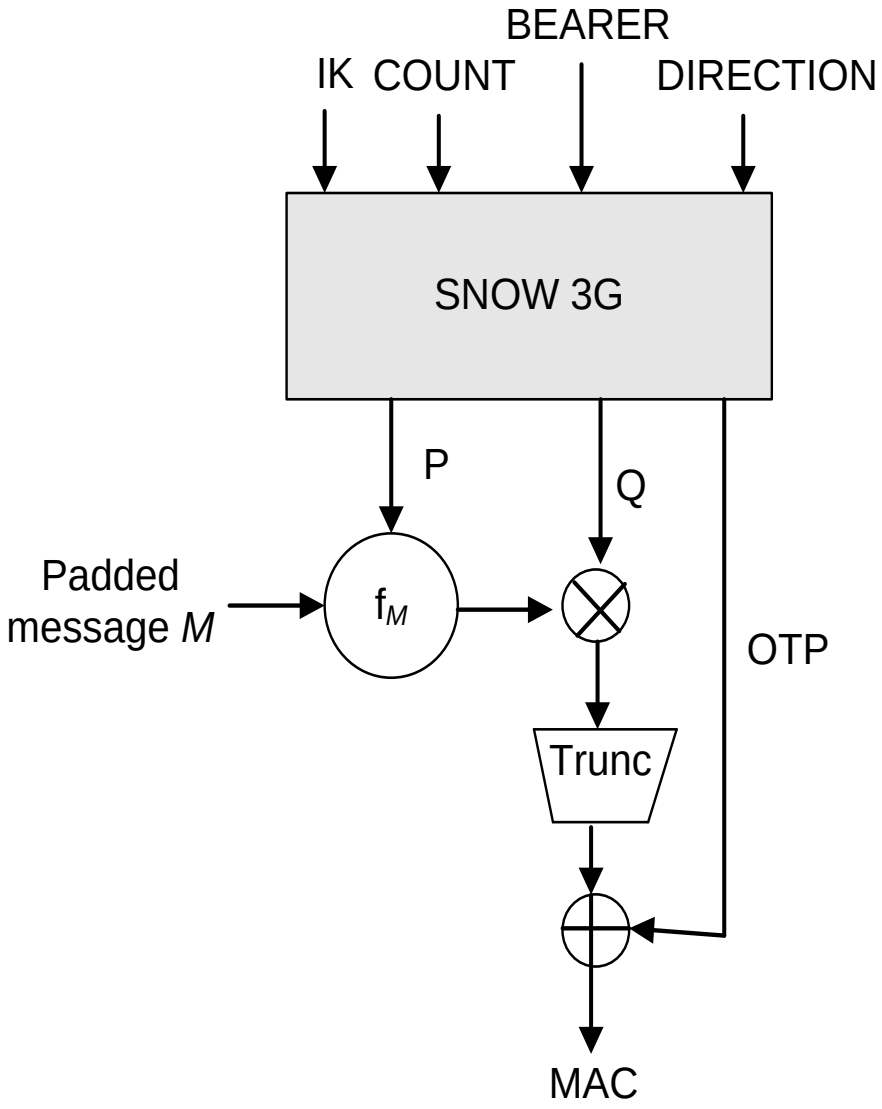
Second set of algorithms based on SNOW3G

- These are called UEA2 and UIA2
- Added in 3GPP release 7 (in 2006)
- SNOW3G is a stream cipher
  - based on SNOW 2.0 (Nordic origin)
  - structure of UEA2 is straight-forward

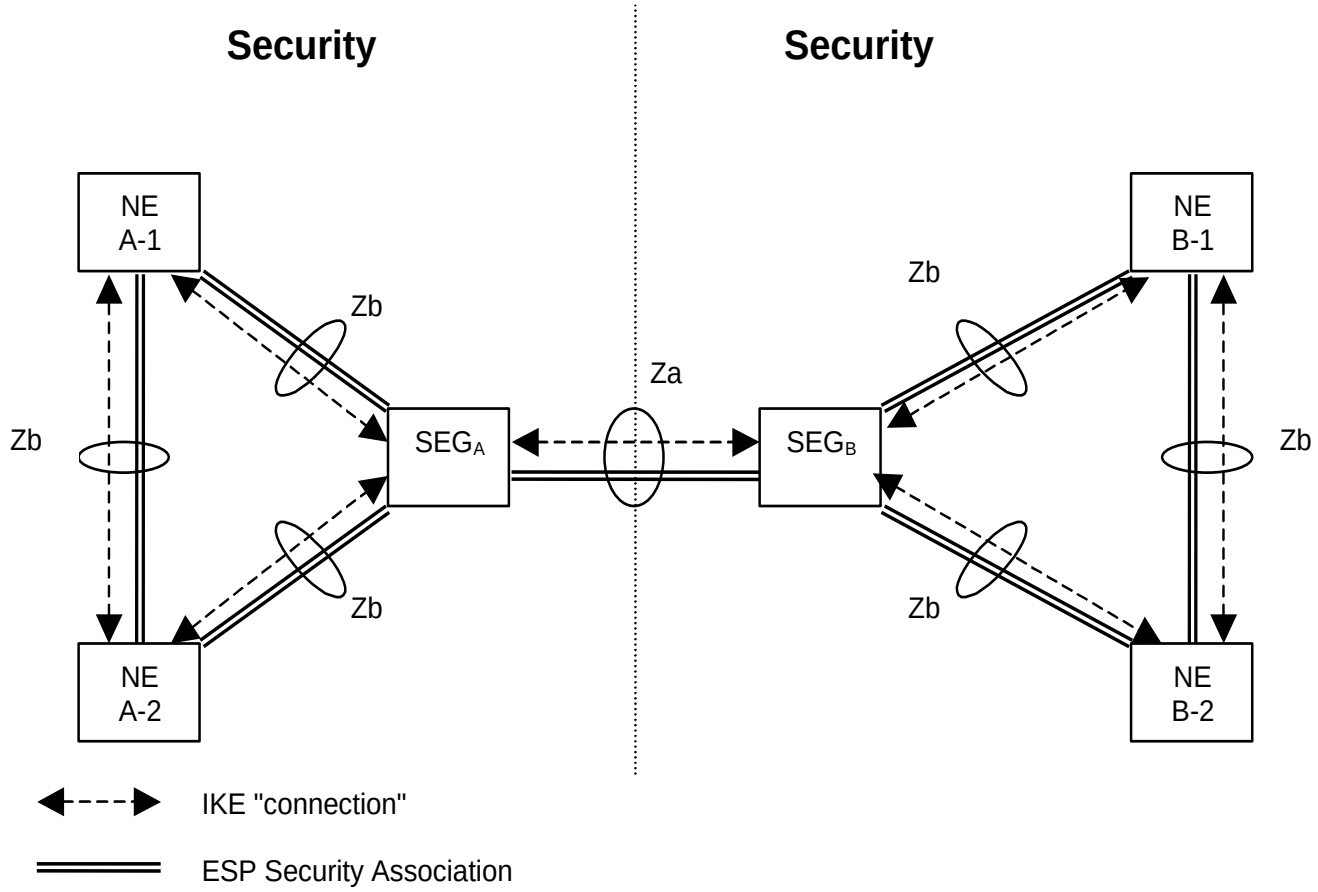
SNOW 3G : structure



UIA2 based on SNOW 3G



Network domain security (based on IPsec)



Status on 3G security today

- 3G security resilient against security analyses
- No significant attacks known on cryptographic algorithms
- No false base station attacks seem possible
- 3G security seems still sufficient for 3G networks

Brief introduction to LTE (and SAE)

SAE / LTE: What and why?

SAE = System Architecture Evolution

LTE = Long Term Evolution (of radio networks)

- LTE offers higher data rates, up to 100 Mb/sec
  - Multi-antenna technologies
  - New transmission schema based on OFDM
  - Signaling/scheduling optimizations
- SAE offers optimized (flat) IP-based architecture
  - Two network nodes for user plane
  - Simplified protocol stack
  - Optimized inter-working with legacy cellular, incl. CDMA
  - Inter-working with non-3GPP accesses, incl. WiMAX

SAE / LTE: What and why?

SAE = System Architecture Evolution

LTE = Long Term Evolution (of radio networks)

- Technical terms:
  - E-UTRAN = Evolved UTRAN (LTE radio network)
  - EPC = Evolved Packet Core (SAE core network)
  - EPS = Evolved Packet System (= RAN + EPC)

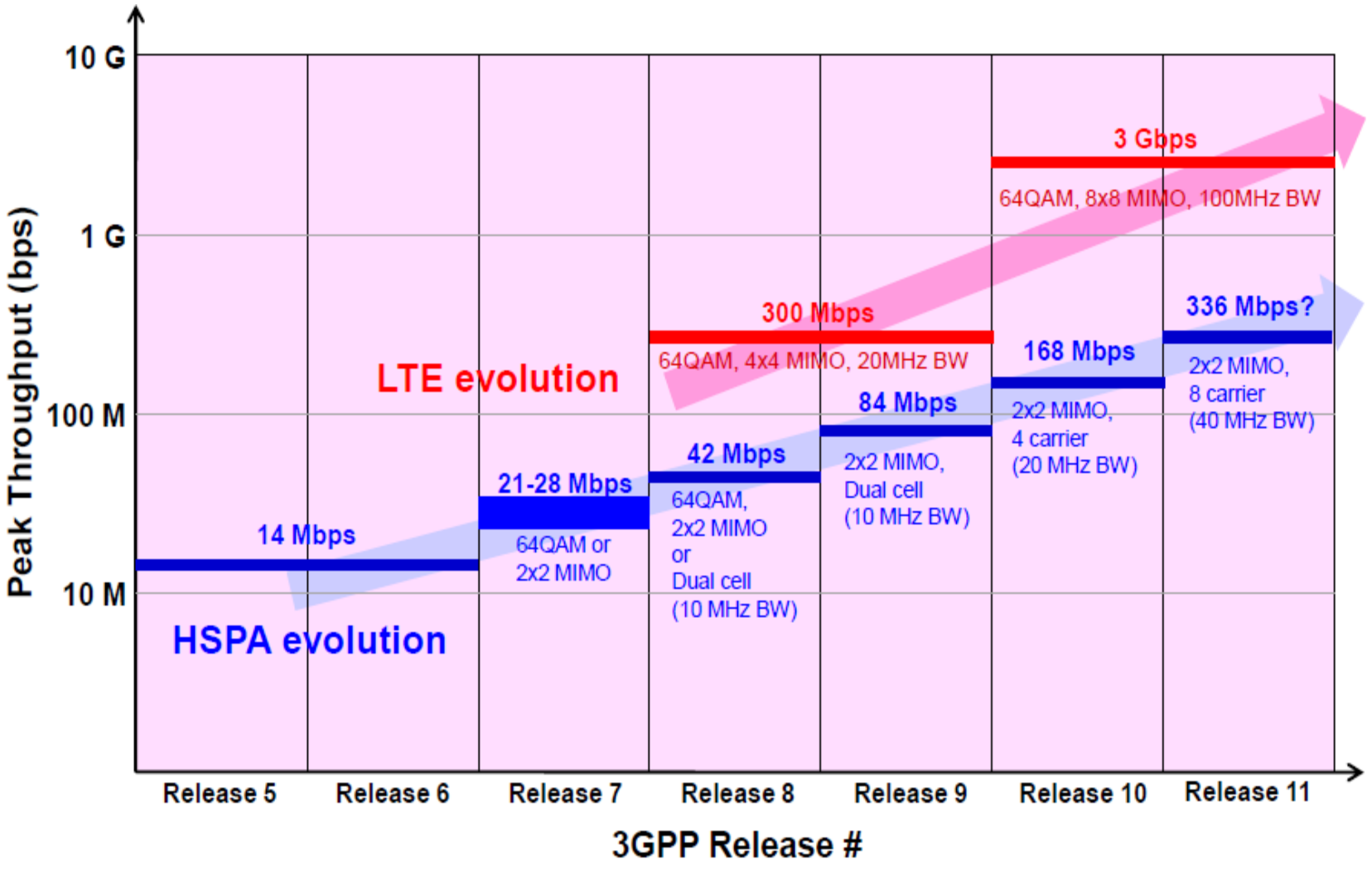
SAE / LTE : designed by whom?

3GPP TSG SA : stage 2 specifications for LTE/SAE
3GPP TSG RAN: stage 3 specs for LTE
3GPP TSG CT: stage 3 specs for SAE

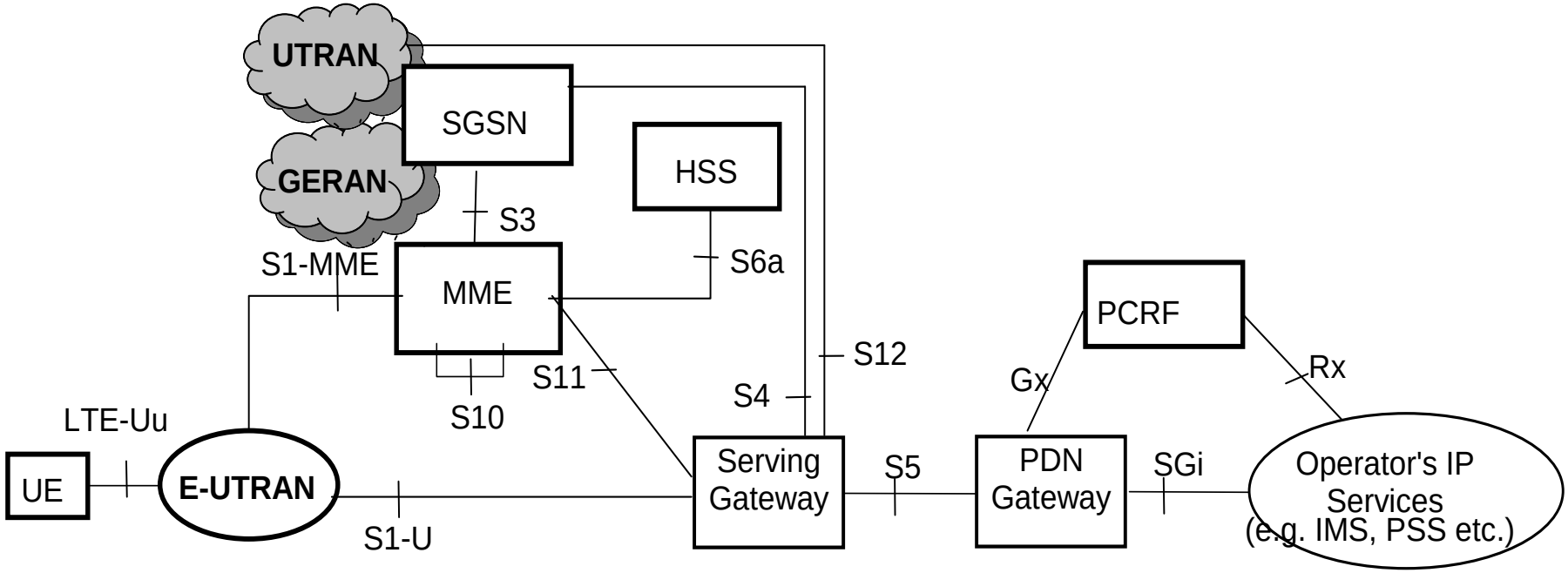
LTE/SAE is included in 3GPP *Release 8* specifications

Security design by 3GPP TSG SA Working Group 3 (SA3)

LTE evolution (from RAN chair Takehiro Nakamura)

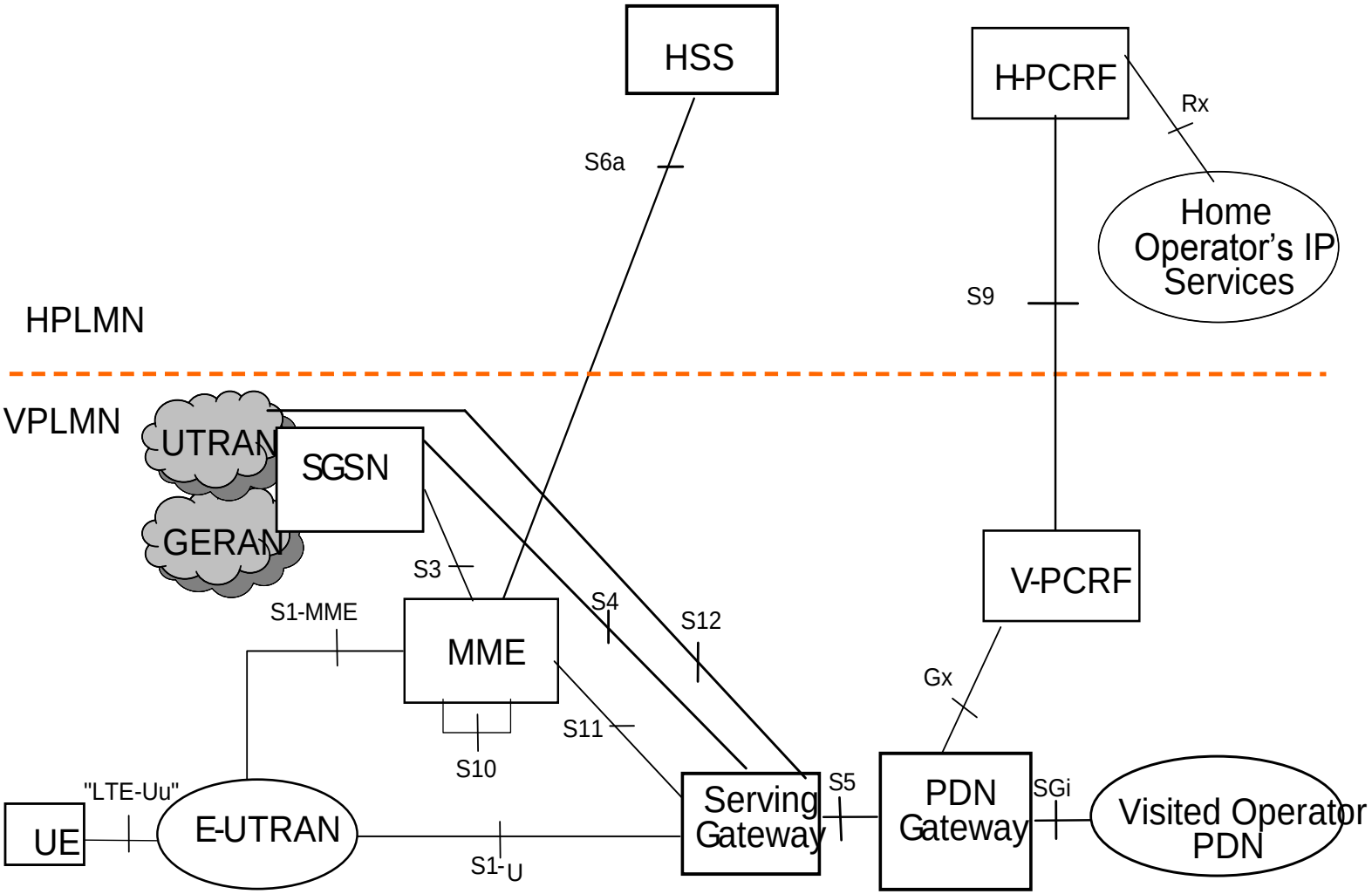


EPS architecture (non-roaming case)



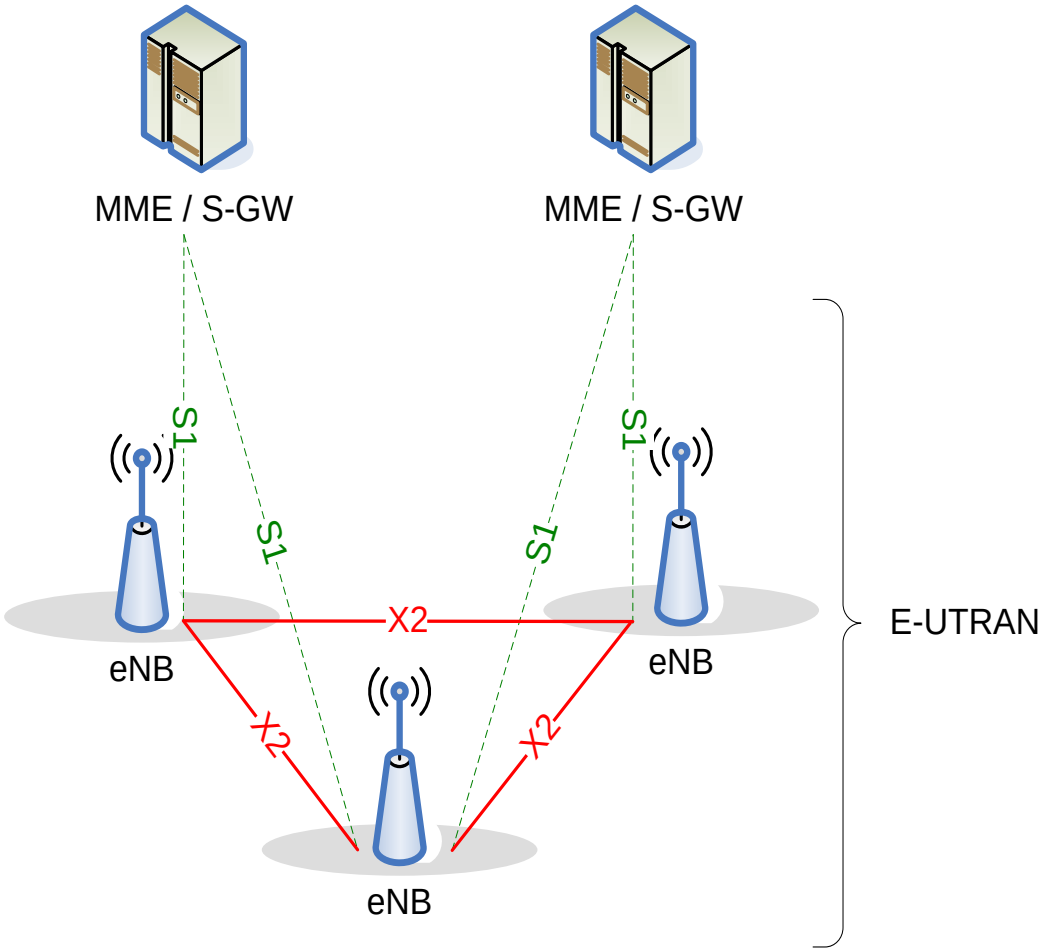
From 3GPP TS 23.401

EPS architecture (one of the roaming variants)



