LTE REDIRECTION

Forcing Targeted LTE Cellphone into Unsafe Network

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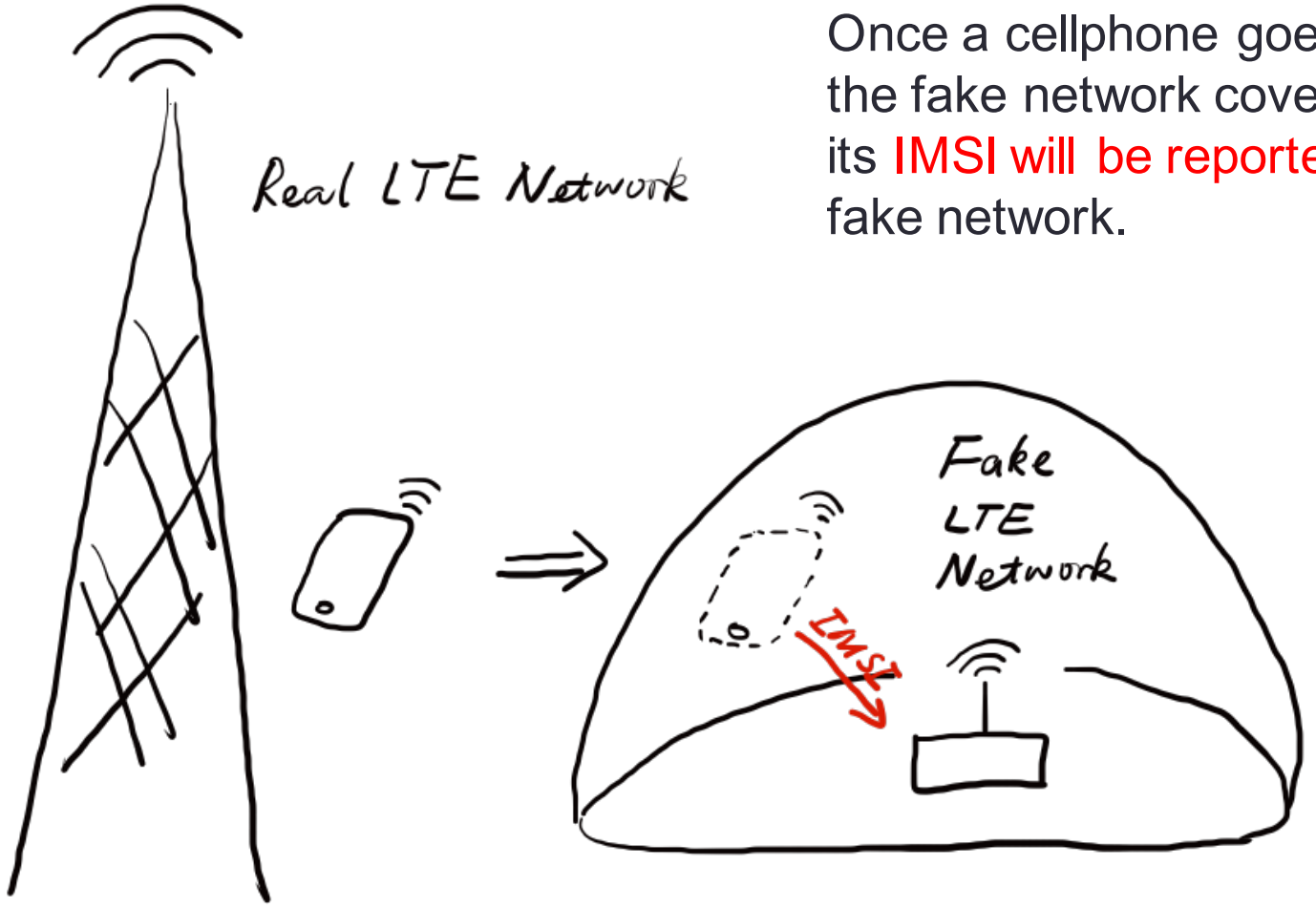
LTE and IMSI catcher myths

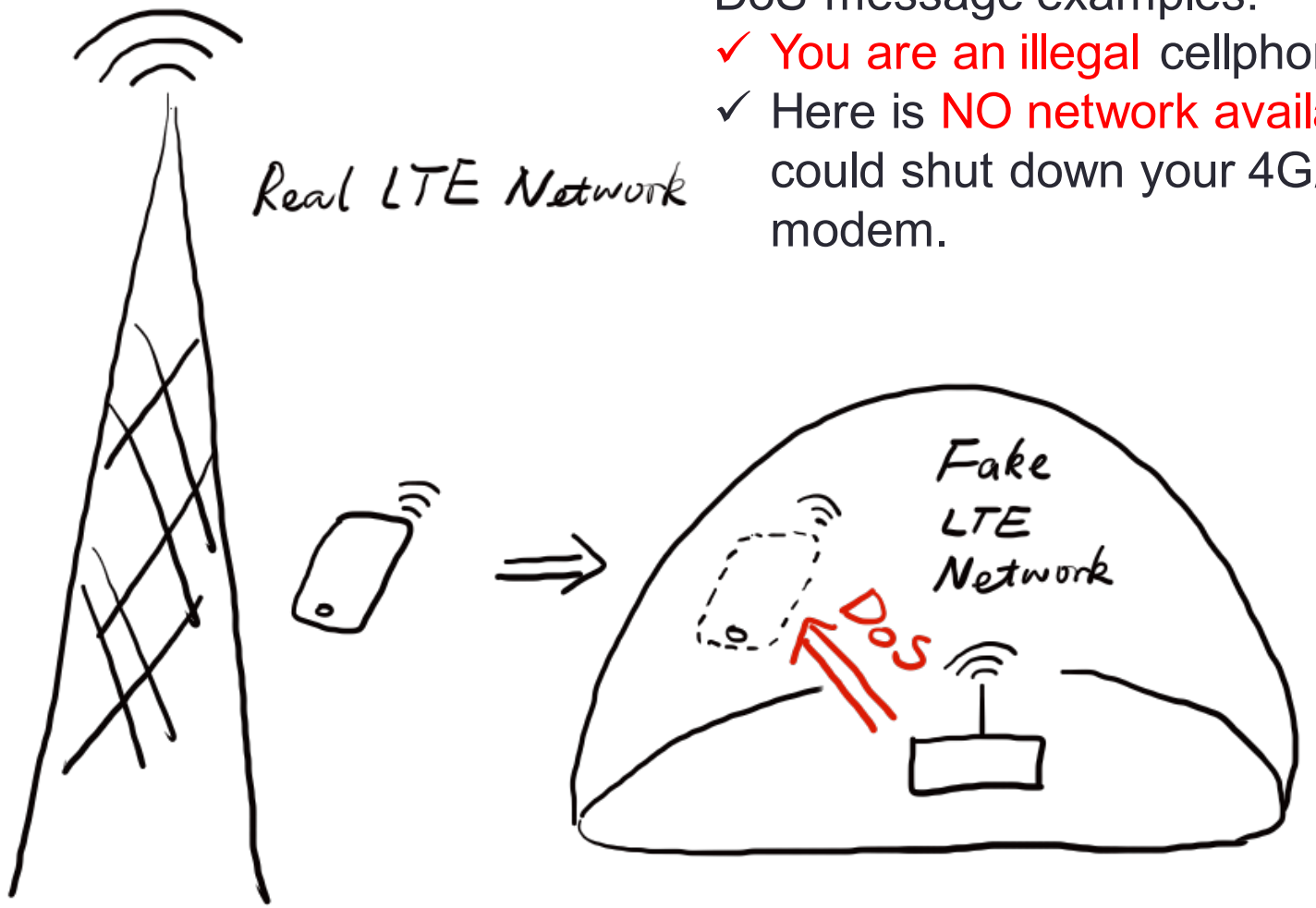
- In Nov. 2015, BlackHat EU, Ravishankar Borgaonkar, and Altaf Shaik etc. introduced the LTE IMSI catcher and DoS attack.

