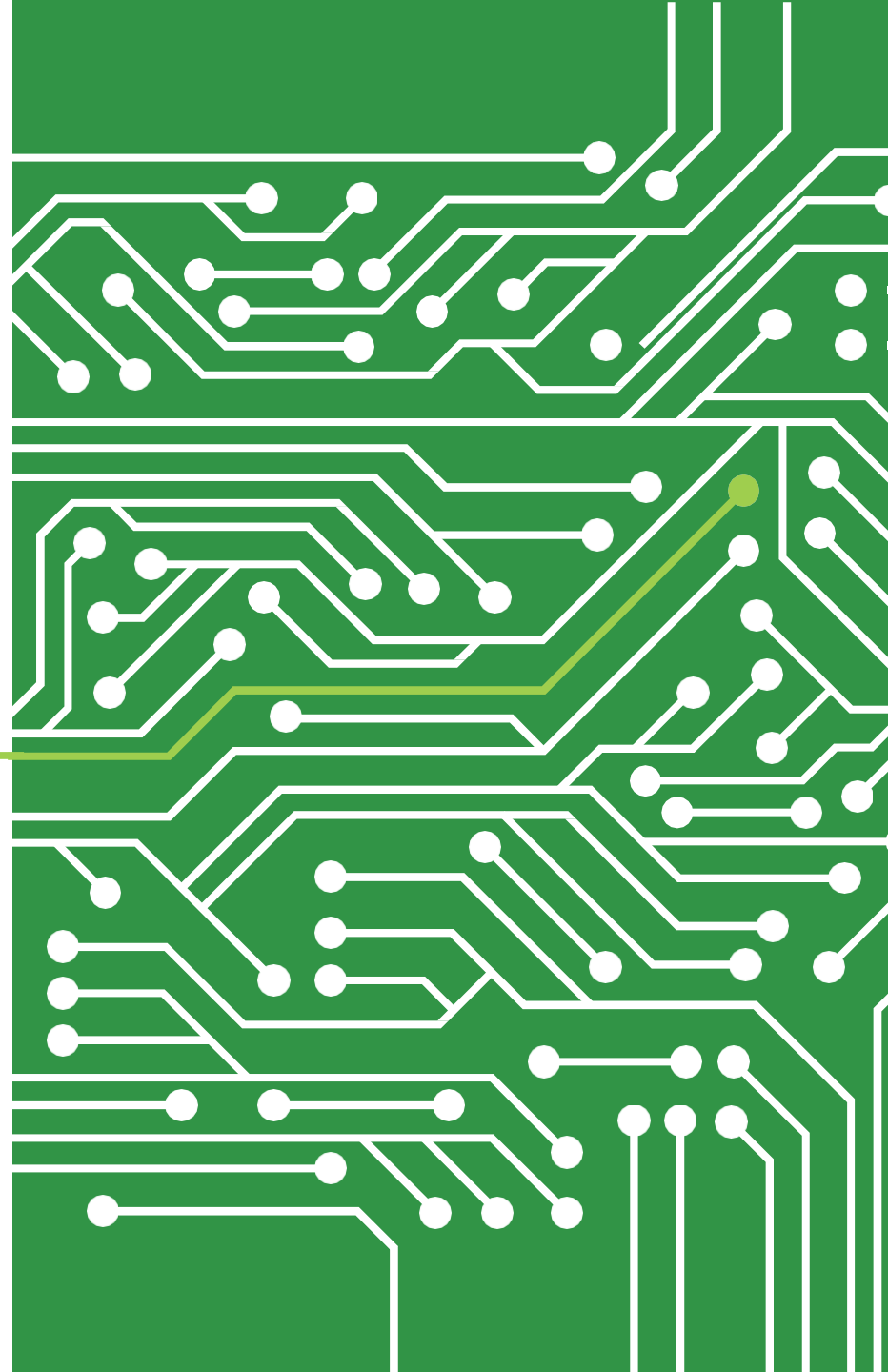

CrowdCell: Configuring and monitoring for LTE

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CrowdCell configuration – intro

- CrowdCell has 4 main blocks that need to be configured for proper operation:

1. Backhaul unit;
2. Front-End module;
3. Software defined radio module;
4. General purpose processing (GPP) unit and associated software;