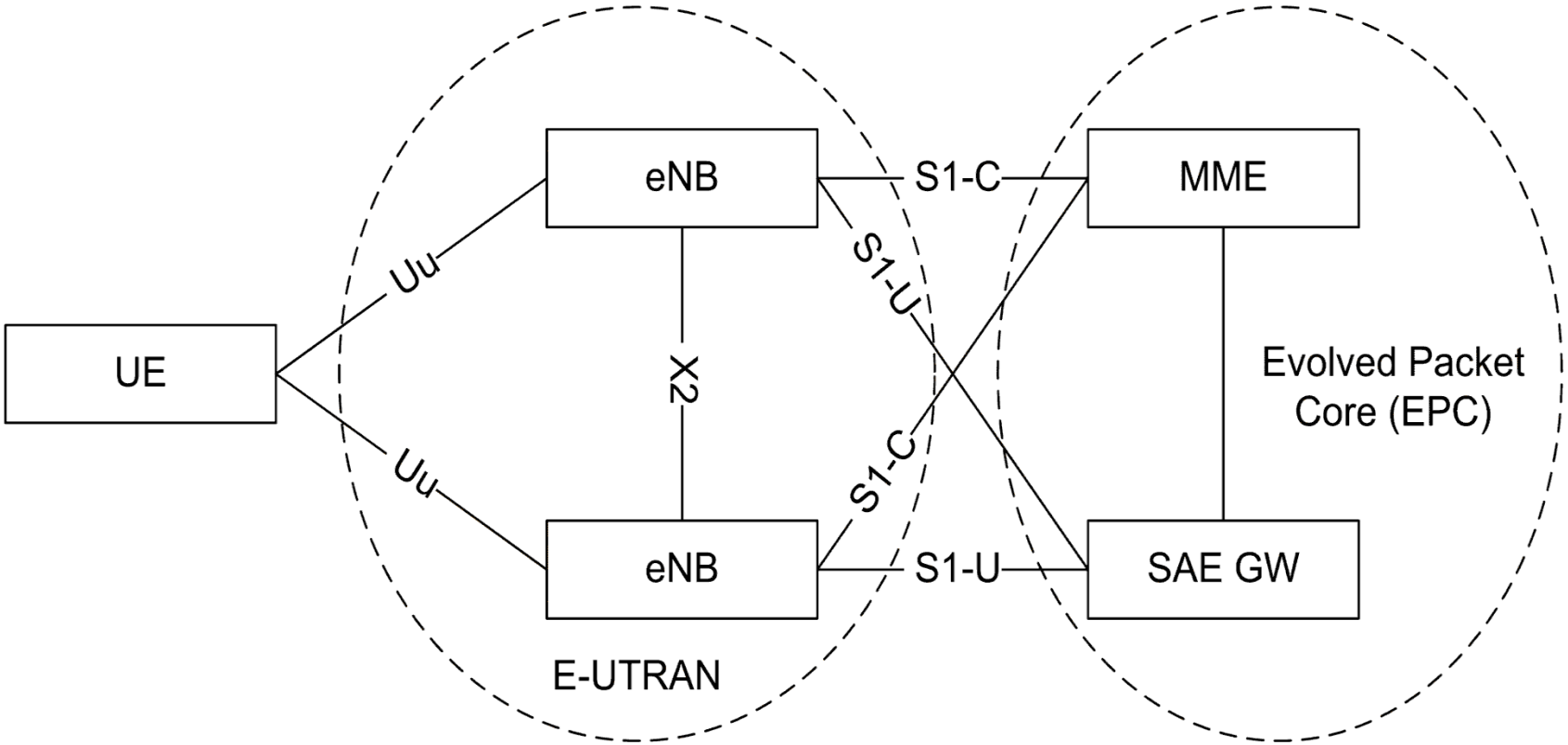
From TS 23.401

E-UTRAN architecture



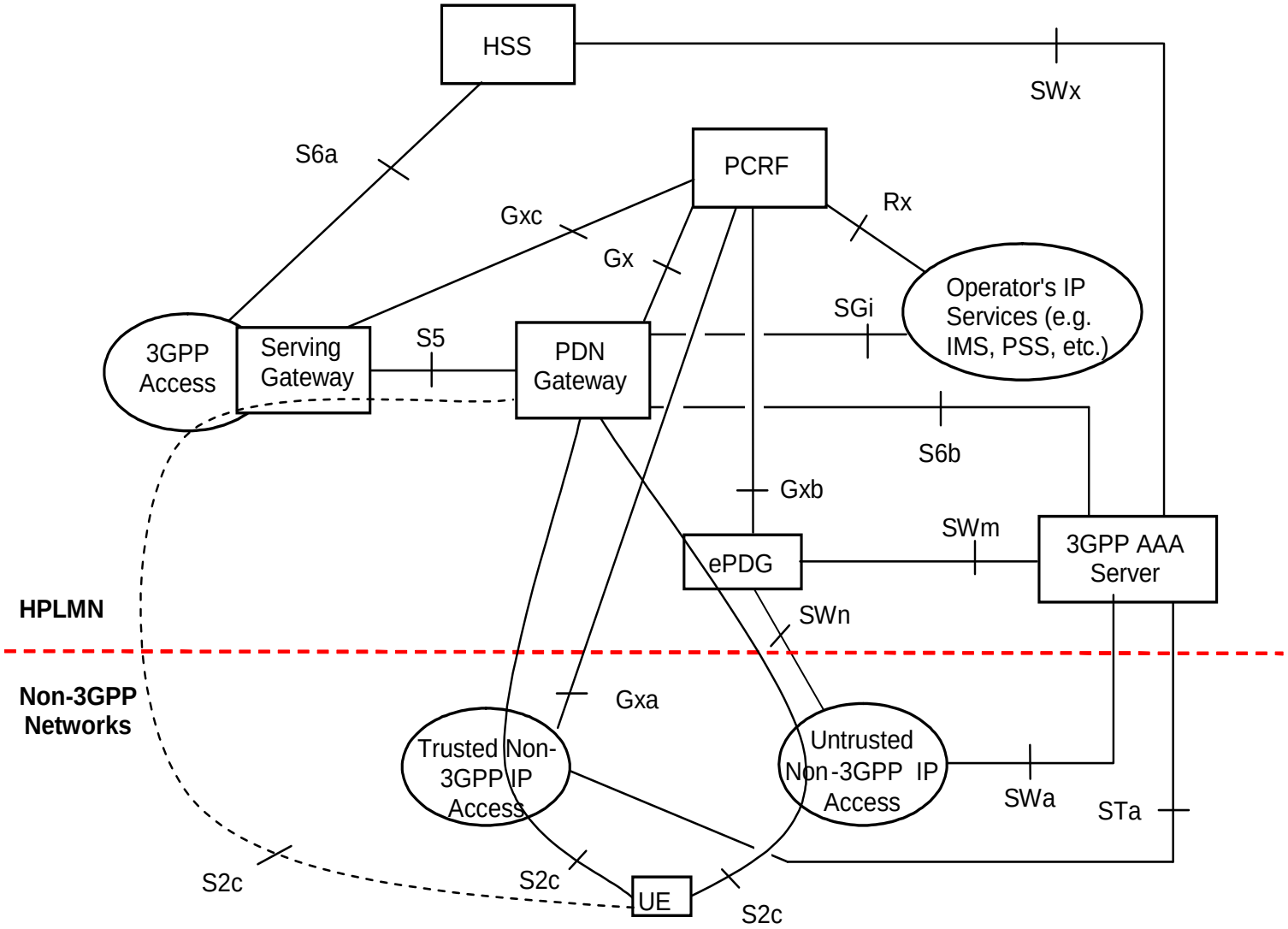
From 3GPP TS 36.300

Essential elements of EPS



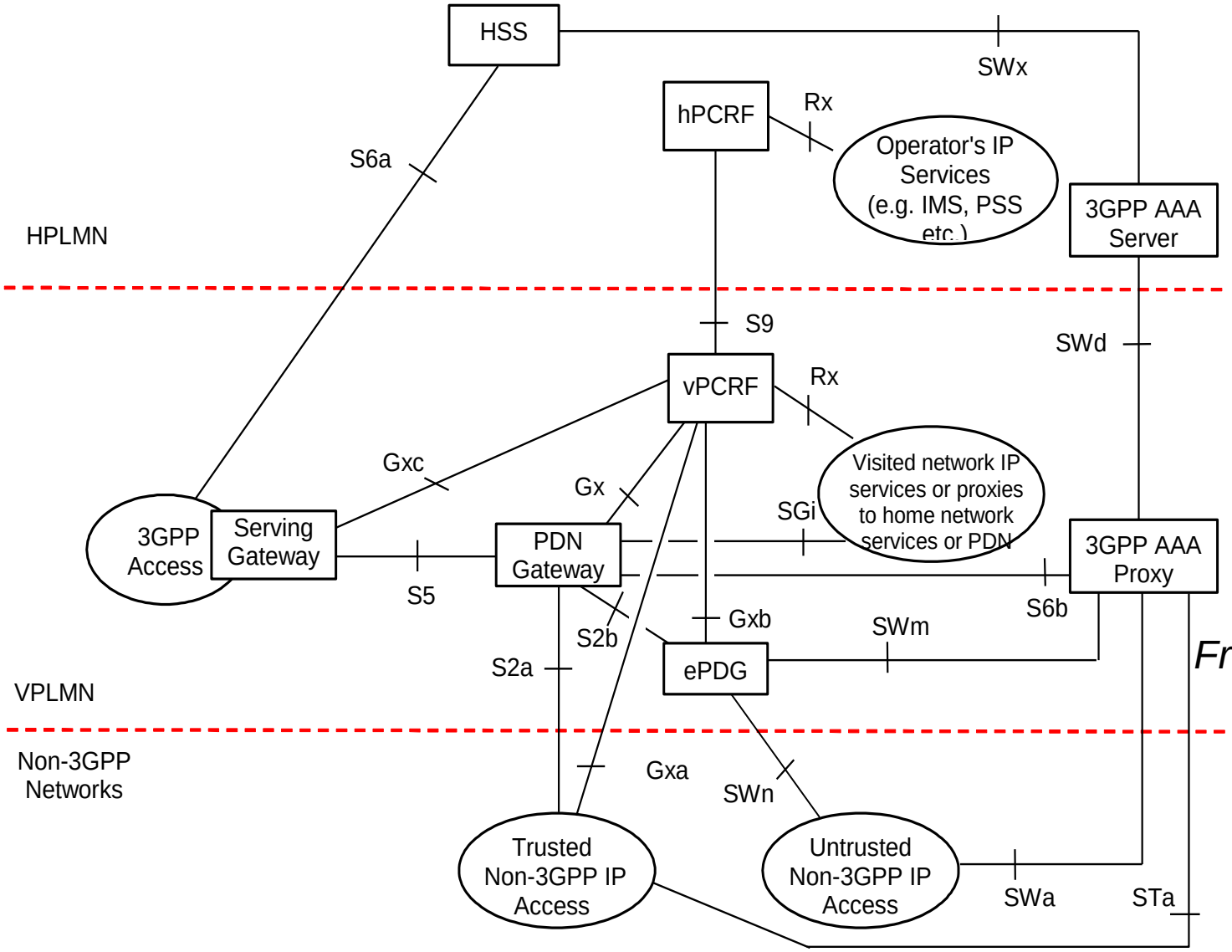
From "LTE security"

EPS archi with non-3GPP access (non-roaming)



From TS 23.402

Roaming case (one variant)



From TS 23.402

LTE Security

Implications of LTE/SAE architecture on security

- Flat architecture:
  - All radio access protocols terminate in one node: eNodeB
  - IP protocols also visible in eNB
- Security implications due to
  - Architectural design decisions
  - Interworking with legacy and non-3GPP networks
  - Allowing eNB placement in untrusted locations
  - New business environments with less trusted networks involved
  - Trying to keep security breaches as local as possible
- As a result (when compared to UTRAN/GERAN):
  - Extended Authentication and Key Agreement
  - More complex key hierarchy
  - More complex interworking security
  - Additional security for eNB (compared to NodeB/BTS/RNC)

Threats against EPS (1/2)

- Threats against user identity
- Other threats against privacy
- Threats of UE tracking:
  - e.g. tracking a user based on an IP address that could potentially be linked to an IMSI
- Threats related to handovers:
  - e.g. forcing a handover to a compromised base station by a powerful signal;
- Threats related to base stations and last-mile transport links:
  - e.g. injecting packets directly into the last-mile transport link or physical compromise of base stations in vulnerable locations;
- Threats related to multicast or broadcast signalling:
  - e.g. broadcasting false system information
- Threats related to denial of service:
  - e.g. by means of radio jamming or launching a distributed attack from many UEs

Threats against EPS (2/2)

- Threats of misusing network services:
  - e.g. flooding the network from inside the network by compromised elements or from outside
- Threats against the radio protocols:
  - e.g. faking or modifying the first radio connection establishment messages from UE
- Threats related to mobility management:
  - e.g. disclosure of sensitive data about users' locations;
- Threats of manipulation of control plane data
- Threats of unauthorised access to the network

EPS security requirements (high-level)

- EPS shall provide a high level of security.
- Any security lapse in one access technology shall not compromise other accesses.
- EPS should provide protection against threats and attacks.
- EPS shall support authenticity of information between the terminal and the network.
- Appropriate traffic protection measures should be provided.
- EPS shall ensure that unauthorised users cannot establish communications through the system.

EPS security requirements (service-related)

- EPS shall allow a network to hide its internal structure from the terminal.
- Security policies shall be under home operator control.
- Security solutions should not interfere with service delivery or handovers in a way noticeable for end-users.
- EPS shall provide support for lawful interception.
- Rel-99 (or newer) USIM is required for authentication of the user towards EPS.
- USIM shall not be required for re-authentication in handovers (or other changes) between EPS and other 3GPP systems, unless requested by the operator.
- EPS shall support IMS emergency calls.

EPS security requirements (privacy-related)

- EPS shall provide several appropriate levels of user privacy for communication, location, and identity.
- Communication contents, origin, and destination shall be protected against disclosure to unauthorised parties.
- EPS shall be able to hide user identities from unauthorised parties.
- EPS shall be able to hide user location from unauthorised parties, including another party with which user is communicating.

EPS security features

- *Confidentiality of the user and device identities*
- *Authentication between the UE and the network*
- *Confidentiality of user and signalling data*
- *Integrity of signalling data*
- *Visibility and configurability of security*
- *Platform Security of the eNodeB*
- *Lawful interception*
- *Emergency calls*
- *Interworking security*
- *Network domain security*
- *IMS security for voice over LTE*

Major design decisions for EPS security (1/2)

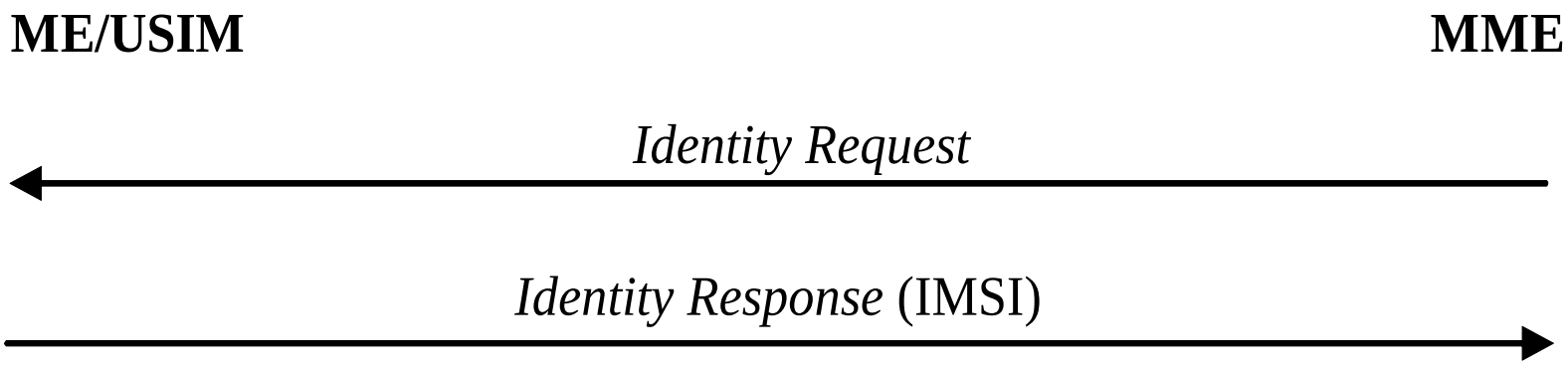
- Permanent security association
  - Inherited from GSM and 3G
- Interfaces in UE and HSS/HLR
  - ME-USIM interface is fully standardized but HSS-AuC is not
- Reuse of 3G USIMs
- **No** reuse of 2G SIMs in EPS
- Delegated authentication
  - Inherited from GSM and 3G
- Reuse of 3G AKA
- Cryptographic network separation
- Serving network authentication

Major design decisions for EPS security (2/2)

- Termination point for encryption and integrity protection
  - Flat architecture required moving to base station site
- New key hierarchy in EPS
- Key separation in handovers
- Homogeneous security for heterogeneous access networks
- User identity confidentiality ***not*** protected against active attackers
- Other „NOT“ – decisions:
  - No integrity protection for user plane on radio interface
  - No (cryptographic) non-repudiation of charging

Identity confidentiality in EPS (1/2)

- Mechanism inherited from GSM and 3G
- User's permanent identity (IMSI) is sent to the network only if network cannot identify the UE otherwise



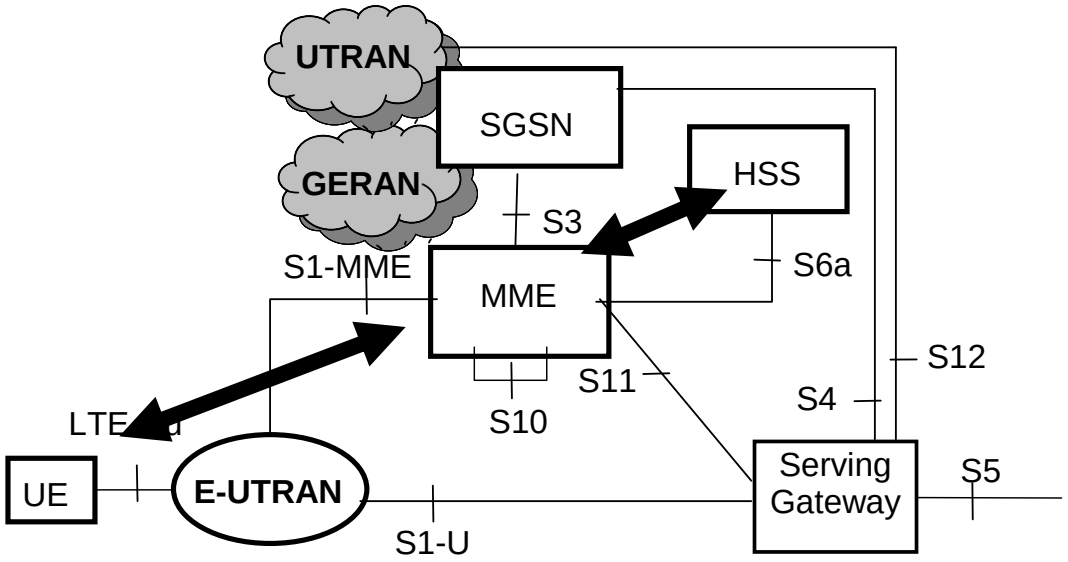
From 33.401

Identity confidentiality in EPS (2/2)

- Network assigns a temporary identity for the UE
- It is sent to the UE in encrypted message
- In GSM/3G the temporary identity is
  - TMSI for CS domain
  - P-TMSI for PS domain
- In EPS the temporary identity is called GUTI (Globally Unique Temporary Identity)

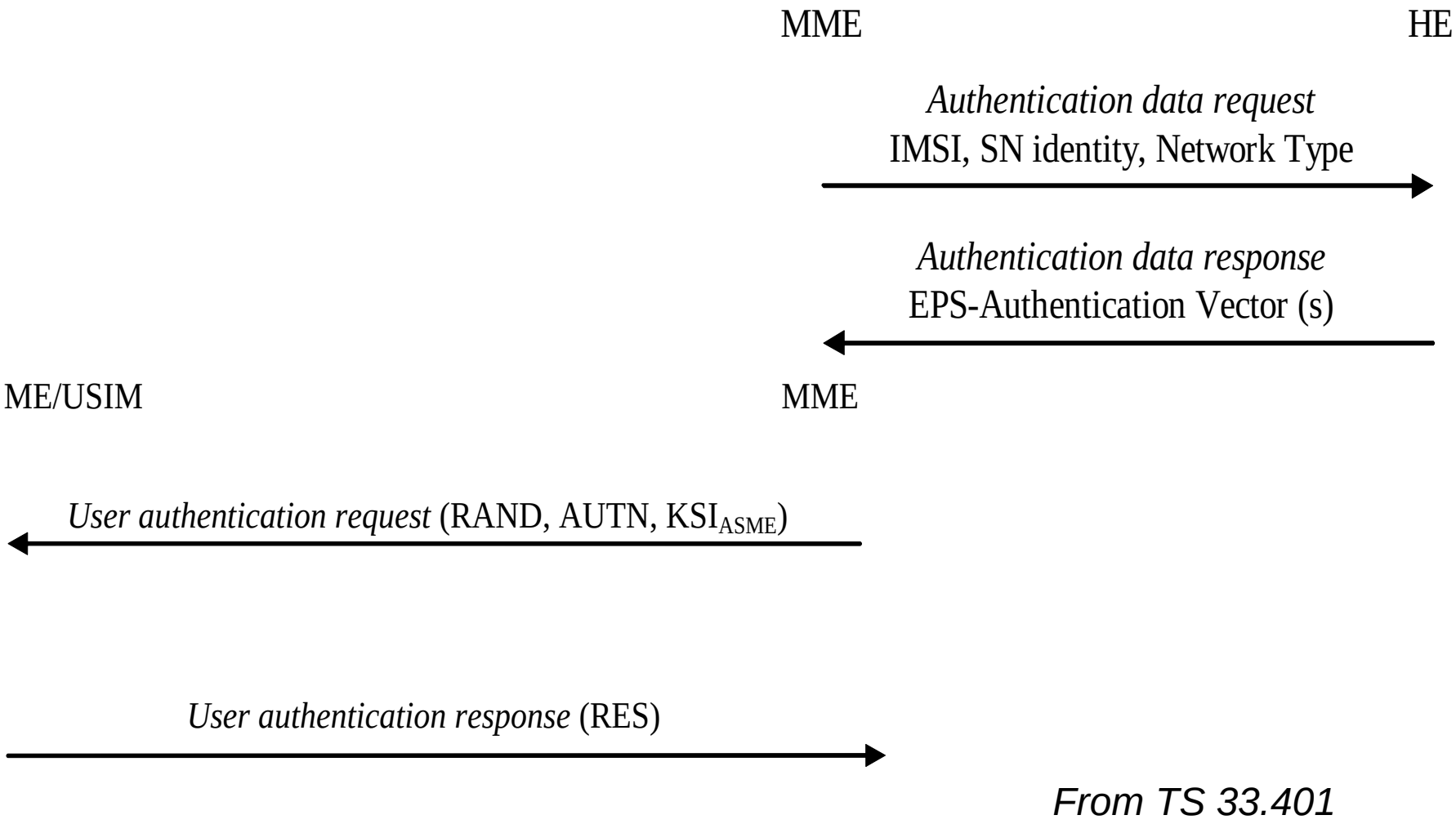
Authentication and key agreement

Authentication and key agreement

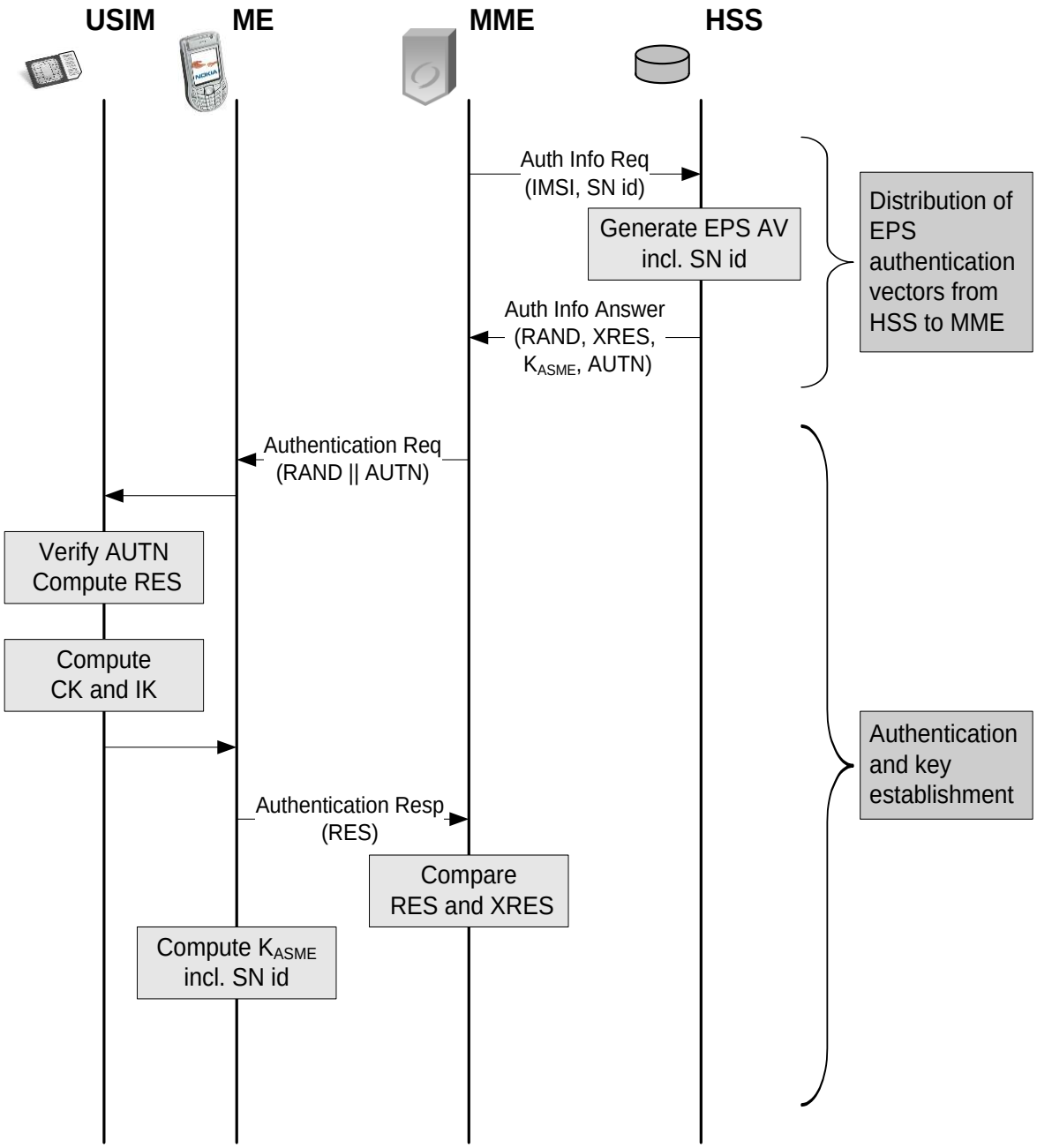


- HSS generates authentication data and provides it to MME
- Challenge-response authentication and key agreement procedure between MME and UE

