5G RuralDorset WP6 Neutral Host Task 8: Dynamic Spectrum Sharing

Task 8: DSS Demonstration

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What is Dynamic Spectrum Sharing?

5G & LTE Dynamic Spectrum Sharing (DSS) is a technology that allows 4G LTE and 5G NR (New Radio) user equipment to connect on a common, single, base station hardware on the same frequency band. This provides a dynamic allocation of spectrum resources between LTE & 5G based on user demand. The licensed frequency band is shared by "4G LTE" and "5G NR" radio access technologies (RAT), avoiding a split into dedicated spectrum for each RAT with separate base stations.

DSS enables a single antenna (or antenna array) and radio base station to operate functionally as both a 4G eNodeB and a 5G NR gNodeB. This is most useful for operators without new 5G spectrum who need to re-farm existing bands to 5G. DSS uses new intelligent scheduler algorithms to set an optimal split in resources for the mix of 4G and 5G devices in the network as it changes in time.

DSS - Technical Details (assumes some knowledge of LTE)

5G NR air interface builds on LTE rather than being completely new: it uses Orthogonal Frequency Division Modulation (OFDM) but extends the capability for much higher data rates, lower overheads, and lower latency. DSS limits the flexibility of the 5G NR signal but can still enable many 5G services.

OFDM uses many narrow band sub-carriers instead of one very wideband carrier. LTE uses 15KHz sub-carriers. 5G NR can use wider bandwidth sub carriers the lower frequency bands though only 15KHz and 30KHz are used.

In one possible DSS implementation, 5gNR uses the same sub-carrier frequency as LTE, 15KHz. This also gives the same symbol duration for LTE and 5G NR which simplifies the configuration. In the time domain LTE and 5GNR both use a 10 msec frame and 1 msec subframes. The user data can be allocated dynamically in time and frequency once the control channels are in place.

The OFDM signals between the base station and UEs for LTE and 5GNR are different. LTE has an always on pilot in fixed positions: the LTE pilot "Cell-specific Reference Signal"(CRS) advertises the presence of a specific cell. This signal needs to be avoided by the 5GNR and the way this is done is using multicast broadcast single frequency network (MBSFN) sub-frames as these have sub-frames free from the CRS. 5G NR signals still need to be placed to avoid the first 2 symbols of each MBSFN sub-frame as these may still be used by LTE physical downlink control channel, PDCCH.

Note: MBSFN is a channel used by the enhanced multimedia broadcast multicast services (eMBMS) which was added for LTE in 3GPP Release 9 in 2009. It can usually be enabled in networks by a software configuration change.

Not all 10 sub-frames can be set to MBSFN. LTE needs to use some subframes:

- Primary synchronisation signal (PSS) and secondary synchronisation signal (SSS) in #0 and #5
- Paging may occur in #4 and #9

That leaves 6 subframes for MBSFN with typically #1 and #2 actually used.

5G NR does not use the always on CRS: there are now synchronisation signal blocks and a tracking reference signal (TRS). These need to be fitted into the MBSFN sub-frames avoiding the first 2 symbols. A 5G NR capable UE receiver performs a search for the strongest SSB beam index and then uses the indicated time and frequency to send the random access channel preamble on the uplink. Normal 5G registration then proceeds.

Note: In theory each base station could be transmitting up to 4 analog beams for carriers under 3GHz (1 antenna per 90-degree quadrant). However, the lower frequency bands, especially those <1Ghz are likely to have a single antenna so only 1 beam index needs to be transmitted.

There are many other aspects and changes needed to make DSS work. These will vary with network equipment supplier along with the needs of network operators to re-use existing hardware installations.

Advantages and Disadvantages of DSS

A big advantage of DSS is that it allows operators to smoothly migrate from 4G LTE to 5G NR as well as hosting both technologies under the same existing antenna infrastructure. This clearly speeds up 5G NR deployments, since no new equipment nor new spectrum re-farming is needed.

Spectrum usage is of key importance as well. Spectrum is a valuable, finite resource and securing its optimal use will benefit operators and end users. This is particularly important for remote, rural areas, where the cost of new infrastructure makes the business case marginal (leading to the continuation of gaps in network coverage). DSS on already licensed radio spectrum allows a network operator to enable new applications for both LTE and 5G NR that make the investment viable. Thus, DSS is most useful in the lower frequency bands where LTE is already deployed.

DSS on the lower frequency bands also gives the potential of large cell sizes for both 4G and 5G in rural areas, which translates into significantly increased coverage compared to the new 5G NR bands around 3.5GHz.

Example (simplified!): If everything else is equal, a 700MHz cell will be $(3500/700)2 = 25$ times the radius of a 3.5GHz cell. That means the average user density would need to be only 1/25th for 700MHz compared to 3.5GHz to have the same positive business case. Clearly a big advantage for more remote areas. Even using the common LTE 2.5GHz bands for DSS compared to 3.5GHz will give a 2 times cell size increase.

