Demo Abstract - Design and Implementation of an Open Source NB-IoT eNB

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Extended Abstract

Narrowband Internet-of-things (NB-IoT) is a new standard developed by 3rd generation partnership project (3GPP) to provide IoT services in licensed spectrum. It adopts existing LTE-Advanced (LTE-A) orthogonal frequency-division multiple access (OFDMA) technology but each carrier only requires 180 kHz bandwidth. It allows an operator to replace a GSM carrier (200 kHz) in 'stand-alone' mode; to utilize a physical resource block of 180 kHz within a normal LTE carrier in 'in-band' mode; or to occupy an unused resource block within the guard-band of a LTE carrier in 'guard band' mode [1].

In April 2017, the OpenAirInterface™ Software Alliance (OSA) launches a new project to develop a software-defined-radio-based NB-IoT Evolved Node B (eNB). This poster summarizes the original research work conducted for the implementation of an open source eNB. This work can be used by researchers and users to validate important research ideas and demonstrate realistic applications [2].

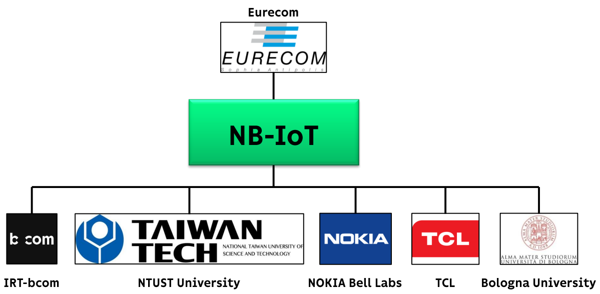

Fig. 1. Contributors for NB-IoT eNB project

The major contributors of the NB-IoT project are shown in Fig. 1 [3]. Nokia Bell Labs, EURECOM, and Taiwan Tech are working together to define the new configuration files. These files are used in OAI to configure the settings of the eNB. Taiwan Tech is responsible for developing the protocol stacks. The packet data convergence protocol (PDCP) and radio link control (RLC) are quite similar to that of LTE and thus, slight modifications of OAI LTE modules are conducted based on TS 36.323 and 36.322, respectively. In radio resource control (RRC) layer, some new procedures and configuration parameters specific in TS 36.331 are implemented. The medium access control (MAC) layer procedures defined in TS 36.321 is the major task in realizing the NB-IoT eNB. It deals with the new frame structure and the scheduling functionality specifically defined for NB-IoT. A new network functional application platform interface (NFAPI) is defined between MAC and physical (PHY) layer to re-define the data structure used in the interface (IF) module in OAI. The NFPAI interface is defined to support a virtualized MAC/PHY split as a smooth evolution path to 5G following the standard specified by Small Cell Forum (SCF). The physical layer procedures of NB-IoT are quite different than LTE and are specified in Sec. 16 of TS 36.213. EURECOM and Taiwan Tech work together to implement NFAPI and the physical layer procedure of upper PHY. The lower physical layer (PHY) functionality such as modulation and channel coding, as specified in Sec. 10 of 3GPP TS 36.211, is realized by B-COM.

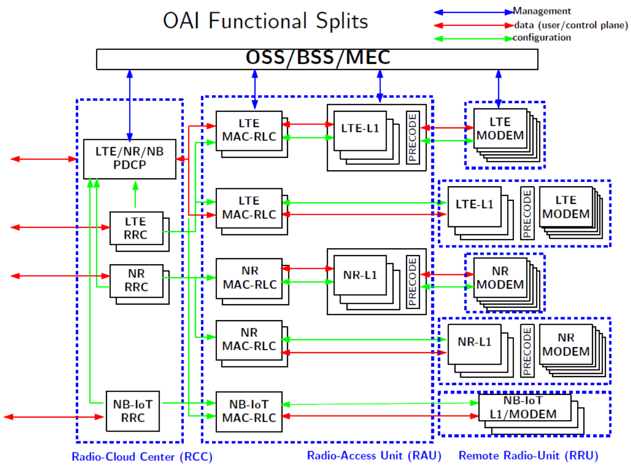

Fig. 2. Software architecture of openairinterface5g

Figure 2 shows a general software architecture of OAI eNB [4]. The architecture is defined to support the new features of 5G new radio (NR), such as dynamic and software-defined radio access network (RAN), functional split, and network slicing [5]. Three computing nodes are proposed in the current architecture. Multiple RRC/PDCP entities can be executed on the radio cloud center (RCC), which corresponds to the 5G NR central unit (CU). Multiple MAC-RLC entities with medium-latency midhaul and potentially L1 entities with low-latency fronthaul are executed in radio-access unit (RAU). An RAU without L1 entities would correspond to the virtual network function (VNF) defined by SCF. The remote radio-unit (RRU) represents the equipment at radio site. It consists in various degrees of processing elements depending on fronthaul/midhaul interface. The RRU with at least one LTE-L1 entity corresponds to a physical network function (PNF) defined by SCF.

