FlexRIC: Installation and Execution

ECE 5984: 5G-Advanced, O-RAN & 6G

Virginia Tech

Install FlexRIC Dependencies

- Open a Terminal
- Install swig 4.1

```
sudo apt install libsctp-dev cmake-curses-gui libpcre2-dev
cd ~/
git clone https://github.com/swig/swig.git
cd swig
git checkout release-4.1
./autogen.sh
./configure --prefix=/usr/
make -j`nproc`
sudo make install
cd ~/
```

```
Installing /usr/share/swig/4.1.1/std/std_wstreambuf.i
Installing /usr/share/swig/4.1.1/std/std_wstring.i
Installing /usr/share/swig/4.1.1/std/std_carray.swg
make[1]: Entering directory '/home/pratheek/swig/CCache'
Installing ccache-swig
Installing /usr/bin/ccache-swig
/usr/bin/install -c -d /usr/bin
/usr/bin/install -c -m 755 ccache-swig /usr/bin/ccache-swig
make[1]: Leaving directory '/home/pratheek/swig/CCache'
Installation complete
```

Clone the FlexRIC repository.

```
git clone https://gitlab.eurecom.fr/mosaic5g/flexric ~/flexric
cd ~/flexric
git checkout df754a85
```

```
pratheek@ubuntu22:~$ git clone https://github.com/openaicellular/flexric.git ~/flexric
Cloning into '/home/pratheek/flexric'...
remote: Enumerating objects: 33829, done.
remote: Counting objects: 100% (1291/1291), done.
remote: Compressing objects: 100% (212/212), done.
remote: Total 33829 (delta 1148), reused 1079 (delta 1079), pack-reused 32538 (from 1)
Receiving objects: 100% (33829/33829), 103.27 MiB | 553.00 KiB/s, done.
Resolving deltas: 100% (26774/26774), done.
pratheek@ubuntu22:~$ git config --global http.postBuffer 524288000
pratheek@ubuntu22:~$
```

Note: Sometimes, when executing commands, you might encounter an error message similar to "command not found" or "unrecognized option". This can be due to font inconsistencies between Windows (on which this ppt has been designed) and Linux. To resolve this, wherever there is a hyphen ("-"), delete it and retype it again manually.

Install FlexRIC (Cont'd)

```
advcell@ubuntu20:~/flexric/build$ cmake ../
-- The C compiler identification is GNU 9.4.0
-- Check for working C compiler: /usr/bin/cc
-- Check for working C compiler: /usr/bin/cc -- works
-- Detecting C compiler ABI info
-- Detecting C compiler ABI info - done
-- Detecting C compile features
-- Detecting C compile features - done
-- Setting build type to 'Debug' as none was specified.
-- Selected LIBRARY TYPE: STATIC
-- Selected xApp DB : SQLITE3_XAPP
-- Selected xApp dir : /tmp/
-- Selected SANITIZER_TYPE: NONE
-- Selected E2AP_ENCODING: ASN
-- Selected KPM SM_ENCODING: ASN
-- Selected RC SM_ENCODING: ASN
-- Selected MAC SM_ENCODING: PLAIN
-- Selected RLC SM_ENCODING: PLAIN
-- Selected PDCP SM_ENCODING: PLAIN
-- Selected SLICE SM_ENCODING: PLAIN
-- Selected GTP SM_ENCODING: PLAIN
-- The CXX compiler identification is GNU 9.4.0
-- Check for working CXX compiler: /usr/bin/c++
-- Check for working CXX compiler: /usr/bin/c++ -- works
-- Detecting CXX compiler ABI info
-- Detecting CXX compiler ABI info - done
-- Detecting CXX compile features
-- Detecting CXX compile features - done
-- Selected SM_ENCODING: PLAIN
-- Found SWIG: /usr/bin/swig4.0 (found suitable version "4.0.1", minimum required is "4.0")
-- Found Python3: /usr/bin/python3.8 (found version "3.8.10") found components: Interpreter
-- Found PythonLibs: /usr/lib/x86_64-linux-gnu/libpython3.8.so (found version "3.8.10")
-- Selected xApp target language: PYTHON_LANG
-- Selected MAC SM_ENCODING: PLAIN
-- Selected RLC SM_ENCODING: PLAIN
-- Selected PDCP SM_ENCODING: PLAIN
-- Selected SLICE SM_ENCODING: PLAIN
-- Selected TC SM_ENCODING: PLAIN
-- Selected GTP SM_ENCODING: PLAIN
-- Selected RC SM_ENCODING: ASN
-- Selected KPM SM_ENCODING: ASN
-- install prefix path /usr/local/flexric
-- Configuring done
-- Generating done
-- Build files have been written to: /home/advcell/flexric/build
```

