Researching Unisoc baseband like in the army

cp<r> Slava Makkaveev

50%
of Chinese
market

UNISOC

10%
of Global
market

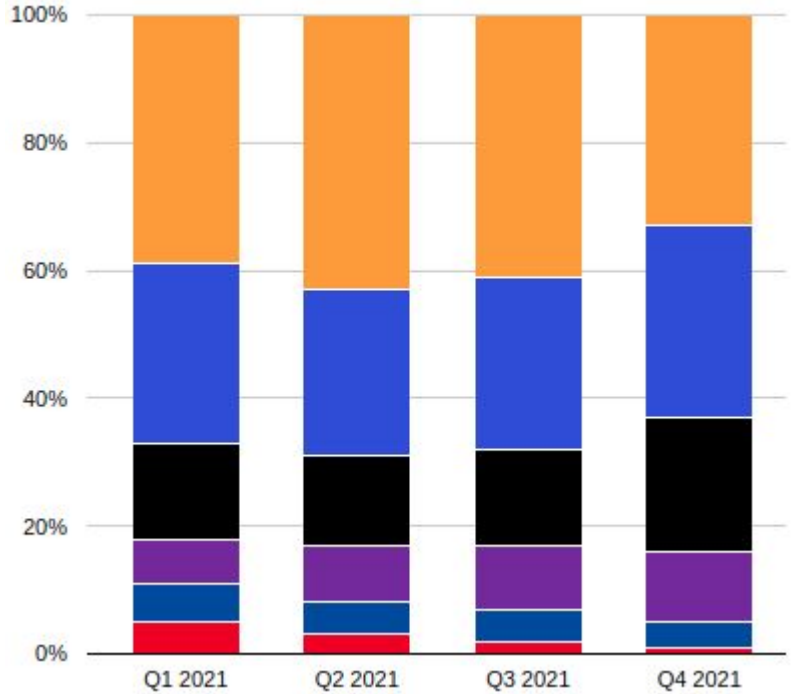
2001

2011

2018

2021

Mobile chip market share



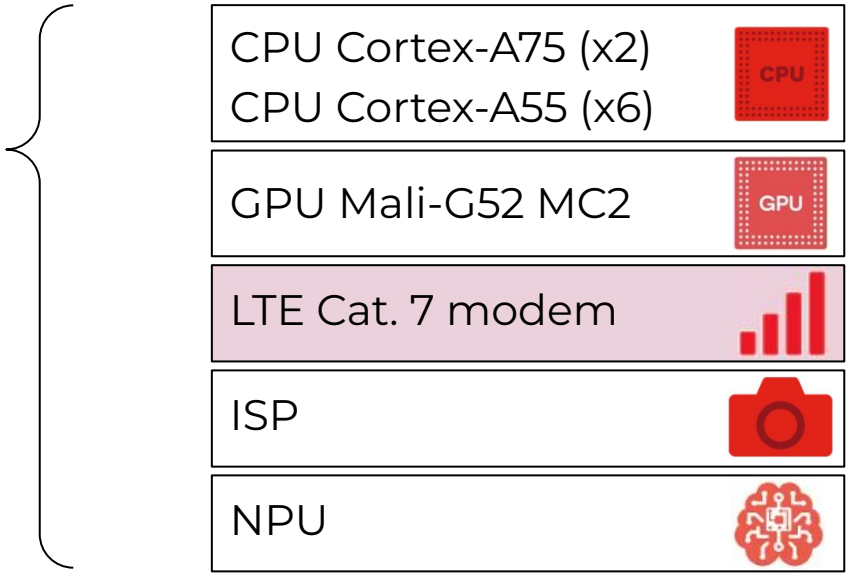
	Q4 2021
Mediatek	33%
Qualcomm	30%
Apple	21%
Unisoc	11%
Samsung	4%
HiSilicon	1%

