Advanced Security for Systems Engineering – VO 11: Mobile Applications

Clemens Hlauschek
Christian Brem

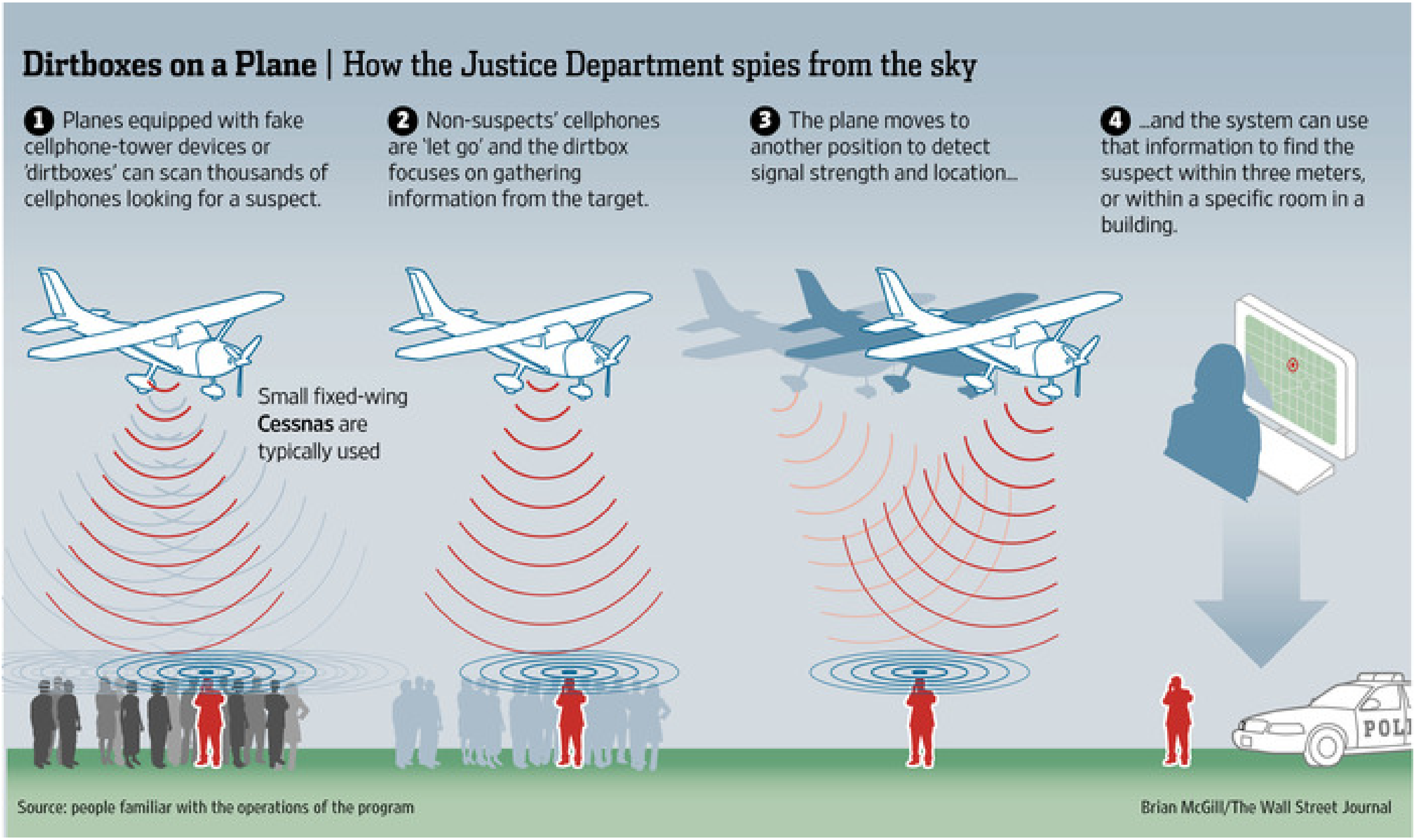
Agenda

GSM/UMTS/LTE Introduction

Attack Overview

IMSI Catcher Internals

Secret US Spy Program



Dirtboxes on a Plane | How the Justice Department spies from the sky

1. Planes equipped with fake cellphone-tower devices or 'dirtboxes' can scan thousands of cellphones looking for a suspect.

2. Non-suspects' cellphones are 'let go' and the dirtbox focuses on gathering information from the target.

3. The plane moves to another position to detect signal strength and location...

4. ...and the system can use that information to find the suspect within three meters, or within a specific room in a building.