However, there is a cost in the total useful capacity for end users with DSS. LTE and 5G NR, like all radio standards, need to use significant bandwidth to allow reliable communications of the wanted user data. Single mode LTE is about 75-80% efficient, 5G NR is about 86% efficient. DSS will reduce efficiency by a further 10-20%. In the early phase of DSS with the number of LTE connections dominating over 5G NR the efficiency could be ~65%. Even with this limitation DSS will still offer a way to deploy 5G NR for many operators.

DSS is an attractive solution for rural areas, like Dorset's coastline, with moderate traffic compared to capacity for much of the year. However, not all the benefits of 5G NR will be available in a DSS network, maximum data rates will be lower than a pure 5G NR network and latency may be higher. It is likely that the overheads will be lower once 5GNR dominates over LTE, but this requires changes to the methods used for DSS (in future 3GPP releases).

5G has an extra protocol sub-layer compared to 4G, the service data adaptation protocol (SDAP). This allows fine grain setting of priority (and related charging) by using what is called a QoS flow. This is different to 4G where the EPC core network uses different bearers to set the QoS.

It will require a sophisticated scheduler to allow this 5G sub-layer to work as expected along with LTE prioritisation. This can be overcome but may mean only the biggest companies can provide solutions.

Experimental DSS setup

The Dynamic Spectrum Sharing (DSS) model used in the demo is shown in Figure 1. In this implementation, two Core Networks are deployed, a 4G Network and a 5G Network, both connected to a single RAN (Radio Access Network). Both 4G LTE and 5G NR are deployed in the same frequency band, which allows a dynamic allocation of spectrum resources between LTE and 5G, based on user demand.

The Core Networks are configured to advertise a single PLMN for selection by User Equipment (UEs) for both 4G and 5G networks: 5G (multi-mode) UEs can connect using 5G-NR and 5G services; LTE. 4G only UEs within the signal range of the same antenna will connect using LTE.

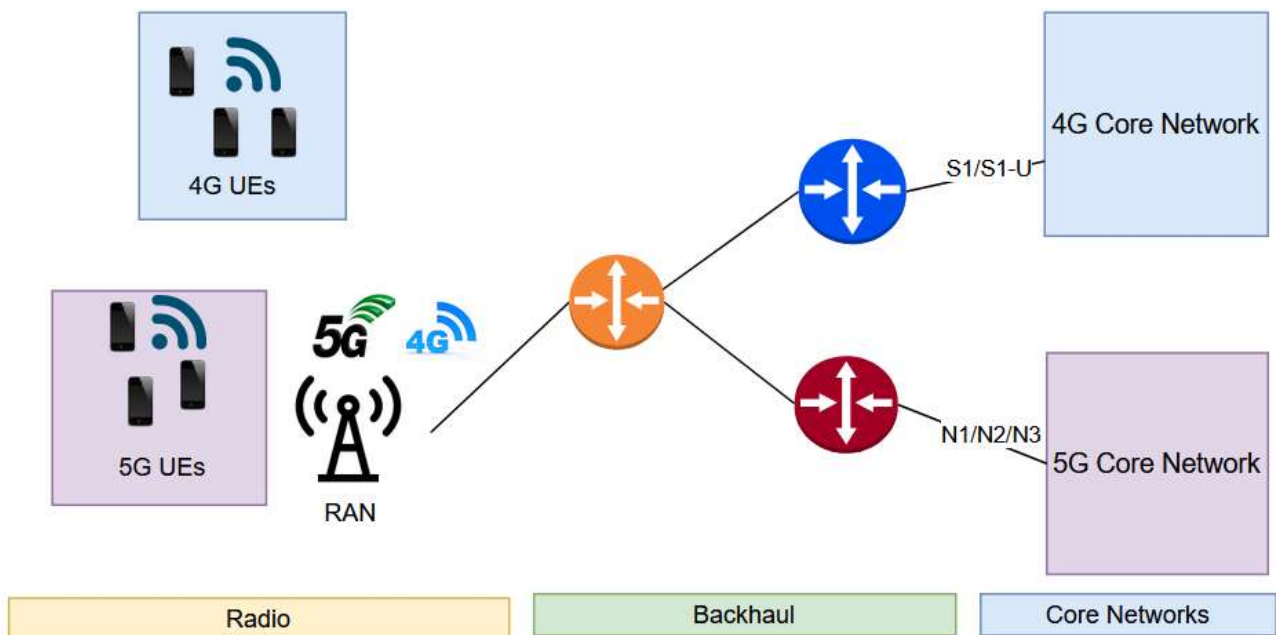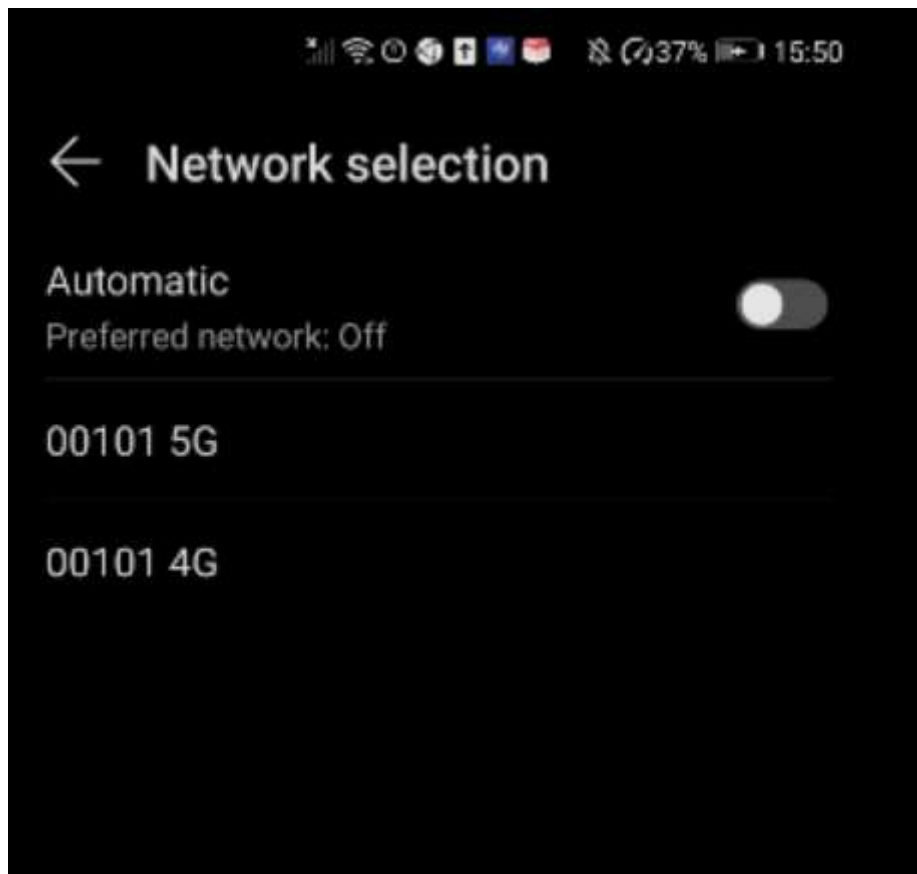Figure 2 is a screenshot taken from a 4G/5G capable phone, able to identify both of these networks.

