How secure are your VoLTE and VoWiFi calls?

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About me : Priya Chalakkal

- **ERNW GmbH, Heidelberg**
- Loves telco, pcaps, binaries, logs, protocols and all security stuff in general.
- Completed Masters in Security and Privacy from TU, Berlin and UNITN, Trento.
- https://priyachalakkal.wordpress.com/
- https://insinuator.net/

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Agenda

- Introduction
- Fundamentals
- PART1: Attacks on OpenIMS (without IPSec)
- PART2: Attacks on real telecom providers (with IPSec)
- Demo
- Mitigation

Introduction - Telephony

Circuit Switched

- PSTN : *Public Switched Telephone Networks*
- Dedicated circuit – "Channel"
- Roots tracked back to 1876
  - Graham Bell got the first patent

Packet Switched

- Data sent as Packets
- Protocol stack: TCP/IP
- Eg:- Internet
- For voice - VoIP

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Introduction - VoIP

Introduction – VoLTE/VoWiFi

VoLTE

- SK Telecom and LG U+Objective South Korea – 2012
- Vodafone Germany – VoLTE – March 2015

VoWiFi:

- Telekom Germany – VoWiFi – May 2016
- WiFi Calling

FUNDAMENTALS

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History of Mobile Communication

- GSM (2G)
  - Relies on Circuit Switching
  - Supports only Voice and SMS
- GPRS
  - Circuit – voice and SMS
  - Packet – Data
- UMTS (3G)
  - Similar to GPRS
  - Other network elements evolved

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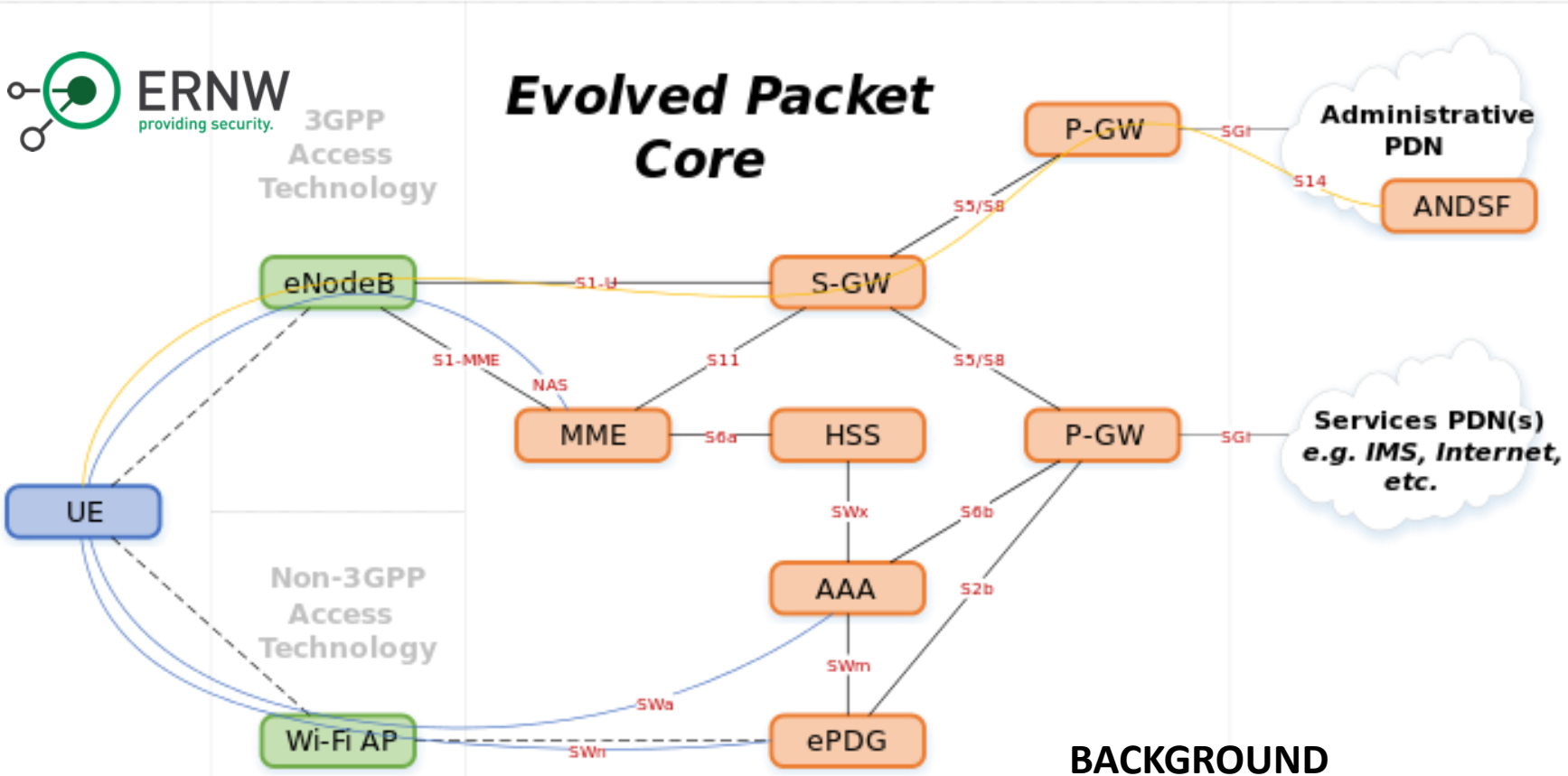
Voice and 4G

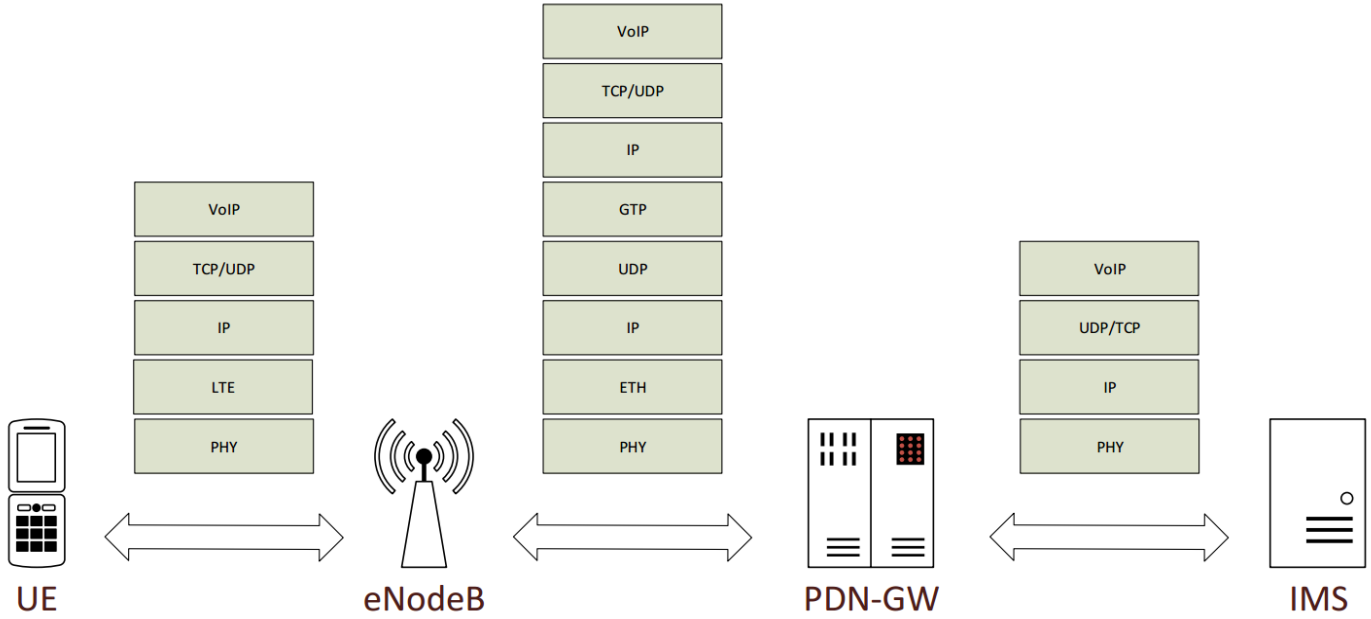
- LTE (4G): Supports only packet switching
- **Voice - VoLTE**
- **Circuit Switched Fall Back (CSFB)**
  - For voice, fall back to circuit switched networks.
- Other approaches
  - Simultaneous voice and LTE

  etc..