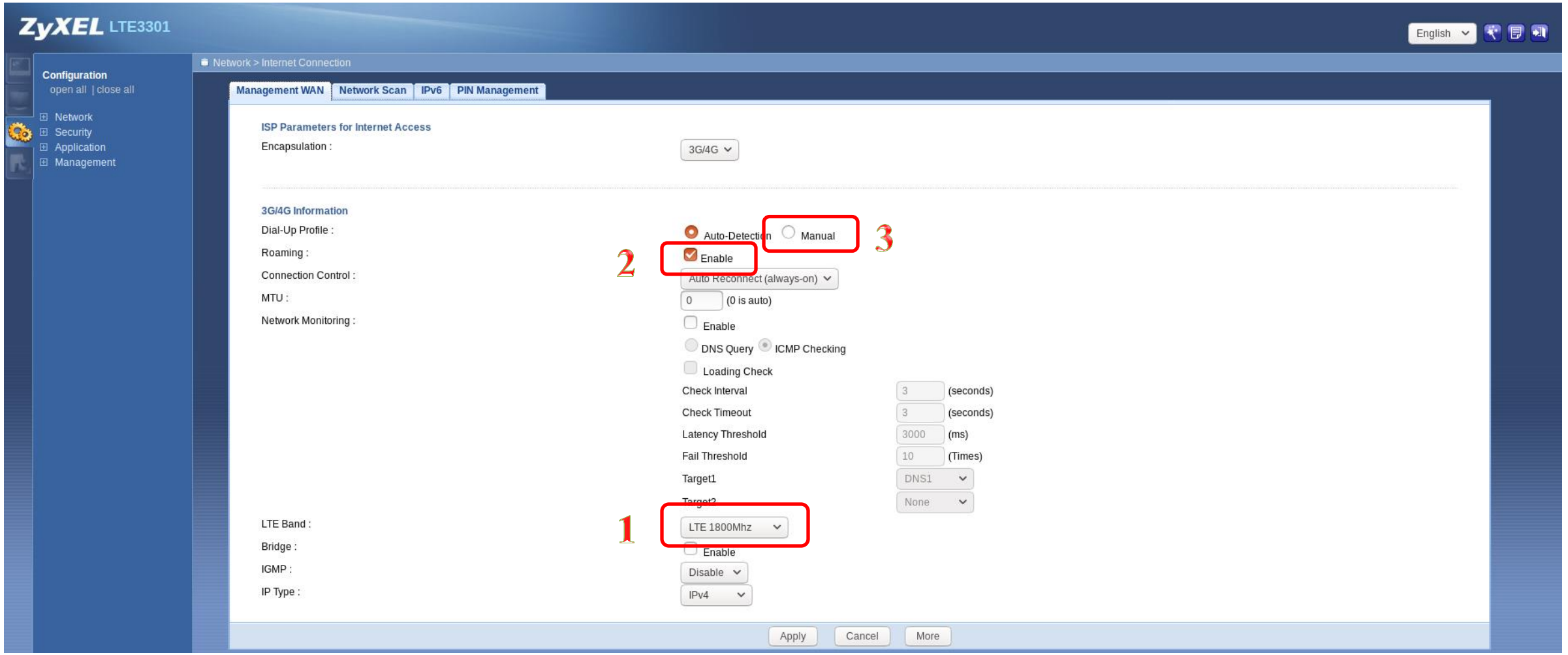
- Easy to guess – GPP side usually takes longest to setup for any new CrowdCell config (application or radio specific)

1. Configuring Backhaul unit

- Backhaul acts as a secondary Radio access node that is used to connect to Macro. Hence, it can become THE “BEST” interference source for local Radio access (via SDR/Front-End board combo) if not configured properly.
- Configuration is done via Web interface. Default address: 192.168.1.1
- Configuration options: standard LTE gateway options. Key configuration notes are:

1. LAN and DHCP server settings – mainly for IP management during network deployment/integration;
2. WAN setting – to separate Backhaul radio frequency from local, specify APN;

