

WiFi-Based IMSI Catcher

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Overview

- What is an IMSI?
- Conventional IMSI Catchers
- WiFi-based IMSI Catcher
 - WiFi Network Authentication 💣
 - WiFi Calling Authentication 💣
- Operator/Vendor/OS Mitigations
- User Mitigations
- Demo

What is an IMSI?

- **International Mobile Subscriber Identity**
 - 15 digit number e.g. 234123456789012
 - Allows for mutual authentication of a device to the network
 - Using SIM's secret authentication Key (K_i) and for 3/4G the Sequence Number (SQN)
- **Stored in two places:**
 - In the 'SIM Card' (USIM/UICC)
 - IMSI is accessible in read only section of SIM
 - Secret key (K_i) and SQN are not directly readable
 - At the Operator
 - IMSI indexes K_i and SQN from HSS/AuC Database
- **An identifier that can be used for tracking**
 - One of a few like WiFi/Bluetooth/NFC Hardware address (e.g. MAC), IMEI, MSISDN (Phone number), etc.



Conventional IMSI Catchers

- Typical features
 - Tracking: IMSI/IMEI, Location
 - Interception: Call/SMS/Data
- Operates on licensed Mobile Bands: GSM/3G/4G
- Acts as a fake base station to lure nearby mobile devices
- Operates in two modes
 - 'Passive' - mainly for tracking (interception when no/weak ciphering)
 - Active – interception and tracking
- Cost
 - Commercial solutions expensive - but now possible with Laptop+SDR board
- Been around since the early 1990s
 - Patented in Europe in 1993

Techniques in Conventional IMSI Catchers

2G

- Exploits protocol flaws (no mutual authentication..)
- Tracking & Interception
- Easily available to buy online
- Use of fake base station



3G/4G

- Exploits architecture issues (Base station > UE..)
- Tracking & difficult to intercept traffic w.r.t 2G
- Commercial products usually downgrades
- Use of legitimate base station also possible



Protection against IMSI Catchers

- No protection for commercial non-rooted mobile devices
- Special phones (expensive though) and apps for rooted phones
- Turn off cellular connection or use WiFi platform for secure calls/data??

WiFi-Based IMSI Catcher

- Features
 - Tracking: IMSI, Location
 - No interception (yet)
- Operates in unlicensed ISM Bands: WiFi
 - Range - few hundred meters – can be extended...
 - Fake Access Points
 - Redirect/Spoofs mobile packet data gateway
 - Exploits protocol & configuration weaknesses
- Based on two separate techniques [3GPP TS33.234]
 - **WiFi Network Authentication ('WLAN direct IP access')**
 - **WiFi-Calling Authentication ('WLAN 3GPP IP access')**
- Cost
 - Low: Virtually any WiFi capable computer

WiFi Network attachment

- Unencrypted WiFi access points
 - Captive Portal approaches
 - Wireless Internet Service Provider roaming(WiSPr) etc
- Normal Encrypted WiFi access points
 - Pre-shared password/credentials
- 'Auto Connect' Encrypted WiFi access points
 - WiFi key is negotiated without user intervention
 - Based on credentials in the USIM/UICC ('SIM Card')
 - Controlled by operator provided configuration
 - Manual
 - Automatic/pre-installed

Automatic configuration

- Some Android and Windows phones automatically connect based on SIM
- iOS configures phone based on inserted SIM
 - Activates an operator specific .mobileconfig file
 - Configures a range of operator specific options
 - Including a list of Auto/EAP supported WiFi SSIDs
- Our analysis of iOS9 profiles showed
 - More than 50 profiles for Auto/EAP WiFi
 - Also other config info

‘Manual’ Configuration

- Some Android devices require initial manual config
 - After which it automatically connects
- Instructions on operator websites
 - Follow simple steps to set up
- Android provides various Carrier controlled mechanisms
 - Lollipop (v5.1 MR1): UICC Carrier Privileges
 - Marshmallow (v6.0): Carrier Configuration
 - “Privileged applications to provide carrier-specific configuration to the platform”

Automatic WiFi Authentication

- Port Based Network Access Control [IEEE 802.1X]
 - Uses **E**xtensible **A**uthentication **P**rotocol (EAP) [RFC3748] over LAN (EAPOL) over WiFi
- Based upon two EAP Methods
 - EAP-SIM [RFC 4186]
 - GSM based security - Currently most widely used
 - EAP-AKA [RFC 4187]
 - 3G based security - Being deployed
- Support in Android, iOS, Windows Mobile, and Blackberry devices
 - We've reported the issue to them all and to operators & GSMA
 - No privacy bounties 😞
 - Apple included 'conservative peer' support due to our work
- Deployed in many countries – adoption growing

