

POC2016

LTE Redirection

Forcing Targeted LTE Cellphone into
Unsafe Network

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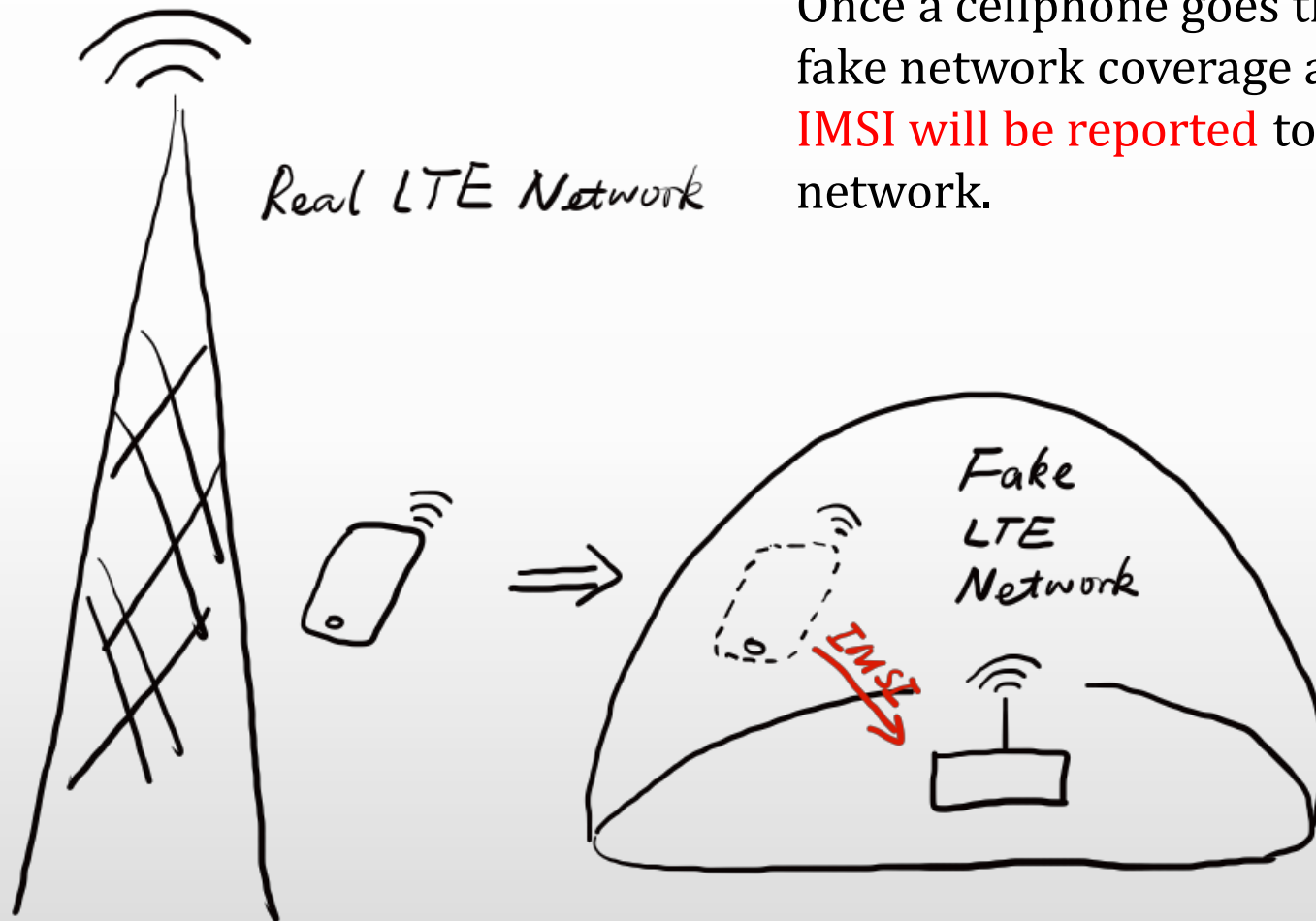


LTE and IMSI catcher myths

- In Nov. 2015, BlackHat EU, Ravishankar Borgaonkar, and Altaf Shaik etc. introduced the LTE IMSI catcher and DoS attack.



IMSI Catcher

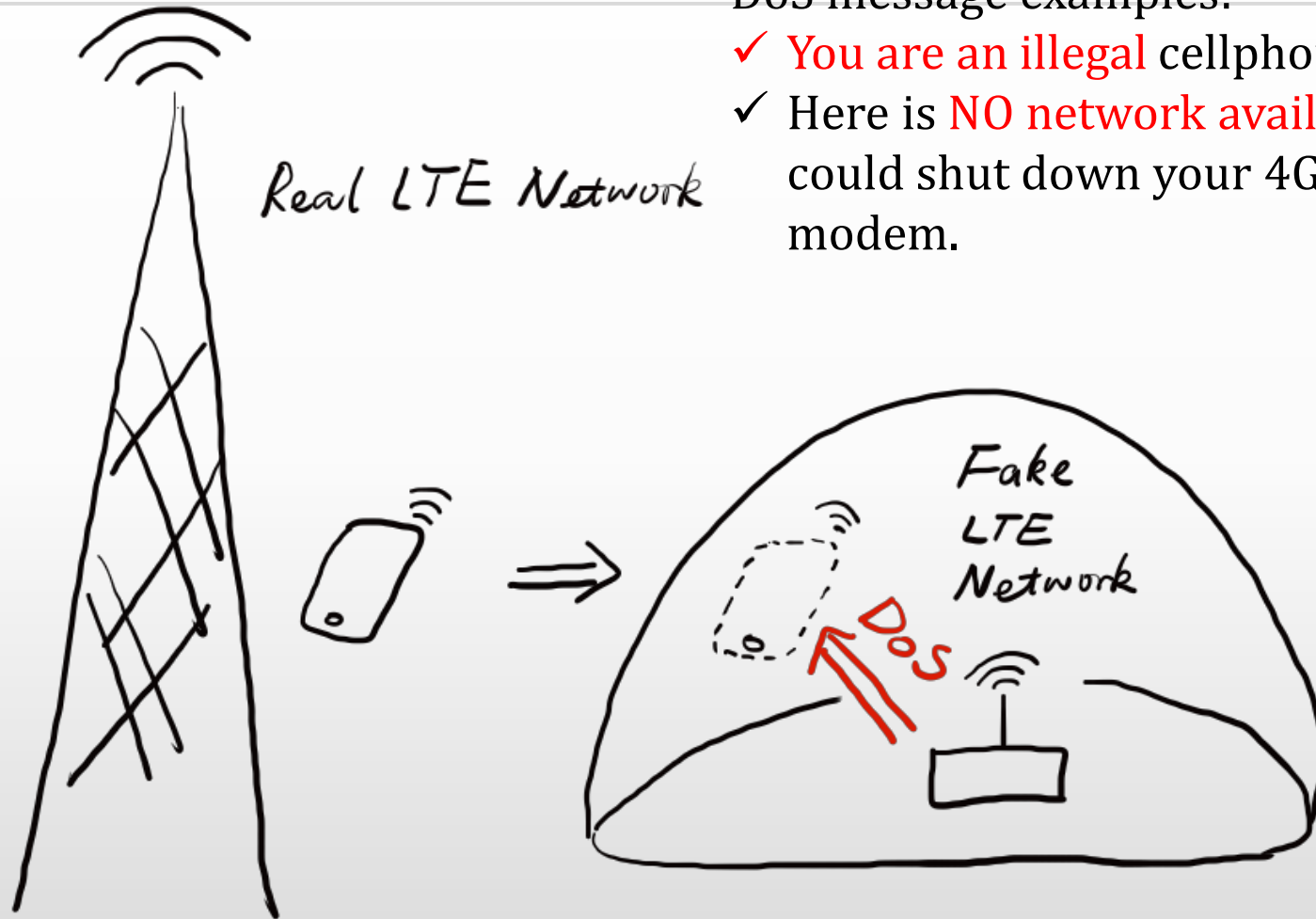


Once a cellphone goes through the fake network coverage area, its **IMSI will be reported** to the fake network.

