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PERFORMANCE ANALYSIS OF 5G NR TOWARDS MACHINE TYPE COMMUNICATION IN LOW POWER NETWORKS

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ABSTRACT

5G New Radio (NR) is the global standard recommended by 3GPP for cellular technology with three different use cases: Ultra Reliable Low Latency Communication (URLLC), enhanced Mobile Broadband (eMBB) and massive Machine Type Communications (mMTC). 5G NR is introduced with wide range of applications such as smart homes, smart cities, smart healthcare, and industrial IoT. Since 5G MTC is suitable in LPWAN technology and FR1 of 5G NR is suitable in MTC. While designing 5G NR technology, the designer must have proper understanding on the concepts of NR specifications. Especially, 5G NR operates in two modes: Standalone (SA) and non-standalone (NSA) mode. The NSA mode is an extension of LTE and uses sub-GHz frequency band <6GHz and SA mode uses completely new radio access technology and is critical to implement. 5G SA uses frequency >28 GHz band which is considered as mmWave communication. 5G NR uses FR1 with sub carrier spacing of 15 kHz and 30 kHz with normal cyclic prefix. The bandwidth for 5G NR in FR1 ranges from 5 MHz to 50 MHz. Initially, we have analyzed the technology drivers for 5G NR technology, and its summary is presented. In this paper, we have designed a 5G NR uplink system as per 3GPP standardization and its performance evaluation are carried out in terms of Throughput, Bit Error Rate (BER) and Block Error Rtae (BLER) to support the wide range of applications in Low Power Networks in 5G.

INDEXTERMS: *5G, New Radio (NR), massive Machine Type Communications (mMTC), Uplink, Standalone (SA), PUSCH.*

I. INTRODUCTION

As per ITU and ETSI, 5G has three major applications in eMBB (Enhanced Mobile Broadband), URLLC (Ultra Reliable Low Latency Communication) and mMTC (Massive Machine Type Communication), which is also called 5G triangle. It is the framework to facilitate the evaluation of quality of services (QoS) and to operate successfully in future 5G network. The initial phase of 5G which operates on NSA (Non-Standalone) mode mainly focus on eMBB, which can provide greater bandwidth with very less latency on both 5G NR and 4G LTE. This will facilitate the network operator to develop use cases such as augmented reality (AR), ultra-HD video (4K Video) streaming and many more broadband applications. In eMBB mode of operation, the broadband access must be available in densely populated area in both indoor and outdoor services and it must be available everywhere, anytime to provide a consistent service to the users. Not just only on entertainment industry, 5G eMBB also supports advance services like cloud computing, big data analytics, edge computing which can assist the developer to create environment for smart offices, smart homes where all devices and sensors are wirelessly and seamlessly connected. This wide range of services in in future 5G technology will become boon to the society and human working lives. In URLLC use case of 5G, it mainly focuses on highly sensitive application like tele surgery where haptic signal transmission is mandatory and Smart transportation which includes installation of radars, lidar, sonar etc. It is a new service category of 5G aiming for mission critical communication, with a very low latency of <1ms and end to end security with 99.99 percent reliability. 5G URLLC offers ultra-fast and ultra-reliable services which will be ideal for low latency sensitive application that includes Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication. This technology ensures the safety of drivers and travelers by processing real time conditions where drivers can react within 100~150ms. The realization of URLLC in 5G connectivity empowers several technological transformations in transport industry that includes key features like automated driving, driverless cars, road safety and traffic efficiency services.The triangular representation of 5G NR use cases is shown in figure 1.

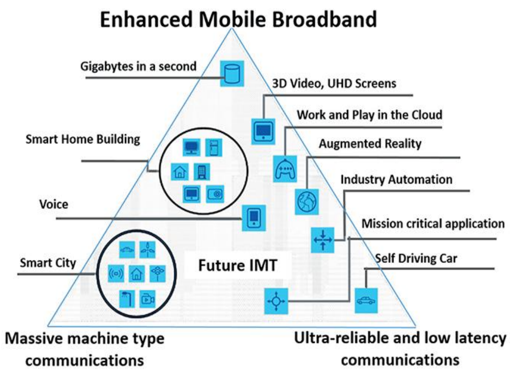

Fig. 1: Triangular representation of 5G NR use cases.