AKA protocol

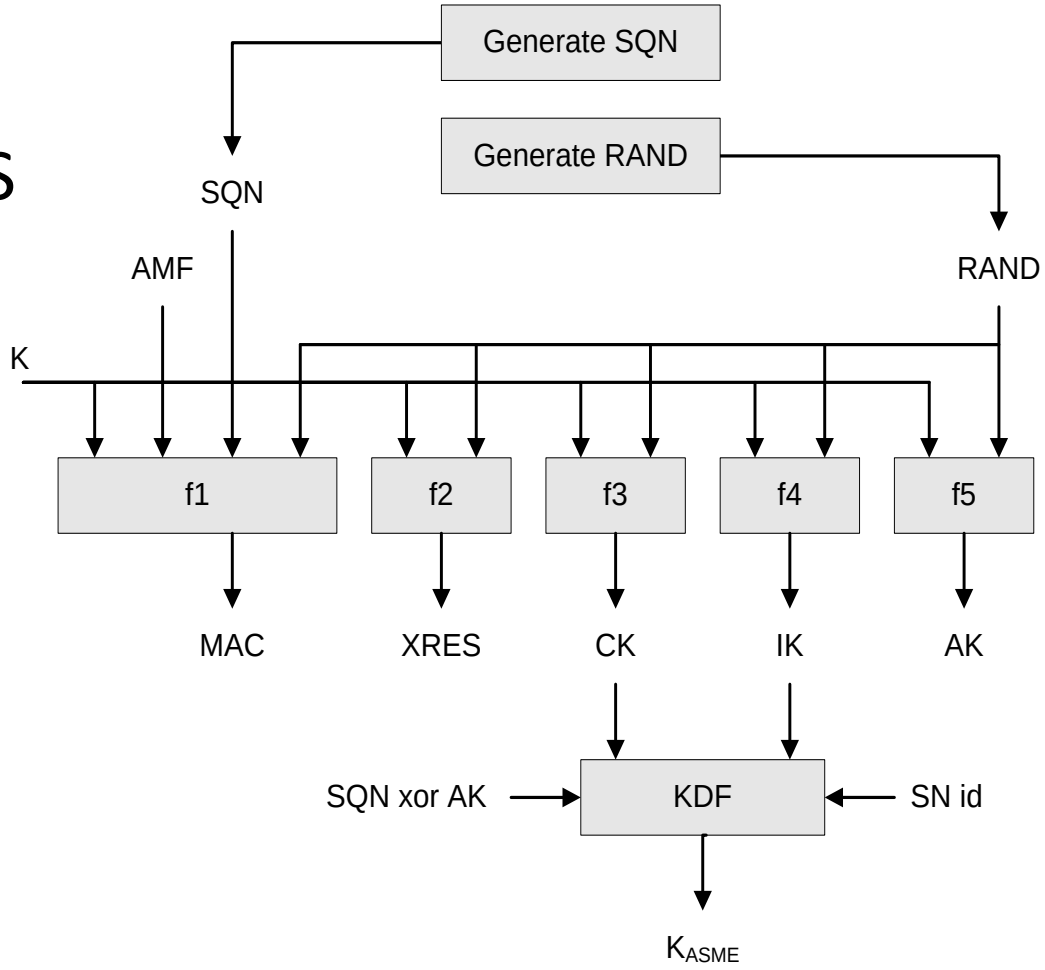


From TS 33.401



From "LTE security"

Generation of UMTS and EPS AV's



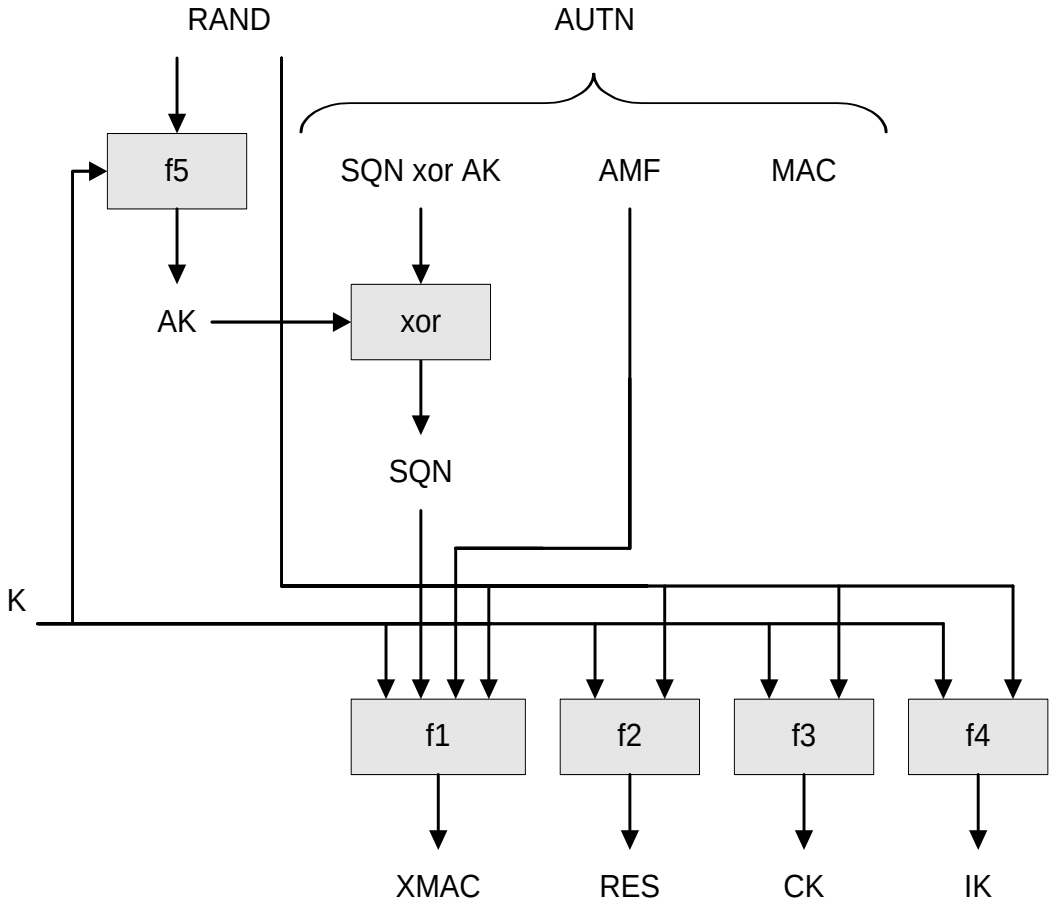
From "LTE security"

AUTN := SQN xor AK || AMF || MAC

UMTS AV := RAND || XRES || CK || IK || AUTN

EPS AV := RAND || XRES || K_{ASME} || AUTN

Verification in USIM



Verify MAC = XMAC

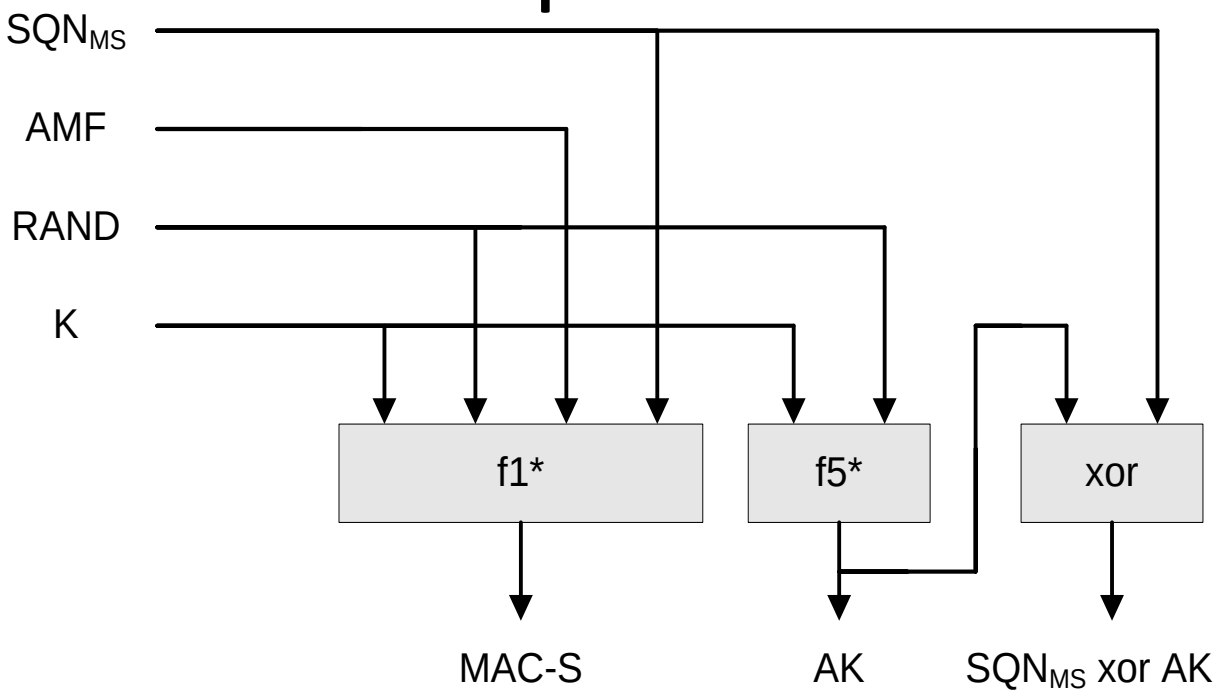
Verify that SQN is in the correct range

From "LTE security"

Authentication failure types

- MAC code failure
  - XMAC differs from MAC
- Synchronization failure
  - SQN not in correct range
  - Re-synchronization is possible (next slide)
- Incorrect type of AV
  - Check a specific AMF separation bit (see later slide)
- Invalid authentication response
  - XRES differs from RES

Authentication re-synchronization parameter

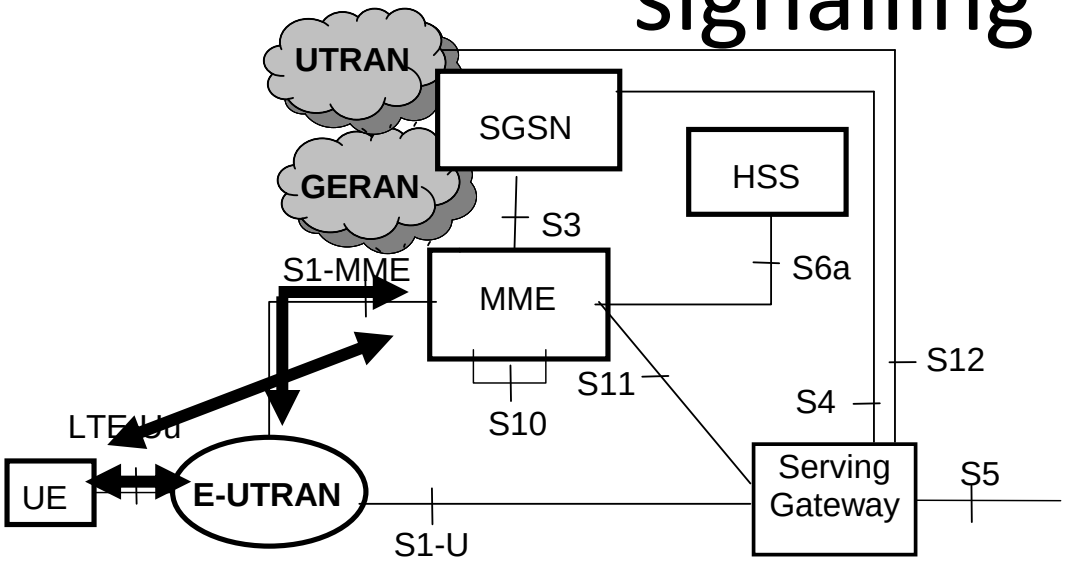


AUTS = SQN_{MS} xor AK || MAC-S

From "LTE security"

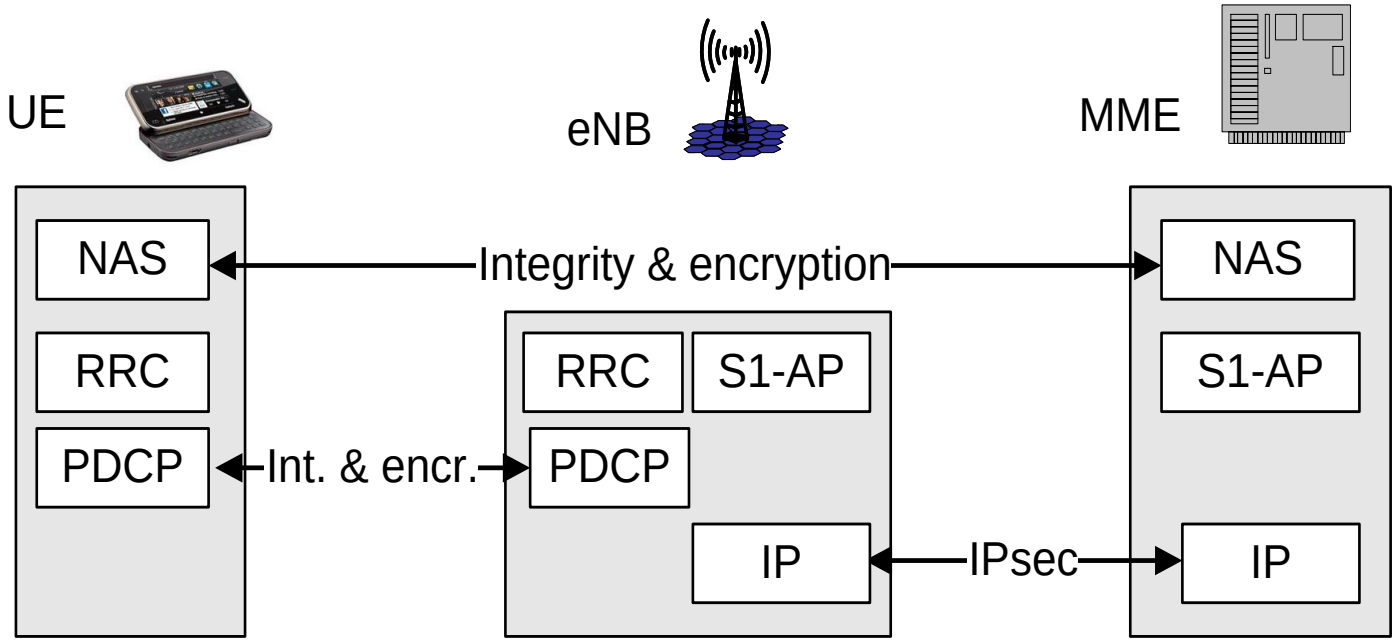
LTE Data protection

Confidentiality and integrity of signalling



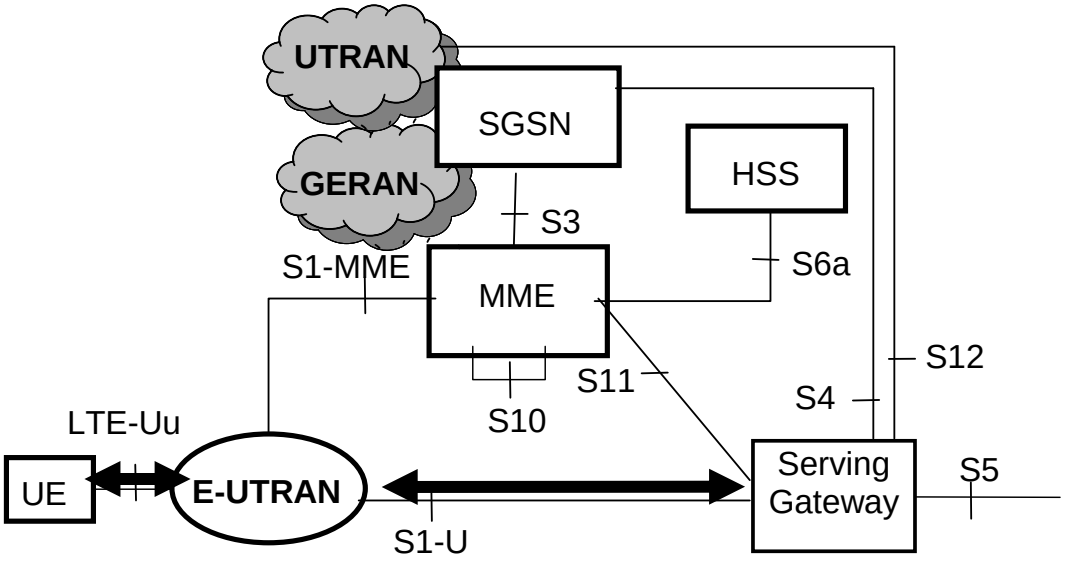
- RRC signalling between UE and E-UTRAN
- NAS signalling between UE and MME
- S1 interface signalling
  - protection is not UE-specific
  - optional to use

EPS signalling protection



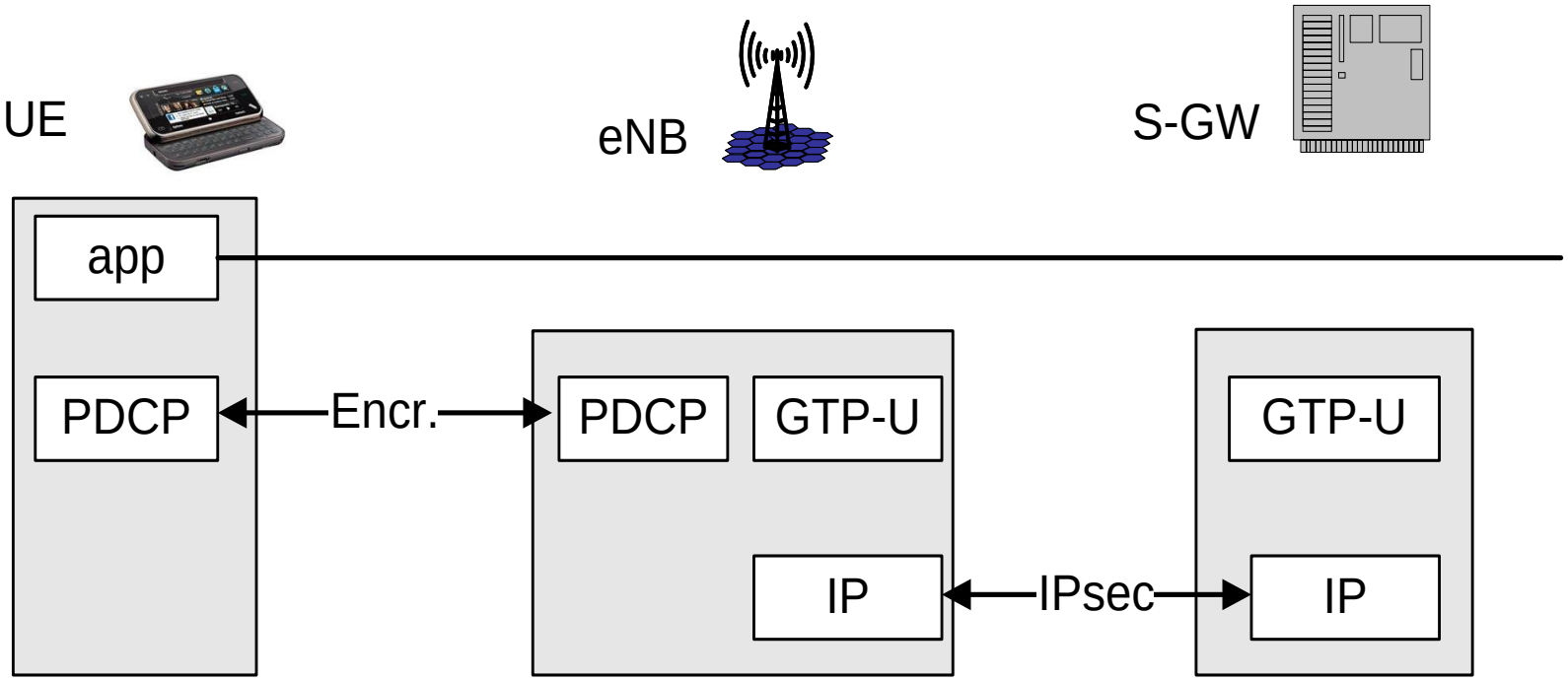
From "LTE security"