You should see ASN encoding for E2AP, KPM SM & RC SM

```
[ 98%] Built target test_gtp_sm
[ 99%] Built target test_rc_sm
[100%] Built target test_kpm_sm
Install the project...
-- Install configuration: "Debug"
-- Installing: /usr/local/lib/flexric/libmac_sm.so
-- Installing: /usr/local/lib/flexric/librlc_sm.so
-- Installing: /usr/local/lib/flexric/libpdcp_sm.so
-- Installing: /usr/local/lib/flexric/libslice_sm.so
-- Installing: /usr/local/lib/flexric/libtc_sm.so
-- Installing: /usr/local/lib/flexric/libgtp_sm.so
-- Installing: /usr/local/lib/flexric/libkpm_sm.so
-- Installing: /usr/local/lib/flexric/librc_sm.so
-- Installing: /usr/local/etc/flexric/flexric.conf
advcell@ubuntu20:~/flexric/build$
```

```
mkdir build
cd build
cmake ../
```

```
make -j`nproc`
sudo make install
cd ~/
```

Run Core Network – Terminal 1

cd ~/oai-cn5g

docker compose up –d

```
pratheek@Pratheek:~/oai-cn5g$ docker compose up -d
[+] Running 11/11
 ✔Network oai-cn5g-public-net  Created
 ✔Container oai-nrf            Started
 ✔Container oai-ext-dn         Started
 ✔Container ims                Started
 ✔Container mysql              Started
 ✔Container oai-udr            Started
 ✔Container oai-udm            Started
 ✔Container oai-ausf           Started
 ✔Container oai-amf            Started
 ✔Container oai-smf            Started
 ✔Container oai-upf            Started
```

Run FlexRIC Near-RT RIC – Terminal 2

- Open a New Terminal.

```
cd ~/
./flexric/build/examples/ric/nearRT-RIC
```

```
[NEAR-RIC]
NEAR_RIC_IP = 127.0.0.1

[XAPP]
DB_DIR = /tmp/
```

Contents of **flexric.conf** file

```
advcell@ubuntu20:~$ ./flexric/build/examples/ric/nearRT-RIC
Setting the config -c file to /usr/local/etc/flexric/flexric.conf
Setting path -p for the shared libraries to /usr/local/lib/flexric/
[NEAR-RIC]: nearRT-RIC IP Address = 127.0.0.1, PORT = 36421
[NEAR-RIC]: Initializing
[NEAR-RIC]: Loading SM ID = 146 with def = TC_STATS_V0
[NEAR-RIC]: Loading SM ID = 2 with def = ORAN-E2SM-KPM
[NEAR-RIC]: Loading SM ID = 148 with def = GTP_STATS_V0
[NEAR-RIC]: Loading SM ID = 3 with def = ORAN-E2SM-RC
[NEAR-RIC]: Loading SM ID = 143 with def = RLC_STATS_V0
[NEAR-RIC]: Loading SM ID = 142 with def = MAC_STATS_V0
[NEAR-RIC]: Loading SM ID = 144 with def = PDCP_STATS_V0
[NEAR-RIC]: Loading SM ID = 145 with def = SLICE_STATS_V0
[iApp]: Initializing ...
[iApp]: nearRT-RIC IP Address = 127.0.0.1, PORT = 36422
fd created with 6
```

Near-RT RIC Console Output

We mainly need E2SM-RC and E2SM-KPM

Start the gNB – Terminal 3

- Edit the gNB configuration file to **enable the** E2 agent (for now since we haven't installed flexRIC yet).

```
cd ~/openairinterface5g/targets/PROJECTS/GENERIC-NR-5GC/CONF/
vim gnb.sa.band78.fr1.106PRB.usrpb210.conf
```

```
#e2_agent = {
#  near_ric_ip_addr = "127.0.0.1";
  #sm_dir = "/path/where/the/SMs/are/located/"
#  sm_dir = "/usr/local/lib/flexric/"
#};
```