For MTC operation, LTE and NB-IoT was firstly introduced by 3GPP in release 13 which offers low power wide area implementation. As per 3GPP release 15 and release 16, 5G NR can be deployed for massive machine type communication with better connectivity, low power consumption and better reliability. 5G network can be deployed in 80-100 MHz spectrum in >6GHz bands. 5G NR for URLLC and eMBB can be deployed in mm wave spectrum band (28GHz). 5G mMTC mainly focuses on NSA mode of 5G NR, which mainly depends on co-existence of LTE and new radio (NR) which was standardized in 2017. 5G NSA uses OFDM technology based on LTE as the control plane anchor for 5G NR. NSA mode must support dual connectivity which means the device should maintain LTE and NR transmission simultaneously.

The salient features of three use cases in 5G are summarized in table 1.

Table 1: Salient Features of 5G NR Use Cases.

Massive Machine Type Communications (mMTC)	Enhanced Mobile Broadband (eMBB)	Ultra-Reliable and Low Latency Communication (URLLC)
High device density (up to 1,000,000/km^2)	Peak spectral efficiency: 30 bps/hz (DL), 15 bps/hz (UL)	99.999 % reliability and availability with 1 ms
Latency: Sec. to Hours	4 ms user plane latency	0.5 ms user plane latency
Low power consumption and battery life up to 15 years	Indoor/Hotspot and enhanced wide area coverage	High Mobility
Suitable in LPWAN especially in Licensed spectrum band (NB-IoT)	Operates specially with 3GPP 5G New Radio (NR) technology	Supports 3GPP standard 5G New Radio (NR)
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In this paper we have mainly focused on Physical Uplink Shared Channel (PUSCH). In 5G NR, PUSCH is responsible in carrying multiplex control information and user application data. The PUSCH in 5G NR is defined by 4G LTE standard providing more reliability and flexibility. The transmitter and receiver of 5G NR PUSCH is designed as per [8][9]. Furthermore, we have done the performance analysis for sub carrier spacing of 15 kHz and 30 kHz.

II: Motivation and Objectives

As per the findings, 50 billion devices are expected to connect in 5G networks by 2025 which represents the 21% of world's population, hence it is necessary to propose and design technology that are more appropriate in connecting such large number of devices in a platform called massive machine type communications (mMTC). As per 3GPP release 13, NB-IoT was chosen as suitable LPWAN technology but it was limited to shorter bandwidth and fixed carrier sub carrier spacing, but 3GPP in its release 17introduced the use of 5G NR as the suitable radio access technology that are suitable for machine type communication. Some of the major challenges in massive machine type communication such as control signaling, access capacity challenge, low power consumption and multi service integration can be overcome by the new radio access technology (RAT) in 5G in the form of 5G New Radio (5G NR). 5G has a huge impact on next generation technology and to provide the global impact on industrial IoT, Smart services 5G NR is proposed to be the promising technology. 5G supported mMTC can be the dominant communication technology for various emerging smart technology such as Industry 4.0, Smart Cities, Logistics, Smart Agriculture and Smart Transportation. Such critical challenges and promising future service motivated us to conduct research and analysis on technology related to 5G NR in for future wireless communication. The main objective of this paper is to provide the technical specification related to 5G NR physical layer system for the better understanding to the readers and the 5G developers. The major contribution of this paper includes.

1) The overview of 5G NR physical layer technology is discussed in detail.
2) 5G NR Uplink System is designed as per 3GPP specifications.
3) Performance analysis of the 5G NR Uplink system is conducted and discussed its impact on machine type communications.

III: Overview OF 5G NR Technology

5G NR is considered as the major technology driver in 5^{th} generation communication technology. To serve the use cases of 5G NR, the design of flexible radio scheme is necessary. The key technical components in 5G includes spectrum band, sub carrier spacing, waveform selection, frame design and the frequency range. There are two frequency band in 5G NR i.e., FR1 and FR2. The frequency rage FR1 is operational in sub-6 GHz frequency band and FR2 is operational in 5G NR mmWave frequency >24 GHz as shown in figure 2.

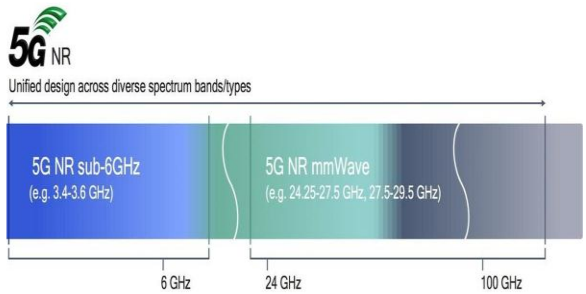

Fig. 2: 5G NR Frequency Band.

mMTC in 5G NR is governed by 3GPP in release 16 standardization. The OFDM with cyclic prefix is used as a multiple access scheme for NR physical layer in both uplink and downlink channels. The transmission is licensed and unlicensed spectrum band; both TDD and FDD are enabled. In this paper, the NSA mode of operation in FR1 is chosen where the spectrum can be dynamically shared between 4G LTE and 5G NR. In other words, the 5G MTC supports the co-existence of LTE and NR which is introduced in 3GPP release 15. Some of the key parameters in 5G NR is discussed below.