1. Configuring Backhaul unit

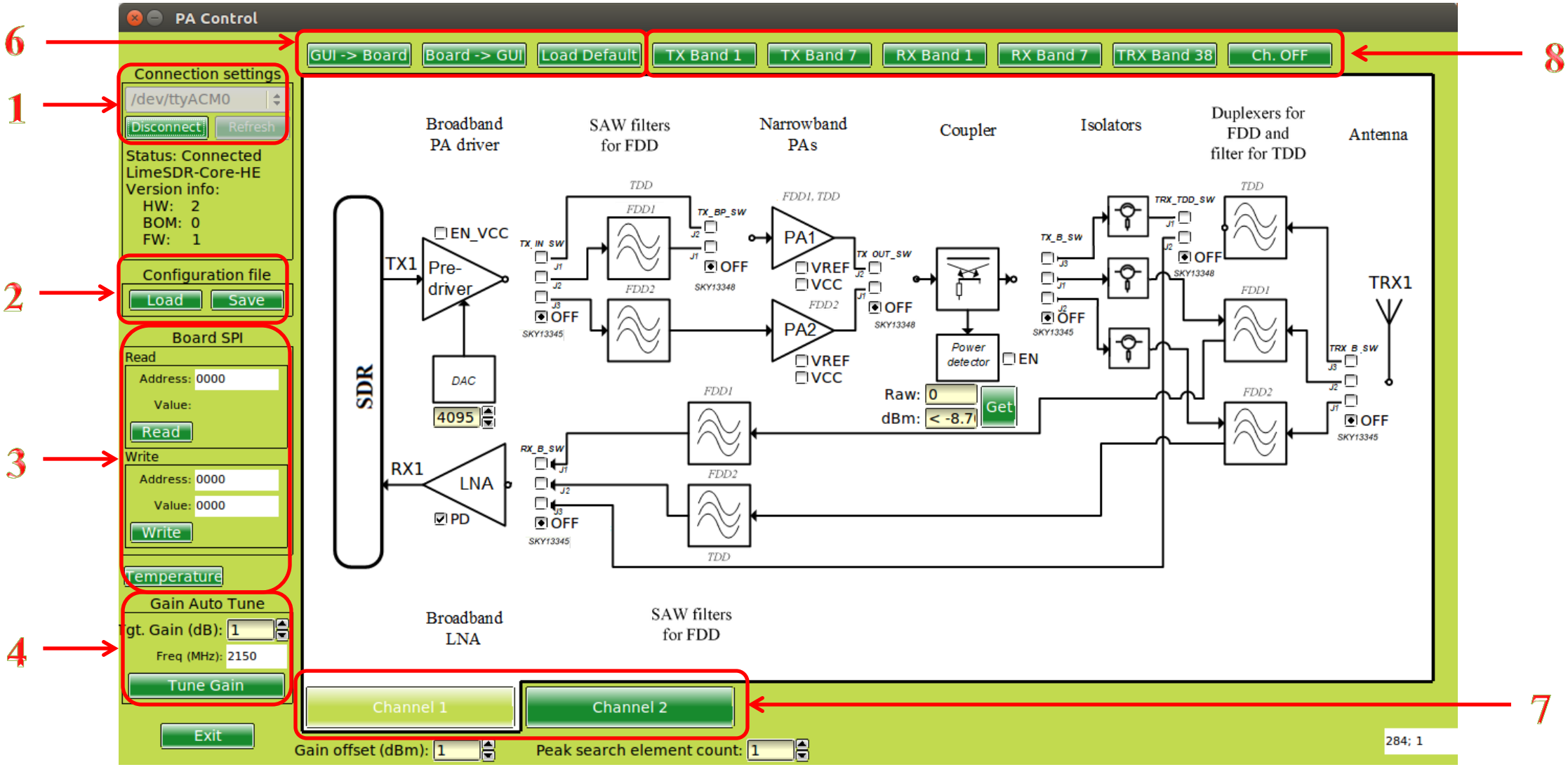


2. Configuring Front-End module

- Front-End module amplifies and filters RF signals in both Downlink and Uplink.
- Standard CrowdCell Front-End module supports 2 FDD and 1 TDD bands (default: Band 1, 7, 38).
- Output power – up to 23 dBm modulated. Can go higher at the cost of distortion and possible damage to device, hence proper handling during configuration is important!
- Front-End module configuration is done via Graphical User Interface (HE_GUI). By default, program can be found in active users home “AmarisoftLTE/” directory. Configuration options:

1. Downlink gain/output power;
2. Downlink and uplink band selection via RF switches/duplexers;
3. Temperature monitoring, configuration state save/load.