Source: https://en.wikipedia.org/wiki/System_Architecture_Evolution

VoLTE Stack


VoIP
TCP/UDP
IP
LTE
PHY
VoIP
TCP/UDP
IP
GTP
UDP
IP
ETH
PHY
VoIP
UDP/TCP
IP
PHY
UE
eNodeB
PDN-GW
IMS

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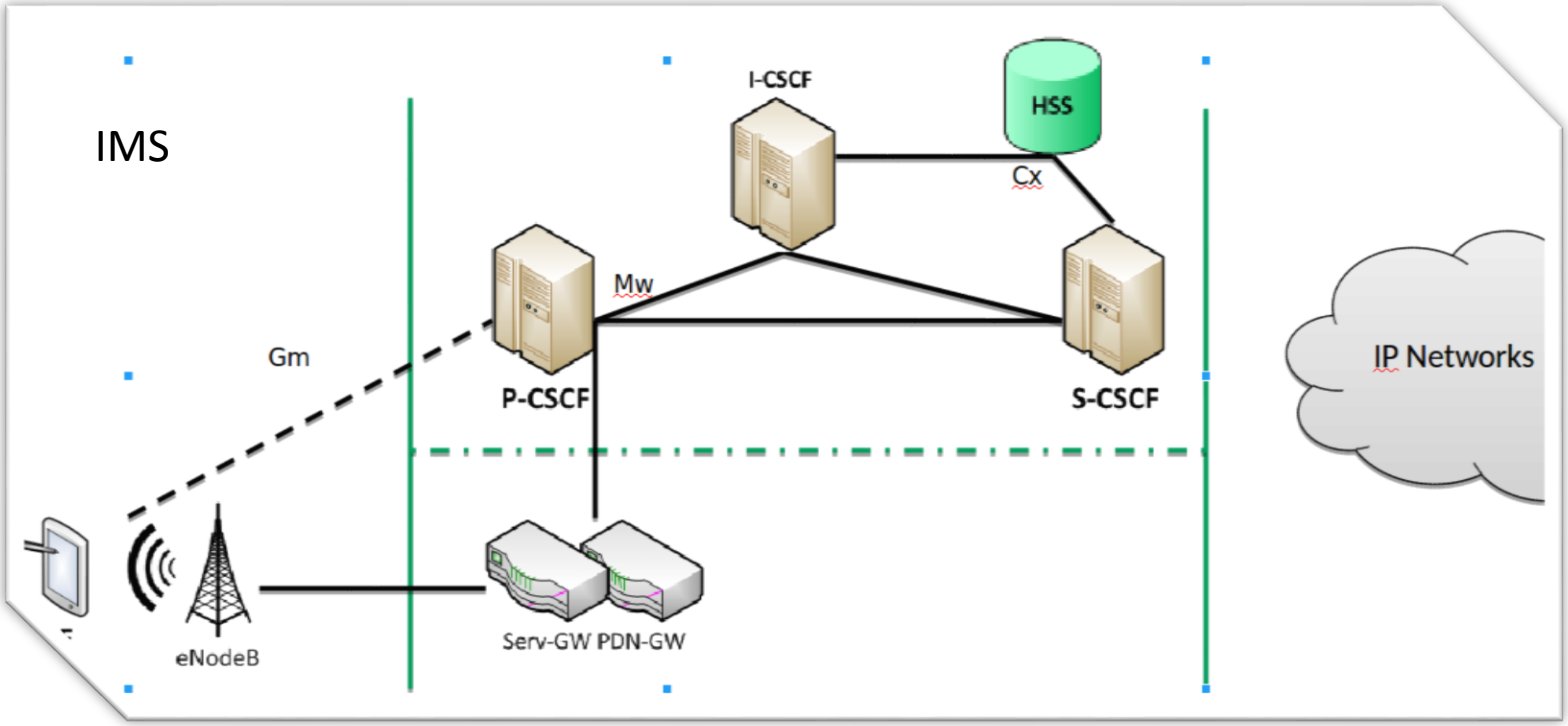
IMS – IP Multimedia Subsystem

- Backend: IMS Core
  - *IP Multimedia Subsystem*
  - Call session control functions (CSCF)
    - P-CSCF
    - S-CSCF
    - I-CSCF


IMS
I-CSCF
HSS
Cx
Mw
Gm
P-CSCF
S-CSCF
IP Networks
eNodeB
Serv-GW PDN-GW

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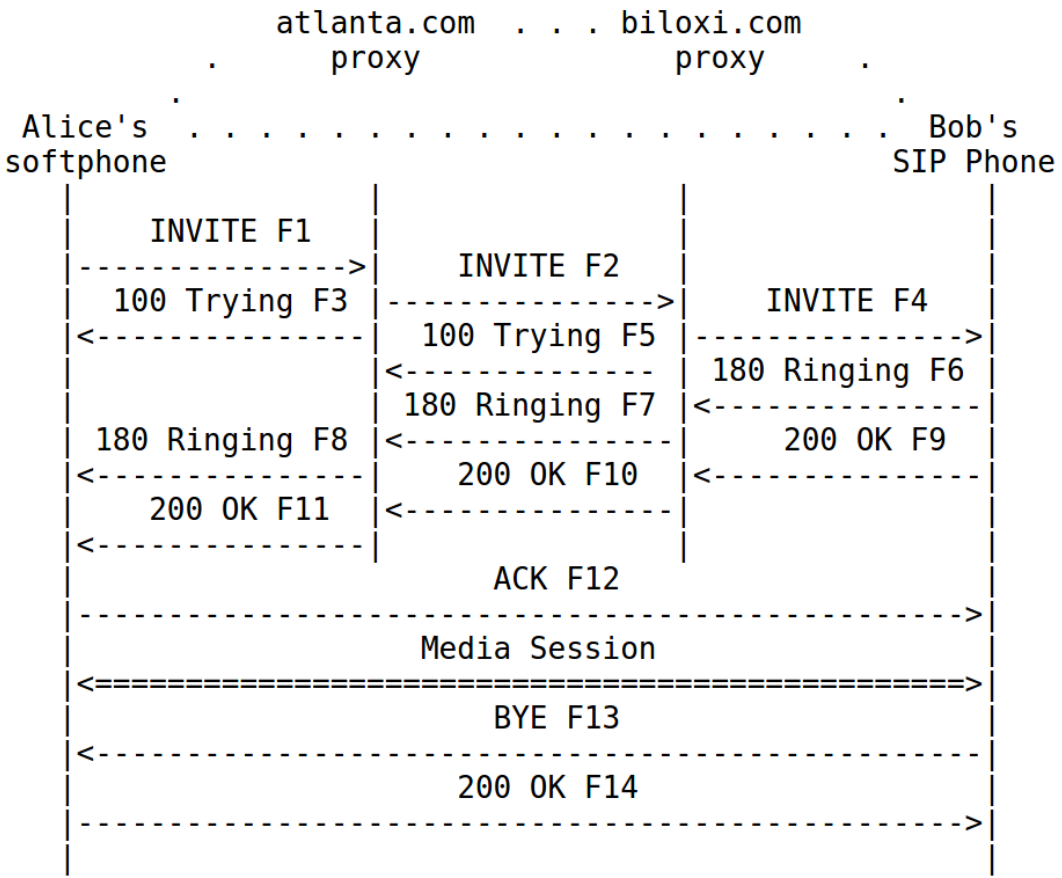
IMS Signaling

SIP - Session Initiation Protocol

- Similar to HTTP (text based)
- TCP or UDP
- Contains SDP
  - Session Description Protocol
  - Describing multimedia session
  - Eg:- audio/video type

SIP call session




```
INVITE sip: jennifer@csp.com SIP/2.0
Via: SIP/2.0/UDP [5555::a:b:c:d]:1400; branch=abc123
Max-Forwards:70
Route: <sip:[5555::55:66:77:88]:7531;lr>,< sip:orig@scscf1.home.fi;lr>
P-Access-Network-Info:3GPP-E-UTRAN-TDD;utran-cell-id-3gpp=244005F3F5F7
P-Preferred-Service: urn:urn-7:3gpp-service.ims.icsi.mmtel
Privacy: none
From: <sip:kristiina@example.com>;tag=171828
To: <sip:jennifer@csp.com>
Call-ID: cb03a0s09a2sdfglkj490333
Cseq: 127 INVITE
Require: sec-agree
Proxy-Require: sec-agree
Supported: precondition, 100rel, 199
Security-Verify: ipsec-3gpp; alg=hmac-sha-1-96; spi-c=98765432;
spi-s=87654321; port-c=8642; port-s=7531
Contact: <sip:[5555::a:b:c:d]:1400;+g.3gpp.icsi-ref="urn%3Aurn-7%
3gpp-service.ims.icsi.mmtel"
Accept-Contact: *;+g.3gpp.icsi-ref="urn%3Aurn-7%
3gpp-service.ims.icsi.mmtel"
Allow: INVITE, ACK, CANCEL, BYE, PRACK, UPDATE, REFER, MESSAGE, OPTIONS
Accept:application/sdp, application/3gpp-ims+xml
Content-Type: application/sdp
Content-Length: (...)

v=0
o=- 2890844526 2890842807 IN IP6 5555::a:b:c:d
s=-
c=IN IP6 5555::a:b:c:d
t=0 0
m=audio 49152 RTP/AVP 97 98
a=rtpmap:97 AMR/8000/1
a=fmtp:97 mode-change-capability=2; max-red=220
b=AS:30
b=RS:0
b=RR:0
a=rtpmap:98 telephone-event/8000/1
a=fmtp:98 0-15
a=ptime:20
a=maxptime:240
a=inactive
a=curr:qos local none
```

SIP

SDP

PART1: Attacking OpenIMS

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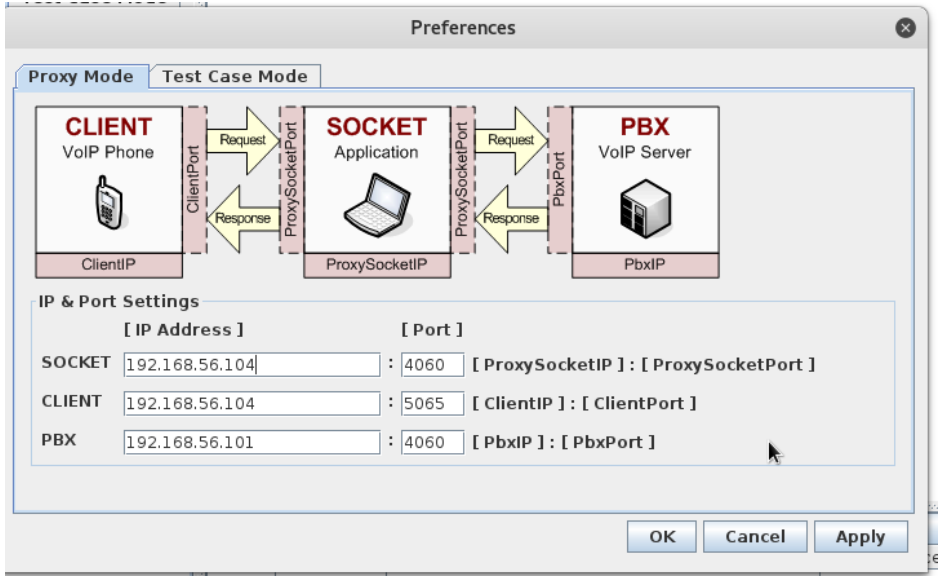
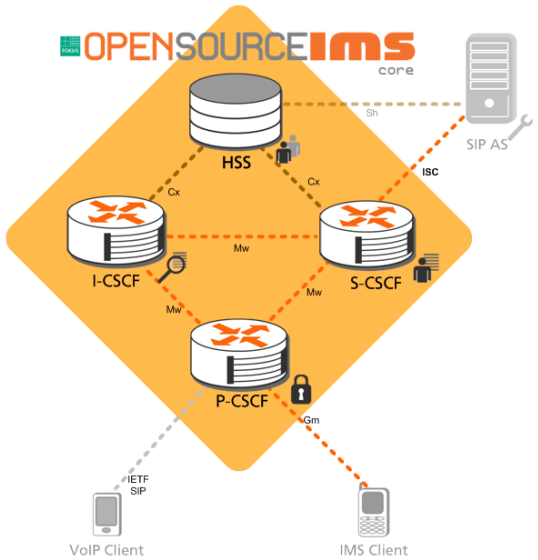
Requirements

