URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019

5G NR Test Bed Integrated with Pathways and Gateways for Access to the Cloud Towards Smart City Communication Applications

Rabindranath Bera[(1)], Soumyasree Bera[(1)], Subhankar Shome[(1)], Samarendra Nath Sur[(1)]
(1) Department of Electronics & Communication Engineering,
Sikkim Manipal Institute of Technology (SMIT) ,
Sikkim Manipal University,
Majitar, Rangpo, East Sikkim, Sikkim-737136, India

Abstract

With the increasing network densification, it has become exceedingly difficult to provide traditional fiber backhaul access to each cell site, which is especially true for small cell base stations (SBSs). The increasing maturity of millimeter wave (mmWave) communication has opened up the possibility of providing high-speed wireless backhaul to such cell sites. Since mmWave is also suitable for access links, the third generation partnership project (3GPP) is envisioning an integrated access and backhaul (IAB) architecture for the fifth generation (5G) cellular networks in which the same infrastructure and spectral resources will be used for both access and backhaul.

Technology trends for millimeter wave small cell field trails following 5G NR 3GPP standard has been noticed in the 5G NR Mobile era as an up gradation to LTE and LTE IOT services. 5G mobile will be fully cloud enabled services. This necessitates several pathways and gateways from IOT end nodes to access to the cloud via LTE/5G CRAN Multiservice Base station. This paper aims at design and development of 5G Network Emulator at SMIT Laboratory for experimental validation of the above concept.

Keywords:-
IOT, SMIT, CRAN. 5G NR, aCore, eMBB, VSA, UE, IAB

1. Introduction

Recent trails for LTE IOT simulation were conducted at the city of Chicago which includes a multiservice LTE IOT base station servicing several services like Smartphone , Utility meters, Street lights and others[1]. The similar multiservice CRAN LTE IOT base station was also conceptualized using different pathways and gateways connecting user terminals to the clouds [2]. Thus LTE/5G Cloud RANs are evolving at faster rate supporting both smartphone services as well as different types of IOT enabled services.

The race to 5G accelerated dramatically when the first 3GPP Release 15 New Radio (NR) specifications were approved in December 2017. Across the telecom ecosystem, component and chipset designers, device manufacturers, network equipment manufacturers, and service providers are racing to simulate, build, and field test 5G NR equipment [3]. 5G NR Phase 2 study items for Integrated Access and Backhaul (IAB) has also been initiated by 3GPP [4] [5].

In coming days, 4G base station will be replaced by 5G NR base stations, supporting multiservice. In a smart city the multiservice may composed of following:

i) <u>5G Mobile Gateway:</u> Existing LTE mobile user will update their mobile with 5G mobile having an additional Application (App) to initiate 5G mobile hotspot. That hotspot may be a Bluetooth or wi-fi or others to be used for controlling of local IOT devices. In other sense 5G mobile will used for eMBB service and will also provide some IoT services and will act as MOBILE GATEWAY.

2) <u>Consumer gateway</u>: The smart city corporation may opt for smart control of the street lamps for efficient energy utilization and saving. Corporation will install small gateway towers for above services which will be a CONSUMER GATEWAY. In turn gateways to be connected to 5G NR base station.

3) <u>Industrial gateway:</u> The smart industry will look forward for dedicated gateway for automation of industrial equipments.

1.1. Commercial FETMO CELL LTE Network set up at SMIT by LTE Operator

aCore is the heart of the present day commercial LTE Network as shown in Figure 1. Airspan aCore system is the LTE Evolved Packet Core (EPC) enabling highest quality for fourth generation LTE Mobile services.

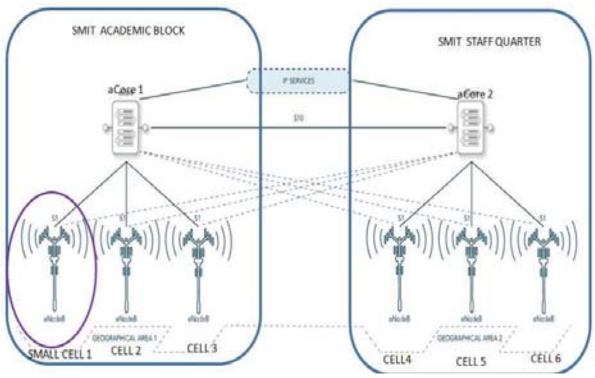

Figure 1: Airspan LTE FEMTO CELL eNode-B installed within SMIT.

