THE PROBLEM OF PRIVATE IDENTIFICATION

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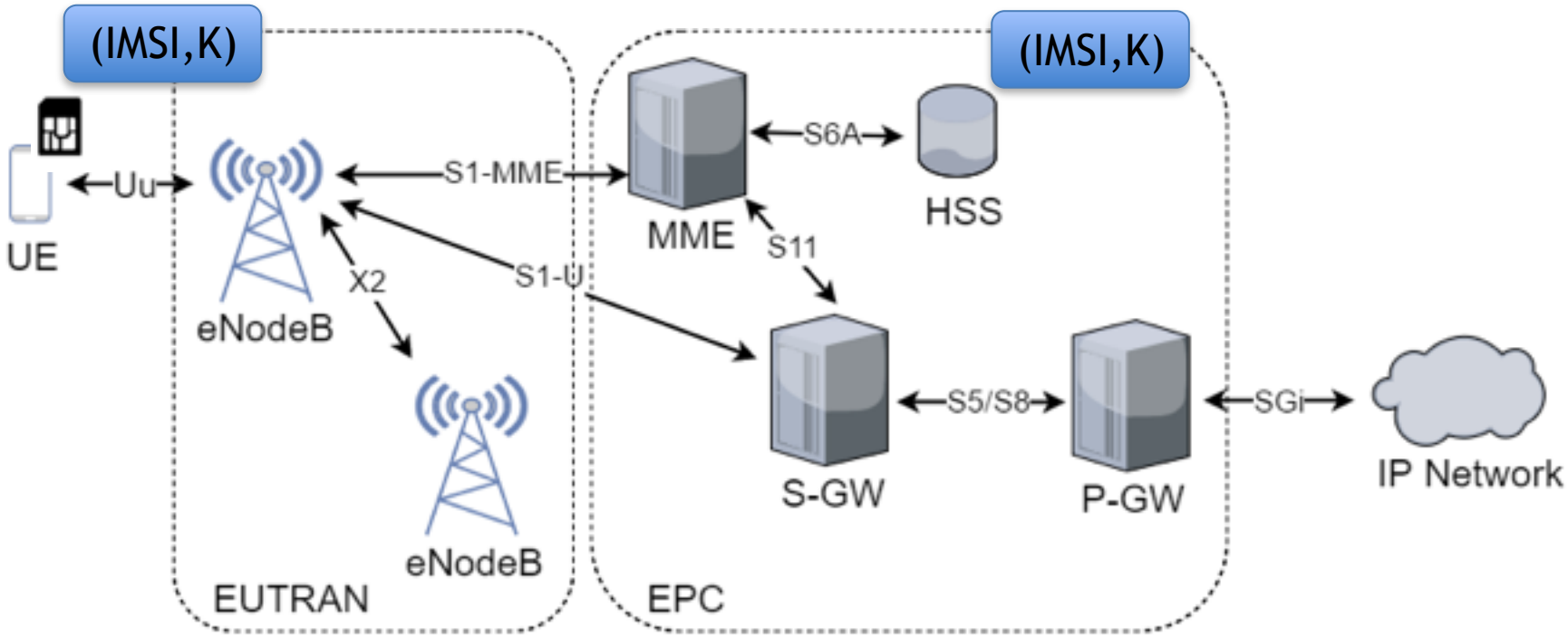
Sutomore, April 5