Uncomment these lines at the end of the file. (Remove the # at the beginning of each line)

```
cd ~/openairinterface5g/cmake_targets/ran_build/build

sudo ./nr-softmodem -O ../../../targets/PROJECTS/GENERIC-NR-5GC/CONF/gnb.sa.band78.fr1.106PRB.usrpb210.conf --gNBs.[0].min_rxtxtime 6 --rfsim
```

Run the gNB process – Terminal 3

```
After RCconfig_NR_E2agent /usr/local/lib/flexric/ 127.0.0.1
[E2 NODE]: mcc = 1 mnc = 1 mnc_digit = 2 nb_id = 3584
[E2 NODE]: Args 127.0.0.1 /usr/local/lib/flexric/
[E2 AGENT]: nearRT-RIC IP Address = 127.0.0.1, PORT = 36421, RAN type = ngran_gNB, nb_id = 3584
[E2 AGENT]: Initializing ...
[E2 AGENT]: Opening plugin from path = /usr/local/lib/flexric/libmac_sm.so
[E2 AGENT]: Opening plugin from path = /usr/local/lib/flexric/libtc_sm.so
[E2 AGENT]: Opening plugin from path = /usr/local/lib/flexric/libslice_sm.so
[E2 AGENT]: Opening plugin from path = /usr/local/lib/flexric/libgtp_sm.so
[E2 AGENT]: Opening plugin from path = /usr/local/lib/flexric/librc_sm.so
[E2 AGENT]: Opening plugin from path = /usr/local/lib/flexric/librlc_sm.so
[E2 AGENT]: Opening plugin from path = /usr/local/lib/flexric/libpdcp_sm.so
[E2 AGENT]: Opening plugin from path = /usr/local/lib/flexric/libkpm_sm.so
[UTIL]   threadCreate() for ru_thread: creating thread with affinity ffffffff, priority 97
[E2-AGENT]: E2 SETUP-REQUEST tx
[E2-AGENT]: E2 SETUP RESPONSE rx
[E2-AGENT]: Transaction ID E2 SETUP-REQUEST 0 E2 SETUP-RESPONSE 0
[PHY]   Starting RU 0 (,synch_to_ext_device) on cpu 2
```

Verify that the gNB received the E2 setup response.

gNB Console Output

```
[iApp]: Initializing ...
[iApp]: nearRT-RIC IP Address = 127.0.0.1, PORT = 36422
[NEAR-RIC]: Initializing Task Manager with 2 threads
[E2AP]: E2 SETUP-REQUEST rx from PLMN   1. 1 Node ID 3584 RAN type ngran_gNB
[NEAR-RIC]: Accepting RAN function ID 2 with def = ORAN-E2SM-KPM
[NEAR-RIC]: Accepting RAN function ID 3 with def = ORAN-E2SM-RC
[NEAR-RIC]: Accepting RAN function ID 142 with def = MAC_STATS_V0
[NEAR-RIC]: Accepting RAN function ID 143 with def = RLC_STATS_V0
[NEAR-RIC]: Accepting RAN function ID 144 with def = PDCP_STATS_V0
[NEAR-RIC]: Accepting RAN function ID 145 with def = SLICE_STATS_V0
[NEAR-RIC]: Accepting RAN function ID 146 with def = TC_STATS_V0
[NEAR-RIC]: Accepting RAN function ID 148 with def = GTP_STATS_V0
```

