Practical attacks against Privacy and Availability in 4G/LTE Mobile Communication Systems

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23 February 2016
NDSS 2016 San Diego USA

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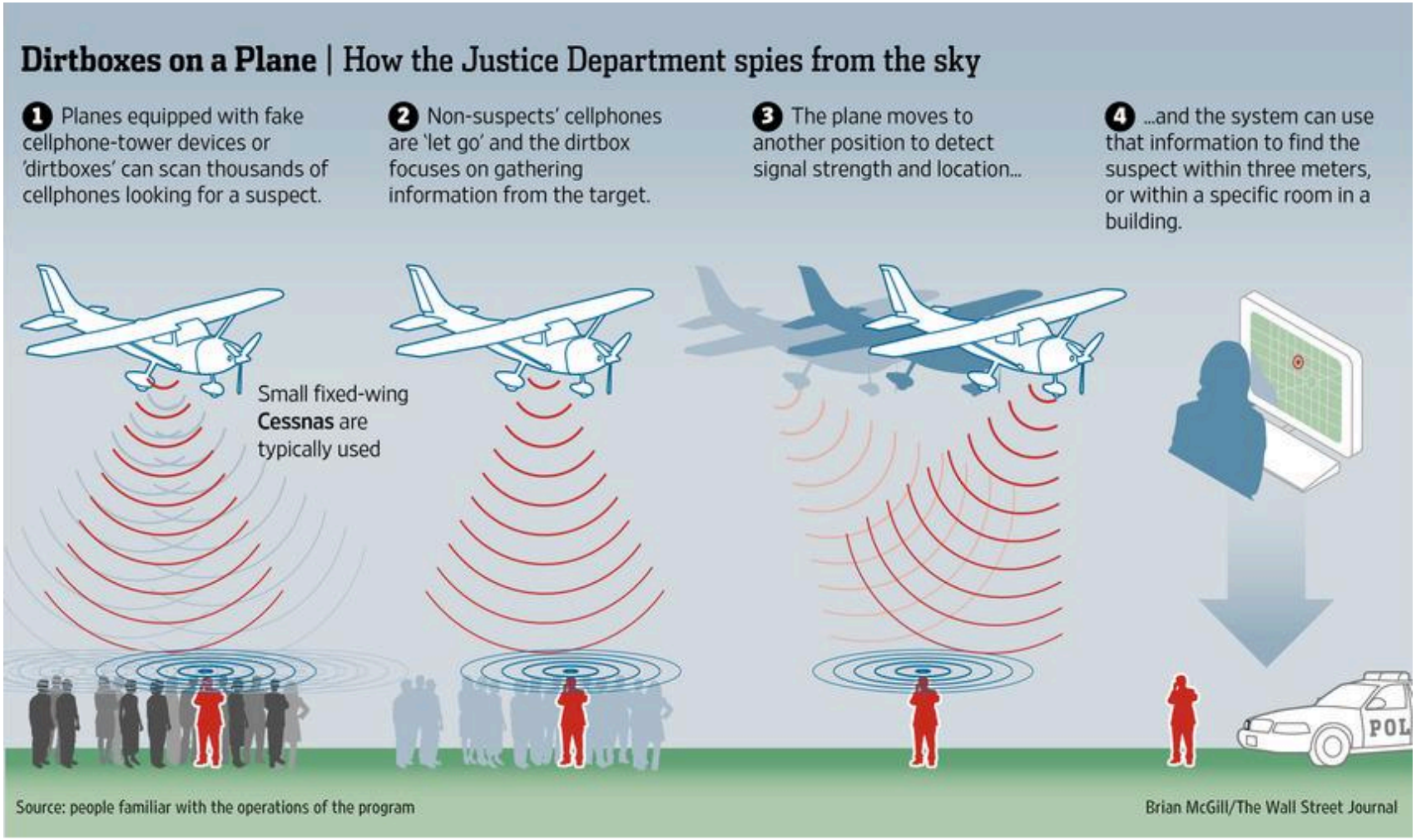
Outline

- Evolution of security in mobile networks
  - ✓ 2G/GSM, 3G/UMTS, 4G/LTE
- Practical attacks against 4G/LTE
  - ✓ Location leaks
  - ✓ Denial of service
- Potential reasons for vulnerabilities
- Impact

Fake base-stations..1

- Used for: IMSI/IMEI/location tracking, call & data interception
- Exploit weaknesses in 2G & 3G (partially)
- Knows as IMSI Catchers
- Difficult to detect on normal phones (Darshak, Cryptophone or Snoopsnitch)

Fake base-stations..2



4G/LTE

- Widely deployed, 1.37 billion users by end of 2015
- More secure than previous generations
- Best effort to avoid previous mistakes

