

DEVELOPMENT OF A SIMULATION MODEL
OF MULTIBAND RADIO TRANSMISSION NETWORK
FOR ACCESS TO AUDIO INFORMATION IN OPEN RAN

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Abstract

The transmission characteristics of audio information in Open RAN networks can be estimated using the appropriate simulation models. Most of the existing models are built for the transmission of specific test signals, not real audio information. Therefore, the goal of this article is to develop an Open RAN simulation model suitable for access to audio information and to use this model to estimate the quality of transmitted audio information. The presented experimental results demonstrate the ability of the proposed model to simulate multiband radio transmission network for access to real audio information and to achieve the maximum capacity of 5789 Mbps.

Key words: Open RAN, simulation model, audio information access, audio quality

Introduction. Wireless radio technology works using the radio frequency (RF) spectrum to transmit different sorts of information like audio as voice and music, video as still pictures and movies, data as text, etc. [1]. Radio transmission network (RTN) is used by all worldwide telecommunications companies [2,3]. There are a lot of articles and firmware documentations for describing, planning, testing and quality of services (QoS) from a general point of view [4,5]. But it is particularly important to evaluate the quality of the specific information (audio, video and data) transmitted through Radio transmission network (RTN). In

this paper, a simulation model of Open RAN network is proposed as a part of aggregated multiband radio transmission system. The aim of this model is to estimate the quality of transmitted audio information. The experimental tests of the proposed simulation model are carried out by integrating physical link aggregation, adaptive modulation (AM) and quality of service (QoS), with the following radio link characteristics to achieve large bandwidth and long distance transmission: base frequency band (6–42 GHz) and a radio link in E-band frequency band (71–76 GHz and 81–86 GHz).

General view of a network of multiband radio transmission network for audio information in Open RAN. Figure 1 presents a general view of an Open RAN radio transmission network for audio information access to be used as a basis for developing a simulation model of an Open RAN multiband radio transmission network for audio information access.

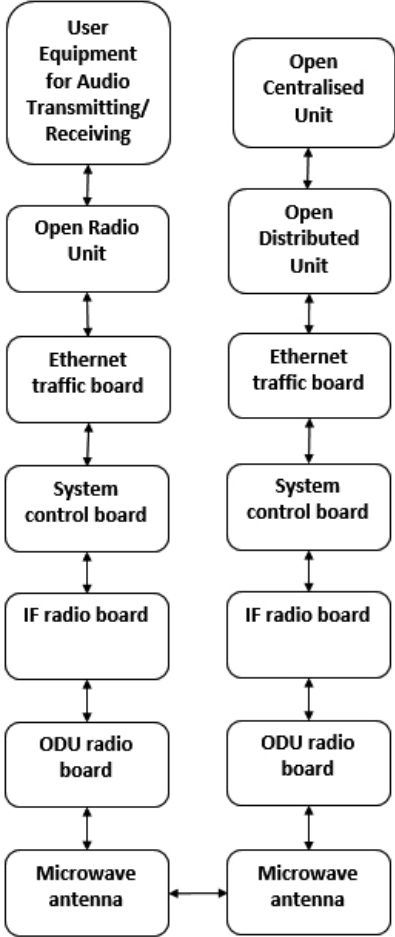


Fig. 1. General view of an Open RAN network suitable for development of multiband Open RAN simulation model of audio information access

In transmit direction the audio signal is picked up by the User Equipment (in most cases smartphone) microphone. The microphone turns the analogue audio signal into a digital audio signal with the help of MEMS sensors and IC. An antenna inside the smartphone receives the digital audio signal and transmits it in the form of electromagnetic waves. Analogically in receive direction, the antenna receives electromagnetic waves and with the help of MEMS sensors and IC processes the signal to the speaker, which turns the digital audio signal to analogue audio signal.

In the cell antenna (Open Radio Unit), the received audio signal is converted by digital-to-analogue (DAC) converter, power amplifiers (PA) and low noise amplifiers (LNA). After the digital processing of the signal, Lower PHY processes follow, encoding, synchronization and sending the signal to the Open Distributed Unit. Through an optical or Ethernet interface, the Radio Unit transmits the received signal to the transmission network to reach the Distributed Unit. In the other direction, the received digital audio signal via Ethernet interface converted by analogue-to-digital converters (ADC), power amplifiers (PA) and low noise amplifiers (LNA) is transmitted by the antenna via electromagnetic waves to the user equipment.