Near-RT RIC Console Output

E2 Setup procedure

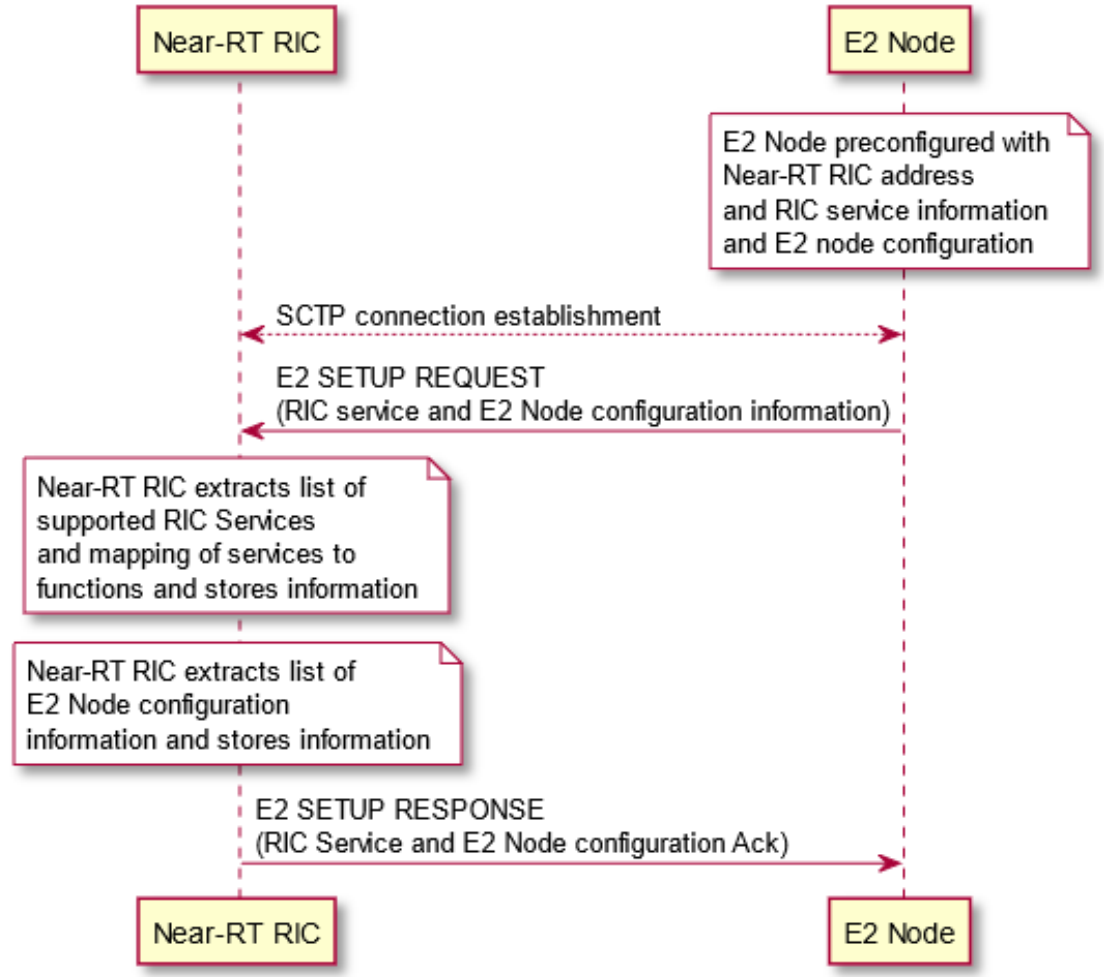

Figure 5.5.2-1: E2 Setup procedure

Run the UE – Terminal 4 and start Traffic – Terminal 5

```
cd ~/openairinterface5g/cmake_targets/ran_build/build

sudo ./nr-uesoftmodem -r 106 --numerology 1 --band 78 -C 3619200000 --uicc0.imsi 001010000000001 --rfsim
```