Figure 1 DSS Network

Figure 2 Single UE can discover both 4G and 5G networks of the same Operator

Conclusion and Further Work

A preliminary DSS demonstration has been carried out in the Satellite Applications Catapult's (SAC) Future Networks Development Centre lab in Westcott. We were able to demonstrate the basic capability to share a band between 4G LTE and 5G NR.

4G and 5G NR will co-exist for many years and DSS can be used to lower the cost of 5G entry for existing 4G operators.

DSS could be an ideal technology for rural areas, with a lower density of users, if a lower frequency band is used. There are still areas with poor 4G coverage so a DSS deployment may help to fill in the gaps.

However, the technology is evolving and there are options for DSS in rural areas that require further study and trial deployments. The following areas are suggestions for further investigation:

- Deploy 2 or 3 base stations for DSS lab-based experiments and investigate high load tests and cell selection

- Combine DSS with OpenRAN platform at SAC's premises and investigate full potential

- Deploy and demonstrate DSS technology in a rural area such as Dorset

- The DSS technology could be combined with the Neutral Host solution already deployed in Dorset

- Integrate DSS network with satellite communications (5G over satellite was already deployed in the 5G RuralDorset Network) for added redundancy and higher link availability.

Exploration of the points above would generate a deeper understanding of this technology and is a good starting point towards commercialisation of Neutral Host in rural and remote areas in the UK.

Annex: Demo and Test results

This annex presents the bench test results which took place in Satellite Applications Catapult's (SAC) Future Networks Development Centre in Westcott.

