LTE and IMSI catcher myths

Ravishankar Borgaonkar, Altaf Shaik, N. Asokan, Valtteri Niemi, Jean-Pierre Seifert

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Aalto University

berlin

UNIVERSITY OF HELSINKI

Outline

- Fake base stations in GSM/3G
- LTE/4G Security
- Types of vulnerabilities in practice
- Building LTE/4G base station
- Attacking methods/demos
- Impact & Analysis

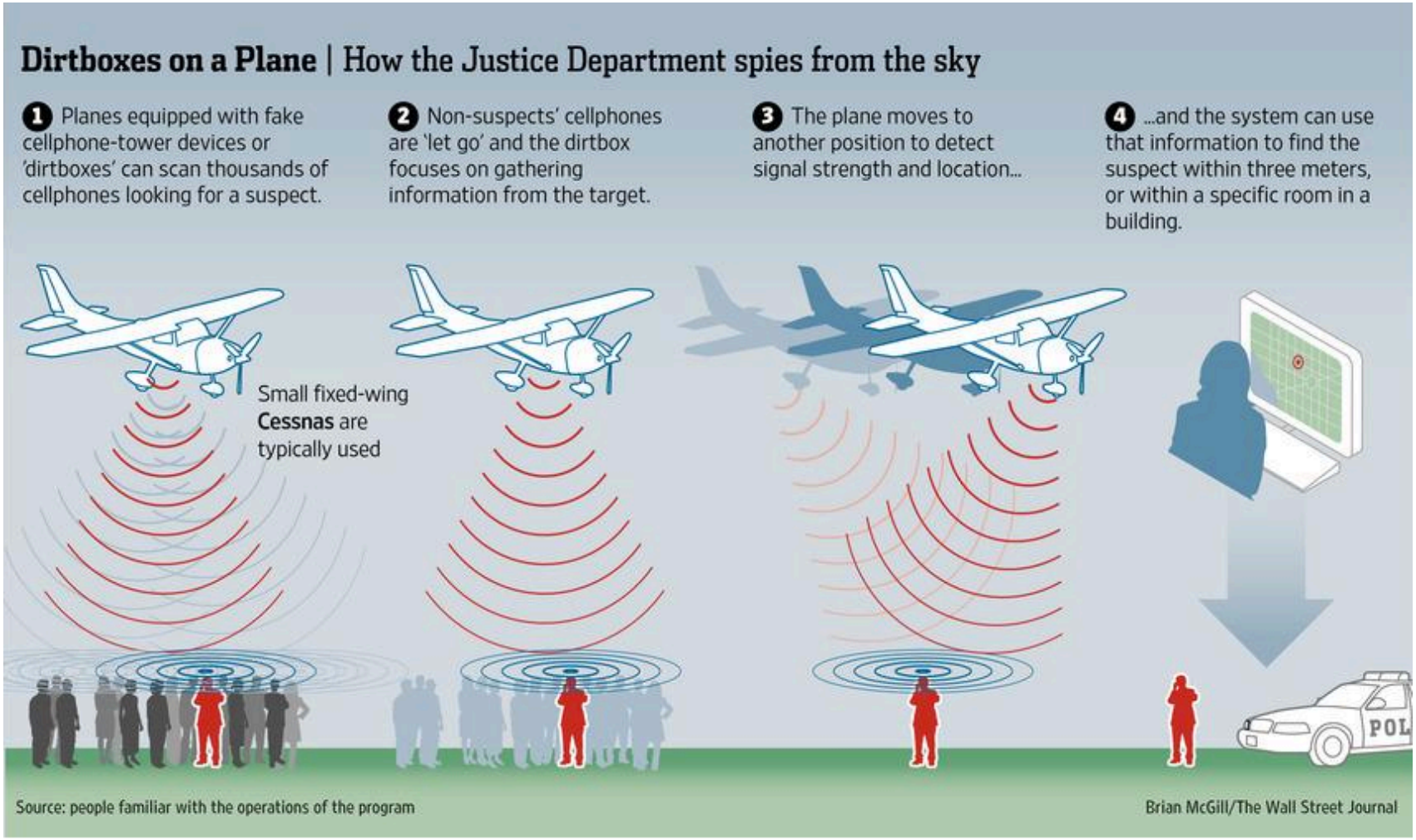
Motivation

- Baseband story
- Platform for practical security research in LTE/4G
- Attacking cost VS security measures (defined in 15 years back)