A. Waveform and Frame Structure

Waveform selection is the important aspect in deploying 5G NR in mMTC. 5G NR is the extension of OFDM technology that is like 4G LTE. The waveform in 5G NR is based on CP-OFDM and DFT_s-OFDM with adaptive modulation technique which includes π/2 BPSK, QPSK, 16 QAM, 64QAM and 256 QAM depending upon the application requirement with some constellation mapping as LTE. In our design we have considered 16 QAM modulation. The frame structure of 5G NR is based upon allocation of resource block in various spectrum bands. Frame structure mainly depends on OFDMA scheme and its parameters such as symbol duration, sub carrier spacing, slot duration and cyclic prefix insertion. The frame of 5G NR is fixed from length and subframe but the allocation is flexible. The frame structure of 5G NR is shown in figure 3.

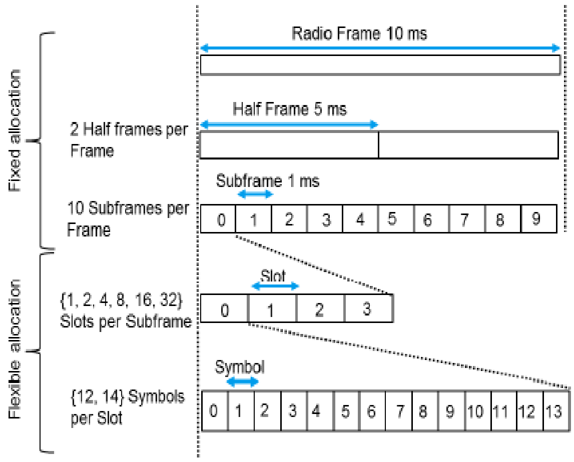

Fig. 3: Frame Structure of 5G NR Technology.

For both uplink and downlink system, the 5G NR frame have a length of 10 ms. Each frame consists of 10 subframes with 1ms duration each. 5G NR is supported with slot base scheduling with 14 OFDM symbols in 1 slot. The slot aggregation is allowed in one possible scheduling unit. The slot length scales with the sub carrier spacing and is given by the equation,

Slot Length = 1ms/2μ

The minimum slot concept is also considered in 5G NR where 7, 4 or 2 OFDM symbol are used.

B. 5G NR Numerology

5G NR is supported with scalable and mixed numerology with additional feature such as implications of slot duration, implication to multiplexing of numerologies and inter sub carrier spacing; where sub carrier spacing is given by,

$\Delta f = 2^{\mu}$ x 15 kHz………… (i)

Here, 'μ' is the numerology and is the integer that depends service requirements. The value of μ ranges from -2 to 4. In case of massive machine type communication, the value of 'μ' is defined as 0 and 1. The scalable numerology uses the single numerical values at a time which results in reduction of inter sub carrier spacing whereas the problem rises in mixed numerology due to the use of multiple numerology value. The main advantage of flexible numerology value in 5G NR over LTE is that we can choose the numerology value as per our design requirements considering the three-use case of 5G. Lower sub carrier spacing value is used inlow bandwidth requirements whereas higher sub carrier spacing is used in URLLC and eMBB. The various technical specifications of 5G NR are summarized in table 2.

Table 2: Summary of 5G NR technical specifications.

Sub Carrier Spacing (μ)	Cyclic Prefix (CP)	Number of OFDM Symbols Per Slot	Number of Slots per Subframe	Number of Slots per Frame	Minimum Resource Block (RB^{min})	Maximum Resource Block (RB^{max})
0 (15 kHz)	Normal (< 6GHz)	14 (1ms)	1 (1 slot * 1ms=1ms)	10 (10 ms)	20	275
1 30 kHz	Normal (< 6GHz)	14 (500μs)	2 (2 slots * 500 μs=1ms)	20 (10 ms)	20	275
2 (60kHz)	Normal, Extended (< 6GHz)	14 (Normal CP) (250μs)	4 (4 slots* 250μs=1ms)	40 (10 ms)	20	275
		12 (Extended CP) (250μs)	4 (4 slots* 250μs=1ms)			
3 (120 kHz)	Extended (> 6GHz)	14 (125μs)	8 (8 slot* 125μs=1ms)	80 (10 ms)	20	275
4 (240 kHz)	Normal (> 6GHz)	14 (62.5μs)	16 (16 slots* 62.5μs=1ms)	160 (10 ms)	20	138
5 (480 kHz)	Normal (> 6GHz)	14 (31.25μs)	32 (32slots* 31.25μs=1ms)	320 (10 ms)	20	69