The experiment uses an Amarisoft base station acting as DSS. Just to note here that Amarisoft RANs are also deployed in all the 4 trial sites in Dorset's coastline. In the same Amarisoft Box a 5G Core Network has been configured. In a different server, an Amarisoft 4G Core Network has been deployed. Necessary routing has been applied so Amarisoft servers are properly connected, as can be seen in Figure 3.
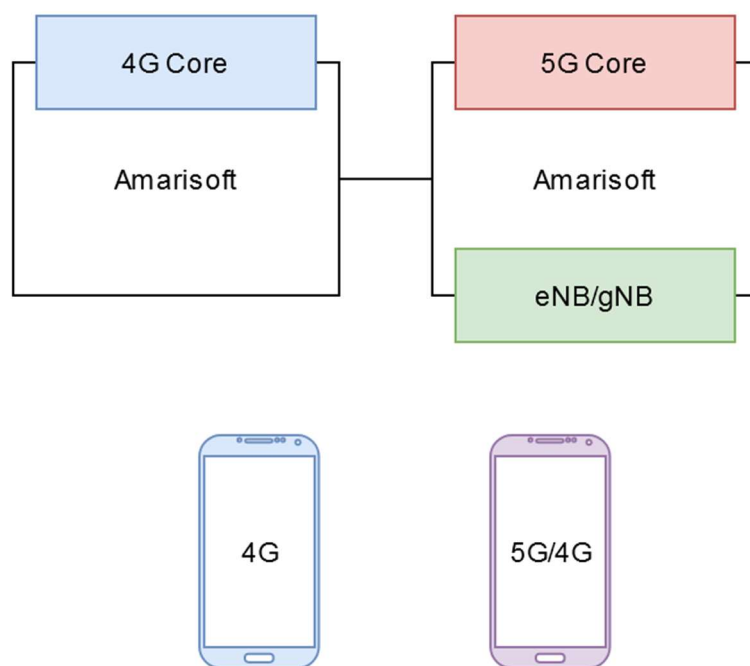
Figure 3 DSS Test Setup

The first Amarisoft box (on the left) is running a 4G Core that is connected with the eNB and the blue UE device marked as 4G is not 5G capable and contains a SIM card that has been whitelisted on this 4G Core. For the purposes of this test, this UE supports 4G only.

On the second Amarisoft box (right), both 5G Core and the eNB/gNB are running, and the second purple UE device marked as 5G/4G is 5G capable and is whitelisted and registered in that 5G core only.

Both 4G LTE and 5G NR are configured in the same frequency band - thanks to DSS, the same spectrum is now shared by the two "4G LTE" and "5G NR" technologies.

Figure 4 shows the screenshot on both UEs (the 4G only and the 5G capable), the one on the left is the 4G only terminal which can only identify and connect to the 4G network whereas the one on the right is the 4G/5G terminal, which can see and have access to 5G network's improved resources and services.
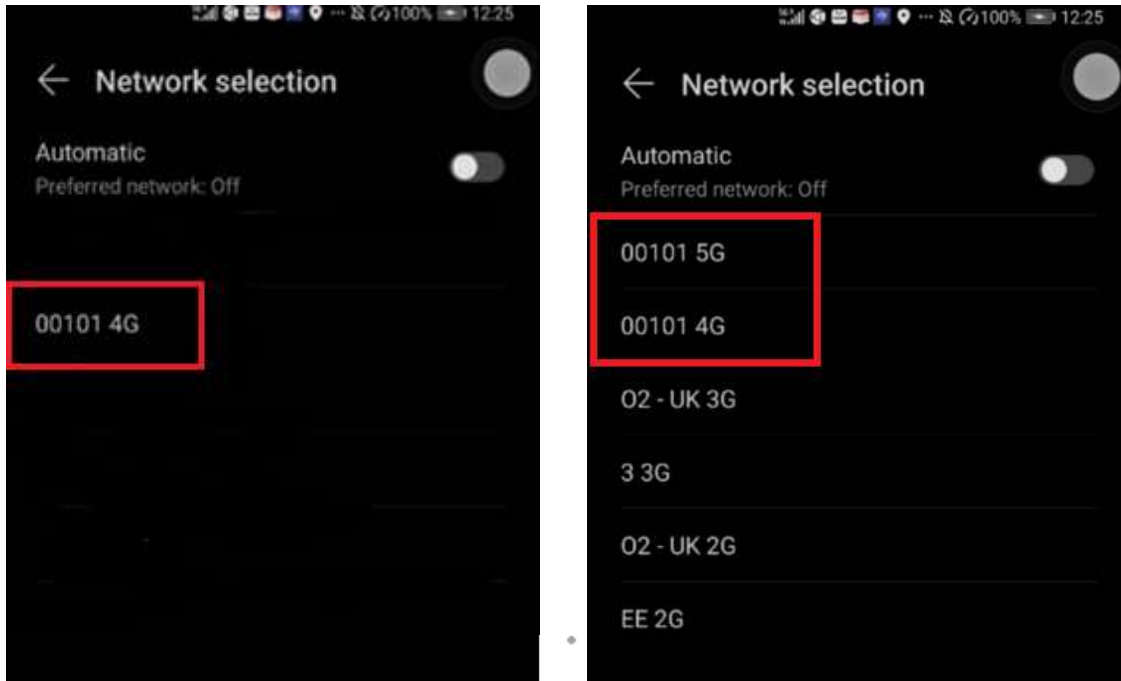

Figure 4 Network selection in UEs

Figure 5 is taken from eNB/gNB showing that same base station is connected to both 4G and 5G networks under the same PLMN (same PLMN implies same Operator – PLMN for both networks is test PLMN 00101). Also Figure 6 depicts the capability of the RAN to support 2 cells, one LTE and one 5G NR, both at 780MHz:

Figure 5 eNB/gNB status

```
(enb) cell
[enb1a2d0] PLMN=00101 eNB_ID=0x1a2d0
[gnb0012345] PLMN=00101 gNB_ID=0x12345
Cell    RAT BAND     TAC dl_arfcn  pci prach_seq dl_gain ul_dis plmn
0x001   LTE  28   0x0001    9435    1       28    0.0      N 00101
0x002    NR n28 0x000064  156100  500        1    0.0      N 00101
(enb)
[ eNB:root ][                        0 MME  [1 ENB]  3 IMS  4 MBMSGW
```

Figure 6 RAN cells

Figure 8 and Figure 8 show the, AMF (for 5G) and MME (for 4G) respectively, connectivity to the enb/gnb.

```
(mme) gnb
  PLMN      RAN_ID                        IP:Port #UEctx     TACs
  00101    0x12345                127.0.1.1:37884       1    0x64
```

Figure 7 AMF status

```
(mme) enb
  PLMN     eNB_ID                        IP:Port #UEctx    TACs
  00101    0x1a2d0             10.30.150.204:43003       0    0x1
```

Figure 8 MME status

The correct attachment and registration of the two devices can be seen on the enb/gnb trace below (Figure 9), which displays the status of the connection with the UEs. Here important to note the parameter UE_ID which shows the S1 eNodeB and NG RAN UE identity, unique among all cells:

```
(enb) t
Press [return] to stop the trace
            ----DL---------------------- --UL----------------------------------------
UE_ID  CL RNTI C cqi ri  mcs retx txok brate  snr puc1  mcs rxko rxok brate     #its phr  pl   ta
 1938 001 4d83 1  14 1    -    0    0     0 29.7 22.5    -    0    0     0        -   0 77    -
    7 001 0043 1  15 1 27.0    0    1 9.68k 19.0 21.6    -    0    1 42.6k 1/1.0/1  -7  64 -0.3
 1938 001 4d83 1  14 1 24.2    1    5 1.92k 26.8 21.9 20.0    1    1   644 4/5.0/6   3  77 -0.2
    7 001 0043 1  15 1 27.0    0    5 2.42k 20.5 21.1  9.8    1    5 2.42k 1/2.0/6  -5  64 -0.2
```