IMSI Catcher



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

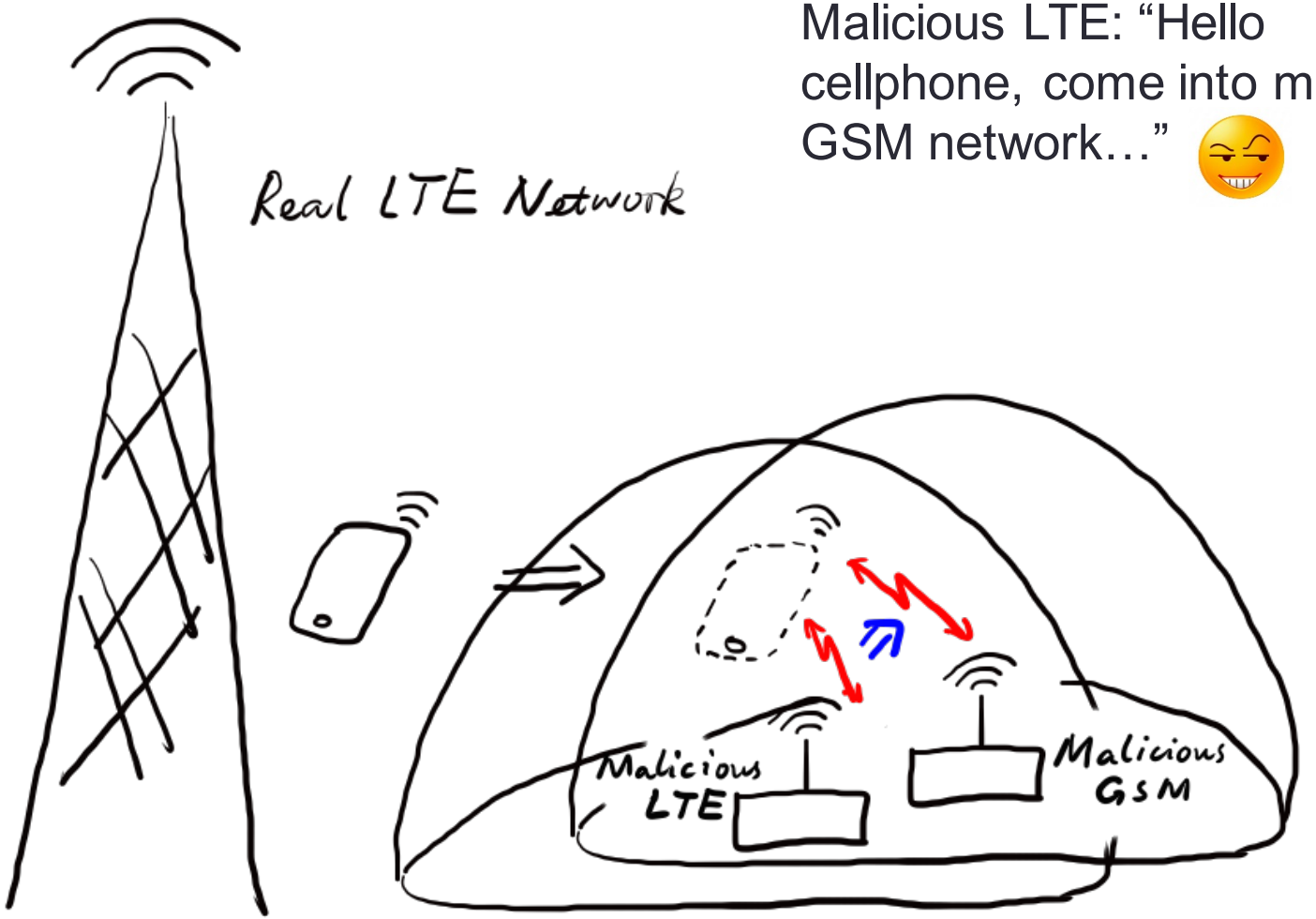
DoS Attack



DoS message examples:

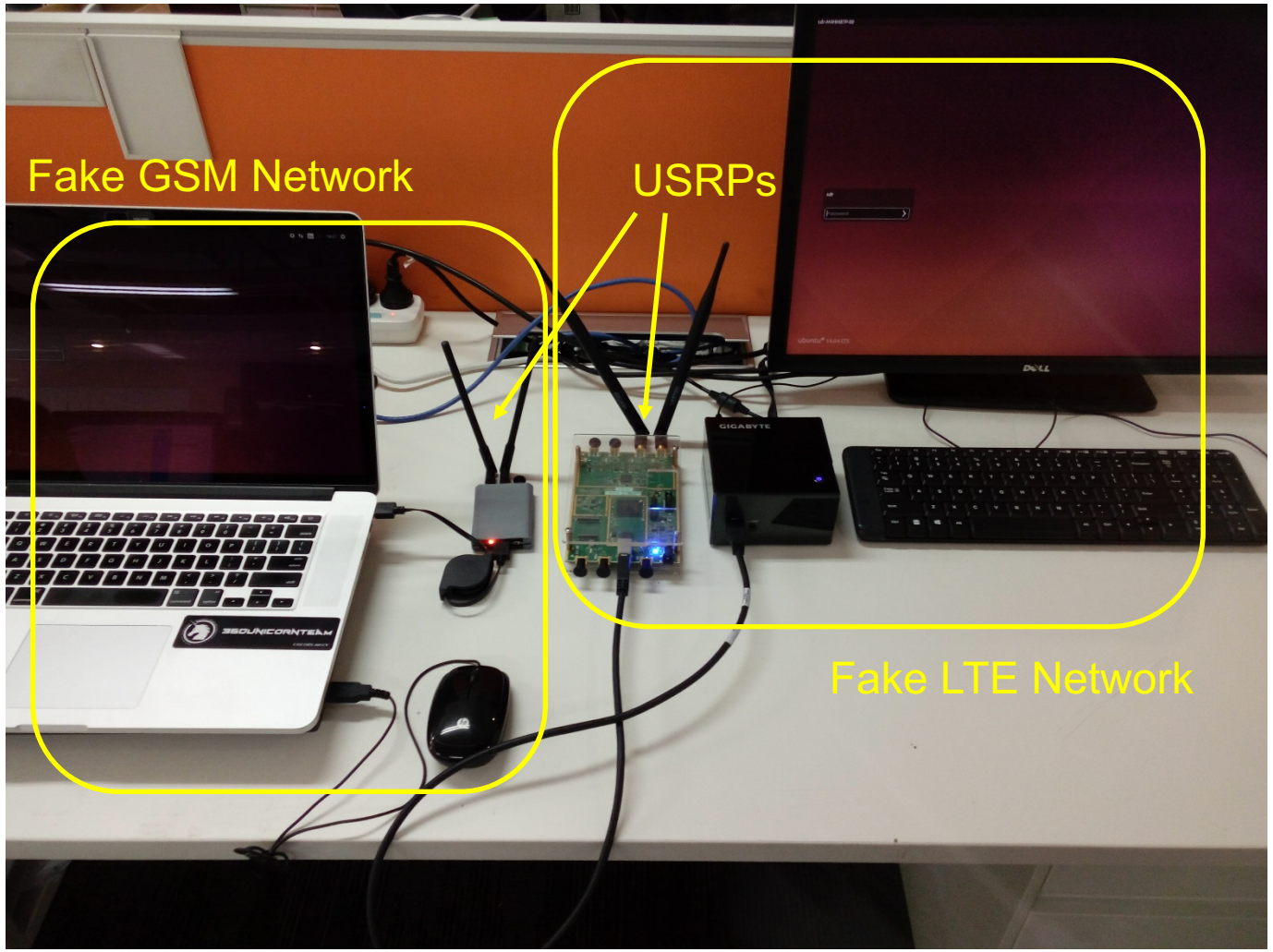
- ✓ You are an illegal cellphone!
- ✓ Here is NO network available. You could shut down your 4G/3G/2G modem.