User plane confidentiality



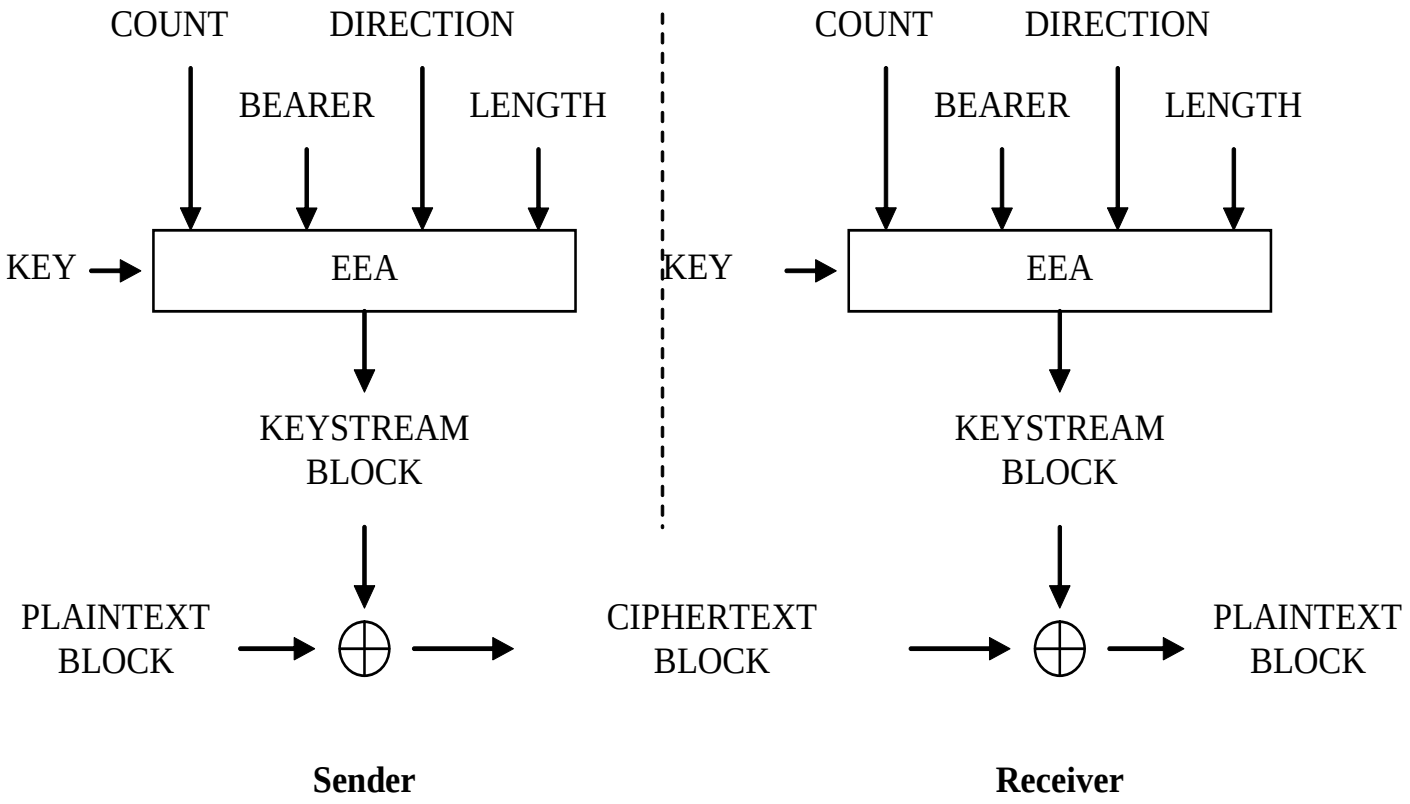
- S1-U protection is not UE-specific
  - (Enhanced) network domain security mechanisms (based on IPsec)
  - Optional to use
- Integrity is not protected for various reasons, e.g.:
  - performance
  - limited protection for application layer

EPS user plane protection



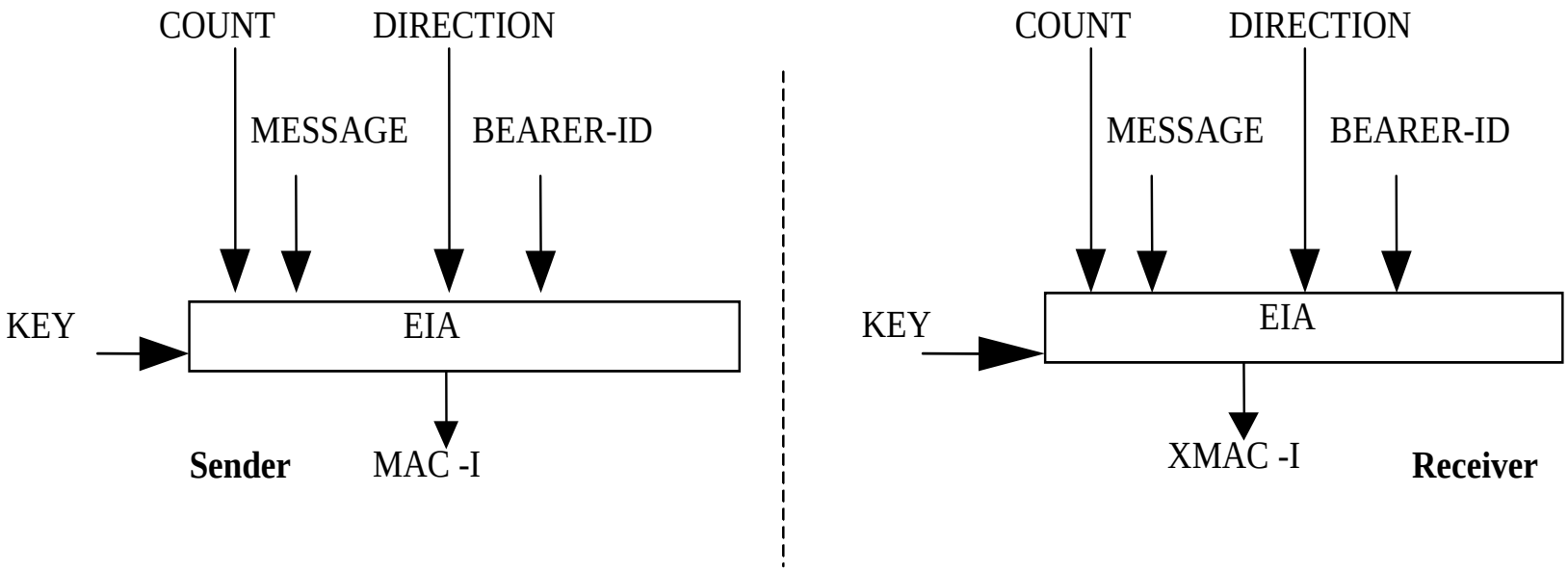
From "LTE security"

Ciphering mechanism

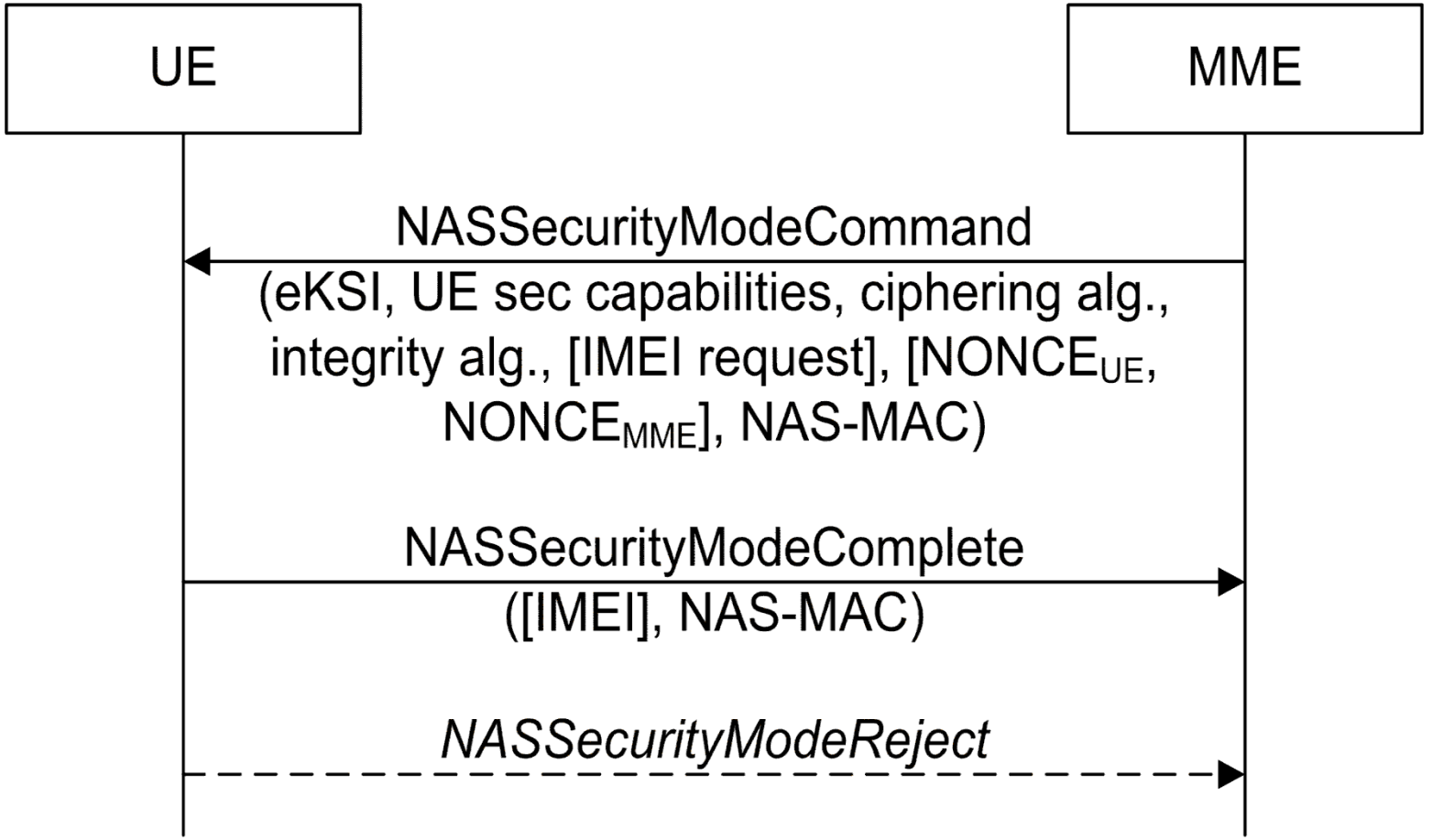


Extract from 3GPP TS 33.401

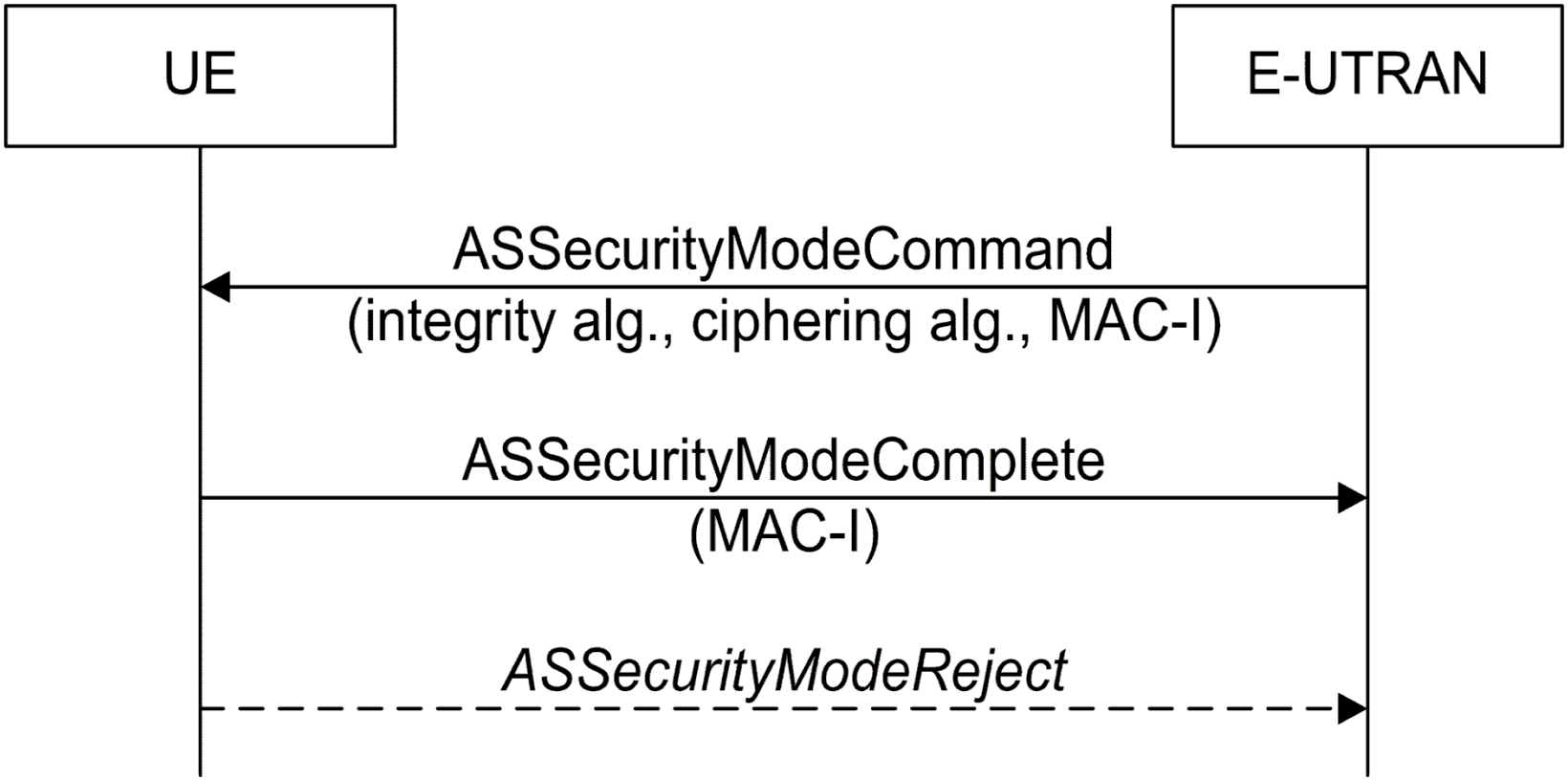
Integrity protection



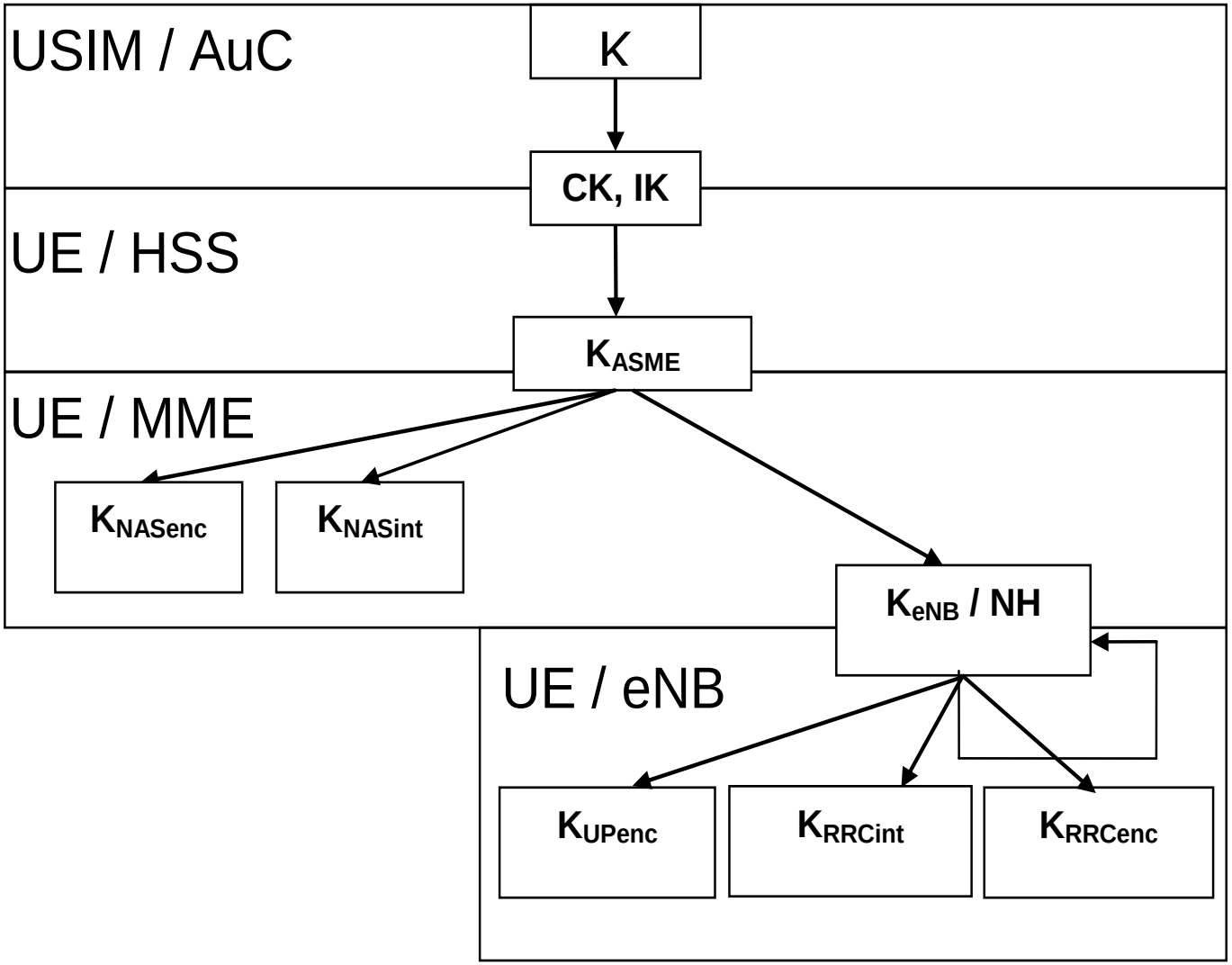
Start of NAS protection

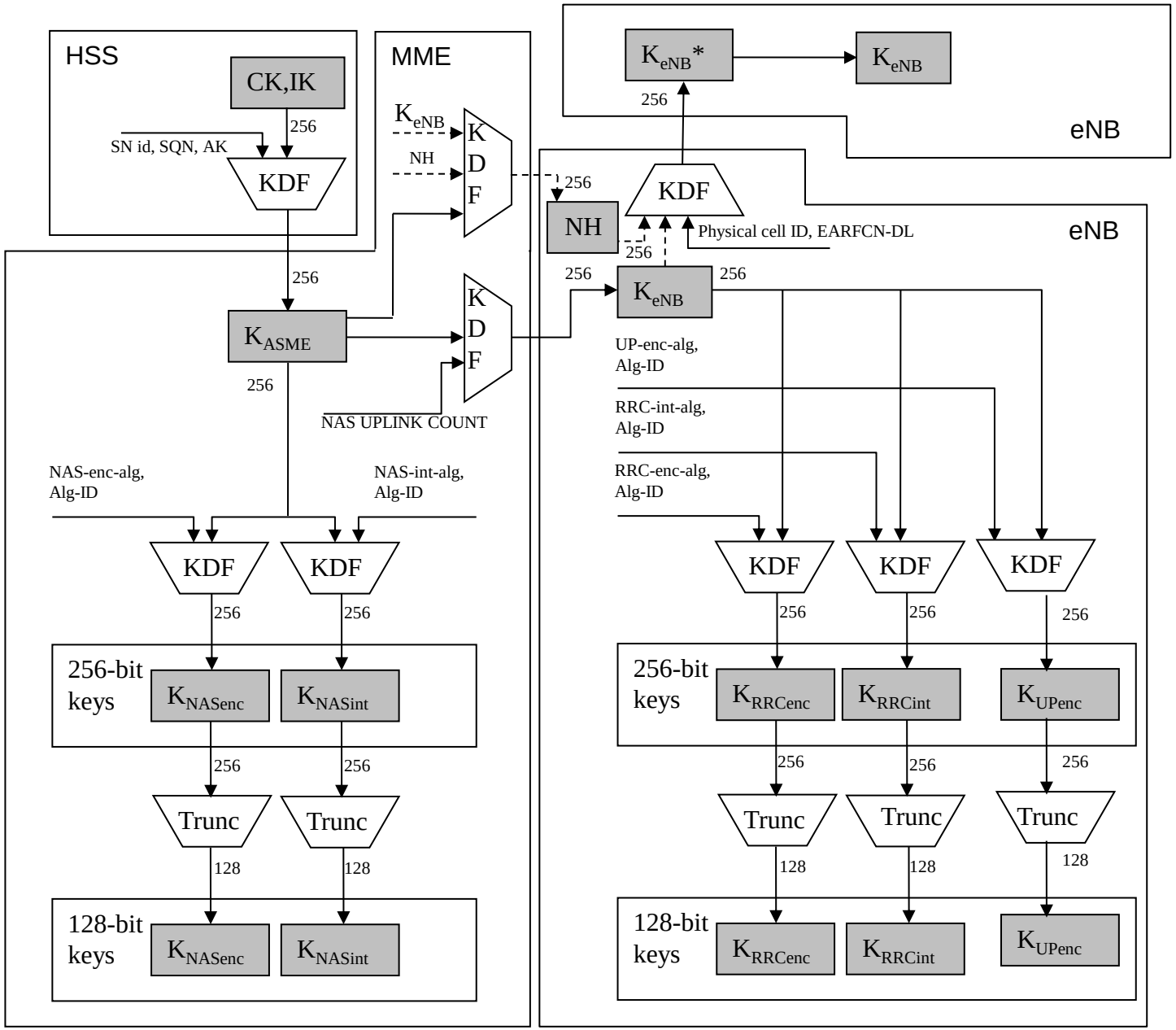


Start of AS protection

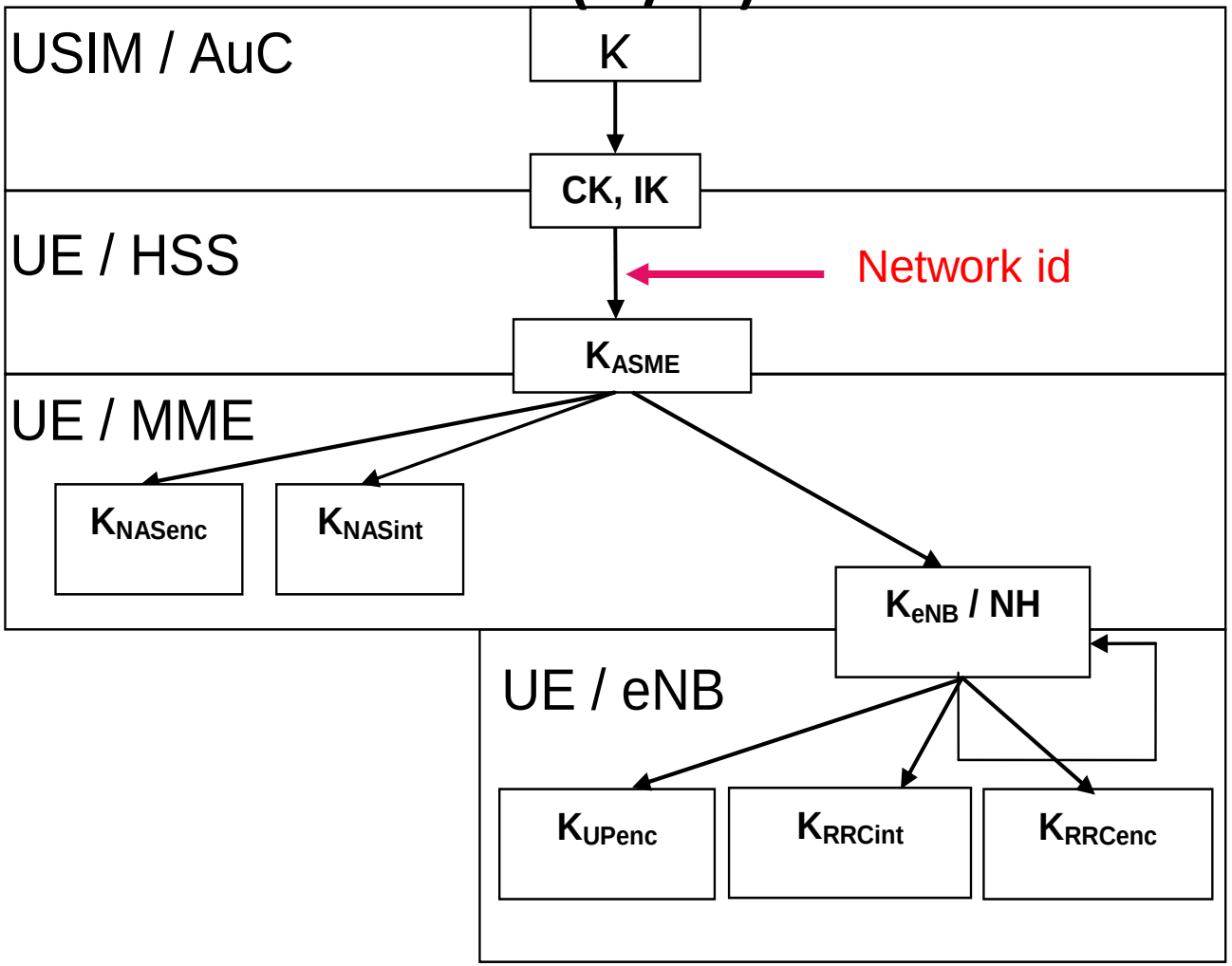


LTE Key hierarchy




HSS
MME
CK,IK
256
SN id, SQN, AK
KDF
256
K_ASME
256
K_eNB
NH
K D F
256
NAS UPLINK COUNT
NAS-enc-alg, Alg-ID
NAS-int-alg, Alg-ID
KDF
KDF
256
256
256-bit keys
K_NASenc
K_NASint
256
256
Trunc
Trunc
128
128
128-bit keys
K_NASenc
K_NASint
K_eNB*
K_eNB
256
eNB
KDF
Physical cell ID, EARFCN-DL
NH
256
256
K_eNB
256
eNB
UP-enc-alg, Alg-ID
RRC-int-alg, Alg-ID
RRC-enc-alg, Alg-ID
KDF
KDF
KDF
256
256
256
256-bit keys
K_RRCenc
K_RRCint
K_UPenc
256
256
256
Trunc
Trunc
Trunc
128
128
128
128-bit keys
K_RRCenc
K_RRCint
K_UPenc