- OpenIMS
- SIP Proxy
- Viproy toolkit for Attack1
- IMS clients – twinkle (in ubuntu), boghe (in windows)


Preferences
Proxy Mode
Test Case Mode
CLIENT
VoIP Phone
ClientIP
ClientPort
Request
Response
ProxySocketPort
SOCKET
Application
ProxySocketIP
ProxySocketPort
Request
Response
PbxPort
PBX
VoIP Server
PbxIP
IP & Port Settings
[IP Address]
[Port]
SOCKET
192.168.56.104
4060
[ProxySocketIP] : [ProxySocketPort]
CLIENT
192.168.56.104
5065
[ClientIP] : [ClientPort]
PBX
192.168.56.101
4060
[PbxIP] : [PbxPort]
OK
Cancel
Apply


OPENSOURCEIMS
core
HSS
SIP AS
Sh
ISC
Cx
Cx
I-CSCF
S-CSCF
Mw
Mw
Mw
P-CSCF
Gm
IETF
SIP
VoIP Client
IMS Client

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Attack modeling

- VoLTE and VoWiFi makes use of SIP
- This is experimental tests on OpenIMS with desktop clients
- Mainly SIP header injection
- Without IPSec in any communication
- Both attacker and victim is a registered user.

Attack1: MSRP fuzzing

- MSRP – protocol for transmission of series of related instant messages in context of communication session
- Evil sends fuzzed input in one of the MSRP header field to Alice
  - a=file-selector:name:"AAAAAAAAAAA…"
- This is an automated test vector in Viproy toolkit.

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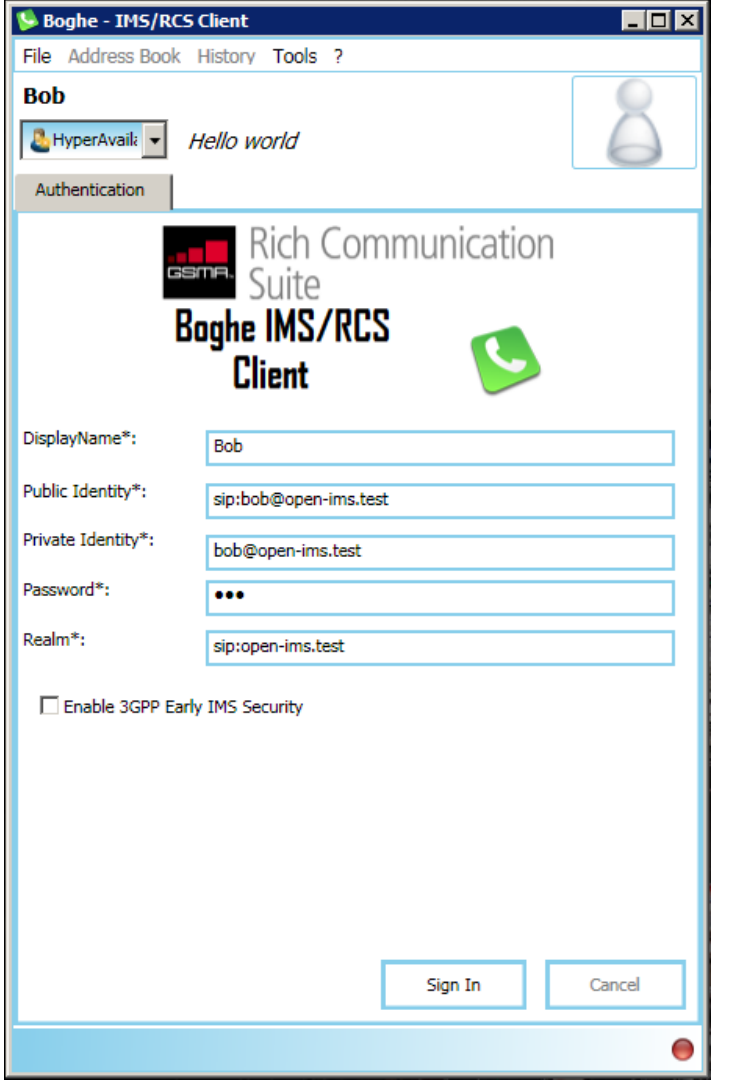
Result 1

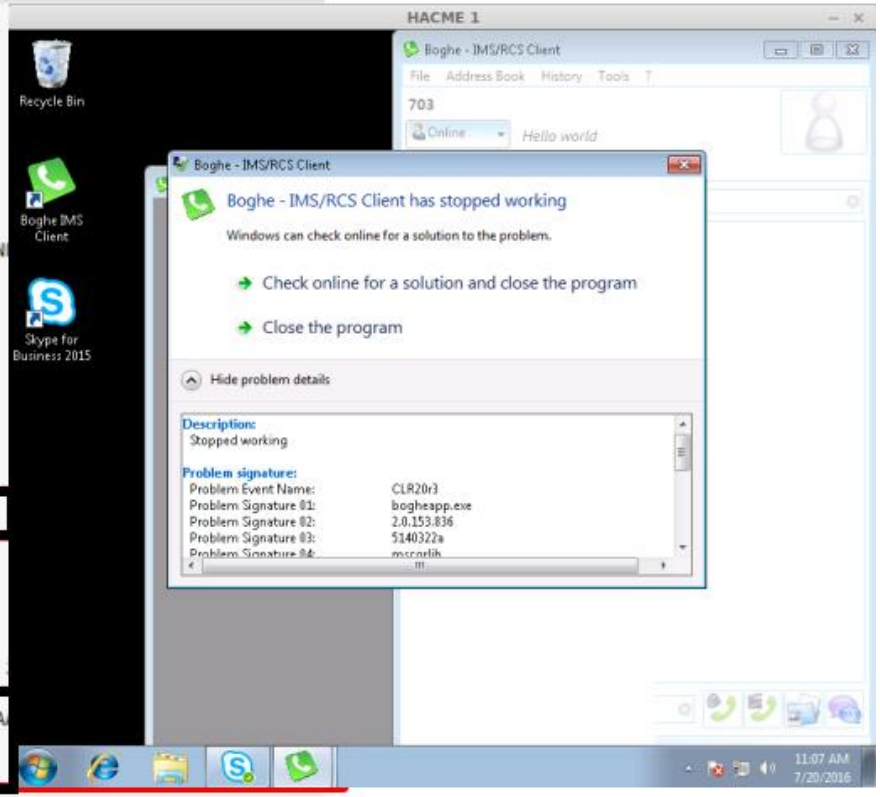
- Crashes the IMS client of Receiver (Boghe IMS client is used in this case)
- Neither IMS nor client performed input validation.



Result1: MSRP fuzzing

```
Session Initiation Protocol (SIP as raw text)
  INVITE sip:703@10.254.254.153 SIP/2.0
  Via: SIP/2.0/UDP 10.254.254.10:5060;rport;branch=branch88zV32Jzva
  Max-Forwards: 70
  From: <sip:hacme@viproy.com>;tag=uUS1n2N6zn
  To: <sip:703@10.254.254.153>
  Call-ID: callBXkppGFxyi4cyN3Kw9yAsHoPn0BDfe@10.254.254.10
  CSeq: 13100 INVITE
  Contact: <sip:hacme@viproy.com>
  User-Agent: Viproy Penetration Testing Kit - Test Agent
  Allow: INVITE, ACK, CANCEL, OPTIONS, BYE, REFER, NOTIFY, MESSAGE, SUBSCRIBE, IN
  Accept: application/sdp
  Content-Type: application/sdp
  Content-Length: 3593

  v=0
  o=doubango 1983 678901 IN IP4 10.254.254.10
  s=-
  c=IN IP4 10.254.254.10
  t=0 0
  m=message 8080 TCP/MSRP *
  a=path:msrp://10.254.254.10:8080/2F6LaaDLCi9glyXTx1XQ;tcp
  a=connection:new
  a=setup:actpass
  a=accept-types:message/CPIM application/octet-stream
  a=accept-wrapped-types:application/octet-stream image/jpeg image/gif image/bmp
  [truncated] a=file-selector:name:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
  a=file-transfer-id:987522753
  a=file-disposition:attachment
```



Source: Fatih Ozvaci- Voip wars: The phreakers awaken

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Attack2: Location manipulation

- P-Access-Network-Info - defines the user location in the access network
- Contains information such as:
  - Mobile Network Code (MNC)
  - Mobile Country Code (MCC)
  - Local Area Code (LAC)
  - Cell Identifier
- The attacker sends an INVITE request to Alice with a crafted location.

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Result2

- Modified P-Access-Network-Info is accepted by IMS and sent to Alice
- No cross validation with HSS for user location.
- Can evade **lawful interception techniques.**
- NOT about privacy

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Attack3: Roaming Information

- P-Visited-Network-ID header field that decides the access network that serves the user.
- Attacker sends a REGISTER request to IMS with an pre-added P-Visited-Network-ID header.