The resource elements in 5G NR are grouped into physical resource block (PRB) where each PRB consists of 12 subcarriers. The minimum resource block (RB) in all sub carrier spacing is 20 for all sub carrier spacing whereas the maximum resource block (RB) is 275 except for 240 kHz and 480 kHz. The maximum RB for 240 kHz is 138 and 69 for 480 kHz. For normal CP, each small length of 15 kHz equals the sum of corresponding 2^{μ}at F_s. other than the first OFDM symbol in every 0.5 ms all symbols within 0.5 ms have the same length. Cyclic Prefix (CP) is an important parameter that greatly influences the sub carrier spacing which determines the performance of the channel. Moreover, the sub carrier is inversely proportional to the phase noise and the sensitivity of the Doppler spread/shift. Hence, it is necessary to choose sub carrier as a tradeoff between overhead due to cyclic prefix and Doppler shift. The alignment of different numerology in the time domain depends upon the multiplication of 2^{μ} so that the duration of 2 OFDM symbols corresponds to 1 OFDM symbols in lower sub carrier spacing.

C. 5G NR Channels

To access the spectrum for 5G mobile communication, 5G NR uses different channels for transmission of data including, physical, transport and logical and transport channels. To support both licensed and unlicensed spectrum bands both FDD and TDD are supported in 5G NR technology. various physical channel that are defined for 5G NR uplink (UL) are:

1. Physical Uplink Shared Channel (PUSCH)
2. Physical Uplink Control Channel (PUCCH).
3. Physical Random-Access Channel (PRACH).

The physical channel defined for 5G NR downlink (DL) are:

1. Physical Downlink Shared Channel (PDSCH
2. Physical Downlink Control Channel (PDCCH).
3. Physical Broadcast Channel (PBCH).

The logical channels in 5G NR can be considered as control channel and traffic channels. The control channel is used to transfer the data from the control plane and the traffic channel is used to transmit data from user plane. The main objective of transport channel in 5G NR is to multiplex the logical data which is to be transmitted by the physical layer and its channel over the radio interface. In addition to 5G NR channels, physical signals are considered which are used by the physical layer for synchronization purpose. The physical channels used in 5G NR uplink are:

1. Demodulation Reference Signal (DM-RS).
2. Phase-Tracking Reference Signal (PT-RS).
3. Sounding Reference Signal (SRS).

The physical channel used in 5G NR downlink (DL) are:

1. Demodulation Reference Signal (DM-RS) for PDSCH and PBCH.
2. Phase-Tracking Reference Signal (PT-RS).
3. Channel-State Information Reference Signal (CSI-RS).
4. Primary Synchronization Signal (PSS).
5. Secondary Synchronization Signal (SSS).

IV. 5G NR UPLINK SYSTEM IMPLEMENTATION

The 5G NR uplink system is implemented with Orthogonal Frequency Division Multiplexing with cyclic prefix (CP-OFDM which is considered as the most suitable candidate for its operation. The system is implemented as per 3GPP specifications. The main motive behind choosing CP-OFDM it has low complexity in implementation, low-cost operation and it can support multiple user equipment with MIMO spatial multiplexing. The Transmitter and receiver block chain of 5G NR uplink system is shown in figure 4.