In terminal 5,

```
ping 192.168.70.135 -I oaitun_ue1
```

```
[PHY]   SSB position provided
[NR_PHY]   Starting sync detection
[PHY]   [UE thread Synch] Running Initial Synch
[NR_PHY]   Starting cell search with center freq: 3619200000, bandwidth: 106. Scanning for 1 number of GSCN.
[NR_PHY]   Scanning GSCN: 0, with SSB offset: 516, SSB Freq: 0.000000
[PHY]   Initial sync: pbch decoded sucessfully, ssb index 0
[PHY]   pbch rx ok. rsrp:51 dB/RE, adjust_rxgain:-1 dB
[NR_PHY]   Cell Detected with GSCN: 0, SSB SC offset: 516, SSB Ref: 0.000000, PSS Corr peak: 99 dB, PSS Corr Average: 61
[PHY]   [UE0] In synch, rx_offset 276480 samples
[PHY]   [UE 0] Measured Carrier Frequency offset 16 Hz
[PHY]   Initial sync successful, PCI: 0
[PHY]   HW: Configuring channel 0 (rf_chain 0): setting tx_freq 3619200016 Hz, rx_freq 3619200016 Hz, tune_offset 0
[PHY]   Got synch: hw_slot_offset 18, carrier off 16 Hz, rxgain 0.000000 (DL 3619200016.000000 Hz, UL 3619200016.000000 Hz)
[PHY]   UE synchronized! decoded_frame_rx=484 UE->init_sync_frame=0 trashed_frames=56
[PHY]   Resynchronizing RX by 276480 samples
[HW]   received write reorder clear context
[HW]   Gap in writing to USRP: last written 1590681599, now 1590772959, gap 91360
[NR_RRC]   SIB1 decoded
[NR_PHY]   ============================================
[NR_PHY]   [UE 0] Harq round stats for Downlink: 1/0/0
[NR_PHY]   ============================================
[NR_MAC]   Initialization of 4-step contention-based random access procedure
[NR_MAC]   PRACH scheduler: Selected RO Frame 631, Slot 19, Symbol 0, Fdm 0
[PHY]   PRACH [UE 0] in frame.slot 631.19, placing PRACH in position 2828, msg1 frequency start 0 (k1 0), preamble_offset 9,
[NR_MAC]   Trying to process acknack for an inactive harq process (0)
[NR_MAC]   [UE 0][RAPROC][RA-RNTI 0005] Got BI RAR subPDU 267 ms
[NR_MAC]   [UE 0][RAPROC][RA-RNTI 010b] Got RAPID RAR subPDU
[NR_MAC]   [UE 0][RAPROC][632.7] Found RAR with the intended RAPID 37
[MAC]   received TA command 31
[PHY]   RAR-Msg2 decoded
[NR_MAC]   [RAPROC][632.17] RA-Msg3 transmitted
[MAC]   [UE 0]Frame 633 Contention resolution identity: 0x15c608f230e6 Terminating RA procedure
[MAC]   [UE 0][633.12][RAPROC] RA procedure succeeded. CB-RA: Contention Resolution is successful.
[NR_RRC]   [UE0][RAPROC] Logical Channel DL-CCCH (SRB0), Received NR_RRCSetup
[RLC]   Added srb 1 to UE 0
[MAC]   [UE 0] Applying CellGroupConfig from gNodeB
[NR_RRC]   State = NR_RRC_CONNECTED
[NR_RRC]   [UE 0][RAPROC] Logical Channel UL-DCCH (SRB1), Generating RRCSetupComplete (bytes33)
```

- Output will be the same as what we observed previously, since the UE is not “aware” of the near-RT RIC.

Start the KPM xApp – Terminal 6

- KPM – Stands for Key performance metrics. This xApp is responsible for collecting metrics collected by the RAN and forwarding it to relevant xApps to help in RAN control
- Per O-RAN specifications, 5G measurements supported by KPM are specified in 3GPP TS 28.552.

```
cd ~/flexric
./build/examples/xApp/c/monitor/xapp_kpm_moni
```

```
[xApp]: DB filename = /tmp/xapp_db_1760032798072493
 [xApp]: E42 SETUP-REQUEST tx
[xApp]: E42 SETUP-RESPONSE rx
[xApp]: xApp ID = 7
[xApp]: Registered E2 Nodes = 1
Connected E2 nodes = 1
[xApp]: E42 RIC SUBSCRIPTION REQUEST tx RAN_FUNC_ID 2 RIC_REQ_ID 1
[xApp]: SUBSCRIPTION RESPONSE rx
[xApp]: Successfully subscribed to RAN_FUNC_ID 2
```

KPM xApp console output

```
      3 KPM ind_msg latency = 1760031043084728 [µs]
UE ID type = gNB, amf_ue_ngap_id = 1
ran_ue_id = 1
DRB.PdcpSduVolumeDL = 0 [kb]
DRB.PdcpSduVolumeUL = 0 [kb]
DRB.RlcSduDelayDl = 0.00 [µs]
DRB.UEThpDl = 0.00 [kbps]
DRB.UEThpUl = 0.00 [kbps]
RRU.PrbTotDl = 5 [PRBs]
RRU.PrbTotUl = 65 [PRBs]
```

Metrics from 3GPP TS 28.552 that are supported in FlexRIC/OAI.