Performance Analysis of 3GPP NB-IoT Downlink System towards 5G Machine Type Communication (5G-MTC)

Lalit Chettri, Rabindranath Bera, and Jayanta Kumar Barauh
5G IoT Lab, Sikkim Manipal Institute of Technology, Sikkim Manipal University, Gangtok, 737101, India
Email: {lalitelectricalengineer; rbera50}@gmail.com; jayanta.b@smit.smu.edu.in

Abstract — 5G Technology is the most recent scientific development in wireless communication and it is evolving day by day to meet the demand of near future. As per 3GPP, NB-IoT is chosen as a most promising technology that has been specified for 5G machine type communication (5G-MTC). Since 5G relies on low power wide area networks (LPWAN) and NB-IoT is suitable low power technology in deploying MTC in 5G networks. NB-IoT operates in a licensed spectrum bands and has the potential to guarantee quality of service (QoS). NB-IoT is a specified LPWAN that is based upon system bandwidth of 180 kHz and sub carrier spacing can be considered as 3.75 kHz and 15 kHz as per 3GPP, NB-IoT in downlink system only supports 15 kHz sub carrier spacing. NB-IoT is a top competitor for other low power networks that operates in both licensed and unlicensed spectrum ad 3GPP has specialized NB-IoT as a top priority in 5G networks to support massive machine type communication. In this article, we have studied the technologies for NB-IoT and its implementation in 5G MTC. We also designed a NB-IoT downlink system based on 3GPP guidelines considering sub carrier spacing as 15 kHz and its performance analysis is carried out for MTC scenario. The analysis is performed with two different antenna configurations and compared its performance analysis in terms of BER, FER and QPSK constellation of NPDCCH and NPDSCH after channel estimation. The BER and FER of both NPDCCH and NPDSCH decrease with SNR, resulting the better performance towards machine type communications in 5G.

Index Terms — 5G, NB-IoT, MTC, Downlink, NPDCCH, NPDSCH, OFDMA

I. Introduction

The communication technology is growing day by day and is looking for smart world in near future. Billions of devices and machines will connect and communicate with the concept of internet of things (IoT). massive Machine Type Communication (MTC) is the premium use cases of 5G IoT, where massive machines will be connected within a network [1].The major application of 5G mMTC includes, smart cities, smart factories, e-healthcare, smart agriculture and many more. The data communication in 5G mMTC can occur between devices and server or between the devices [2]. The evolution of NB-IoT in 5G will evolve just like other 5G technologies and serve 5G massive IoT access soon. As per ITU, NB-IoT qualifies the standard of 5G and meets the vision of 5G [3]. To deploy efficient 5G MTC architecture, the most suitable technology needs to be identified for the particular use cases. 5G mMTC is very much suitable in Low Power Wide Area Networks (LPWAN) [4]. There are different LPWAN technologies such as SigFox, e-MTC, LoRa, and NB-IoT. For a better performance in 5G mMTC, 3GPP has specified NB-IoT as a suitable technology [5]. The existing technology cannot fulfill the demand of massive connectivity; hence it is necessary to investigate the appropriate technology and aspirations of the users. Many mobile operators and service providers has set up a dedicated M2M or IoT units to serve the growing demands of cellular use cases. As the market is growing day by day and it is obvious that there are many IoT applications for which the existing cellular networks are not suitable. To support billions of devices with reliability it is necessary to deploy the system with LPWAN and NB-IoT is suitable for low power networks in 5G MTC. NB-IoT operates in lower bandwidth of 180 kHz in licensed spectrum band. The NB-IoT ensures quality of service, better system performance and reliability due to less interference, extended coverage, high capacity, and longer battery life [6]. So far, NB-IoT is a standard LPWAN technology that is especially dedicated to deploying massive machine type communication in 5G networks. NB-IoT is based on OFDMA (orthogonal frequency division multiple access technology with 180 kHz system bandwidth [7]. Working on a bandwidth of 180 kHz with low power consumption LTE control and signals such as NSS, PSS, NPDSCH, NPDCCH, DMRS, NPUSCH, NPUCCH, NPRACH has been introduced to fit in a single physical resource block (PRB) in NB-IoT [8]. NB-IoT has three deployment modes i.e., Standalone, In-Band and Guard band mode. The triangle test-bed for NB-IoT is introduced in [9] and its features are discussed. The NB-IoT positioning is performed and analysis is carried out based on observed time difference of arrival (OTDOA). Radio propagation and interference emulation is tested for normal and robust condition. The healthcare monitoring is a major application of 5G MTC. The NB-IoT in healthcare system is presented in [10]. The performance evaluation is carried out by the authors for both in-band and standalone deployments for over 5000 random samples. The transmission of medical data is presented in terms of latency, which is the average time required to complete the transmission along with the required overhead control information. The authors found

Manuscript received February 25, 2021; revised July 1, 2021.
Corresponding author email: lalitelectricalengineer@gmail.com
doi:10.12720/jcm.16.8.355-362

that the transmission time required for the packet increases with the increase in packet size. NB-IoT can be realized in 5G heterogeneous networks (HetNets). The NB-IoT in HetNets provides the gain up to 24% in average throughput and 72% of energy consumption can be reduced [11]-[14]. The major contribution of this paper includes:

a) Brief review on NB-IoT technology is analyzed and discussed.
b) NB-IoT downlink system is designed as per 3GPP specifications.
c) System performance of NB-IoT downlink system under different antenna configuration is carried out and analysis is done in terms of BER and FER.