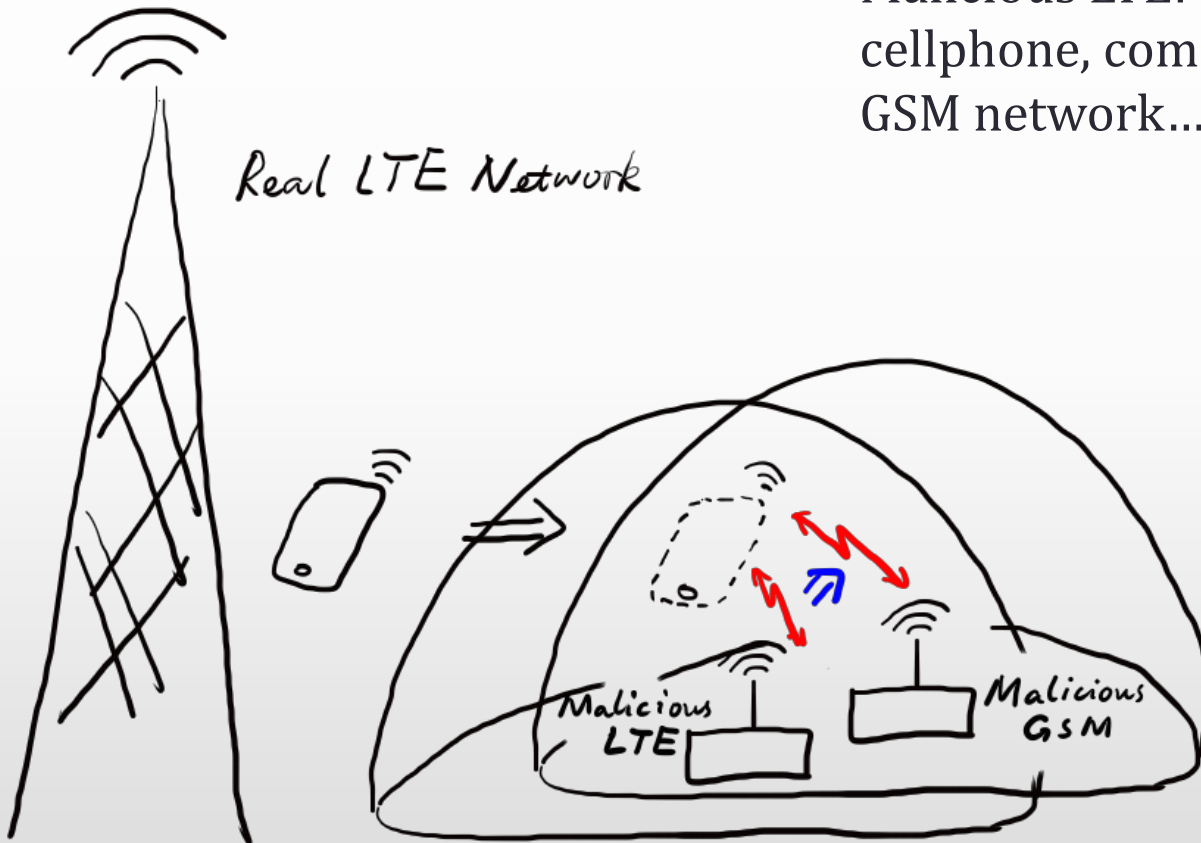
DoS Attack

DoS message examples:

- ✓ You are an illegal cellphone!
- ✓ Here is **NO network available**. You could shut down your 4G/3G/2G modem.



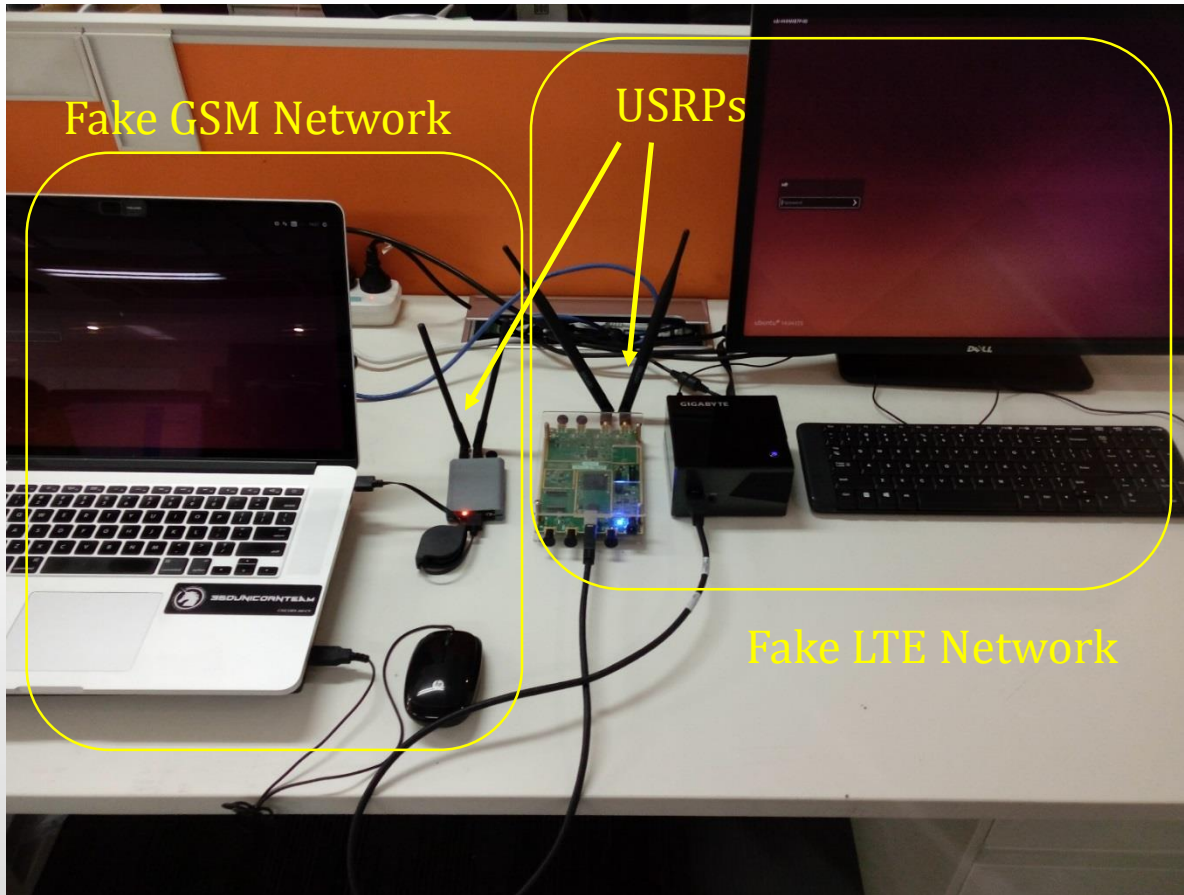
Redirection Attack



Malicious LTE: “Hello cellphone, come into my GSM network...”