Figure 9 enb/gnb trace

The configuration file used for this setup is shown in Figure 10. This was built considering the parameters discussed in chapter "DSS – Technical Parameters" and with info provided by Amarisoft.

```
/* lteenb configuration file version 2022-03-08

 * Copyright (C) 2019-2022 Amarisoft

 * LTE FDD cell + NR FDD cell at the same frequency

 */

 /* Values: 1 (SISO), 2 (MIMO 2x2), 4 (MIMO 4x4) */

#define N_ANTENNA_DL        1

 /* Values: 0 (NSA NR), 1 (SA and NSA NR) */

#define ALLOW_SA            1

 /* define it to disable LTE-CRS: schedule NR only in LTE MBMS subframes */

//#define MBMS_ONLY

 {

 //log_options: "all.level=debug,all.max_size=1",

 log_options:
"all.level=error,all.max_size=0,nas.level=debug,nas.max_size=1,s1ap.level=debug,s1ap.max_size=1,ngap.level=debug,ngap.max_size
=1,x2ap.level=debug,x2ap.max_size=1,rrc.level=debug,rrc.max_size=1",

 log_filename: "/tmp/gnb0.log",

  /* Enable remote API and Web interface */

 com_addr: "0.0.0.0:9001",

#if 1

 rf_driver: {

    name: "sdr",

     /* list of devices. 'dev0' is always the master. */

    args: "dev0=/dev/sdr0",

    /* TDD: force the RX antenna on the RX connector (NR does not

      support yet sharing TX and RX on the TX connector) */

    rx_antenna: "rx",

     /* synchronisation source: none, internal, gps, external (default = none) */

    // sync: "gps",

 },
```

```
  tx_gain: 90.0, /* TX gain (in dB) */

  rx_gain: 60.0, /* RX gain (in dB) */

#else

  include "rf_driver/config.cfg",

#endif


  rf_ports: [

   {

      /* RF port for the LTE cell */

   },

 ],

  mme_list: [

   {

     /* address of MME for S1AP connection. Must be modified if the MME runs on a different host. */

     mme_addr: "10.30.150.207",

     s1ap_bind_addr: "10.30.150.204",

   },

 ],

 /* GTP bind address (=address of the ethernet interface connected to

    the MME). Must be modified if the MME runs on a different host. */

 gtp_addr: "127.0.1.1",


 /* high 24 bits of SIB1.cellIdentifier */

 enb_id: 0x1A2D0,

#if ALLOW_SA

 gnb_id_bits: 28,

 gnb_id: 0x12345,

  amf_list: [

   {

     /* address of AMF for NGAP connection. Must be modified if the AMF runs on a different host. */

     amf_addr: "127.0.1.100",
```

```
      },
   ],
#endif
   en_dc_support: true,

   /* list of cells */

  cell_list: [

  {

   rf_port: 0,

   /* Broadcasted PLMN identities */

   plmn_list: [

     "00101",

   ],

   dl_earfcn: 9435, /* 780.50 MHz band 28*/

   n_id_cell: 1,

   cell_id: 0x01,

   tac: 0x0001,

   root_sequence_index: 28, /* PRACH root sequence index */

   en_dc_scg_cell_list: [ { cell_id: 0x02 } ],

  },

  ], /* cell_list */

  nr_cell_list: [

  {

   rf_port: 0,

#if ALLOW_SA

   plmn_list: [ {

     tac: 100,

     plmn: "00101",

     reserved: false,

     },

   ],

#endif
```

```
    cell_id: 0x02,

    band: 28,

    dl_nr_arfcn: 156100, /* 780.50 MHz band 28*/

    ul_nr_arfcn: 145100,

    ssb_subcarrier_spacing: 15,

    ssb_nr_arfcn: 156010,

    root_sequence_index: 1, /* PRACH root sequence index */

},
], /* nr_cell_list */
 /* default cell parameters */
cell_default: {

  n_antenna_dl: N_ANTENNA_DL,

  n_antenna_ul: 1,

  n_rb_dl: 50, /* Bandwidth: 25: 5 MHz, 50: 10 MHz, 75: 15 MHz, 100: 20 MHz */

  cyclic_prefix: "normal",


  phich_duration: "normal",

  phich_resource: "1", /* ratio of NG */

   /* SIB1 */

  si_value_tag: 0, /* increment modulo 32 if SI is modified */

  cell_barred: false, /* SIB1.cellBarred-r13 */

  intra_freq_reselection: true, /* SIB1.intraFreqReselection */

  q_rx_lev_min: -70, /* SIB1.q-RxLevMin */

  p_max: 10, /* maximum power allowed for the UE (dBm) */

  si_window_length: 40, /* ms */

  sib_sched_list: [

    {

      filename: "sib23_nosrs.asn",

      si_periodicity: 16, /* frames */

    },

  ],
```

```
    /* MCS for Msg3 (=CCCH RRC Connection Request) */

    pusch_msg3_mcs: 0,

    si_coderate: 0.20,   /* maximum code rate for SI/RA/P-RNTI messages */

    /* Scheduling request period (ms). Must be >= 40 for HD-FDD */

    sr_period: 80,

    /* CQI report config */

    cqi_period: 80, /* period (ms). Must be >= 32 for HD-FDD */

    /* this CQI value is assumed when none is received from the UE */

    initial_cqi: 3,

    n_symb_cch: 0,

    si_pdcch_format: 2, /* 2 or 3. Log2 of the number of CCEs for PDCCH

                  for SI/RA/P-RNTI */

    /* PDSCH dedicated config (currently same for all UEs) */

    pdsch_dedicated: {
#if N_ANTENNA_DL >= 4

    p_a: -6,
#elif N_ANTENNA_DL == 2

    p_a: -3,
#else

    p_a: 0,
#endif

    p_b: -1, /* -1 means automatic */

  },

    /* If defined, force for number of CCEs for UE specific PDCCH to

      2^pdcch_format. Otherwise it is computed from the reported

      CQI. Range: 0 to 3. */

    /* pdcch_format: 2,  */

    /* if defined, force the PDSCH MCS for all UEs. Otherwise it is

      computed from the reported CQI */

    /* pdsch_mcs: 12, */

    dl_256qam: true,
```

```
    prach_config_index: 3, /* subframe 1 every 10 ms */

    prach_freq_offset: -1, /* -1 means automatic */

     /* PUCCH dedicated config (currently same for all UEs) */

    pucch_dedicated: {

      n1_pucch_sr_count: 11, /* increase if more UEs are needed */

      cqi_pucch_n_rb: 1, /* increase if more UEs are needed */

    },

     /* PUSCH dedicated config (currently same for all UEs) */

    pusch_dedicated: {

      beta_offset_ack_index: 9,

      beta_offset_ri_index: 6,

      beta_offset_cqi_index: 6,

    },

     pusch_hopping_offset: -1, /* -1 means automatic */

     /* if defined, force the PUSCH MCS for all UEs. Otherwise it is

       computed from the last received SRS/PUSCH. */

    /* pusch_mcs: 26, */
#if N_ANTENNA_DL >= 2

    /* RI reporting is done with a period of m_ri * cqi_period.

      m_ri = 0 (default) disables RI reporting. */

    m_ri: 8,

    /* transmission mode */

    transmission_mode: 3,
#endif

     /* MAC configuration (same for all UEs) */

    mac_config: {

      ul_max_harq_tx: 5, /* max number of HARQ transmissions for uplink */

      dl_max_harq_tx: 5, /* max number of HARQ transmissions for downlink */

    },

     /* CPU load limitation */

    //pusch_max_mcs: 18, /* max MCS value */
```

```
//pusch_max_its: 6, /* max number of turbo decoder iterations */

 /* dynamic power control */

dpc: true,

dpc_pusch_snr_target: 25,

dpc_pucch_snr_target: 20,


/* RRC/UP ciphering algorithm preference. EEA0 is always the last. */

cipher_algo_pref: [],

