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Enhancing Performance of NB-IOT Cellular LTE Network using OFDM Modulation for WAN

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***Abstract*—Cellular licensed networks are now widely being used for Internet of Things (IOT) network deployment. The prime goal is to enhance the coverage and capacity of the data usage. Any performance enhancement is highly recommended for these IOT networks. The NB-IOT cellular communication network is a narrow-band IOT technology developed for wide-area network (WAN}) applications. NB-IOT can be used to upload data to internet servers by practically all mobile devices. The physical layer performance of the NB-IOT network is evaluated in this research using the efficient Orthogonal-Frequency Division Multiplexing (OFDM) technology used in long-term evaluation (LTE) communication standards. For larger capacity OFDM system design, a predefined set of phase offsets and bandwidth is taken into account. The higher FFT levels' bit error rate (BER) performance is compared to M-PSK modulation approaches.**

***Index Terms*— NB-IOT, LTE, OFDM, FFT, Cellular Network, AWGN, Phase Offset, BER.**

I. Introduction

Until last decades communication was solely reliant on licensed users. However, poor bandwidth use is caused by a lack of traffic density. However, technological advancements have made it feasible to share the licensed band for services like as IOT networks in order to improve WAN coverage.IOT-services present a slew of issues, including communication, coverage, energy efficiency, economics, and management. The technological challenges based on parametric study to increase communication capability of huge IOT services at the physical layer are the subject of this article.

As a result, this paper looked into the unavoidable phenomena of larger sub-carriers depending on optimal LTE physical layer communication performance for the NB-IOT system [1]. The improved data payload capabilities expected to go from Mb's to Gbps may be due to efficient modulation across the physical layer.OFDM satisfies the LTE need for spectrum flexibility [1], while also allowing for cost-effective solutions for large networks with sustained high rates.

The NB-IOT is a cellular based LPWAN network technology also abbreviated as LTE-M2. It is used as option to basic GSM band. The major benefits of adopting NB-IOT are as follows;

- **Reliability** : By deploying NB-IoT with better guaranteed resource allocation will results increased reliability and controlled service Quality (QoS).
- **Cost Effective:** Less power and nerrow bandwith requirments along with buffering of NB-IOT may leads to the significant cost saving.
- **Coverage Enhancement:** Due to celular network the global wide coverage is achievable.

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- **Power Efficency :** NB-IOT uses low power devices thus overall power efficient.

Figure 1 Frequent Applications of the NB-IOT cellular networks

II. APPLICATIONS OF NB-IOT

Because cellular-IoT (C-IoT) technology will be the newest market entrant, it's critical to know C-IOT connectivity challenges compare to existing cellular, and low-power wide area network (LPWAN) technologies NB-IOT. At the same time, establishing IOT solutions based on C-IOT technology. Mostly NB-IOT is used for >10 KM indoor or extremely deep underground environments where conventional cellular network doesn't have coverage. There are wide ranges of possible applications of NB-IOT based networks [2]. The most frequent fields of applications are represented in the Figure 1. These applications include remote Health Care monitoring, smart city uses as traffic monitoring, smart packing, or tracking, IOT based precision agricultural and environmental and hazard monitoring systems.

Therefore, this paper primarily focused on the efficient design of the Physical layer modulation for the capacity and performance enhancement of NB-IOT based networks for WAN. In this context the systematic experimentations have been performed for optimum parameter selection for performance enhancement.

III. LITERATURE REVIEW

Ther are various research have been focused to develop and enhance LPWaN performance in recent years. The relivant related literature are reviewd in this section. The clasification of performance enhancement methods for NB-IOT are shown in Figure 2 and are reviewd sequentiaally. Bradlly performance enhancement is achieved by considering mobality, channel etimation, capacity enhancement aad BER evaluation.

