5G for Technobothnia

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***Abstract*—This paper presents the procedure of setting a 5G network for Technobothnia laboratory using Firecell solutions. The procedure includes 5G frequency band allocation, range coverage calculation, IP network configuration, 5G parameter tuning, and corresponding communication performance test results. The paper can be used as a reference for setting private 5G networks.**

***Keywords*—5G cellular, Coverage, Frequency band, IP-based networking, Communication Performance**

I. Introduction

The 5th-Generation Cellular Networks (5G) is considered as one of the key technologies for industry 4.0 [1]. Comparing to other solutions such as Wi-Fi, WiMAX, Ethernet, etc., 5G has unparalleled advantages. Firstly, a cellular network is a Wide-Area Network (WAN), meaning the range/coverage of such a network can be extended indefinitely by either increasing the transmitter power or adding new cells. A Wi-Fi network is a Local Area Network (LAN), even with Extended Service Set (ESS) mode the coverage is still limited within a campus, a factory facility, or an office building. Secondly, a cellular system provides guaranteed communication performance. The Quality of Service (QoS) is ensured by the system so that the throughput (communication speed), reliability and delay, and the number of terminal devices can be all achieved under one control facility [2]. These QoS criteria are essential for next generation applications, including manufacturing, warehouse management, electricity production, transmission, and distribution, mining, forestry, farming, etc. Thirdly, 5G is considered as “greener” solution than its predecessors and competitors. This is contributed by the fact that 5G enables a large number of IoT devices and with the elegant control algorithms, the energy consumption of the communication is minimized. [3]

Technobothnia laboratory is a modern facility jointly invested by three local universities in Vaasa. The laboratory is constructed and configured for over 2400 students studying in different disciplines, and also functions as a platform for research and close interaction with the local industries. All to ensure the regions position as one of the leading technology hubs of Finland. [4] In year 2024, a decision was made to upgrade the laboratory to the next level for future, advanced education and research, especially for industry 4.0. The upgrade includes to deploy a 5G cellular system which would provide high QoS communication for the robots, smart sensors, circuit breakers, relays, and many other laboratory devices in the house.

This article describes the procedure of how the 5G network was planned and deployed in Technobothnia. The procedure includes frequency band application, antenna power calculation, antenna location, edge server setting, fine tuning of 5G parameters for best communication performance, and the communication performance testing.

The rest of the paper is organized as follows. Section II discusses frequency allocation of 5G. Section III describes the configuration, connection, and networking of Firecell Orion100 5G system. Section IV presents the communication testing result using “iperf” between a User Equipment and an edge server. The results are helpful for the future use and deployment of 5G network. Section V concludes this work.

II. Frequency Band

5G comes with a variety of bands [4], ranging from 450MHz to 7GHz (for Frequency Range 1 - FR1, FR2 goes to millimeter waves - mmWave). In FR1, bands n1, n2, n3, n5, n7, n8, n12, n13, n14, n18, n20, n24, n25, n26, n28, n30, n65, n66, n70, n71, n74, n85, n91, n92, n93, n94 are designed to work in Frequency Division Duplex (FDD) mode, which allows the communication between a terminal and its base station goes simultaneously using two separate frequencies, one denoted as uplink and the other direction denoted as downlink. On the other hand, bands n34, n38, n39, n40, n41, n46, n47, n48, n50, n51, n53, n77, n78, n79, n90, n96, n101, n102 are designed to work in Time Division Duplex (TDD) mode, which allows the communication between a terminal and its base station goes alternatively in time using the same frequency.

Need to note that 3GPP has decided that 5G deployment can be carried out in two phases, with phase 1 using the existing 4G LTE core network for signaling and control. When deploying a 5G network, a 4G LTE band (called “anchor frequency”) should be reserved to make the system down-compatible with existing 4G network. A 5G system using 4G for signaling and control is called Non-Stand Alone (NSA); and a 5G system using its own signaling and control elements is called Stand Alone (SA).

However, in Finland, not every band is available for 5G. Co-existing 2G/3G/4G are still using some aforementioned bands. A frequency band is exclusive, which means the bands already taken by the commercial operators (Elisa, Telia, DNA) [5] are not allowed to be used by anyone else. Finnish Transport and Communication Agency TRAFICOM is the authority which guarantees the exclusive use of frequencies. An application was sent to TRAFICOM for both NSA and SA use of 5G bands and approved that in Technobothnia, we are allowed to use 50MHz in 5G band n77 (3800-4100MHz), and 2300-2320MHz as “anchor frequency”. We chose to use 3900-3950MHz in n77.

