5Greplay: a 5G Network Traffic Fuzzer - Application to Attack Injection

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Outline

1. Introduction
2. Background
3. Architecture
4. Experimental Evaluation
   - Malformed packets against open-source 5G cores in real-time
   - NAS-5G SMC Replay attack
   - High-bandwidth traffic generation
5. Conclusion
   - Future works

Introduction: 5G key enabling technologies

1. Software defined networks (SDN)
2. Network functions virtualization (NFV)
3. Mobile Edge computing (MEC)
4. Network Slicing (NS)

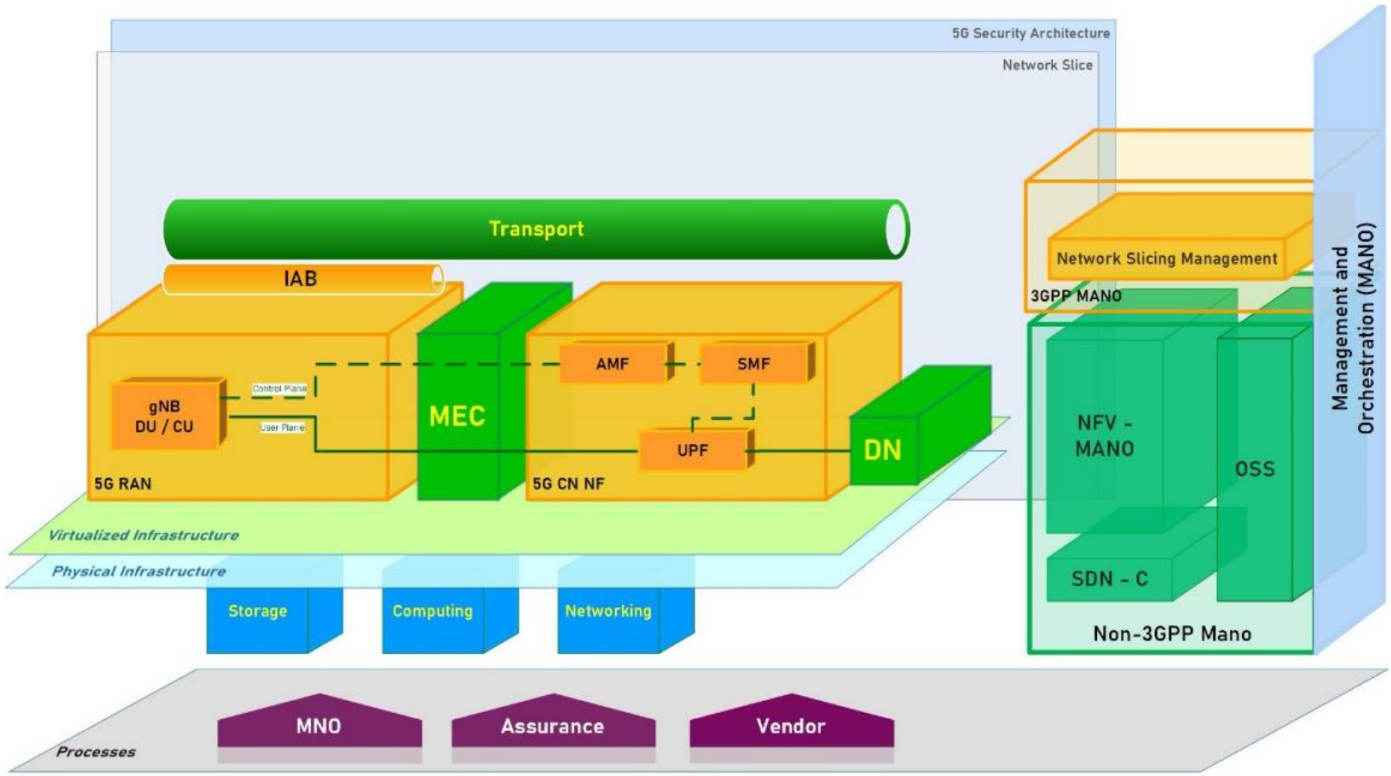

Figure 1: 5G Architecture by ENISA [5]

Introduction: 5G Security Challenges

- 5G new technologies require to be **tested** from a **functional** and **non-functional**

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- **New** cybersecurity threats
- Previously adopted security and privacy **mechanisms** become **ineffective**[3]

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- **New** cybersecurity threats
- Previously adopted security and privacy **mechanisms** become **ineffective**[3]

This requires...