Unisoc SoC

Released in 2021/22

- T606
- T616
- T700
- T760

Tiger T700 SoC



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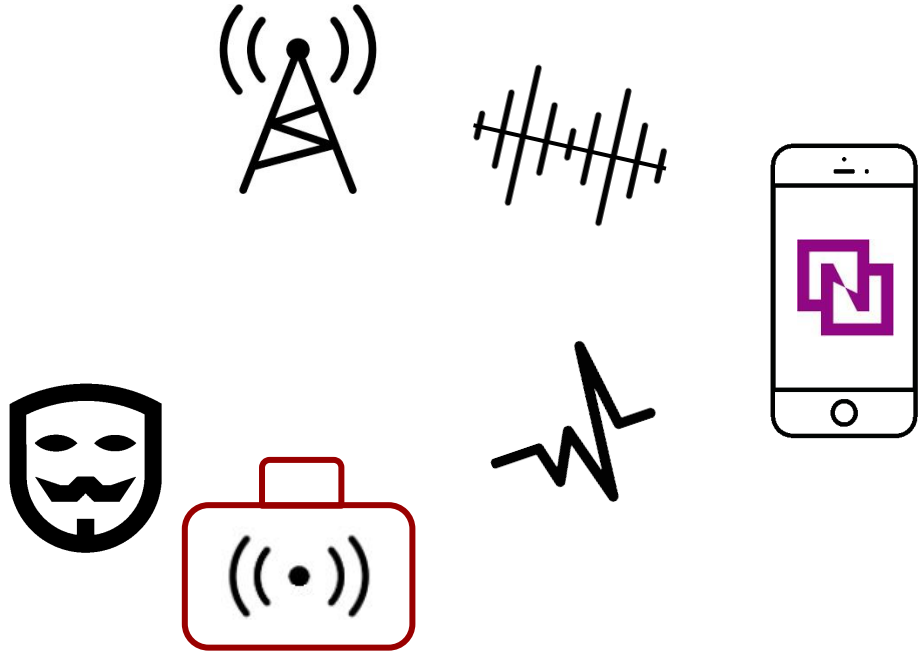
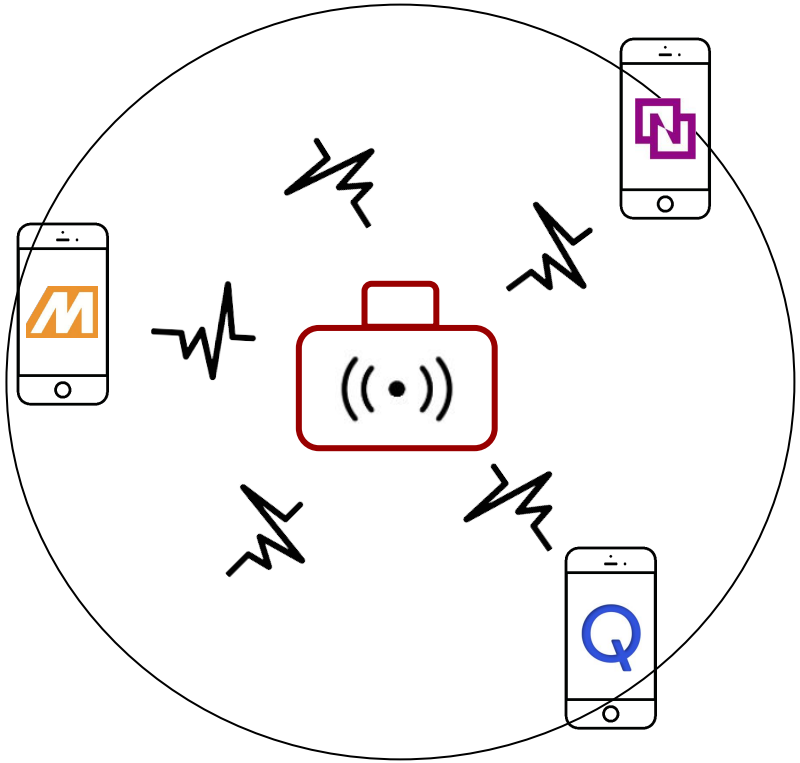
Why is the cyber-army researching Unisoc?