Redirection Attack

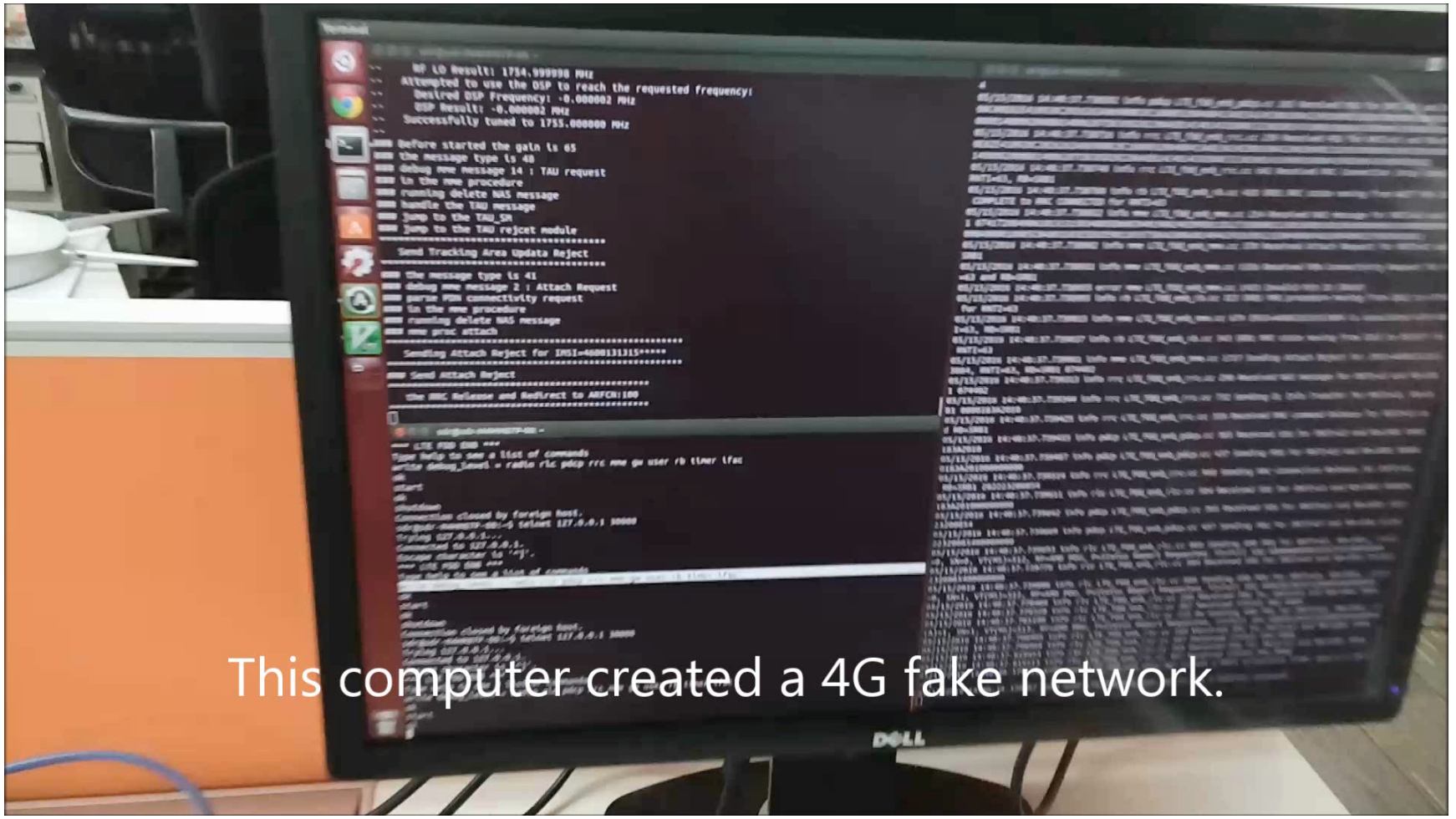


Malicious LTE: “Hello cellphone, come into my GSM network…”

Demo



Demo Video



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.