/* RRC integrity algorithm preference. EIA0 is always the last. */

integ_algo_pref: [1, 2],

 /* (in ms) send RRC connection release after this time of network

   inactivity */

inactivity_timer: 10000,

 /* measurement configuration */

meas_config_desc: {

 a1_report_type: "rsrp",

 a1_rsrp: -70,

 a1_hysteresis: 10,

 a1_time_to_trigger: 320,

 a2_report_type: "rsrp",

 a2_rsrp: -110,

 a2_hysteresis: 0,

 a2_time_to_trigger: 640,

 a3_report_type: "rsrp",

 a3_offset: 6,

 a3_hysteresis: 0,

 a3_time_to_trigger: 256,

 rsrp_filter_coeff: 3,

 nr_b1_report_type: "rsrp",

 nr_b1_rsrp: -100,

 nr_b1_hysteresis: 0,
```

```
      nr_b1_time_to_trigger: 100,

      nr_rsrp_filter_coeff: 3

    },

    meas_gap_config: "gp0",

     /* DRB configuration */

    drb_config: "drb.cfg",



    /* reserved MBMS subframes for the NR SSB */

    reserved_mbms_subframes: {

      sf_alloc: [ {
#ifdef MBMS_ONLY

        /* 2 subframes every 10 ms reserved for NR */

        radio_frame_allocation_period: 1, /* 10 ms */

        radio_frame_allocation_offset: 0,

        subframe_allocation: "100100", /* subframe 1 and 6 */
#else

        radio_frame_allocation_period: 2, /* 20 ms */

        radio_frame_allocation_offset: 0,

        subframe_allocation: "100000", /* subframe 1 */
#endif
      } ],

      n_symb_cch: 1,

    },

  },

  nr_cell_default: {

  subcarrier_spacing: 15, /* kHz */

  bandwidth: 10, /* MHz */

  n_antenna_dl: N_ANTENNA_DL,

  n_antenna_ul: 1,

   n_id_cell: 500,

  ssb_pos_bitmap: "0001",
```

```
    ssb_period: 20, /* in ms */

#if ALLOW_SA

    cell_barred: false,

    intra_freq_reselection: true,

    q_rx_lev_min: -70,

    q_qual_min: -20,

    inactivity_timer: 10000,

    si_window_length: 40,

#endif

    p_max: 10, /* maximum UE power in dBm */

    /* Scheduling request period (slots). */

    sr_period: 40,

    dmrs_type_a_pos: 3,

    n_timing_advance_offset: 0, /* to align with LTE */

    ul_frequency_shift_7p5_khz: true, /* to align with LTE */

#ifndef MBMS_ONLY

    lte_crs: "auto",

#endif

    prach: {

    prach_config_index: 16, /* subframe 1 every frame, LTE PRACH

                     at the same position */

    msg1_fdm: 1,

    msg1_frequency_start: 4,

    zero_correlation_zone_config: 11,

    preamble_received_target_power: -110, /* in dBm */

    preamble_trans_max: 7,

    power_ramping_step: 4, /* in dB */

    ra_response_window: 10, /* in slots */

    restricted_set_config: "unrestricted_set",

    ra_contention_resolution_timer: 64, /* in ms */

    ssb_per_prach_occasion: 1,
```

```
    cb_preambles_per_ssb: 8,

  },

  pdcch: {
#if ALLOW_SA

    n_rb_coreset0: 48,

    n_symb_coreset0: 1,

    search_space0_index: 1, /* 1 symbol, starting at symbol 1 for odd SSB */

    si_al_index: 2,

    dedicated_coreset: {

      rb_start: -1, /* -1 to have the maximum bandwidth */

      l_crb: -1, /* -1 means all the bandwidth */

      duration: 1,

      precoder_granularity: "sameAsREG_bundle",

    },

#else

    common_coreset: {

      rb_start: -1, /* -1 to have the maximum bandwidth */

      l_crb: -1, /* -1 means all the bandwidth */

      duration: 1,

      precoder_granularity: "sameAsREG_bundle",

    },

#endif

    css: {

      n_candidates: [ 0, 0, 1, 0, 0 ],

      start_symb: 1,

    },

    rar_al_index: 2,


    uss: {

      n_candidates: [ 4, 2, 1, 0, 0 ],

      dci_0_1_and_1_1: true,
```

```
        start_symb: 1,

    },

    al_index: 1,

  },

  pdsch: {

    mapping_type: "typeA",

    start_symb: 2,

    n_symb: 12,

    dmrs_add_pos: 1,

    dmrs_type: 1,

    dmrs_max_len: 1,

    /* k0 delay in slots from DCI to PDSCH: automatic setting */

    /* k1 delay in slots from PDSCH to PUCCH/PUSCH ACK/NACK: automatic setting */

    mcs_table: "qam256",

#if N_ANTENNA_DL >= 2

    x_overhead: 12, /* 12 REs reserved for LTE CRS */

#else

    x_overhead: 6, /* 6 REs reserved for LTE CRS */

#endif

    rar_mcs: 2,

#if ALLOW_SA

    si_mcs: 6,

#endif

    /* If defined, force the PDSCH MCS for all UEs. Otherwise it is computed

     * based on DL channel quality estimation */

    /* mcs: 24, */

  },

  pucch: {

    pucch_group_hopping: "neither",

    hopping_id: -1, /* -1 = n_cell_id */

    p0_nominal: -90,
```

```
#if 0
    pucch0: {
      initial_cyclic_shift: 1,

      n_symb: 1,

    },
#else
    pucch1: {
      n_cs: 3,

      n_occ: 3,

      freq_hopping: true,

    },
#endif
#if 1
    pucch2: {
      n_symb: 2,

      n_prb: 1,

      freq_hopping: true,

      simultaneous_harq_ack_csi: false,

      max_code_rate: 0.25,

    },
#endif
#if 0
    pucch3: {
      bpsk: false,

      additional_dmrs: false,

      freq_hopping: true,

      n_prb: 1,

      simultaneous_harq_ack_csi: false,

      max_code_rate: 0.25,

    },
#endif
```

```
#if 0

    pucch4: {

      occ_len: 4,

      bpsk: false,

      additional_dmrs: false,

      freq_hopping: true,

      simultaneous_harq_ack_csi: false,

      max_code_rate: 0.25,

    },
#endif

  },

  pusch: {

  mapping_type: "typeA",

  n_symb: 14,

  dmrs_add_pos: 1,

  dmrs_type: 1,

  dmrs_max_len: 1,

  tf_precoding: false,

  mcs_table: "qam256", /* without transform precoding */

  mcs_table_tp: "qam256", /* with transform precoding */

  ldpc_max_its: 5,

  /* k2, msg3_k2 delay in slots from DCI to PUSCH: automatic setting */

  p0_nominal_with_grant: -84,

  msg3_mcs: 4,

  msg3_delta_power: 0, /* in dB */

  beta_offset_ack_index: 9,


  /* hardcoded scheduling parameters */

  n_dmrs_cdm_groups: 1,

  n_layer: 1,

  /* if defined, force the PUSCH MCS for all UEs. Otherwise it is
```

```
                computed from the last received PUSCH. */

            /* mcs: 16, */

        },


    /* MAC configuration */

    mac_config: {

        msg3_max_harq_tx: 5,

        ul_max_harq_tx: 5, /* max number of HARQ transmissions for uplink */

        dl_max_harq_tx: 5, /* max number of HARQ transmissions for downlink */

        ul_max_consecutive_retx: 30, /* disconnect UE if reached */

        dl_max_consecutive_retx: 30, /* disconnect UE if reached */

        periodic_bsr_timer: 20,

        retx_bsr_timer: 320,

        periodic_phr_timer: 500,

        prohibit_phr_timer: 200,

        phr_tx_power_factor_change: "dB3",

        sr_prohibit_timer: 0, /* in ms, 0 to disable the timer */

        sr_trans_max: 64,

    },

    cipher_algo_pref: [],

    integ_algo_pref: [2, 1],

    srb3_support: false,

    drb_config: "drb_nr.cfg",

  },

}
```