The creation of **new sets of security test cases** and **tools** specifically targeting 5G security concerns

SoA: Testing the 5G

<table>
<tr><th>Threat and vulnerability reports</th><th>Security test cases</th><th>Application</th></tr>
<tr><td>ENISA [5]</td><td rowspan="2">3GPP Catalogue of General Security assurance requirements [1]</td><td>Python Scapy</td></tr>
<tr><td>3GPP [1]</td><td>Tcpreplay</td></tr>
<tr><td>Academic research [3, 4]</td><td rowspan="2">3GPP 5G Security Assurance Specification of the AMF [2]</td><td rowspan="2">5Greplay</td></tr>
<tr><td>Industrial reports [7, 6]</td></tr>
</table>

Table 1: Testing in 5G previous works

Challenge: The testing of 5G network components and IDSs

5Greplay

An **open-source** solution to perform **fuzz testing of 5G networks**, allowing to forward network packets from one NIC to another with or without modifications.

http://5greplay.org

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5Greplay atomic operators

Definition

Let **P** denote a **5G network packet** in a PCAP file or a specific real-time flow of network packets. **5Greplay** performs **fuzz testing** in 5G VNFs, IDSs, apps, etc, relying in the following operators...

Atomic operator	Description
DEL_PKT(*P*)	Delete a packet
CH_ATTR(*P*)	Change a specific attribute of a message header
ORD(*P1, P2*)*	Exchange the order of two consecutive packets
DUP_PKT(*P*)	Duplicate packet