II. Overview of NB-IoT Technology

NB-IoT is considered as major low power wide area networks that are specified by 3GPP for various applications in 5G MTC. Different radio technology operates in different frequency band on both licensed and unlicensed spectrum bands. Comparing to other LPWAN technologies, NB-IoT is most suitable in 5G MTC and operates in licensed spectrum band occupying 180 kHz bandwidth in both downlink and uplink with half duplex frequency division duplexing (FDD) [3]. As per 3GPP, NB-IoT mainly operates in three different modes i.e., Standalone, in band and guard band. The three deployments modes of NB-IoT are shown in Fig. 1.

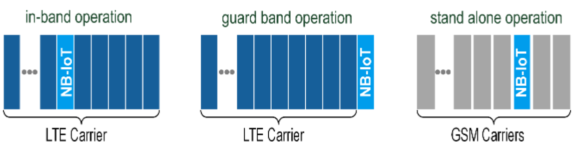

Fig. 1. NB-IoT deployments modes

In standalone operation, bandwidth of 200 kHz provides a guard buffer of 10 kHz on both the sides of its neighboring GSM channels. For standalone operation, the GSM carrier is shown to indicate that this is a possible NB-IoT development. Standalone mode also operates without neighboring GSM carriers. In In-Band mode of operation, it reuses the frequencies that are not used by LTE inside the bandwidth. In Guard-band mode of operation, NB-IoT utilizes resource block in the guard band of an LTE channel. In downlink system, NB-IoT uses downlink numerology from existing LTE technology. Thus, Orthogonal Frequency Division Multiplexing (OFDM) technology with sub carrier spacing of 15 kHz can be used in NB-IoT downlink system [5], [13]. The two-transmission mode is possible in uplink NB-IoT. Multitone transmission in narrowband IoT is based on single carrier frequency division multiple access (SC-FDMA) and single tone transmission is based on FDMA. Each transmission depends on the separation of the spectrum available in orthogonal subcarrier. In single tone transmission, two different sub carrier spacing can be used, 15 kHz and 3.75 kHz whereas multitone transmission uses only 15 kHz sub carrier spacing [5]. mMTC with NB-IoT aims to increase coverage by 20 dB by adapting the means of repetition, adaptation of MCS and transmission power [11]. The NB-IoT downlink is based upon OFDM technology and uses 15 kHz sub carrier spacing and occupies all 12 sub carriers. The resources in downlink are allocated as sub frames with a time slot of 1 ms and each allocated sub frames contains 2 PRBs. The radio channel in NB-IoT is estimated with the use of narrowband reference signal (NRS) [15]. In the NB-IoT uplink, either 3.75 kHz or 15 kHz sub carrier spacing can be used in resource grid [16]-[21]. The resource grid with sub carrier spacing in NB-IoT is shown in Fig. 2.

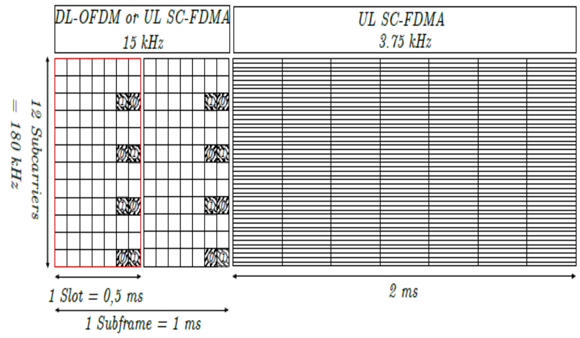

Fig. 2. Resource grid of NB-IoT uplink and downlink system

The NB-IoT in both downlink and uplink consists of 1024 hyperframes and each hyperframe is divided into frames of 10 ms each. Each frame is divided into sub frames of 1 ms each and each sub frames are divided into slots of 0.5 ms each. In 3.75 kHz sub carrier spacing there is no concept of sub frames. The frame structure of 15 kHz sub carrier spacing for both uplink and downlink is shown in Fig. 3.

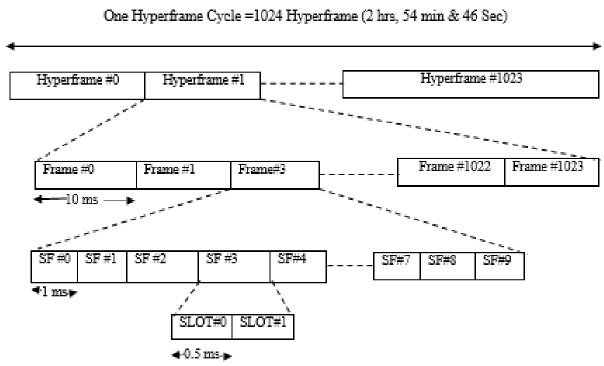

Fig. 3. Frame structure of NB-IoT with sub carrier spacing of 15 kHz in both downlink and uplink.