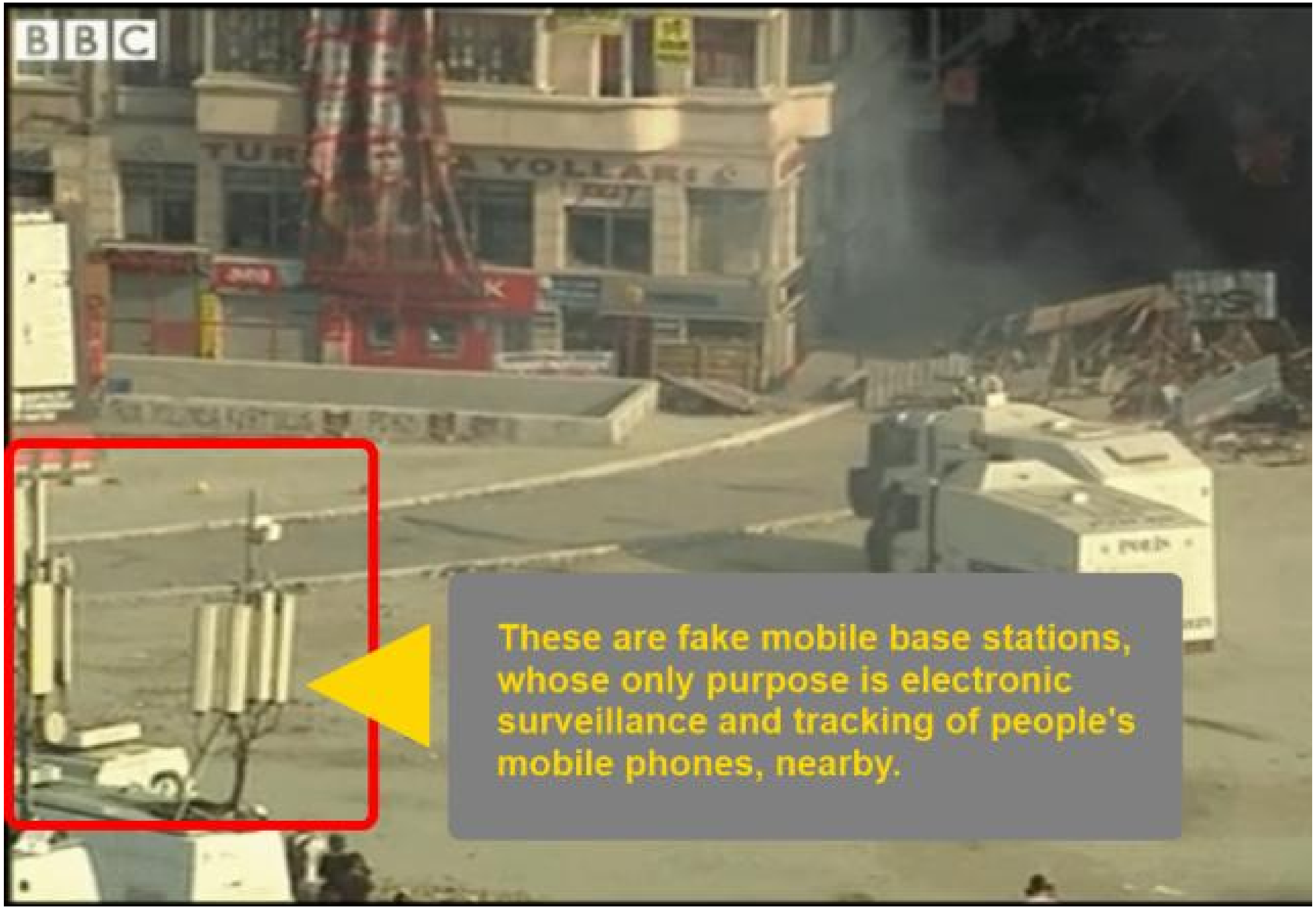
Small fixed-wing **Cessnas** are typically used

Source: people familiar with the operations of the program

Brian McGill/The Wall Street Journal

(See Wall Street Journal – Nov 2014)

IMSI Catcher: Identify Protesters



These are fake mobile base stations, whose only purpose is electronic surveillance and tracking of people's mobile phones, nearby.

(See https://gitlab.com/Hounge/Android-IMSI-Catcher-Detector)

IMSI Catcher / Stingray

- Reseachers found 18 IMSI Catcher in Washington D.C within 2 days

Attacks:

- Location Tracking
- Call / SMS eavesdropping
- MitM against data link
- SMS injection

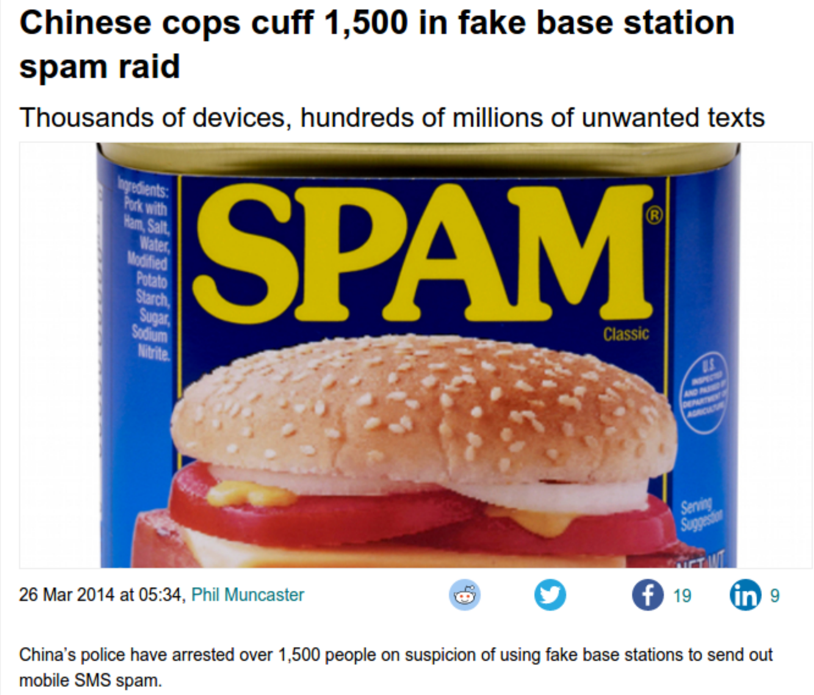
IMSI Catcher: Low Cost

- Attacks can be launched by anyone nowadays
- Huge security and privacy problem!
- Starting 1000 EUR for HW-Equipment
- OpenSource projects:
  - Osmocon OpenBSC
  - OpenBTS
  - OpenLTE
  - srsLTE/srsRAN