Table 2: 5Greplay atomic operators. *Currently not implemented

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General Architecture

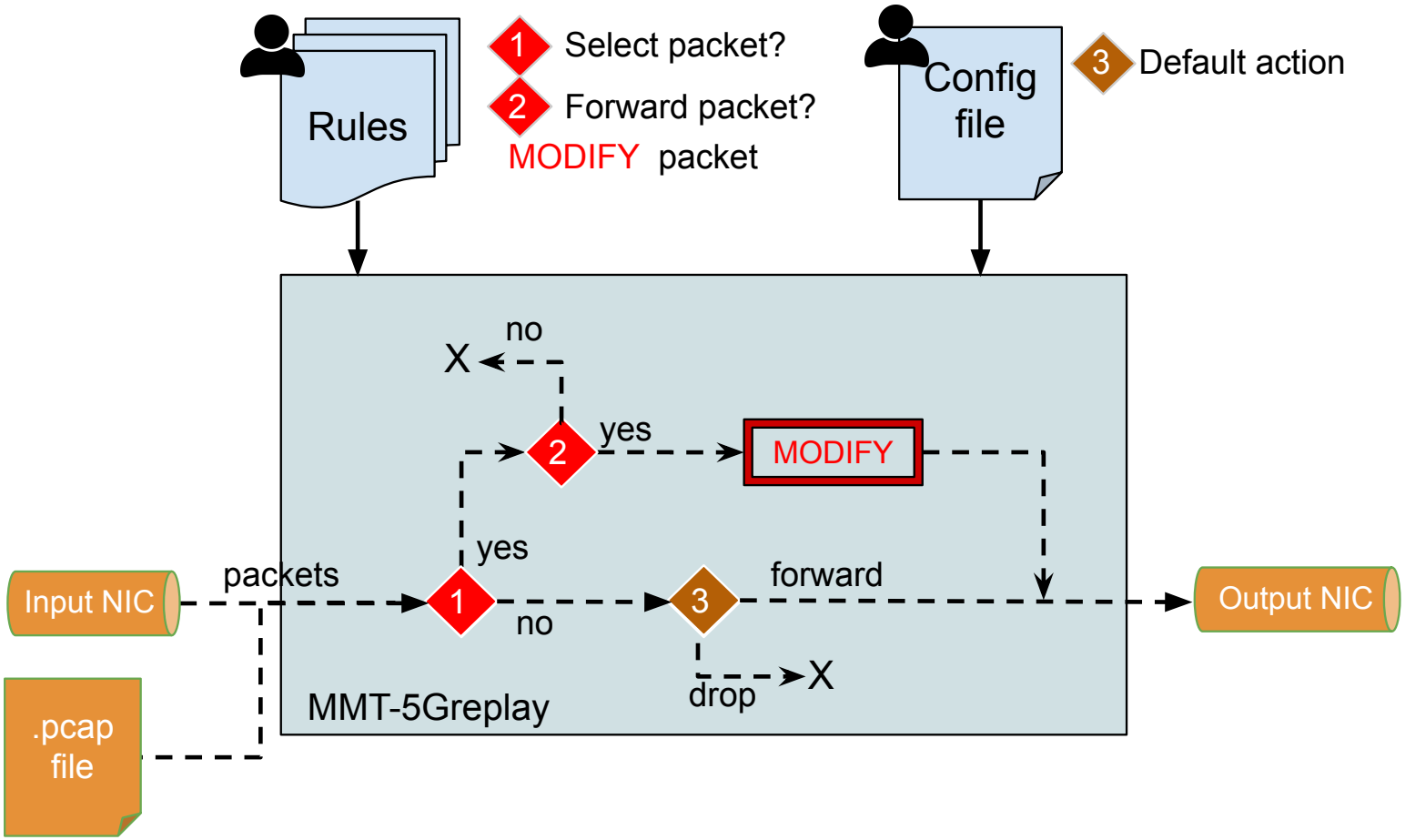

Figure 2: 5Greplay main process. Incoming network packets are filtered according to predefined rules that determine which packets will be modified, forwarded, or dropped before being sent to the output NIC

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Scenario 1: Sending malformed packets against open-source 5G cores in real-time

Objective

Create and **send malformed packets** to a 5G core network, to evaluate robustness against unexpected entries at run-time.