Motivation - LTE

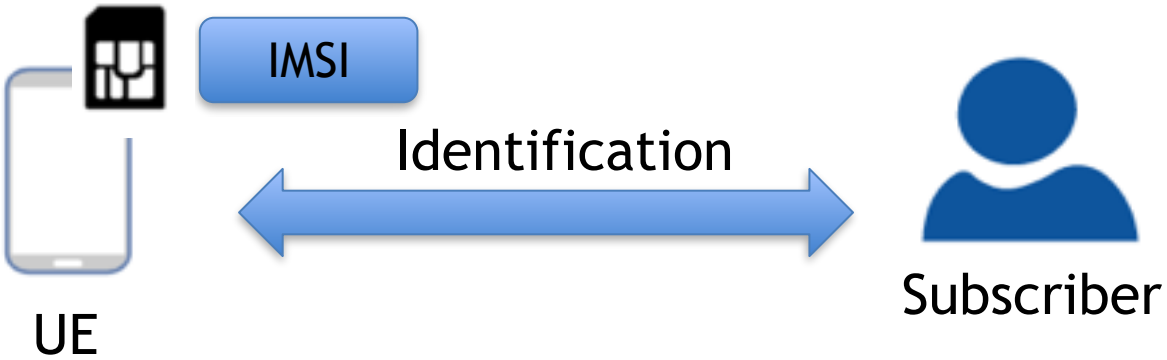
LTE - Subscriber's Identification

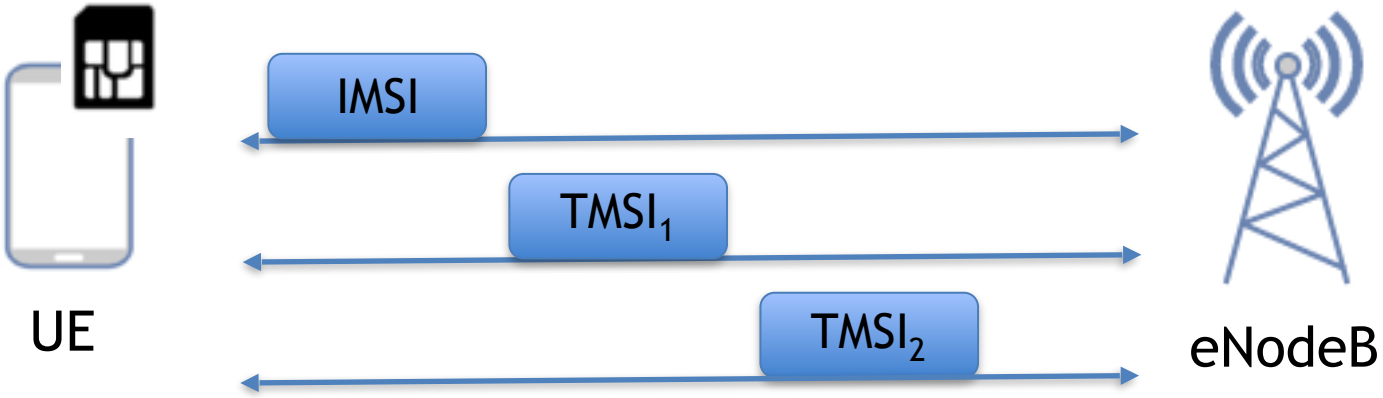


IMSI (International Mobile Subscriber Identity)

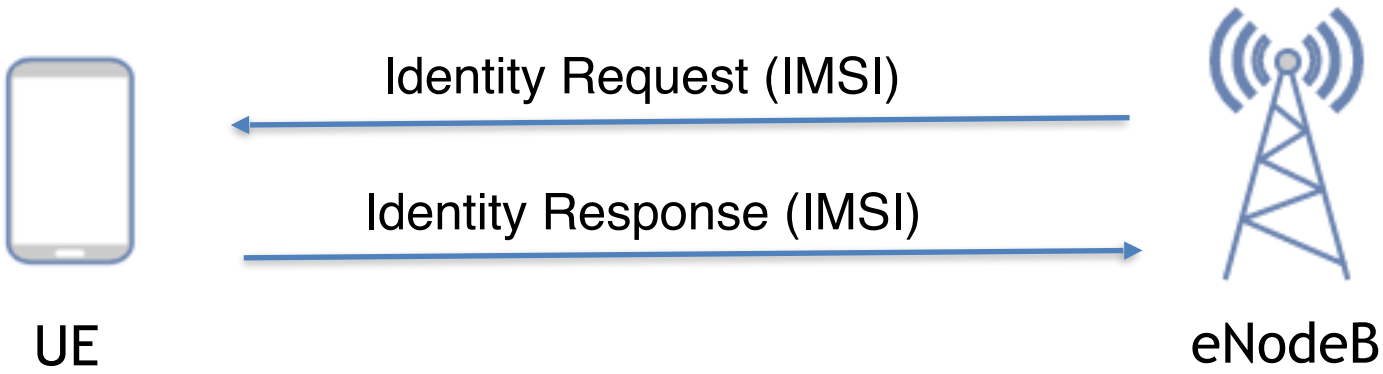
MCC (Mobile Country Code)	**MNC** (Mobile Network Code)	**MSIN** (Mobile Subscriber Identification Number)

LTE - Subscriber's Identification





LTE - Privacy Breach



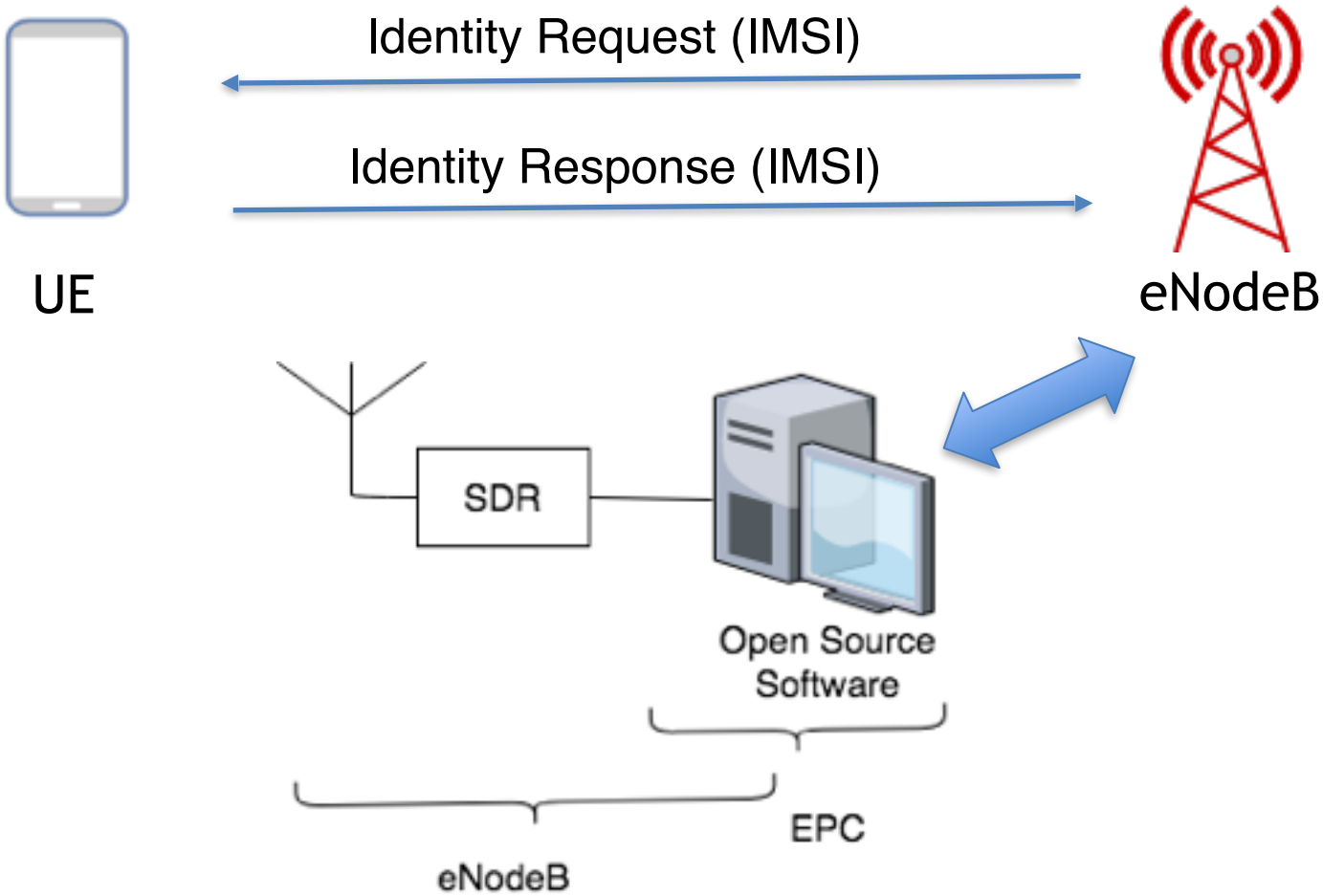
[. . .] requests the user to send its permanent identity. The user's response contains the IMSI in cleartext. This represents ***a breach in the provision of user identity confidentiality****.*