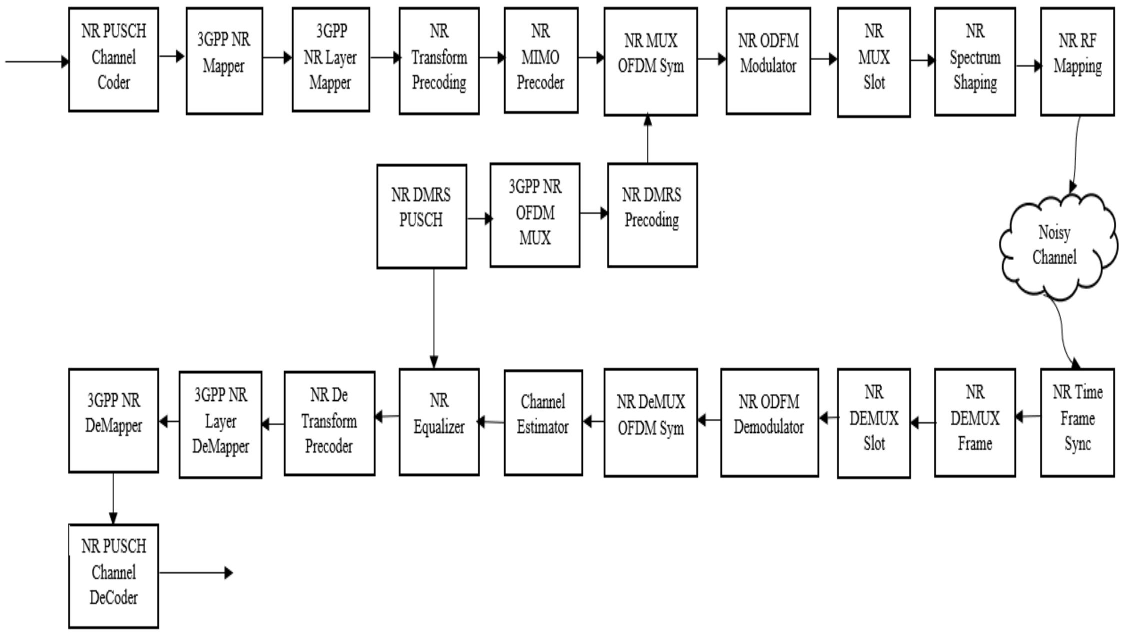

Fig. 4: Transmitter and Receiver Block Chain of 5G NR Uplink System.

A. 5G NR Transmitter

The NR PUSCH Channel Coder is the actual transport channel that carries the Uplink input data sequence. In addition to this, it also carries multiplexed control information and user application data. With reference to figure 4, CRC encoder is first added to input data sequence. CRC encoder is used to perform CRC attachment on transport block and computes the input bits of CRC by a_0,a_1,a_2,a_3………… aA_{-1} and the parity bity by p_0, p_1,p_2,p_3……………. pL_{-1} where ‘A’ is the input sequence size and ‘L’ is the number of parity bits. In this design, we have considered CRC length as 24A. Therefore, the parity bits are generated by, $G_{CRC24A}(D) = [D^{24} + D^{23} + D^{18} + D^{17} + D^{14} + D^{11} + D^{10} + D^{24} + D^{7} + D^{6} + D^{5} + D^{4} + D^{3} + D+1$. ……………….. (ii)

The total length B= 32+24= =56 bits viz c_0, c_1, c_3……., c_5^{5} after CRC attachment are obtained and sent to LDPC encoder. The encoding is performed in a symmetric form, which means the polynomial:

$a_0D^{A+L-1} + a_0D^{A+L-2}$ …+ $a_{A-1}{}^{D} + p_0D^{L-1} + p_0D^{L-2} + \ldots + p_{L-2}D^{1} + p_{L-1}$ yields a reminder equal to 0 when divided by the corresponding CRC generator polynomial. The total payload builds up to 32 as nine bits are added for timing. The bits after CRC attachment are given by b_0, b_1, b_2, b_3………b_{B-1}, where B = A+L.

Therefore, the relation between a_k and b_k is given by,

$$\left.\begin{array}{ll} A_k = b_k & \text{for } k = 0,1,2 \ldots\ldots\ldots A-1 \\ B_k = p_{k-A} & \text{for } k = A, A+1, A+2 \ldots A+L-1 \end{array}\right\} \quad \ldots \text{iii}$$

The efficient design and performance of Low-Density Parity Check (LDPC) is the key in 5G NR PUSCH. In each firing, one matrix-based token is consumed in the input data. The matrix size is the size before LDPC coding. The bit sequence input for a given code block of a channel coding is denoted by c_0, c_1,c_2,………… C_{K-1}, where 'K' is the number of bits to encode. After coding the bits are denoted by d_0, d_1,d_2,………… D_{N-1}, where $N=66Z_c$ for LDPC base graph 1 and $N= 50Z_c$ for base graph 2. LDPC code in 5G NR is defined by lifting size Z_c in addition to sub matrix size and base graph number, so we have considered base graph 1. The encoding is based on partitioning of the parity check matrix 'H' [8] of size m x n, where n is the code word length and m is the number of redundancy bits when $H_d= 0$ is satisfied. The transmitter chain after LDPC encoder Rate Matching, Scrambling of encoded bits OFDMA modulation and generation of Demodulated Reference Signal (DMRS). The rate matching for UL-SCH LDPC coding is defined for code block which consists of bit selection and bit interleaving. The input bit sequence of rate matching in LDPC code is given by d_0, d_1,d_2…. D_{N-1}. The output of bit sequence after rate matching is given by f_0, f_1,f_2………f_{E-1}. The flow chart of PBCH generation and mapping of 24A is shown in figure 5.