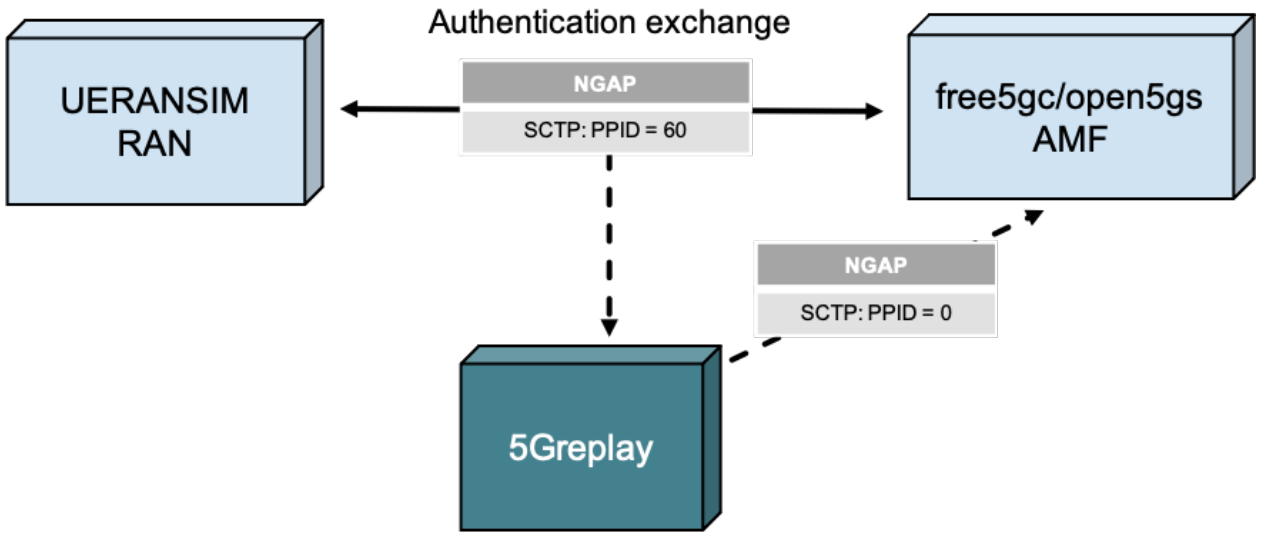


Figure 3: Sending malformed NGAP packets against free5GC

Scenario 1: Sending malformed packets against open-source 5G cores in real-time

Evaluation of 5G core simulators

- **free5GC** show an AMF warning, but the simulator keep running and allowed new UE connections
- **Open5GS** was not able to handle this packet and the simulator crashed

```
05/12 17:23:47.069: [gmm] INFO: [suci-0-901-70-0000-0-0-0000000001]    SUCI (../src/amf/gmm-handler.c:72)
05/12 17:23:47.069: [amf] WARNING: GUTI has already been allocated (../src/amf/context.c:1045)
05/12 17:23:47.070: [gmm] ERROR: Invalid service name [nudm-sdm] (../src/amf/gmm-sm.c:625)
05/12 17:23:47.070: [gmm] WARNING: gmm_state_authentication: should not be reached. (../src/amf/gmm-sm.c:626)
05/12 17:23:47.070: [core] FATAL: backtrace() returned 9 addresses (../lib/core/ogs-abort.c:37)
/usr/bin/open5gs-amfd(+0x17418) [0x55f750b1d418]
/usr/lib/x86_64-linux-gnu/libogscore.so.2(ogs_fsm_dispatch+0x16) [0x7ff86bb4ec76]
/usr/bin/open5gs-amfd(+0x1bb4e) [0x55f750b21b4e]
/usr/lib/x86_64-linux-gnu/libogscore.so.2(ogs_fsm_dispatch+0x16) [0x7ff86bb4ec76]
/usr/bin/open5gs-amfd(+0x5ec6) [0x55f750b0bec6]
/usr/lib/x86_64-linux-gnu/libogscore.so.2(+0xd718) [0x7ff86bb46718]
/lib/x86_64-linux-gnu/libpthread.so.0(+0x76db) [0x7ff869f416db]
/lib/x86_64-linux-gnu/libc.so.6(clone+0x3f) [0x7ff869c6aa3f]
Open5GS daemon v2.2.7
```

Figure 4: open5GS AMF log when receiving a malformed NGAP packet

Scenario 1: Sending malformed packets against open-source 5G cores in real-time

Evaluation of 5Greplay

Replay and **modify** 5G network packets in a **online way** by using the fuzz operator CH_ATTR(P).

Scenario 2: NAS-5G SMC Replay attack

Objective

Perform **security tests** by modifying and injecting network traffic into a specif target. Test proposed in the **3GPP TS33.512** [2].