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Result3

- P-CSCF just appends the network identity to the existing header field
- Attacker can use this to make his roaming calls as local calls

Output from S-CSCF packet dump:

P-Visited-Network-ID: open-ims_fake.test, open-ims.test

Attack4: Extra header field

- SIP protocol is an extensible protocol
  - Allows to add customized header fields
- Evil sends an INVITE request to Alice containing a custom header field X-Header

Result4

```
▷ Via: SIP/2.0/UDP 127.0.0.1:6060;received=127.0.0.1;rport=6060;branch=z9hG4bK3fc4
▷ Via: SIP/2.0/UDP 127.0.0.1:6060;branch=z9hG4bK3fc4.07ebc004.0
▷ Via: SIP/2.0/UDP 0.0.0.0:4060;received=127.0.0.1;branch=z9hG4bK3fc4.d87f5ce1.0
▷ Via: SIP/2.0/UDP 192.168.56.103:5060;rport=40303;branch=z9hG4bK79178419f7f6d3d08
  Max-Forwards: 13
  X-Header: "This is an extra header, I will send it to you for free"
  Content-Type: application/sdp
```


Source https://insinuator.net/2017/02/exploitation-of-ims-in-absence-of-confidentiality-and-integrity-protection/

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More attack possibilities

- Spoofing
- Injection – XML, SQL,
- Denial of Service
- Fuzzing
- …
- …

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Attacking OpenIMS summary

- 4 attacks on OpenIMS
  - MSRP fuzzing
  - User location manipulation
  - Roaming information manipulation
  - Extra header field injection
- These are **Man in the End** attacks
- **Without** IPSec

How to prevent tampering SIP Attacks?

- Bring integrity protection?
- Can IPSec solve this?
- Many real telecom provides actually have IPSec in place.
- Can we still mess with SIP headers in real providers?

PART2: ATTACKING TELECOM PROVIDERS

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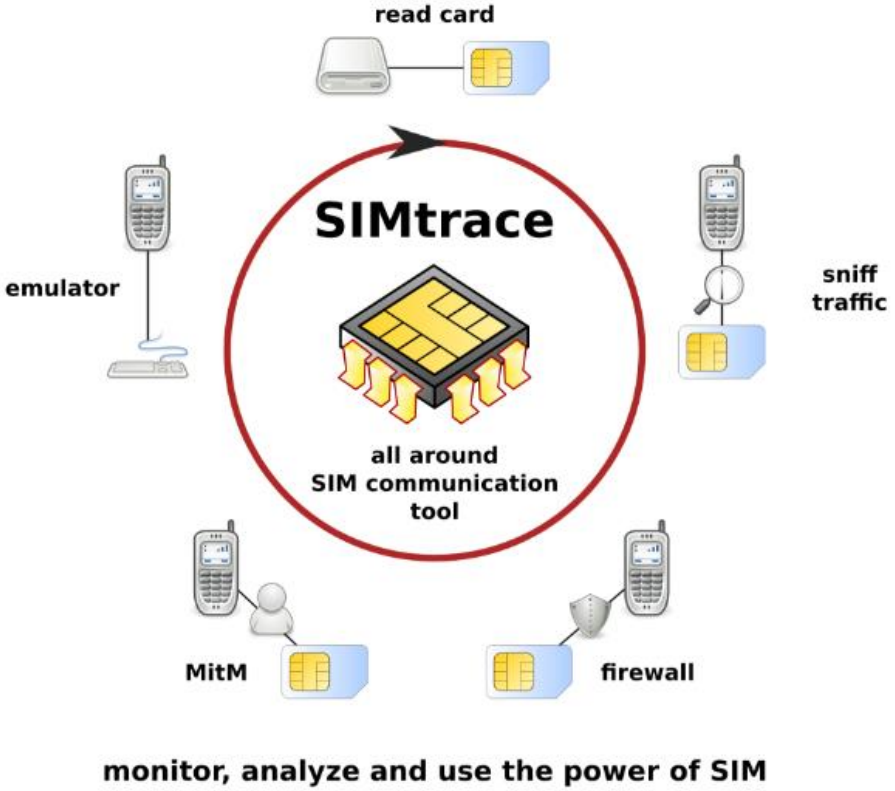
Requirements

- VoLTE/VoWiFi enabled SIM cards
- SIMTrace hardware
- VoLTE/VoWiFi enabled phones
- Wireshark - Gcrypt



http://shop.sysmocom.de/products/simtrace

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Attack modeling

- Sniffing VoLTE – rmnet0, rmnet1
- Sniffing VoWiFi – epdg1, wlan0
- Sniffing ISIM interface using SIMTrace
- IPSec
  - ESP encapsulation for both VoLTE and VoWiFi
  - Integrity protection enabled for VoLTE/VoWiFi
  - Encryption for VoWiFi (only in wlan0)

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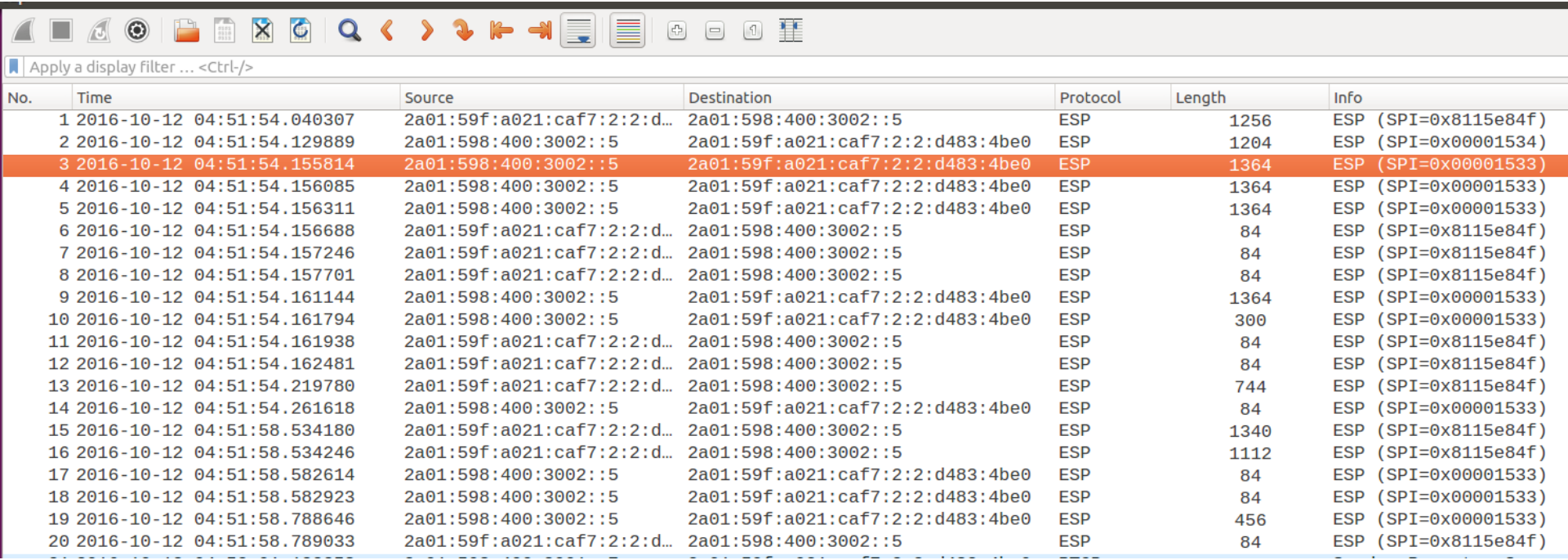
ESP Packets



Apply a display filter … <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
1	2016-10-12 04:51:54.040307	2a01:59f:a021:caf7:2:2:d…	2a01:598:400:3002::5	ESP	1256	ESP (SPI=0x8115e84f)
2	2016-10-12 04:51:54.129889	2a01:598:400:3002::5	2a01:59f:a021:caf7:2:2:d483:4be0	ESP	1204	ESP (SPI=0x00001534)
3	2016-10-12 04:51:54.155814	2a01:598:400:3002::5	2a01:59f:a021:caf7:2:2:d483:4be0	ESP	1364	ESP (SPI=0x00001533)
4	2016-10-12 04:51:54.156085	2a01:598:400:3002::5	2a01:59f:a021:caf7:2:2:d483:4be0	ESP	1364	ESP (SPI=0x00001533)
5	2016-10-12 04:51:54.156311	2a01:598:400:3002::5	2a01:59f:a021:caf7:2:2:d483:4be0	ESP	1364	ESP (SPI=0x00001533)
6	2016-10-12 04:51:54.156688	2a01:59f:a021:caf7:2:2:d…	2a01:598:400:3002::5	ESP	84	ESP (SPI=0x8115e84f)
7	2016-10-12 04:51:54.157246	2a01:59f:a021:caf7:2:2:d…	2a01:598:400:3002::5	ESP	84	ESP (SPI=0x8115e84f)
8	2016-10-12 04:51:54.157701	2a01:59f:a021:caf7:2:2:d…	2a01:598:400:3002::5	ESP	84	ESP (SPI=0x8115e84f)
9	2016-10-12 04:51:54.161144	2a01:598:400:3002::5	2a01:59f:a021:caf7:2:2:d483:4be0	ESP	1364	ESP (SPI=0x00001533)
10	2016-10-12 04:51:54.161794	2a01:598:400:3002::5	2a01:59f:a021:caf7:2:2:d483:4be0	ESP	300	ESP (SPI=0x00001533)
11	2016-10-12 04:51:54.161938	2a01:59f:a021:caf7:2:2:d…	2a01:598:400:3002::5	ESP	84	ESP (SPI=0x8115e84f)
12	2016-10-12 04:51:54.162481	2a01:59f:a021:caf7:2:2:d…	2a01:598:400:3002::5	ESP	84	ESP (SPI=0x8115e84f)
13	2016-10-12 04:51:54.219780	2a01:59f:a021:caf7:2:2:d…	2a01:598:400:3002::5	ESP	744	ESP (SPI=0x8115e84f)
14	2016-10-12 04:51:54.261618	2a01:598:400:3002::5	2a01:59f:a021:caf7:2:2:d483:4be0	ESP	84	ESP (SPI=0x00001533)
15	2016-10-12 04:51:58.534180	2a01:59f:a021:caf7:2:2:d…	2a01:598:400:3002::5	ESP	1340	ESP (SPI=0x8115e84f)
16	2016-10-12 04:51:58.534246	2a01:59f:a021:caf7:2:2:d…	2a01:598:400:3002::5	ESP	1112	ESP (SPI=0x8115e84f)
17	2016-10-12 04:51:58.582614	2a01:598:400:3002::5	2a01:59f:a021:caf7:2:2:d483:4be0	ESP	84	ESP (SPI=0x00001533)
18	2016-10-12 04:51:58.582923	2a01:598:400:3002::5	2a01:59f:a021:caf7:2:2:d483:4be0	ESP	84	ESP (SPI=0x00001533)
19	2016-10-12 04:51:58.788646	2a01:598:400:3002::5	2a01:59f:a021:caf7:2:2:d483:4be0	ESP	456	ESP (SPI=0x00001533)
20	2016-10-12 04:51:58.789033	2a01:59f:a021:caf7:2:2:d…	2a01:598:400:3002::5	ESP	84	ESP (SPI=0x8115e84f)