A. *NB-IoT Downlink Signals and Channels*

The physical channels in NB-IoT are designed based on legacy LTE. The downlink consists of physicals signals such as NPSS (Narrowband Primary Synchronization Signal) and NSSS (Narrowband Secondary Synchronization Signal) and NRS (Narrowband Reference Signal) [12]. It helps the users to synchronize downlink to the NB-IoT cell. The NPSS in downlink is used for synchronization in both time and frequency domain [16]. The NSSS is used to detect the identity of cell and generates maximum information about the frame structure. The synchronization signals in NB-IoT used to perform cell search. The NRS in NB-IoT is used to provide the phase reference for demodulation in downlink channel. NPDCCH (Narrowband Physical Downlink Control Channel) is used in carrying downlink control information [22]. It occupies full one downlink sub frames and repetition may be used to improve coverage. It further carrier the HARQ information. The NPBCH (Narrowband Physical Broadcast Channel) carries the master information block (Master Information Block) and it is transmitted in sub frame #0 in every frame. The NPDSCH carries data and information that is not transmitted in NPBCH i.e., SIBs-NB, paging or dedicated RRC. The NPDSCH uses QPSK modulation scheme only with single HARQ process. The TBS in NPDSCH is ≤ 680 bits. The repetition up to 2048 can be used to achieve maximum coverage and supports only 15 kHz sub carrier spacing [17].

B. NB-IoT Uplink Signals and Channels

In NB-IoT uplink, the DMRS (Demodulated Reference Signal) is multiplexed with the data so that it is only transmitted in Resource Unit (RU) which contains data transmission. DMRS in NB-IoT uplink is used for channel estimation. In NPRACH the preamble is transmitted. The preamble is based on symbol group on a single carrier. Each symbol in NPRACH consists of a cyclic prefix followed by 5 symbols. The preamble is defined in two format, format 0 and format 1. The NPRACH preamble is repeatable and can extend up to 128 for coverage extension. The NPUSCH is used to transport uplink user data and control information and it supports format 0 and format 1. NPUSCH supports 15 kHz and 3.75 kHz in single tone transmission [16], [17].

III. NB-IoT Downlink System Design

The NB-IoT downlink (DL) transmitter is designed using PBCH and it is used to add the cyclic redundancy check to the broadcast channel bits. In each firing, PBCH CRC encoder consumes the token and A+L tokens are generated where 'A' is the transport block size (TBS) in evert transmission time interval (TTI) of 40 ms and 'L' is the number of parity bits and L =16. The transmitter and receiver of NB-IoT downlink for link level simulation is shown in Fig. 4.