Fake base-stations..1

- Used for: IMSI/IMEI/location tracking, call & data interception
- Exploit weaknesses in GSM & 3G networks (partially)
- Knows as IMSI Catchers
- Difficult to detect on normal phones (Darshak, Cryptophone or Snoopsnitch)

Fake base-stations..2



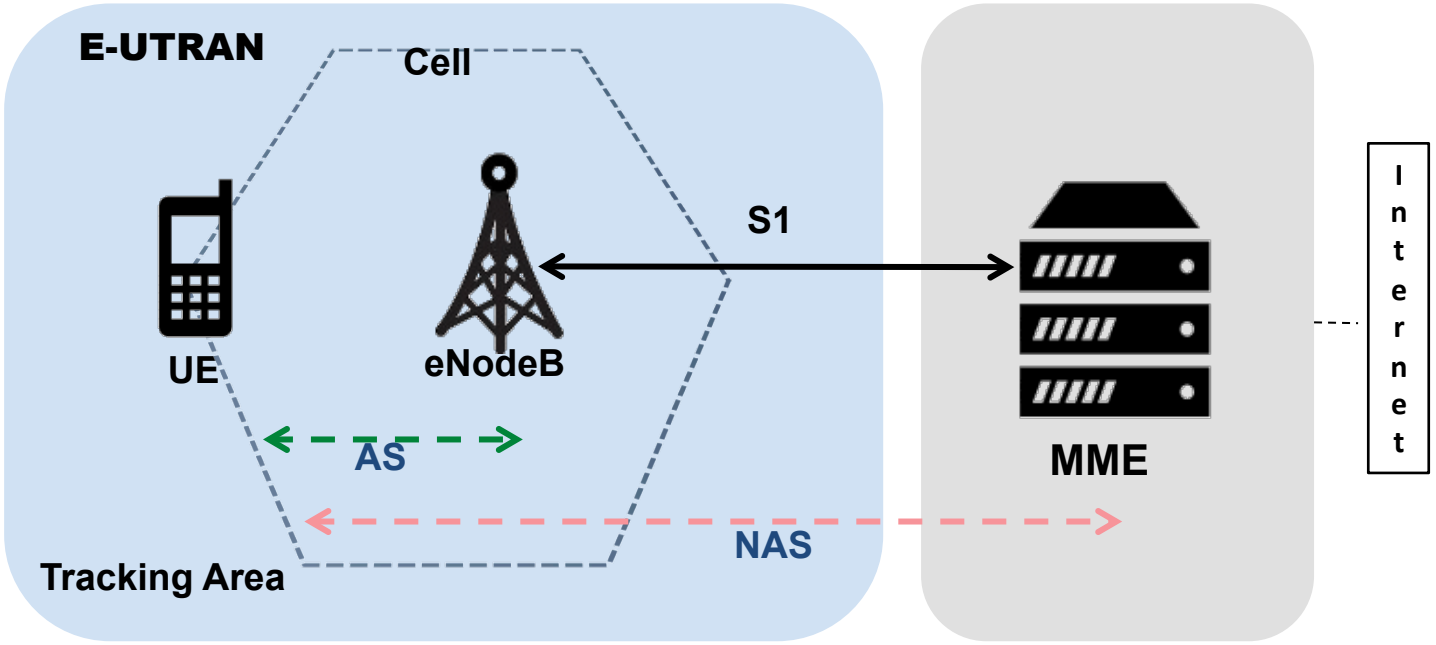
Why in GSM & 3G

- GSM - lack of mutual authentication between base station and mobiles
- 3G – no integrity protection like in LTE, downgrade attacks
- GSM/3G – power is to base station, decides when and how to authenticate/encrypt
- IMSI/IMEI can be requested any time

LTE/4G networks

- Widely deployed, 1.37 billion users at the end of 2015
- Support for VoLTE
- High speed data connection and quality of service
- More secure than previous generations
- Best effort to avoid previous mistakes