1.2. 5G Network Emulator Set up at SMIT Laboratory

Figure 2 is a multi cell architecture serving IOT devices involving i) IOT Devices ii) Wireless connectivity to Gateways iii) 5G NR base stations iv) Backhaul connection for remote access v) and finally the cloud. Thus several Pathways and Gateways need to be integrated with 5G NR base stations. Here cell structure is considered based on their services which mean every cell is providing different services. Cells are served by a 2 in 1 base station, which provide 2 different services simultaneously to different cells using Multi-standard Radio (MSR). Backhaul connectivity is done by millimeterwave. Two millimeter wave 60 GHz transceivers are used for this backbone connectivity. One 60 GHz transverse is connected with one 5G NR multiservice base station in one location and another 60 GHz transceiver is connected with global cloud. A LOS link is established between this two 60 GHz backhaul.

Figure 2: 5G pathways and Gateways for connection between cloud and IoT smart devices

Now looking towards cell architecture, different cells is designed for different services, even operating cell frequency is also different. Cell1 is designed for broadband data service along with IoT services which is a goal of 5G NR. Second cell is designed as consumer gateway for IoT services. These cells are served by the 2 in 1 5G NR base station using 28 GHz frequency range. Further 5G NR gateways are having a transponder for 28 to 2.4/5 GHz transformation. Hotspots thus created are used to connect smart IoT within the cells.

The subsystems within the 5G gateways are described as below which are mounted over a Mobile trolley to act as mobile gateway

1) UE at 28 GHz: User is served by the 5G NR base station with eMBB services for high speed internet over 28 GHz.
2) Laptop with Ethernet: laptop is used on mobile trolley to verify the eMBB services including 4K TV and others. In the same laptop app will be available to redirect the IoT Control signal further to the smart devices. IoT control signal will pass over 2.4 GHz band or 5 GHz band.

The detailed design of individuals subsystems of figure 2 are described in article 2.

2. Design and development of Network Emulator

2.1 28 GHz Multiservice 5G NR Base station

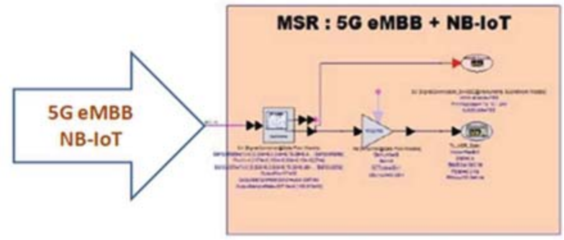

Figure 3 All signals for respective services sent to MSR

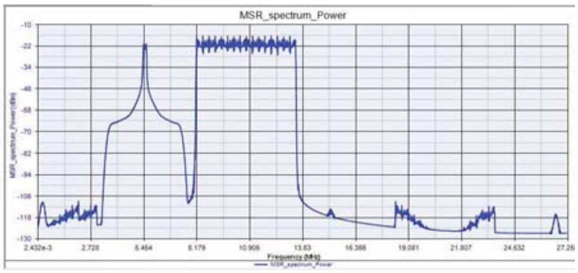

Figure 4: MSR Spectrum with IoT and eMBB services

The multi standard radio (MSR) will be designed in the following way with the help of a signal combiner. The challenge is to combine multiple input signals with different sample rates and different bandwidths into a composite single signal. So, the integration of 2 different signals are to be done in a software platform where, the utility of specifying a row vector containing the desired set of sample rates, bandwidths is important. The condition of specifying the sample rate is as below.

Sample Rate is an array parameter specifying the sample rate of each individual input signal. The order of the sample rate values in the array parameter must match the order of the input signals at the input multiport. Similar condition will be adopted for specifying bandwidth of each signal. The out coming signal must be a single signal at the specified characterization frequency and sample rate [3]. If the above conditions are fulfilled, the Signal Combiner will be capable to automatically compute data flow production and consumption rates for individual input and output ports. Signal Combiner resamples and characterizes the input signals to the output sample rate and output characterization frequency. It also synchronizes the resampled signals (due to different latencies introduced from different sample rates) before combining them into one signal. The combined signal is generated from the combined port characterized at Output RF carrier (specified) and the output sampler rate. Signal Combiner also outputs each re-sampled and re characterized signal at the output multiport (characterized at Output RF and the output sampler rate). The order of the output signals from the output multiport is in the same the order as the input

signals at the input multiport. To design a 5G-IoT Base station with 2-in 1 service, a model is to be developed. Using the programming platform 2 individual spectrums will be generated by following the 3GPP 5G-NR standard. The model will integrate the 2 services
(i)5G Enhanced Mobile Broadband (eMBB) for faster internet,
(ii) Narrow band IoT based Massive Machine Type Communications service for smart lamp control and

Finally, the composite signal is up converted to a carrier of 28 GHz frequency with an integrated antenna for the radiation. A 28 GHz 5G NR base station is thus ready for the transmission as well as reception having the detailed specification as mentioned in figure 5. The Rx level and the MSE (Mean Square Error) of the 28 GHz base station are also recoded for studying radio wave propagation performance and shown in figure 6.