In the radio transmission equipment the digital audio signal is received by the Ethernet traffic board. The system control board processes the digital audio signal and transmits it to the IF radio board. Then it communicates with Outdoor Unit (ODU radio board) which converts IF audio signals into RF audio signals and transmits them via microwave antenna using electromagnetic microwaves. The received by antenna RF audio signals are converted into IF audio signals by the ODU radio board. The IF radio board processes the digital audio signal with the system control board and transmits it via an Ethernet traffic board to an open distributed device. Analogically in the reverse direction from Open Distributed Unit to the Open Radio Unit can transport the audio signals.

The Open Distributed Unit is a key component of the 5G network architecture that connects to multiple radio units (RUs) in the southbound interface. It is responsible for managing and controlling the RUs, which are typically located at the cell sites. In Open RAN, the Distributed Unit (O-DU) is a processing powerhouse stationed near the Radio Unit (RU). It handles crucial layers like Radio Link Control (RLC), Medium Access Control (MAC), and parts of the Physical (PHY) layer, acting as a subset of the traditional eNB/gNB functions depending on the chosen configuration. Importantly, the O-DU operates under the control of the Central Unit (CU) for seamless network management.

The DU is composed of the following:

1. **OAM (Operations, Administration and Maintenance).** This box manages the operation and maintenance of the network elements. It sits above all the other functional blocks and interacts with them to ensure proper operation.

2. **F1-U and F1-C.** These boxes represent the split functionalities within the front haul interface (between the DU and the RU). F1-U carries the user plane traffic, while F1-C carries the control plane traffic.
3. **vRLC (Virtual Radio Link Control).** This split point separates the upper layer functionalities (scheduling, error correction) from the lower layer functionalities (radio signal processing) traditionally performed by the RUs. The box for VRLC sits above the box for VPHY High, indicating that it handles a higher layer in the protocol stack.
4. **vMAC (Virtual MAC).** This split point goes further down the protocol stack, placing the MAC layer processing in the DU, with the RU handling only physical layer functions. The VMAC box sits above the VPHY High box, indicating that it also represents a higher layer function than the PHY layer.
5. **vPHY High.** This split point is where even some of the high-band PHY layer functionalities reside in the DU, leaving the RU with minimal tasks. The VPHY High box represents a section of the PHY layer that is virtualized and handled by the DU.
6. **Synchronization.** The DU is responsible for providing synchronization signals to ensure that the RUs are properly synchronized for efficient communication. This synchronization is crucial for maintaining the integrity and quality of the wireless signals.

Simulation model of multiband radio transmission network for access to audio information in Open RAN. The general view of an Open RAN network suitable to develop multiband Open RAN simulation model of audio information access described in Fig. 1 has been developed as a corresponding simulation model. The main functional blocks in the proposed multi-band Open RAN simulation model for access to audio information are Ethernet traffic board, Control system board, IF radio board, and ODU radio board, corresponding to real-life blocks [6, 7]. Figure 2 presents in more detail only the simulated Ethernet traffic board as more important because this block is directly related with transmission/reception of digital audio signal (in Fig. 2 input audio). The other simulated blocks: Control system board, IF radio board, and ODU radio board are also included in the following description in order to complete the entire description of the proposed simulation model.

Ethernet signal access unit receives/transmits digital audio signals. Then deframing, decoding and serial/parallel conversion are performed for Ethernet signals. The next processing is frame splitting, preamble removal, CRC and Ethernet throughput calculation for the signals in the frame. Ethernet signal processing unit adds tags identifying ingress ports to Ethernet audio data frames. Processes