EAP-SIM/AKA Identities

- Three basic identity types for authentication
 - Permanent-identity (IMSI)
 - Typically used initially after which temporary ids are used
 - Pseudonym identity
 - A pseudonym for the IMSI has limited lifetime
 - Fast reauthentication-identity
 - Lower overhead re-attachment after initial exchange
- Behaviour affected by peer policy
 - “Liberal” peer - Current default
 - Responds to any requests for permanent identity
 - “Conservative” peer – Future deployment option
 - Only respond to requests for permanent identity when no Pseudonym identity available

EAP-SIM/AKA transport

- Basic EAP protocol is not encrypted
- Currently EAP-SIM/AKA in EAPOL is unencrypted
 - Thus IMSI is visible (to a passive attacker) when permanent identity used for full authentication 🤖
 - Also open to active attacks by requesting full auth 🤖
- WiFi Access keys not compromised
 - All content still protected
- There are encrypted tunnel EAP methods
 - EAP-TTLSv0, EAP-TLS...
 - But support required in both mobile OS and operator

WiFi-Calling Connection

- Phone connects to Edge Packet Data Gateway (EPDG) over WiFi
 - Voice calls over WiFi
 - Phone connects on low/no signal
 - Also connects in Airplane mode + WiFi ...
- Connection to EPDG uses IPsec
 - Authenticates using Internet Key Exchange Protocol (IKEv2)
- Supported on iOS, Android, and Windows devices
 - WiFi-Calling available in a number of countries
 - The issue also been reported to OS makers and Operators

IPsec brief overview

- **Internet Protocol Security**
 - Confidentiality, data integrity, access control, and data source authentication
 - Recovery from transmission errors: packet loss, packet replay, and packet forgery
- **Authentication**
 - Authentication Header (AH) - RFC 4302
- **Confidentiality**
 - Encapsulating Security Payload (ESP) - RFC 4303
- **Key management**
 - Internet Key Exchange v2 (IKEv2) - RFC7296
- **Two modes**
 - Tunnel - used for connection to Gateway (EPDG)
 - Transport

Internet Key Exchange (IKEv2)

- Initiates connection in two phases
 - IKE_SA_INIT
 - Negotiate cryptographic algorithms, exchange nonces, and do a Diffie-Hellman exchange
 - IKE_AUTH
 - Authenticate the previous messages, **exchange identities (e.g. IMSI)**, and certificates, and establish the child Security Association(s) (SA)
- IKE_AUTH uses EAP-AKA
 - IMSI exchange not protected by a certificate
 - Open to MitM attacks on identity (IMSI) 🤖
- IPsec ESP keys are not compromised
 - Call content still safe

Operator/Vendor Mitigations

- Deprecate EAP-SIM in favour of EAP-AKA
 - EAP-SIM is weaker as it only uses GSM triplets
- Deploy EAP-AKA/SIM with conservative peer pseudonym
- Deploy Certificate based approach
 - Deploy certificates on suitable AAA infrastructure
 - Deploy certificate protected tunnelled EAP-AKA for WLAN access
 - E.g. EAP-TTLS+EAP-AKA on 802.1X
 - Deploy certificate protected IPsec/IKEv2 to EPDG
 - E.g. EAP-TTLS+EAP-AKA for IKE_AUTH, or multiple IKEv2 auth exchange
- (Re)investigate other potential solutions
 - IMSI encryption – 5G-ENSURE project has proposed an ‘enabler’
 - E.g. 3GPPP TD S3-030081 – ‘Certificate-Based Protection of IMSI for EAP-SIM/AKA’
- Standards bodies should re-evaluate approaches

Mobile OS Mitigations

- Support conservative peer for EAP-AKA/SIM with pseudonym support
 - Emerging in some Oses (e.g. iOS10)
- Certificate based approach
 - Support for EAP-TTlv0 + EAP-AKA in IKEv2 & EAPOL
 - Other approaches?
- Allow for more user choice with automatic WiFi network access
 - Preferably allow for editing of all stored associations

User Mitigation

- WiFi Network Access Control
 - iOS
 - Turn off 'Auto-Join' toggle for Auto-WiFi networks
 - Only possible when network in range
 - iOS10 may provide better protection (once operators deploy support)
 - It has conservative peer pseudonym support – due to us 😊
 - Android
 - 'Forget' Auto-WiFi profiles
 - Depending on version only possible when network in range
- WiFi-Calling
 - Android/iOS: Selectively disable WiFi-Calling
- Switch off WiFi in untrusted environments

Summary

- Exposed two IMSI catching new techniques
 - WiFi Network authentication protocols
 - WiFi-Calling authentication protocols
- Most of the world's smartphones implement these protocols
 - Both techniques rely upon installed operator automatic configuration for these popular services
- We've been working with Operators/Vendors/OS companies to fix the issue
 - But it's a complex issue

Conclusions & Future Work

- Investigating other uses of EAP-SIM/AKA
- Exploring use of USIM credentials in other WiFi based protocols
- Continuing work in [5GENSURE.EU](https://5gensure.eu) Project
 - Security Architecture and enablers

Demo and Questions...