IMSI Catcher: More Attacks

Deliver Spam:

- IMSI Catcher concealed in car, drive through city
- Spammers injected 6000 messages in half an hour
- Charged 1.000 Yuan (142 EUR) per 1000 users



Chinese cops cuff 1,500 in fake base station spam raid

Thousands of devices, hundreds of millions of unwanted texts

SPAM®
Classic
Ingredients: Pork with Ham, Salt, Water, Modified Potato Starch, Sugar, Sodium Nitrite.
Serving Suggestion

26 Mar 2014 at 05:34, Phil Muncaster 19 9

China's police have arrested over 1,500 people on suspicion of using fake base stations to send out mobile SMS spam.

- Attack vulnerable UICC / Baseband firmware / . . .
- Reconfigure phone – permanent MitM via Access Point Name (APN) change
- Intercept 2-factor auth (mTan)

History of 3GPP Networks and Main Security Issues

- 2G/GSM since 1991, GPRS
  - Location privacy
  - No mutual authentication
  - Weak encryption: A5/1, A5/2
- 3G/UMTS since 2001
  - Location privacy
  - Mutual authentication / strong encryption but
  - Downgrade to 2g often possible

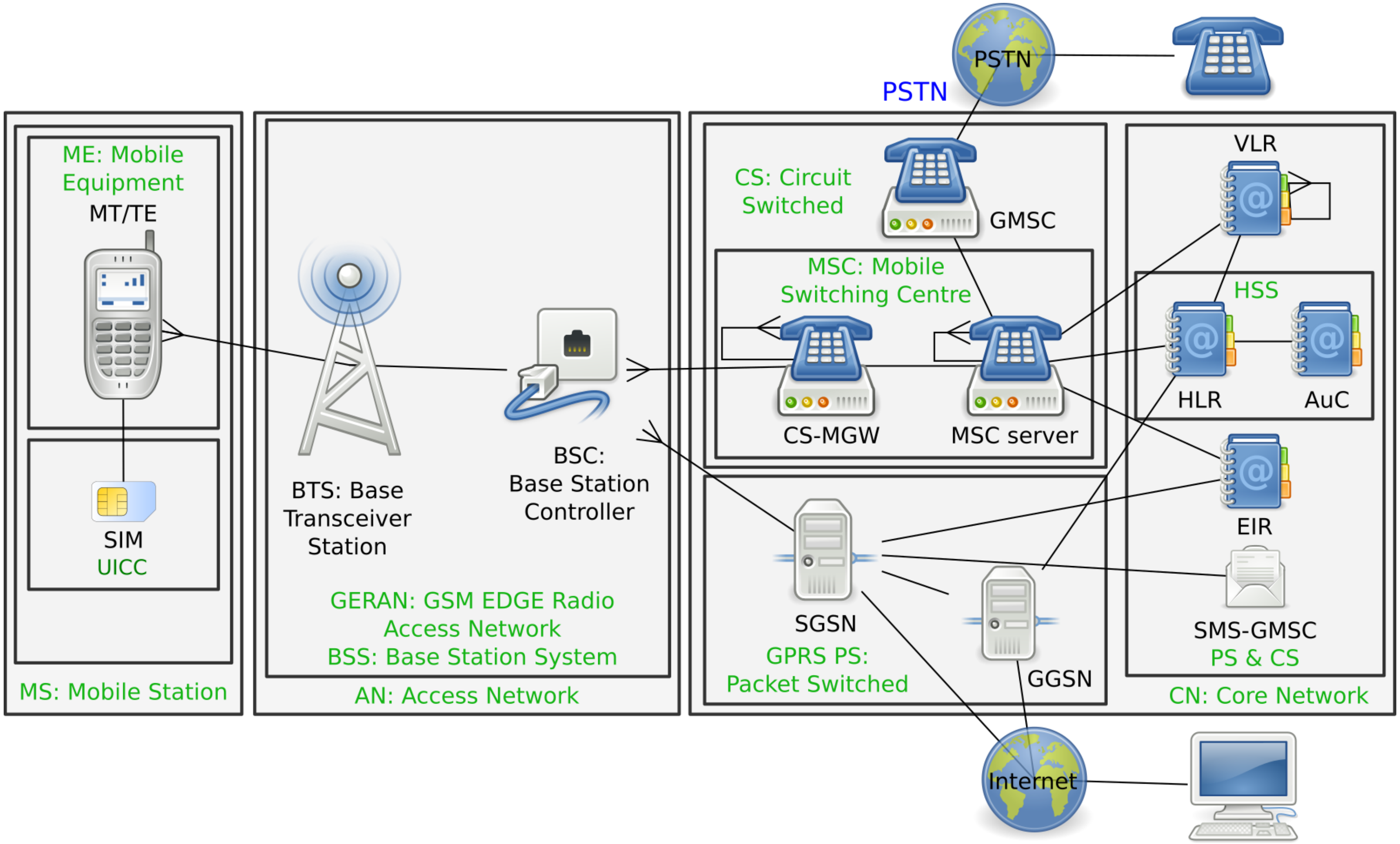
History of 3GPP Networks and Main Security Issues