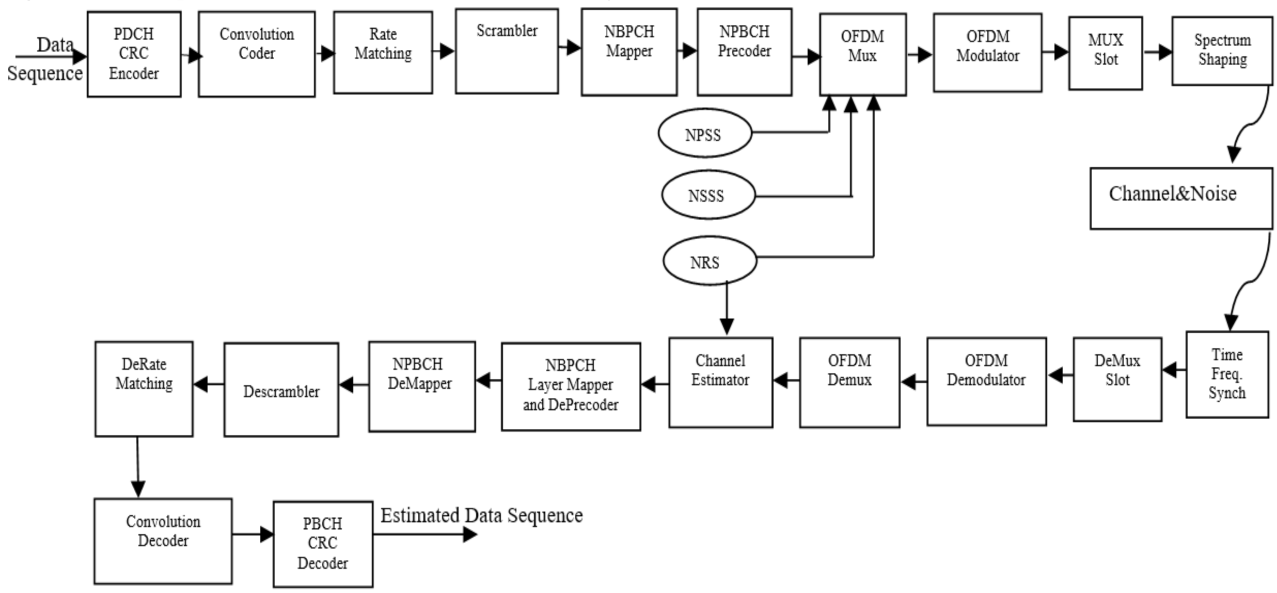

Fig. 4. Transmitter and receiver of NB-IoT downlink for link level simulation

In this system, we have used PBCH block size as 34. The parity bits are computed and further attached to the BCH transport block setting with L=16 bits. After the CRC attachment, the input bits are scrambled according to e-node B transmit antenna configuration. The convolutional encoder performs the tail biting convolutional coding with the constraint length 7. Further, the NB-IoT NBPCH is rate matched and scrambled. The rate matching consumes 3*(A+16) tokens, and 1600 tokens are generated, where A is 34 and TTI is 640 ms and 1600 is the transmitted bits on the PBCH of 64 radio frames with repetition. In this system we have considered the physical signal such as NPSS, NSSS and NRS as per 3GPP specifications [16]. The sequence $d_l(n)$, that is used for NPSS is generated from a frequency domain with Zadoff-Chu sequence and the sequence generation is given by,

$$d_l(n) = s(l)\, e^{-j\,\pi u n(n+1)/11}, \quad n=0,1,....10; \qquad (1)$$

here μ= 5 is Zadoff-Chu root sequence and s(l) are the different symbol indices.

The sequence d(n) for NSSS is also generated from frequency domain Zadoff-Chu sequence and the sequence is generated when,

$$d(n) = b_q(m) e^{-j\pi\theta_f n} e^{-j\pi u n'(n'+1)/131} \qquad (2)$$

where, n = 0,1,……131

$\acute{n}$= n mod 131
m = n mod 128
u = N_{ID}^{Ncell} mod 126 + 3
q= [N_{ID}^{Ncell}/126]

The narrowband reference signal sequence for NB-IoT downlink is defined by,

$$r_{l,Ns}(m) = 1/\sqrt{2}\,(1\text{-}2.\ C\,(2m)) + j\ 1/\sqrt{2}\,(1\text{-}2.\ C\,(2m+1))$$

where, N_s is the number of slots within a radio frame and l is the OFDM symbol within the slot.

$$m = 0, 1, \ldots\ldots 2N_{RB}^{max,DL} - 1$$

the NPSS will be mapped to first 11 resource element in each OFDM symbols of the last 11 the OFDM symbols when sub frame is equal to 5 and the NSSS will be mapped to last OFDM symbols when sub frame number equals to 9 and radio frame number is even. The OFDM symbol mux is used to multiplex NPDCCH, NPDSCH, NPBCH, NPSS, NSSS, NRS in one OFDM sub frame. In NB-IoT receiver, the time frequency synchronization is used to achieve the downlink symbol timing synchronization and frequency offset estimation [16]. OFDM symbol demux is used to demultiplex all the downlink channel and signals from one OFDM subframe. The channel estimator is used to estimate the NB-IoT downlink channel response with NRS. The MMSE channel estimation method is used to determine the channel response. The NBPCH layer demapper and de precoder is used for layer demapping. It consists of MIMO layer demapper and MIMO precoder. The NPBCH demapper demaps the uniform QPSK to bits used for NB-IoT channel coding [21]. The NB-IoT NPBCH descrambling is used to perform in receiver section for the benefit of soft decision decoding. The rate dematching is performed followed by Viterbi decoder. The Viterbi decoder is used for convolutional decoding. The input information sequence with a Viterbi is used. In this algorithm the entire received sequence is compared with all the possible transmitted sequence. The number of transmitted sequences increases exponentially with time, so an efficient system of comparing is necessary. It is also used to measure the similarity of received sequence by calculating the path metrix. Finally, the CRC decoder is used to decode the NB-IoT NPBCH. The wireless fading channel with noise density is used to transmit the input sequence for 1X1 antenna pattern and MIMO channel with noise density for 2X2 antenna pattern following the 3GPP specifications.

IV. Results and Discussion

The performance analysis of NB-IoT downlink is carried out for standalone mode of operation with antenna configuration 1x1 and 2x2. The NB-IoT downlink system is designed with payloads of 104 with NPDCCH and NPDSCH repetition of 64. As per 3GPP, the modulation for NB-IoT downlink is considered as QPSK. The analysis is performed in terms of BER, FER, and constellation of NPDCCH and NPUSCH. The design and simulation parameters for NB-IoT downlink is shown in Table I.