~~Targeted attack~~

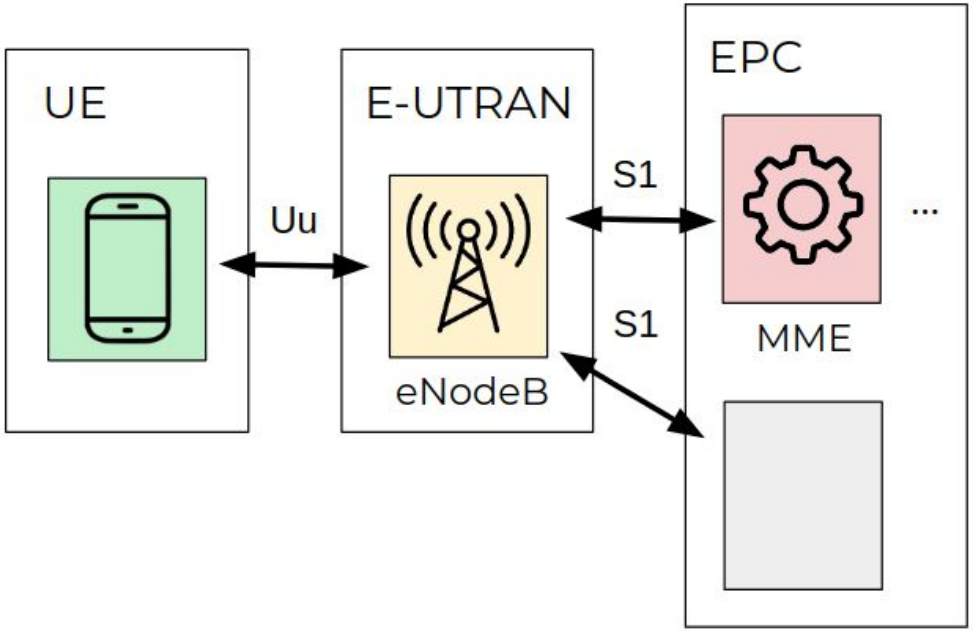


Broadcast to neutralize communication

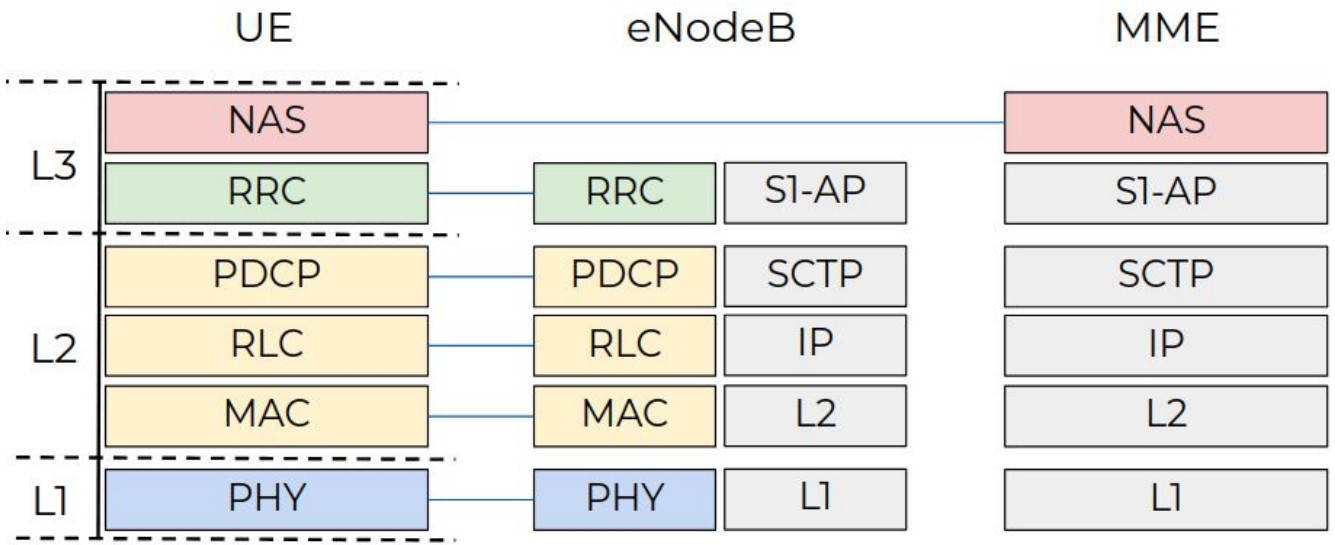


Where is the smartphone modem in the LTE network?

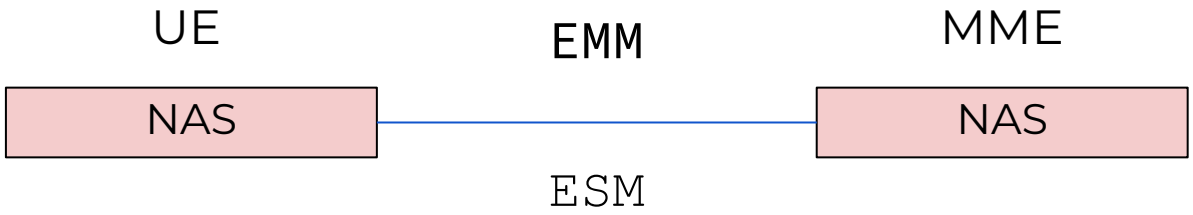
Long-Term Evolution network



LTE protocol stacks



Non-access stratum



- security control
- tracking area management
- mobility between access networks
- bearer management

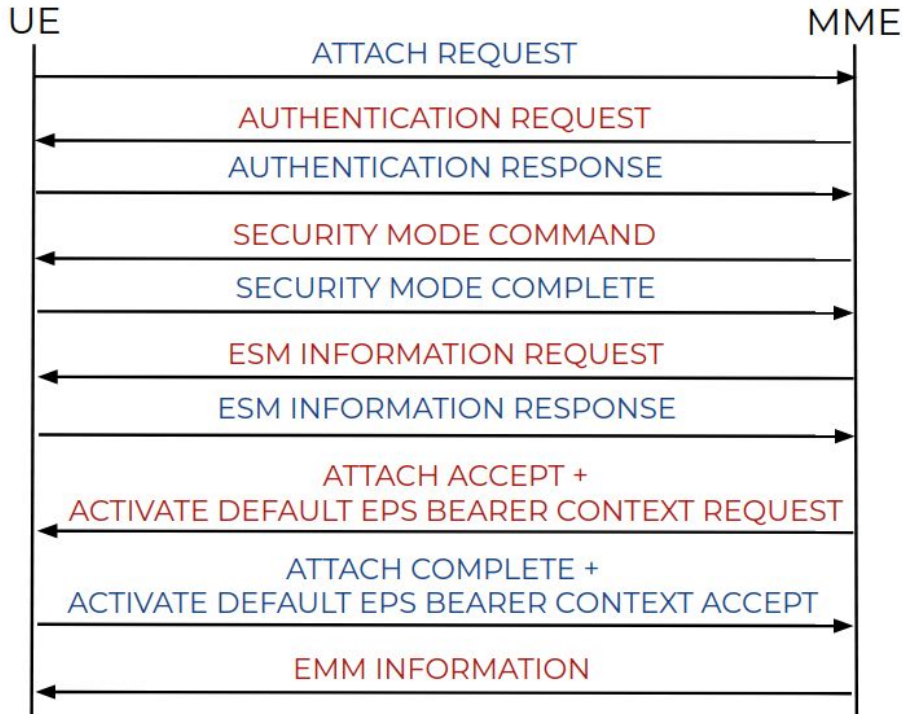
...