LTE Architecture



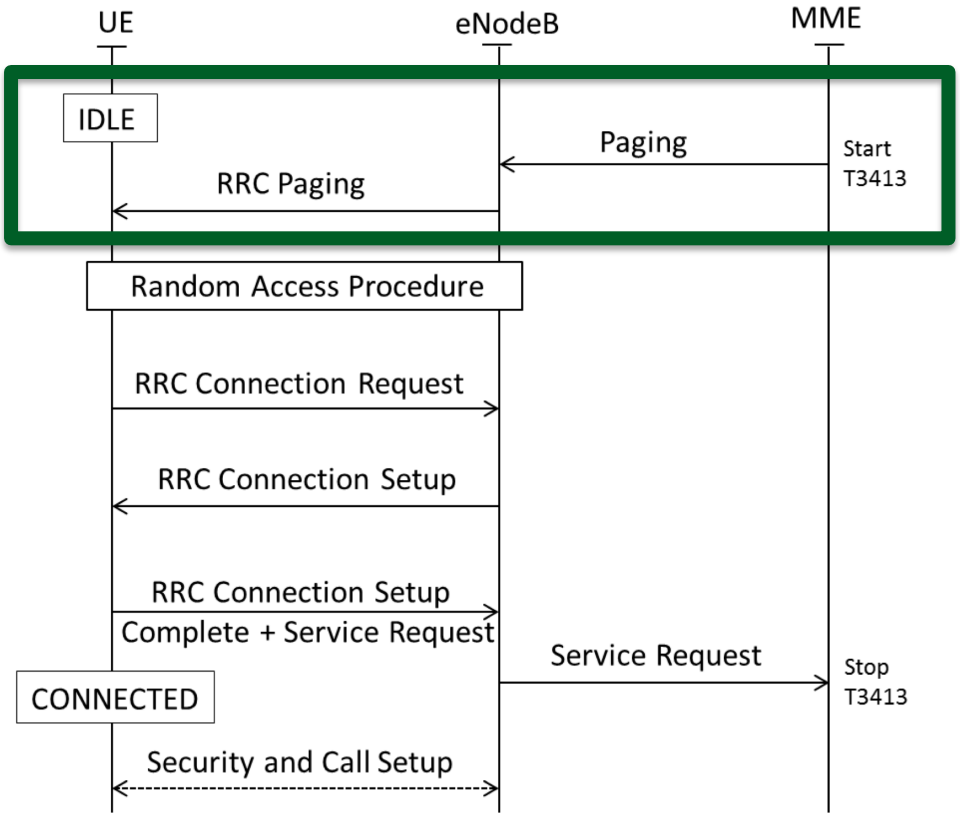
AS : Access Stratum
NAS : Non-Access Stratum
E-UTRAN: Evolved Universal Terrestrial Access Network