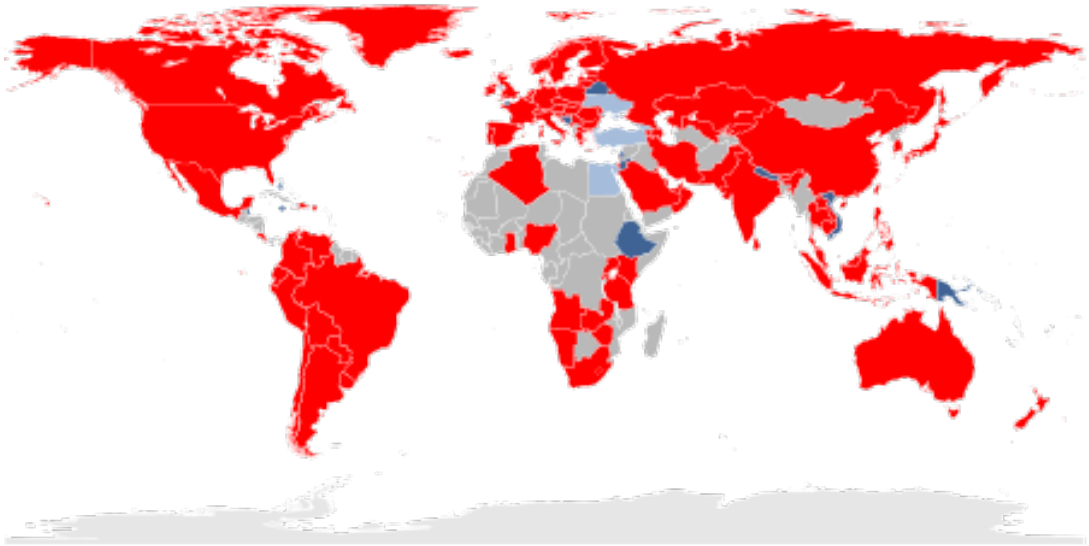
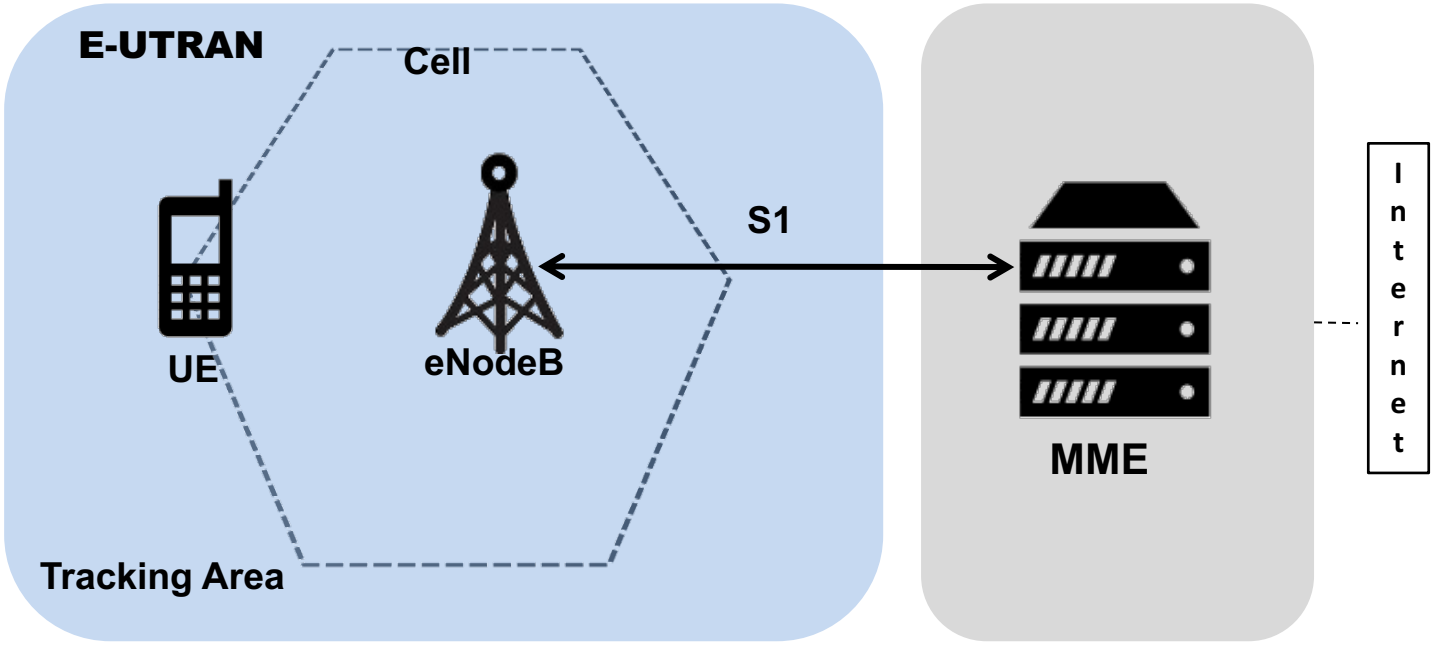