Network attach flow

Modem: 10.90.10.1
MME: 10.201.150.41

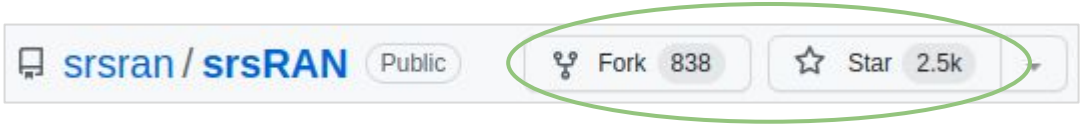
Source	Destination	Protocol	Length	Info
10.90.10.1	10.201.150.41	S1AP/NAS-EPS	176	InitialUEMessage, Attach request, PDN connectivity request
10.201.150.41	10.90.10.1	S1AP/NAS-EPS	140	DownlinkNASTransport, Authentication request
10.90.10.1	10.201.150.41	S1AP/NAS-EPS	140	UplinkNASTransport, Authentication response
10.201.150.41	10.90.10.1	S1AP/NAS-EPS	124	DownlinkNASTransport, Security mode command
10.90.10.1	10.201.150.41	S1AP/NAS-EPS	148	UplinkNASTransport, Security mode complete
10.201.150.41	10.90.10.1	S1AP/NAS-EPS	116	DownlinkNASTransport, ESM information request
10.90.10.1	10.201.150.41	S1AP/NAS-EPS	176	UplinkNASTransport, ESM information response
10.201.150.41	10.90.10.1	S1AP/NAS-EPS	288	InitialContextSetupRequest, Attach accept, Activate default EPS bearer context request
10.90.10.1	10.201.150.41	S1AP/NAS-EPS	124	UplinkNASTransport, Attach complete, Activate default EPS bearer context accept
10.201.150.41	10.90.10.1	S1AP/NAS-EPS	140	DownlinkNASTransport, EMM information
10.90.10.1	10.201.150.41	S1AP/NAS-EPS	132	UplinkNASTransport, Detach request (Combined EPS/IMSI detach / switch-off)

Network attach flow



Open-source UE stack

srsRAN




```
switch (msg_type) {
  case LIBLTE_MME_MSG_TYPE_ATTACH_ACCEPT:
    parse_attach_accept(lcid, std::move(pdu));
    break;
  case LIBLTE_MME_MSG_TYPE_AUTHENTICATION_REQUEST:
    parse_authentication_request(lcid, std::move(pdu), sec_hdr_type);
    break;
  case LIBLTE_MME_MSG_TYPE_SECURITY_MODE_COMMAND:
    parse_security_mode_command(lcid, std::move(pdu));
    break;
  case LIBLTE_MME_MSG_TYPE_ESM_INFORMATION_REQUEST:
    parse_esm_information_request(lcid, std::move(pdu));
    break;
  ...
```

“Attach accept” message

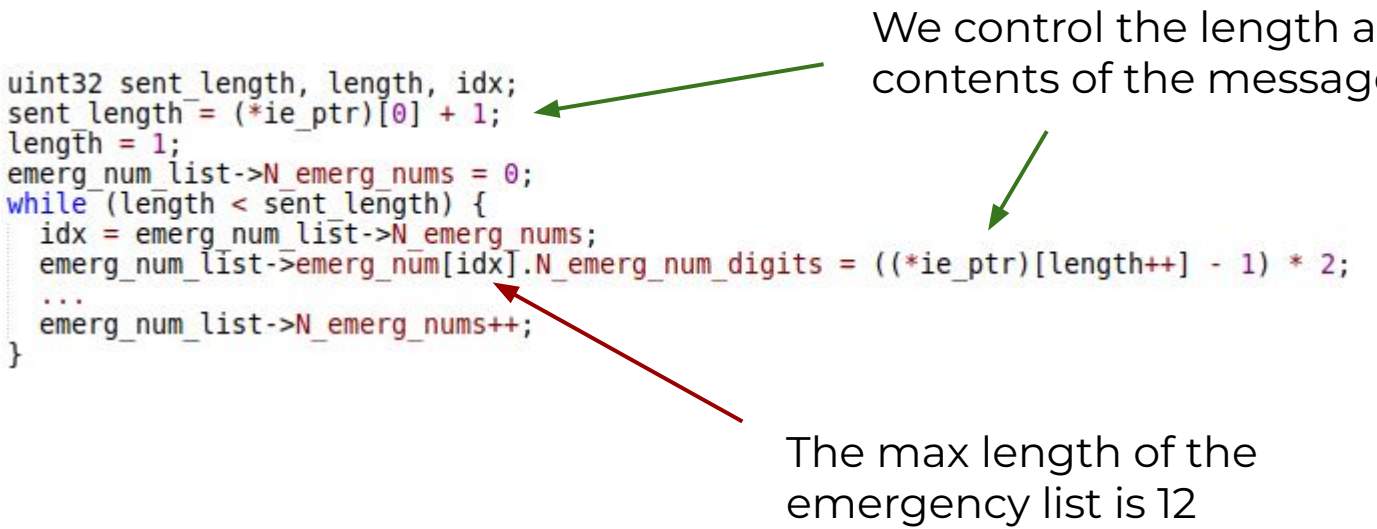
```
▾ Non-Access-Stratum (NAS)PDU
    0010 .... = Security header type: Integrity protected and ciphered (2)
    .... 0111 = Protocol discriminator: EPS mobility management messages (0x7)
    Message authentication code: 0xa9c0b9f0
    Sequence number: 2
    0000 .... = Security header type: Plain NAS message, not security protected (0)
    .... 0111 = Protocol discriminator: EPS mobility management messages (0x7)
    NAS EPS Mobility Management Message Type: Attach accept (0x42)
    0000 .... = Spare half octet: 0
    .... 0... = Spare bit(s): 0x00
    .... .010 = Attach result: Combined EPS/IMSI attach (2)
  ▸ GPRS Timer - T3412 value
  ▸ Tracking area identity list - TAI list
  ▸ ESM message container
  ▸ EPS mobile identity - GUTI
  ▸ GPRS Timer - T3423 value
  ▸ EPS network feature support
```