The frequency band and its bandwidth (as we are allowed to use only 50MHz in 3800-4100MHz band) is further defined by Absolute Radio Frequency Channel Number (ARFCN),

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which should be specified in the configuration file of a 5G system. ARFCN is calculated by (1) [6]:

$$F = F_{roffs} + \Delta F_G(ARFCN - N_{roffs}) \qquad (1)$$

where F_{roffs} is the offset frequency; ΔF_G is called global frequency spacing; N_{roffs} is the offset number. For 5G NR FR1, F_{roffs} =3000MHz, ΔF_G =15kHz, N_{roffs} =600000. If F=3900MHz, ARFCN=660000.

III. 5G Network Setup: Hardware and Addressing

After a careful market investigation, we decided to use FireCell Orion-100 5G solution as seen in Figure 1. This decision is based on following considerations: 1) it has to be a Software Defined Radio (SDR) system with open source support so that it meets academic research purposes, and the compatibility to the future 5G standards is guaranteed; 2) the system must have transmitter power to cover the whole Technobothnia laboratory (50x100m indoor with lots of machinery and electricity equipment); 3) the system must support 5G n77 band so that our TRAFICOM license is valid.

Figure 1. FireCell Orion-100

The FireCell Orion-100 comes as four separate elements, as illustrated in Figure 2. On the left is the 5GController (5GC), an Linux-based computer containing an SDR card interfacing the radio unit via an optic fiber link (a.k.a. backhaul). In the radio unit (RU Panther n77), the baseband signal is converted to 2x2 MIMO band n77 signal and power-amplified into 4 D-type RF ports. Four pre-calculated-length coaxial cables connect radio unit to the antenna, which is a 2x2 MIMO directional element (see Figure 3. 2x2 connection between the RU and antenna). The package comes with one smartphone and 10 pre-set SIM cards.

Figure 2. Unpacking Orion 100. From left to right: 5G contoller, Radio unit (Panther n77), Antenna, gSIM and UE

Figure 3. 2x2 connection between the RU and antenna

The overall connection of 5G network can be seen in Figure 4. A Linux PC is used as edge computing server (IP: 192.168.69.216/24). To ensure the cable connection is not the bottleneck between 5G devices and the edge server, a 10G-Ethernet switch is used between 5GC and the edge server. Both 5GC and the Edge Server have a 10G-Ethernet port. One port of the switch is connected to school 192.168.69.0/24 subnet. 5GC will obtain an IP address via DHCP, and in our case it is 192.168.69.80. 5GC is acting as NAT for its UEs. The default subnet of cellular subnet is 12.1.1.0/24. Network Slicing is also supported by the 5G controller. Four subnets are defined in 5GC configuration as 192.168.127-130.0/24. In our case 192.168.127.1 is enabled to connect to RU.

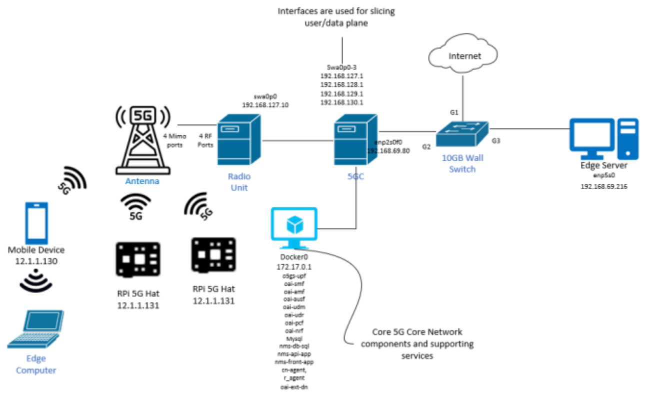

Figure 4. Orion 100 system connections

To test 5G radio link performance, we also setup two Raspberry Pi 4 devices each with a Warehouse SIM8200-EA M2 5G hat (Figure 1). SIM8200 is a 5G terminal based on Qualcomm snapdragon X55 multimode multi band platform, supporting band n77 2x2 MIMO, with the 5th antenna for GPS receiver.

Figure 5. Warehouse SIM8200-EA M2 5G hat

The configuration of 5GC is done in the file /etc/conf/firecell/5G/ran/gNB.conf. Table 1 shows some important radio configuration parameters. Because the system is set as TDD SA mode, uplink and downlink frequency parameters are identical. The TDD time-slot allocation is different in UL and DL, but will not be covered in this article due to its complexity.