- 4G/LTE, deployment started: 2009
  - Security problems of 3G mostly not solved
  - Mainly performance improvements
- 5g, deployment started: 2019
  - Better privacy (encrypted SUPI/IMSI)

3GPP Networks: Main Security Issues

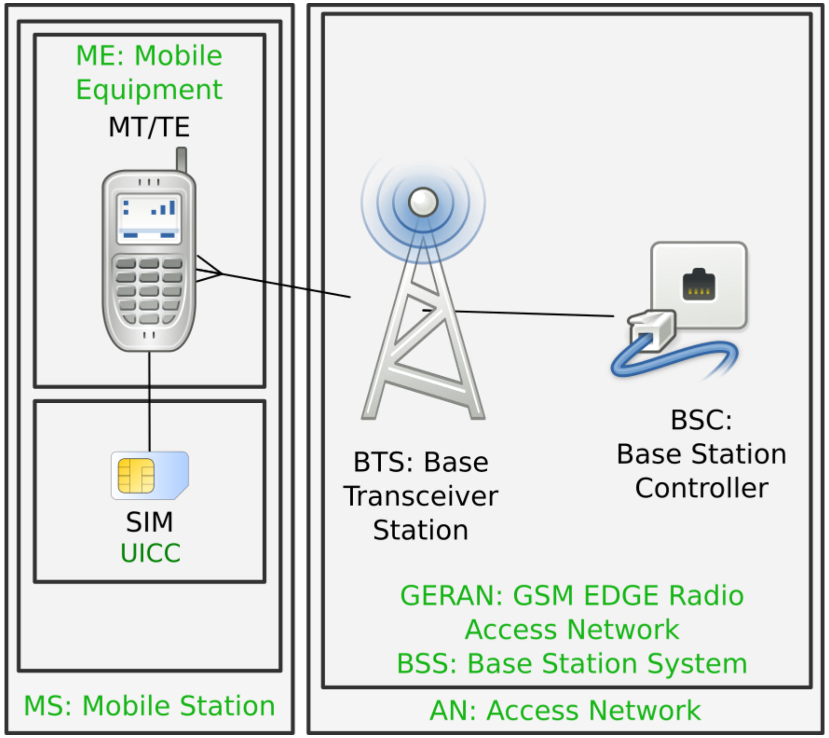
- 2G backward compatibility will remain for some time
- Devices always connect to base station with strongest signal
- Base station decides protocol version / encryption
- Core Network (Switching, SS7): No authentication
  - Query encryption key (2G,3G)
  - Inject spoofed SMS
  - Reroute and eavesdrop on calls
  - Track subscribers worldwide
- Large-Scale DoS attacks
  - Race condition: Pageing requests
- Femtocells: Cheap MitM attacks for 3g/4g

Structure of a GSM network



Mobile Station (MS)

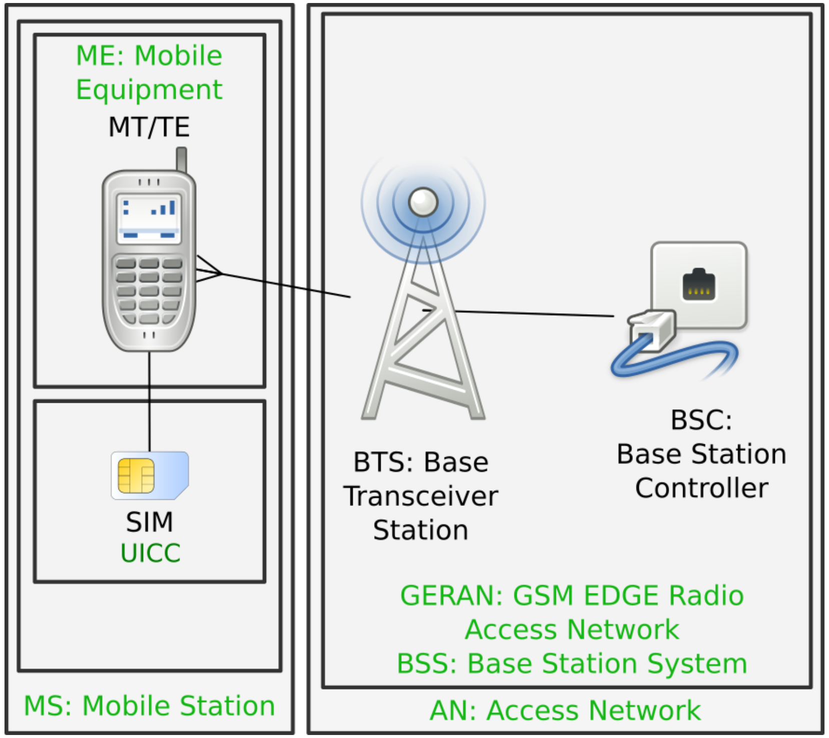
- Universal Integrated Circuit Card (UICC)
  - Secure Smart Card
  - Contains Subscriber Identity Module (SIM/USIM)
  - Often: Javacard: Install additional applets (EMV Payment, Ticketing)