The cell configuration can be seen here:

(enb) cell phy

[enb1a2d0] PLMN=00101 eNB_ID=0x1a2d0

[gnb0012345] PLMN=00101 gNB_ID=0x12345

--------Global-------- ----------DL---------- ----------UL---------- ----SSB---

Cell   RAT BAND BW P ARFCN ANT NL SCS QAM ARCFN ANT NL SCS QAM ARFCN SCS

```
0x001   LTE   28  10 0   9435   1  1  15  256  27435  1  1  15   16     -  -

0x002    NR  n28  10 0 156100   1  1  15  256 145100  1  1  15  256 156010  15
```

(enb) rf_info

(enb) TRX API version 15

 Chan Port Gain(dB)   Freq(MHz)

  TX0   0   89.8 780.500000

  RX0   0   60.0 725.500000

TX underflows=0 RX overflows=0

TRX SDR driver 2021-09-09, API v15

PCIe RFIC /dev/sdr0:

  Hardware ID: 0x4b01

  DNA: [0x11282252262066260]

  FPGA revision: 2021-09-01

  FPGA vccint: 1.00 V

  FPGA vccaux: 1.79 V

  FPGA vccbram: 1.00 V

  FPGA temperature: 45.8 °C

  AD9361 temperature: 27 °C

  Clock tune: -1.6 ppm

DMA0: TX buffer Usage=8/3072 (0%)

DMA0: RX buffer Usage=8/3072 (0%)

Figure 10 Amarisoft DSS Config file

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