2. Configuring Front-End module



2. Configuring Front-End module

- Each CrowdCell comes with a pre-installed configuration setup for each supported band in MIMO mode, configured for maximum output power;
- Configuration files can be located in active users home “AmarisoftLTE/front-end/” directory.
- Configuration file name example – “CC_RF_MIMO_B7.cfg”. It corresponds to MIMO (2x2) configuration for Band 7.
- Please note, that only MIMO config is provided by default, since SISO mode can be generated by disabling either one of the two channels.
- Configuration file ”CC_RF_OFF.cfg” is used to disable the Front-End module.
- Front-End module is connected to GPP via USB to serial interface and also has controls routed to the FPGA in the SDR module.
- For TDD operation, switch toggling is controlled by the SDR module (speed purposes) – Front-End module control software is not involved anymore after initial config is performed.

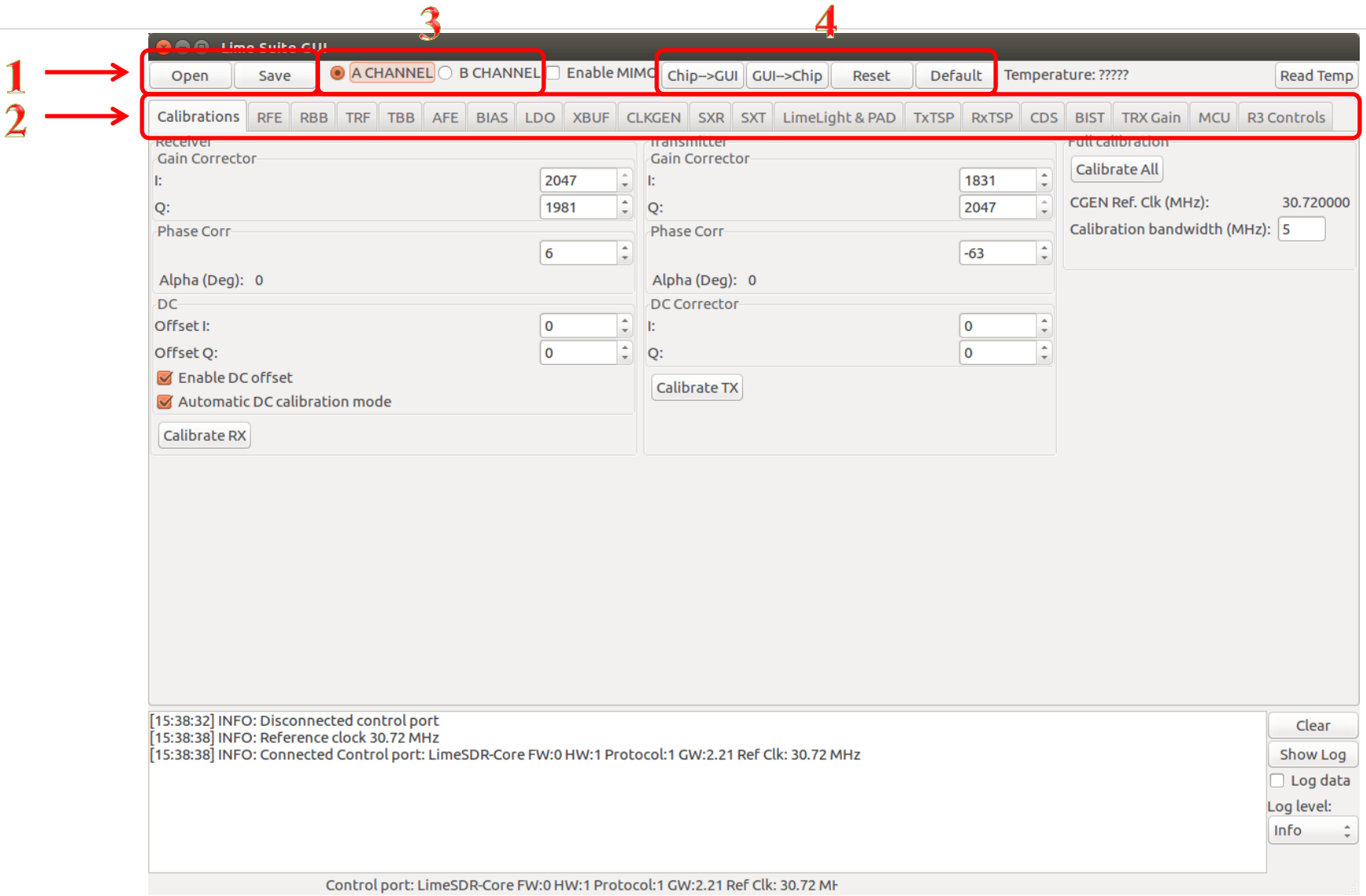
3. Configuring Software defined radio module