[ETSI TS 133 401 V14.4.0 (2017-10)]

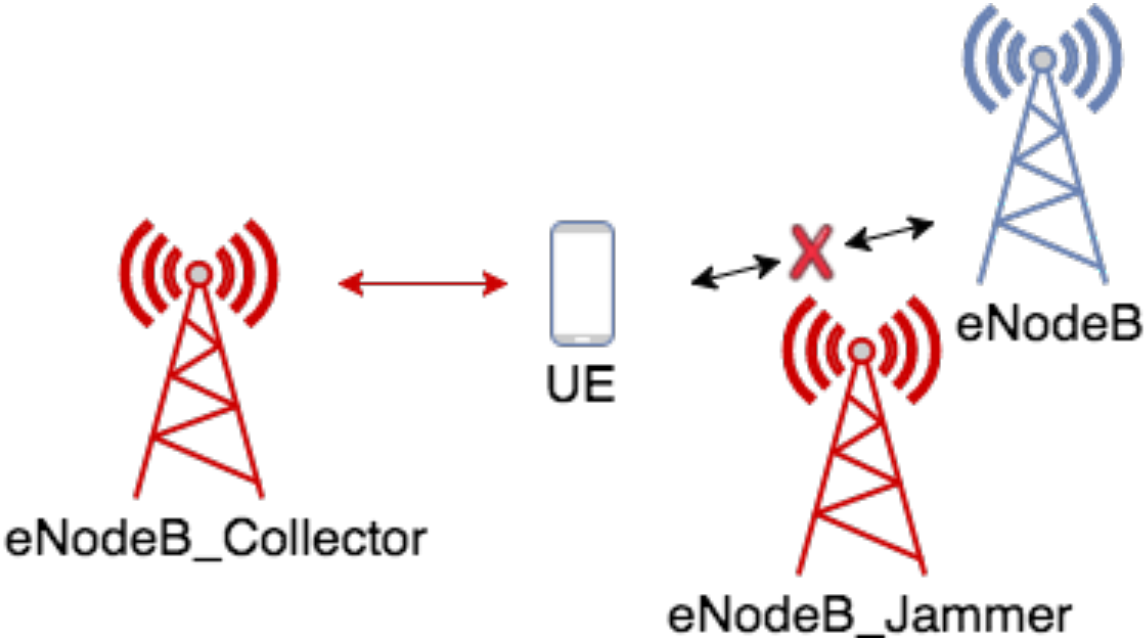
Experimental Work

- S.F.Mjølsnes, R.F.Olimid: *Easy 4G/LTE IMSI Catchers for Non-Programmers*, MMM-ACNS 2017
- S.F.Mjølsnes, R.F.Olimid: *Experimental Assessment of Private Information Disclosure in LTE Mobile Networks*, Secrypt 2017

Experimental Work

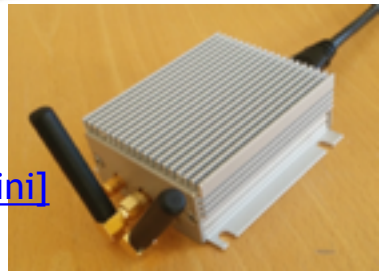


Our LTE IMSI Catcher



- `eNodeB_Jammer:` causes the UE to detach from the serving cell it camps on
- `eNodeB_Collector:` masquerades as an authorized eNodeB running on the (second) highest **priority frequency**, but with higher signal power, causing the UE to try reselection and expose the IMSI

Tools: **Hardware**



- Software radio peripherals (USRPs)
  - Ettus B200mini + antennas
    [https://www.ettus.com/product/details/USRP-B200mini]
- Computers (access and core network)
  - Standard desktops or laptops: Intel NUC D54250WYK (i5-4250U CPU@1,30GHz), Lenovo ThinkPad T460s (i7-6600U CPU@2,30GHz)

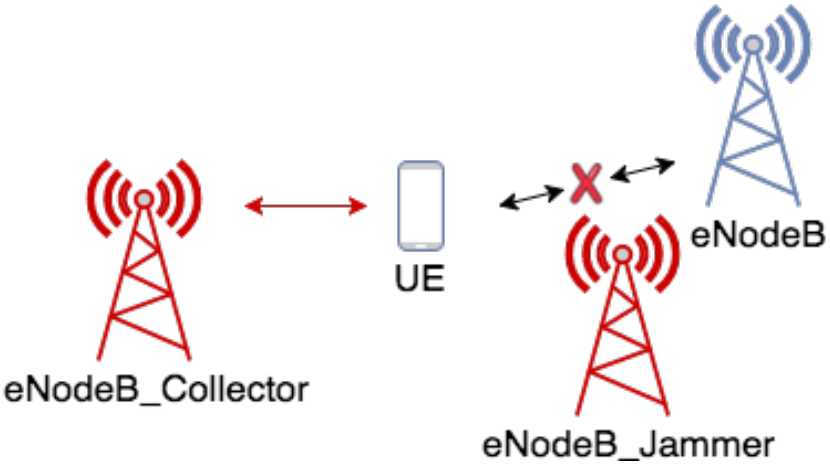
- Mobile terminals:
  - Samsung Galaxy S4 device, used to find the LTE channels and TACs used in the targeted area
  - Two LG Nexus 5X phones running Android v6, used to test our IMSI Catcher
- SIM cards