ME: Mobile Equipment
MT/TE
SIM
UICC
MS: Mobile Station
BTS: Base Transceiver Station
BSC: Base Station Controller
GERAN: GSM EDGE Radio Access Network
BSS: Base Station System
AN: Access Network

- Mobile Termination (MT):
  - Handles radio transmission, signaling, etc.
  - Smartphone: runs on baseband processor (!= app cpu)

Base Station System (BSS)

- Handles all (server-side) radio communication
- Base Transeiver Station (BTS) – 2g, Node B – 3g
  - handles radio communication
- Base Station Controller (BSC) – 2g, Radio Network Controller (RNC) – 3g
  - Controls $>= 1$ BTS
  - Terminates Link encryption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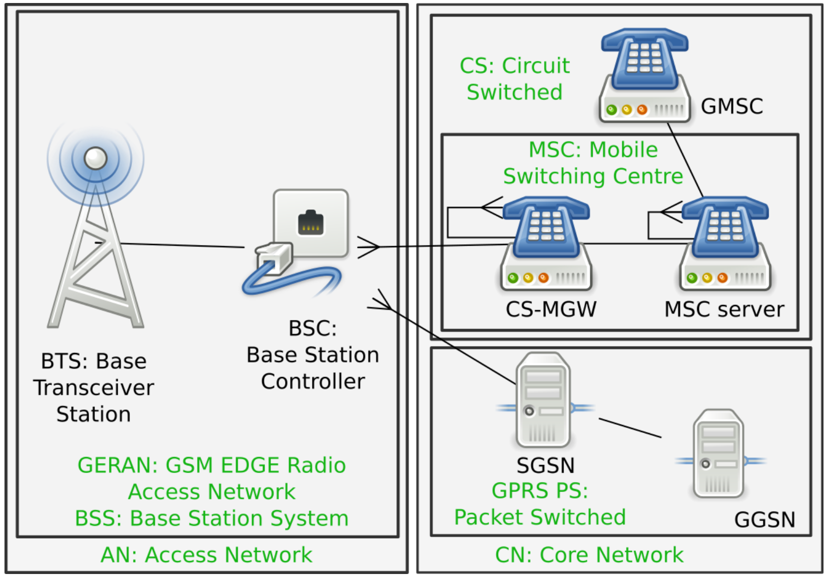
Base Station System (BSS)

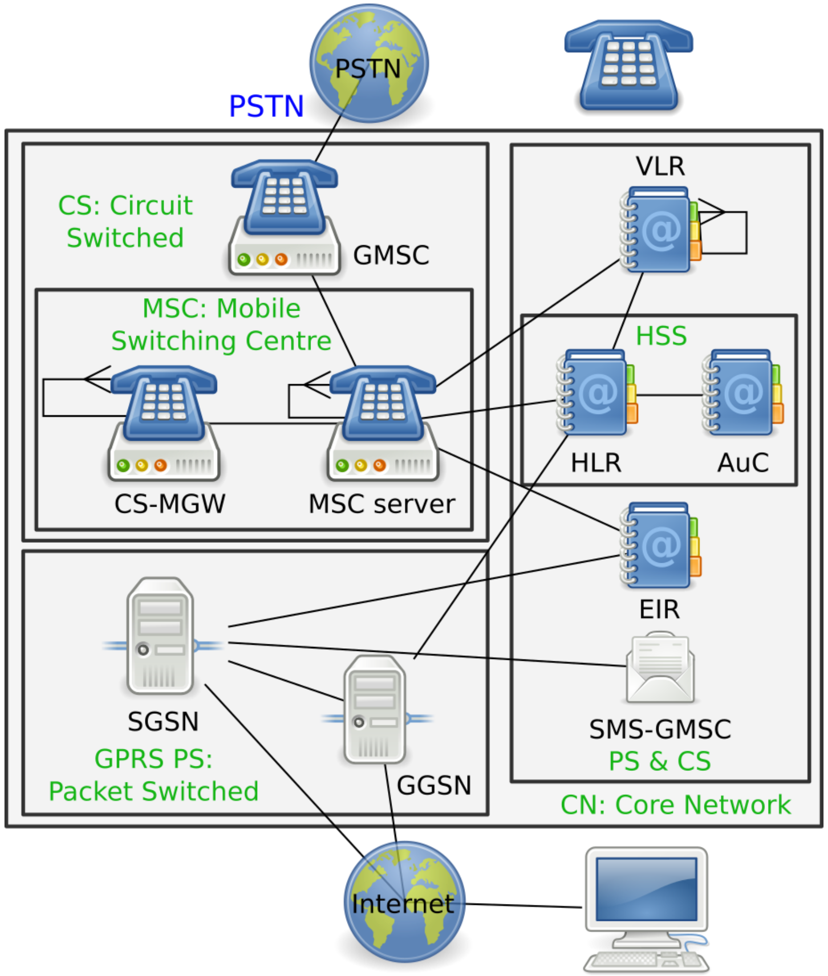
- Base Station Controller (BSC) – 2g, Radio Network Controller (RNC) – 3g
  - Connect (SS7 signaling) to Core Network / Network Switching Subsystem