TABLE I: SIMULATION PARAMETERS

Parameter	Value
Carrier Bandwidth	`900 MHz
System Bandwidth	180 kHz
Operation Mode	Standalone
Antenna Pattern	1x1, 2x2
Sub- Carrier Spacing	15 kHz
Modulation Type	QPSK
Window Type	Raised Cosine
NPDSCH Repetition	1
NPDCCH Repetition	1
Channel Estimation	MMSE
Payload Bits	104
Transmission Mode	Single Tone
SNR in Frequency Domain	4 dB
Cyclic Interval	4

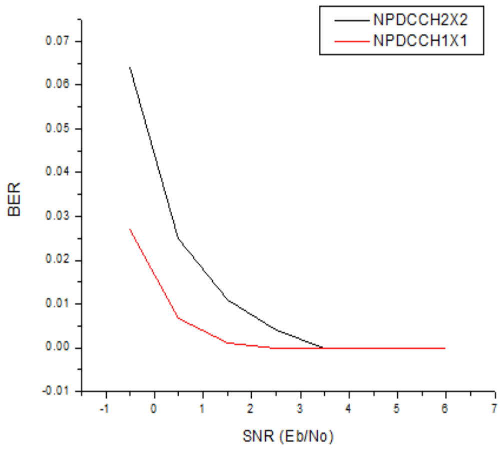

Fig. 5. BER of NPDCCH, Antenna= 2X2 and 1X1, Mod=QPSK, Repetition=1, Operation mode= Standalone

Fig. 5 shows the BER of NPDCCH and NPDSCH of 1X1 antenna pattern and observe that the BER in both the case are decreasing with the increase with SNR which shows that NB-IoT performs well in uplink system. Higher the SNR better will be the BER. The main source affecting BER are adaptive white Gaussian noise (AWGN) and ICI. In this simulation, the bits are successfully transmitted from transmitter to receiver with less error.

From the Fig. 6, we have analyzed that the FER of NPDSCH and NPDCCH decreases with SNR providing the better transmission of data in NB-IoT system with minimum interference. For the simulation, we have considered the system bandwidth of 180 kHz and 15 kHz subcarrier spacing as per 3GPP. The study is performed for NPDCCH and NPDSCH in two antenna pattern and found that the BER of both NPDCCH and NPDSCH is slightly more in 2X2 configuration as compared to 1X1. Furthermore, we have also compared the system in terms of FER and found that FER is also decreased in 1X1 antenna pattern. From the simulations results, we found that the NB-IoT system gives better performance in 1X1 antenna pattern as compared to 2x2 pattern in 5G MTC scenario.

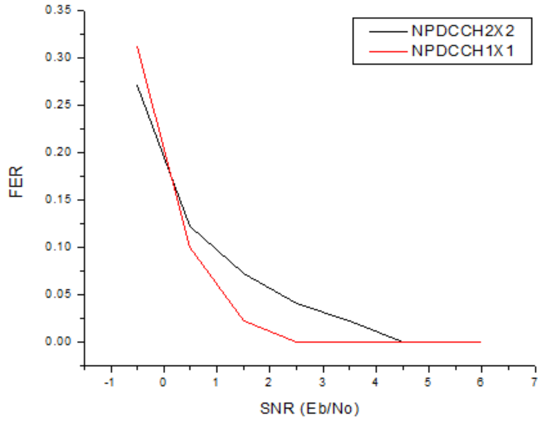

Fig. 6. FER of NPDCCH, Antenna= 2X2 and 1X1, Mod=QPSK, Repetition=1, Operation mode= Standalone

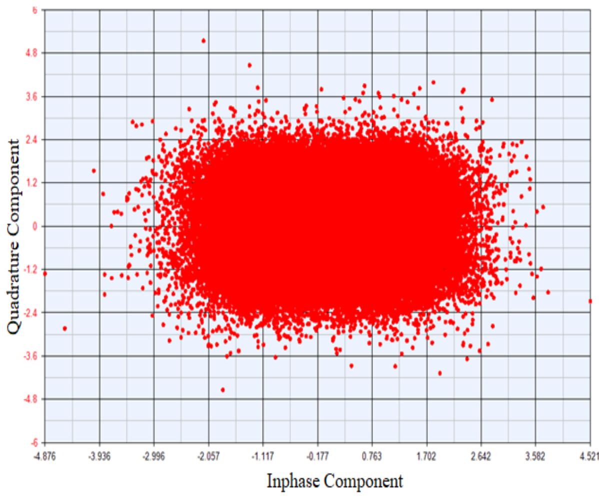

Fig. 7. Constellation of NPDCCH at Antenna=1X1, Mod=QPSK, Repetition=1, Operation mode= Standalone

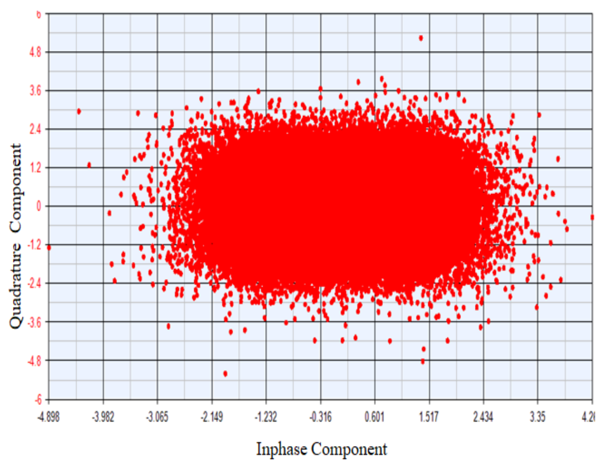

Fig. 8. Constellation NPDCCH at Antenna=2X2, Mod=QPSK, Repetition=1, Operation mode= Standalone