UE: User Equipment
S1 : Interface
MME : Mobility Management Entity

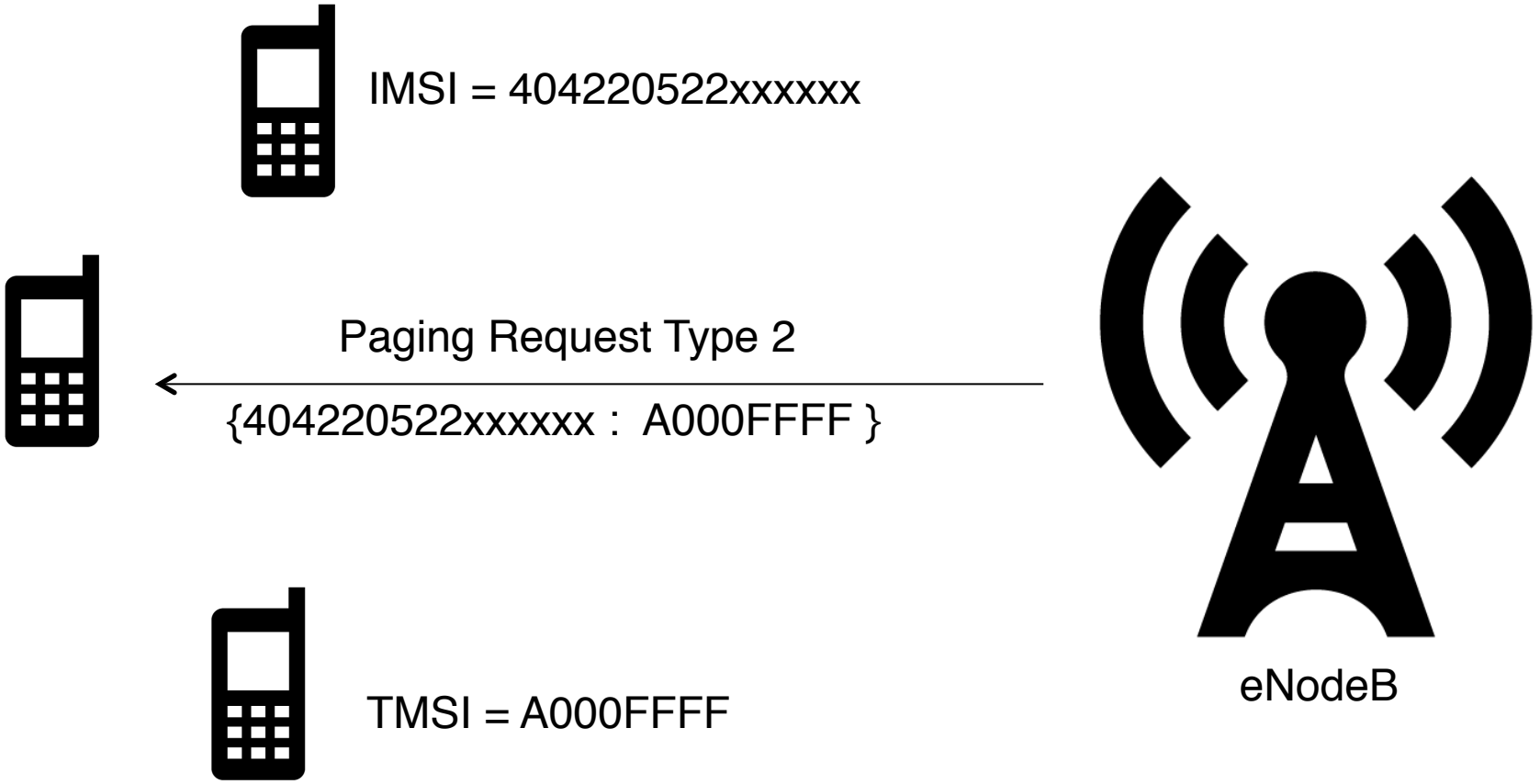
Enhanced security in LTE

- Mutual authentication between base station & mobiles
- Mandatory integrity protection for signaling messages
- Extended AKA & key hierarchy
- Security algorithms
- Other features (not relevant for this talk)