- Software defined radio (SDR) module is used to configure Lime Microsystems Radio IC, send and/or receive IQ data to/from the GPP.
- Similarly to LimeSDR USB, SDR module has 3 main components regarding configuration:

1. Cypress FX3 USB 3.0 interface controller – primarily configured via firmware updates;
2. Intel Cyclone IV FPGA – primarily configured via gateware updates. Main purpose: glue logic between FX3 and LMS7002M, packet synchronization, board controls;
3. LMS7002M software defined radio IC – highly configurable radio interface.

- All of the components can be configured and controlled by using provided API commands or by using LimeSuiteGUI graphical user interface or third party software.
- LimeSuiteGUI is not needed for normal operation – it provides a more convenient way to debug or build custom configurations for the SDR module; built-in tools for quick radio spectrum analysis, firmware or gateware updates. By default, program is pre-installed and can be called via terminal by typing “LimeSuiteGUI”.

3. Configuring Software defined radio module



3. Configuring Software defined radio module

- For Amarisoft LTE eNodeB, SDR module is configured using two files:

1. LMS7002M state file – used to configure the radio IC.
2. SDR module configuration file – used to configure interface, board controls, calibration options. Is part of the Amarisoft eNodeB configuration with the “rf_driver” part separated along with any radio oriented controls.

- Both files can be located in active users home “AmarisoftLTE/enb/config/rf_driver/” directory.
- State and configuration file name example – respectively “CC_mimo-2x2-20mhz_Band_7.ini” and “CC_mimo-2x2-20mhz_Band_7.cfg”. It corresponds to MIMO (2x2) configuration for Band 7 with a bandwidth of 20 MHz.
- Please note, that only MIMO config for the LMS7002M state file is provided by default, since SISO mode can be generated by disabling either one of the two channels.
- All SDR module configuration file control parameters can be viewed in detailed in the TRX Driver, which, by default, is located in active users home “AmarisoftLTE/trx-lms7002m /” directory.

3. Configuring Software defined radio module

SDR module configuration file example for FDD mode, Band 7, MIMO 2x2, 20 MHz bandwidth configuration