A. Review of LTE-OFDM based Methods

The reliability of the network is extensively examined by the K Riyazuddin et al. [1]. The signal-to-noise ratio and bandwidth efficiency are used to assess the system by the Riyazuddin and his colleagues

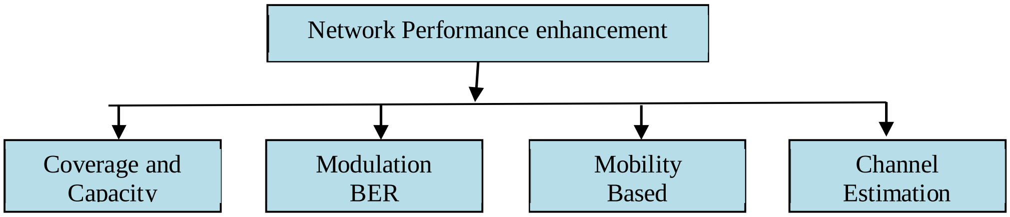

Figure 2. Classification of the Performance Enhancement methods for NB-IOT

They utilized MATLAB to run the systems simulation. With the help of a prepared algorithms, the simulation is carried out in both the indoor and outdoor environments of LTE. They simulated BER for different bandwidths in both the indoor and outdoor LTE environments for bandwidths of 5 to 25 MHz wirh the 5 MHz increments. A Wavelet-based LTE-MIMO-OFDM modulation technique with multi equalisation is developed by J. Simon et al. [4]. This enhances the system's performance by lowering PAPR and BER, Result,show how well scheme performs when compared to conventional MMSE and Multi equaliser MMSE, It can be seen that BER, Uploading throughput, Downlink throughput, and bandwidth efficiency have higher performance curves than that of other wavelets.

LTE downlink performance was evaluated and analyzed by N. R. Raajan et al. [5] method employs the Synchronization algorithm to improve the OFDM system's performance. It is used in conjunction with MIMO to get a higher data rate while simultaneously increasing channel capacity. They consider N transmitters and M number of receivers, N*M channels are calculated. Sharma et al. [6] believe that OFDM is chosen as the best technique for meeting and overcoming both problems. The performance of the OFDM system is presented in this work, which achieves a high data rate. BPSK, QPSK, 16QAM, and 64QAM are the modulation techniques utilized herein order to address the expectations of NB-IoT use cases, A. TUSHA et al. [7] investigate OFDM using index modulation (OFDM-IM). Data is carried by modulated subcarriers as well as indices for fractionally utilized subcarriers with OFDM-IM systems'. B. Mwakwata, et al. [8] presents a complete summary of the NB-IoT standardization's architecture and revisions. It also proposes specific research advancements from the physical and MAC layers' perspectives'. Sharma et al. [9] offer a transceiver to meet all requirements for very low power and delay insensitive (VNB-IoT) applications.Nghia H, et al. [10] have investigated a hybrid OFDM based on index modulation for approach of (NB-IoT). Design for high value of SNR.

B. Review of Channel Estimation Methods

Downlink channel estimate (CE) for NB-IoT is discussed by J. W. Won et al. [11]. The averaging technique, interpolation approach, and quasi-interpolation approach are the three basic approaches used in IT. Because there are so many different types of NB-IoT CE methods, comparing them can help determine which is the best. As a result, the study concludes that the average strategy is the most effective. The outcome demonstrates this plainly. As a result, when it comes to cost optimization, calculating capacity, and better performance, this technique is best recommended.

C. Review of Mobality based Methods

The operational parameters of NB-IoT cell reselection were described by Y. Moon et al. [12]. It also includes a mechanism for using test results to optimize cell reselection settings. The tests are conducted in both a test-bed and a real-world operating field environment. As NB-IoT becomes more popular, mobile operators strive to deliver the finest NB-IoT services. NB-IoT mobility has been subjected to a number of performance tests in both a test-bed and a commercial network environment. As a result, a shorter messaging DRX cycle and a shorter reselect timer may result in improved NB-IoT mobility.Chen, X., et al [13] have given the brief introduction of the Cellular IOT convergence. Yuxiang Lv, et al. [14] presented method of channel synchronization for designing NB-IOT network.Yiteng [15] and Han, [16] have presented the low complicity methods for NB-IOT channel identification for OFDM based design.

Overall, it is found that efficient OFDM-LTE design may significantly improve the capacity of IOT networks thus is the focus of this research.