Fig. 7 to Fig. 10 shows the constellation of NPDCCH and NPDSCXH for both 1X1 and 2X2 antenna pattern in NB-IoT uplink and found that all the symbols are transmitted in the system as a collection of points. From the obtained graph, we can see the probability of error is low. The bandwidth requirement is very low in NB-IoT downlink system. From the obtained received constellation diagram of NPDSCH and NPDCCH we found that the selected antenna pattern is suitable in NB-IoT for 5G MTC and it is more efficient in terms of bandwidth perspective. Also, we found that that the interference is low in NB-IoT downlink system using QPSK modulation. The QPSK modulation in NB-IoT downlink is used for data improvement. The obtained constellation diagram indicates the transmission of input data with reduced complexity.

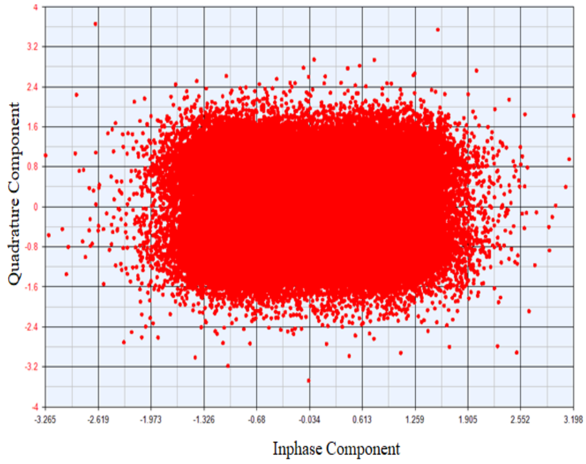

Fig. 9. Constellation NPDSCH at Antenna=1X1, Mod=QPSK, Repetition=1, Operation mode= Standalone

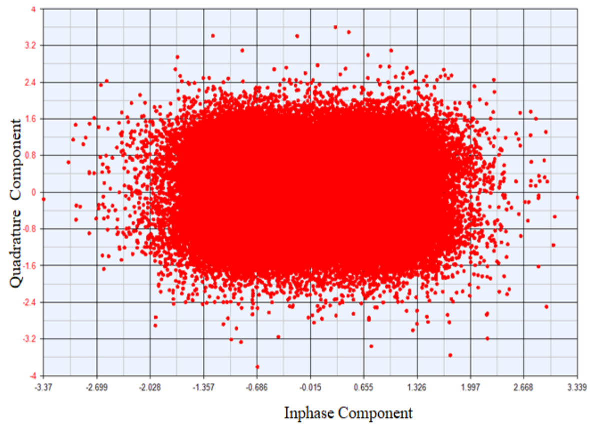

Fig. 10. Constellation NPDSCH at Antenna=2X2, Mod=QPSK, Repetition=1, Operation mode= Standalone

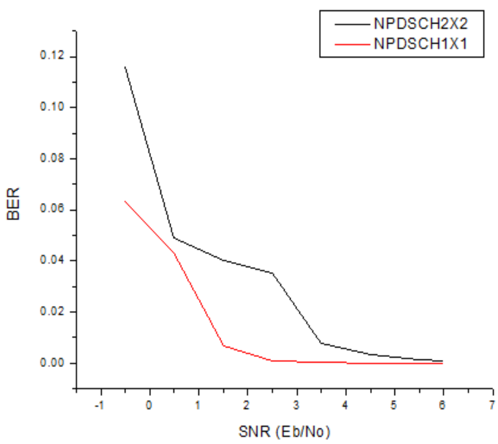

Fig. 11. BER of NPDSCH, Antenna= 2X2 and 1X1, Mod=QPSK, Repetition=1, Operation mode= Standalone

Similarly Fig. 11 and Fig. 12 shows the SNR vs BER of NPDCCH and NPDSCH of 2x2 antenna pattern and the graph shows that the BER decreases with SNR resulting the better performance of the system in NB-IoT.

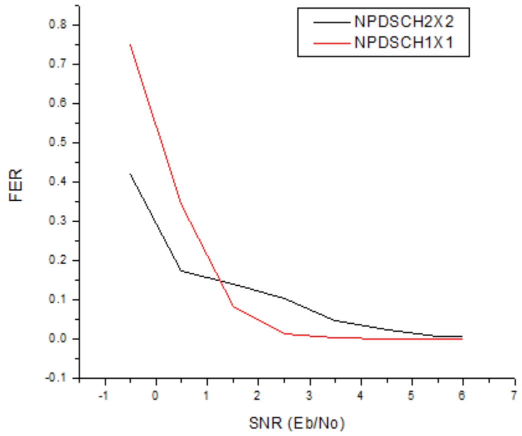

Fig. 12. FER of NPDSCH, Antenna= 2X2 and 1X1, Mod=QPSK, Repetition=1, Operation mode= Standalone

As seen from the results obtained above the interference tolerance is more in NB-IoT downlink system due to the higher transmission power. Whereas in NB-IoT uplink, due to lower transmit power the interference tolerance is low and even small interference provides more impact in data transmission.