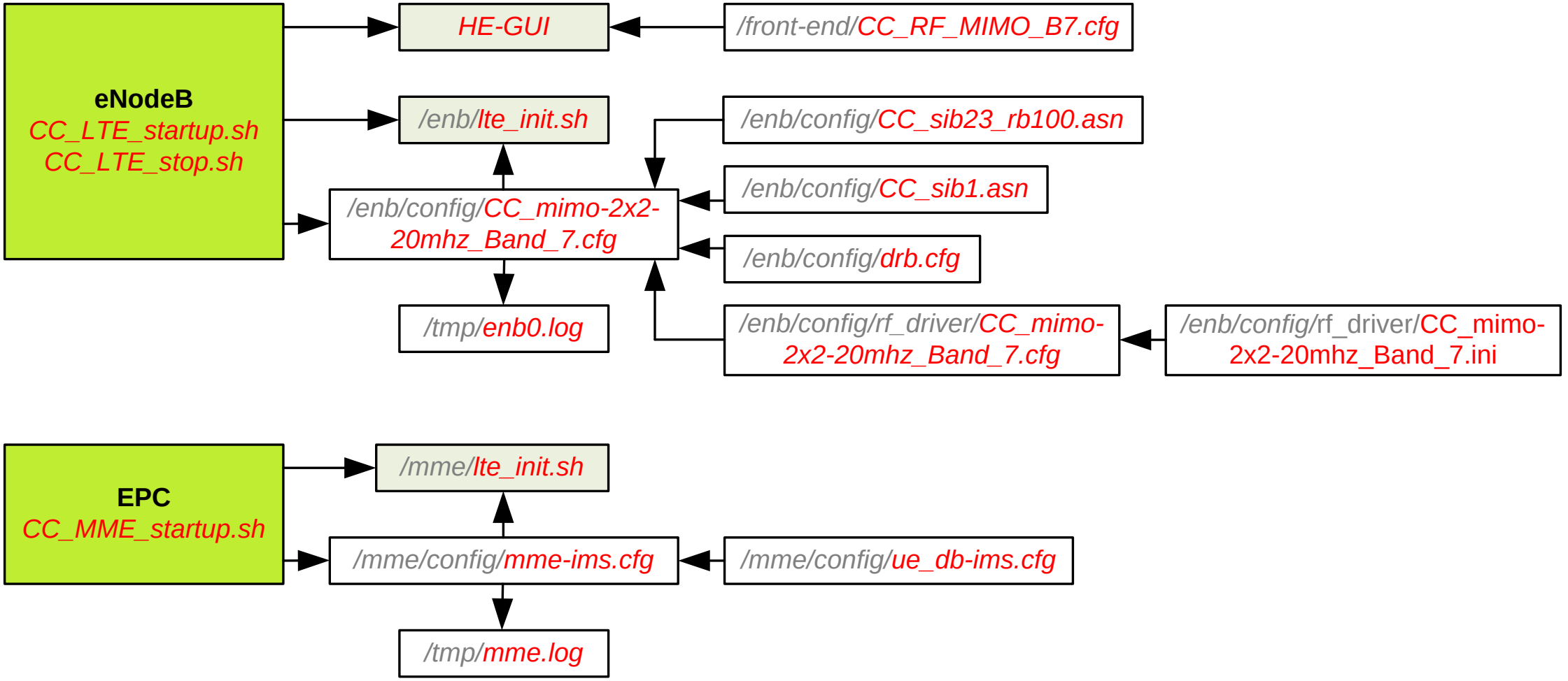
```
tx_time_offset: -70,                                    /*Time offset (in samples) for the downlink*/
rf_driver: {
        name: "lms7002m",
        //sample_rate: 30.72,                           /*Comment for individual sample rate from .ini */
        //dec_inter: 2,                                 /*2,4,8,16,32 Comment for individual sample rate from .ini */
        lms7002_index: 0,                               /*Selects which SDR is used if more than one is present*/
        rx_power: -70,                                  /*Currently does nothing*/
        tx_power: 23,                                   /*Designates TX output power for gain control loop*/
        tcxo_calc: 45000,                               /*SDR module TCXO tune control word 0-65535*/
        sample_format: "12b",                           /*Comment out if sample_rate is smaller than 15.36/*
        config_file:  "CC_mimo-2x2-20mhz_Band_7.ini",   /*LMS7002 config file*/
        calibration: "iq_dc",                           /*Calibration options – “all, none, filter, iq_dc” */
        TDD_TRX_EN_START_DELAY: 0x1,                    /*TDD mode sample delay at start*/
        TDD_TRX_EN_STOP_DELAY: 0x1,                     /*TDD mode sample delay at start*/
        TDD_TRX_SWITCH_MODE: 0x31,                      /*If FDD active, set to 0x31. If TDD active, set to 0x1*/
        TDD_TRX_SWITCH_DIR: 0x31,                       /*If FDD active, set to 0x31. If TDD active, set to 0x1*/
        TDD_TX_EN_CTRL: 0,                              /*If FDD active, set to 0. If TDD active, set to 1*/
},
```

4. General purpose processing (GPP) unit and associated software

- By default, CrowdCell uses Amarisoft eNodeB (LTEENB) and EPC (LTEMME) services to enable full private network experience.
- LTEENB is a LTE base station (eNodeB) implemented entirely in software and running on a GPP. The GPP generates a baseband signal which is sent to the software defined radio block which does the digital to analog and reverse conversions. eNodeB interfaces with a LTE Core Network (LTEMME) thru the standard S1 interface. LTEENB also supports NB-IoT and NR (5G) cells.
- LTEMME is a LTE MME (Mobility Management Entity) implementation. It has a built-in SGW (Serving Gateway), PGW (Packet Data Network Gateway), PCRF (Policy and Charging Rule Function), HSS (Home Subscriber Server) and EIR (Equipment Identity Register). Naming is a bit confusing – it actually is not only a MME, but an EPC.
- eNodeB and EPC configurations are separate and both services can be launched independently of one another.
- LTEENB (eNodeB) documentation can be found in in active users home “AmarisoftLTE/enb/doc/” directory.
- LTEMME (EPC) documentation can be found in in active users home “AmarisoftLTE/mme/doc/” directory.