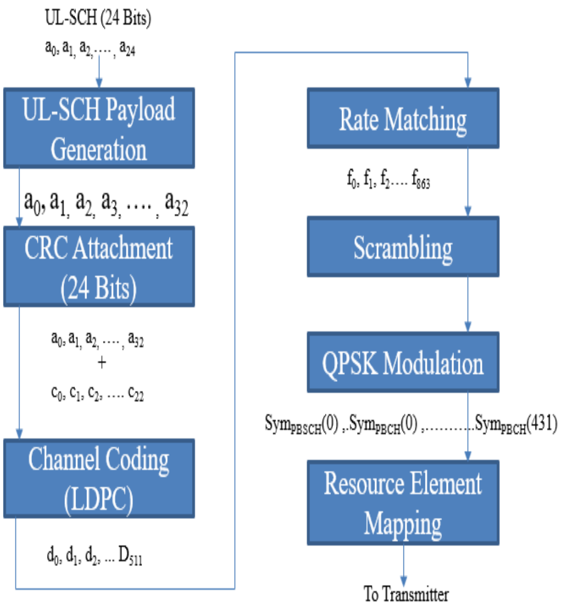

Fig. 5: PBCH Generation and Mapping.

The scrambling and OFDMA modulation are performed as per.[8,9] The scrambled bit sequence $f_0', f_1', f_2' \ldots, f_{E-1}'$ is modulated by 16 QAM modulation. After modulation, the total symbol obtained is 432 along with 144 DMRS symbols are mapped to the 576 sub carriers which are resource element available in the bandwidth part of UL-SCH transmission. In this design, NR-DMRS mapping is specific to each uplink NR physical uplink channel. It can beamform within a schedule resource and transmit it only when it is necessary. The transform precoding is disabled; therefore, the sequence generation r(n) is given by,

$r(n) = 1/\sqrt{2}\ (1\text{-}2.\ c(2n)) + j\ 1/\sqrt{2}\ (1\text{-}2.\ c(2n+1))$ ……... (iv)

The layer mapping is used to map PUSCH DMRS onto its bandwidth parts (BWP_S) physical resource grid. In each firing, the token consumed by each bus at the inputs are 1, which means one matrix. The user shall assume that complex value modulation symbol for each of the code words to be transmitted is mapped onto one or several layers. The matrix at SCS is of size Num_{RE} $*Num_{ports}$. Num_{RE} is the total number of RE_S of the BWP within one slot. We have considered PUSCH enabled, hence $Num_{Ports} = Num_{Layer}$. The SCS mapped data symbols are OFDMA modulated through FFT modulation and the FFT size is the size after oversample. The RF mapping is done to map signals associated with specific ports to specific RF chains. Here, only 0 and 1 exist in the mapping matrix where 1 in the Mth row and Nth column means signals associated with Nth port is mapping to Mth chain. Finally, the complex value modulated symbol is mapped to Resource Block (RB), which generates the signal for all antenna ports. The OFDM signal is then fed to the wireless channel.

B. 5G NR RECEIVER

Considering a two-layer transmission with m_t {0,1} transmit antenna and m_r {0,1}, the receiver of 5G NR uplink system includes data extraction, channel estimation, demodulation and decoding to obtain the transmitted data. Firstly, the time and frequency synchronization are performed. It is used to achieve uplink symbol timing synchronization with the aid of OFDM symbols, cyclic prefix (CP) and estimate the frequency offset less than the sub carrier spacing where time synchronization interval is given by,

$$\text{SyncTimeInterval} = \begin{cases} 5\text{ms}, & \text{if slot is less than 5ms} \\ \text{Slot Time}, & \text{Otherwise} \end{cases}$$

After successful cyclic prefix removal and OFDM demodulation through IFFT operation, the receiver must perform channel estimation and correction of Sample Time Offset (STO) and

Carrier Frequency Offset (CFO) and it must be performed in in frequency domain because of superposition of received signal coming from multiple users multiplexed in frequency. CFO is estimated through the phase rotation between pilot signals of different OFDM symbols and it is equalized by circular convolution in frequency domain. The STO is estimated by using DFT method. Once the time and frequency are corrected, the next step involves the channel estimation and equalization to compensate the loss due to multipath propagation. The flow chart of receiver operation is shown in figure 6.

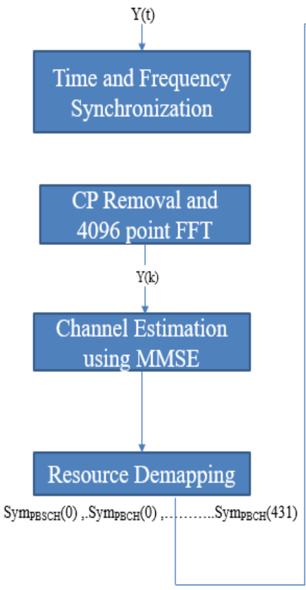

Fig. 6: Receiver Process flow of 5G NR Uplink System.