Cryptographic network separation (1/2)



Cryptographic network separation (2/2)

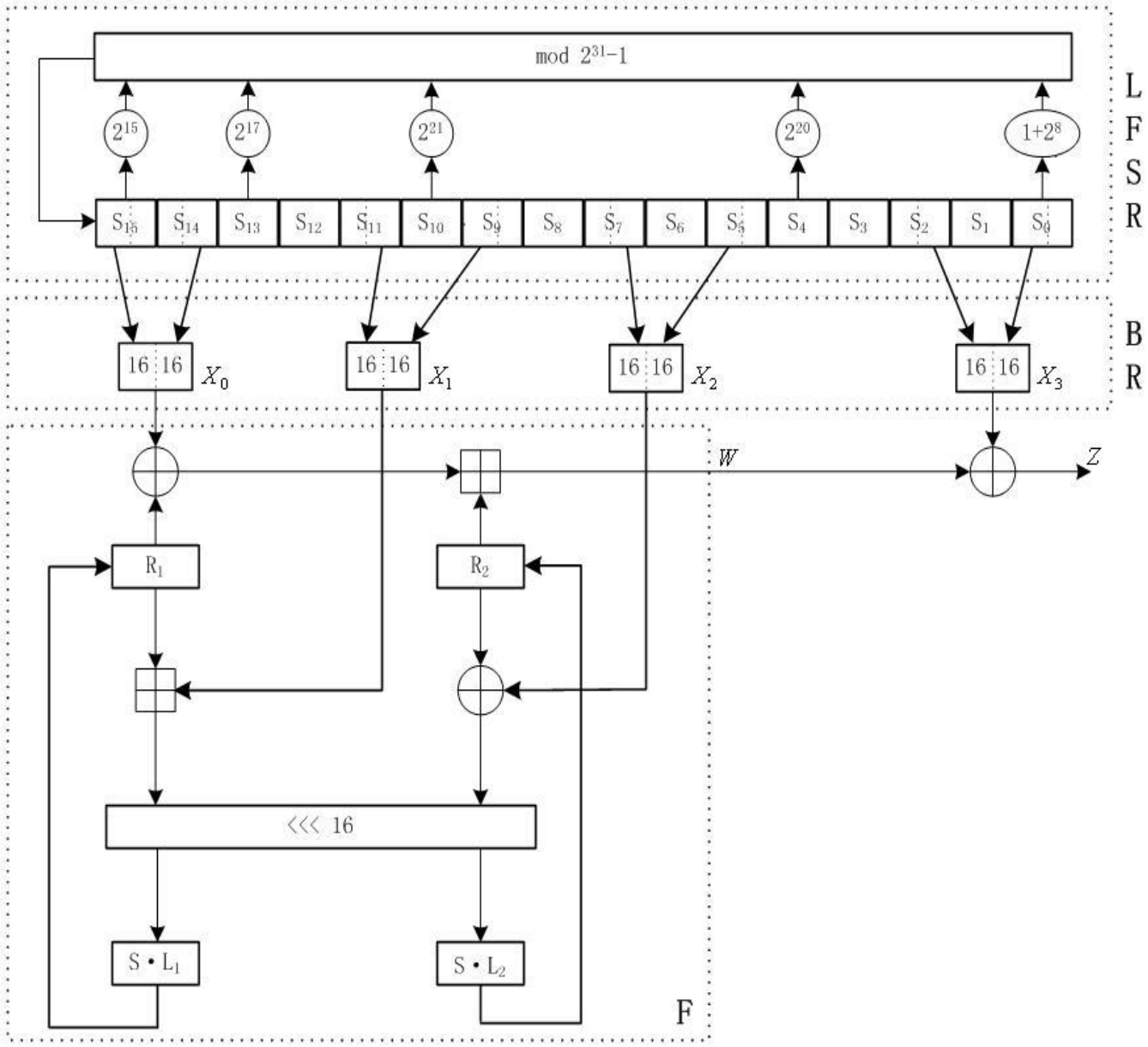
- Authentication vectors in EPS are specific to the serving network
  - → AV's usable in EPS cannot be used in GERAN or UTRAN
- AV's usable for UTRAN/GERAN access cannot be used for E-UTRAN access
  - Solution by a "separation bit" in AMF field
- On the other hand, Rel-99 USIM is sufficient for EPS access
  - → ME has to check the "separation bit" (when accessing E-UTRAN)
- As one consequence, "EAP-AKA' " was created in IETF

LTE crypto-algorithms

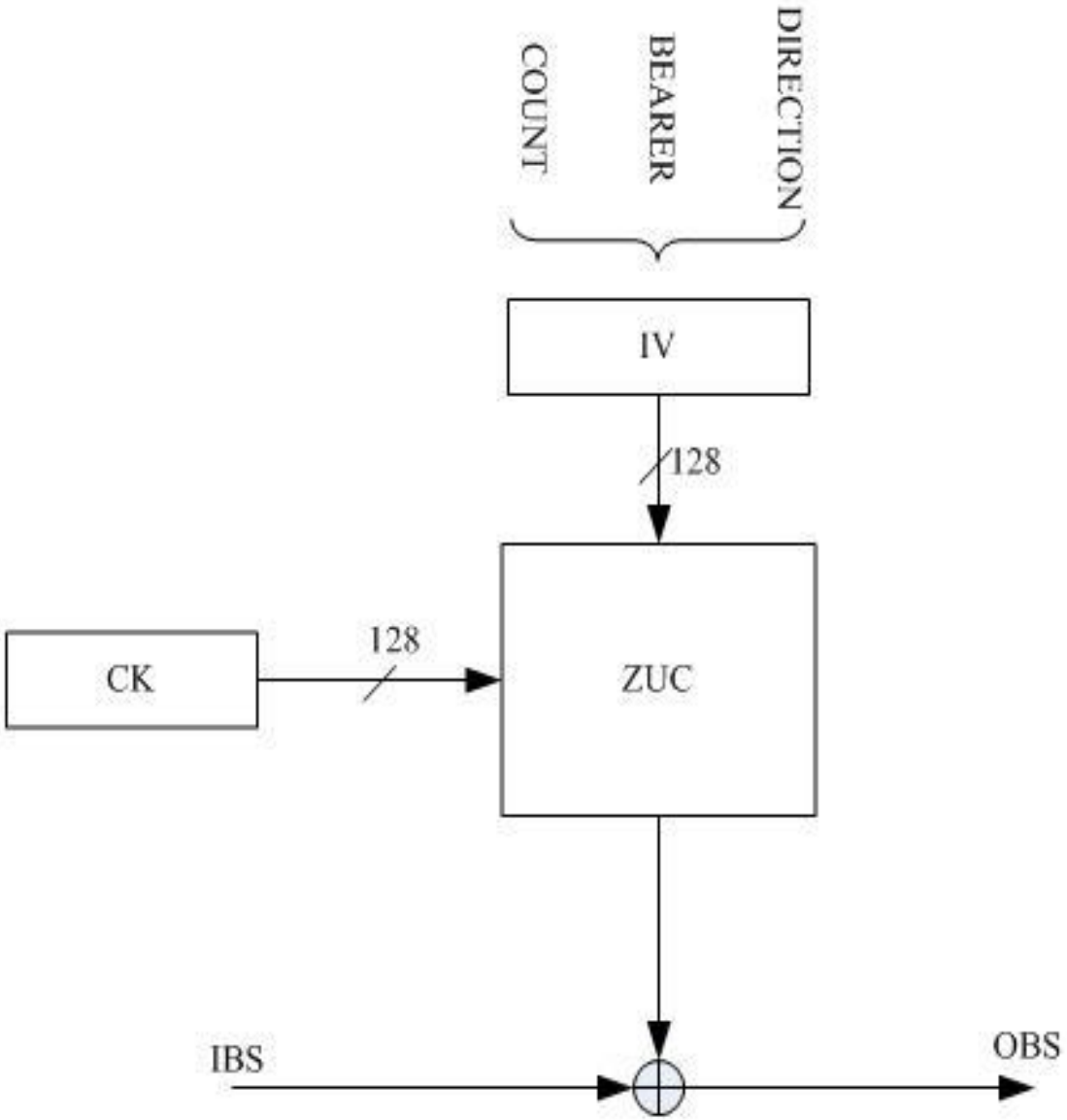
Crypto-algorithms

- Two sets of algorithms from Day One
  - If one breaks, we still have one standing
  - Should be as different from each other as possible
  - AES and SNOW 3G chosen as basis → ETSI SAGE has specified/chosen modes
- A third algorithm set added for Release 11
  - The base algorithm ZUC is of Chinese origin and usable in China
- Rel-99 USIM is sufficient → master key 128 bits
  - All keys used for crypto-algorithms are 128 bits but included possibility to add 256-bit keys later (if needed)
- Deeper key hierarchy → (one-way) key derivation function needed
  - HMAC-SHA-256 chosen as basis

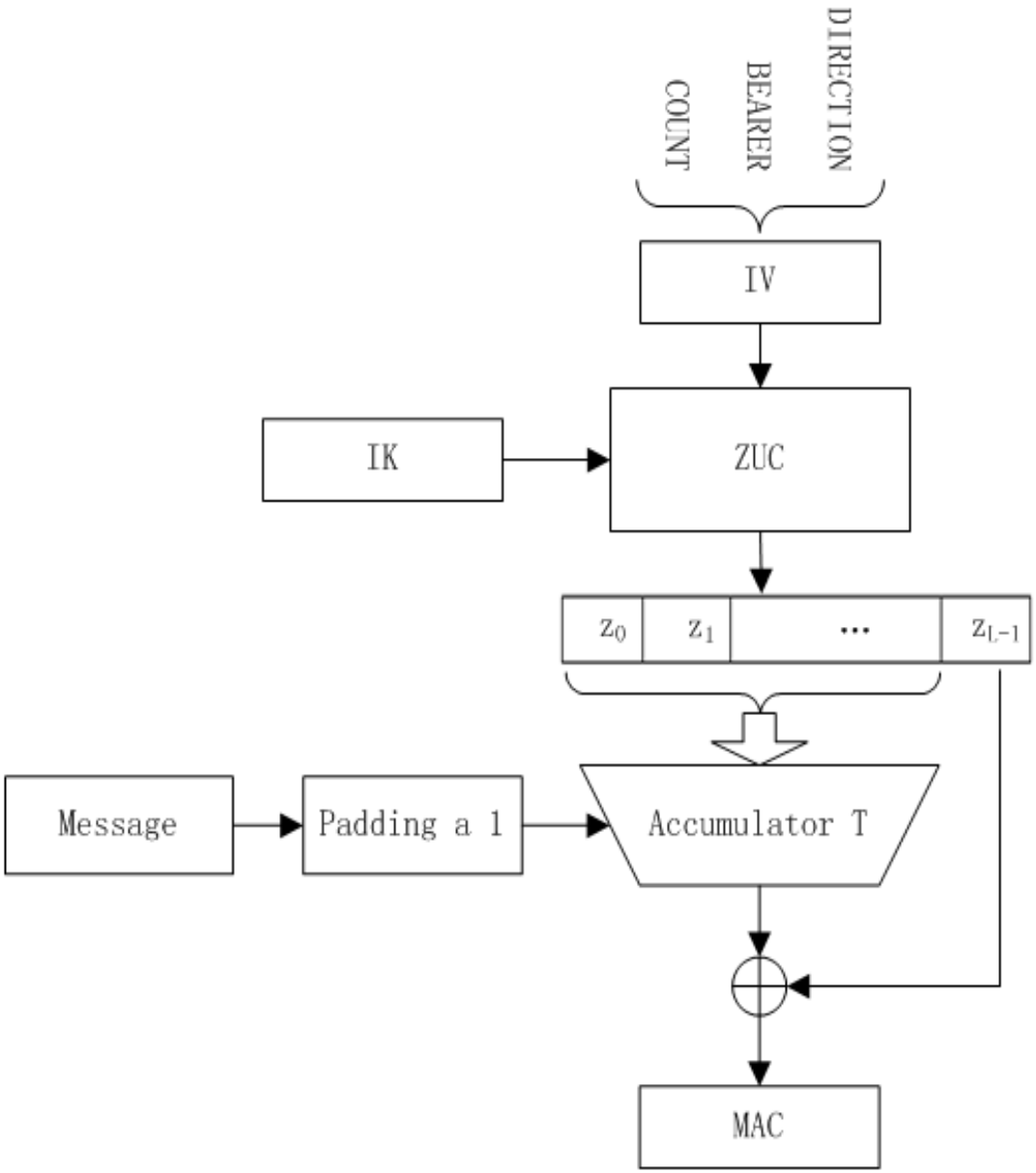
Structure of ZUC



Structure of EEA3



Structure of EIA3



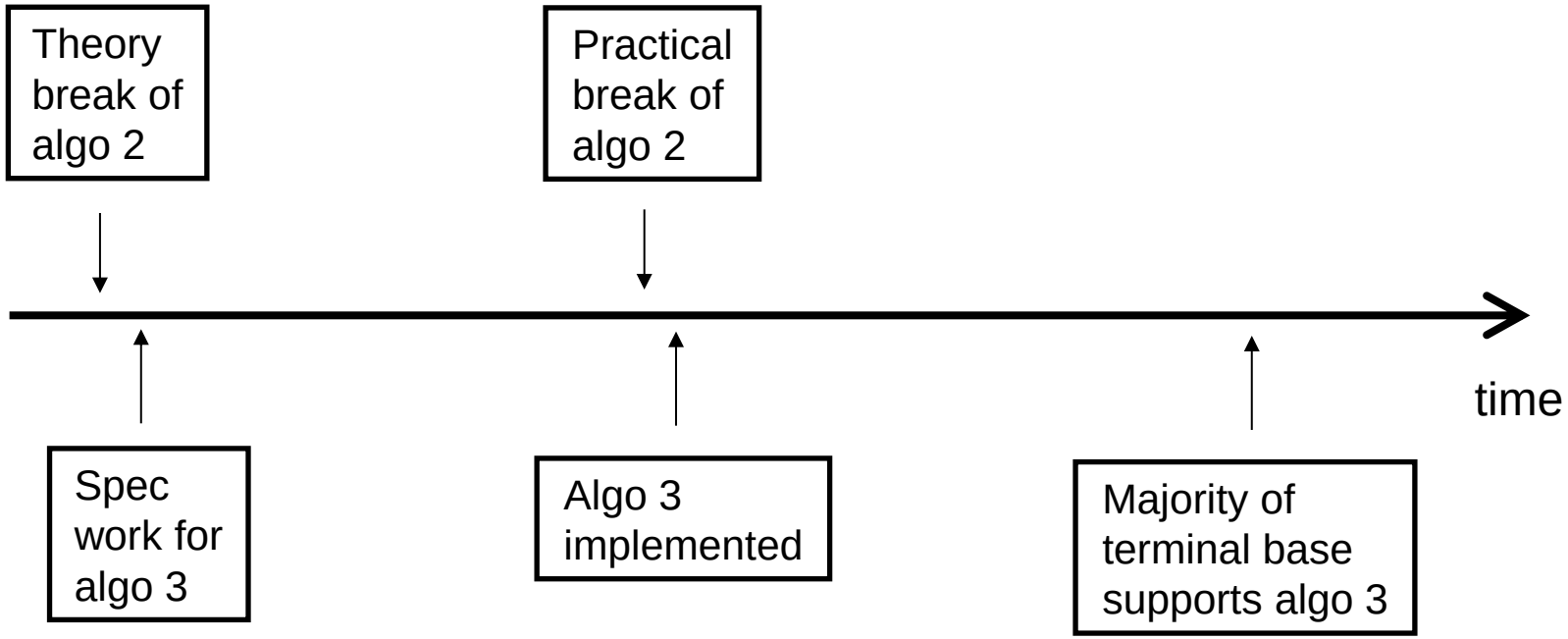
ZUC resistance verified against:

- Weak key attacks
- Guess-and-Determine Attacks
- BDD Attacks
- Inversion Attacks
- Linear Distinguishing Attacks
- Algebraic Attacks
- Chosen IV Attacks
- Time-Memory-Data Trade-Off Attacks
- Timing Attacks

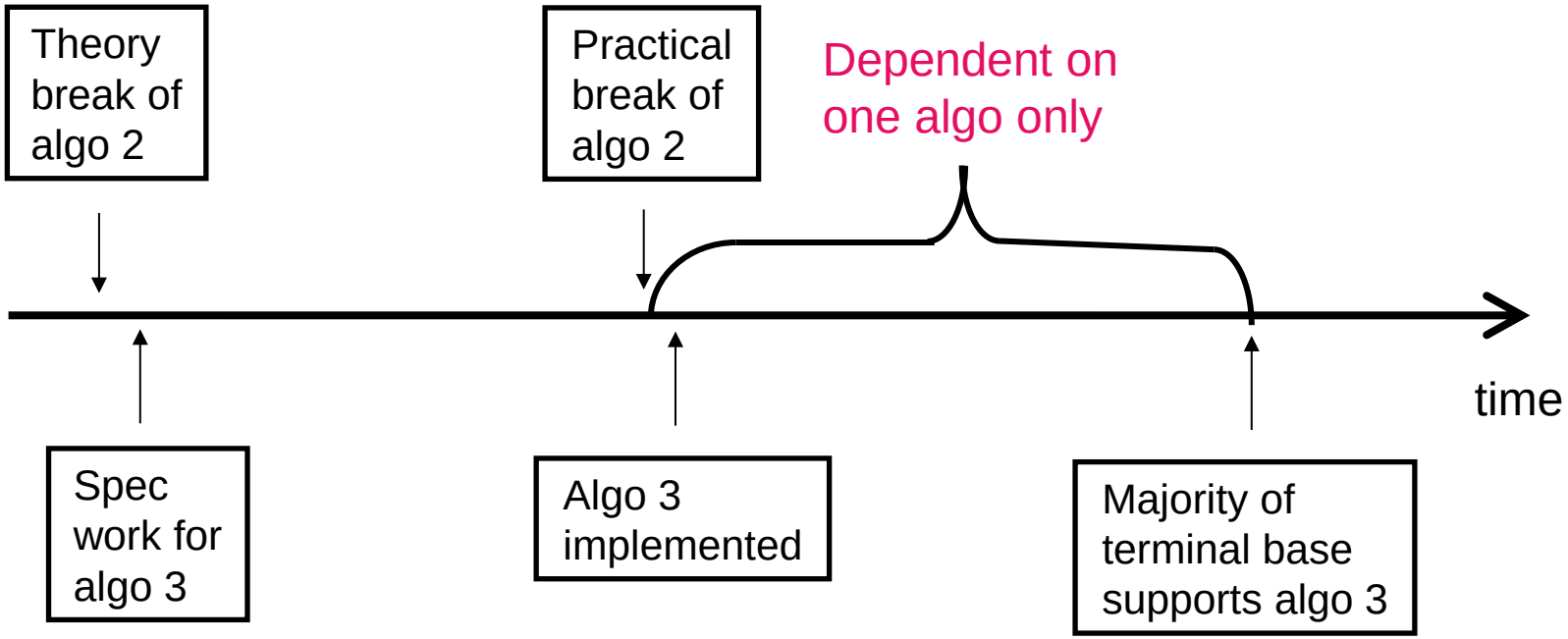
Conclusions of ETSI SAGE evaluations of EEA3/EIA3

- "One stated objective for the design was that the new algorithms be substantially different from the first and second LTE algorithm sets, in such a way that an attack on any one algorithm set would be unlikely to lead to an attack on either of the others. In SAGE's view this objective is not fully met – there are some architectural similarities between ZUC and SNOW 3G, and it is possible that a major advance in cryptanalysis might affect them both. However:
  - there are important differences too, so ZUC and SNOW 3G by no means "stand or fall together";
  - and in any case the raison d'être of this new algorithm set is very different from that of the first two, so the objective is considerably less important than making the first and second algorithm sets different from each other.
- SAGE therefore does not consider this a barrier to acceptance of the new algorithms. Indeed, both of the paid evaluation teams noted that the ZUC design inherits some strong security properties from SNOW 3G, while adding further protection against as yet unknown attacks."