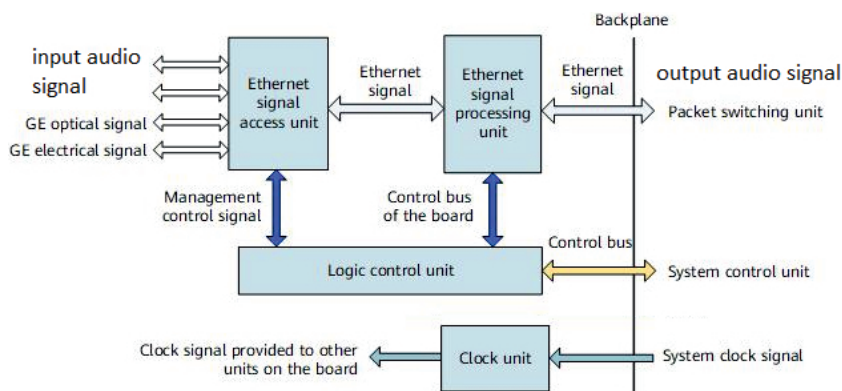


Fig. 2. Functional block diagram of simulated Ethernet traffic board

VLAN tag in Ethernet audio data frames and labels in MPLS/PWE3 packets. Ethernet frames with audio data are transmitted to the active and standby packet switching modules.

The logic control unit communicates with the system control and communication unit over the system control bus. The logic control unit delivers configuration and query commands from the system control and communication unit to other units on the board, and reports command responses, alarms, and performance events reported by other units on the board to the system control and communication unit. The clock unit receives the system clock signals from the control bus in the backplane and provides clock signals for other units of the board.

The control system board consists of the system control and communication unit, packet switching unit, cross-connect unit, clock unit, and service unit.

The system control and communication unit consists of the CPU and logic control unit, and performs the following functions to control boards:

The CPU controls and manages the other boards in the IDU and collects alarms and performance events through the control bus, controls and manages the ODU through the ODU control signals transmitted between the SMODEM unit of the IF board and the backplane control bus.

The CPU enables the packet switching unit to groom Ethernet service packets through the control bus. The CPU processes network management messages in DCCs through the logic control unit. The logic control unit cross-connects the overheads between the auxiliary interface unit, the CPU, and other boards.

After receiving protocol packets from the Ethernet interface unit of the board or from an Ethernet board, the packet switching unit transmits the protocol packets to the system control and communication unit for processing. The system control and communication unit processes the protocol packets and sends the processed protocol packets back to the packet switching unit. Then, the packet switching unit transmits the protocol packets to the Ethernet interface unit of the board or to the Ethernet board.

The cross-connect unit grooms services over the entire system using the higher order cross-connect module and the lower order cross-connect module.

The IF radio board with ODU radio board receives and transmits two channels of IF signals, and provides a management channel and -48 V power supply to the ODU. Combiner interface unit separates ODU control signals from microwave service signals. SMODEM unit demodulates and transmits ODU control signals to the system control and communication unit. IF processing unit filters signals, performs analogue/digital conversion, and transmits the converted signals to the MODEM unit. MODEM unit performs forward error correction (FEC) decoding and time-domain adaptive equalization.

Ethernet processing unit sends the processed audio signals to the packet switching unit. Logic processing unit transmits overhead audio signals to the system control and communication unit.

To transmit the audio signal to Outdoor unit (ODU) the radio board requires IF feeder cable. The ODU radio board converts IF signals into RF signals and amplifies RF signals. The multiplexer splits the audio signal coming from the IF cable into a 350 MHz IF service signal, a 5.5 MHz O&M uplink signal and a -48 V DC power signal.

In the transmit direction, the IF service audio signal is processed as follows:

1. The IF service signal is converted into an RF signal by means of frequency up-conversion, filtering and amplification, and then is sent to the amplifier unit (AMP).
2. The AMP amplifies the RF signal (the output power of the signal can be regulated by IDU software).
3. The amplified RF signal is sent to the antenna through the duplexer.

The O&M uplink signal is a 5.5 MHz ASK-modulated signal and is demodulated in the control unit (CTRL). The -48 V DC power signal is sent to the power unit (PWR) where the secondary power supplies are generated and provided to the modules of the ODU (Fig. 2 down).

At the opposite location, in receive direction the duplexer separates the RF audio signal from the antenna signal. The low noise amplifier (LNA) amplifies the RF audio signal. The amplified RF audio signal is converted into a 140 MHz IF service signal by means of frequency down-conversion, filtering and amplification, and then is sent to the multiplexer.