Test 1: Sniffing VoLTE/VoWiFi Interfaces

- VoLTE – rmnet1/rmnet0
- VoWiFi –
  - Epdg1 – hidden virtual interface with **non-encrypted** traffic
  - Wlan0 – encrypted traffic

```
Sniffing VoLTE interface :
$ adb shell
$ tcpdump -i rmnet1 -n -s 0 -w - | nc -l 127.0.0.1 -p 11233
$ adb forward tcp:11233 tcp:11233 && nc 127.0.0.1 11233 | wireshark -k -S -i -
```

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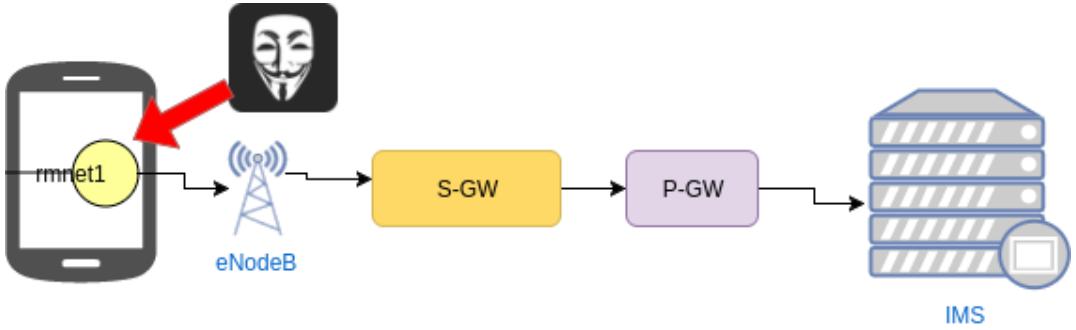
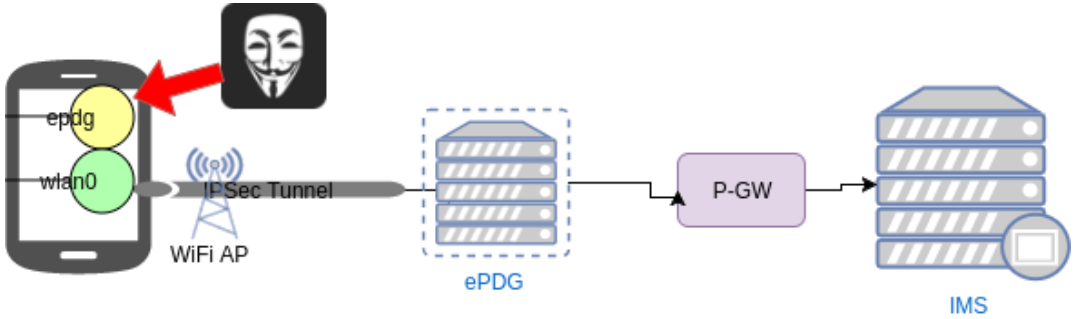
VoLTE sniffing



VoWiFi sniffing



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Observations

- No encryption in VoLTE
  - Only integrity with ESP
- Encryption in VoWiFi
- Hidden interface with **non-encrypted** traffic detected in VoWiFi

Results1: Information disclosures

- IMEI in SIP REGISTER (before authentication)

```
Contact:
<sip:262011202xxxxxx@[x.x.x.x]:6000>;q=0.50;+g.3gpp.icsi-ref=
"urn%3Aurn-7%3A3gpp-service.ims.xxx";
+g.3gpp.smsip;+sip.instance="<urn:gsma:imei:35490xxx-xxxxxx-0>"
```

- UTRAN Cell ID
  - outgoing packets like SIP REGISTER, outgoing SIP INVITE, SIP SUBSCRIBE messages contains the location information

```
##FOR VOLTE
INVITE sip:alice@open-ims.test SIP/2.0
...
User-Agent: Samsung IMS/5
P-Access-Network-Info: 3GPP-UTRAN-TDD; utran-cell-id-3gpp=00000001
Content-Length: 117

##FOR VOWIFI
P-Access-Network-Info:IEEE-802.11;i-wlan-node-id=003a9axxxxxx
```

- IMEI of caller
  - SIP INVITE incoming request consists of a parameter that contains the IMEI number of the caller.

```
Accept-Contact:*;+sip.instance="<urn:gsma:imei:354xxxxx7-xxxxxx-0>";+g.3gpp.icsi-ref="urn%3Aurn-7%3A3gpp-service.ims.xxxx";explicit;require
```

- **IMSI of caller leaked**
  - In SIP INVITE incoming request

```
INVITE sip:262011202xxxx@[x.x.x.x]:6000 SIP/2.0
```

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Private IP of IMS

- Found within SIP INVITE in incoming calls

```
To: <sip:+49151xxxxxxxx@62.xxx.xxx.xxx>
From: <sip:+49176xxxxxxxx@10.xxx.xxx.xxx>;
tag=h7g4Esbg_mavodi-a-10b-3c-2-ffffffff-
_000050ED9CA4-1224-xxxx-xxxx
```

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Test 2: ISIM sniffing for extracting CK/IK

```
[~/thesis/simtrace/host]> sudo ./simtrace
simtrace - GSM SIM and smartcard tracing
(C) 2010 by Harald Welte <laforge@gnumonks.org>

Entering main loop
ATR APDU: 3b 9f 96 80 1f c6 80 31 e0 73 fe 21 1b 66 d0 02 06 e2 0f 18 01 f0
PPS(Fi=9/Di=6) APDU: 00 a4 00 04 02 3f 00 61 2e
APDU: 00 c0 00 00 2e 62 2c 82 02 78 21 83 02 3f 00 a5 09 80 01 61 83 04 00 00 57 6a 8a 01 05 8b 03
APDU: 00 a4 00 0c 02 2f e2 90 00
APDU: 00 b0 00 00 0a 98 94 20 00 00 21 09 68 85 19 90 00
APDU: 00 a4 00 04 02 2f 05 61 1e
APDU: 00 c0 00 00 1e 62 1c 82 02 41 21 83 02 2f 05 a5 03 80 01 61 8a 01 05 8b 03 2f 04 04 02 00 08
APDU: a4 00 04 02 a4 2f 06
APDU: 61 21 00 c0 00 00 21
APDU: c0 62 1f 82 05 42 21
APDU: 00 38 08 83 02 2f 06
APDU: a5 03 80 01 61 8a 01
APDU: 05 8b 03 2f 06 01 80
APDU: 02 01 c0 88 01 30 90
APDU: 00 00 b2 04 04 38 b2
APDU: 80 01 18 a4 06 83 01
APDU: 0b 95 01 08 80 01 02
APDU: a0 18 a4 06 83 01 01
APDU: 95 01 08 a4 06 83 01
APDU: 0b 95 01 08 a4 06 83
APDU: 01 0c 95 01 08 80 01
APDU: 01 90 00 84 01 d4 a4
APDU: 06 83 01 0b 95 01 08
APDU: 90 00 00 a4 00 04 02
APDU: a4 2f 05 61 1e 00 c0
APDU: 00 00 1e c0 62 1c 82
APDU: 02 41 21 83 02 2f 05
APDU: a5 03 80 01 61 8a 01
APDU: 05 8b 03 2f 06 04 80
APDU: 02 00 08 88 01 28 90
APDU: 00 00 b0 00 00 08 b0
APDU: 64 65 65 6e ff ff ff
APDU: ff 90 00 80 10 00 00
APDU: 20 10 ff ff ff ff 7f
APDU: 9d 00 df ff 00 1f e2 00 00 00 c3 eb 00 00 00 01 48 00 50 00 00 00 00 08 00 00 60 91 0f 00 a4
83 02 2f 00 a5 03 80 01 61 8a 01 05 8b 03 2f 06 07 80 02 00 2c 88 01 f0 91 0f 00 a4 00 04 02 a4 2f
03 80 01 61 8a 01 05 8b 03 2f 06 01 80 02 01 c0 88 01 30 91 0f 00 b2 07 04 38 b2 80 01 1a a4 06 83
ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff 91 0f 00 a4 00 04 02 a4
```