Need for algorithm agility: example



Need for algorithm agility: example



Caveat: Security of algorithm capability negotiation

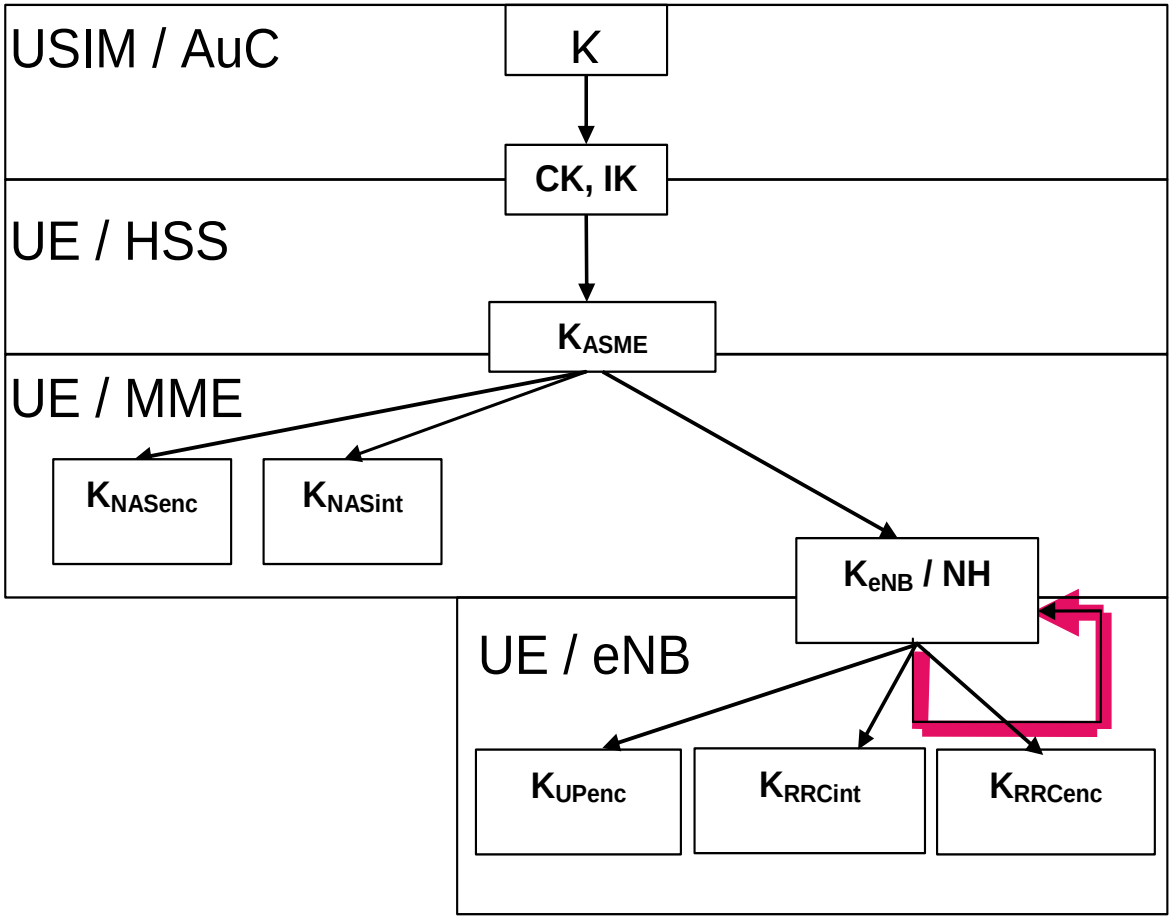
- Algorithm capabilities exchanged first without protection
- Re-exchanged and verified once integrity protection is turned on

  → all integrity algorithms should resist real-time attacks in the beginning of the connection

- If this is not the case anymore, broken algorithm has to be withdrawn completely from the system
  - In the same way as A5/2 is withdrawn from GSM

Handovers and interworking

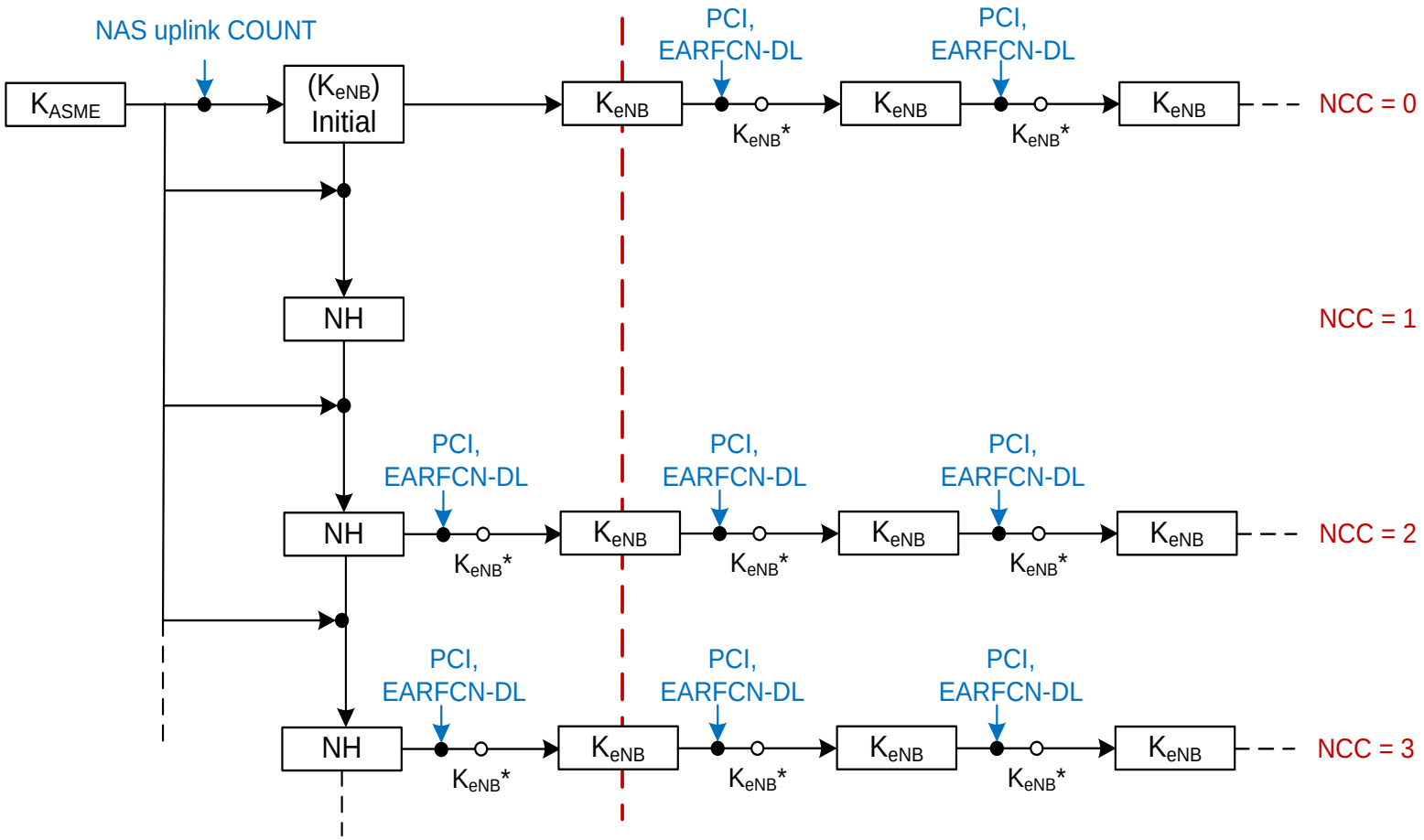
Handovers without MME involvement (1/2)



Handovers without MME involvement (2/2)

- Handovers are possible directly between eNB's for performance reasons
- If keys would be passed as such, all eNB's in a "HO chain" would know all the keys → one compromised eNB would compromise all eNB's in the "HO chain"
- Countermeasures:
  - One-way function used before key is passed (*Backward security*)
  - MME is involved after the HO for further key passes (*Forward security*, effective after two hops)
  - When MME involved already during the HO, Forward security is effective already after one hop

K_{eNB} derivations



From TS 33.401

Interworking with UTRAN/GERAN (1/2)

- UE may be registered in both SGSN and MME simultaneously

  → when moving from one system (*source*) to the other (*target*) *both*

  native keys (created earlier in the *target* system)

  and

  mapped keys (converted from the keys in the *source* system)

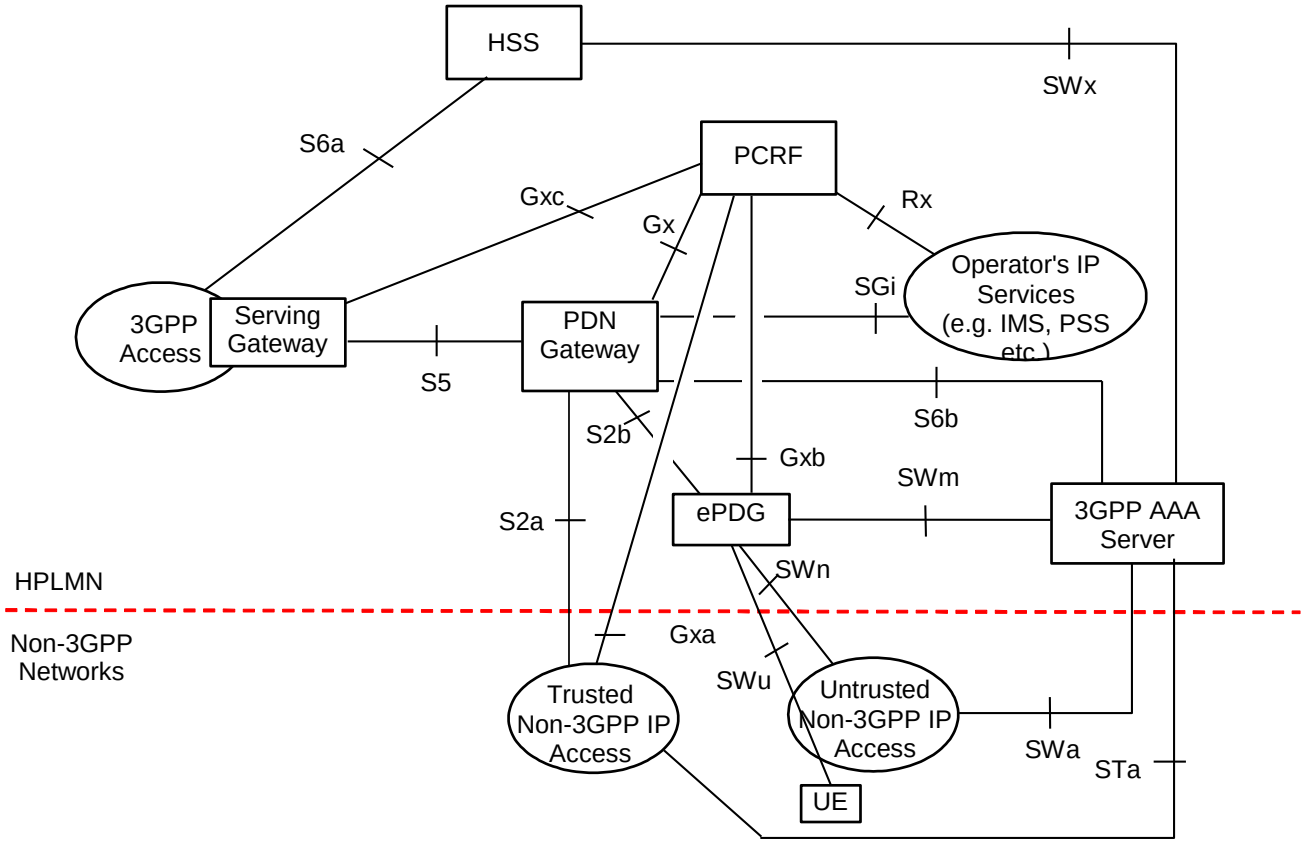
  may exist

  – Note: native keys exist only for Rel-8 SGSN, not for legacy SGSN

Interworking with UTRAN/GERAN (2/2)

- Idle mode transition
  - From E-UTRAN to UTRAN: either *mapped* or *native* keys are used (depending on the identity used in *Routing Area Update Request*)
  - From UTRAN to E-UTRAN: *native* keys are used *but* an exceptional case exists also
- Handover
  - From E-UTRAN to UTRAN: *mapped* keys are used
  - From UTRAN to E-UTRAN: *mapped* keys are used *but* it is possible to activate the *native* keys after HO completed (using *key-change-on-the-fly* procedure)

Interworking with non-3GPP networks (1/2)

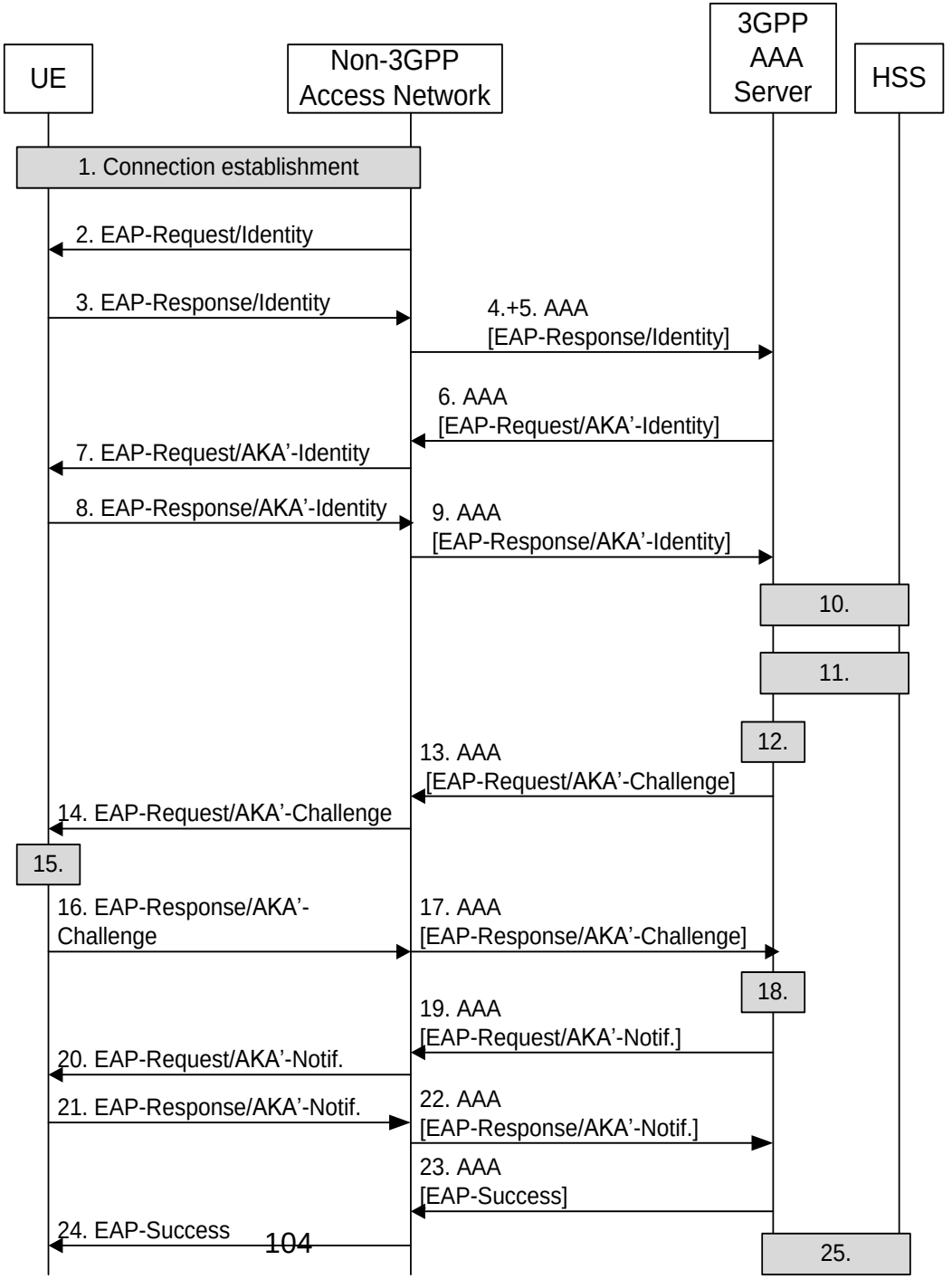


Extract from TS 23.402 (one of several architecture figures)

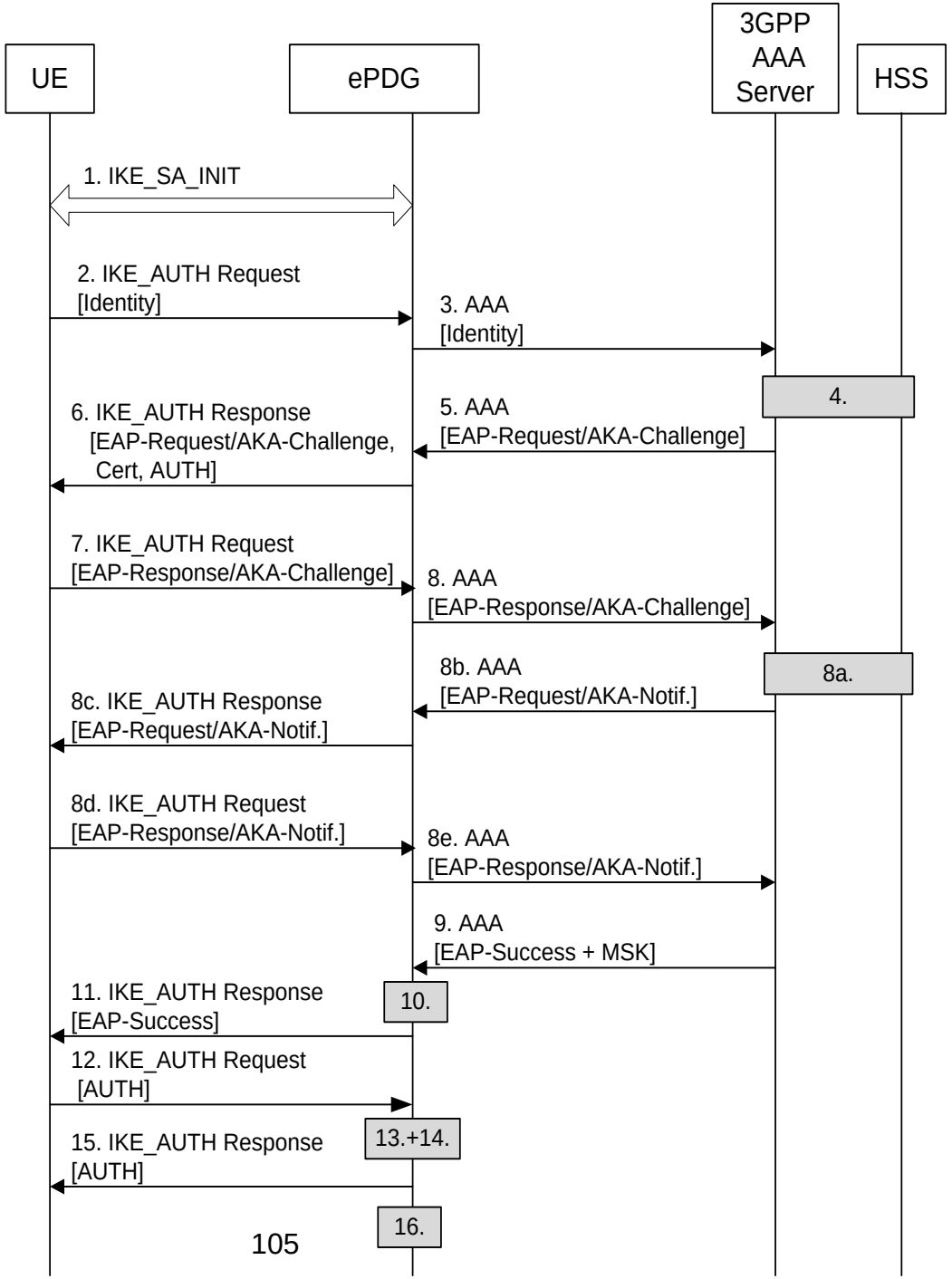
Interworking with non-3GPP networks (2/2)

- Three options for mobility between 3GPP and non-3GPP networks:
  - Proxy Mobile IP: no user-specific security associations between the Proxy and Home Agent
  - Client MIPv4: tailor-made security mechanisms are used
  - Dual Stack MIPv6: IPsec with IKEv2 is used between UE and HA
- IPsec tunnel (with evolved Packet Data Gateway) is used in case the non-3GPP network is untrusted by the operator (of EPS network)
- Authentication is run by EAP-AKA or EAP-AKA' procedures, in both cases based on USIM

EAP-AKA' authentication for trusted non-3GPP access

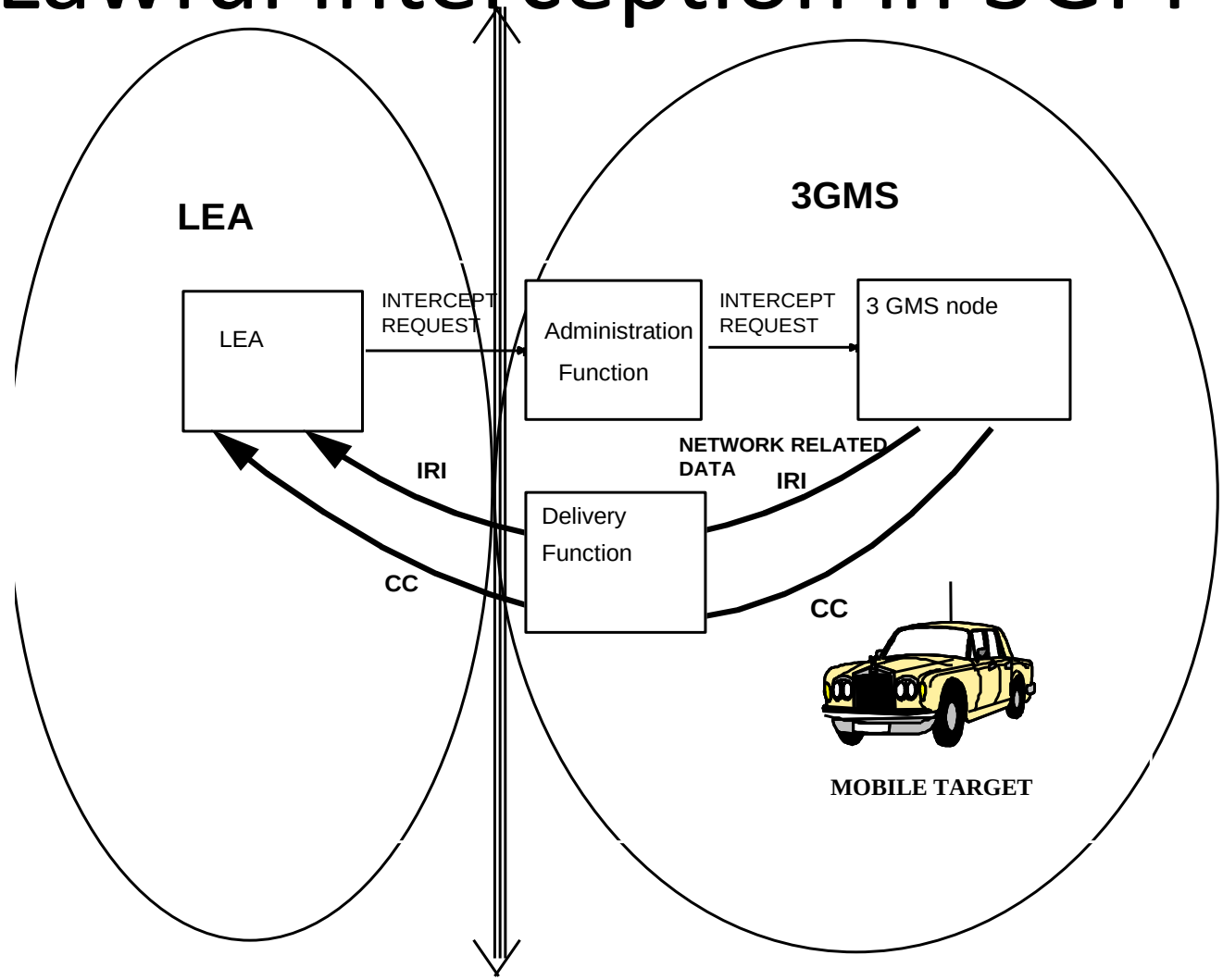


IKEv2 and EAP AKA for untrusted non-3GPP access



Lawful interception

Lawful interception in 3GPP



LI specifications

- Requirements in TS 33.106 (11 pages)
- Architecture, functions, information flows in TS 33.107 (129 p.)
- Description of the Handover Interfaces, incl. ASN1, in TS 33.108 (189 p.)