A femtocell controlled by attacker

LTE Basic Procedure

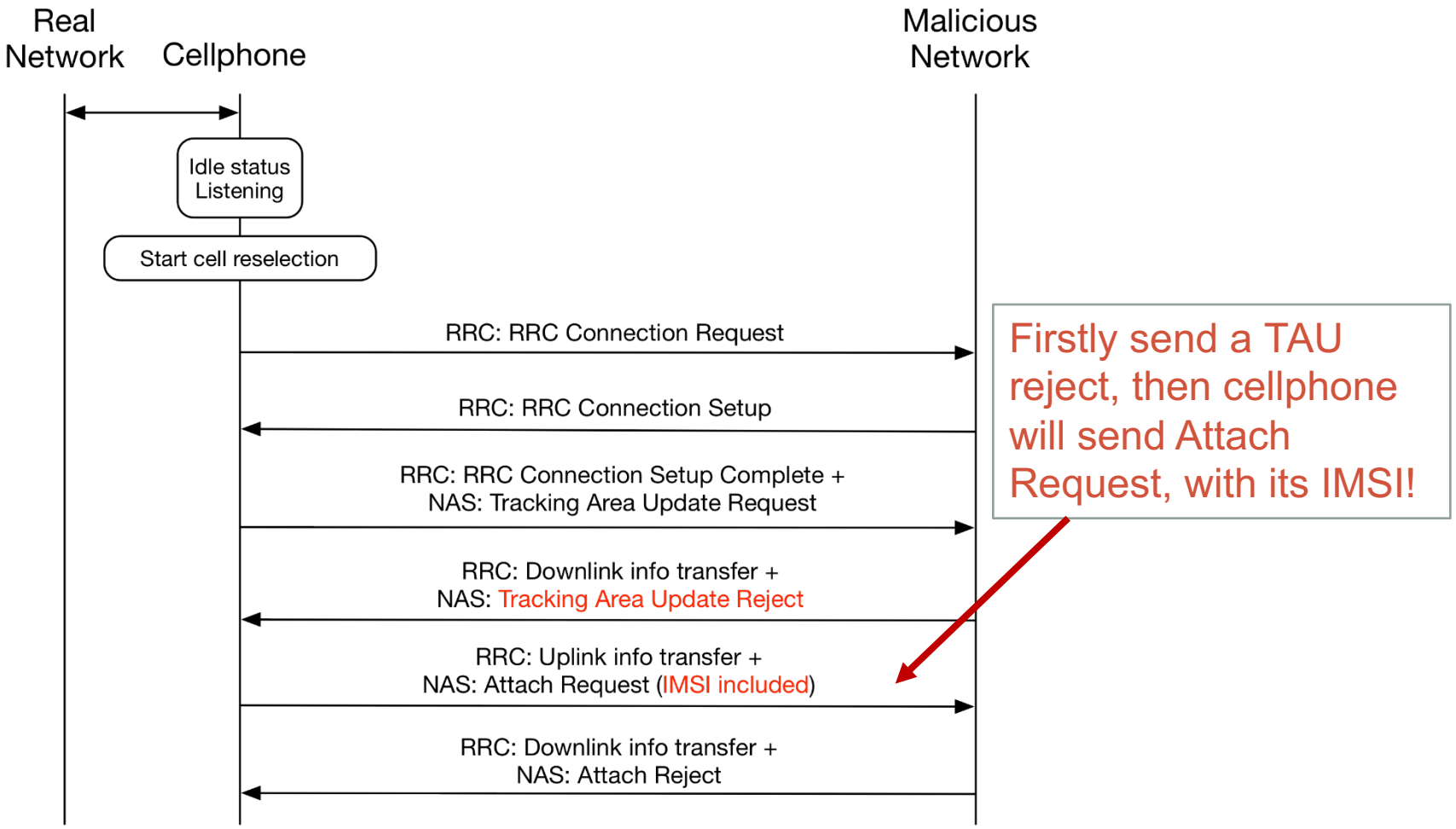
- (Power on)
- Cell search, MIB, SIB1, SIB2 and other SIBs
- PRACH preamble
- RACH response
- RRC Connection Request
- RRC Connection Setup
- RRC Connection Setup Complete + NAS: Attach request + ESM: PDN connectivity request
- RRC: DL info transfer + NAS: Authentication request

Unauthorized area

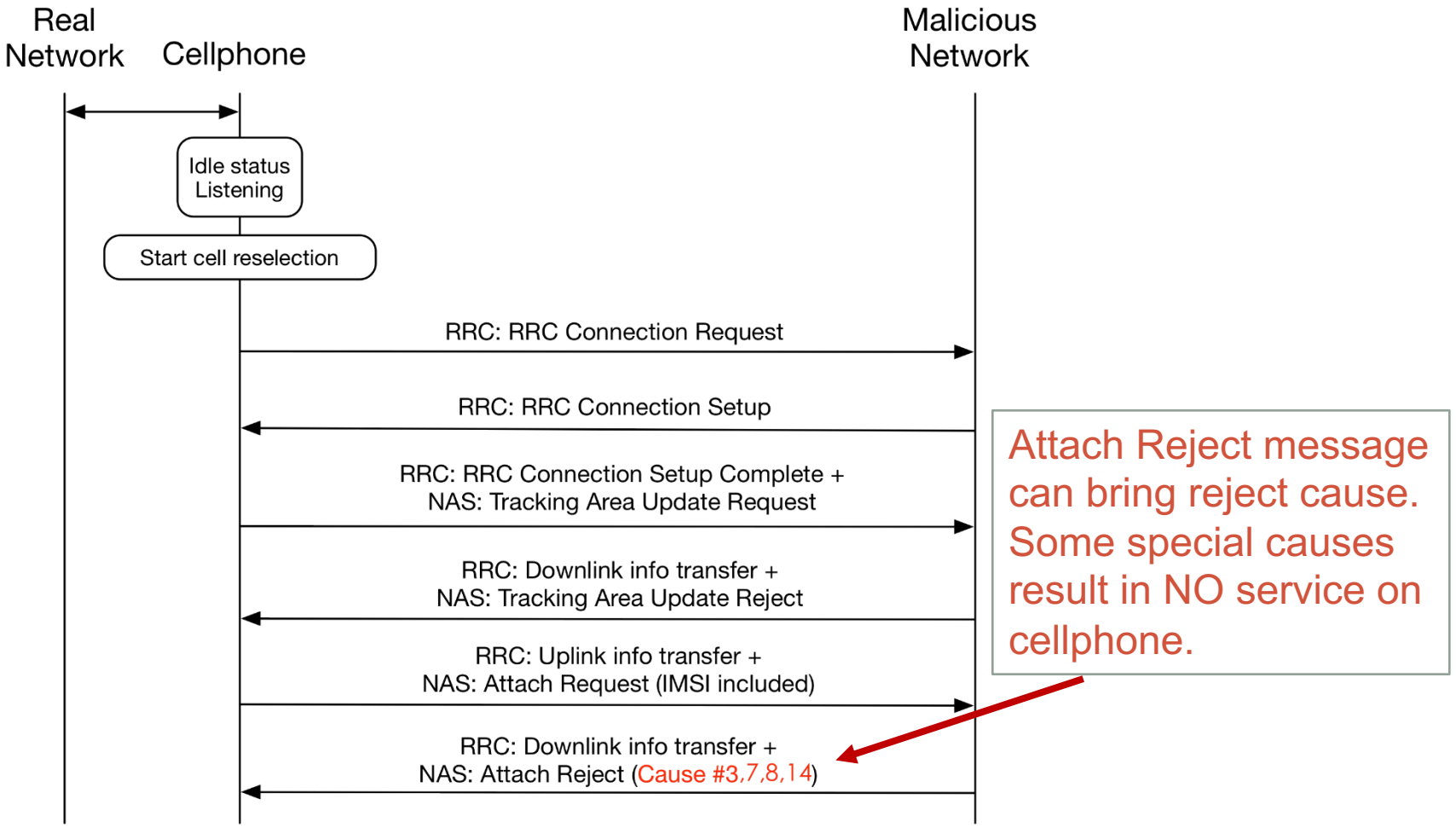
Attack Space!