The CTRL unit performs ASK modulation on the O&M downlink signal, and sends the generated 10 MHz modulation signal to the multiplexer. The CTRL unit also detects the receive signal power through the RSSI detection circuit and provides the RSSI interface. The multiplexer combines the received IF service audio signal and O&M downlink signal, and sends the combined signal to the IDU through the IF cable.

Experimental verification and results of the experiments conducted with the developed multiband Open RAN simulation model of audio information access model. The proposed in Fig. 1 simulation model of a transport network for access to audio information via Open RAN has been experimentally studied using the Huawei Company's Enterprise Network Simulator Platform (eNSP) simulation platform shown in Fig. 3a with it corresponding configurations

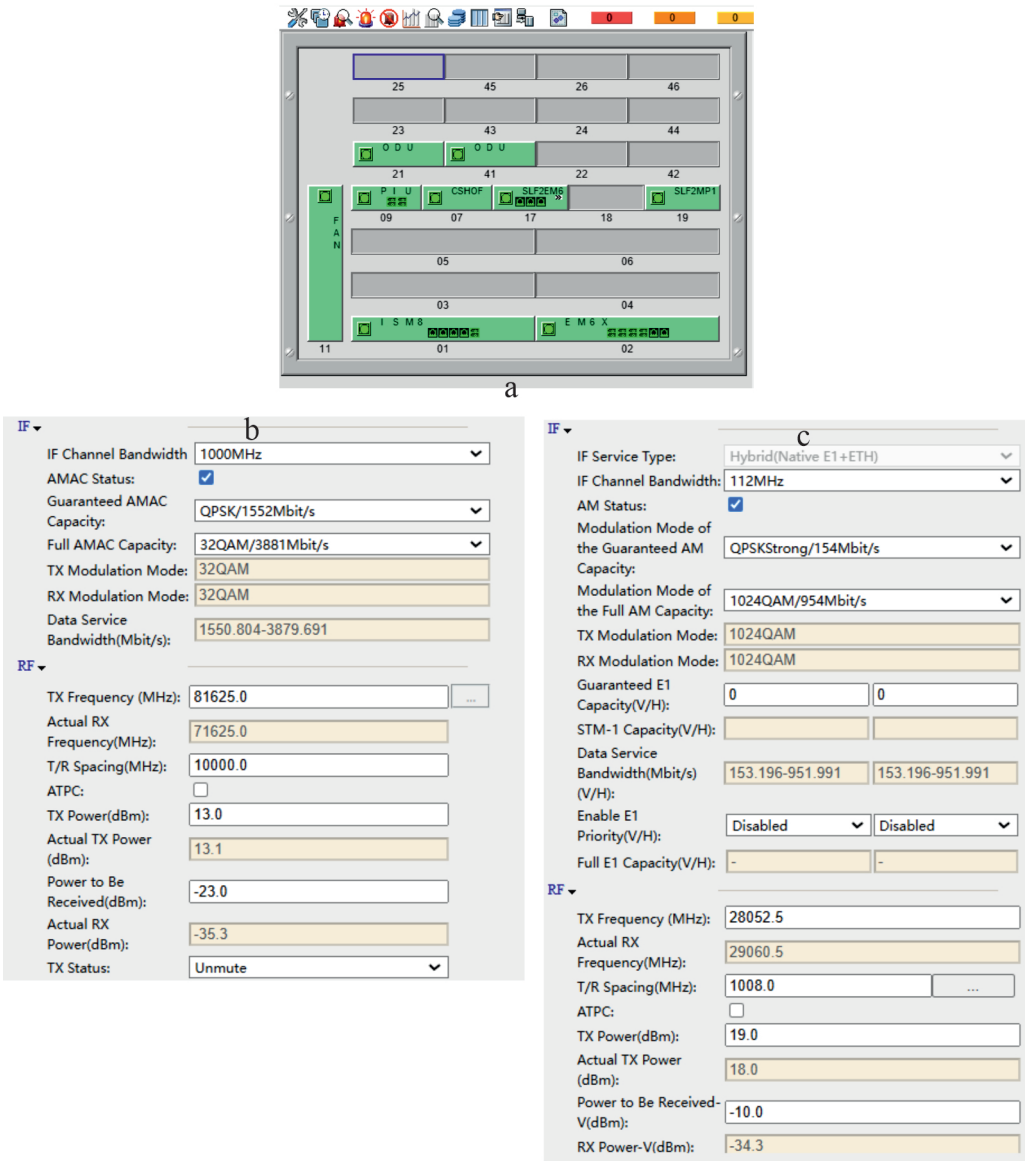


Fig. 3. Simulation block (a) of radio transmission network for audio signals transport with its corresponding configurations for E-band link at 80 GHz in eNPS (b), and 28 GHz in eNPS (c)

for E-band link at 80 GHz in eNPS (left down) and 28 GHz in eNPS (right down). The eNSP was developed by Huawei Technology Ltd for the employees, partners, and customers to verify their planned network solutions without the need to use expensive physical hardware devices. Each of the software components has its own functions. Oracle VirtualBox provides the virtualization platform for the network devices to be simulated as the real equipment in the network scenario. Wireshark and WinPcap provide packets and frames capturing for troubleshooting analysis while the key software Huawei eNSP is the working environment for the network solution deployment with the pre-bundled network devices as routers, switches, firewalls, WLAN access controllers & access points together with some host machines (e.g. desktops, servers and clients) for the live simulated network deployment as per in the cases of proof of concepts, classroom-based training, and personal network testing solutions without the costly real hardware [6, 7].