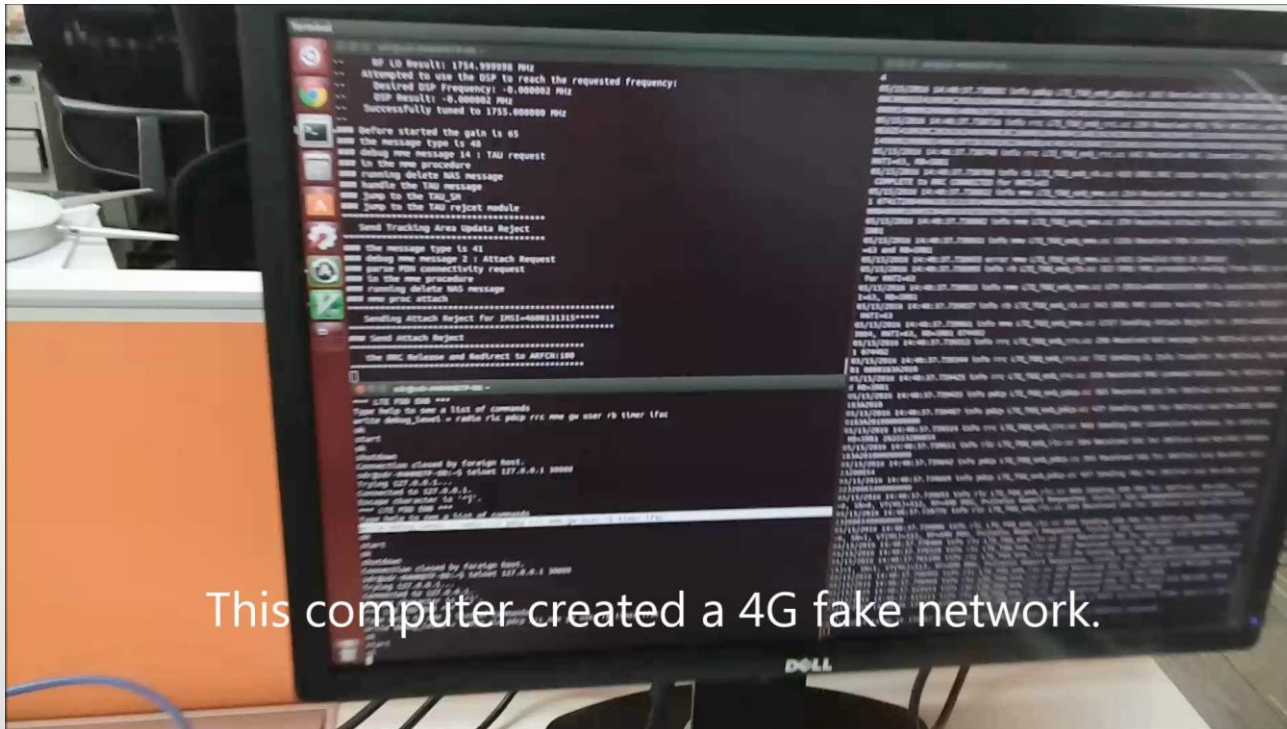
Demo



Demo Video



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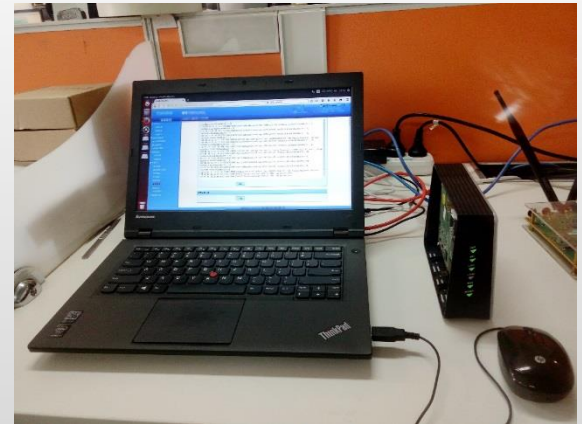
This computer created a 4G fake network.



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Risk

- If forced into fake network
 - The cellphone will have no service (DoS).
 - The fake GSM network can make malicious call and SMS.
- If forced into rogue network
 - All the traffic (voice and data) can be eavesdropped.



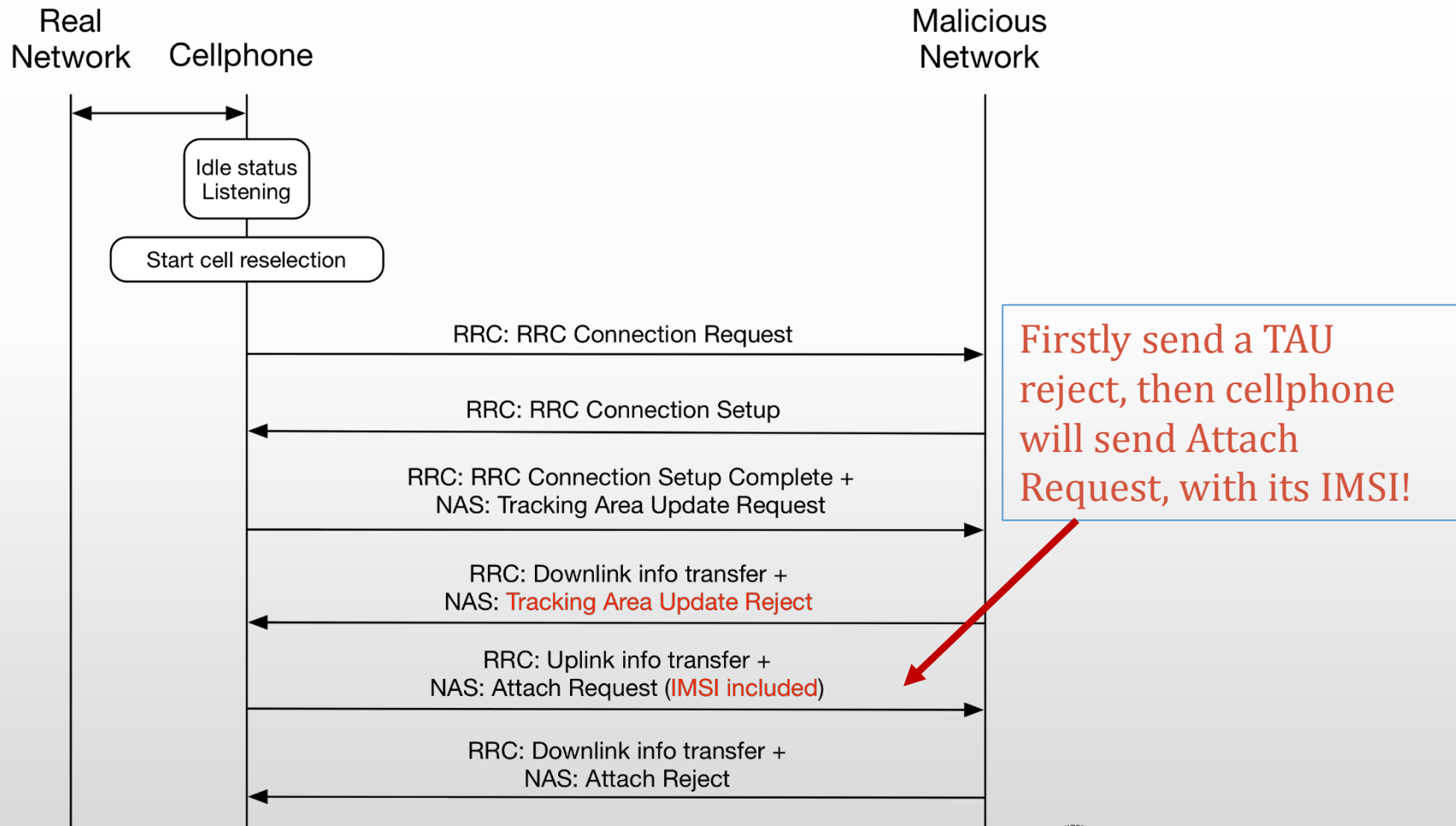
LTE Basic Procedure

- (Power on)
- Cell search, MIB, SIB1, SIB2 and other SIBs
- PRACH preamble
- RACH response
- RRC Connection Request
- RRC Connection Setup
- RRC Connection Setup Complete + NAS: Attach request + ESM: PDN connectivity request
- RRC: DL info transfer + NAS: Authentication request
- RRC: UL info transfer + NAS: Authentication response
- RRC: DL info transfer + NAS: Security mode command
- RRC: UL info transfer + NAS: Security mode completer
-