- RRC: UL info transfer + NAS: Authentication response
- RRC: DL info transfer + NAS: Security mode command
- RRC: UL info transfer + NAS: Security mode completer
- ……

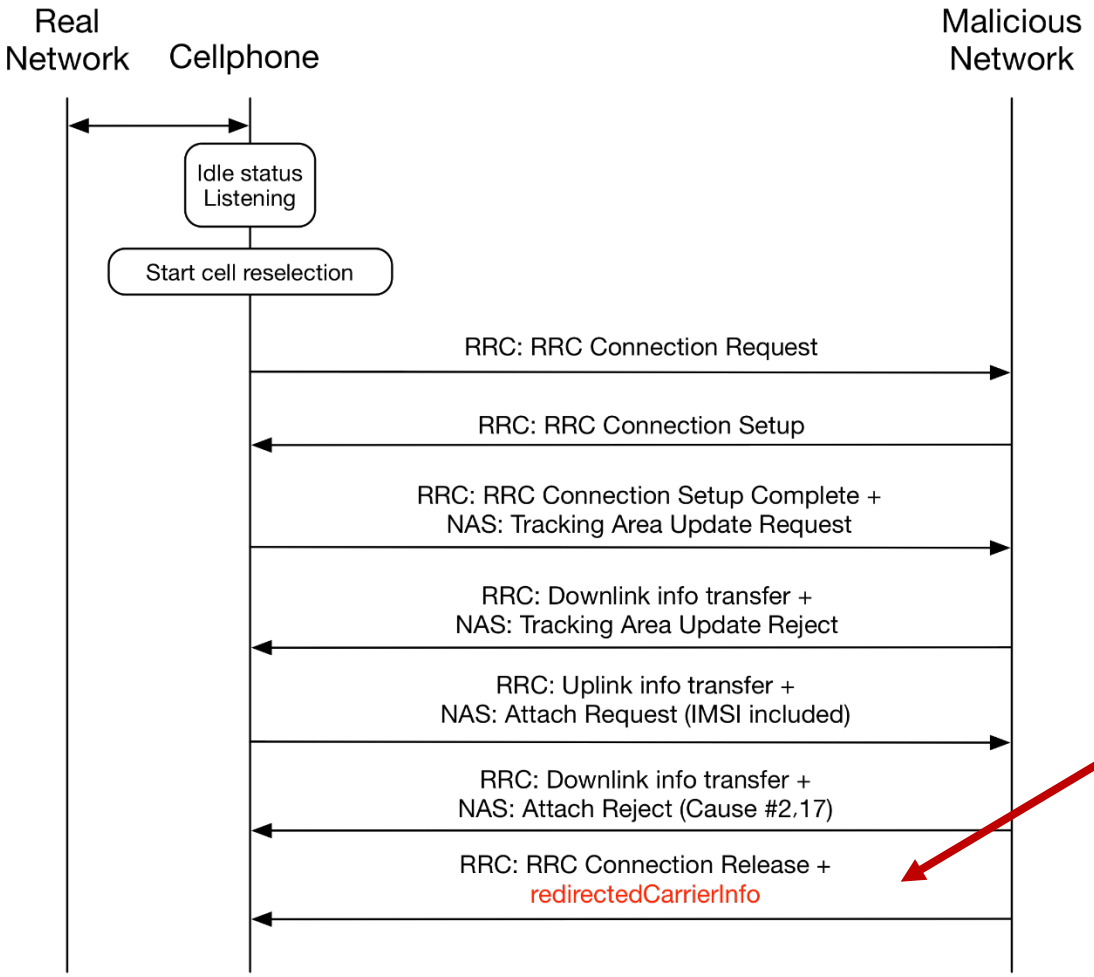
Procedure of IMSI Catcher



Procedure of DoS Attack



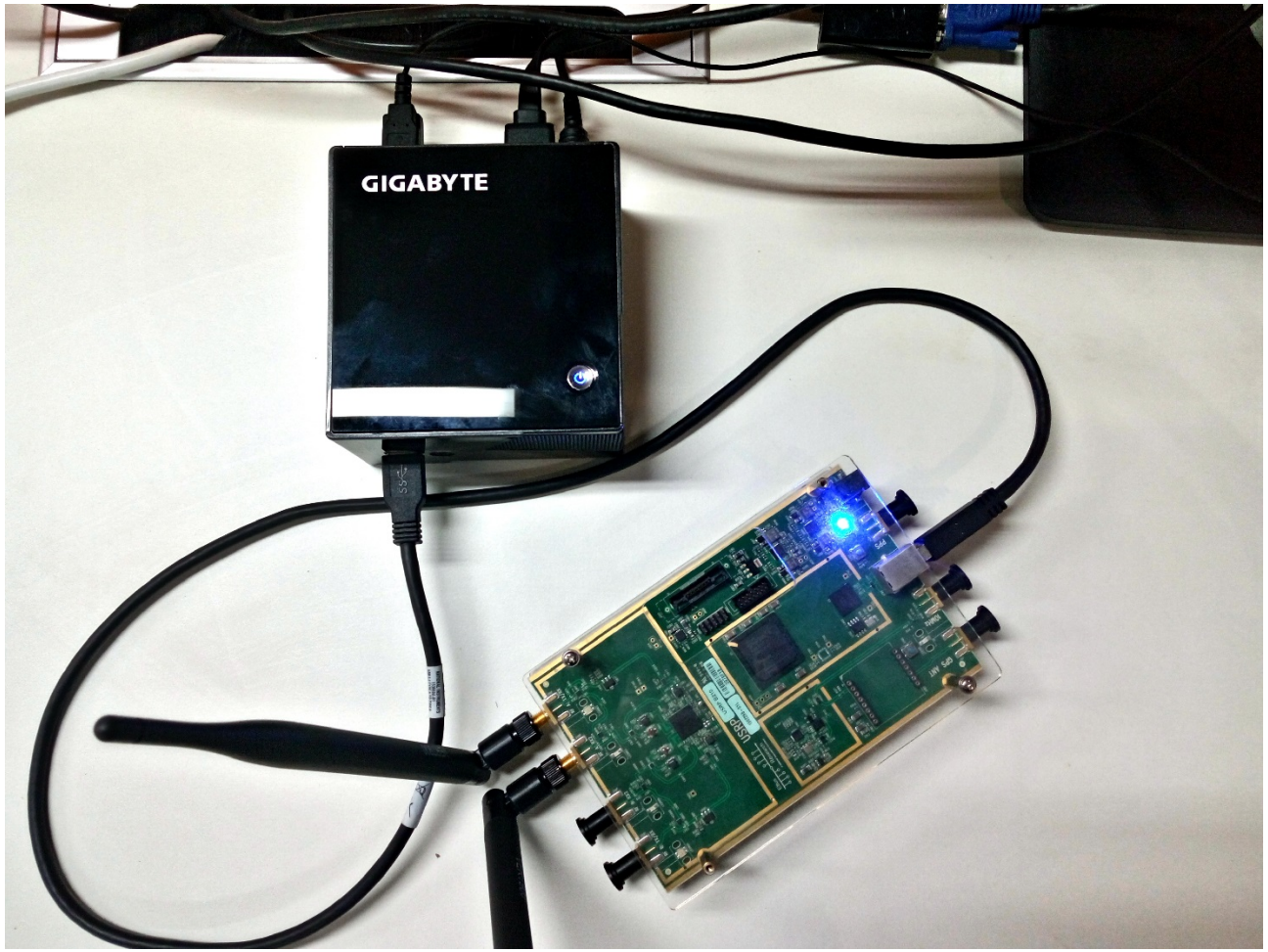
Procedure of Redirection Attack



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:
- 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
- OpenLTE by Ben Wojtowicz
  - 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