Tools: **Software**

- LTE Emulator:
  - **Open Air Interface (OAI),** an open source software that provides a (partially) standard compliant implementation of LTE

- Service Mode:
  - Dial *#0011# on Samsung Galaxy S4 device
  - Read configuration of the commercial network: EARFCN DL, TAC, MCC, MNC, Cell ID

Construction



- **Phase 1. Gather the configuration parameters:**
  - Find the EARFCN DL and TAC (using the Samsung device)
  - Run `eNodeB_Jammer` using MCC, MNC and the EARFCN DL of the commercial cell
  - Read new EARFCN DL after reselection
- **Phase 2. Configure and run the LTE IMSI Catcher:**
  - Run `eNodeB_Collector` using MCC, MNC and the new EARFCN DL after reselection in the commercial network, but a different TAC
  - Run `eNodeB_Jammer` configured as in Phase 1

Results

- Low-cost **IMSI Catcher** (< 3000 EUR):
  - COTS hardware and readily available software only
  - No (or very basic) changes in the source code

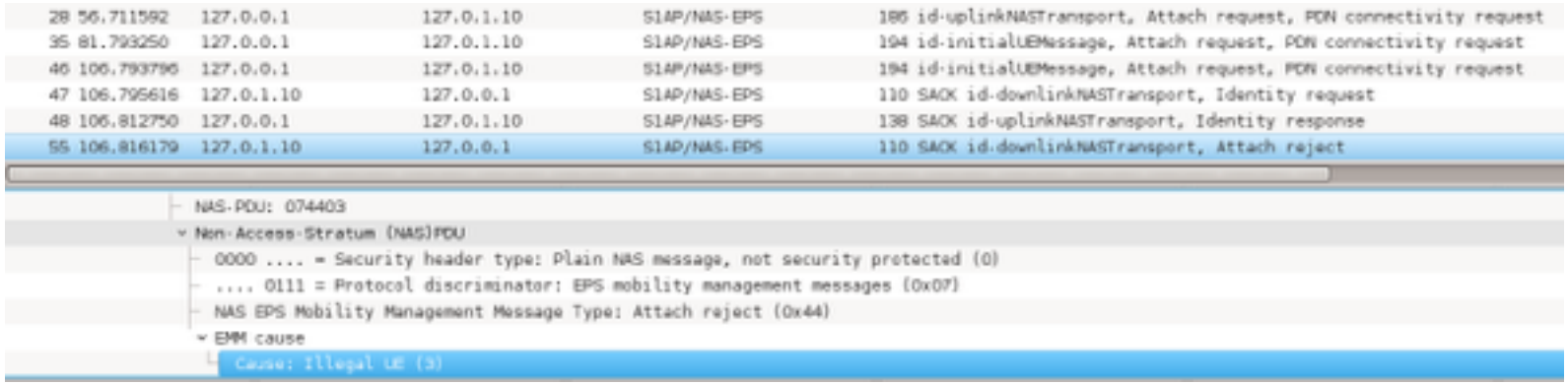
```
110 SACK id-downlinkNASTransport, Identity request
146 SACK id-uplinkNASTransport, Identity response
182 id-initialUEMessage, Tracking area update request
110 SACK id-downlinkNASTransport, Tracking area update reject
 94 id-downlinkNASTransport, EMM status
214 id-initialUEMessage, Attach request, PDN connectivity request

NAS-PDU: 17f49d7386090756082924505902830303
Non-Access-Stratum (NAS)PDU
    0001 .... = Security header type: Integrity protected (1)
    .... 0111 = Protocol discriminator: EPS mobility management messages (0x07)
    Message authentication code: 0xf49d7386
    Sequence number: 9
    0000 .... = Security header type: Plain NAS message, not security protected (0)
    .... 0111 = Protocol discriminator: EPS mobility management messages (0x07)
    NAS EPS Mobility Management Message Type: Identity response (0x56)
    Mobile identity - IMSI [redacted]
```

```
80 [MESSAGE] 9 -> 9 0 0103:990956EMMREG_COMMON_PROC_CNF ue id 0x00000002
81 [EVENT] 9 0103:991075EMM state DEREGISTERED UE 0x00000002
82 [MESSAGE] 8 -> 13 0 0103:9911920 S6A_AUTH_INFO_REQ IMSI 242[redacted] visited_plmn 242.[redacted] re_sync 0
83 [MESSAGE] 13 -> 8 0 0103:9921110 S6A_AUTH_INFO_ANS imsi 242[redacted] DIAMETER_AUTHENTICATION_DATA_UNAVAILABL
84 [EVENT] 7 0103:9921680 S6A_AUTH_INFO_ANS S6A Failure imsi 242[redacted]
85 [MESSAGE] 8 -> 9 0 0103:9921820 EMMCN_AUTHENTICATION_PARAM_FAIL
```

Results

- Behaviour:
  - Denial-of-Service (DoS) until reboot - *cause 3* (`Illegal UE`)
  - Downgrade to non-LTE services - *cause 7* (`EPS services not allowed`)
  - Reconnection to the commercial network - *cause 15* (`No suitable cells in tracking area`)