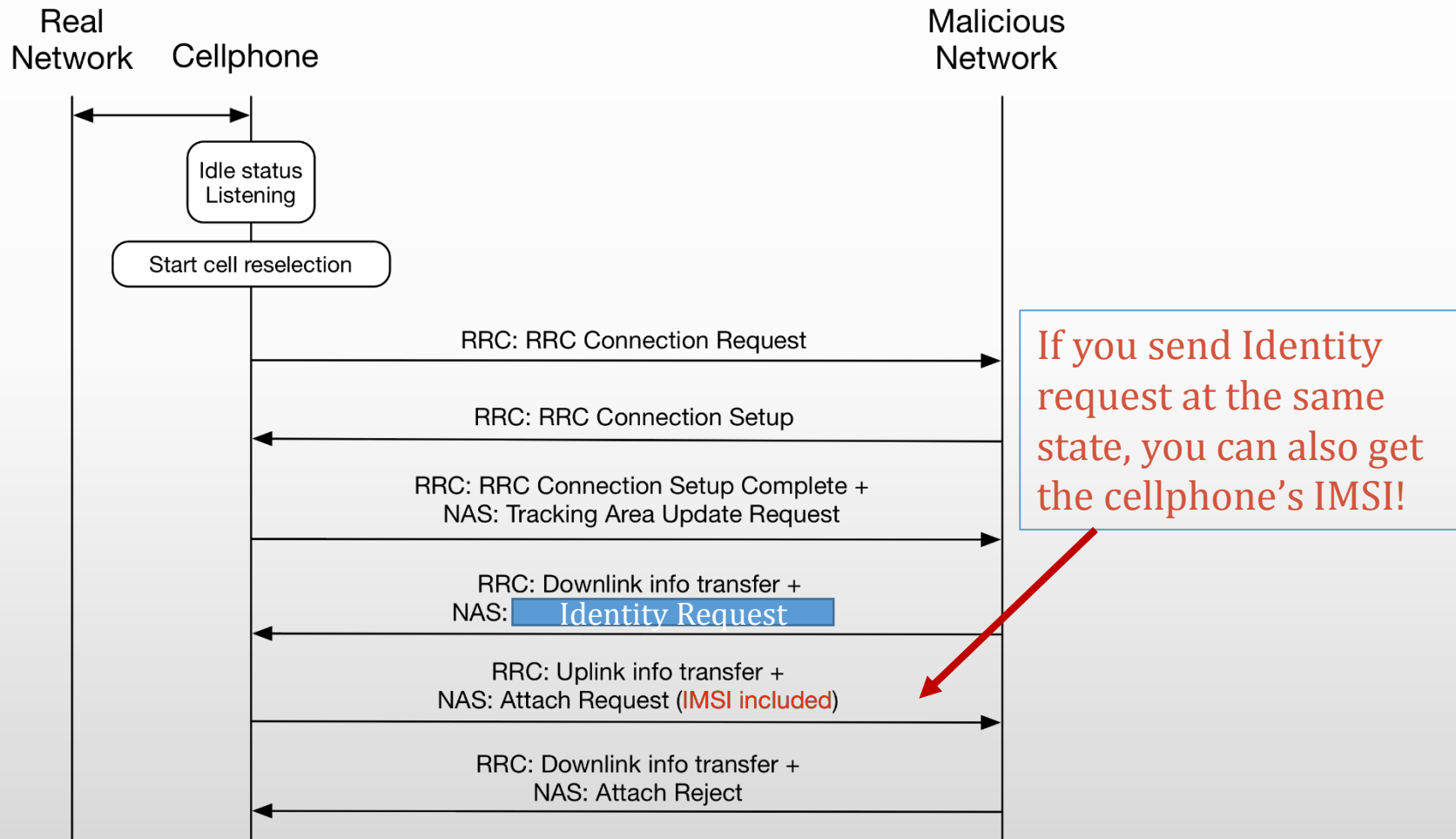
Unauthorized area
Attack Space!