OpenLTE Source Code (1/3)

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

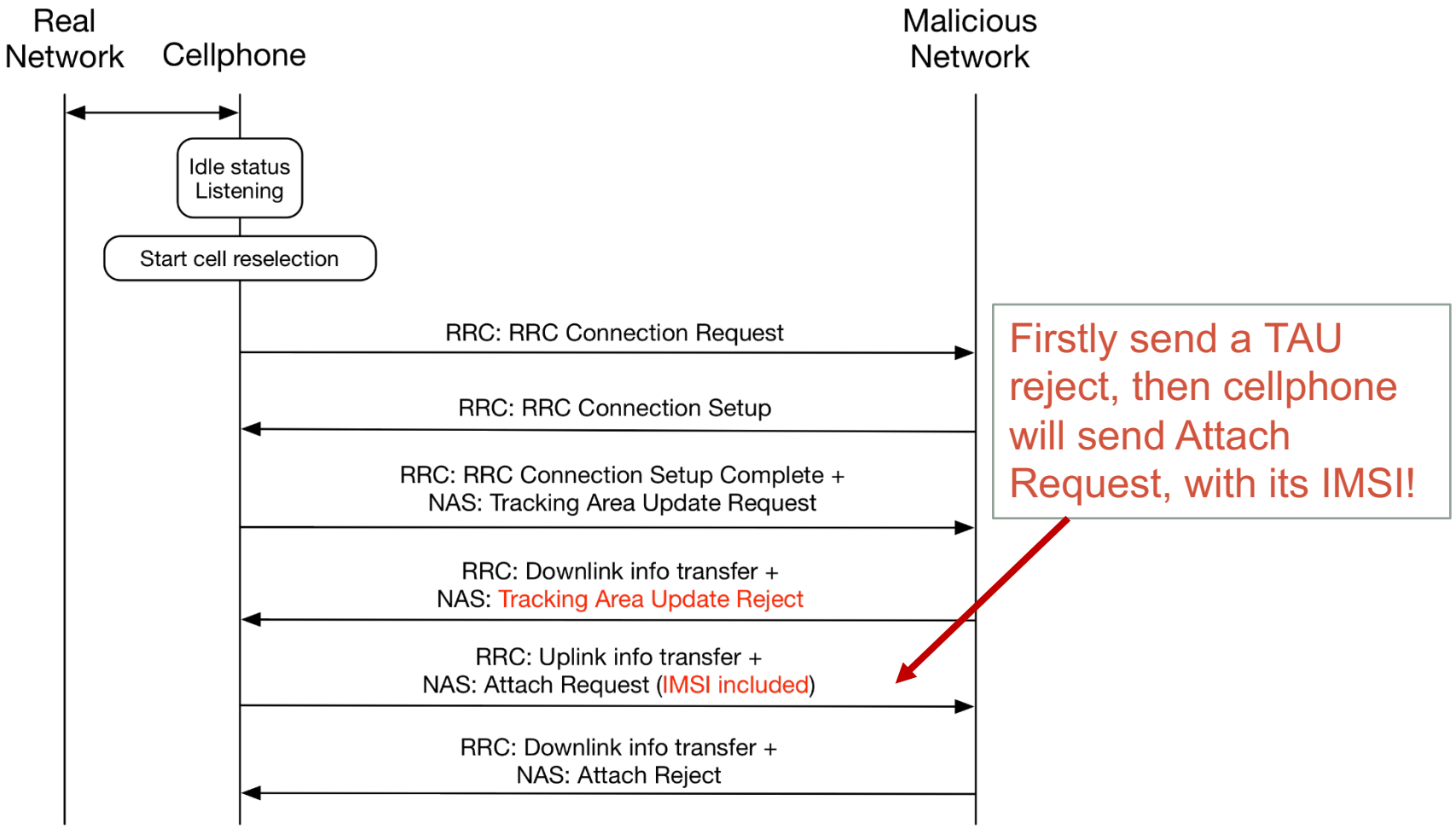
```
case LIBLTE_MME_MSG_TYPE_TRACKING_AREA_UPDATE_REQUEST:
    interface->send_debug_msg(LTE_FDD_ENB_DEBUG_TYPE_ERROR,
                              LTE_FDD_ENB_DEBUG_LEVEL_MME,
                              __FILE__,
                              __LINE__,
                              "Not handling 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)
```

So we could add some codes to handle TAU case and give appropriate TAU reject cause.

Procedure of IMSI Catcher



OpenLTE Source Code (1/3)

Set the mme procedure as TAU REQUET

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

Call the TAU reject msg packing function

```
(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);
```