V. Conclusion and Future Research Scope

A. Conclusion

In this article, we have discussed the overview of NB-IoT technology and its possible deployment in 5G machine type communication. Different modes of operation of NB-IoT are discussed. The frame structure supporting both uplink and downlink in NB-IoT is discussed. The resource grid for both uplink and downlink in NB-IoT technology is shown. From our analysis, we can conclude that NB-IoT downlink operates in sub carrier spacing of 15 kHz with OFDM technology and NB-IoT uplink operates in sub carrier spacing of 3.75 kHz and 15 kHz with SC-FDMA technology. Also, the link level simulation of NB-IoT downlink system is considered as per 3GPP specifications. We have considered QPSK modulation since it specialized for NB-IoT downlink that supports single tone transmission. The MMSE method is considered for channel estimation. We have simulated the NB-IoT downlink system with two antenna configuration (1X1 and 2X2) and compared the performance of NPDCCH and NPDSCH in terms of BER, FER and constellation. From the results obtained, we found that NB-IoT with 1X1 antenna performs well as compared to 2X2 in 5G MTC. From the constellation diagram we observe that the possible symbols are successfully transmitted in both NPDCCH and NPDSCH. The QPSK modulation in NB-IoT downlink is more efficient in terms of bandwidth perspective. From the results obtained after simulation, we can conclude that the antenna configuration of NB-IoT downlink is suitable for successful deployment of low power 5G MTC.

B. Future Research Scope

There is a huge scope of research in 5G and NB-IoT towards machine type communications. Some of the research areas that can contribute in future MTC are:

a) Co-existence of NB-IoT with 5G NR for achieving high data rates and reliable communication.
b) NB-IoT can be used to increase the capacity of 5G system.
c) NB-IoT can relate to 5G core.
d) With the low bandwidth and sub carrier spacing, NB-IoT can be used in 5G MTC for transmission of data with low power consumption and increased data rate.
e) 5G NR technology can be suitable in deployment of 5G use cases with the use of MIMO and mmWave technology.

Conflict of Intrest

We declare that there are no conflicts of interest in publishing this article.

Author Contributions

Lalit Chettri is the main author; he explored the information on 5G Technology and conducted the research which is under the supervision of Prof. Rabindranath Bera, analyzed the result cooperatively. Jayanta Kumar Barauh has contributed in writing this research paper. All authors have approved the final version of the paper.

References

[1] P. A. Maldonado, J. Prados, P. Amelgeiras, and J. Navarro-Ortiz, “Narrowband IoT data transmission procedures for massive machine type communications,” *IEEE Networks*, September 2017.

[2] C. Bockelmann, T. Svensson, and C. Stefanovic, “Masssive machine-type communication in 5G: Physical and MAC-layer solutions,” *IEEE Communication Magazine*, June 2016.

[3] A. Höglund, X. Lin, O. Liberg, A. Behravan, *et al.*, “Overview of 3GPP release 14 enhanced NB-IoT,” *IEEE Networks*, November-December 2017.

[4] K. Mekki, E. Bajic, F. Chaxel, and F. Meyer, “A comparative study of LPWAN technologies for large-scale IoT deployment,” *ICT Express*, 2018.

[5] P. A. Maldonado, J. Prados, P. Amelgeiras, and J. Navarro-Ortiz, “Narrowband IoT data transmission procedures for massive machine type communications,” *IEEE Networks*, September 2017.

[6] H. Wang and A. O. Fapojuwo, “A survey of enabling technologies of low power and long-range machine-to-machine communications,” *IEEE Communications Surveys & Tutorials*, vol. 19, no. 4, 2017.

[7] K. Technologies, *Narrowband IoT (NB-IoT): Cellular Technology for the Hyperconnected IoT, Application Note*, Published in USA, August 8, 2017.

[8] W. Yang, M. Wang, J. Zhang, J. Zou, M. Hua, T. T. Xia, and X. You, "Narrowband wireless access for low-power massive internet of things: A bandwidth perspective," *IEEE Wireless Communications*, June 2017.

[9] R. Mozny, P. Masek, M. Stusek, K. Zeman, A. Ometovy, and J. Hosek, "On the performance of narrow-band Internet of Things (NB-IoT) for delay-tolerant services," in *Proc. 42nd International Conference on Telecommunications and Signal Processing*, 2019.

[10] H. Malik, M. M. Alam, Y. L. Moullec, and A. Kuusik, "NarrowBand-IoT performance analysis for healthcare applications," *Elsevier B.V., Procedia Computer Science*, 2018, pp. 1077–1083.