- list of tracking area identifiers
- GPRS timers
- access point name
- mobile identity
- emergency numbers
- protocol configuration options

...

A vulnerability in the NAS parser

`liblte_mme_unpack_emergency_number_list_ie()`



Looking for the NAS parsing functions in the Unisoc modem

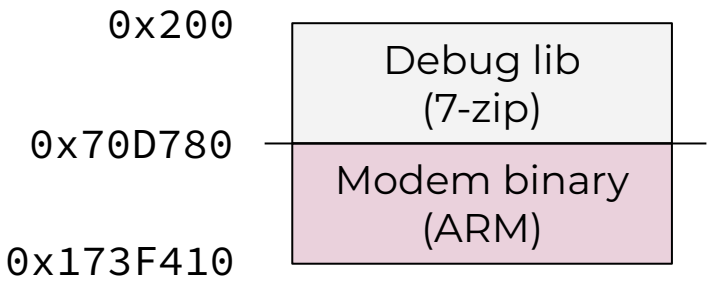
Moto G20 [Unisoc T700]

boot.img	prodnv.img	super.img
cache.img	SC9600_sharkl5pro_pubcp_modem.dat	teecfg-sign.bin
dtbo.img	sharkl5pro_cm4.bin	tos-sign.bin
EXEC_KERNEL_IMAGE-sign.bin	sharkl5pro_pubcp_AGCP_DSP.bin	u-boot-sign.bin
fdl1-sign.bin	sharkl5pro_pubcp_CDMA_DSP.bin	u-boot-spl-16k-sign.bin
fdl2-sign.bin	sharkl5pro_pubcp_customer_deltanv.bin	userdata.img
gnssmodem-sign.bin	sharkl5pro_pubcp_customer_nvitem.bin	vbmeta_product.img
logo.bin	sharkl5pro_pubcp_DM_DSP.bin	vbmeta-sign.img
odmko.img	sharkl5pro_pubcp_LTEA_DSP.bin	vbmeta_system.img
p352.xml	sml-sign.bin	vbmeta_system_ext.img
persist.img	socko.img	vbmeta_vendor.img

Modem image

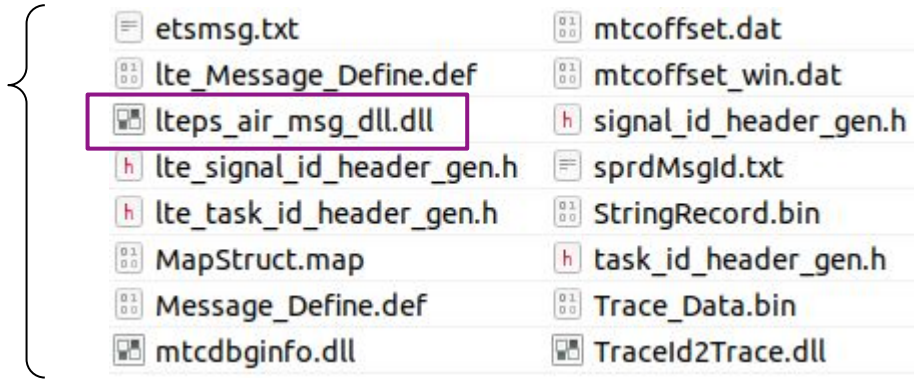
```
struct data_block_header_t {
  uint32_t type;
  uint32_t offset;
  uint32_t length;
};
```

```
          0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F    0123456789ABCDEF
0000h:  53 43 49 31 00 00 00 00 00 00 00 00 02 04 00 00   SCI1............
0010h:  00 02 00 00 77 D5 70 00 01 03 00 00 80 D7 70 00   ....wÕp.....€×p.
0020h:  90 1C 03 01 00 00 00 00 00 00 00 00 00 00 00 00   ................
```