- Calls via Media Gateway (MGW) to ciruit switched Mobile Switching Center (MSC)
- Data / SMS via Serving GRPRS Support Node (GGSN) to packet switched network

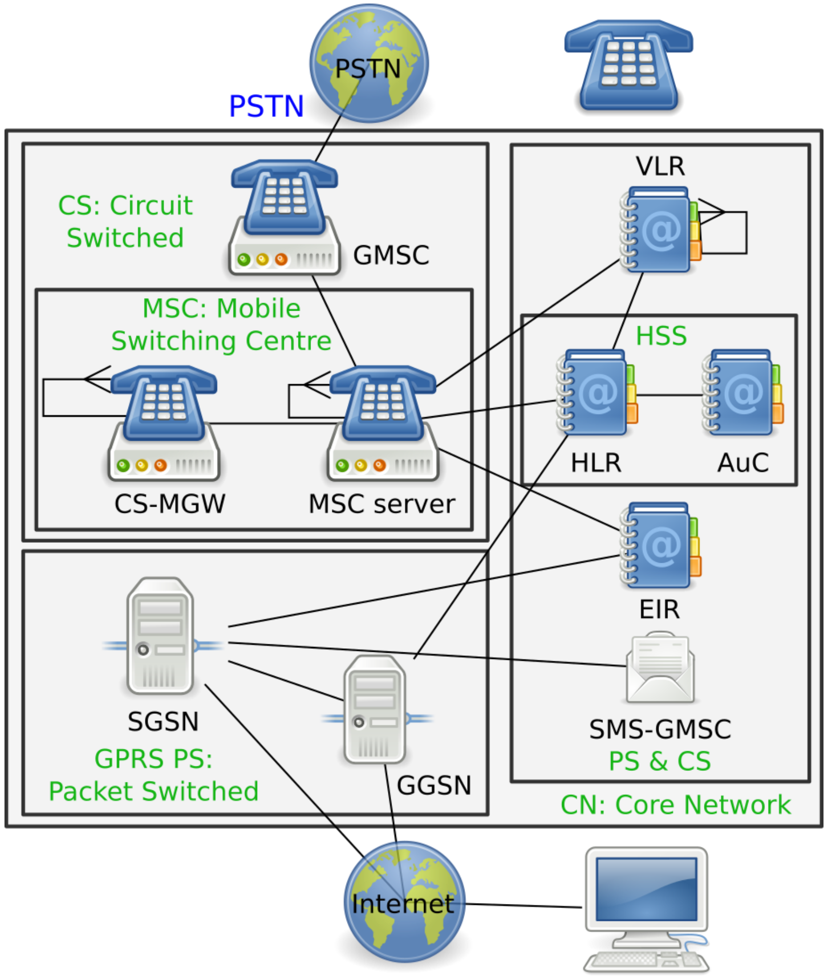
Core Network (CN)

- Mobile Switching Center (MSC) routes calls to other MSCs; to the Public Switched Telephone Network
- GPRS Support Node (GSN) routes data to the Internet / SMS to Short Message Service Center (SMSC)



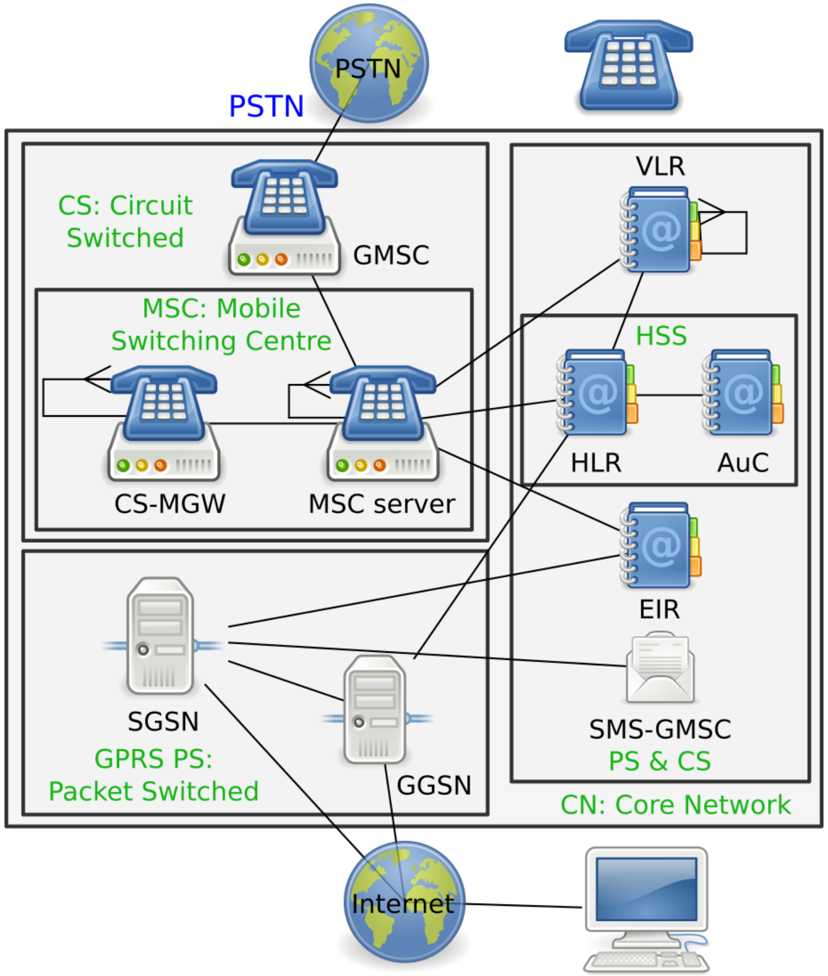
Core Network (CN)