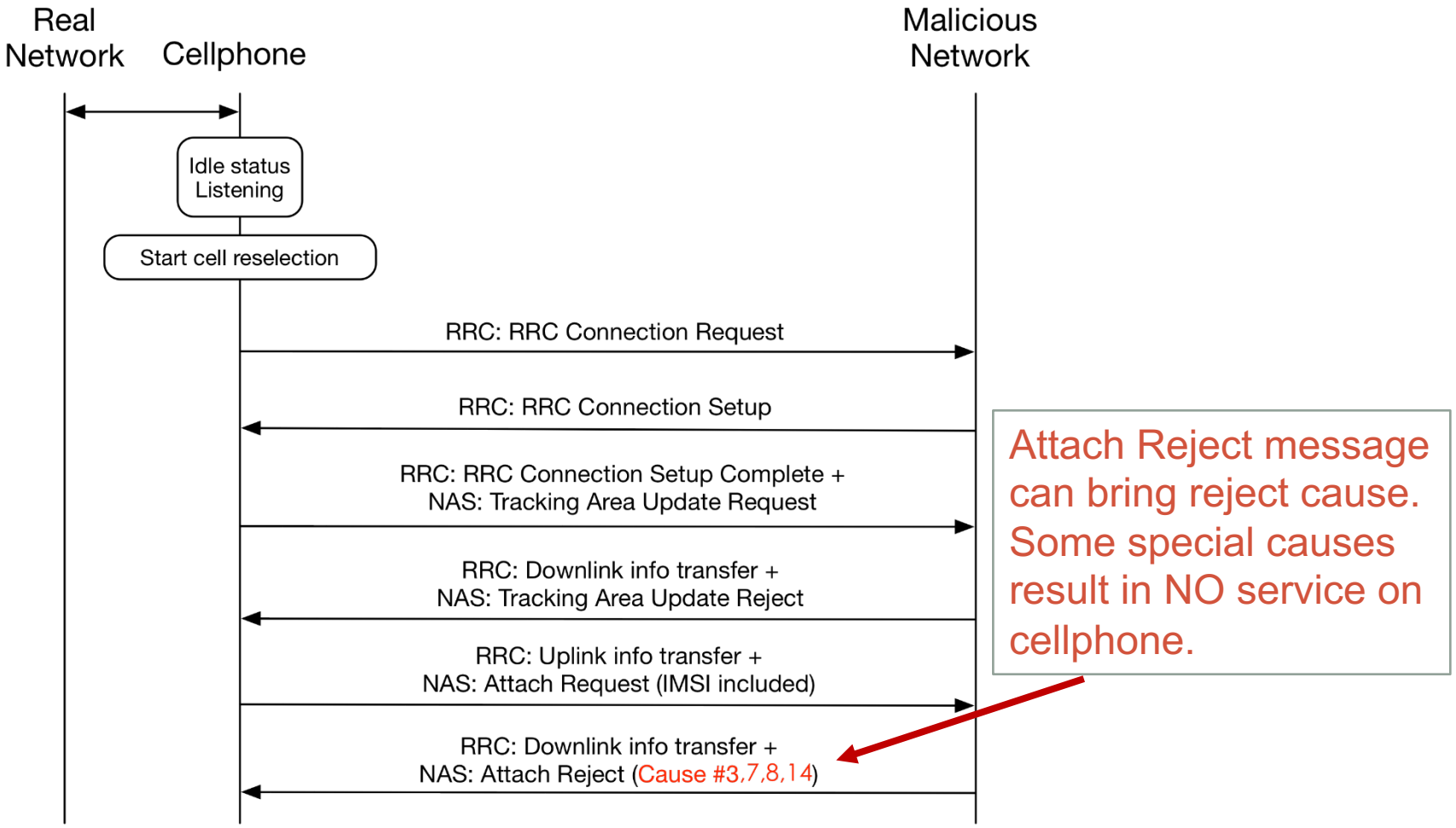
Refer to Attach reject function

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,
```

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
                                                      &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);
```

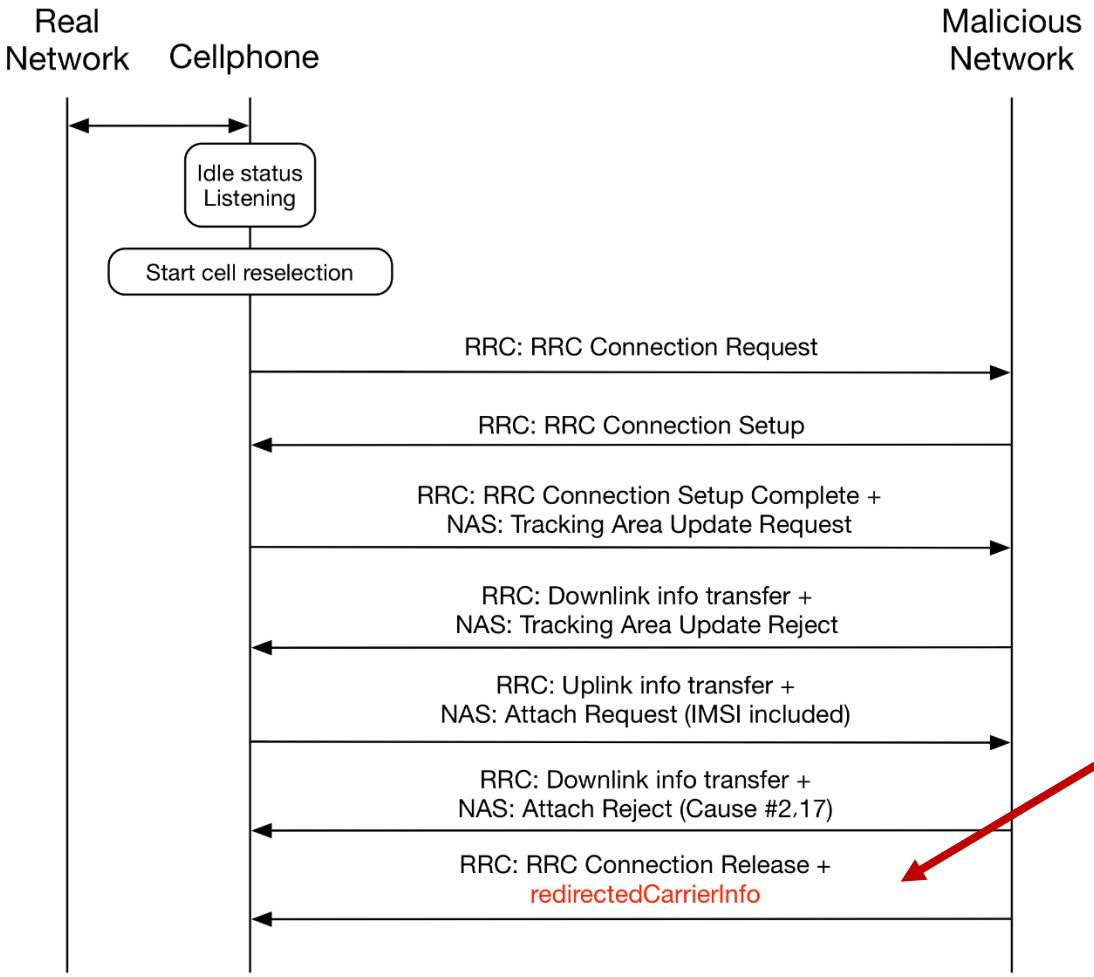
```
14:43:20.360 ⇩ RRC/DCCH/dlInformationTransfer
14:43:20.380 ⇩ RRC/DCCH/rrcConnectionRelease
14:43:20.910 ⇩ RRC/BCCH_DL_SCH/systemInformationBlo.
14:43:20.910 ⇩ RRC/BCCH_DL_SCH/systemInformation

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
```

OpenLTE Source Code (3/3)