4. General purpose processing (GPP) unit and associated software

- At the highest level, the configuration structure for LTE using Amarisoft looks something like this:



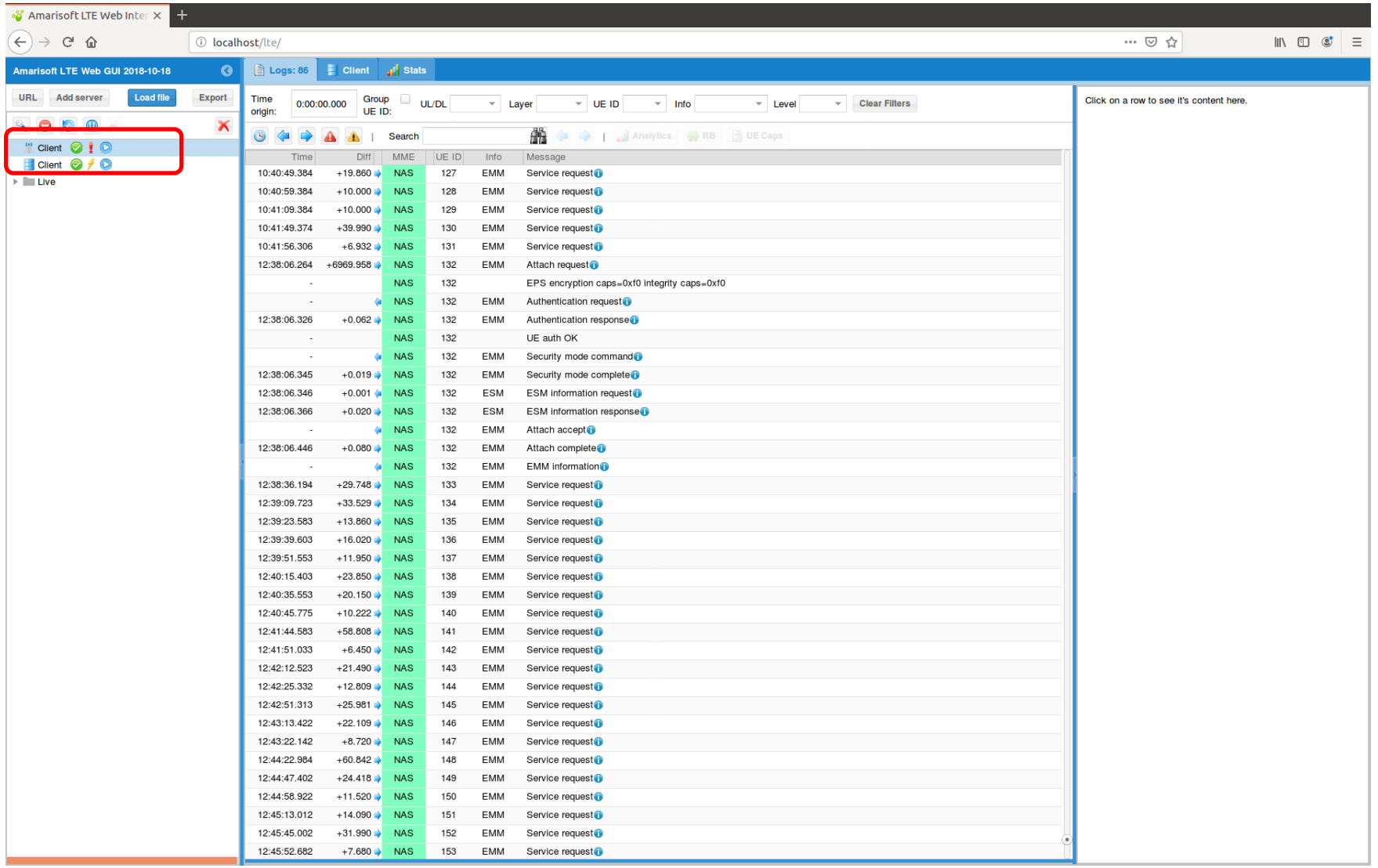
4. General purpose processing (GPP) unit and associated software