The general experiment is aggregation of common band at 28 GHz and E-band at 80 GHz in radio transmission network for audio signals transport.

As shown in Fig. 3 for the simulation at both sides was used RTN950A chassis. For a system control board was used CSHOF, which is configured on slot 7. For Ethernet traffic board was used EM6X, which is configured on slot 2. For IF radio board was used ISM8, which is configured on slot 1 and for ODU radio board was used ODU which is configured on 21 and 41 slots. An RTN380AX chassis for E-band was used to perform the experiments. For E-band was used frequency 81 625 MHz (TX Frequency in Fig. 3b). The microwave link was configured with maximum channel bandwidth at 10 000 MHz, transmit power of ODU was 13 dBm and maximum amplitude modulation of 32 QAM. To aggregate both microwave links in multiband link was used Super Enhanced Physical Link Aggregation option. It combines every different link virtual tunnel in one common virtual tunnel with combination of the all tunnels capacity. Via this virtual tunnel was configured static tunnel with Layer 3 IP address to route a service.

To transfer audio signals was configured PWE3 service type between both sides Ethernet traffic boards (EM6X). On EM6X interface was connected a device which transmits digital audio signal. At another side, on EM6X interface was connected a device which receives digital audio signal. This service has a capacity of full virtual tunnel in multiband link.

At a common band was used frequency 28 052.5 MHz (Fig. 3c). The microwave link was configured with maximum channel bandwidth at 112 MHz, transmit power of ODU was 19 dBm and maximum amplitude modulation of 1024 QAM.

Experimental results. The results in Fig. 4a are from experiments for simulation model with the following configuration: 5 km distance between transmitter and receiver sides; carrier frequency 28 GHz; transmitter power of 19 dBm and the received signal power for optimal performance is 34.5 dBm. In this experiment is achieved 954 Mbps as the maximum capacity of link, but it is possible