Fig. source: Wikipedia

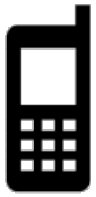
4G Architecture



eNodeB: Evolved Node B (“base station”)
E-UTRAN: Evolved Universal Terrestrial Access Network
MME : Mobility Management Entity

UE: User Equipment
S1 : Interface

Security evolution in mobile networks



Phone

no mutual authentication **2G**

mutual authentication
integrity protection **3G**

mutual authentication
deeper mandatory integrity protection **4G**

Base Station

decides encryption/authentication
requests IMSI/IMEI

Research Motivation

- Analysis of access network protocols and integrity protection in practice

- LTE fake base stations: thought to be complex* and less effective

- But in practice:
  - ✓ Implementation/configuration flaws, specification/protocol deficiencies?

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

Evaluating 4G Security: Experiment Set-up

Set-up cost - little over 1000 Euros!

- Hardware – USRP, 4G dongle, 4G phones
- Software – OpenLTE & srsLTE

Thanks to OpenLTE and srsLTE group!

Results

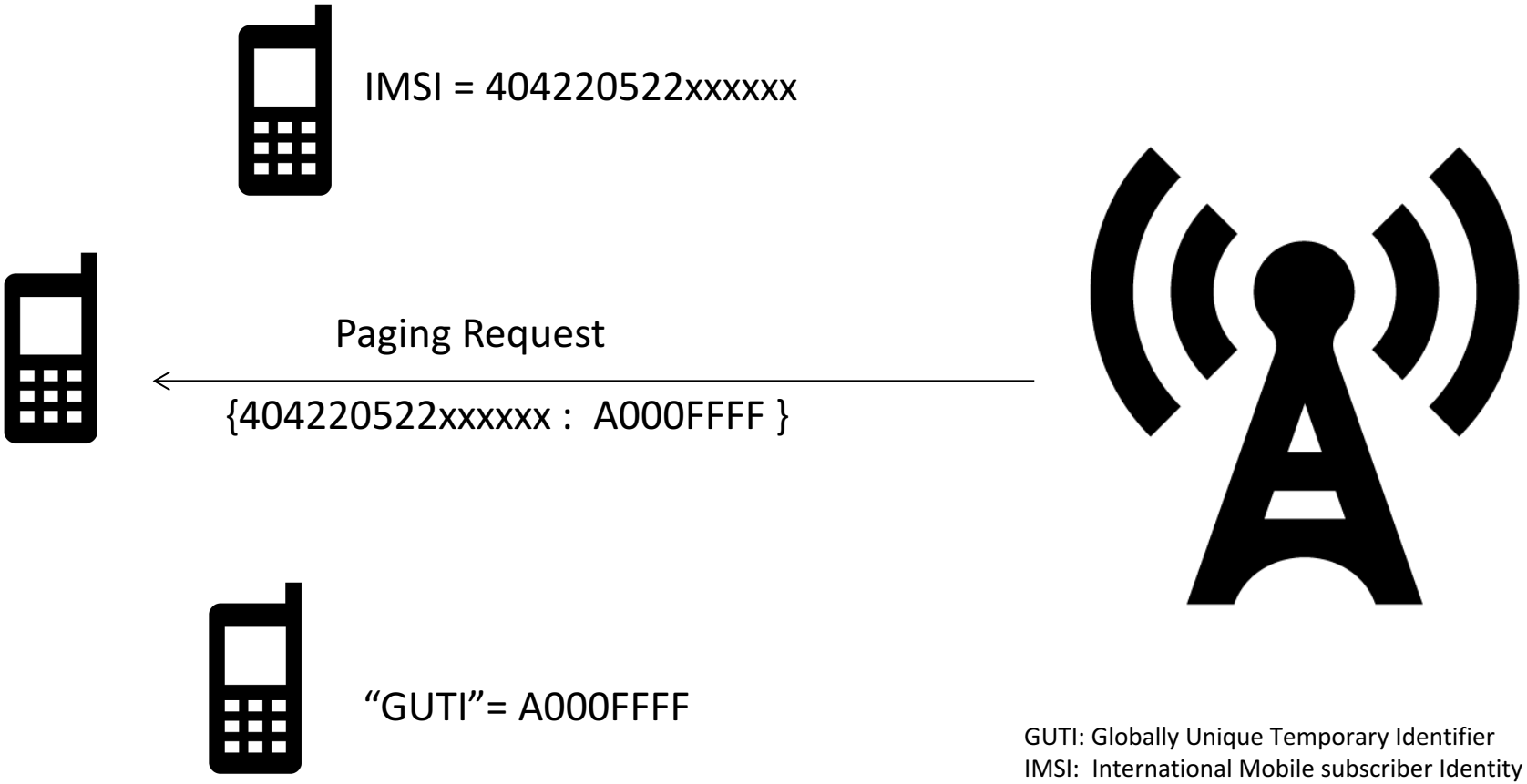
- Vulnerabilities in 4G specifications and networks
- Demonstrating impact by practical attacks
  - ✓ Location leaks
  - ✓ Denial-of-service