- Visitor Location Register (VLR)
  - In serving network
  - Keeps track of currently connected MS
- Home Location Register (HLR)
  - In subscriber's home network
  - Keeps track of current location of subscribers



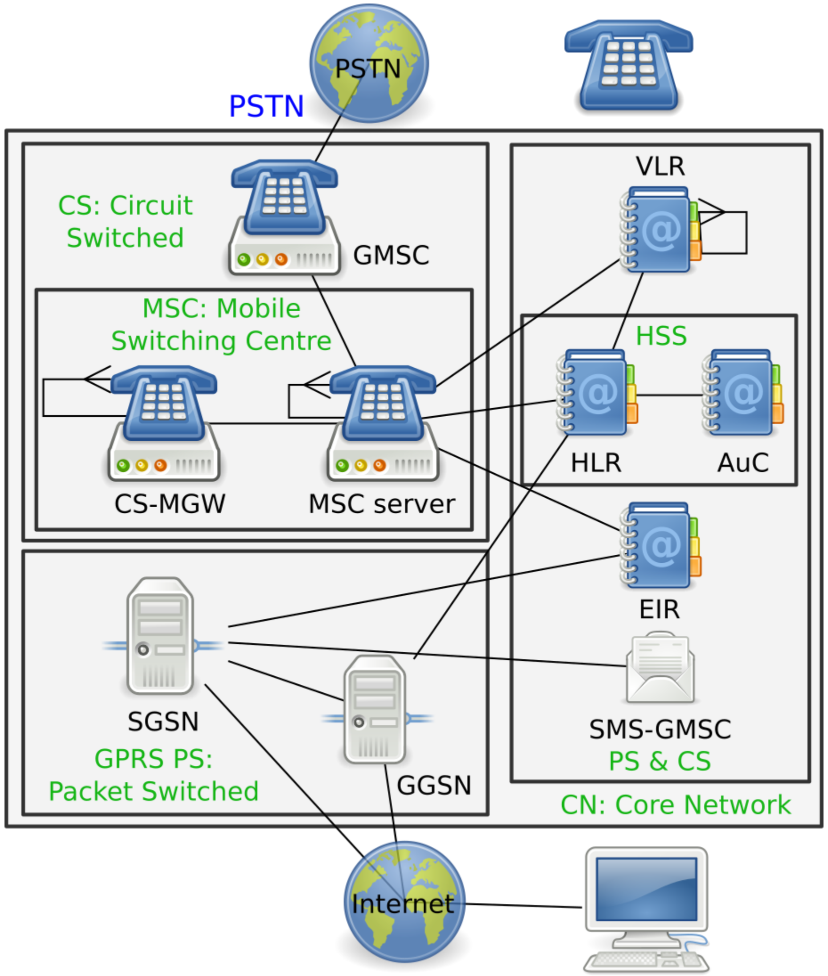
Core Network (CN)

- Home Location Register (HLR)
  - Provides authentication data / link encryption key to serving network via Authentication Center AuC
- Authentication Center (AuC)
  - Holds shared secret K_i for each SIM
  - Generates authentication data and link encryption key for each session



Core Network (CN)

- Equipment Identity Register (EIR)
  - Holds globally unique identifiers of stolen, banned, or defective mobile phones
  - Unique identifier of MS devices: International Mobile Station Equipment Identity (IMEI)
  - Globally synchronized database