Name	Value	Description
MCC	001	Mobile Country Code (001: test network)
MNC	01	Mobile Network Code (01: test network)
absoluteFrequencySSB	663360	ARFCN for SSB, 3950.400MHz
dl_absoluteFrequencyPointA	660084	Lowest subcarrier ARFCN, 3901.260MHz
dl_frequencyBand	77	5G band number
dl_subcarrierSpacing	1	SC spacing, 1=30kHz
dl_carrierBandwidth	273	273*PRB (1PRB=12 ARFCN)=49.14MHz

Table 1. 5G configuration parameters in gNB.conf file

Once the configuration is done, start the 5GC, power on RU, insert SIM cards into RPis and the smartphone. We are able to see 3 devices connected to 5GC, see Table 2.

5G Hat	5G_Hat_RPiOS_2	Active	001010000059451	12.1.1.132
5G Hat	5G_hat_RPiOS_1	Active	001010000059450	12.1.1.131
Smartphone	Core-Z5	Active	001010000059449	12.1.1.130

Table 2. Connected device list in the network management center

IV. Result Analysis and Assessment

We have performed both TCP and UDP test between a RPi and the edge server (192.168.69.216) using "iperf" tool. RPi is set as iperf client and the edge server as iperf server. With TCP test, which measures the best effort throughput between two hosts, we obtained up to 50Mbps throughput but channel fluctuation is obvious (Figure 6). With UDP test (Figure 7), we are able to see the bandwidth usage is more stable than that of TCP, which could be contributed by the radio link scheduling algorithm in 5G controller. The jitter of UDP datagrams is also very low as the worst-case scenario is still below 1ms. The packet loss ratio is good but we could see that link fluctuations can worsen it up to 3%.

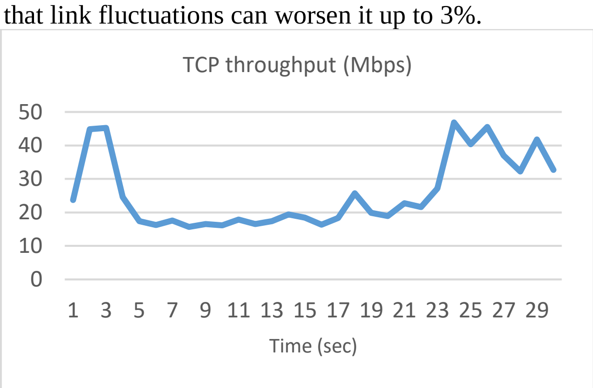

Figure 6. TCP test in 30 seconds

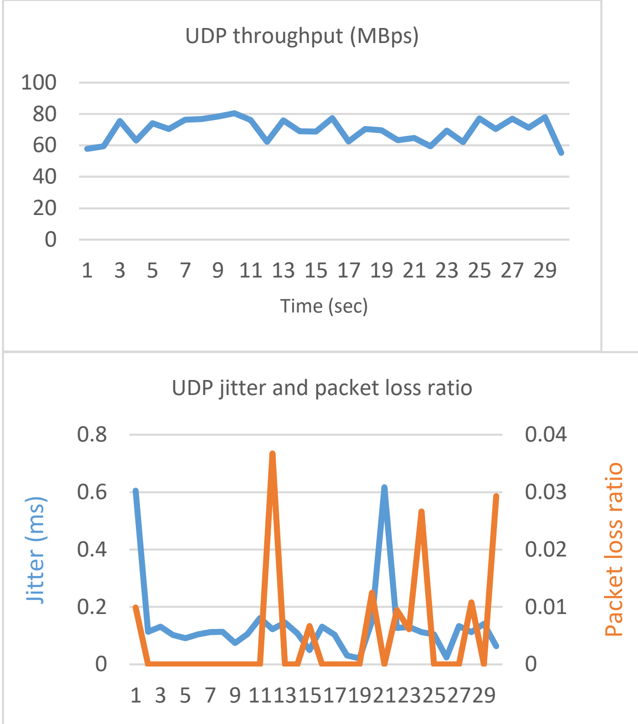

Figure 7. UDP test result (upper: bandwidth in MB/sec, lower: Jitter in ms and Packet loss ratio)

V. Conclusion

The whole procedure of enabling Technobothnia laboratory with a state-of-the-art 5G technology is not an easy job. Luckily before this job, we have conducted another 5G project with Vaasa University and Novia University of Applied Sciences and accumulated a lot knowledgebase and experience. Choosing Firecell 5G is the correct decision because its radio unit coming with power amplification is able to cover the whole laboratory area, which is a complex radio propagation environment with metal walls, structure columns, industrial robots, electricity circuit breakers, wires, and transformers, etc. This procedure has given us opportunity to combine 5G technology with research and development as well as advanced education in the future.

VI. Bibliography

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