Relevant 4G Features

- (Smart) Paging
- Diagnostic Reports from UE
- Mobility Management

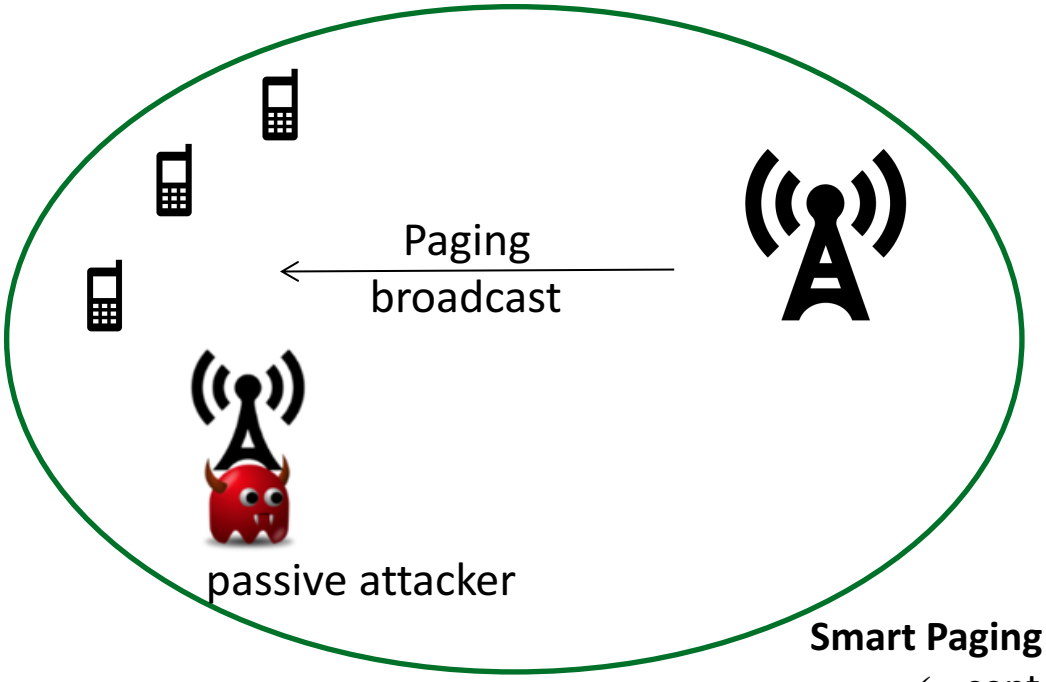
Feature: Paging in 4G

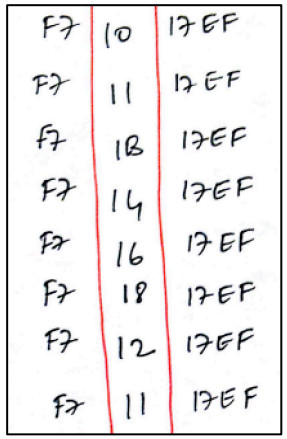
Why: locate subscriber to deliver calls/messages

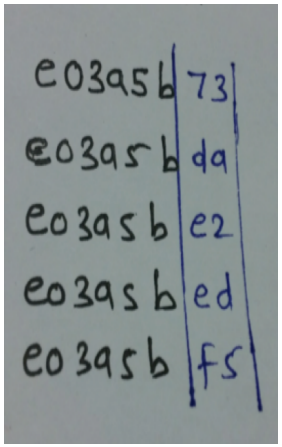


GUTI: Globally Unique Temporary Identifier
IMSI: International Mobile subscriber Identity