28	56.711592	127.0.0.1	127.0.1.10	S1AP/NAS-EPS	186 id-uplinkNASTransport, Attach request, PDN connectivity request
35	81.793250	127.0.0.1	127.0.1.10	S1AP/NAS-EPS	194 id-initialUEMessage, Attach request, PDN connectivity request
46	106.793796	127.0.0.1	127.0.1.10	S1AP/NAS-EPS	194 id-initialUEMessage, Attach request, PDN connectivity request
47	106.795616	127.0.1.10	127.0.0.1	S1AP/NAS-EPS	110 SACK id-downlinkNASTransport, Identity request
48	106.812750	127.0.0.1	127.0.1.10	S1AP/NAS-EPS	138 SACK id-uplinkNASTransport, Identity response
55	106.816179	127.0.1.10	127.0.0.1	S1AP/NAS-EPS	110 SACK id-downlinkNASTransport, Attach reject

```
NAS-PDU: 074403
Non-Access-Stratum (NAS)PDU
  0000 .... = Security header type: Plain NAS message, not security protected (0)
  .... 0111 = Protocol discriminator: EPS mobility management messages (0x07)
  NAS EPS Mobility Management Message Type: Attach reject (0x44)
  EMM cause
    Cause: Illegal UE (3)
```

Similar Work

Practical Attacks Against Privacy and Availability in 4G/LTE Mobile Communication Systems

Altaf Shaik*, Ravishankar Borgaonkar†, N. Asokan‡, Valtteri Niemi§ and Jean-Pierre Seifert*
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Email: valtteri.niemi@helsinki.fi

[NDSS 2016]

LTE security, protocol exploits and location tracking experimentation with low-cost software radio

Roger Piqueras Jover
Bloomberg LP, New York, NY
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International Conference on Mathematical Methods, Models, and Architectures for Computer Network Security
MMM-ACNS 2017: Computer Network Security pp 235-246

Easy 4G/LTE IMSI Catchers for Non-Programmers

Authors Authors and affiliations

Stig F. Mjølsnes, Ruxandra F. Olimid

Experimental Assessment of Private Information Disclosure in LTE Mobile Networks

Topics: Security and Privacy in Mobile Systems

In **Proceedings of the 14th International Joint Conference on e-Business and Telecommunications - Volume 6: SECRYPT**, 507-512, 2017, Madrid, Spain

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NTNU

IMSI Catchers in the Real World

”Real World” IMSI Catchers

[Aftenposten, Dec.16, 2014]

[ArsTechnica, Apr. 3, 2018]

SPY VS. SPY —

Feds: There are hostile stingrays in DC, but we don’t know how to find them

There’s also “anomalous activity”—probably stingrays—in other US cities, too.

CYRUS FARIVAR - 4/3/2018, 9:27 PM

Enlarge / US Capitol Building in Washington, DC.

”Real World” IMSI Catchers

Piranha - 2G, 3G, and 4G IMSI Catcher

Piranha is a 2G, 3G and 4G (LTE) IMSI Catcher System that enables gathering mobile phone identities in the area of the system.

[http://www.rayzoneg.com/en.piranha.html]

”Real World” IMSI Catchers

[https://theintercept.com/2016/09/12/long-secret-stingray-manuals-detail-how-police-can-spy-on-phones/]

The Intercept_

Photo: U.S. Patent and Trade Office

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LONG-SECRET STINGRAY MANUALS DETAIL HOW POLICE CAN SPY ON PHONES

Sam Biddle

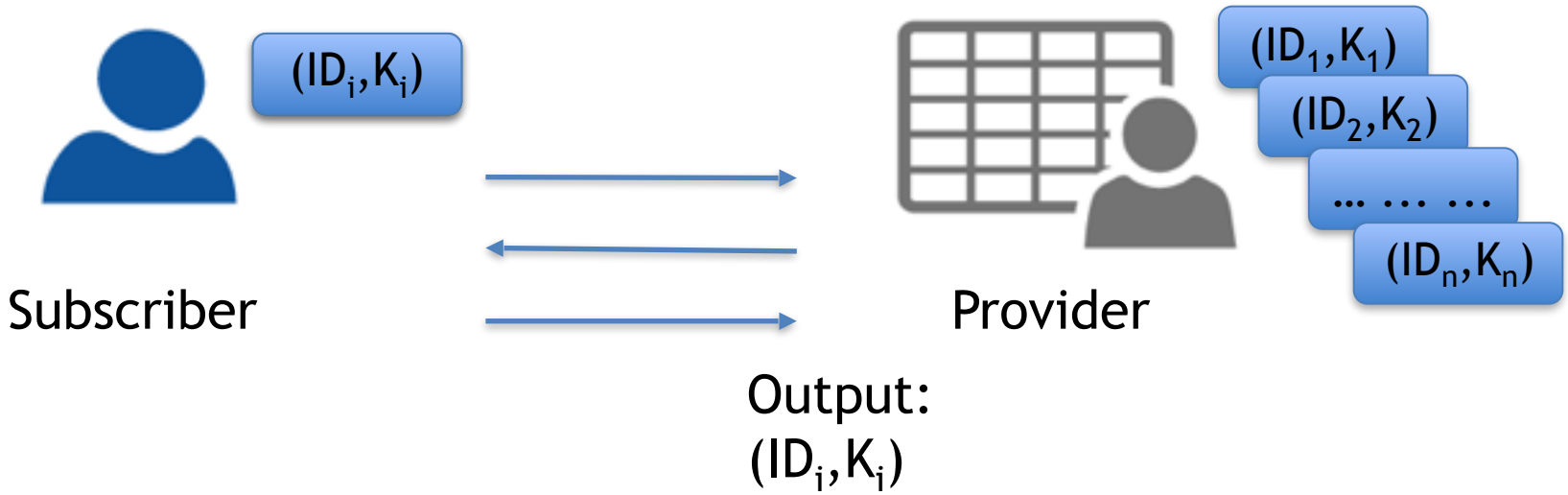
September 12 2016, 9:33 p.m.