RRCConnectionRelease message

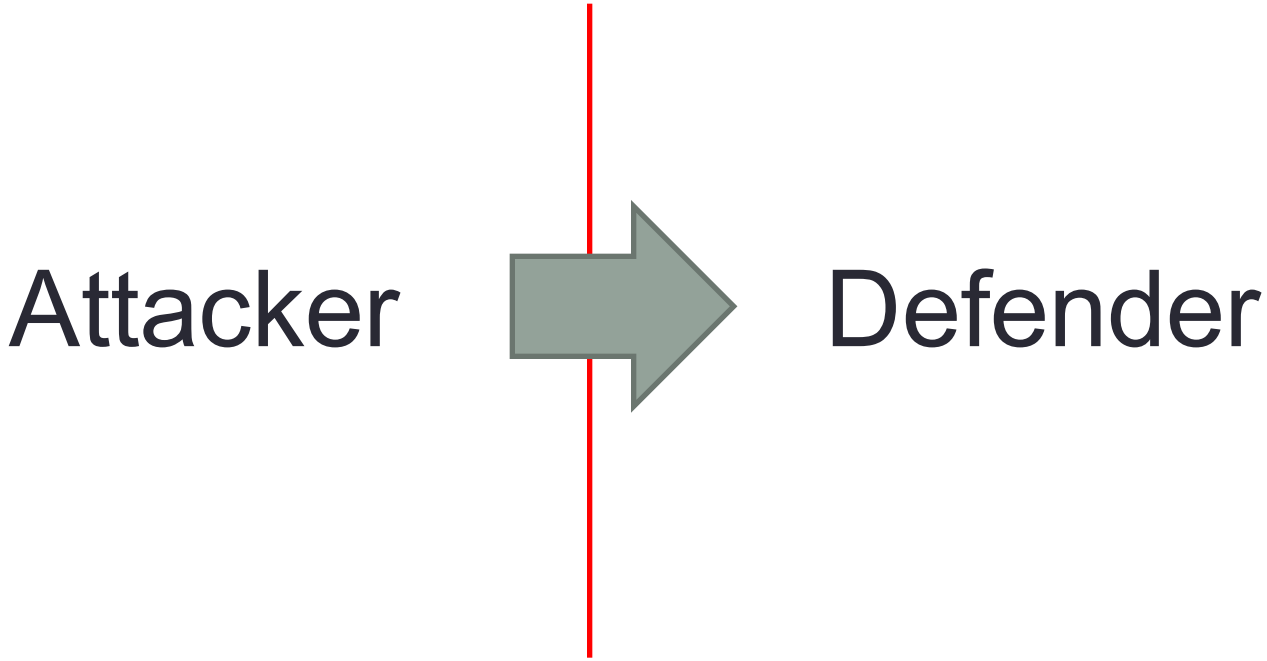
```
-- ASN1START
RRCConnectionRelease ::=          SEQUENCE {
    rrc-TransactionIdentifier           RRC-TransactionIdentifier,
    criticalExtensions                  CHOICE {
        c1                                  CHOICE {
            rrcConnectionRelease-r8             RRCConnectionRelease-r8-IEs,
            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
}
```

Procedure of Redirection Attack



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

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.

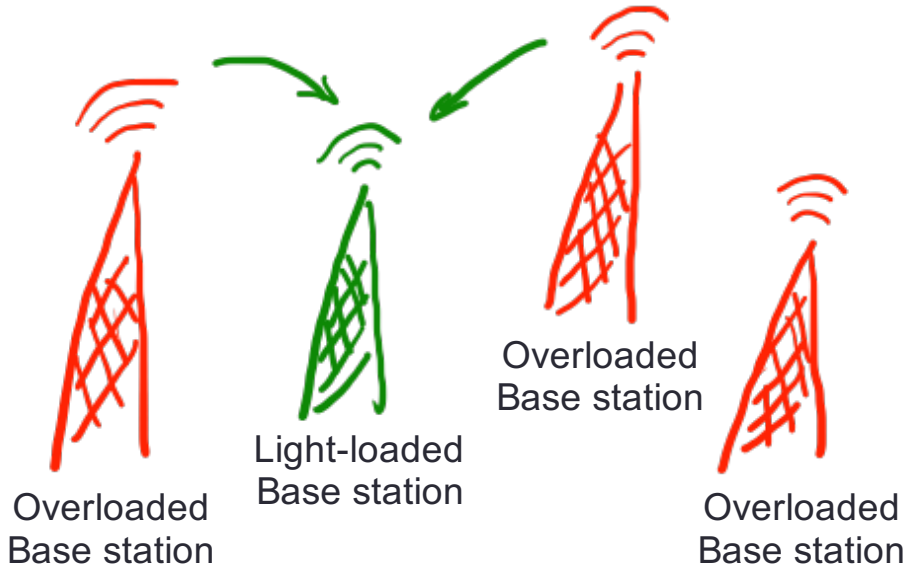
3GPP's Decision

- "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 de-activated 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, 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
- Battery energy saving
- Load balance

VS.

- IMSI Catcher

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

Basic requirement

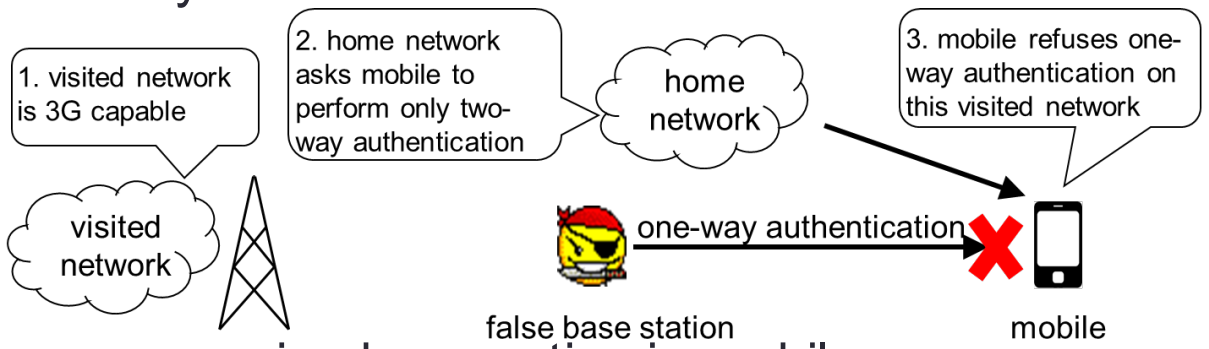
High level requirement

Countermeasures (1/2)

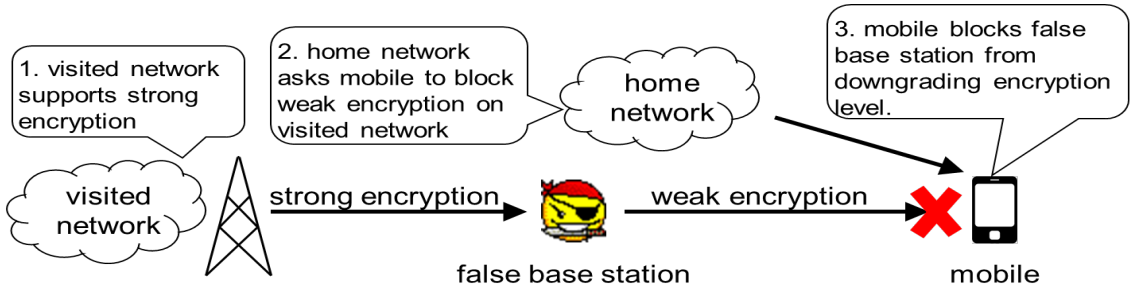
- Cellphone manufacture – smart response
  - Scheme 1: Don't follow the redirection command, but auto-search other available base station.
  - Scheme 2: Follow the redirection command, but raise an alert to cellphone user: Warning! You are downgraded to low security network.

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

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  - Apple product security team

Thank you!