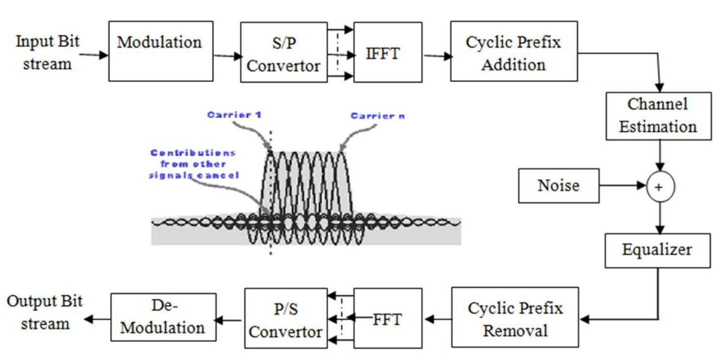

Figure 3 OFDM system Architecture for LTE based NB-IOT

IV. LTE-OFDM Architecture

Paraller multi-sub carrers are produced by OFDM based modulations and bock of data streams are trasmitted orthogonally. The architecture of the OFDM is shown in Figure 3 for NB-IOT PHY layer. It seans OFDM divides the available bandwidth channel into k numbers of frequency sub-carriers based on IFFT that seem to be orthogonal to one another.Each baseband subcarrier is of the form

$$\phi_k(t) = ej2f_k^t \qquad (1)$$

The incoming data stream is divided into N blocks of reduced data rates with parallel data streams.

$$s(t) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} x_k \emptyset_k(t), \qquad 0 < t < NT, \qquad (2)$$

These data stream are then PSK modulated and transmitted it on their own sub-carriers.The subcarrier frequencies f_k are equally spaced as $f_k = \frac{k}{NT}$and are generated using IFFT as

$$s(k) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} x_k\, e^{j2\pi\frac{nK}{N}t} \qquad 0 < t < NT \qquad (3)$$

As a result, the symbol duration has increased. Inter Symbol Interference (1ST) induced by multipath propagation reduces as the signal duration increases. It is possible to send multiple low-rate data streams in parallel rather than just single higher-rates the data streams. This in turn saves the time of individual sub data streams also. This process therefore completely avoided ISI by selecting the correct guard interval. .thus it is expected to minimize the BER usng optimum design parameters.

V. Results and Discussion

In this paper series of experiments have been performed for setting the optimum design parameters. The Range of the parameters for the optimum performance are given in the Table 1. The evacuation is performed for higher FFT size for capacity enhancement. The initial validation results are shown for Symbol Error rate (SER) in Figure 4.

TABLE I. DESIGN OPTIMUM PARAMETERS SELECTED F BER MINIMIZATION

S. No.)	Parameter Description		
	Details	Notations	Value/Range
8	Size of the FFT	N	1024-2048
2	Kind of Physical Layer <modulation	/OFDM	For LTE
3	Number of Sub carriers	S	50 and 75
4	Selected Phase Offset	ρ	7.5 degree
5	Number of Castellation or PSK order.	M	2 t0 16
6	Range of Cyclic Prefix	Ncep	1or 2

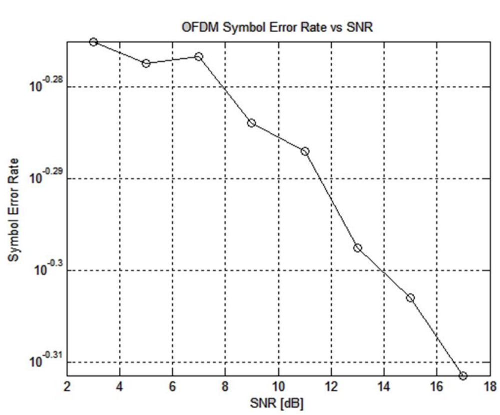

Figure 4. Validation of BER performance for the LTE-OFDM

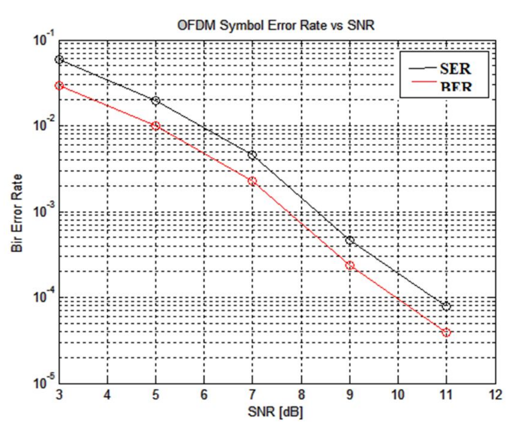

Figure 5. Comparison of the SER and BER for LTE-OFDM

A. Validation of OFDM System

The random values of the number of FFT and castellation order are used for validating the SER of the OFDM system first for NB=IOT, the validated SER result is shown in Figure 4 for SNR upto 17 dB for N=1024, M=4 and CP length of 16 for 50 sub carriers. It is observed from Figure 4 that there is significant chance of performance enhancement based on the optimum selection of the parameters.