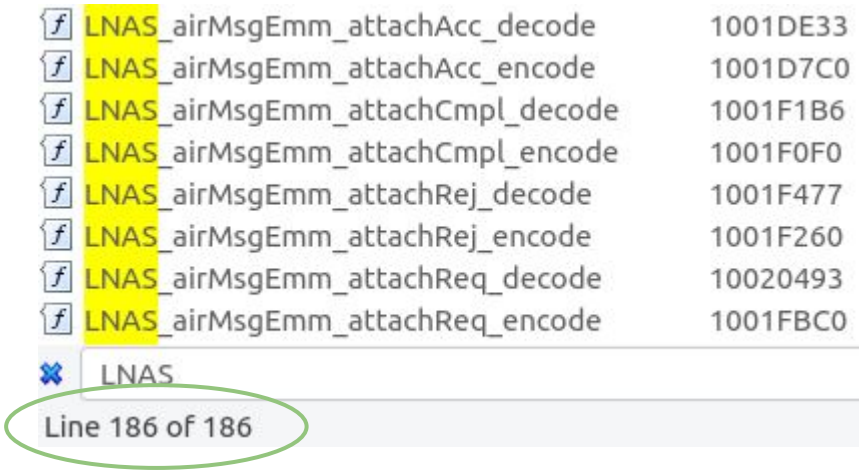
Debug lib?

Debug lib
(7-zip)



Do you also see these x86 DLLs on the ARM chip?!

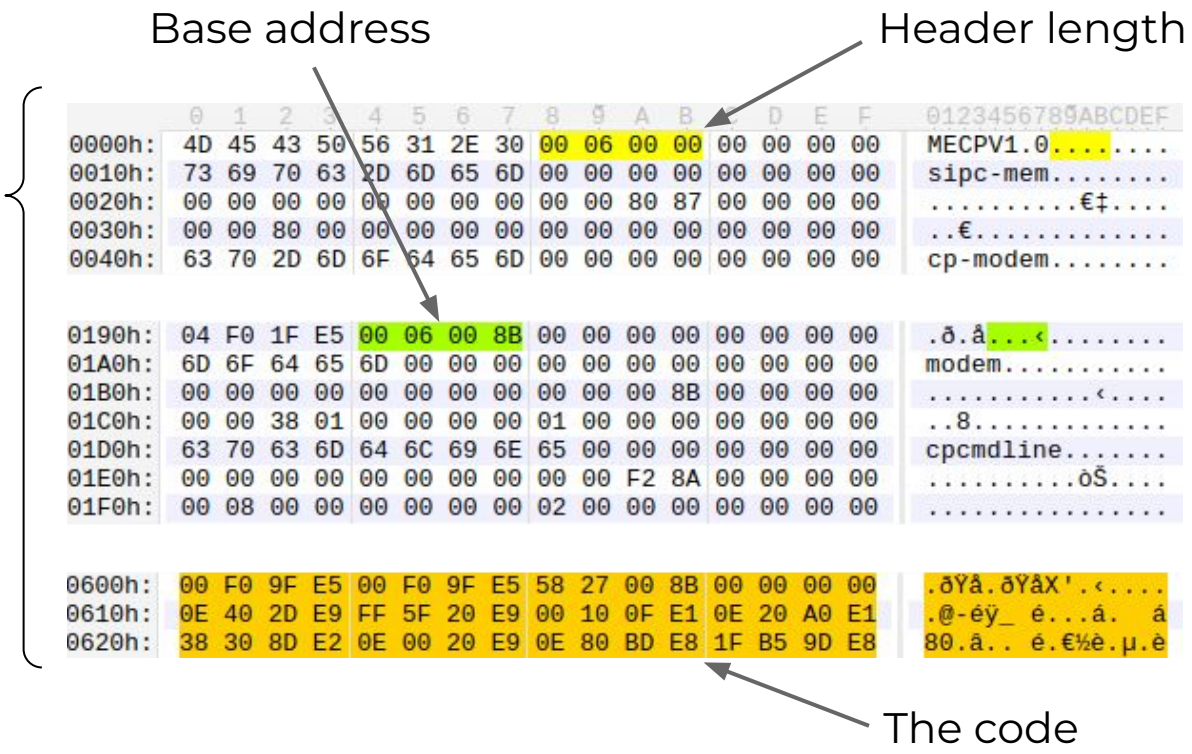
lteps_air_msg_dll.dll




```
typedef int (__stdcall *LNAS_airMsgIE_mobileId_decode)(void* out, void* in, void* offset);
```