The cryptographic problem

- S.F.Mjølsnes, R.F.Olimid: *The challenge of private identification, iNetSec 2017*

The Problem

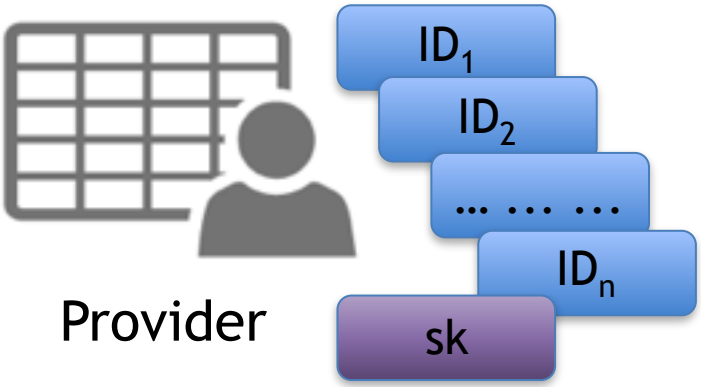
(*How*) *Can we construct efficient and scalable secure identification mechanisms in (mobile) communication systems?*



We **decouple** the protocol from *registration* and *authentication*, to gain independence in design and analysis - the private identification challenge becomes a *general standalone problem*

Public Key - Trivial Solution

Subscriber



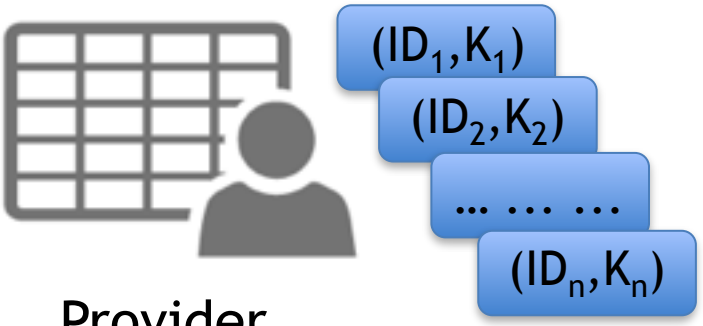
Provider

$Enc_{pk}(ID_i)$

$Dec_{sk}(Enc_{pk}(ID_i)) = ID_i$

Key Search - Linear Solution

(ID_i, K_i)



Subscriber

Provider

*key-indistinguishable MAC

$r_j \leftarrow^R \mathcal{R}$

$r_j, Enc_{Ki}(r_j)$ →

Linear time

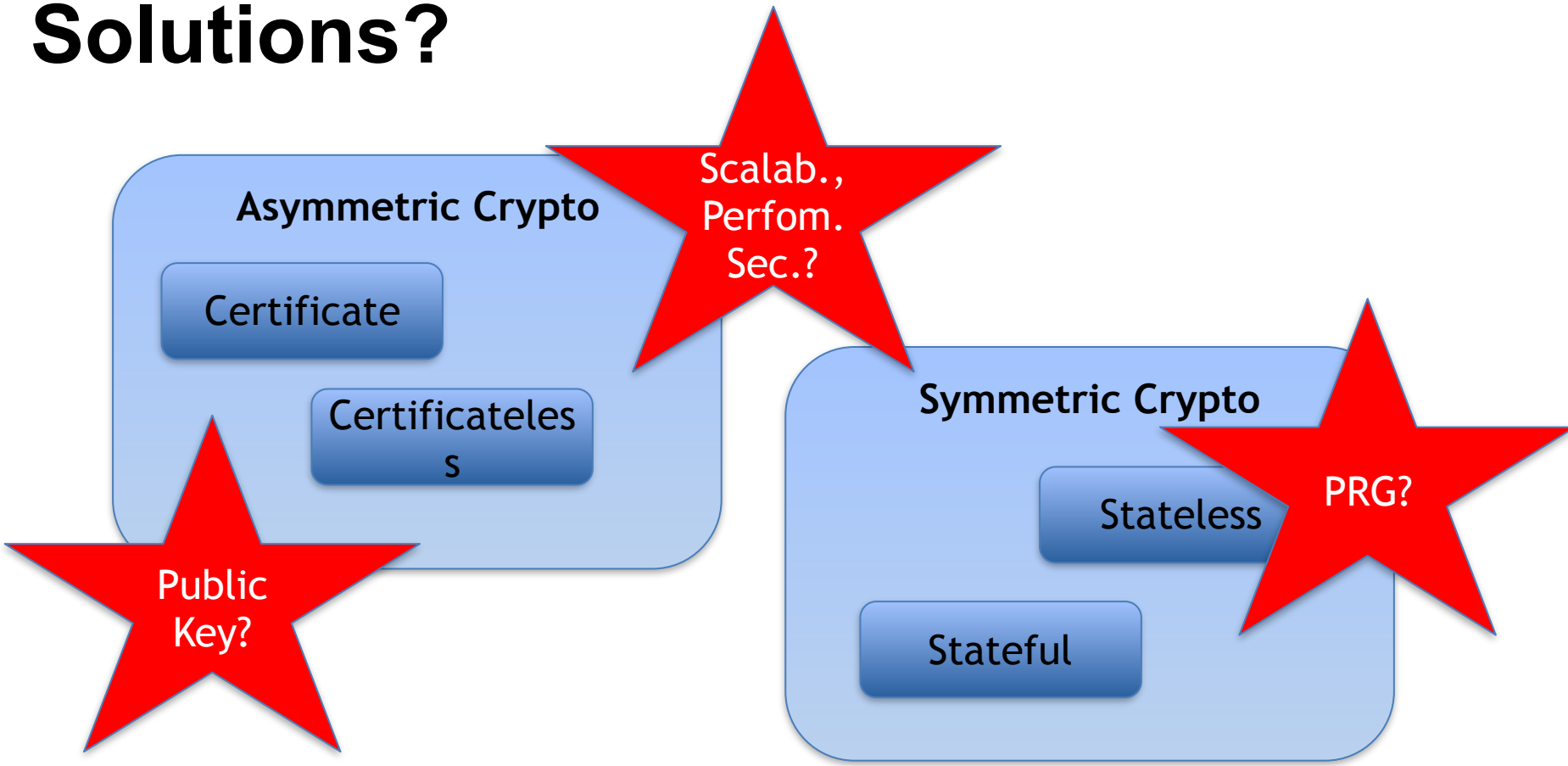
Try all $\{K_i\}$ until successfully decryption of r_j