When LI is invoked: examples

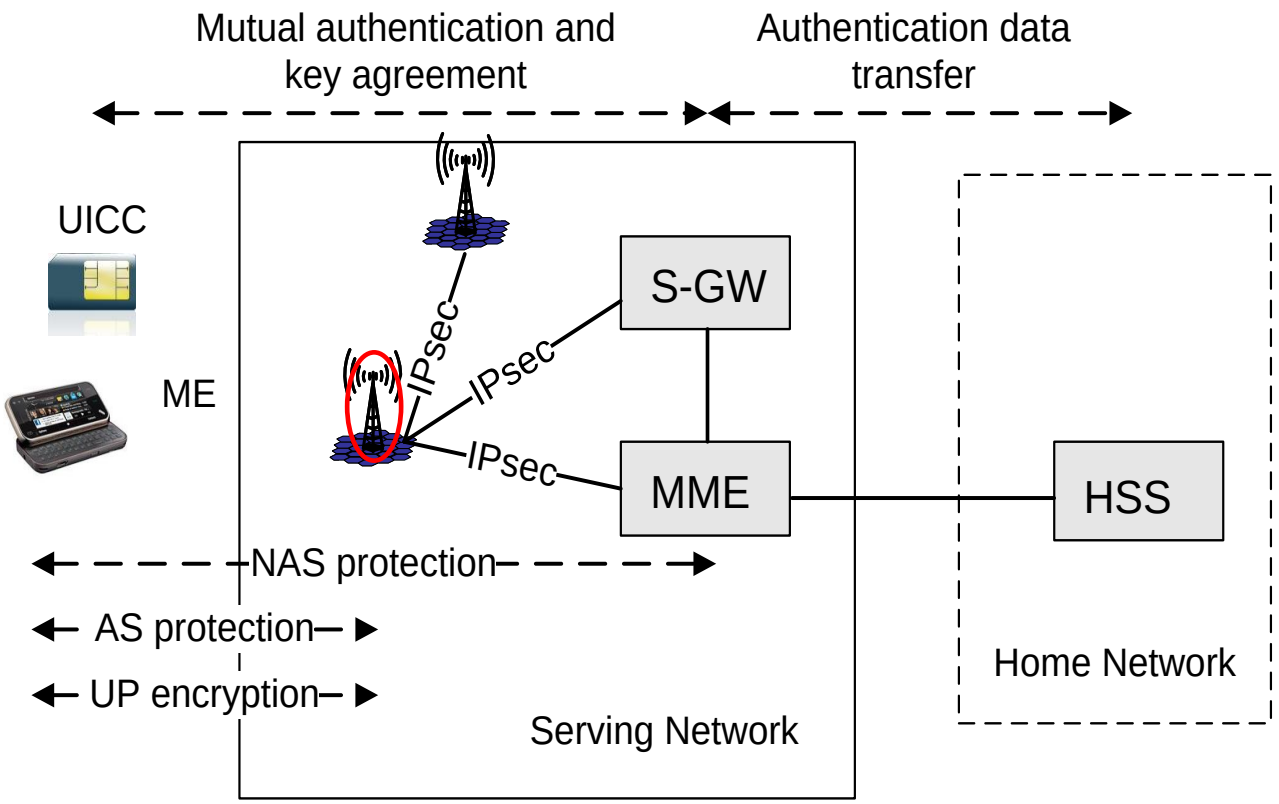
- A circuit switched call is requested originated from, terminated to, or redirected by the target
- Location information related to the target facility is modified by the subscriber attaching or detaching from the network, or if there is a change in location
- An SMS transfer is requested - either originated from or terminated to the target
- A data packet is transmitted to or from a target

What is intercepted ?

- CC = Content of Communications
  - Intercepted from media plane entities, e.g. in EPS: Serving Gateway
- IRI = Intercept Related Information
  - E.g. in the case of *Attach:*
    - *Observed MSISDN*
    - *Observed IMSI*
    - *Observed ME Id*
    - *Event Type*
    - *Event Time*
    - *Event Date*
    - *Network Element Identifier*
    - *Location Information*
    - *Failed attach reason*
    - *Etc.*

Base station security

NDS enhancements for EPS



From "LTE security"

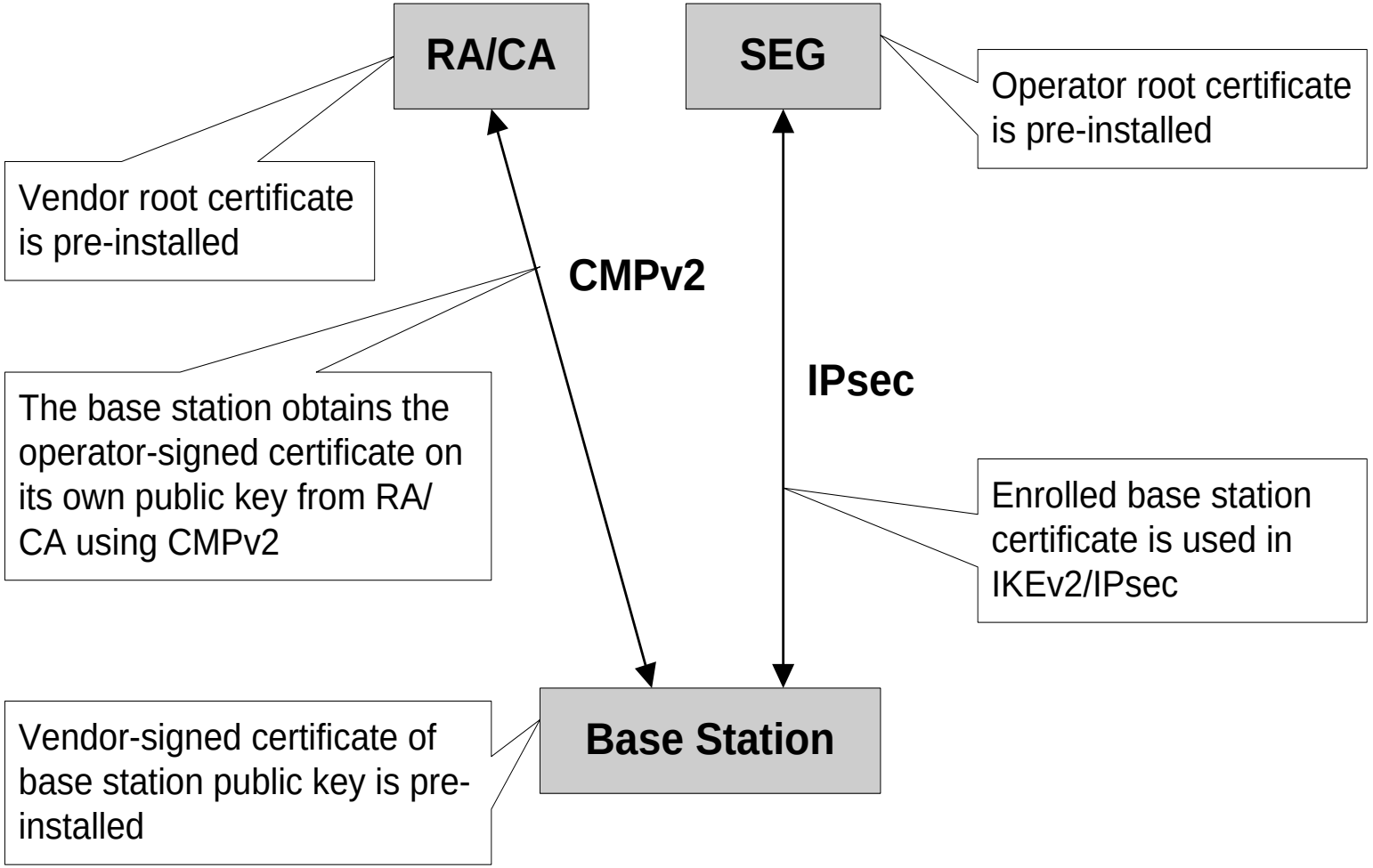
Configuration of eNB

- Communication between the remote/local O&M systems and the eNB mutually authenticated.
- The eNB shall be able to ensure that software/data change attempts are authorized
- Confidentiality and integrity of software transfer towards the eNB ensured.
- etc.

Secure environment inside eNB

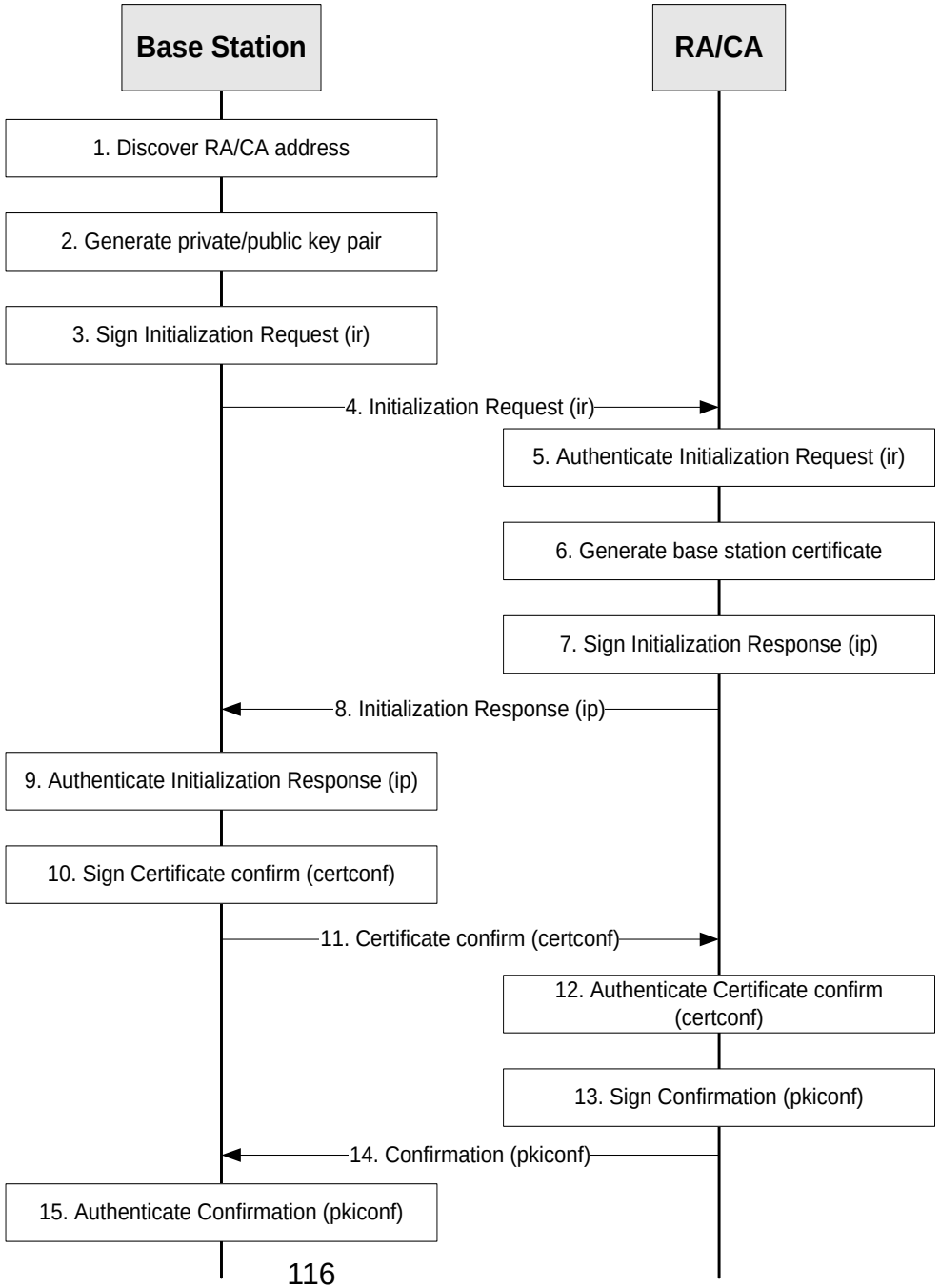
- Secure storage of sensitive data, e.g. long term cryptographic secrets and vital configuration data.
- The secure environment shall support the execution of sensitive functions, e.g. en-/decryption of user data.
- The secure environment shall support the execution of sensitive parts of the boot process.
- Only authorised access shall be granted to the secure environment.
- etc.

Certificate enrolment for base stations

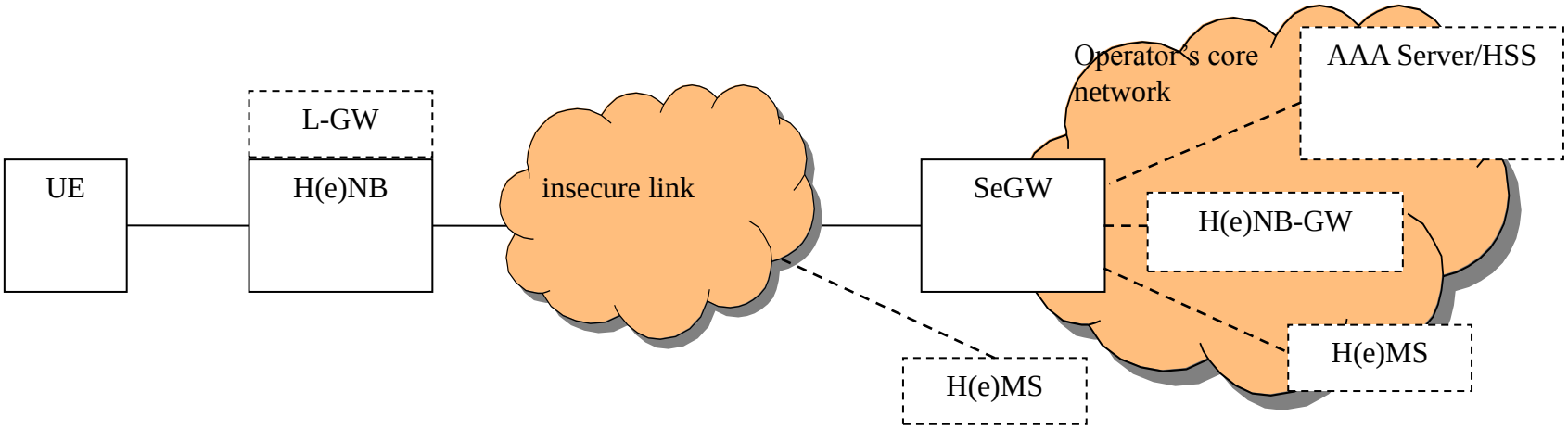


From "LTE security"

Example message flow



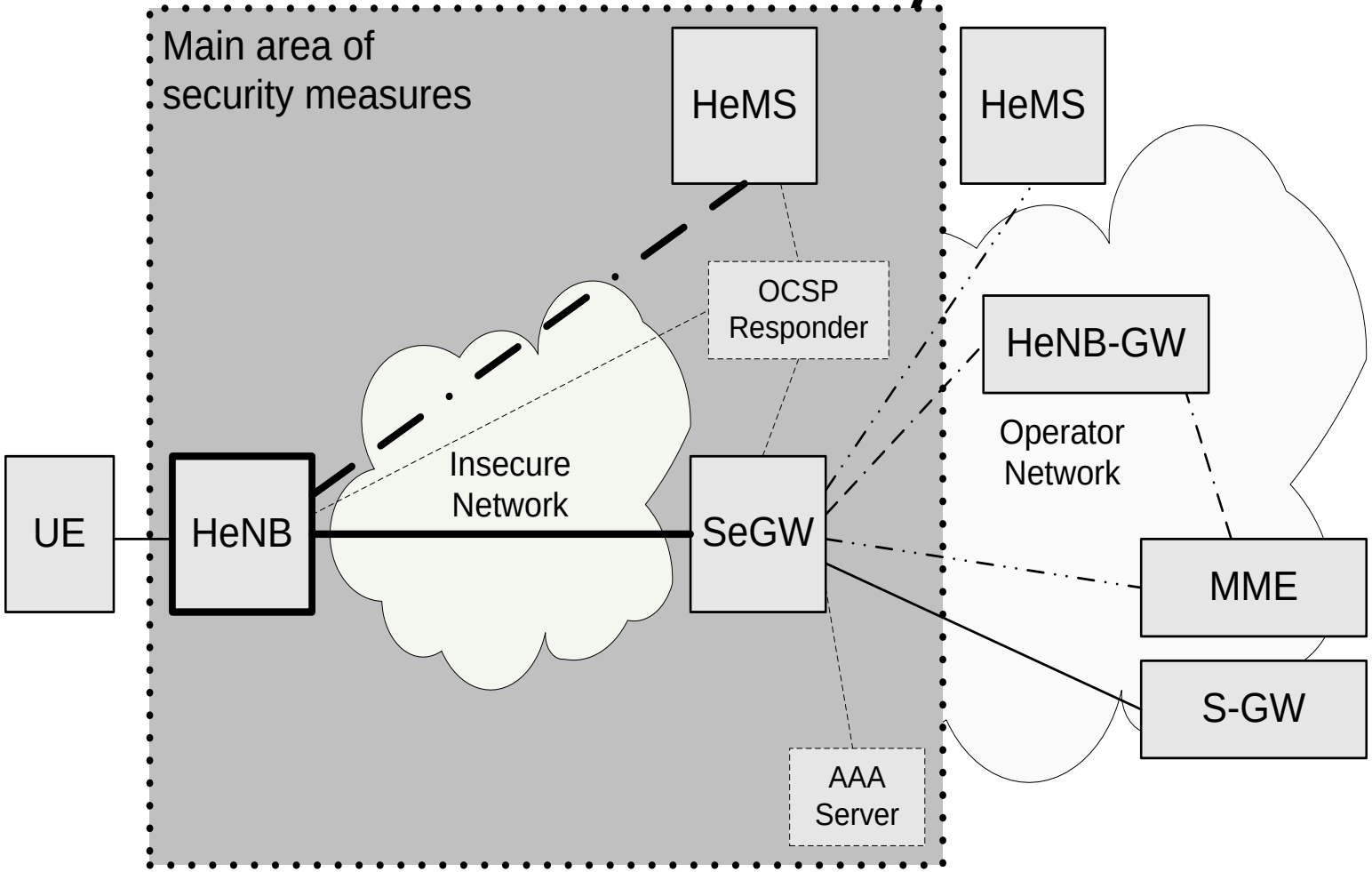
Home base stations: new architecture



Extract from 3GPP TS 33.320

- Concept of *Closed Subscriber Group* introduced
- Applies also to HSPA base stations

Main area of security for HeNB's

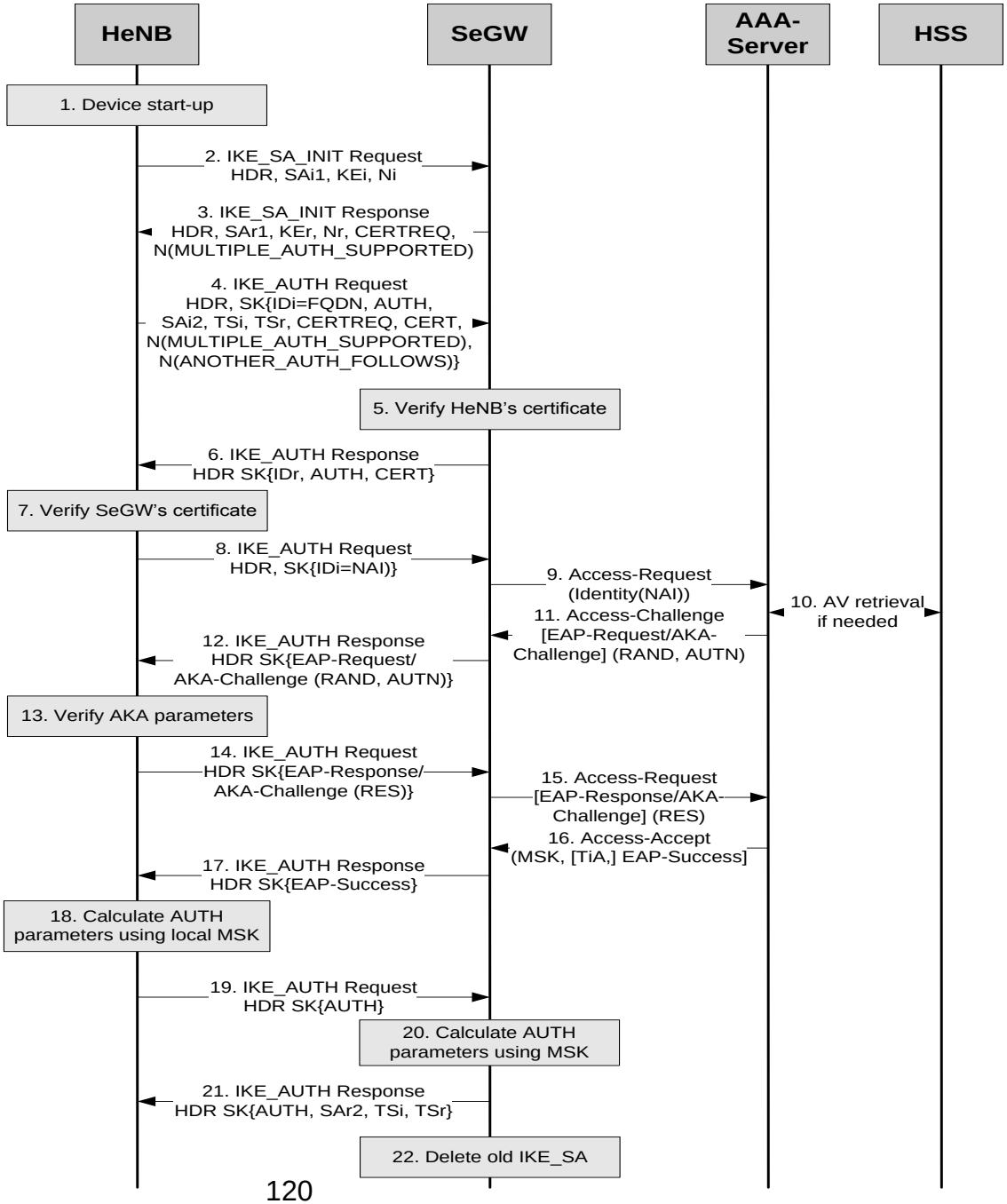


From "LTE Security"

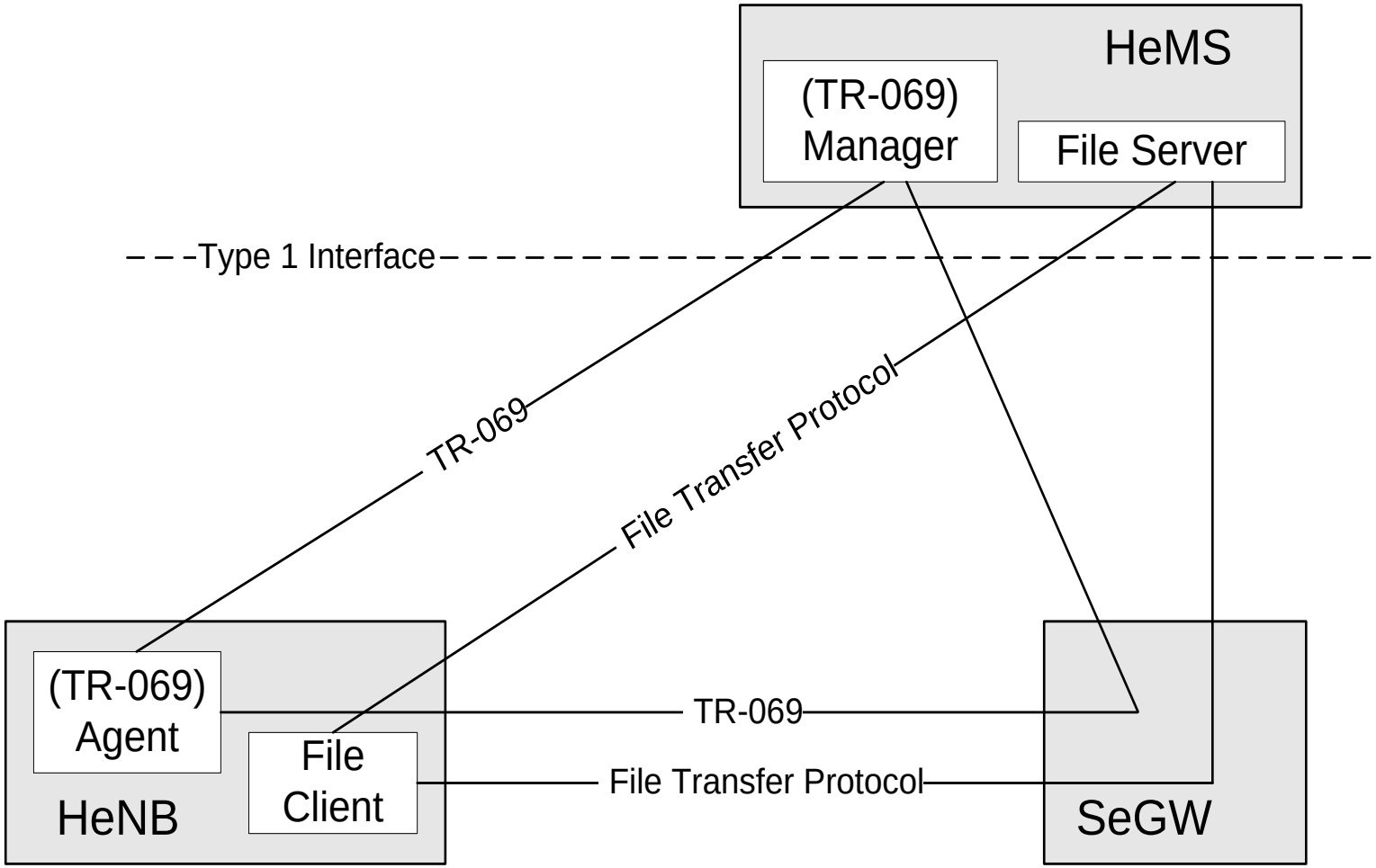
Security mechanisms for Home base stations