B. SER Vs BER Comparison

An experiment is performed for validated parameter to simulate BER of LTE-OFDM the results are plotted in the Figure 5. It is clear that BER is having same pattern as of SER and is lower than it. The minimum BER is obtained at SNR of 17 dB with order of 0.3 x 10^{-3}. It needs significant performance improvement.

C. BER for Different FFT size and PSK ORDER

A simulation is performed for different higher order FFT sizes and larger sub carrier numbers for capacity enhancementof NB-IOT system. The BER is plotted in the Figure 6 for M=4 and cyclic prefix samples are Ncp=16 for phase offset=7.5, for NB-IOT. The FFT size is increased from the 1024 to 2048 for simulation. It is found that minimum BER is achieved for N=2048 for M=4. The minimum SER and the BER performance achieve as per Figure 6 are shown in the Table 2 for quantitative comparison. For N-2048 the less BER is achieved at almost at 60 % SNR. It is also clear from Tale 2 that even doubling the N-FFT value the BER is less. Although, the results are random in nature, and due to simulation may change.

The simulation results are shown for the comparison of BER for M=2 sub carriers S=75 for phase offset=7.5 for N =2048 and 1024 in the Figure 7. This can be observed that even increasing the sub carrier number 1.5 times the BER is almost same there is very minor reduction in rate.

VI. CONCLUSIONS

The prime focus of the paper is to enhance the physical layer performance of the NB-IOT based on LTE standards. The capacity is increased by considering the higher FFT size for LTE-OFDM modulation. The OFDM modulation performance is evaluated based on the BER and SER comparison. Various NB-IOT physical layer performance enhancement methods are reviewed. The order of PSK, M and number of FFT is increased for capacity enhancement. The fixed phase offset is considered for evaluation. The cyclic prefix (CP) length is tuned for optimum BER performance.

Initially basic OFDM is validated and the minimum BER is obtained at SNR of 17 dB with order of 0.3 x 10^{-3}. It needs significant performance improvement. Therefore, parameters are tuned for different higher order FFT sizes and larger sub carrier numbers for capacity enhancement of NB-IOT system. The minimum BER is achieved for N=2048 for M=4. For N-2048 the less BER is achieved at almost at 60 % SNR. Overall good performance enhancement is achieved for NB-IOT physical layer in this paper.

TABLE II. DESIGN PERFORMANCE FOR OPTIMUM PARAMETERS BER SIMULATION

Parameter	N=1024	N=2048
SER	8.3023 e-05	3.90625e-05
BER	3.870625e-05	1.953125e-05

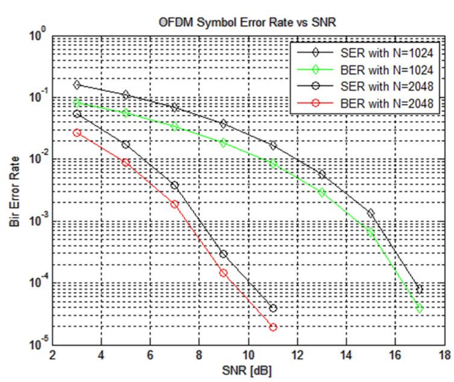

Figure 6 Comparison of BER and SER for M=4 and Ncp=16 for phase offset=7.5, for NB-IOT

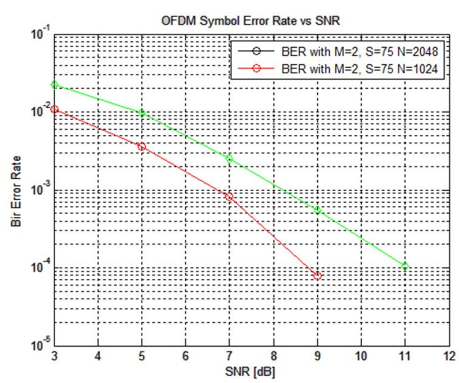

Figure 7 Comparison of BER for M=2sub carriers S=75 for phase offset=7.5

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