The MMSE channel estimation is chosen to minimize an error between actual and estimated channel realization and the estimation is done in slot basis.[9] The channel after MMSE estimation is then interpolated in the time and frequency domain. Then the MMSE equalization is performed on executed data symbol to reverse the effect of MIMO channel. As per 3GPP, the operation including descrambling, demultiplexing, and rate dematching are performed before LDPC decoding. The 864 LLR_s are de rate matched to 512 in bit di-selection and de-interleaving. The LDPC decoding is performed using LDPC Normalized Min-Sum algorithm. It has been chosen because it can reduce the computational complexity. The process flow of LDPC decoder is shown in figure 7.

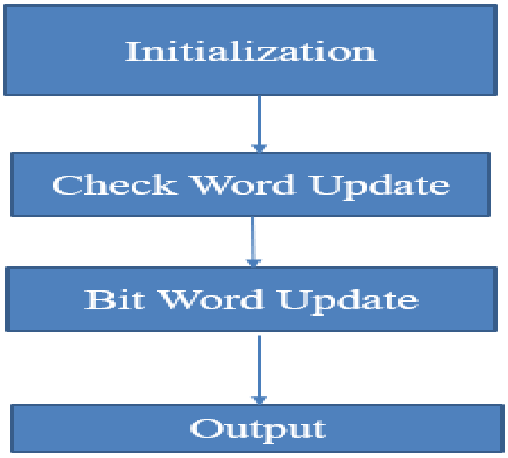

Fig. 7: Process flow of LDPC Decoder.

The LDPC code can be represented in the form of bipartite matrix with parity check matrix 'H' of size M x N. Here, M is the parity check nodes and N is the variable nodes (received code word bits). The LDPC code word is implemented to decode (N,K) systematic low density parity check (LDPC) code specified by parity check matrix. The parity matrix should be (N-K) x N matrix. The parity check matrix should satisfy the equation,

$H \times C^T = 0$ …………………… (v)

Where, $C = [i_0, i_1 \ldots i_{(K-1)}), p_0, p_1, p_{(N-K-1)}]$ is the error free codeword vector (output bits).

$0 = [0_0, 0_1, 0_2, \ldots\ldots\ldots 0_{(N-K-1)}]^T$ is the parity vector,

$i_0, i_1 \ldots\ldots\ldots i_{(K-1)}$ are the information bits and

$p_0, p_1, p_0, \ldots\ldots\ldots p_{(N-K-1)}$ are the parity bits.

Since we have considered negative polarity input for LDPC decoder and it should be the log-likelihood ratio (LLR) of each bit and is given by ln p (1)/p (0). We have considered N=12 and K=4 and in each execution of LDPC decoder, N soft bits are consumed, and K bits are generated at the output.

V. RESULTS AND DISCUSSION

The performance of 5G NR uplink system was evaluated in terms of Throughput, Block Error Rate (BLER) and Bit Error Rate (BER). The analysis is performed for two different sub carrier spacing to study the performance of 5G NR uplink system. The simulations were conducted as per 3GPP guidelines and the parameters are summarized in table 3.

Table 3: Simulation Parameters.

Parameters	Value
Bandwidth	50 MHz
Carrier Frequency	6GHz
Cyclic Prefix	Normal
Sub Carrier Spacing	15 kHz, 30kHz
MCS	16
LDPC Base Graph	1
Payload Size	24
FFT Size	2048
Modulation	16 QAM
No. of allocated slots for each PUSCH	10
Transform Precoding	Disabled
Channel Estimator	MMSE
Channel Equalizer	MMSE
LDPC Decoding Algorithm	Normalized Min-Sum
PTRS Configuration	Disabled
No. of PRB in BWP	270
Transmission Channel	TDL
Transport Block Size (TBS)	2555

The study is performed for 5G NR at two different sub carrier spacing. The throughput analysis is performed and shown in figure 8 and figure 9 for 15 kHz and 30 kHz, respectively. We have observed that the throughput increases with SNR values with the increase in sub carrier spacing and selected MCS. Considering the same MCS for both sub carrier spacing we have observed that the throughput is slightly enhanced with the higher sub carrier spacing. Better system performance can be achieved in higher sub carrier spacing in 5G NR uplink system.