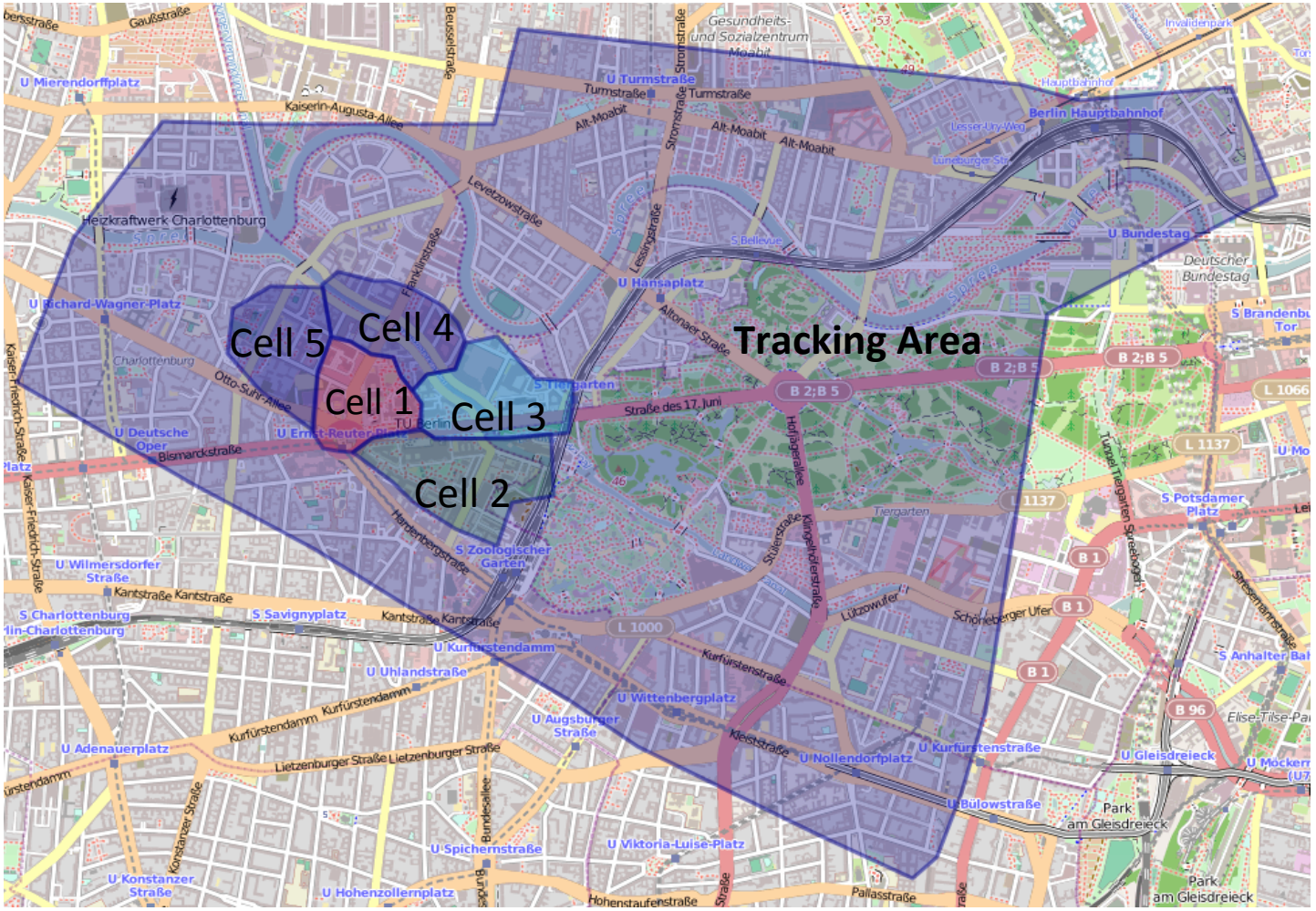
Paging in LTE



Paging in LTE



LTE Smart Paging



Enhanced security w.r.t fake base station

- Mutual authentication between base station & mobiles
- Mandatory integrity protection for signaling messages
- IMEI is not given in non-integrity messages
- Complexity in building LTE fake base station*
- But in practice:
  - ✓ implementations flaws, specification/protocol deficiencies?

* https://insidersurveillance.com/rayzone-piranha-lte-imsi-catcher/

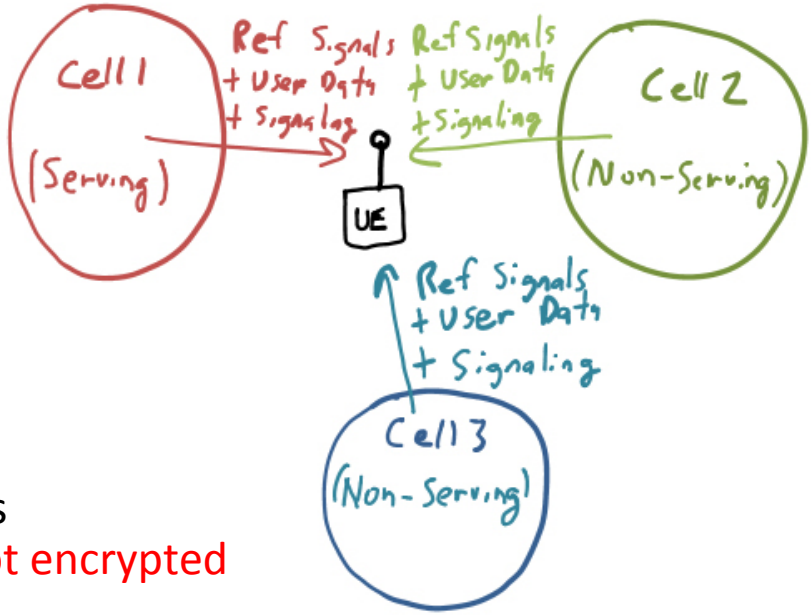
Specification Vulnerabilities

LTE RRC protocol* : specification vulnerability

RRC protocol – setup & manage over-the-air connectivity!

- Broadcast information
  - ✓ UE identities
  - ✓ Network information (SIB) messages
  - ✓ Neither authenticated nor encrypted

- UE measurement reports
  - ✓ Necessary for smooth handovers
  - ✓ UE sends "Measurement Report" messages
  - ✓ Requests not authenticated: reports are not encrypted



*3GPP TS 36.331 : E-UTRA; RRC protocol
Fig. source: http://lteuniversity.com/

LTE RRC protocol* : specification vulnerability

RRC protocol – setup & manage over-the-air connectivity!