Radio	Local	Remote
Radio side	High	Low
Tx mute	Disabled	Disabled
Tx power	0 dBm	0 dBm
ATPC	Disabled	Disabled
Duplex shift	1008 MHz	1008 MHz
Tx frequency	28780.50 MHz	27772.50 MHz
Rx frequency	27772.50 MHz	28780.50 MHz
Rx level	-55 dBm	-57 dBm
Modem	**Local**	**Remote**
Bandwidth	60 MHz ETSI	60 MHz ETSI
Modem profile	4QAM FEC	4QAM FEC
ACM engine	Disabled	Disabled
Acquire status	Locked	Locked
MSE	-28.3 dB	-26.9 dB
FEC load	0.0e+00	0.0e+00
Current Rx modulation	4QAM FEC	4QAM FEC
Current Tx modulation	4QAM FEC	4QAM FEC
Current Rx Ethernet capacity	72.0 Mbps	72.0 Mbps
Current Tx Ethernet capacity	72.0 Mbps	72.0 Mbps

Figure 5: 28 GHz Link parameters

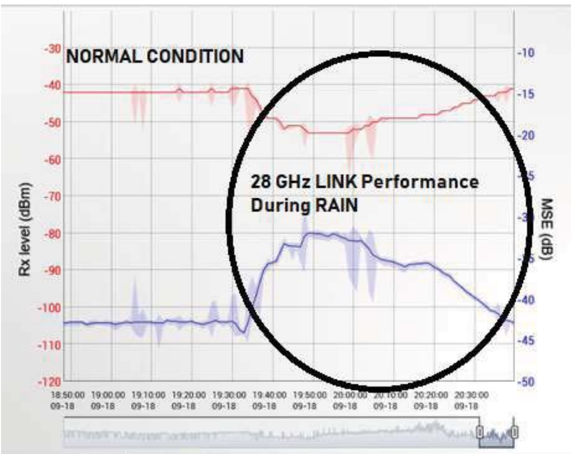

Figure 6: 28 GHz Link Fading Performance recorded on a PC

2.2 5G Mobile Gateway development

Mobile gateway is connected and served by the 5G base station using 28 GHz Link. 28 GHz is receiving the MSR spectrum from the base station. Broadband spectrum is used for broadband data operation in a Laptop to access 4K TV. 28 GHz receiver is having a LAN port for data communication, which can be directly connected with the Laptop. Laptop is placed on a moving trolley to emulate the mobile condition. In this laptop one application is launched to redirect the narrowband control data towards control devices using 2.4 GHz hotspot, if user wants to select the IoT services instead of eMBB services. User is having a choice of either eMBB or IoT services. Figure 7 and 8 depicts the mobile gateway activities.

Figure 7: 5G Mobile Gateway on Mobile trolley

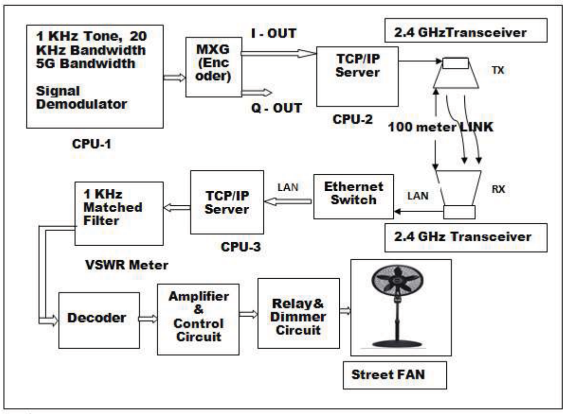

Figure 8: IoT Smart FAN Control Using 5G Mobile Gateway

2.3 5G Consumer Gateway development

Monitoring and controlling remote devices wirelessly is most vital requirement for machine automation. In coming generation of "internet of things", every device can communicate and can be monitored and controlled from any part of the world. The link for communication must be secure and with very low latency for effective communication.

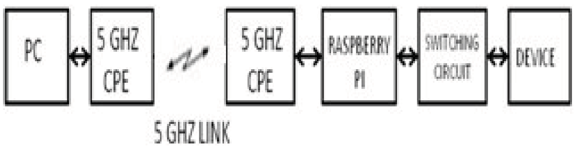

Figure 9: Hardware set up for Wireless remote device control.

In configuration shown in figure 9 and 10, the remote device can be monitored and controlled using 5 GHZ link. The controller on remote end is RASPBERRY Pi which is programmed to control the device connected with it based on the instruction received from the PC at the base station. The switching circuit will turn ON or OFF the device as instructed by the pi. The status of the remote device can be sent to base station using the same path in backward direction.