- *CC_LTE_startup.sh* – starts eNodeB software stack and loads the specified LTE configuration file (in example "/enb/config/CC_mimo-2x2-20mhz_Band_7.cfg"). Also, loads the specified Front-End module configuration file (in example "/front-end/CC_RF_MIMO_B7.cfg" via "HE_GUI" program).
- *CC_LTE_stop.sh* – loads a configuration file to the disable Front-End module after eNodeB software stack is killed.
- */enb/config/CC_mimo-2x2-20mhz_Band_7.cfg* – used to configure LTE parameters. Some parameters are distributed and grouped over different files. In example System Information Block (SIB) is split into two files – "/enb/config/CC_sib1.asn" and "/enb/config/CC_sib23_rb100.asn", also Data Radio Bearer (DRB) information is stored separately in "/enb/config/drb.cfg". Other files can be added if needed (for example SIB4, SIB5 and etc.).
- */enb/config/rf_driver/CC_mimo-2x2-20mhz_Band_7.cfg* – extension of the LTE parameter configuration file, that primarily stores parameters for the radio interface (SDR) configuration. It specifies which LMS7002M config (.ini) file to use (in example "/enb/config/rf_driver/CC_mimo-2x2-20mhz_Band_7.ini").
- *CC_MME_startup.sh* – starts EPC software stack and loads the specified configuration file (in example "/mme/mme-ims.cfg"). *"/mme/lte_init.sh"* can be used to change external network interface (for example Wi-Fi or ethernet). *"/mme/config/ue_db-ims.cfg"* is used for UE database management.

4. General purpose processing (GPP) unit and associated software

- Dedicated LTE monitoring server can be accessed via web-browser “localhost/lte/”.
- Both eNodeB and EPC can be monitored. eNodeB monitor port is 9001, while EPC is 9000 (can be changed in the config files).
- Log files can be loaded or saved with wanted message level filter.
- Real-time parameters can be monitored.
- NOTE: as any graphical interface, this will load the GPP. It is recommended to remotely access CrowdCell for monitoring purposes and, ideally, disable graphical interface altogether when using higher LTE bandwidths.
- Another way to monitor both eNodeB and EPC is through command line monitor. Commands for both services are given in their documentation.

4. General purpose processing (GPP) unit and associated software



Time	Diff	MME	UE ID	Info	Message
10:40:49.384	+19.860	NAS	127	EMM	Service request
10:40:59.384	+10.000	NAS	128	EMM	Service request
10:41:09.384	+10.000	NAS	129	EMM	Service request
10:41:49.374	+39.990	NAS	130	EMM	Service request
10:41:56.306	+6.932	NAS	131	EMM	Service request
12:38:06.264	+6969.958	NAS	132	EMM	Attach request
-		NAS	132		EPS encryption caps=0xf0 integrity caps=0xf0
-		NAS	132	EMM	Authentication request
12:38:06.326	+0.062	NAS	132	EMM	Authentication response
-		NAS	132		UE auth OK
-		NAS	132	EMM	Security mode command
12:38:06.345	+0.019	NAS	132	EMM	Security mode complete
12:38:06.346	+0.001	NAS	132	ESM	ESM information request
12:38:06.366	+0.020	NAS	132	ESM	ESM information response
-		NAS	132	EMM	Attach accept
12:38:06.446	+0.080	NAS	132	EMM	Attach complete
-		NAS	132	EMM	EMM information
12:38:36.194	+29.748	NAS	133	EMM	Service request
12:39:09.723	+33.529	NAS	134	EMM	Service request
12:39:23.583	+13.860	NAS	135	EMM	Service request
12:39:39.603	+16.020	NAS	136	EMM	Service request
12:39:51.553	+11.950	NAS	137	EMM	Service request
12:40:15.403	+23.850	NAS	138	EMM	Service request
12:40:35.553	+20.150	NAS	139	EMM	Service request
12:40:45.775	+10.222	NAS	140	EMM	Service request
12:41:44.583	+58.808	NAS	141	EMM	Service request
12:41:51.033	+6.450	NAS	142	EMM	Service request
12:42:12.523	+21.490	NAS	143	EMM	Service request
12:42:25.332	+12.809	NAS	144	EMM	Service request
12:42:51.313	+25.981	NAS	145	EMM	Service request
12:43:13.422	+22.109	NAS	146	EMM	Service request
12:43:22.142	+8.720	NAS	147	EMM	Service request
12:44:22.984	+60.842	NAS	148	EMM	Service request
12:44:47.402	+24.418	NAS	149	EMM	Service request
12:44:58.922	+11.520	NAS	150	EMM	Service request
12:45:13.012	+14.090	NAS	151	EMM	Service request
12:45:45.002	+31.990	NAS	152	EMM	Service request
12:45:52.682	+7.680	NAS	153	EMM	Service request