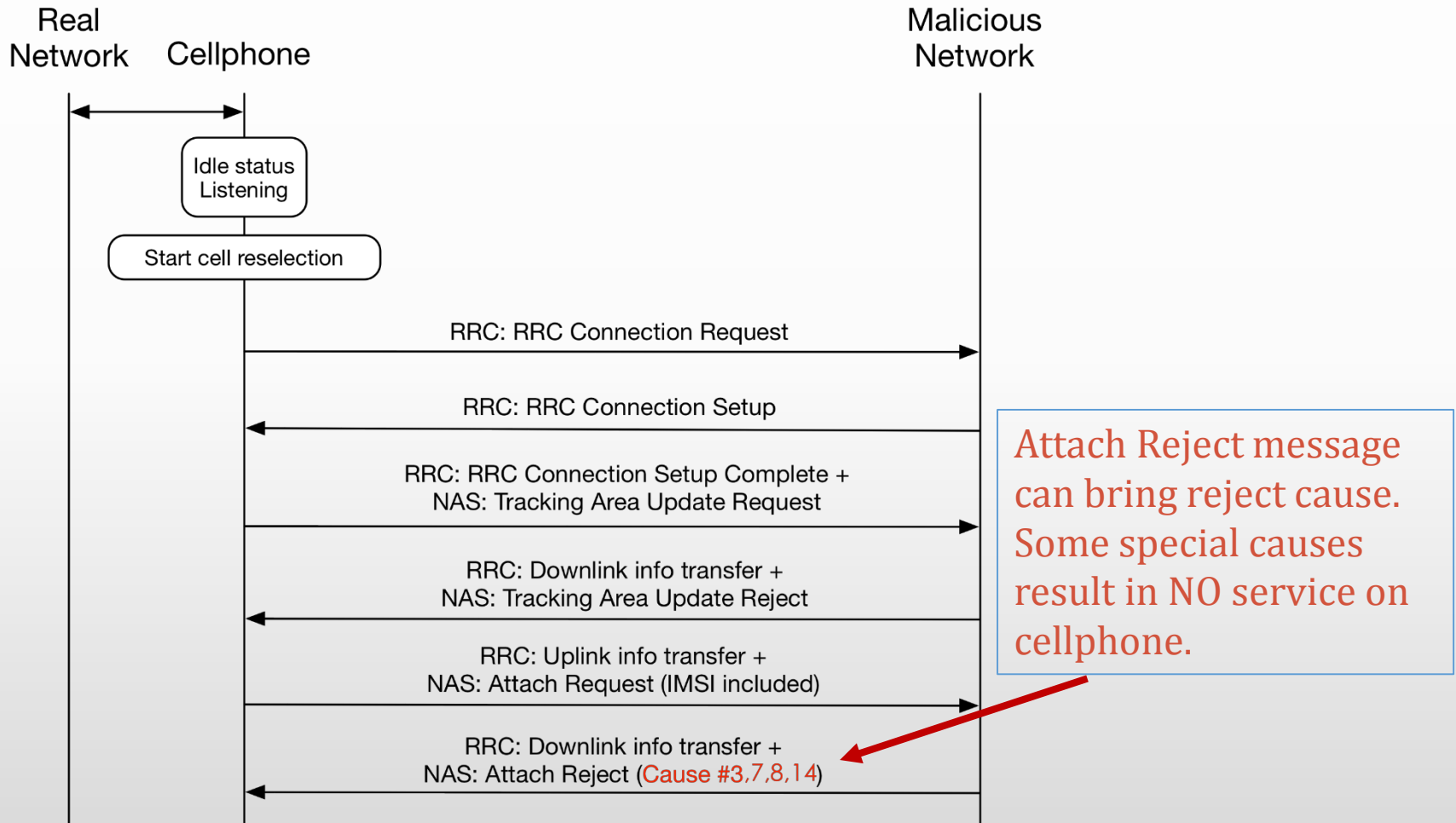
Procedure of IMSI Catcher



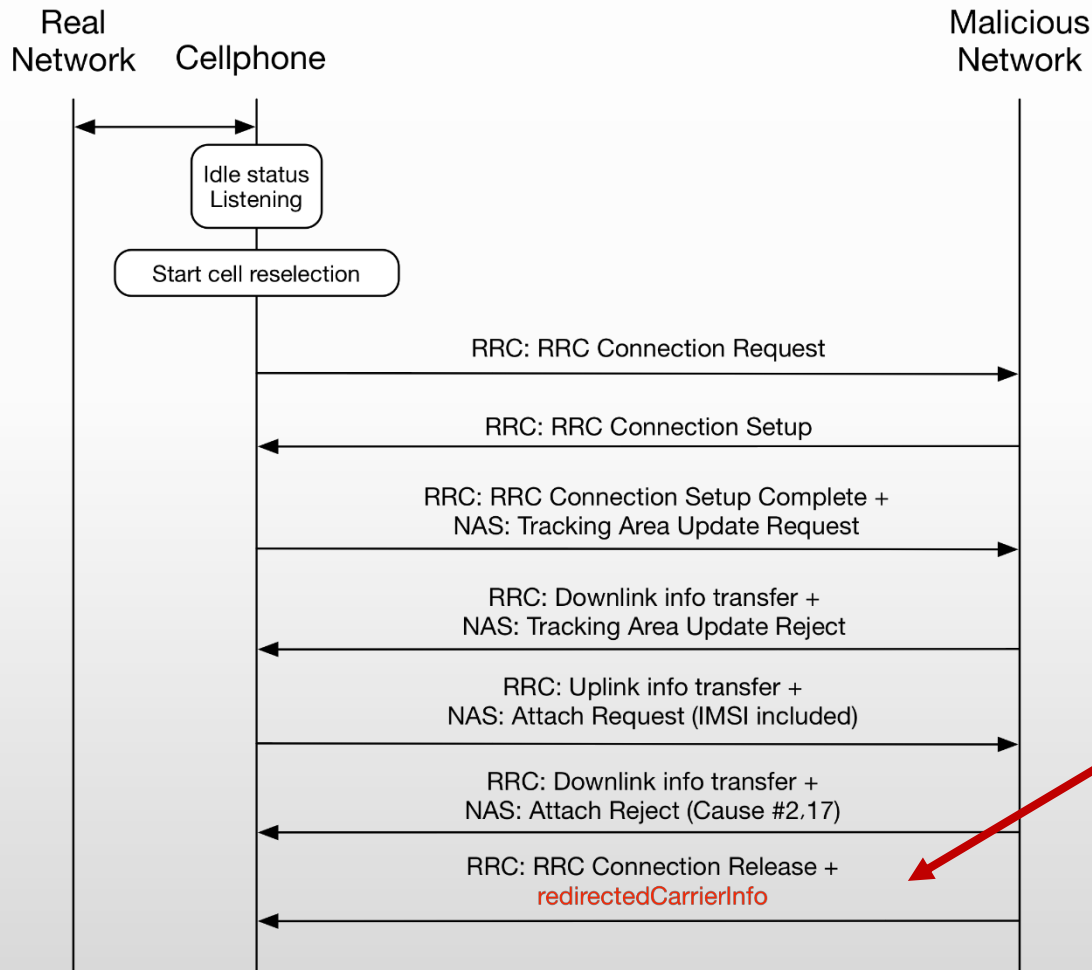
Procedure of IMSI Catcher



Procedure of DoS Attack



Procedure of Redirection Attack



RRC Release message can bring the cell info which it can let cellphone re-direct to.

How to Build Fake LTE Network

- Computer + USRP



How to Build Fake LTE Network

- There are some popular open source LTE projects:

- (1) Open Air Interface by Eurecom

- <http://www.openairinterface.org/>



- The most completed and open source LTE software
 - Support connecting cellphone to Internet
 - But have complicated software architecture



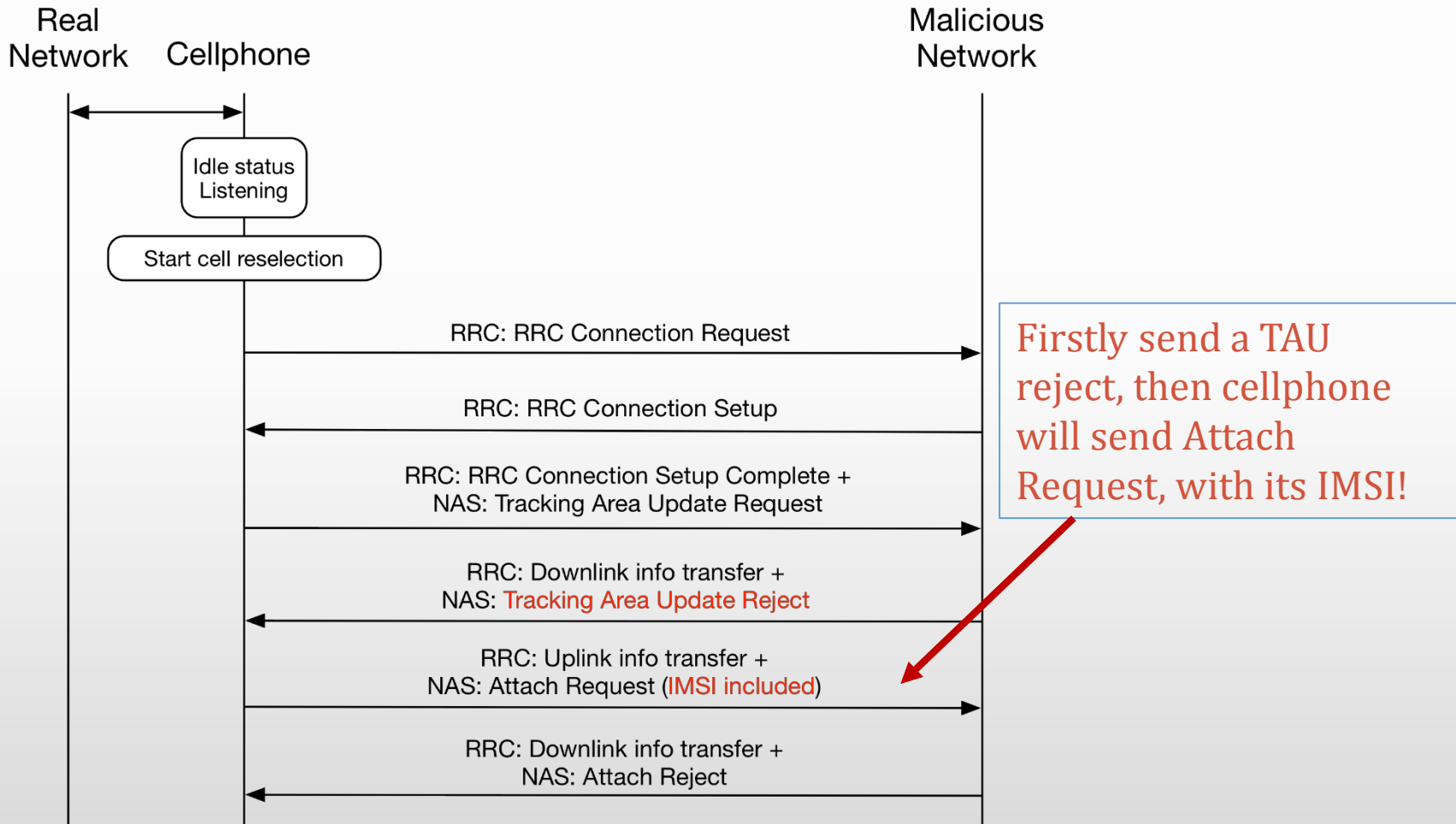
Advanced Technology of Fake Base Station by Seeker



How to Build Fake LTE Network

- There are some popular open source LTE projects:
- (2) **OpenLTE by Ben Wojtowicz** **OpenLTE**
 - <http://openlte.sourceforge.net/>
 - Haven't achieved stable LTE data connection but functional enough for fake LTE network
 - Beautiful code architecture
 - More popular in security researchers