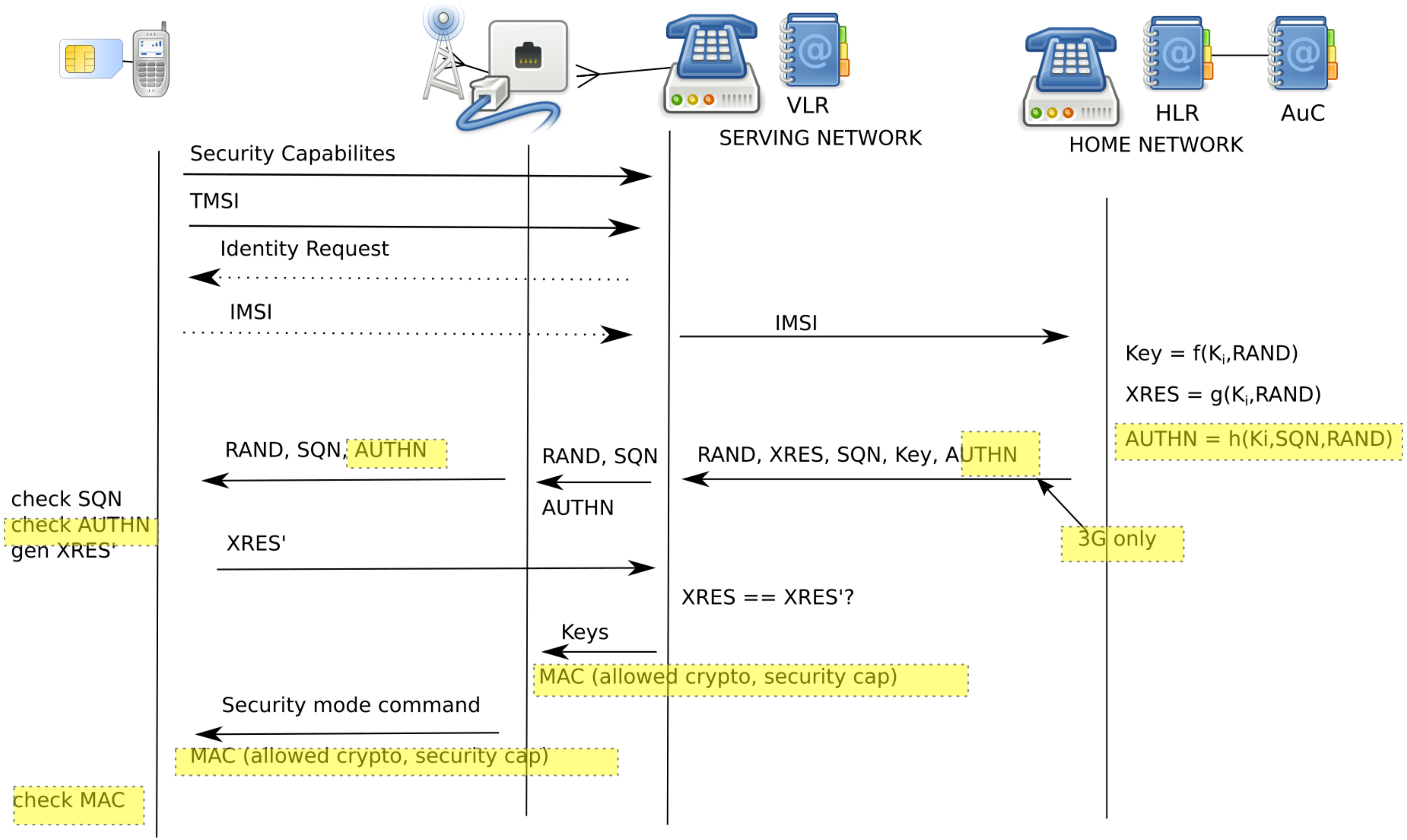


Data in SIM Application

SIM / USIM application on UICC contains

- Shared secret K_i (with AuC)
- International Mobile Subscriber Identifier (IMSI)
  - Needed to look up K_i, caculate auth data and session key
- Temporary Mobile Subscriber Identifier (TMSI)
  - Stored at VLR together with IMSI
  - Mask IMSI against against passive eavesdropping attacks: limited location privacy

Authentication in 2G/3G



IMSI Catching: Location Tracking

Two different location privacy attacks

- Monitoring: Retrieve identities at a location
- Tracking: Retrieve a person's location
  - Network of Antennas
  - Triangulation

Furthmore:

- Passive Attack: Limited Protection from TMSI (does not change often)
- Active Attack: Send `Idendity Request` Message. (Prior to authentication)

MitM via 3g to 2g Downgrade

First phase

- Attacker impersonates phone
- Attacker queries currently valid authentication data
- Obtains (RAND, SEQ, AUTHN)

Second phase:

- Attacker impersonates serving network (2g)
- Attacker sends (RAND, SEQ, AUTHN) to phone
- Attacker choses no or weak encryption (A5/1, A5/2)
- A5/1, A5/2 can be broken in seconds
- Attacker establishes valid connection to network
- Attacker forwards call, sms, data; has plaintext

Conclusion Mobile Network Security

- Security GSM/UMTS/LTE completely broken
- Always use end-to-end encryption for sensitive information
  - TLS Certificate Pinning
  - Signal
- Beware 2-factor Authentication via SMS (mTan, etc)
- SS7 attacks can be launched from anywhere with modest budget

Literature / Links

- Meyer (2004): A Man-in-the-Middle Attack on UMTS
- Wehrle (2009): Open Source IMSI Catcher (Masterarbeit)
- Weinmann (2012): Baseband Attacks (WOOT'12)
- Dabrwoski (2014): IMSI-Catch Me If You Can (ACSAC'14)
- Broek (2015): Defeating IMSI Catchers (CCS'15)
- Golde (2012): Weaponizing Femtocells (NDSS'12)
- Borgaonkar (2019): New Privacy Threats on 3G, 4G, and Upcoming 5G AKA Protocols (PETS'19)
- Jover (2019). The current state of affairs in 5G security and the main remaining security challenges (arXiv)

Links

- The vector drawings in slide 32-39 are licensed under GPLv3, the sources are available at `https://security.inso.tuwien.ac.at/downloads/ws19/advsecsyseng/gsmstructure/`

Thank’s for your attention!

`https://security.inso.tuwien.ac.at/`