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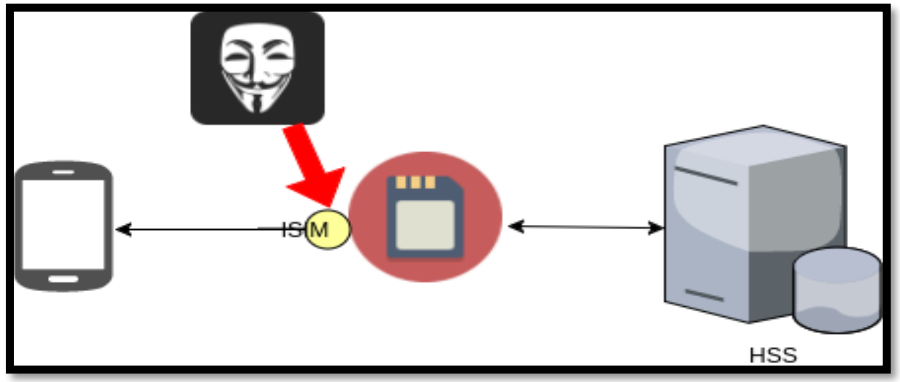
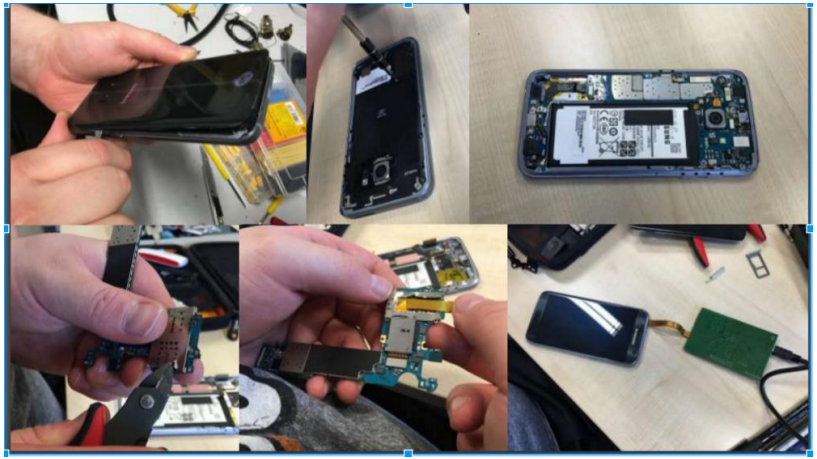
ISIM sniffing with SIMTrace





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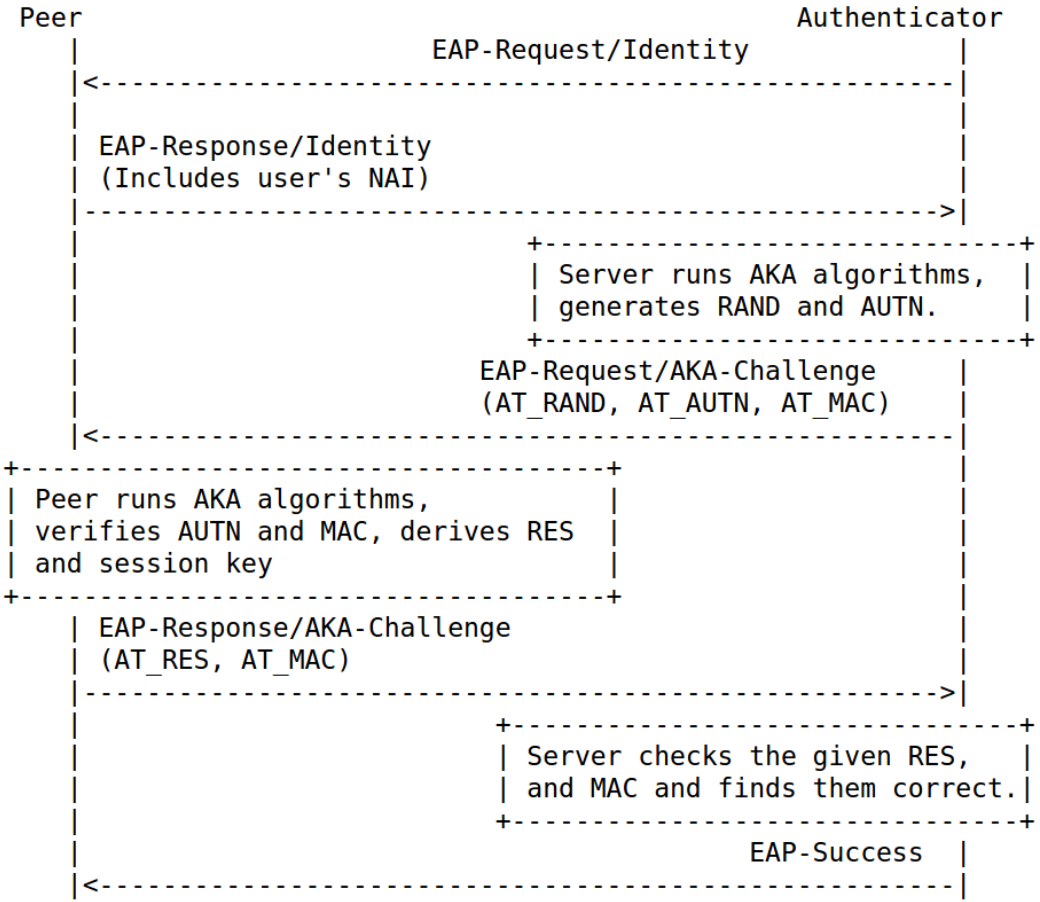
Security protocol: EAP-AKA



GSM SIM traffic

Source	Destination	sport	dport	Protocol	Info
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 UPDATE BINARY Offset=35072
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 SELECT File DF.GSM-ACCESS
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 SELECT File 4f52
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 GET RESPONSE
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 UPDATE BINARY Offset=0
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 SELECT File ADF
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 SELECT File EF.PSLOCI
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 GET RESPONSE
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 UPDATE BINARY Offset=0
127.0.0.1	127.0.1.1	49482	53	DNS	Standard query 0x5e58 A prx1.ernw.net
127.0.1.1	127.0.0.1	53	49482	DNS	Standard query response 0x5e58 A prx1.ernw.net A 62.159.96.83
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 UPDATE BINARY Offset=36608
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 UPDATE BINARY Offset=36608
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 SELECT /ADF
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 RUN GSM ALGORITHM / AUTHENTICATE
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 GET RESPONSE
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 UPDATE BINARY Offset=40448
127.0.0.1	127.0.0.1	42129	4729	GSM SIM	ISO/IEC 7816-4 UPDATE BINARY Offset=35584

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What can we find here?

- AKA parameters –
  - RAND - random challenge
  - AUTN – server authentication
- IPSec keys
  - IK – integrity key
  - CK – cyphering key

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How to extract it?

- Wireshark dissector

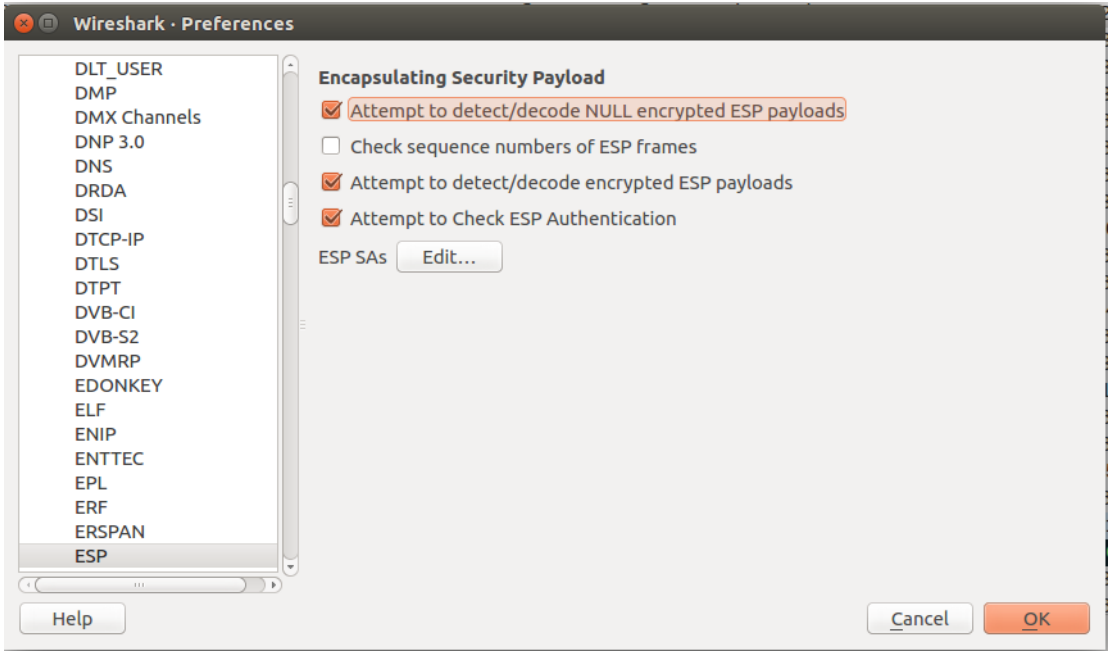
Byte(s)	Description	Length
1	'Successful 3G authentication' tag = 'DB'	1
2	Length of RES (L3)	1
3 to (L3+2)	RES	L3
(L3+3)	Length of CK (L4)	1
(L3+4) to (L3+L4+3)	CK	L4
(L3+L4+4)	Length of IK (L5)	1
(L3+L4+5) to (L3+L4+L5+4)	IK	L5

Table 4.4: Parsing the ISIM Authenticate response to get IK and CK

Result2: Extracting IK/CK

```
▸ User Datagram Protocol, Src Port: 52725 (52725), Dst Port: 4729 (4729)
▾ GSM SIM 11.11
    0000 .... = Class Coding: ISO/IEC 7816-4 (0x00)
    .... 00.. = Secure Messaging Indication: No SM used between terminal and card (0x00)
    .... ..00 = Logical Channel number: 0
    Instruction: GET RESPONSE (0xc0)
    Length of Expected Response Data: 53
    RES Length: 08
    RES Value: f74105e9ac41cc7a
    CK Length: 10
    CK: 3ee2824f414d4be3ddea7807a68632fa
    IK Length: 10
    IK : 347c59d30bba9f1968285908f89f996c
    Status Word: 9000 Normal ending of the command
```

Are the keys used in ESP?