- Device Integrity Check upon booting, based on Trusted Environment
- secured Clock synchronization
- Device authentication
  - Mutual authentication between H(e)NB and SeGW
  - Based on IKEv2 and certificates
- IPsec tunnel between H(e)NB and SeGW
- Optionally Hosting Party authentication, based on UICC
- Location verification

HeNB authentication

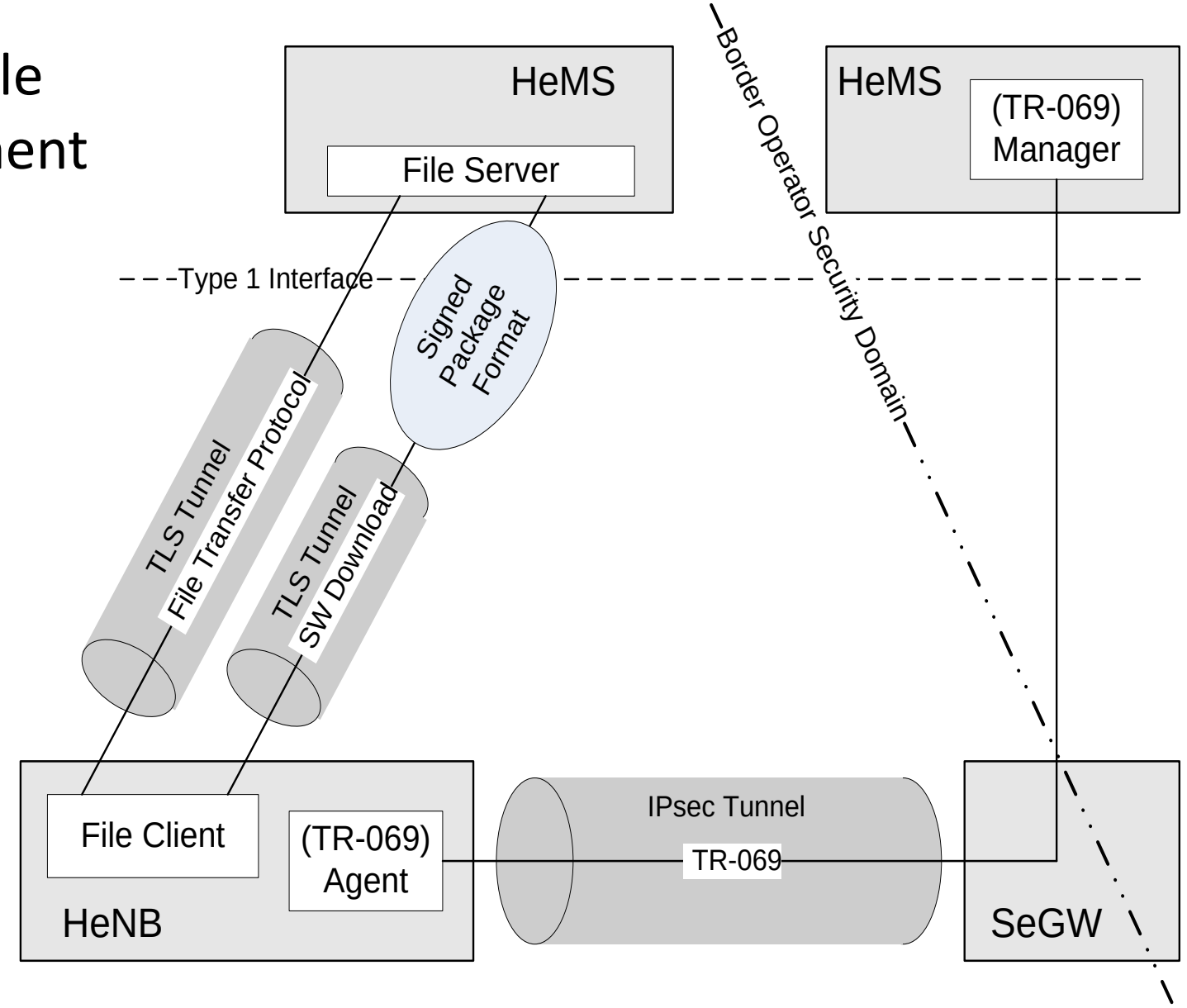


Management of HeNB's



From "LTE Security"

Example deployment



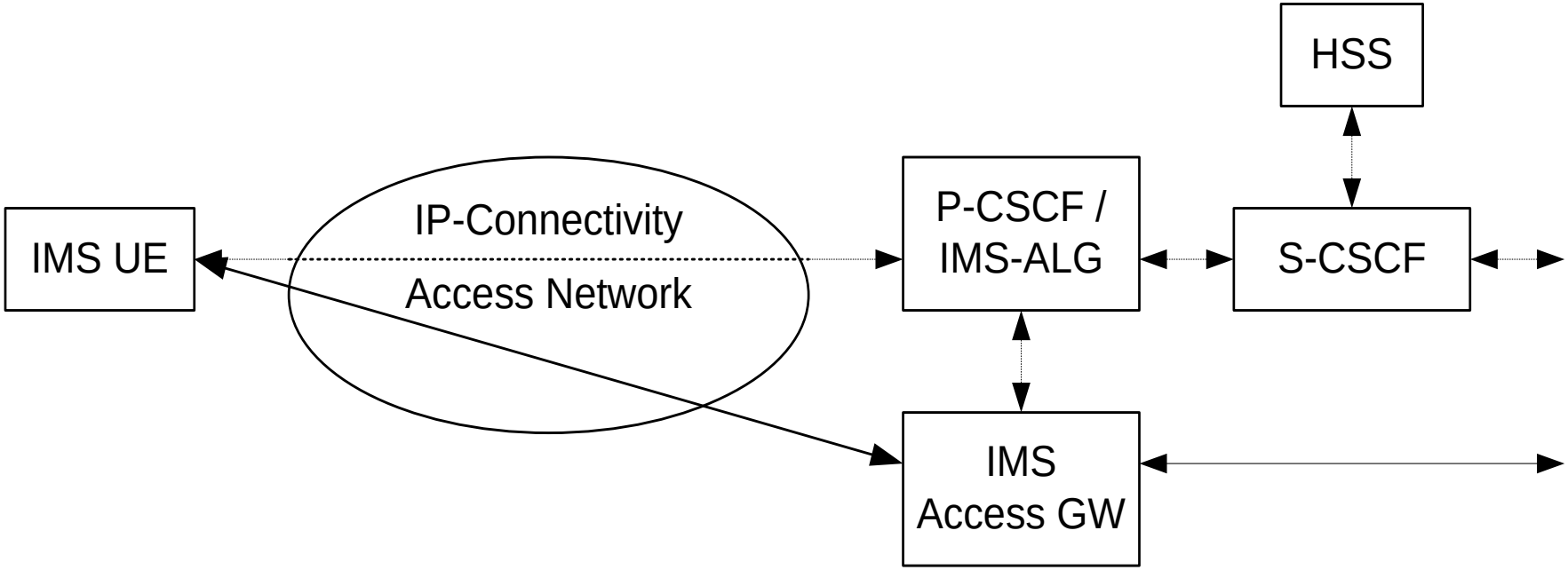
Base stations and Lawful interception

- Usually lawful interception is not applied in base stations
- However, current work for Local IP Access and Selective IP Traffic Offload may change the situation

Security for Voice over LTE

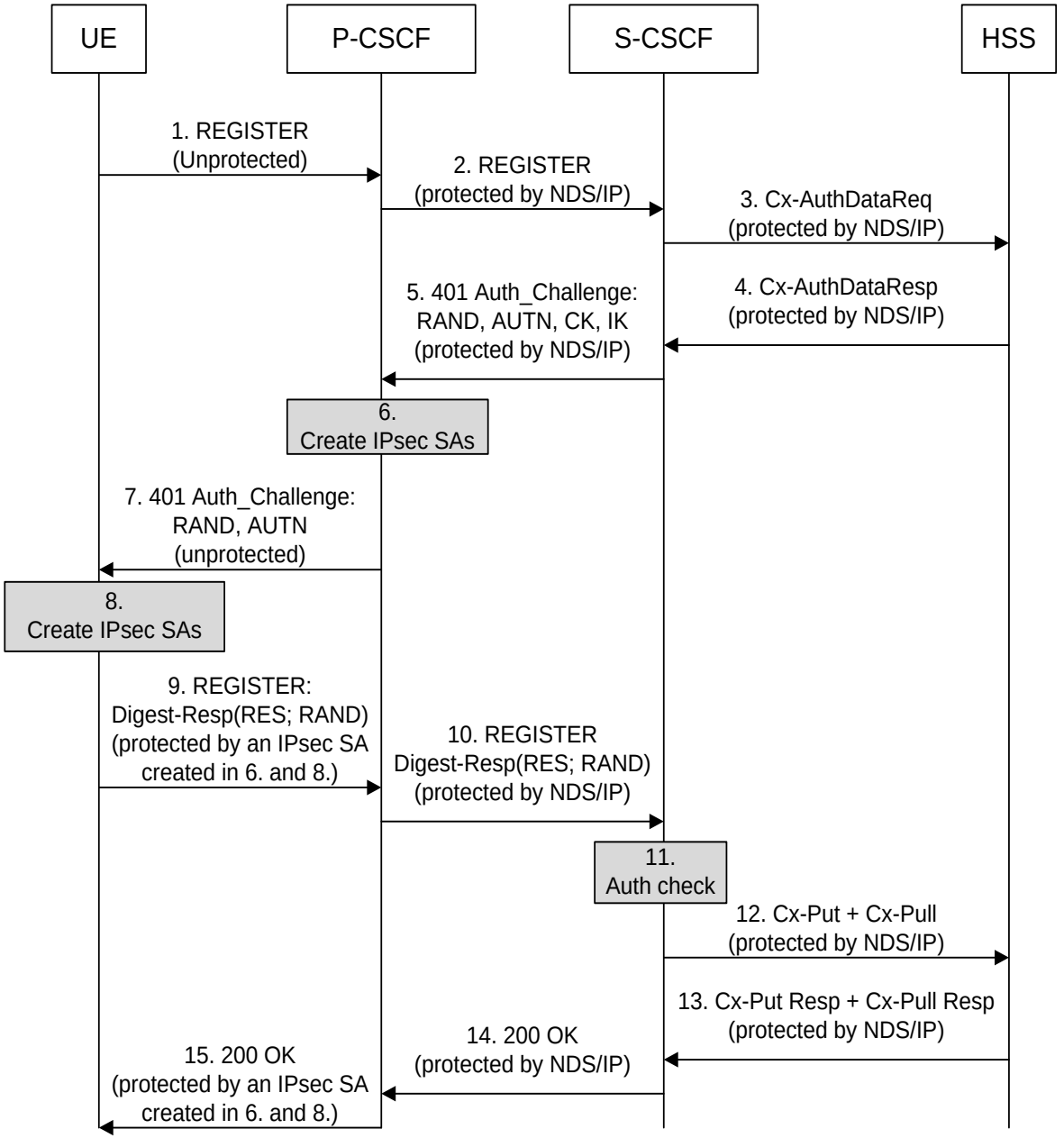
- Two standardized methods:
  - IMS over LTE
  - Circuit Switch Fallback
- Complemented with
  - Single Radio Voice Call Continuity

IMS architecture

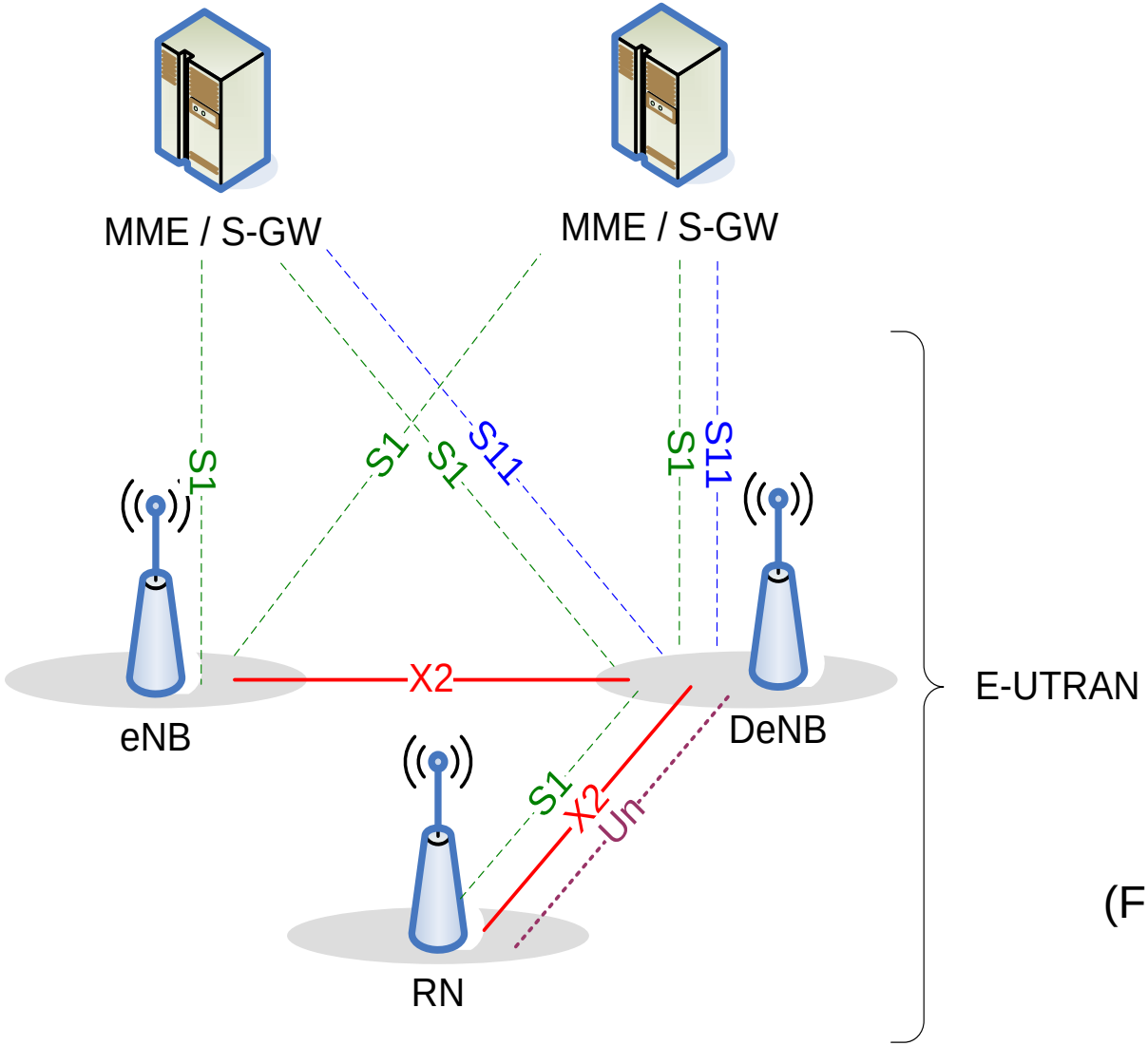


From "LTE Security"

IMS AKA

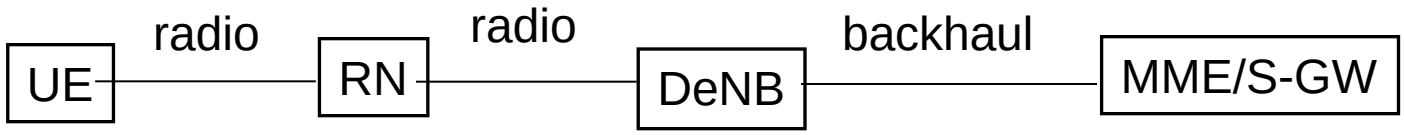

UE
P-CSCF
S-CSCF
HSS
1. REGISTER
(Unprotected)
2. REGISTER
(protected by NDS/IP)
3. Cx-AuthDataReq
(protected by NDS/IP)
4. Cx-AuthDataResp
(protected by NDS/IP)
5. 401 Auth_Challenge:
RAND, AUTN, CK, IK
(protected by NDS/IP)
6.
Create IPsec SAs
7. 401 Auth_Challenge:
RAND, AUTN
(unprotected)
8.
Create IPsec SAs
9. REGISTER:
Digest-Resp(RES; RAND)
(protected by an IPsec SA
created in 6. and 8.)
10. REGISTER
Digest-Resp(RES; RAND)
(protected by NDS/IP)
11.
Auth check
12. Cx-Put + Cx-Pull
(protected by NDS/IP)
13. Cx-Put Resp + Cx-Pull Resp
(protected by NDS/IP)
14. 200 OK
(protected by NDS/IP)
15. 200 OK
(protected by an IPsec SA
created in 6. and 8.)

Relay Node architecture



(From TS 36.300)

Relay Node architecture (cont'd)

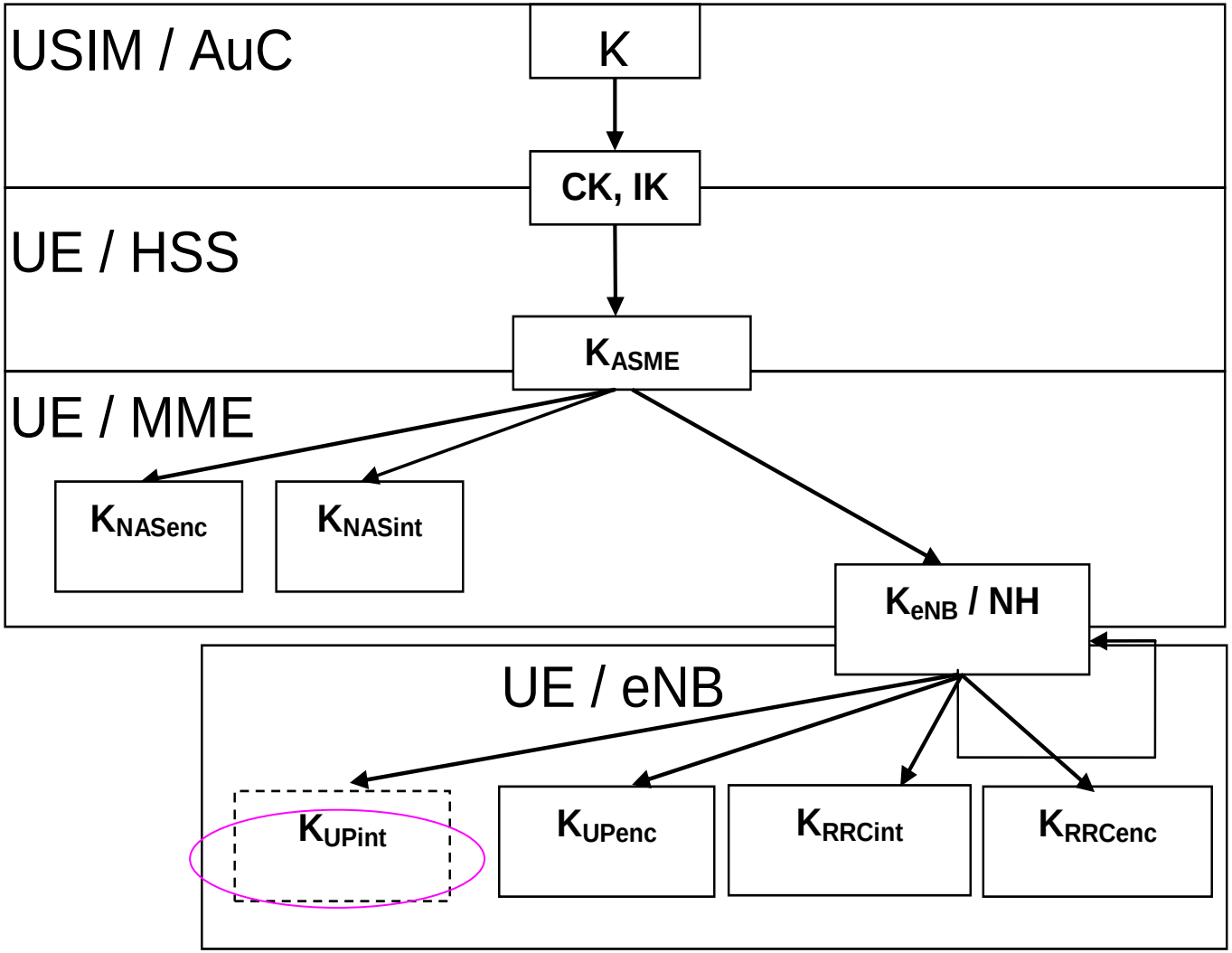


- RN appears as regular eNB towards UE
- In some aspects, RN acts like UE towards network
- Goal is to extend coverage and throughput

Relay node security

- Security between RN and network based on UICC and AKA
- Secure channel between the UICC and the RN, established based on
  - Pre-shared keys or
  - Certificates
- RN meets platform security requirements similar to those of Home eNB
- User plane integrity is provided between RN and DeNB (unlike between “normal” UE and “normal” eNB)
  - Key hierarchy extended because of this (see next slide)

Relay node security (cont'd)



Security aspects typically not standardized

- Product implementations
  - Secure SW development
  - HW security
  - Security testing and audits
- Organizational aspects
  - Organization of security in a corporation
  - Security awareness
  - CERT
- Operational aspects
  - Anti-virus, vulnerability scanning
  - Firewalls
  - Intrusion detection and prevention
  - Fraud management systems

Some future challenges

- Machine-to-machine communications
- Internet of Things / Internet-connected smart objects
- Sensor networks
- Device-to-device communications
- Privacy enhancements
- Impacts of Cloud computing

LTE security: Summary

Summary

- New architecture and business environment require enhancements to 3G security
- Radio interface user plane security terminates in base station site
- Cryptographic separation of keys
- New security requirements for base stations
- New architecture for Home base stations
- Security mechanisms extended to support Relay Nodes
- New architectures create challenges with Lawful interception

More information

www.3gpp.org