- Broadcast information
- UE Identities – IMSI, TMSI
- Network information messages (SIB)
- Neither authenticated nor encrypted

eNodeB

*3GPP TS 36.331 : E-UTRA; RRC protocol
SIB : System Information Blocks

EMM protocol* : specification vulnerability

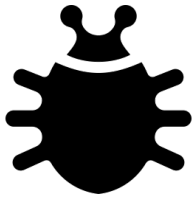
EMM protocol - Controlling UE mobility in LTE network!

- Tracking Area Update(TAU) procedure
  - ✓ UE sends "TAU Request" to notify TA
  - ✓ During TAU, MME & UE agree on network mode
  - ✓ "TAU Reject" used to reject some services services (e.g., LTE services) to UE
  - ✓ However, reject messages are not integrity protected

- LTE Attach procedure
  - ✓ UE sends its network capabilities
  - ✓ Unlike security algorithms, no protection
  - ✓ Network capabilities are not protected against bidding down attacks

Vulnerabilities in baseband chipset

IMEI leak : implementation vulnerability

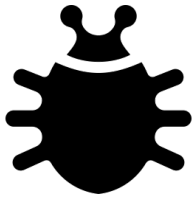


TAU reject – special cause number!

- IMEI is leaked by popular phones
- Triggered by a special message
- Fixed now but still your device leak ;)
- IMEI request not authenticated correctly

```
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: Identity response (0x56)
    Mobile identity - IMEI (357506057669310)
        Length: 8
        0011 .... = Identity Digit 1: 3
        .... 1... = Odd/even indication: Odd number of identity digits
        .... .010 = Mobile Identity Type: IMEI (2)
        BCD Digits: 357506057669310
```

LTE RRC* : implementation vulnerability



RLF reports – network troubleshooting!

- When Radio Link Failure happens
- Informs base station of RLF
- UE sends “RLF report” message
- Privacy sensitive information in RLF report
- Request not authenticated: reports are not encrypted

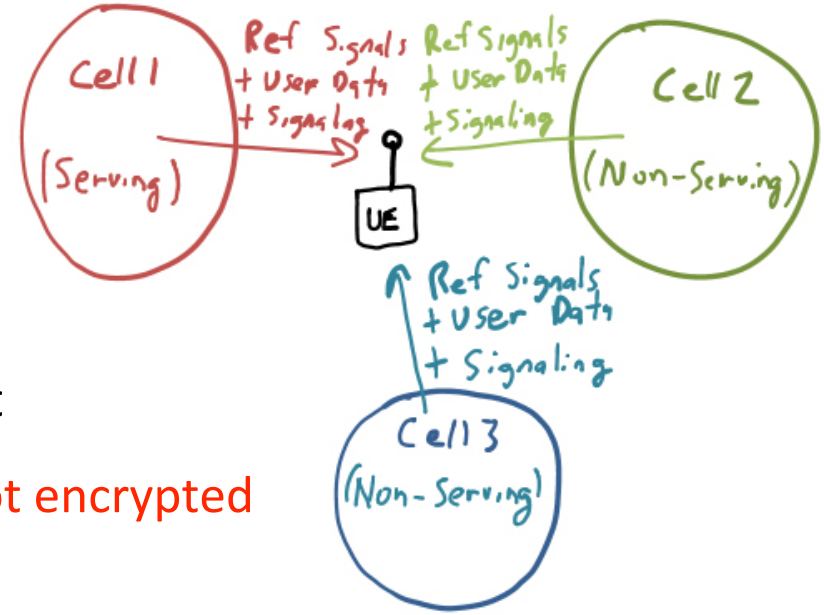
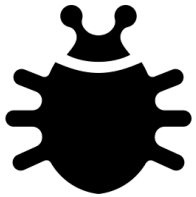