Paging configuration vulnerabilities







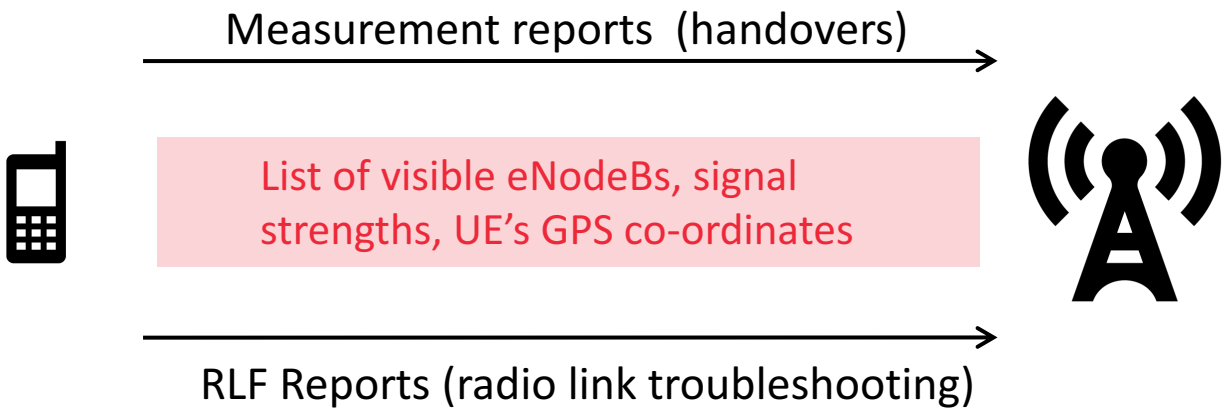
Smart Paging

- ✓ sent onto a small cell instead of a big tracking area
- ✓ Allows attacker to locate 4G subscriber in a cell

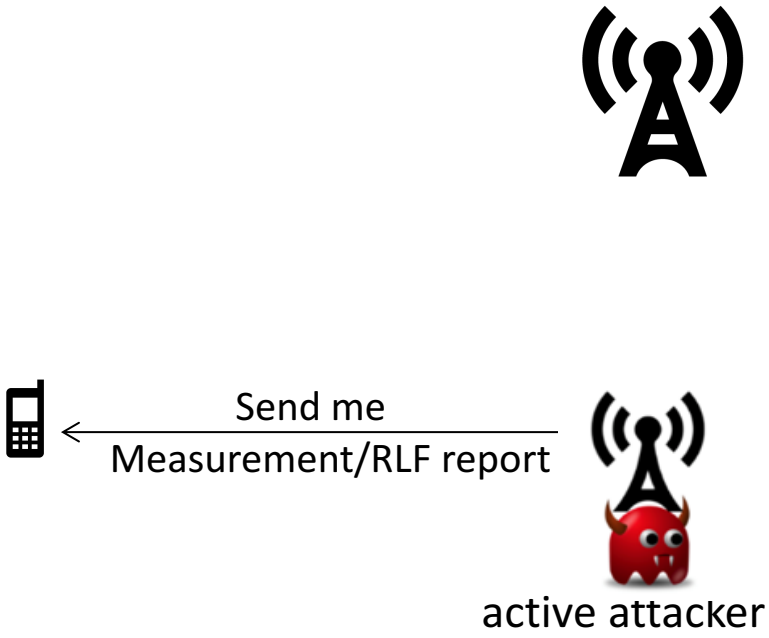
GUTI persistence

- ✓ MNOs don't change GUTI sufficiently & frequently

Feature: Reports from UE to eNodeB



Vulnerabilities in the feature



Specification

UE measurement reports

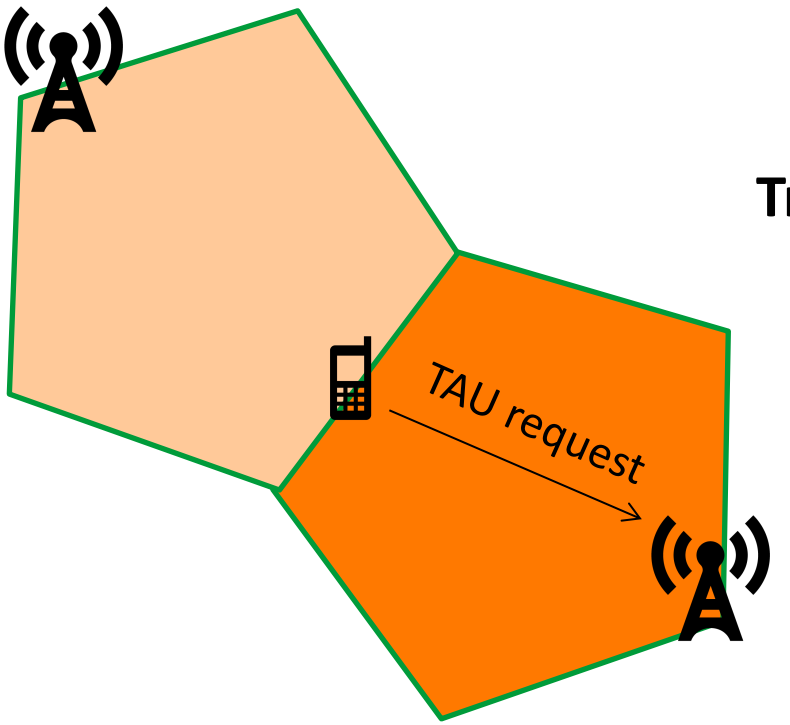
- ✓ Requests not authenticated
- ✓ Reports are not encrypted