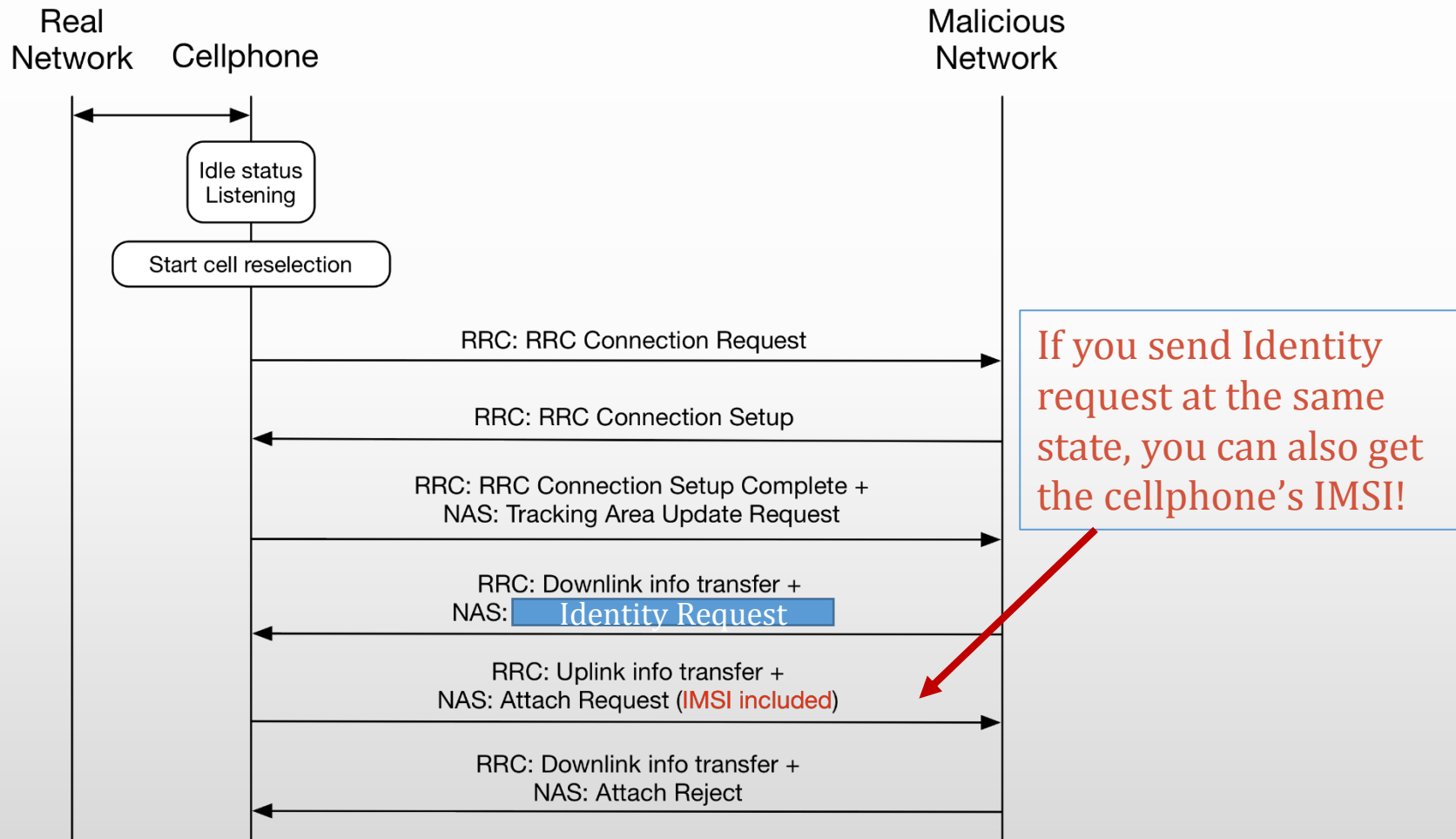
Procedure of IMSI Catcher



LTE Redirection



Procedure of IMSI Catcher



OpenLTE Source Code (1/3)

- In current OpenLTE release, the TAU request isn't handled.

```
case LIBLTE_MME_MSG_TYPE_TRACKING_AREA_UPDATE_REQUEST:
    interface->send_debug_msg(LTE_FDD_ENB_DEBUG_TYPE_ERROR,
                             LTE_FDD_ENB_DEBUG_LEVEL_MME,
                             __FILE__,
                             __LINE__,
                             "Not handling Tracking Area Update Request");

    break;
```

- But TAU reject msg packing function is available.

```
*****
Message Name: Tracking Area Update Reject

Description: Sent by the network to the UE in order to reject the
            tracking area updating procedure.

Document Reference: 24.301 v10.2.0 Section 8.2.28
*****
LIBLTE_ERROR_ENUM liblte_mme_pack_tracking_area_update_reject_msg(LIBLTE_MME_TRACKING_AREA_UPDATE_REJECT_MSG_STRUCT *ta_update_rej,
                                                                    uint8 sec_hdr_type,
                                                                    uint8 *key_256,
                                                                    uint32 count,
                                                                    uint8 direction,
                                                                    LIBLTE_BYTE_MSG_STRUCT *msg)
```



OpenLTE Source Code (1/3)

Set the mme procedure as TAU REQUEST

```
⋮  
(*rb)->set_mme_procedure(LTE_FDD_ENB_MME_TAU_REQUEST);
```

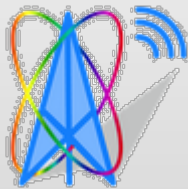
Call the TAU reject message packing module

```
(user)->set_emm_cause(LIBLTE_MME_EMM_CAUSE_UE_IDENTITY_CANNOT_BE_DERIVED_BY_THE_NETWORK);  
track_rej.emm_cause = user->get_emm_cause();  
track_rej.t3446_present = false;  
liblte_mme_pack_tracking_area_update_reject_msg(&track_rej, sec_hdr_type, &key_256, count, direction, &msg);
```

*Refer to Attach reject module



Procedure of IMSI Catcher



Network Optimization Master

The screenshot shows the '网优大师' (Network Optimization Master) app interface. The 'L3信令' (L3 Signaling) tab is selected, displaying a list of RRC messages. A red box highlights two specific messages:

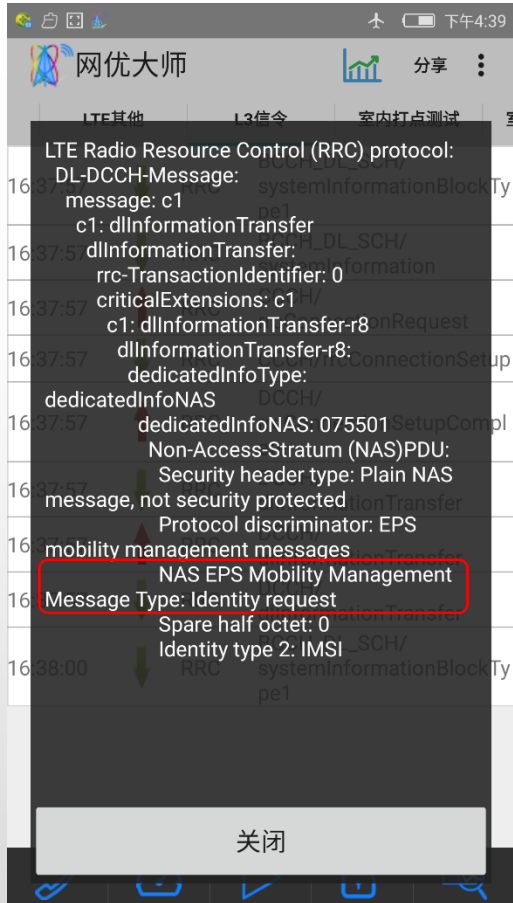
Time	Direction	Protocol	Message Name
16:37:57	↓	RRC	BCCH_DL_SCH/ systemInformationBlockType1
16:37:57	↓	RRC	BCCH_DL_SCH/ systemInformation
16:37:57	↑	RRC	CCCH/ rrcConnectionRequest
16:37:57	↓	RRC	CCCH/rrcConnectionSetup
16:37:57	↑	RRC	DCCH/ rrcConnectionSetupComplete
16:37:57	↓	RRC	DCCH/ dlInformationTransfer
16:37:57	↑	RRC	DCCH/ ulInformationTransfer
16:37:57	↓	RRC	DCCH/ dlInformationTransfer
16:38:00	↓	RRC	BCCH_DL_SCH/ systemInformationBlockType1

LTE Redirection

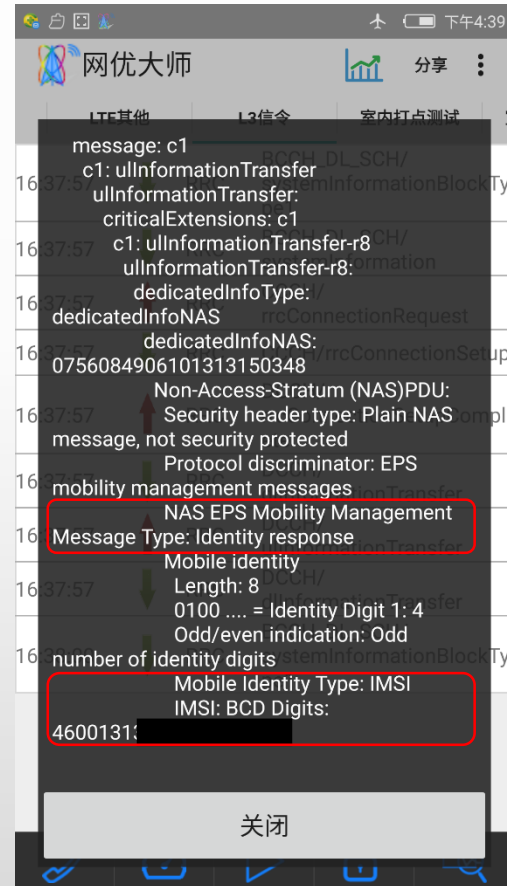


Procedure of IMSI Catcher

Identity Request



Identity response



OpenLTE Souce Code (2/3)

DoS attack can directly utilize the cause setting in Attach Reject message.