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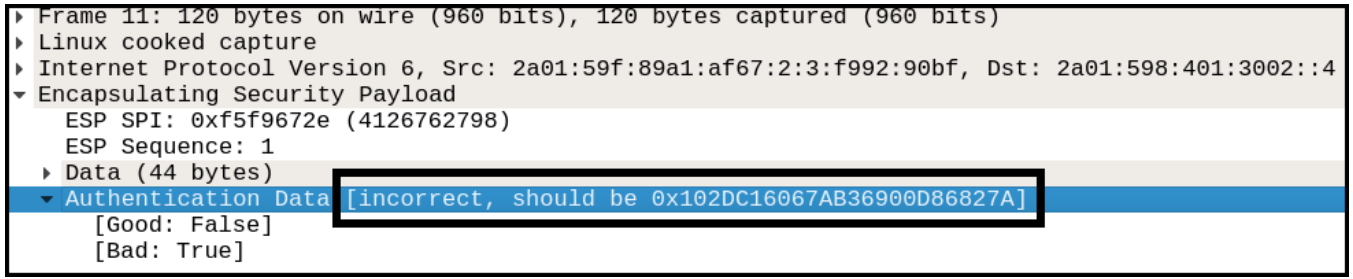
Failed authentication



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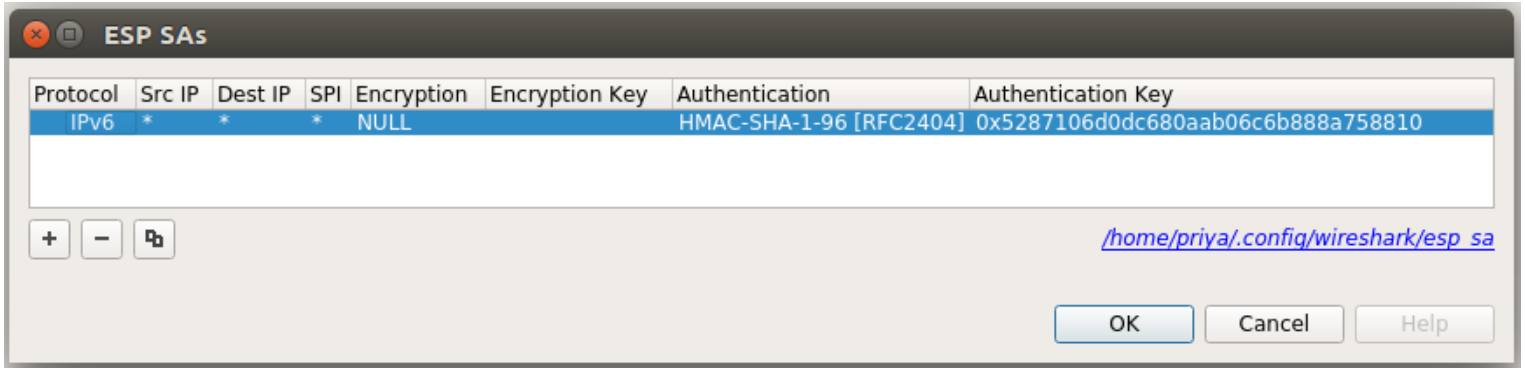
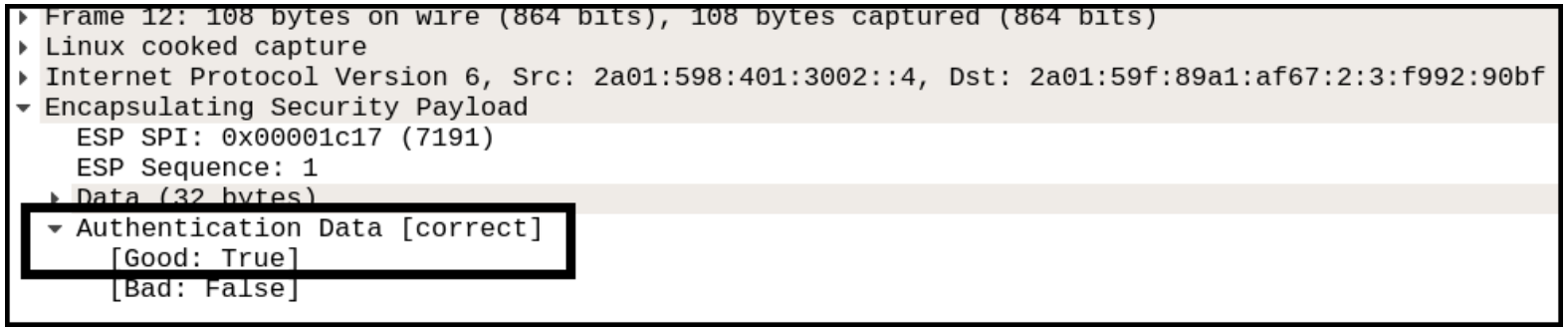
Set up SA with obtained IK



Success: Key validation



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Summary: Testing UE

- Test1: Sniffing VoLTE/VoWiFi interfaces
  - Use case identification
  - Results: Information disclosures like **IMEI, IMSI, private IPs**.
- Test2: ISIM sniffing with SIMTrace
  - Result: IK/CK
  - Wireshark dissector for extraction
  - Validation using Wireshark Gcrypt with authentication check in ESP

Simple demo of replay attack of SIP INVITE in a hidden non-IPSec channel

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Final Summary

- Current implementations of VoLTE/VoWiFi make use of IPSec
- 4 experimental attacks on OpenIMS without ipsec
- Sniffing on VoLTE/VoWiFi interfaces with ipsec
  - Information disclosures identified
- ISIM Sniffing with SIMTrace
- Wireshark dissector
  - Extracted CK/IK
  - Verified obtained IK with wireshark Gcrypt

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Mitigation

- **Never rely on user end security**
- Traffic monitoring
  - In PDN gateways that performs deep packet inspection
  - Whitelist rules in place that determines the expected value in each SIP header field.
- Encryption
  - To protect against info disclosures