Implementations

RLF reports

- ✓ Requests not authenticated
- ✓ Reports are not encrypted
- ✓ **All baseband vendors**

Feature: Mobility Management in 4G

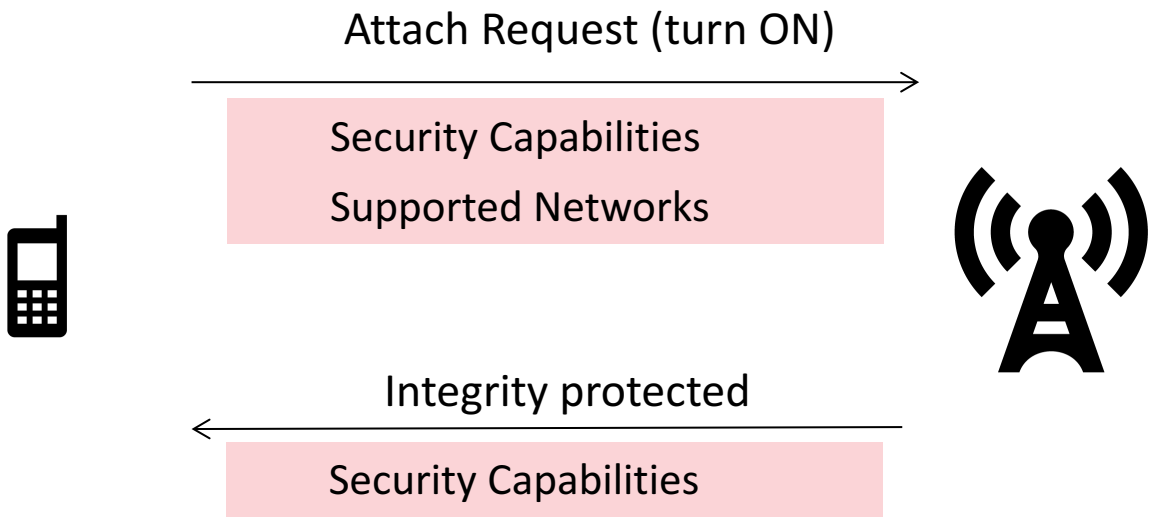


Tracking Area Update (TAU) procedure

- ✓ During TAU, MME & UE agree on network mode (2G/3G/4G)
- ✓ "TAU Reject" used to reject some services services (e.g., 4G) to UE

Specification vulnerability: Reject messages are not integrity protected

Feature: Mobility Management in 4G



Specification vulnerability:
Network capabilities not protected - bidding down attacks

Discovered Vulnerabilities in 4G

Specification

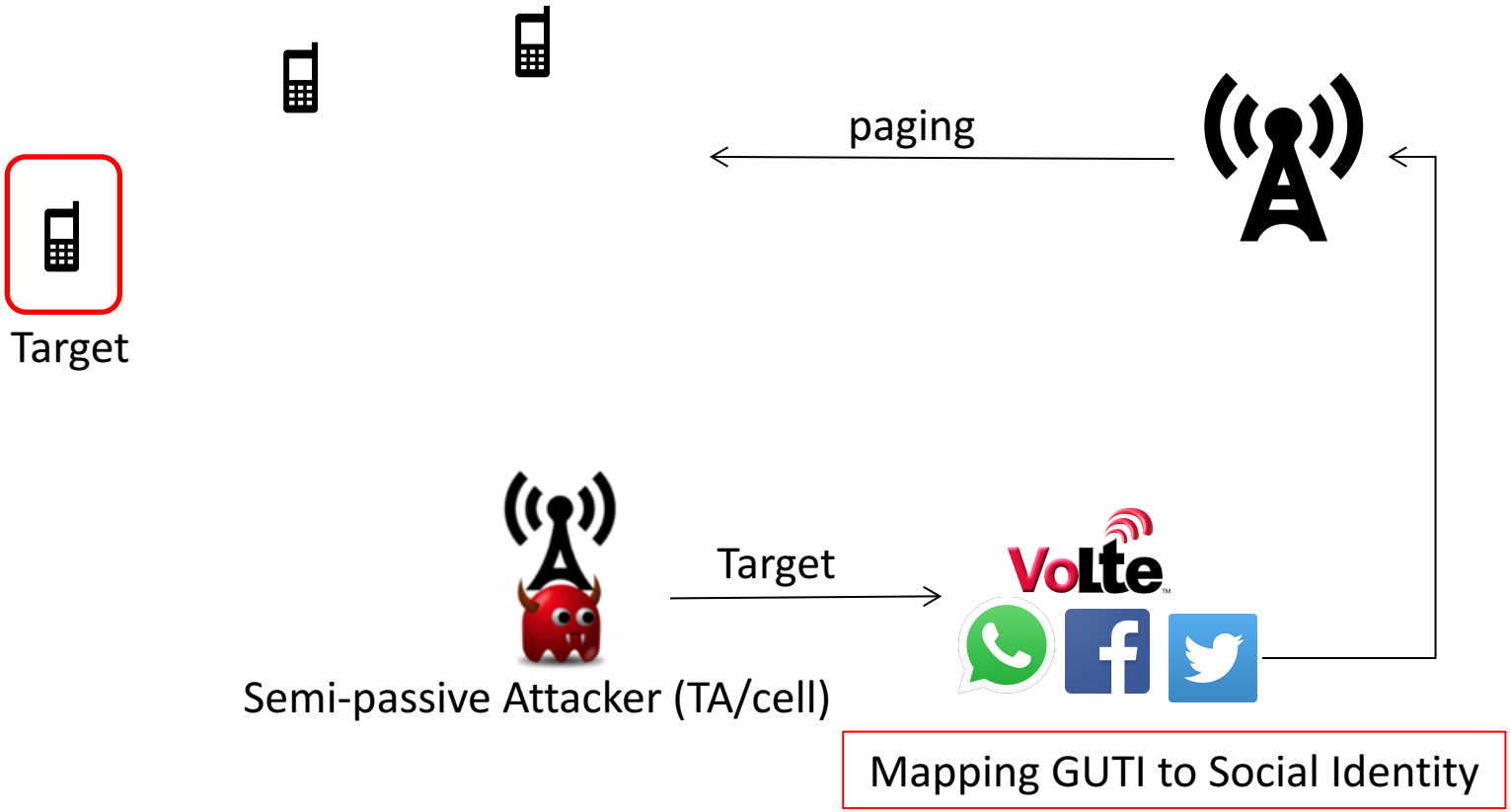
- UE measurement reports
  - ✓ Requests not authenticated: reports are not encrypted
- Tracking Area Update (TAU) procedure
  - ✓ Reject messages are not integrity protected
- Attach procedure
  - ✓ Network capabilities are not protected against bidding down attacks