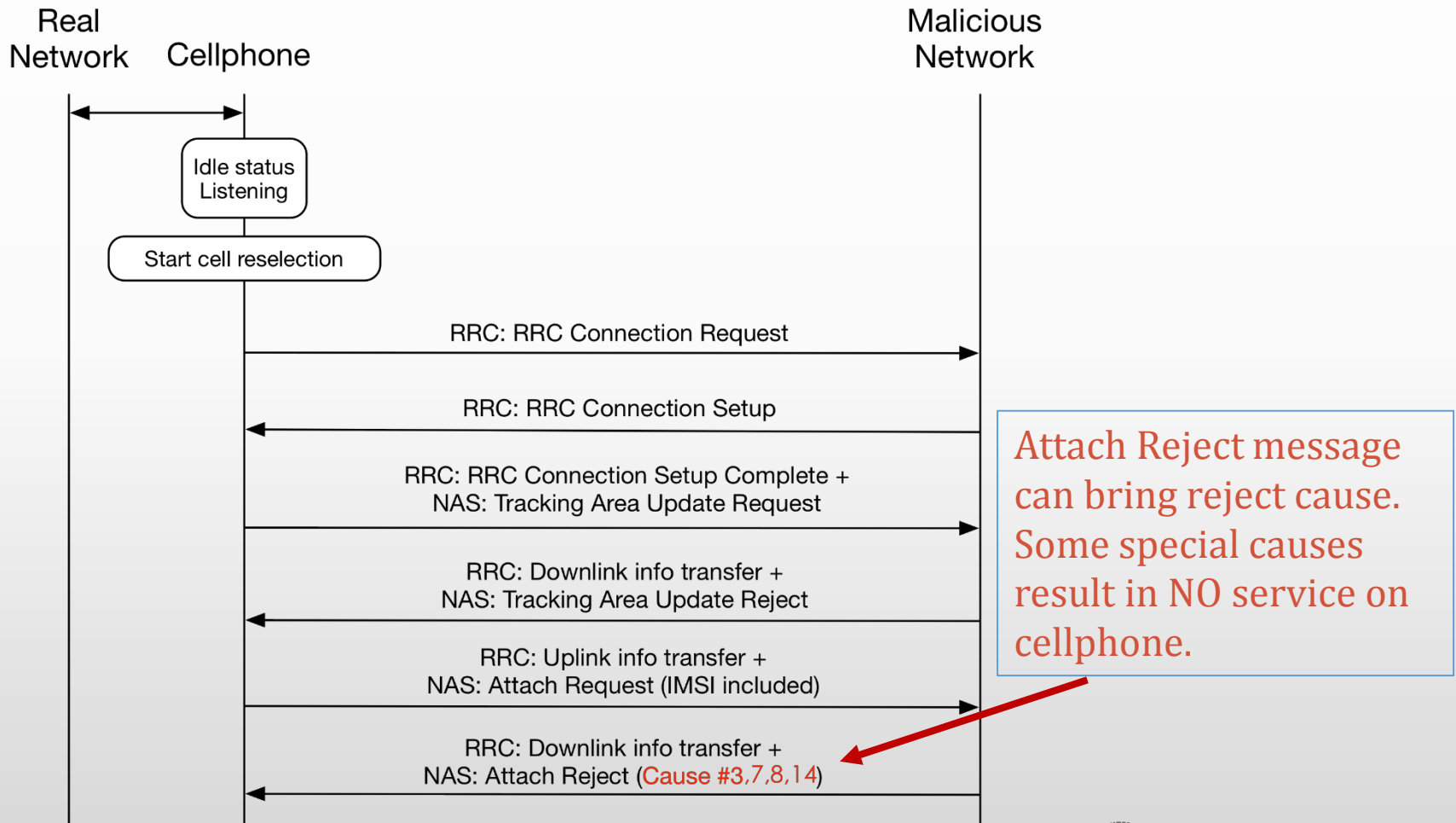
```
void LTE_fdd_enb_mme::send_attach_reject(LTE_fdd_enb_user *user,
                                         LTE_fdd_enb_rb  *rb)
{
    LTE_FDD_ENB_RRC_NAS_MSG_READY_MSG_STRUCT nas_msg_ready;
    LIBLTE_MME_ATTACH_REJECT_MSG_STRUCT      attach_rej;
    LIBLTE_BYTE_MSG_STRUCT                   msg;
    uint64                                    imsi_num;

    if(user->is_id_set())
    {
        imsi_num = user->get_id()->imsi;
    }else{
        imsi_num = user->get_temp_id();
    }

    attach_rej.emm_cause          = user->get_emm_cause();
    attach_rej.esm_msg_present    = false;
    attach_rej.t3446_value_present = false;
    liblte_mme_pack_attach_reject_msg(&attach_rej, &msg);
    interface->send_debug_msg(LTE_FDD_ENB_DEBUG_TYPE_INFO,
                              LTE_FDD_ENB_DEBUG_LEVEL_MME,
                              FILE
```



Procedure of DoS Attack



OpenLTE Source Code (3/3)

redirectCarrierInfo can be inserted into RRC Connection Release message.

```
/*
*****
Message Name: RRC Connection Release

Description: Used to command the release of an RRC connection

Document Reference: 36.331 v10.0.0 Section 6.2.2
*****
LIBLTE_ERROR_ENUM liblte_rrc_pack_rrc_connection_release_msg(LIBLTE_RRC_CONNECTION_RELEASE_STRUCT *con_release,
                                                             LIBLTE_BIT_MSG_STRUCT *msg)
{
    LIBLTE_ERROR_ENUM err = LIBLTE_ERROR_INVALID_INPUTS;
    uint8 *msg_ptr = msg->msg;

    if(con_release != NULL &&
        msg != NULL)
    {
        // RRC Transaction ID
        liblte_rrc_pack_rrc_transaction_identifier_ie(con_release->rrc_transaction_id,
                                                    &msg_ptr);

        // Extension choice
        liblte_value_2_bits(0, &msg_ptr, 1);

        // C1 choice
        liblte_value_2_bits(0, &msg_ptr, 2);

        // Optional indicators
        liblte_value_2_bits(0, &msg_ptr, 1);
        liblte_value_2_bits(0, &msg_ptr, 1);
        liblte_value_2_bits(0, &msg_ptr, 1);

        // Release cause
        liblte_value_2_bits(con_release->release_cause, &msg_ptr, 2);
    }
}
```

OpenLTE Source Code (3/3)

RRCConnectionRelease message

```
-- ASN1START..
..
RRCConnectionRelease ::= SEQUENCE {..
    rrc-TransactionIdentifier      RRC-TransactionIdentifier,..
    criticalExtensions             CHOICE {..
        c1                       CHOICE {..
            rrcConnectionRelease-r8      RRCConnectionRelease-r8-IEs,..
            spare3 NULL, spare2 NULL, spare1 NULL..
        },..
        criticalExtensionsFuture        SEQUENCE {}..
    }..
}..
..
RRCConnectionRelease-r8-IEs ::= SEQUENCE {..
    releaseCause                  ReleaseCause,..
    redirectedCarrierInfo         RedirectedCarrierInfo                OPTIONAL, -- Need ON
    idleModeMobilityControlInfo   IdleModeMobilityControlInfo        OPTIONAL, -- Need OP
    nonCriticalExtension          RRCConnectionRelease-v890-IEs        OPTIONAL..
}..
..
```



OpenLTE Source Code (3/3)

14:43:20.360 ↓ RRC/DCCH/dlInformationTransfer

14:43:20.380 ↓ RRC/DCCH/rrcConnectionRelease

14:43:20.910 ↓ RRC/BCCH_DL_SCH/systemInformationBlo.