Output: (ID_i, K_i)

[Weis, Sarma, Rivest, Engels - Security and Pervasive Computing'03]

[Alwen, Hirt, Maurer, Patra, Raykov - Anonymous Authentication with Shared Secrets'14]

Solutions?



Paradox: private identification requires encryption (under the secret key), but how to know which secret key to use?

[Alomair, Poovendran – Privacy vs. Scalability in RFID Systems'10]

Related Work

- Models and definitions:
  - Mobile Networks, include authentication [Alwen et al.'14, Abadi & Fournet'15]
  - RFIDs [Vaudenay'07], [Canard et al.'10], [Hermans et al.'14], [Yang et al.'17]
- Mobile networks (LTE):
  - Several IMSIs for each USIM [Kahn & Mitchel'15]
  - New temporary identifiers: *DMSI* (Dynamic Mobile Subscriber Identities) [Choudhury et al.'12], *PMSI* (Pseudo Mobile Subscriber Identities) [Broek et al.'15], *CMSI* (Changing Mobile Subscriber Identities) [Muthana &Saeed.'17]
  - Public-key solutions [Arapinis et al.'12], [Hermans et al.'14], [Chandrasekaran et al.'17]
- RFID:
  - Linear complexity in the number of subscribers [Weis et al.'03],
  - Surveys [Jules'06], [Langheinrich.'09], [Song et al.'09], [Song et al.'11], [Yang et al.'17]

3GPP

- History:
  - 3GPP(3rd Generation Partnership Project): 2G/3G/4G
  - TS 33.501 *Technical Specification Group Services and System Aspects; Security architecture and procedures for 5G system*

- Solution:
  - Elliptic Curve Integrated Encryption Scheme (ECIES)
  - Hybrid encryption: Diffie Hellman (EC) + symmetric encryption

Subscription Identifier Privacy in 5G Systems

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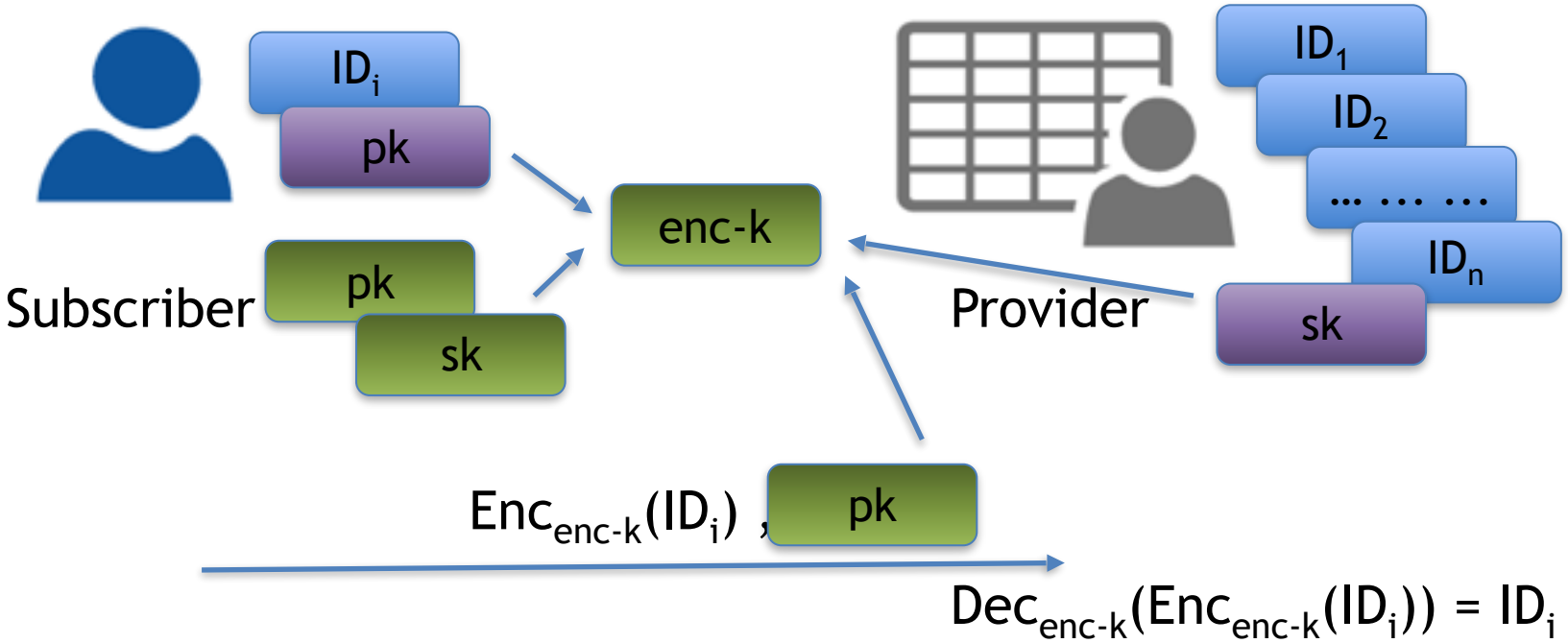
Abstract—Privacy is a main concern for mobile network users, and there are many proposed enhancements for the protection of the long-term subscription identifier. Some enhancements require asymmetric key operations, which increase both processing requirements and protocol message sizes. To the best of our knowledge, there has been no practical