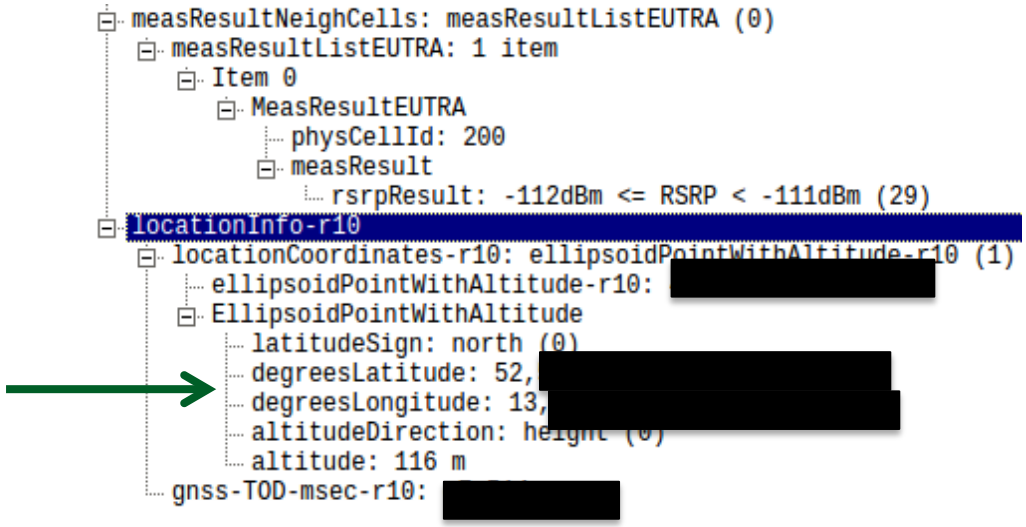
Fig. source: http://lteuniversity.com/

LTE RRC* : implementation vulnerability



Measurement reports – GPS co-ordinates!

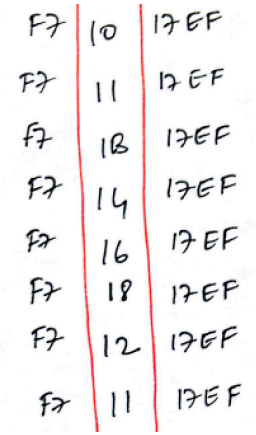
- For handover
- Privacy sensitive information in the report
- Request not authenticated
- reports are not encrypted



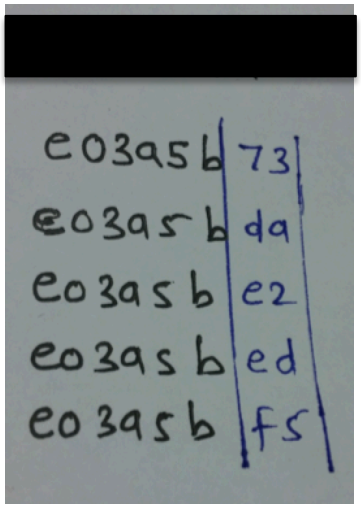
Network Configuration Issues

Configuration issues

Deployments all over the world!



- Smart Paging
  - ✓ Directed onto a small cell rather than a tracking area
  - ✓ Allows attacker to locate LTE subscriber in a cell
- GUTI persistence
  - ✓ GUTI change – handover/attach/reallocation procedure
  - ✓ MNOs tend not to change GUTI sufficiently frequently
- MME issues



Building 4G fake base station and attack demos

Ethical Consideration

Experiment Set-up

Set-up cost - little over 1000 Euro!

- Hardware – USRP, LTE dongle, LTE phones
- Software - OpenLTE & srsLTE
- Implementation – passive, semi-passive, active

Thanks to OpenLTE and srsLTE folks!

Location Leak Attacks

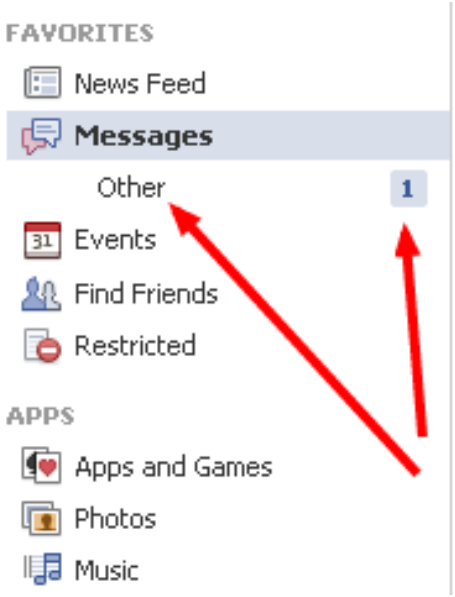
Exploit specification/implementation flaws in RRC protocol!