Implementations: (all baseband vendors)

- RLF reports
  - ✓ Requests not authenticated: reports are not encrypted

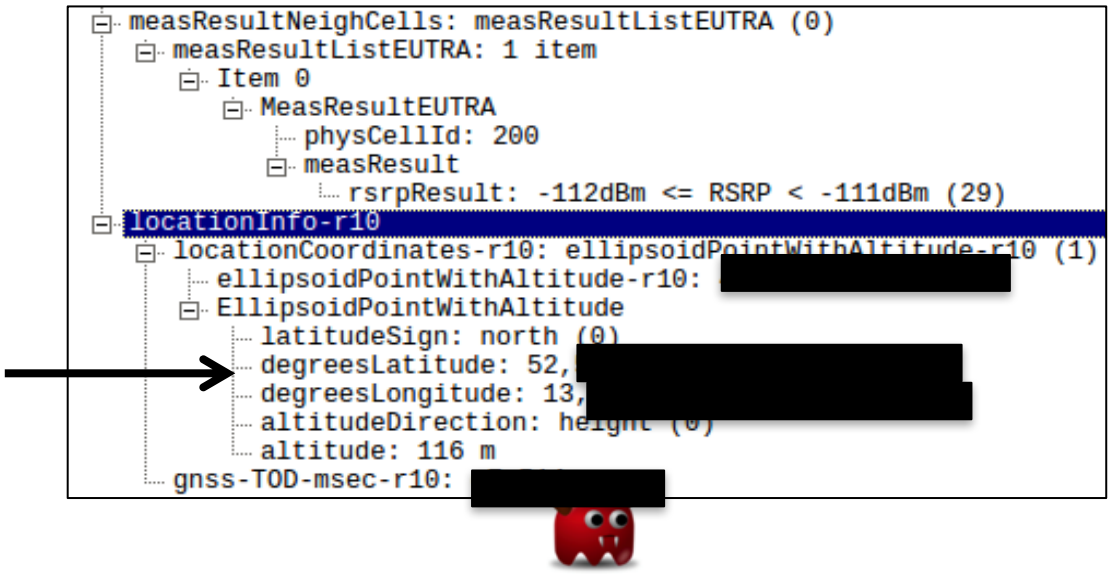
Attacks: Location leaks

Location Leaks: tracking coarse level



Location Accuracy: 2 Sq. Km

Location Leaks: tracking precise level



Active attacker

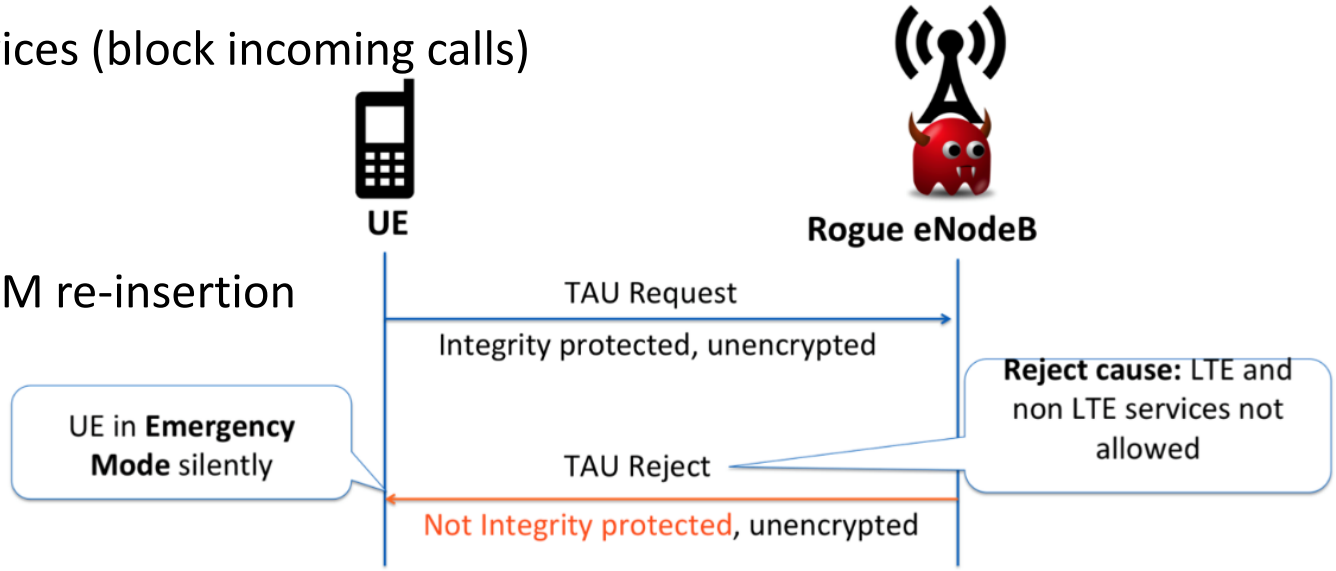
Location Accuracy: 50 meters (or) GPS co-ordinates

Attacks: Denial of service

DoS Attacks

Exploiting specification vulnerability in EMM protocol!

- Downgrade to non-LTE network services (2G/3G)
- Deny all services (2G/3G/4G)
- Deny selected services (block incoming calls)
- Persistent DoS
- Requires reboot/SIM re-insertion

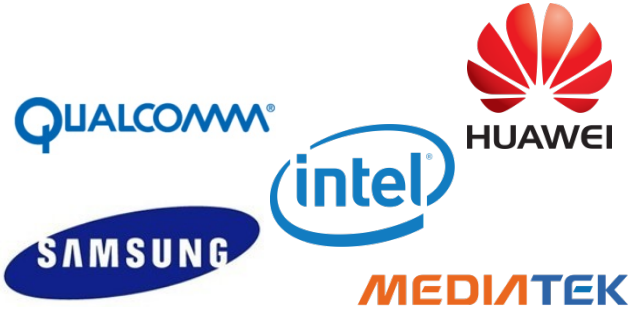


Reasons for vulnerabilities

Trade of between security and

- Performance
  - ✓ Phone restricts to connect to network- saving power
  - ✓ saving network signaling resources (avoid unsuccessful attach)
  - ✓ Operator do not refresh temporary identifiers often
- Availability
  - ✓ operators require unprotected reports for troubleshooting
- Functionality
  - ✓ Smartphone apps on generic platforms not mobile-network-friendly
- Attacking cost Vs Security measures (defined in 15 years back)

Impact



All (4) affected baseband manufacturers

- ✓ Responsible disclosure of bugs: acknowledged and patches released
- ✓ But OEMs do not yet have security updates to phones

Network operators

- ✓ Configuration issues were acknowledged and fixed

Standards organizations

- ✓ Security issues presented at SA3 (in Anaheim, Nov 2015) and GSMA
- ✓ Changes into LTE specifications are in progress

Social network applications

- ✓ Facebook no longer supports completely silent messages

Conclusions

- New vulnerabilities in 4G standards/chipsets
- Configuration by operators do not follow best practices

- Lead to attacks:
  - ✓ Social applications used for silent tracking
  - ✓ Locating 4G devices using trilateration , GPS co-ordinates!
  - ✓ DoS attacks are persistent & silent to users

- Design trade-offs made a decade ago no longer effective

Thank You.

Questions?

Shout for a demo!

This work was supported in part by the Intel Collaborative Research Institute for Secure Computing, Academy of Finland (“Cloud Security Services” project #283135), Deutsche Telekom Innovation Laboratories (TLabs), and 5G-Ensure (grant agreement No. 671562, www.5Gensure.eu).