Modem binary

Modem binary



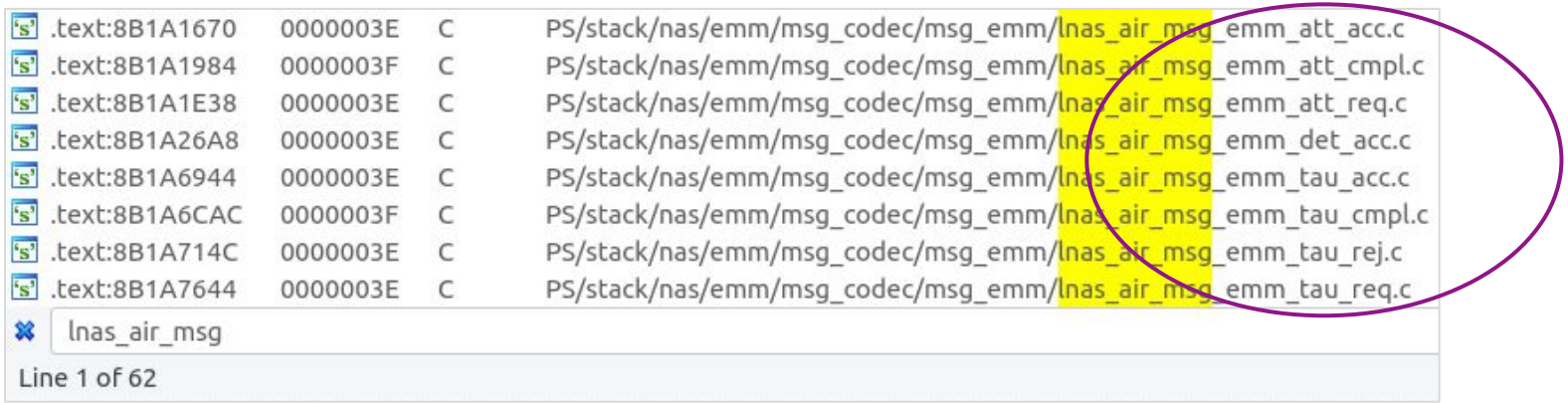
Modem code

- For convenience, we:
  - wrapped the code blob with an ELF32 header
  - added the data segment

Name	Start	End
.text	8B000600	8C031C90
.data	8D0C0000	8DF00000

- Not compressed/encrypted
- No symbols
- There are many strings

Where are the NAS handlers?




```
v7 = _malloc(0, 724, 1, 140, 648);
if ( !v7 )
  _loge(
    0,
    "PS/stack/nas/emm/src/control/adm/adm.c",
    649,
    (int)"LOGGER NULL POINTER",
    (int)"attachAccept_Ptr");
v9 = _liblte_mme_unpack_attach_accept_msg((int)v7, *(char **)(a1 + 0x18), (unsigned int *)(a1 + 0x1C));
```

srsRAN vs Unisoc

srsRAN

```
#define LIBLTE_MME_MS_IDENTITY_IEI 0x23

LIBLTE_ERROR_ENUM liblte_mme_unpack_attach_accept_msg (LIBLTE_BYTE_MSG_STRUCT*              msg,
                                                       LIBLTE_MME_ATTACH_ACCEPT_MSG_STRUCT* attach_accept) {
    uint8* msg_ptr = msg->msg;

    if (LIBLTE_MME_MS_IDENTITY_IEI == *msg_ptr) {
      msg_ptr++;
      liblte_mme_unpack_mobile_id_ie(&msg_ptr, &attach_accept->ms_id);
```

Modem

```
int __fastcall _liblte_mme_unpack_attach_accept_msg(int a1, char *msg_buf, unsigned int *a3)
{
  v18 = read_from_msg((int)msg_buf, &offset, 8);
  if ( v18 == 0x23 )
  {
    _liblte_mme_unpack_mobile_id_ie(v62, (int)msg_buf, &offset);
```

srsRAN vs Unisoc

srsRAN

```
LIBLTE_ERROR_ENUM liblte_mme_unpack_mobile_id_ie (uint8** ie_ptr, LIBLTE_MME_MOBILE_ID_STRUCT* mobile_id) {
    uint32 length;

    length = **ie_ptr;
    *ie_ptr += 1;

    mobile_id->type_of_id = **ie_ptr & 0x07;
```

Modem

```
void __fastcall _liblte_mme_unpack_mobile_id_ie(int *a1, int msg_buf, int *a3)
{
  offset[0] = *a3;
  id_len = read_from_msg(msg_buf, offset, 8);
  if ( (unsigned int)(id_len - 1) < 9 )
  {
    offset[0] += 5;
    id_type = read_from_msg(msg_buf, offset, 3);
```

Looking for vulnerabilities

The unified parsing function format

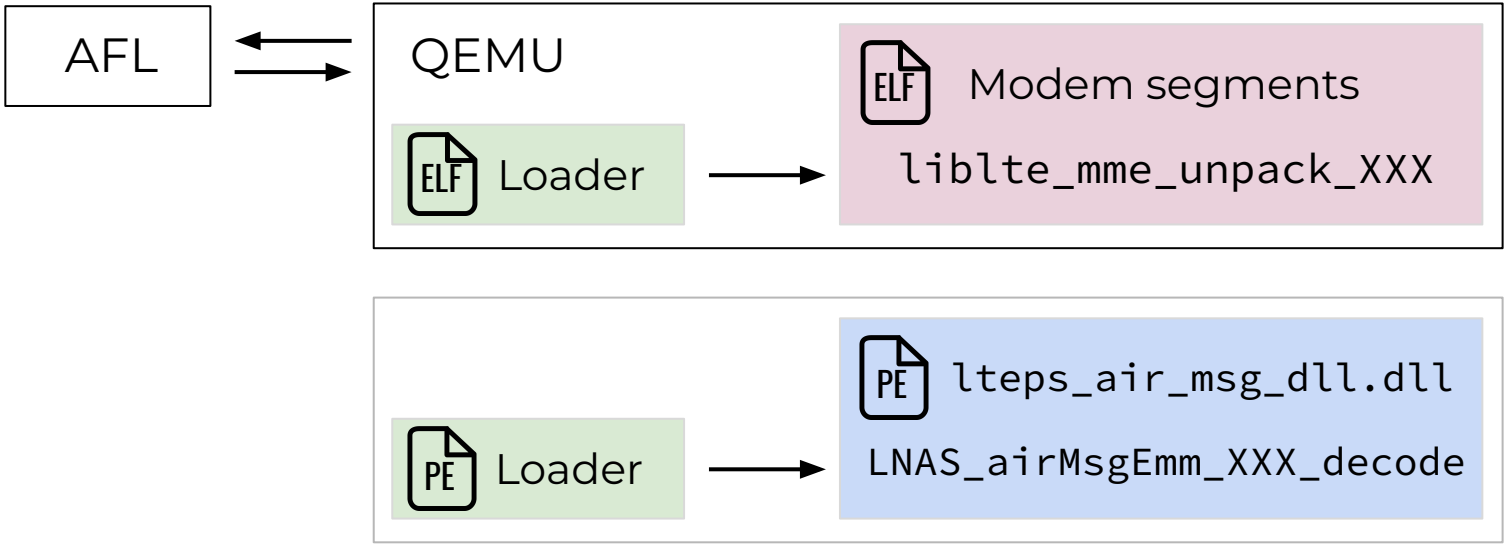
```
int __fastcall _liblte_mme_unpack_tracking_area_identity_list_ie(
        unsigned __int8 *out,
        unsigned __int8 *in,
        int *offset)
```