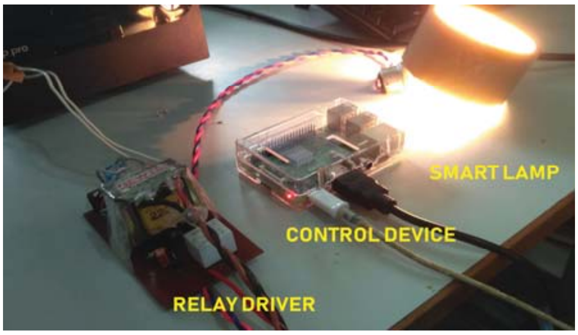

Figure 10: IoT control for Consumer Gateway

2.4. 60 GHz Backhaul design

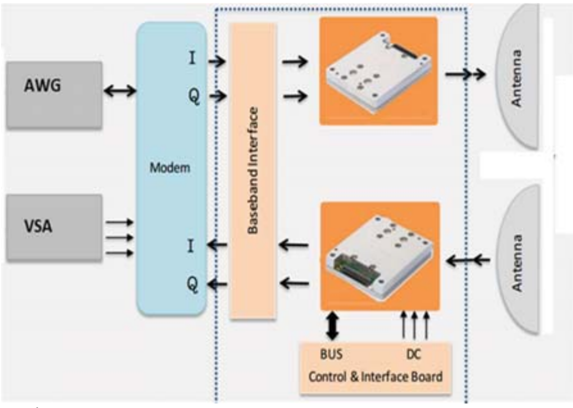

Figure 11: 60GHz BACKHAUL LOS LINK SET UP

The experimental setup as in figure 11, consists of a desktop PC, an arbitrary signal generator (AWG) , and a SiversIMA FC2121V 60 GHz up-converter/down-converter and VSA. The computer generates the baseband signal downloaded to AWG via LabView. The AWG up converts the signal to an intermediate frequency (IF) of 1.6 GHz that is then fed to the SiversIMA to be up converted and transmitted in the 60 GHz band. The RF up conversion chain is consist of Variable gain amplifier, driver amplifier and a power amplifier. Whereas RF down conversion chain is consist of low noise amplifier, multi stage variable gain amplifier.To transmit the signal, we use either a horn antenna having 7◦ beam width. Again, the received signal down converted to IF level by SiversIMA down converter and fed to vector signal analyzer (VSA) for the further signal processing to a PC.

The above scheme is repeated for a Full duplex LOS 60 GHz Link.

2.5 Access to the Cloud

The PC after the 60 GHz Transceiver as mentioned Figure 11 is used for the DSP for the above 60 GHz Link. This PC is further connected to another Cloud Server PC using wired Ethernet connection thus accessing the Cloud.

4. Summary and Conclusion

A 5G NR eMBB link over 28 GHz has been established with the upper portion of the set up in figure 2. Here with the realization of multi standard radio, the same 5G NR base station is also offering 5G IOT service. Following 28 GHz pathways, the MSR 5G IOT signals is available to two Gateways namely Mobile Gateway and Consumer gateway.

Gateways are further follows 2.4 GHZ and 5 GHz pathways in cell1 and cell2 to connect the IOT smart devices.

Other side of 5G NR base station follows a 60 GHZ pathways to connect to a distant cloud.

The received signals are measured and analyzed for EVM, CDF, BER at every stage using a Vector Signal Analyzer and performances of the different link are ensured with repeated trials. The reproduced video, voice and IOT control signals quality are excellent giving high level of satisfaction to the designers.

5. Acknowledgements

The Authors are thankful to Dr. RamdasPai& Mrs. Vasanthi Pai Endowment Fund, for giving Project on 5G based IoT, which is running under Center of Excellence of Electronics & Communication Department, SMIT.

6. References

1. Qualcomm White Paper, “LTE IoT Network Simulation”. https://www.qualcomm.com/videos/lte-iot-network-simulation, May 15, 2018

2. Keysight Application Notes, “IoT insights - poster”. 2017 https://literature.cdn.keysight.com/litweb/pdf/5992-1217EN.pdf?id=2788751

3. “De-Risking 5G Product Development-White Paper,” Website:- www.keysight.com. 9th July 2018.

4. Boon Leong, “ Integrated Access and Backhaul ..a 5G NR Phase 2 study item”, file:///C:/Users/smit/Desktop/New%20folder/IAB%20SAMSUNG.pdf/

5. Chiranjib Saha, Mehrnaz Afshang, and Harpreet S. Dhillon, “Integrated mmWave Access and Backhaul in 5G: Bandwidth Partitioning and Downlink Analysis”, arXiv:1710.06255v1 [cs.IT] 17 Oct 2017