but active attacks on privacy (such as the ones mentioned in [1]) were still left completely unaddressed. With increased off-the-shelf availability of technology such as Software Defined Radio, those active attacks have become a major concern, with a number of attack vectors recently exploited [2].

[MoWNeT'17]

3GPP - ECIES


ID_i
pk
Subscriber
pk
sk
enc-k
Provider
ID_1
ID_2
… … …
ID_n
sk
$Enc_{enc\text{-}k}(ID_i)$,
pk
$Dec_{enc\text{-}k}(Enc_{enc\text{-}k}(ID_i)) = ID_i$

3GPP

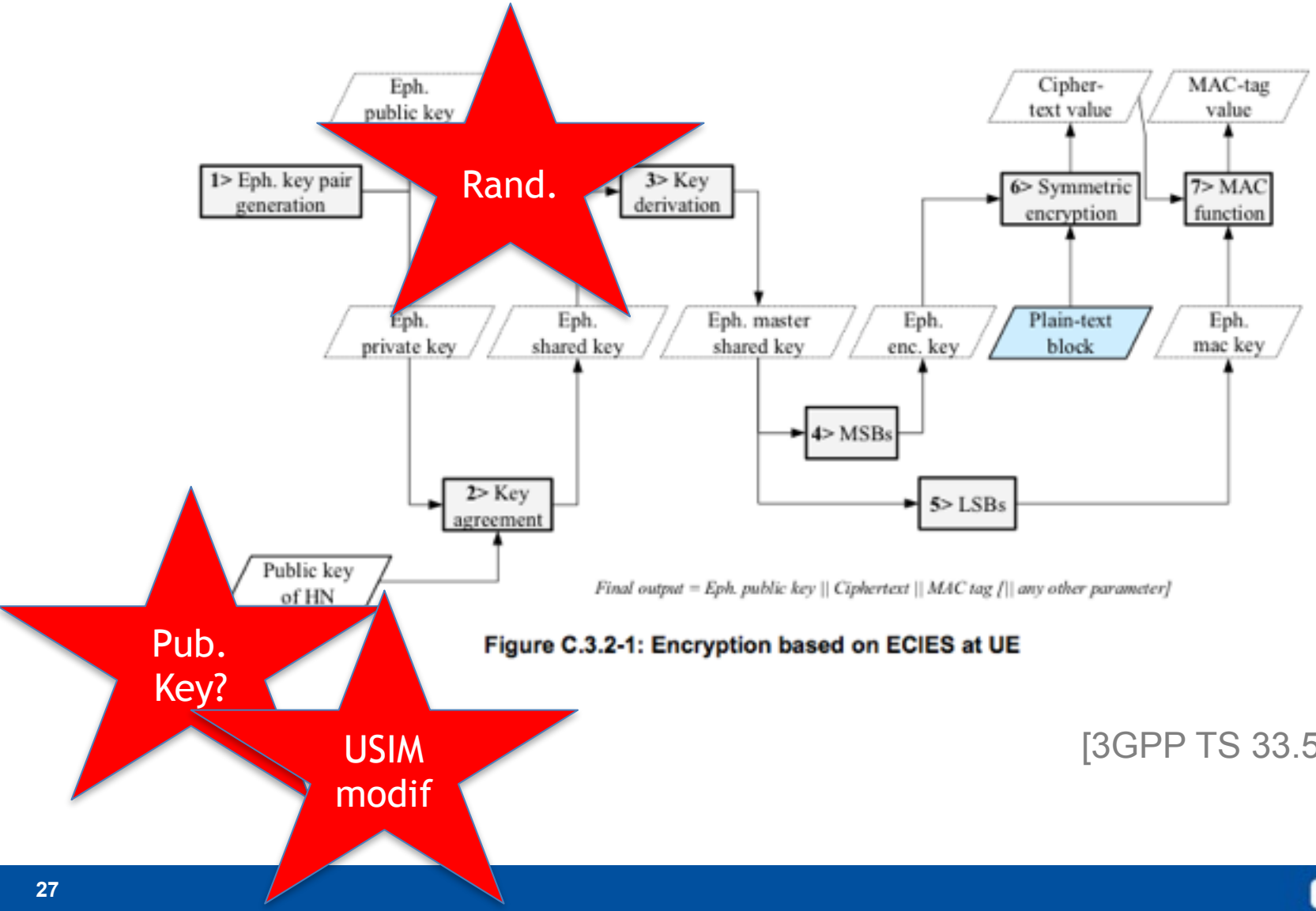


Figure C.3.2-1: Encryption based on ECIES at UE

[3GPP TS 33.501]

Summary

- 4G/LTE IMSI-catchers
  - is IMSI-catching a bug or a feature?
  - this problem is now considered for 5G

- Private Identification Problem – symmetric settings:
  - ***existing efficient and scalable solutions in private key settings ?***
  - no impossibility result, no lower bounds for computational power on the network side

- 3GPP-ECIES:
  - 5G IMSI-catchers? (*null-scheme,* recommendations)
  - public key refresh (in USIM)
  - hiding MCC, MNC?
  - post-quantum resistance?
  - …

Thank you!