qemu-arm

`out`	an output buffer	`malloc(XXX)`	Redirect + modem's `malloc` to `libc::malloc`
`in`	the message blob	`Test data`	
`offset`	the current offset in the `in`	`0`	

Fuzzing

The classic combo: AFL + QEMU



Mobile identity

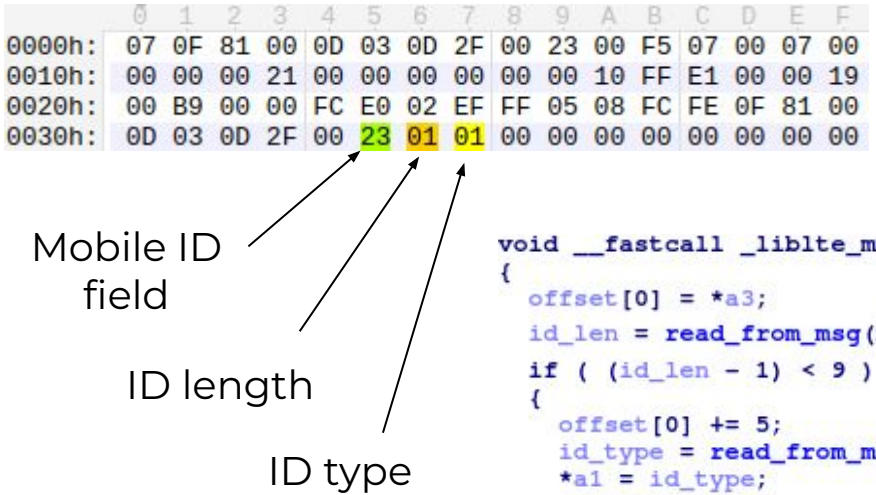
```
liblte_mme_unpack_attach_accept_msg, …
    └→ liblte_mme_unpack_mobile_id_ie
```

IMSI	313 460 000 000 001
IMEI	35 161508 297879 5

IMEISV, TMSI, TMGI, …

Malformed mobile ID

“Attach accept” message




```
void __fastcall _liblte_mme_unpack_mobile_id_ie(int *a1, int msg_buf, int *a3)
{
  offset[0] = *a3;
  id_len = read_from_msg(msg_buf, offset, 8);   // The ID length is 1
  if ( (id_len - 1) < 9 )
  {
    offset[0] += 5;
    id_type = read_from_msg(msg_buf, offset, 3);// The ID type is 1 (IMSI)
    *a1 = id_type;
    switch ( *a1 )
    {
      case 1:
        offset[0] -= 8;
        parse_imsi(a1 + 4, msg_buf, offset, id_len);// This is IMSI parser
```

Integer underflow

The `length-2` bytes of the message data are copied to the output buffer
What if the `length` is `0` or `1`?

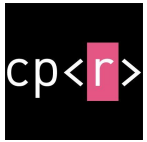
```
void __fastcall parse_imsi(unsigned __int8 *out_buf, int msg_buf,
{                          int *offset_, int imsi_data_len)
  offset[0] = *offset_;
  out_buf[1] = read_from_msg(msg_buf, offset, 4);// 0
  v1 = read_from_msg(msg_buf, offset, 1);        // 0
  offset[0] += 3;
  v2 = 2 * imsi_data_len - 2;                    // 2 * 1 - 2 = 0
  v3 = v2 + (v1 == 1);                           // 0
  *out_buf = v3;
  if ( v1 == 1 )                                 // 0 - 1 = 0xFFFFFFFF
    v4 = v3 - 1;
  else
    v4 = v3 - 2;                                 // 0 - 2 = 0xFFFFFFFE
  copy((out_buf + 2), msg_buf, offset, v4);      // the overflow
```

What have we achieved?

- For the first time, we looked at the Unisoc baseband as an attack target
- We discovered DoS vulnerabilities in the NAS protocol
- 5G Unisoc devices are also affected

- Unisoc fixed the CVE-2022-20210 (9.4) in May 2022
- The open source srsRAN is still vulnerable

Thank you!



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