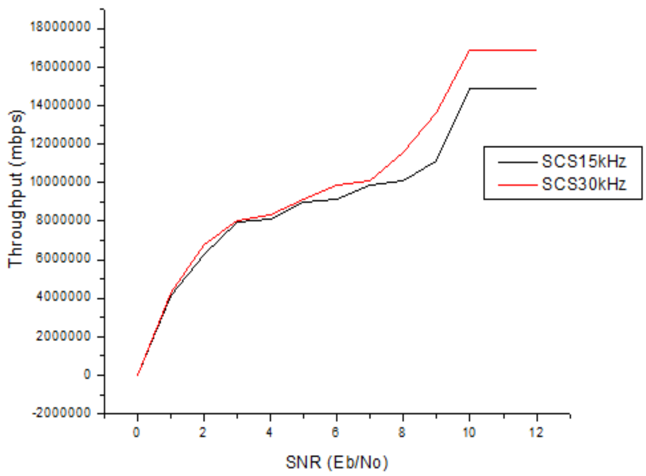

Fig. 8: Throughput of 5G NR at 15 kHz SCS, MCS=16, Modulation= 16 QAM and FFT size 2048.

We have also analyzed the BER at SCS=15 kHz and SCS=30 kHz as shown in figure9. From the BER graphs we have found that the BER decreases with the increase in SNR values and the system performs better in 30 kHz SCS as compared to 15 kHz.

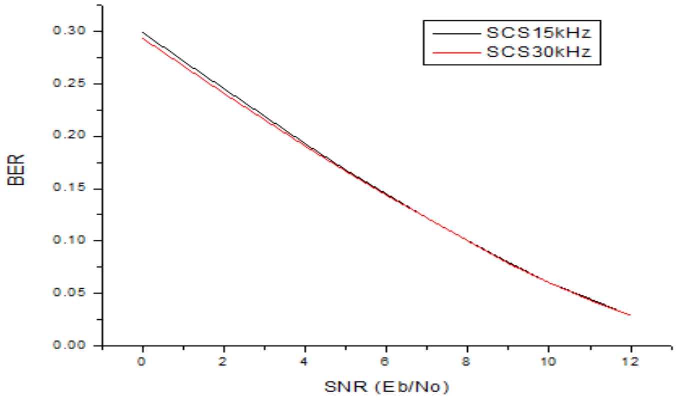

Fig. 9: BER of 5G NR at SCS= 15 kHz and 30 kHz, MCS=16, Modulation =16 QAM and FFT size 2048.

The analysis has also been performed in terms of Block Error Rate (BLER) as shown in figure 10.

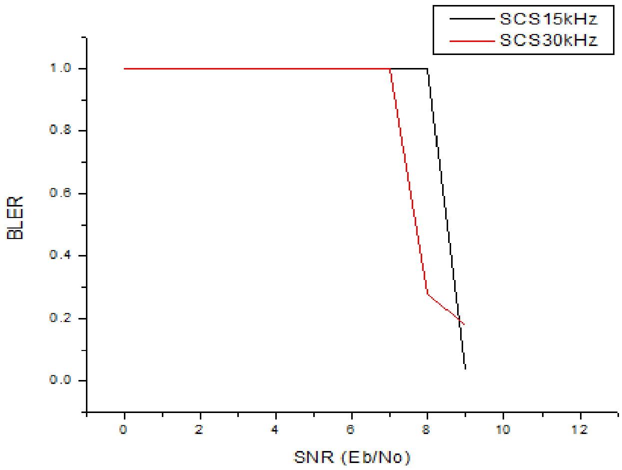

Fig. 10: BLER of 5G NR at SCS= 15 kHz and 30 kHz, MCS=16, Modulation =16 QAM and FFT size 2048.

The obtained graph shows that there is a sharp waterfall decrease in BLER at SNR threshold for the considered 5G NR parameters. The steepness of BLER curves decreases with the sub carrier spacing which determines that the performance of the system increases with the increase in sub carrier spacing.

VI. CONCLUSION

In this article, the 5G NR system has been implemented as per 3GPP guidelines and its performance analysis has been carried out. This paper also provides the overview of 5G NR technical specification for the better understanding to the readers. The performance evaluation of the proposed system has been carried out in terms of Bit Error Rate (BER), Block Error Rate (BLER) and Throughput. We have found that the throughput increases with the increase in sub carrier spacing. From the simulation results, we can analyze that the 5G NR uplink system performs better in higher sub carrier spacing. As per the obtained BER and BLER plots, the interference rejection is more, and signal loss is less as compared to other radio technologies. We believe that this simulation results may help other readers to analyze 5G physical layer more critically. Furthermore, the system can be extended for analysis on different 5G NR physical parameters.

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