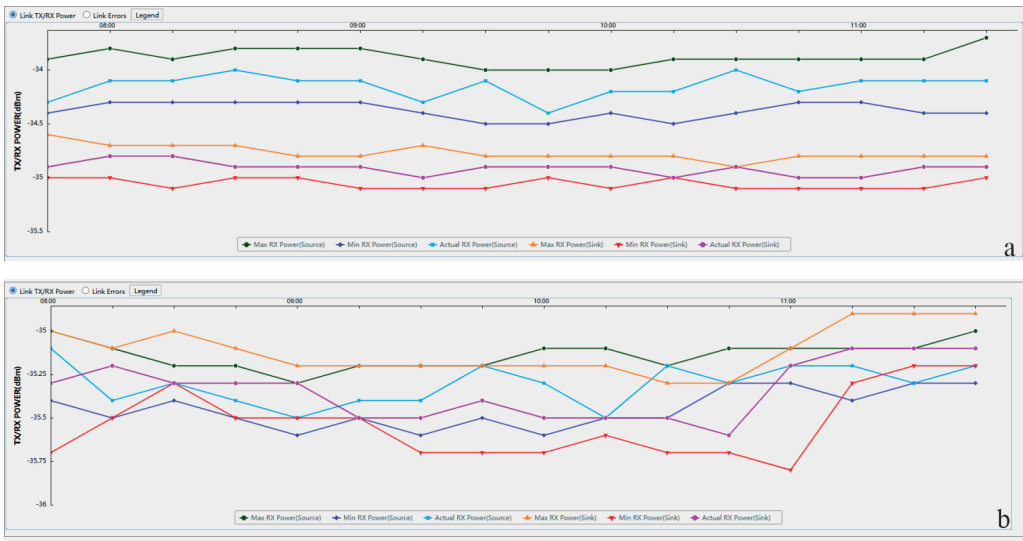


Fig. 4. Received radio signal levels after simulation in common band link at 28 GHz in eNPS (a), and in E-band link at 80 GHz in eNPS (b)

to reach the capacity $2 \times 954 = 1908$ Mbps if double polarization (horizontal and vertical) is used.

In the same way, Fig. 4b shows the results from experiments for simulation model if the distance between transmitter and receiver sides is also 5 km, but the following configuration parameters are different: carrier frequency 80 GHz; transmit power of 13 dbm and the received signal power for optimal performance is 35.5 dbm. in this case the maximum capacity of E-band link of 3881 Mbps is achieved. Therefore, the presented two cases of the experiments demonstrate the ability of the proposed model to simulate multiband radio transmission network for access to audio information with the common capacity of $1908 + 3881 = 5789$ Mbps.

Conclusion. The results from the carried out experiments can be analyzed with respect to which of the following Open RAN network parameters definition are important and affect the quality of the transmitted audio information:

- The capacity to transmit audio information, respectively, the quality of the transmitted audio information, depends on increasing the IF Channel Bandwidth and index of Amplitude Modulation (AM);
- Increasing of TX power in Open RAN network can increase a RX Power, but also increase the noise, i.e. the worse Signal to Noise Ratio (SNR) therefore, this negatively affects the quality of the received audio information;
- Also the low RX Power can decrease the amplitude modulation and the capacity to transmit audio information;

- In the same way low SNR can decrease the amplitude modulation and capacity to transmit audio information;
- to achieve the sufficient quality of the received audio information it is necessary to keep XPIC (Cross-polarization) symmetric.

In addition to the abovementioned and achieved from the experiments basic parameters affecting the quality of transmitted and received audio information, the following characteristics of open range can be presented.

- **Common band.** It has low rain attenuation, minimal losses, high availability, and it covers long distances, however, its capacity and channel bandwidth are relatively low.
- **E-band.** This band is actively utilized, offering high capacity and a wide channel bandwidth, making it capable of achieving excellent data rates. However, its coverage is limited to shorter distances.

The multiband link aggregation allows improved capacity, availability, performance and long-distance transmission of audio information. The enhanced physical link aggregation (EPLA) technology aggregates the data sent over the two bands into a single stream, optimizing the traffic flow. Applying quality of service (QoS) during configuration ensures that high-priority traffic is allocated to the common band, benefiting from its superior availability. However, low-priority traffic is directed to the E-band. Adaptive modulation plays a vital role in maintaining data reliability by adjusting the modulation scheme based on changing channel conditions, including fading and interference. In case of an E-band link failure, the common band takes over the traffic until the E-band link becomes available again, ensuring seamless connectivity. The multiband technology in microwave transmission is revolutionizing wireless communication systems, enabling higher data rates, improved spectral efficiency, and enhanced reliability for audio information.

The proposed and tested Open RAN simulation model will be used in future researches and publications in different scenarios and configurations to estimate the audio information quality and to recommend the appropriate configuration of Open RAN, for which the audio information quality is the best.

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