The NB-RRC receives non-access-stratum (NAS) information from the core network (MME) via the S1-C interface. The interface between RRC and PDCP is OAI-specific but will later follow the E1 interface defined by 3GPP. The interface between PDCP and MAC-RLC and the between RRC and MAC-RLC are OAI-specific but will later follow the so-called F1-U and F1-C interfaces defined in 3GPP. The input and output packets structure of L1 on the transport channel interface follows the NFAPI P7 standard interface. L1 also receives configuration information from the RRC entity and are relayed by MAC-RLC entity according to the NFAPI P5 interface. The MODEM comprises the basic functionality to prepare and process the signals going to and coming from the radio units. Precoding functions may be implemented for sharing physical antenna ports across several logical protocol instances.

Several new physical channels are defined for NB-IoT. An example showing the time-frequency allocation of the physical channels is shown in Fig. 3 [3]. The narrowband primary synchronization signal (NPSS) and narrowband secondary synchronization signal (NSSS) are used by a user equipment (UE) to synchronize its frequency and timing with the eNB. The UE acquires master information block (MIB) from narrowband physical broadcast channel (NPBCH) and system information block (SIBs) from narrowband physical downlink control channel (NPDSCH). The newly defined MIB-NB and SIB1-NB are broadcasted once every 640 ms and 2560 ms, respectively. The timing of remaining SIBs-NB is configured in SIB1-NB. Narrowband physical random access channel (NPRACH) is used by UEs to perform initial association to the network, to request transmission resources, and to re-establish a connection to the eNB upon failure. The DL and UL data packets are carried by narrowband physical downlink shared channel (NPDSCH) and narrowband physical uplink shared channel (NPUSCH), respectively. NPUSCH can support single-tone and multi-tone (i.e., 3, 6, and 12 tones) transmissions. Each tone occupies 3.75 or 15 kHz bandwidth. A base station (i.e., eNB) uses downlink control information (DCI) to specify the scheduling information for a downlink /uplink transmission in NB-IoT. The scheduling information is used to identify the allocated resources over NPDSCH and NPUSCH, respectively. The DCIs are carried in narrowband physical downlink control channel (NPDCCH). In each NPDCCH, a maximum of 2 DCIs can be transported, and each UE can receive up to one DCI. The time interval between two successive NPDCCH opportunities is referred as a NPDCCH period (PP). Each UE will be assigned by a UE-specific PP based on the chosen CE level during radio resource control (RRC) connection establishment procedure. In general, a higher CE level may set a longer PP since a higher repetition is used. The multiplexing and modulation of NB-IoT is specified in Sec. 6 of TS 36.213. The basic coding scheme is the same as LTE except DCIs formats that are newly defined.

The way that NB-IoT schedule resource is quite different than LTE. LTE adopts a subframe-based scheduling but NB-IoT performs scheduling once every NPDCCH period. Different values of repetition are used to support different coverage enhancement (CE) level. The sizes of resource unit can have many options which depend on the NPUSCH format, sub-carrier spacing and the number of tones. To validate the scheduling results of our scheduler, we developed a graphical user interface (GUI) to show the scheduling results of all physical channels (NPSS, NSSS, NPBCH, NPDCCH, and NPDSCH in downlink and NPRACH and NPUSCH in uplink) according to the log. Fig. 4. shows an example of the scheduling result from GUI. Details of the design of an NB-IoT MAC uplink scheduler can be found in [6].

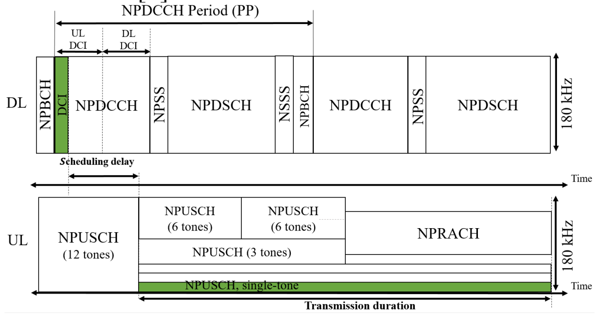

Fig. 3 Timing diagram of NB-IoT physical channels.

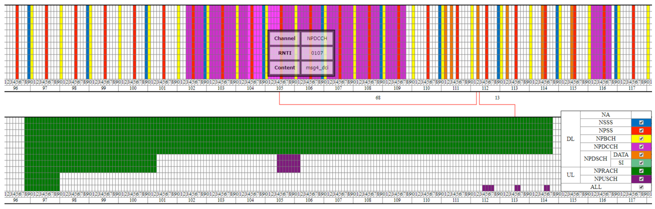
Fig. 4 Result of the scheduling simulator.

NB-IoT project adopts a two phases development plan. The major tasks in Phase I include the development of NB-IoT eNB functionalities (PHY, MAC, etc.); the adaption of NFAPI interface for NB-IoT; the integration with Nokia's core network and the testing with commercial NB-IoT UE modules. Currently, we are integrating the MAC and PHY. In Phase II, the NB-IoT channels simulator will be developed additionally to a code developer guide and wiki web page.

ACKNOWLEDGMENT

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