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```
##IPTABLES ON ANDROID TO ROUTE TRAFFIC TO LAPTOP AND BACK

iptables -F
iptables -t nat -F
echo 1 > /proc/sys/net/ipv4/ip_forward
RMNET=`ip addr show dev rmnet1 |grep -oE "([0-9]{1,3}\.){3}[0-9]{1,3}"`
WLAN=`ip addr show dev wlan0 | grep inet | grep -oE "([0-9]{1,3}\.){3}[0-9]{1,3}" | grep -v 255`
IMS="10.0.0.1"
MITM="192.168.0.2"
iptables -t nat -A OUTPUT -d $IMS -j DNAT  --to-destination $MITM
iptables -t nat -A POSTROUTING -o wlan0 -d $MITM   -j SNAT --to-source $WLAN
iptables -t nat -A POSTROUTING -o rmnet1 -s $MITM  -d $IMS -j SNAT --to-source $RMNET
iptables -t nat -L -vn
```

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Questions?

White paper:
https://www.ernw.de/download/newsletter/ERNW_Whitepaper_60_Practical_Attacks_On_VoLTE_And_VoWiFi_v1.0.pdf

Thanks to Hendrik, my mentor.

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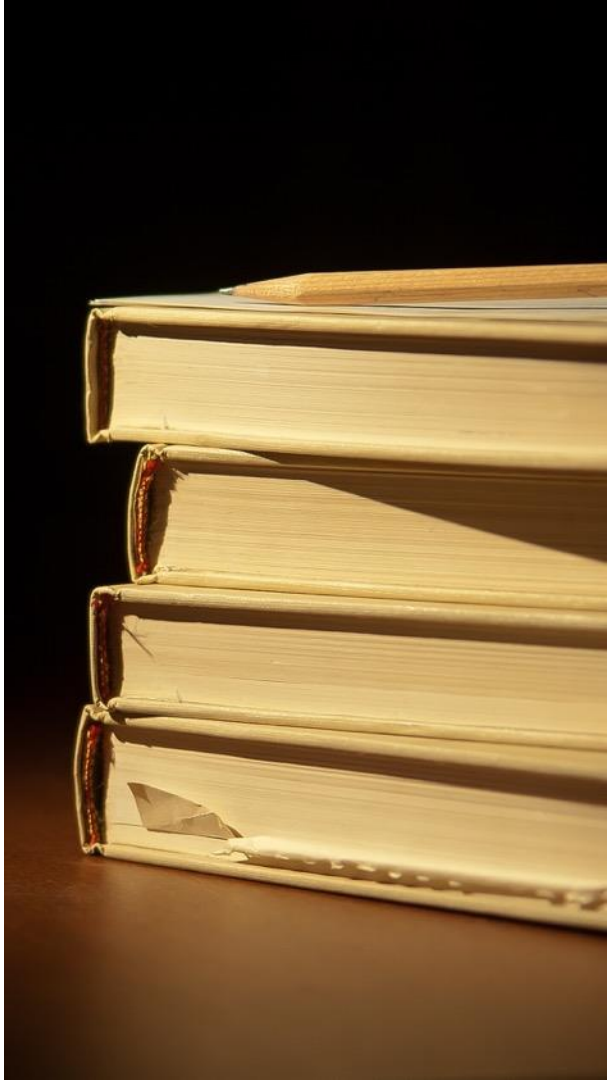
Additional slides below



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Related Work

- IMS-
  - Fatih Ozvaci : VoIP wars, Viproy toolkit - fake software updates, injected XSS, bogus content types, fuzzing and eavesdropping attacks
  - Ahmad Abolhadid – IMS testing - spoofing, DoS and location manipulation
- VoLTE
  - Li et al. **free data service** (ICMP packet encapsulation that gets forwarded from 4G gateway directly to the Internet), DoS through the signaling bearer .

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Related work

- VoLTE
  - Tu et al. - **DoS attack** where attacker makes 50 consequent VoLTE calls and hangs up.
  - Kim et al. **Side channel attack** to bypass IMS and about **permission mismatch issue** in android VoLTE telephony apps
- AKA
  - Ravi et al – WiFi based IMSI catcher

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VoLTE components

- Mobility Management Entity (MME)
  - a management entity that accounts for main control element for mobility in a LTE network
- Serving Gateway
  - a user plane proxy for 3GPP mobility over 2G,3G and LTE accesses
- PDN Gateway
  - user plane anchor between 3GPP and non-3GPP accesses

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VoWiFi components

- ePDG
  - a termination node of IPsec tunnels established with the UE
- PDN Gateway
  - user plane anchor between 3GPP and non-3GPP accesses

IP Multimedia Subsystem (IMS)

- CSCF
  - Proxy call session control function
  - Interrogating call session control function
  - Serving call session control function
  - Emergency call session control function

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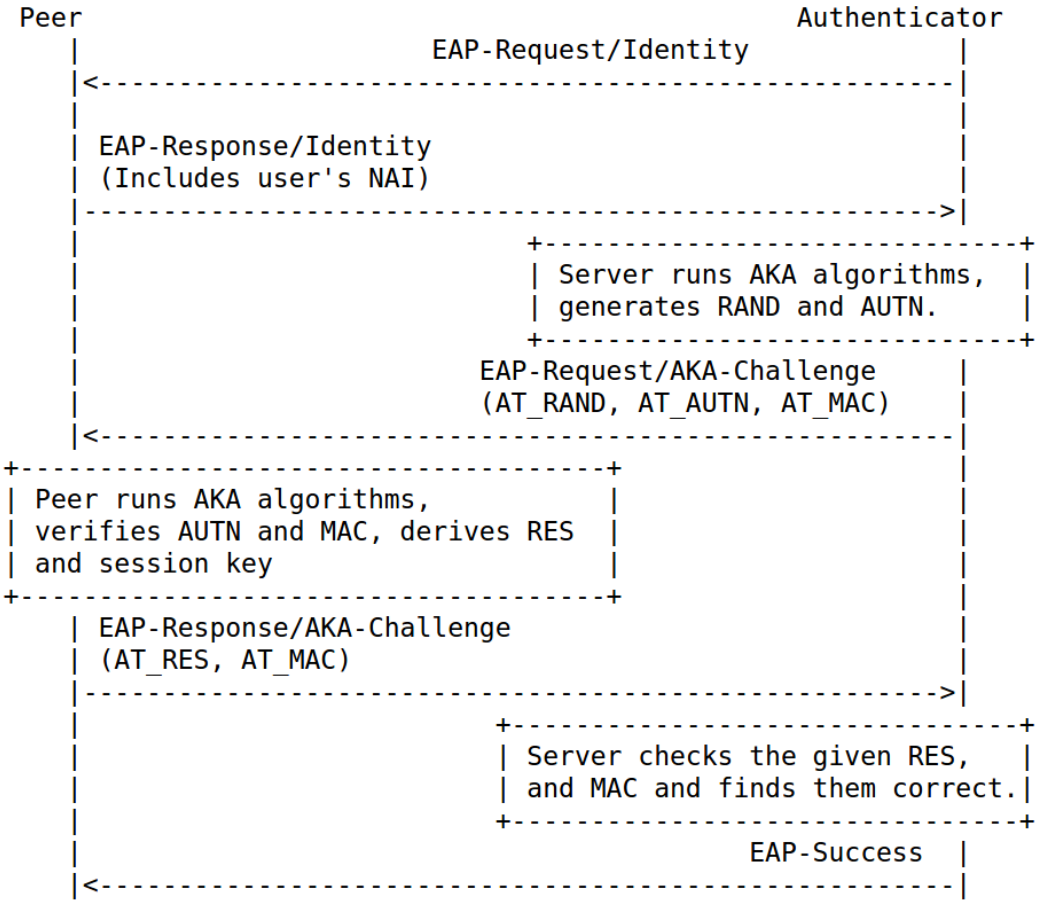
Security protocol: EAP-AKA



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Security protocols: IKE and ESP

Protocol	Length	Info
ISAKMP	374	IKE_SA_INIT MID=00 Initiator Request
ISAKMP	94	IKE_SA_INIT MID=00 Responder Response
ISAKMP	398	IKE_SA_INIT MID=00 Initiator Request
ISAKMP	330	IKE_SA_INIT MID=00 Responder Response
ISAKMP	442	IKE_AUTH MID=01 Initiator Request
ISAKMP	186	IKE_AUTH MID=01 Responder Response
ISAKMP	186	IKE_AUTH MID=02 Initiator Request
ISAKMP	218	IKE_AUTH MID=02 Responder Response
ISAKMP	154	IKE_AUTH MID=03 Initiator Request
ISAKMP	122	IKE_AUTH MID=03 Responder Response
ISAKMP	138	IKE_AUTH MID=04 Initiator Request
ISAKMP	474	IKE_AUTH MID=04 Responder Response
ESP	174	ESP (SPI=0x1a28cded)
ESP	158	ESP (SPI=0x784dd6a2)
ESP	142	ESP (SPI=0x1a28cded)
ESP	1422	ESP (SPI=0x1a28cded)
ESP	494	ESP (SPI=0x1a28cded)
ESP	142	ESP (SPI=0x784dd6a2)
ESP	142	ESP (SPI=0x784dd6a2)
ESP	1006	ESP (SPI=0x784dd6a2)
ESP	142	ESP (SPI=0x1a28cded)
ESP	190	ESP (SPI=0x1a28cded)
ESP	174	ESP (SPI=0x784dd6a2)

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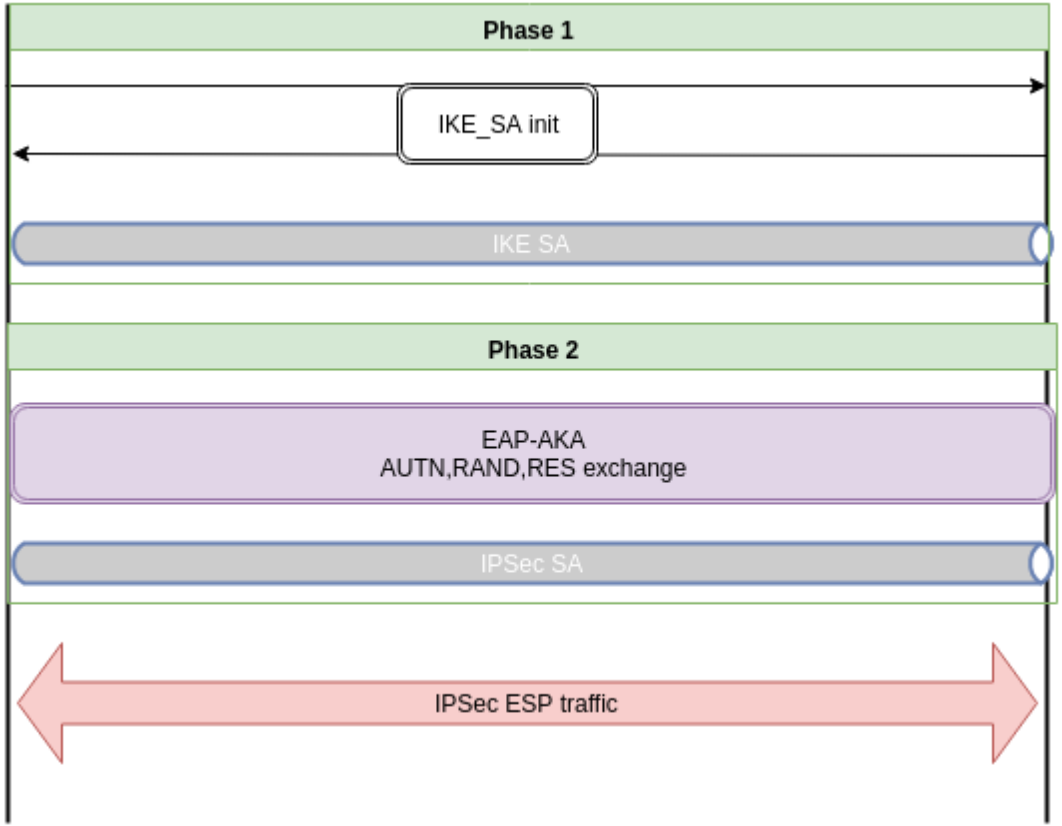
Security protocols: IKE and AKA



Other tests/Analysis

- Routing Technique for Mobile Clients
  - Use IPTABLES
  - Route the traffic from mobile to our desktop
  - Perform the injection using tools like Burp
  - Send the packet back to mobile client which then send the packet via LTE/WiFi to IMS

Service	Telekom S6	Telekom S7	O2 S6	O2 S7
VoWiFi	Yes	No	No	No
VoLTE	Yes	Yes	No	Yes

Table 4.1: VoLTE/VoWiFi feature support in Telekom and O2

Use Cases	Status
VoLTE to VoLTE	Call: ✗, Message: ✓
VoLTE to VoWiFi	Call: ✓, Message: ✓
VoWiFi to VoLTE	Call: ✗, Message: ✓
VoLTE to PSTN	Call: ✓, Message: ✓
VoWiFi to PSTN	Call: ✓, Message: ✓
PSTN to VoWiFi	Call: ✓, Message: ✓
VoWiFi to VoWiFi	Call: ✓, Message: ✓

Table 4.2: VoLTE/VoWiFi usecase identification for Telekom.