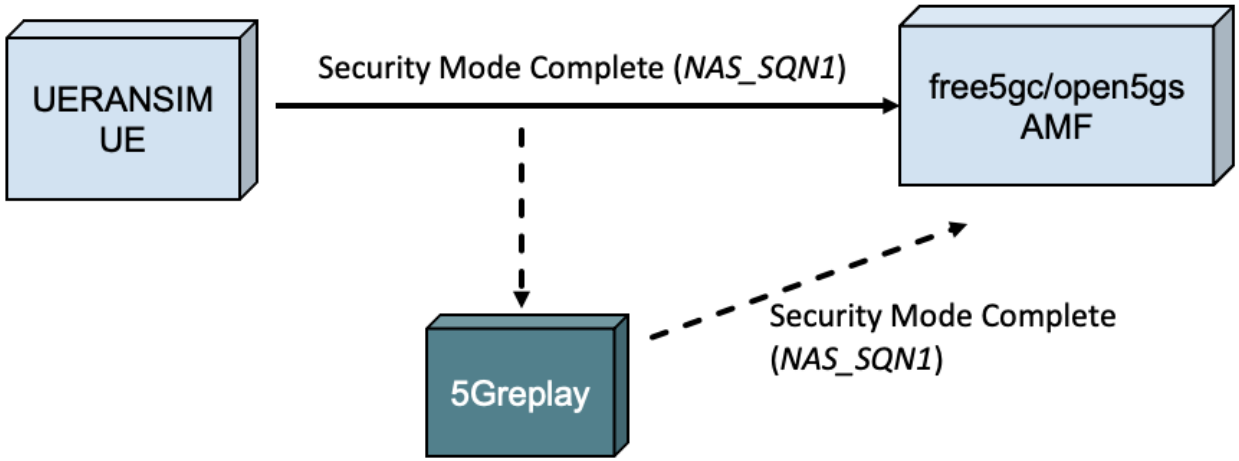


Figure 5: Sending malformed NGAP packets against free5GC

Scenario 2: NAS-5G SMC Replay attack

Evaluation of free5Gc

The AMF identified the replayed packets as not belonging to the same NGAP security context. **free5Gc** AMF **passed** the test.


```
2021-05-19T08:40:28-07:00 [INFO][AMF][GMM][AMF_UE_NGAP_ID:7][SUPI:imsi-208930000000003] Send Security Mode Command
2021-05-19T08:40:28-07:00 [INFO][AMF][NGAP][192.168.49.4:35118][AMF_UE_NGAP_ID:7] Send Downlink Nas Transport
2021-05-19T08:40:28-07:00 [INFO][AMF][NGAP][192.168.49.4:35118] Handle Uplink Nas Transport
2021-05-19T08:40:28-07:00 [INFO][AMF][NGAP][192.168.49.4:35118][AMF_UE_NGAP_ID:7] Uplink NAS Transport (RAN UE NGAP ID: 2)
2021-05-19T08:40:28-07:00 [INFO][AMF][GMM][AMF_UE_NGAP_ID:7][SUPI:imsi-208930000000003] Handle Security Mode Complete
2021-05-19T08:40:28-07:00 [INFO][AMF][GMM][AMF_UE_NGAP_ID:7][SUPI:imsi-208930000000003] Handle InitialRegistration
2021-05-19T08:40:28-07:00 [INFO][NRF][DSCV] Handle NFDiscoveryRequest
2021-05-19T08:40:28-07:00 [INFO][AMF][NGAP] Create a new NG connection for: 192.168.49.4/172.16.151.12/10.45.0.1:49183
2021-05-19T08:40:28-07:00 [INFO][AMF][NGAP][192.168.49.4/172.16.151.12/10.45.0.1:49183] Handle Uplink Nas Transport
2021-05-19T08:40:28-07:00 [ERRO][AMF][NGAP][192.168.49.4/172.16.151.12/10.45.0.1:49183] No UE Context[RanUeNgapID: 2]
2021-05-19T08:40:28-07:00 [INFO][AMF][NGAP][192.168.49.4/172.16.151.12/10.45.0.1:49183] Handle Uplink Nas Transport
2021-05-19T08:40:28-07:00 [ERRO][AMF][NGAP][192.168.49.4/172.16.151.12/10.45.0.1:49183] No UE Context[RanUeNgapID: 2]
```

Figure 6: Free5Gc AMF log when replaying Security Mode Complete messages (SMC)

Scenario 2: NAS-5G SMC Replay attack

Evaluation of 5Greplay

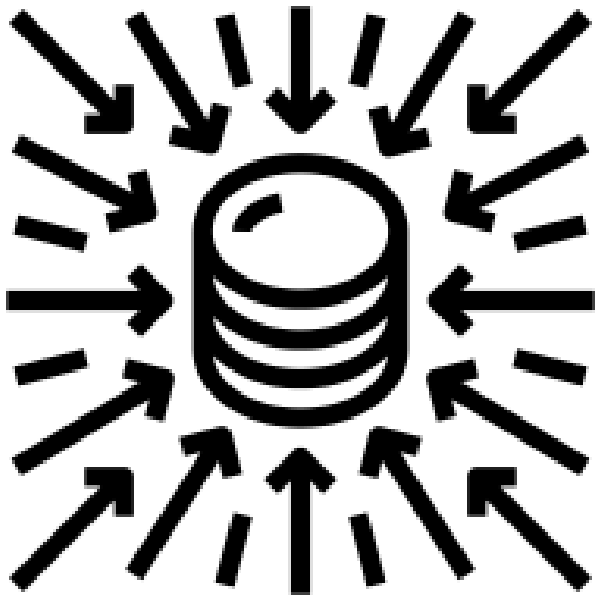
We tested the utility of 5Greplay to perform standardized security tests by using the fuzz operator CH_ATTR(P).

Scenario 3: High-bandwidth traffic generation

Objective

Scalability of 5Greplay[a]. **DoS attacks or stress tests** on open5GS and free5GC.

[a] while using only one thread on a Intel Ethernet Network Adapter X710



Scenario 3: High-bandwidth traffic generation

Evaluation of 5G core simulators

	#packet copies	Avg. packets/s	Avg. kbit/s
open5Gs	1780	509.5	834
free5GC	3000	594.9	974

Table 3: Endurance of 5G AMF services against traffic replaying

Scenario 3: High-bandwidth traffic generation

Evaluation of 5Greplay

5Greplay can be used to test the robustness of 5G core services by using in the fuzz operator DUP_PKT(P).

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Conclusion

The tool is capable to...

- Receive online and offline entries
- Systematically create and send malformed packets that are accepted by 5G simulators
- Evaluate the robustness against unexpected entries of a target
- Perform 5G security test cases
- Stress testing a target

Future works

- Defining new 5G attacks that can be performed by the tool
- Techniques to manage encrypted traffic
- Implement and test new ways to alter packets, such as changing the order of two packets
- Experimental evaluation will be performed on other 5G interfaces

Acknowledgments

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Thanks
Q&A

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