- Passive : link locations over time
  - ✓ Sniff IMSI/GUTIs at a location (e.g., Airport/home/office)
  - ✓ Track subscriber movements (same GUTI for several days)

Demo

Semi-Passive : determine tracking area & cell ID

- VoLTE calls: Mapping GUTIs to phone number
  - ✓ 10 silent calls to victim's number
  - ✓ High priority → paging to entire tracking area(TA)
  - ✓ Passive sniffer in a TA
- Social identities: Mapping GUTIs to Social Network IDs
  - ✓ E.g., 10 Facebook messages, whatsapp/viber
  - ✓ Low priority → Smart paging to a last seen cell
  - ✓ Passive sniffer in a cell

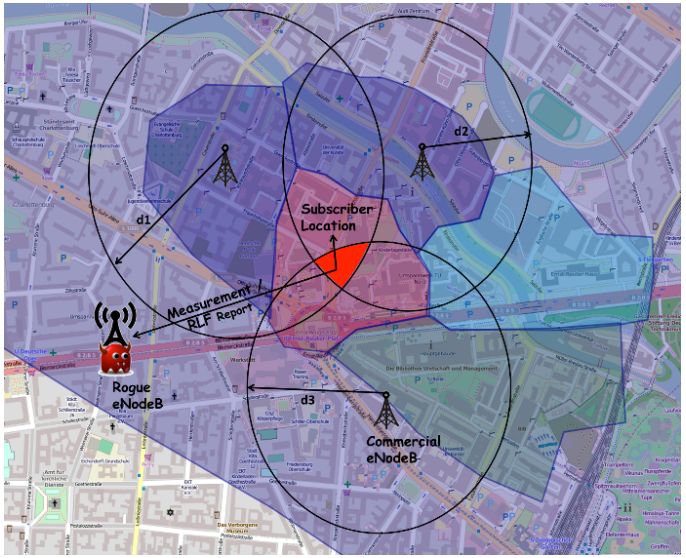


Demo

Active : leak fine-grained location

Precise location using trilateration or GPS !

- Measurement/RLF report
  - ✓ Two rogue eNodeBs for RLF
  - ✓ eNodeB1 triggers RL failure: disconnects mobile
  - ✓ eNodeB2 then requests RLF report from mobile

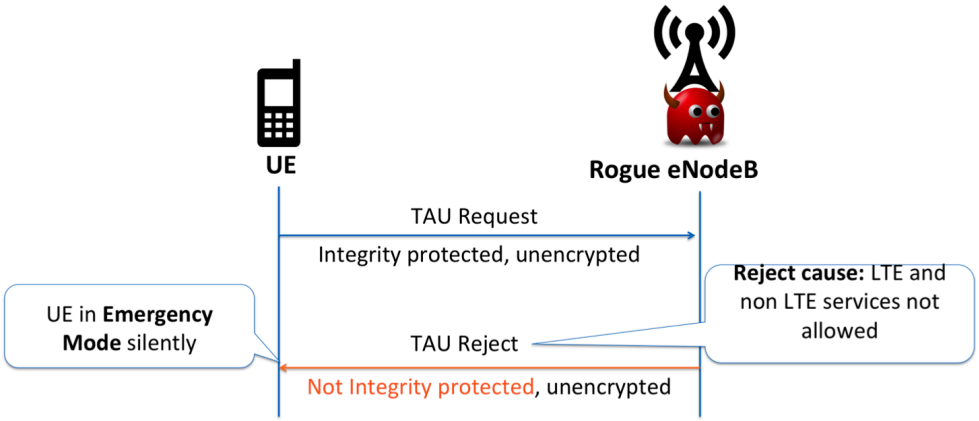


Demo

DoS Attacks

Exploiting specification vulnerability in EMM protocol!

- Downgrade to non-LTE network services (GSM/3G)
- Deny all services (GSM/3G/LTE)
- Deny selected services (block incoming calls)
- Persistent DoS
- Requires reboot/SIM re-insertion



Demo

Summary

- New vulnerabilities in LTE standards/chipsets
- Social applications used for silent tracking
- Locating 4G devices using trialternation , GPS co-ordinates!
- DoS attacks are persistent & silent to users
- Configuration issues in deployed LTE networks

Solution!

Use any old Nokia phone without battery and SIM card!

Impact

Specification vulnerabilities affect every LTE-enabled device!

- Implementation issues are (almost) fixed by baseband chip manufacturers ☺
- 3GPP/GSMA working on fixes
- However no updates from handset manufacturers yet ☹
- No response yet from MediaTek & Samsung ☹
- Mobile network operators (Germany) fixing their network configuration issues; others may affected as well ☹

Thanks

Questions?