14:43:20.910 ↓ RRC/BCCH_DL_SCH/systemInformation

LTE Radio Resource Control (RRC) protocol:

DL-DCCH-Message:

message: c1

c1: rrcConnectionRelease

rrcConnectionRelease:

rrc-TransactionIdentifier: 0

criticalExtensions: c1

c1: rrcConnectionRelease-r8

rrcConnectionRelease-r8:

releaseCause: other

redirectedCarrierInfo: geran

geran:

startingARFCN: 42

bandIndicator: dcs1800

followingARFCNs: explicitListOfARFCNs

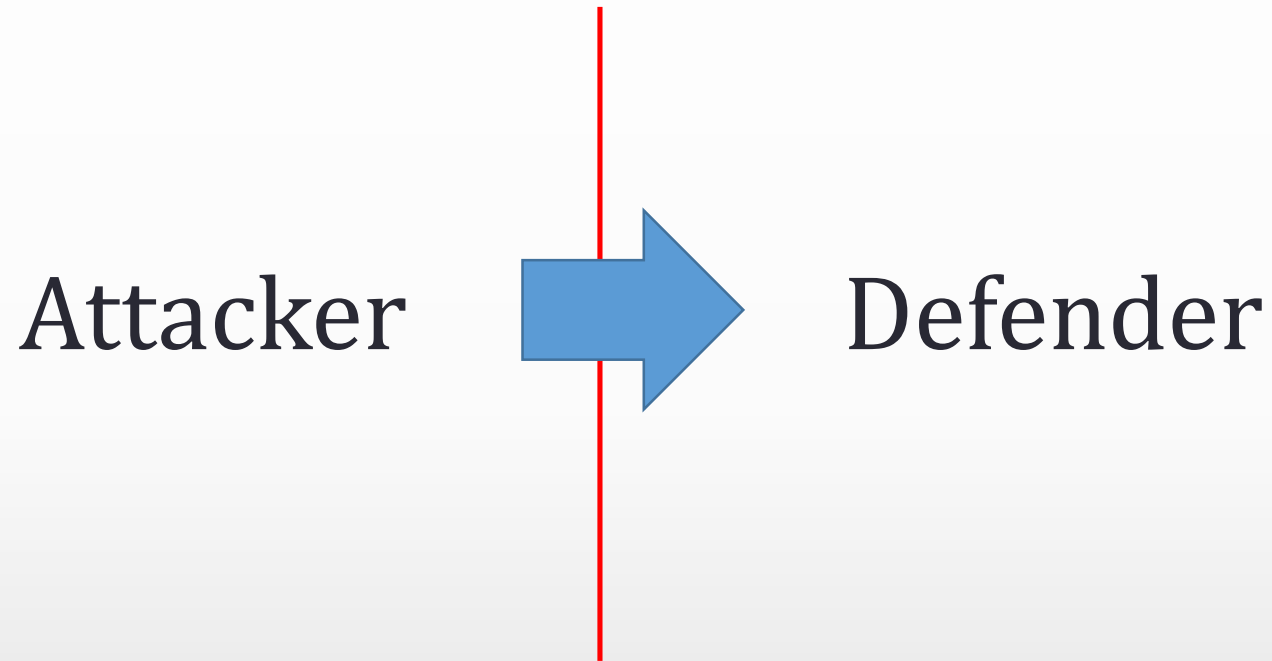
explicitListOfARFCNs: 1 item

Item 0

ARFCN-ValueGERAN: 42



Think from the other side



Why is RRC redirection message not encrypted?

Is This a New Problem?

- "Security Vulnerabilities in the E-RRC Control Plane", 3GPP TSG-RAN WG2/RAN WG3/SA WG3 joint meeting, R3-060032, 9-13 **January 2006**
- This document introduced a 'Forced handover' attack:

An attacker with the ability to generate RRC signaling—that is, any of the forms of compromise listed above—can **initiate a reconfiguration procedure with the UE, directing it to a cell or network chosen by the attacker**. This could function as a denial of service (if the target network cannot or will not offer the UE service) or to allow a chosen network to “capture” UEs.

An attacker who already had full control of one system (perhaps due to weaker security on another RAT) could direct other systems' UEs to “their” network as a prelude to more serious security attacks using the deeply compromised system. Used in this way, the ability to force a handover serves to expand any form of attack to UEs on otherwise secure systems, meaning that a single poorly secured network (in any RAT that interoperates with the E-UTRAN) becomes a point of vulnerability not only for itself but for all other networks in its coverage area.

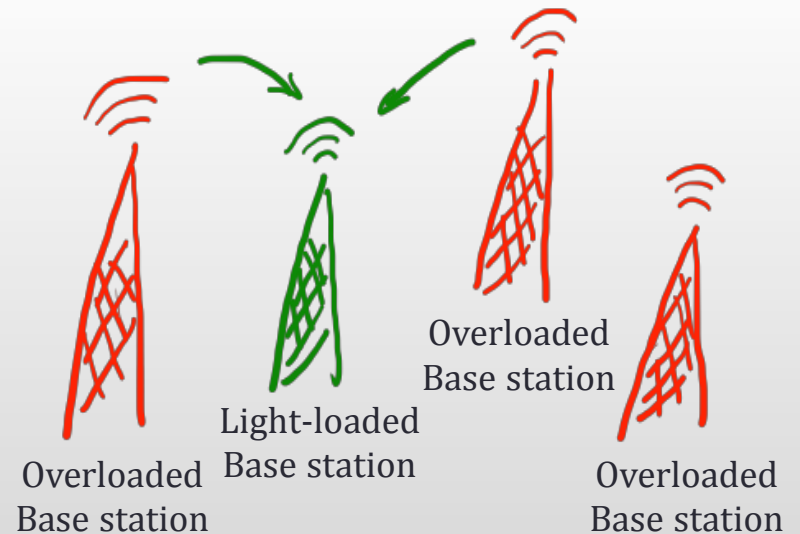
3GPP's Decision

- “Reply LS on assumptions for security procedures”, 3GPP TSG SA WG3 meeting #45, S3-060833, 31st Oct - 3rd Nov 2006

- (1) RRC Integrity and ciphering will be started only once during the attach procedure (i.e. after the AKA has been performed) and can not be deactivated later.
- (2) RRC Integrity and ciphering algorithm **can only be changed in the case of the eNodeB handover.**

Why 3GPP Made Such Decision

- In special cases, e.g. earthquake, disaster, hot events
 - Too many people try to access one base station then make this base station overloaded.
 - To let network **load balanced**, this base station can ask the new coming cellphone to redirect to another base station.
 - If you don't tell cellphones which base station is light-loaded, the cellphones will blindly and inefficiently search one by one, and then increase the whole network load.



Network Availability vs.. Privacy

- Global roaming
- Energy saving
- Load balance

Basic requirement

VS.

- IMSI Catcher
e.g. Wifi MAC addr tracking
- DoS Attack
- Redirection Attack

High level requirement

Countermeasures (1/2)

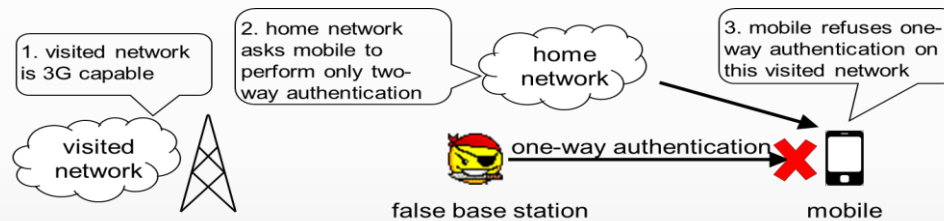
- Cellphone manufacture – smart response
 - Scheme 1: Don't follow the redirection command, but auto-search other available base station.
 - Scheme 2: Follow the redirection command, but raise an alert to cellphone user: Warning! You are downgraded to low security network.



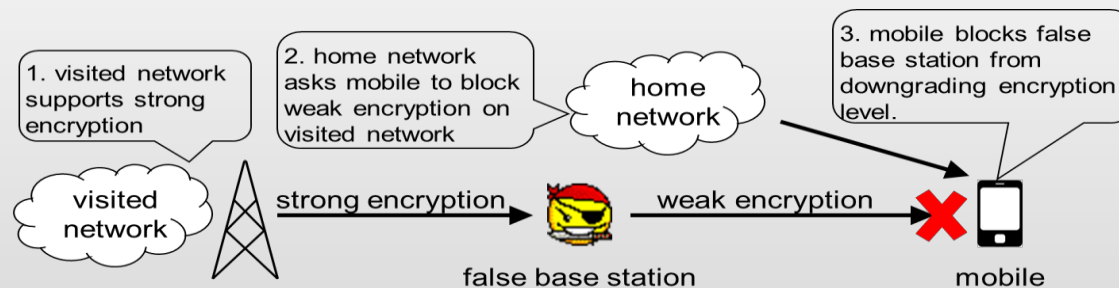
Countermeasures (2/2)

- Standardization effort

- Fix the weak security of legacy network: GSM
- 3GPP TSG SA WG3 (Security) Meeting #83, S3-160702, 9-13 May 2016 Legacy Security Issues and Mitigation Proposals, Liaison Statement from GSMA.
- Refuse one-way authentication



- Disabling compromised encryption in mobile



Acknowledgements

- Huawei
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 - CHEN Jing (3GPP SA3 standardization expert)
- Qualcomm
 - GE Renwei (security expert)
- Apple
 - Apple product security team



Any question?

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Thank you !