[11] A. D. Zayas, F. J. R. Tocado, and P. Rodr ́ıguez, "Evolution and testing of NB-IoT solutions," *MDPI, Appl. Sci.*, November 2020.

[12] C. Bockelmann, N. K. Pratas, G. Wunder, S. Saur, *et al.*, "Towards massive connectivity support for scalable mMTC communications in 5G networks," *IEEE Access*, 2018.

[13] S. A. Gbadamosi, G. P. Hancke, and A. M. Abu-Mahfauz, "Building upon NB-IoT networks: A roadmap towards 5G new radio networks," *IEEE Access*, October 28, 2020.

[14] H. Malik, J. L. R. Sarmiento, M. M. Alam, and M. A. Imran, "Narrowband-Internet of Things (NB-IoT): Performance evaluation in 5G heterogeneous wireless networks," September 2019.

[15] Y. Sano, S. Okuyama, N. Lizasa, T. Takada, K. Ardo, and N. Fujimura, "5G radio performance and radio resource management specifications," *NTT Docomo Technical Journal*, vol. 20, no. 3, January 2019.

[16] *3GPP TS 36.211 v14.2.0*, Physical Channels and Modulation, March 2017.

[17] *3GPP TS 36.211 v13.2.0*, Physical Channels and Modulation, June 2016.

[18] X. J. Yao, L. Wang, Z. Ming, K. Wu, and L. Chen, "Narrowband internet of things: Evolutions, technologies, and open issues," *IEEE Internet Things Journal*, vol. 5, pp. 1449–1461, 2018.

[19] M. Chen, Y. Miao, Y. Hao, and K. Hwang, "Narrow band internet of things," *IEEE Access*, vol. 5, pp. 20557–20577, 2017

[20] 3GPPR1157398, "NB-IoT-System level evaluation and comparison-standalone," Technical Report, Ericsson, 2015.

[21] R. C. J. Neto, E. B. Rodrigues, and C. T. Oliveira, "Performance analysis of resource unit configurations for M2M traffic in the narrowband-iot system," *Brazilian Communications and Signal Processing Symposium*, 2017.

[22] Y. E. Wang, X. Lin, A. Adhikary, A. Gr ̈ovlen, Y. Sui, Y. W. Blankenship, J. Bergman, and H. Shokri-Razaghi, "A primer on 3GPP narrowband Internet of Things (NB-IoT)," *CoRR*, 2016.

Lalit Chettri received the bachelor's in engineering degree in electrical and electronics engineering from Visveswaraya Technological University, Karnataka, India, in 2014, and the MTech. degree in digital electronics and communication engineering from Sikkim Manipal University, Sikkim, India, in 2016, where he is currently pursuing the Ph.D. degree with a dissertation titled "Design of 5G wireless technology enabling machine type communication." He has been involved in 5G research in 2016 and his research work on 5G has been published in different international journal and conference proceedings. His current research interests include 5G technology, cognitive radio, Internet of Things, green communications, industrial Internet, telemedicine, and real-time applications of 5G.

Dr. Chettri was a recipient of the "State Felicitation" from Government of Sikkim in 2017 for his excellency in 5G research and the "Special Performance Award" presented by Sikkim Manipal Institute of Technology in 2016 for his contribution in wireless research. He has also been conferred with the "National Youth ICON Award" by the International Youth Committee on September 27, 2019 for his contribution in Science and Engineering Research He is also the recipient of "Young Scientist Award" conferred by Science Father, Chennai in 2020. He also served as a Technical Program Committee Member for the International Conference on Innovative Applied Energy in March 2019 held at the University of Oxford, London. He also serves as a reviewer for different international journals and conference proceedings and attends different Government Organizations and Technical Institutes as a resource person.

Prof. (Dr.) Rabindranath Bera received B. Tech degree in1982 from University of Calcutta, M. Tech in radio physics and electronicsfrom University of Calcutta in year 1985 & Ph. D degree from the Calcutta University in year 1997. India for Millimeter wave system development.

He worked as a senior engineer in research and development at M/S Sonodyne TV co from 1982-1998. He also served as a Dean, (R&D) Research and Development at Sikkim Manipal Institute of Technology from 2008 to 2011 and Head of Department, Electronics and Communication department at Sikkim Manipal Institute of Technology from 2004 to 2018. Presently, he is a professor at Sikkim Manipal University, Sikkim, India.

He has also been Rewarded as 'BOSE FELLOW' by URSI, Japan and 'IAS Fellow' by Govt. of India for Millimeter wave system development. He has guided more than 20 PhD scholars across India.

Jayanta Kumar Baruah was born in 1977 at Mangaldai, Assam, India. He received his B.E. degree from Jorhat Engineering College and M.Tech. from Tezpur University in the year 1999 and 2002, respectively.

His research interest includes mmwave communication, 5G, cognitive radio, radar, internet of things.

Currently working as Associate Professor, Department of E&C Engineering, Sikkim Manipal University, Sikkim, India. Wireless Mobile Communication, Remote Sensing and cognitive radio are his area of specializations. He has published 4 papers in international journals and conferences.