2023 3rd International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE) | 979-8-3503-9926-4/23/$31.00 ©2023 IEEE | DOI: 10.1109/ICACITE57410.2023.10182757

IoT Narrow Band for Smart Grid

Prof. Sumitra Maneria,
Assistant Professor,
Department of CSE, PIET,
Parul University,
sumitra.menaria@paruluniversity.ac.in

Kundan Kumar Pramanik,
Assistant Professor,
Department of Engg. & IT,
ARKA JAIN University,
kundan.parmanik@arkajainuniversity.ac.in

***Abstract*-Because to their superior characteristics of low energy, long range, and large capacity, low energy wide area networking technologies, which are currently embracing a flourishing period with the expansion inside the Internet of things (IoT), can offer a completely new answer for present Smart Grid (SG) connectivity. The services and the gadgets must have rising of services connections that are secure and reliable for the mission-critical SG interactions (QoS). Due to the busy license-free spectrum, this is challenging for unregistered systems to accomplish. As a licensed LPWAN system, Narrowband IoT (NB-IoT) was created based on the LTE services and requirements already in place. As a result, it can offer cellular-level QoS, making it an attractive alternative for SG communication. In this study, we bring NB-IoT to the SG and compared its data rate, latency, and range performance with that of the current represented communication technologies (CT) inside the context of SG communication. The total needs of connections in the SG are thoroughly analyzed from both statistical and subjective aspects, and each is rigorously evaluated for NBIoT. We investigate the SG's typical uses in further detail and assess the viability of NB-IoT in those contexts. Additionally, using Monte Carlo models, the efficiency of NB-IoT in typical SG connectivity situations, such as urban and rural regions, is extensively assessed.**

Keywords-Smart Grid, NB-IoT, Advanced metering infrastructure (AMI), LPWAN,

I. INTRODUCTION

As implied by its name, the Internet of Things (IoT) refers to the idea that each object is linked and capable of transmitting and receiving data. The easy connection of virtually any device the with Network is crucial to enabling the Internet of Things (IoT) paradigm. This leads to the emergence of new forms of machine-to-machine (M2M) interactions, which are interactions between machines and people. Since most IoT facilities are anticipated to create a comparatively small quantity of traffic and lesser power usage from a very large quantity of equipment, upcoming wireless cellular structures, or M2M scenarios in specific, are seen as facing significant challenges [2]. In contrast, current mobile communications architectures are intended for wideband offerings going to aim for greater data rates and spectral efficiency. As a result, a new generation of cellular technologies is immediately needed to complete the fifth era of mobile systems (5G) [3].

Because to its long, limited, and inexpensive transmission capabilities, a new wireless technology known as low power wide area network (LPWAN) has recently attracted extraordinary impetus and economic interests from both academic and the industry [4]. It is currently regarded as the upcoming wireless connectivity standards for the Internet of Things. With the ability to handle millions of items per cell, a wide range of service, and a lengthy power life of up to 10 years, LPWAN technologies can flawlessly suit the majority of IoT systems. According to Cisco, the market for LPWAN is anticipated to accounted for 28% of M2M links by 2020 with such a development rate of 38% CAGR [5]. LPWAN systems can be split into two groups based on the frequencies ranges in which they operate. Non - licensed commercial, research, and medicinal radio frequencies are where one set of LPWAN solutions, such LoRa (Long Range) [6] & Sigfox [7], operate. The other group uses licensed bands for things like narrowband Internet of Things (NB-IoT) and improved device type interactions [8]. The IoT has several applications for LPWAN technologies, including smart cities [9], smart buildings, etc.

In order to increase the effectiveness, dependability, and safety of the current electricity grid, a new idea known as the "smart gird" incorporates automated control and contemporary telecommunications technology into the architecture of the electric grid [10]. Since every machine in the network may be thought of as a linked object, several initiatives have been launched as the SG evolves to include the IoT as a key enabler. The SG contains many gadgets and sensors that independently transmit their data to the grid system.

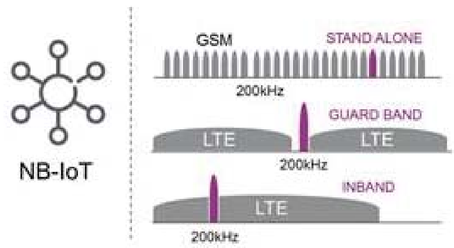

Fig. 1. shows the NB-IoT [46] installation choices.

Power disruptions and outages brought on by device breakdowns, capacity limitations, etc., can be largely prevented with the usages of IoT technology through continuous power system state surveillance, analysis, and protection. Numerous technologies are currently available that can meet the SG's communication demands. For instance, wireless technology like ZigBee, wireless local area networks (WLANs), wirelessly mesh networks, and WiMAX [11], as well as wired connectivity systems like fiber optic, digital subscriber line (DSL), & power line communications (PLC), are all potential alternatives. However, despite enabling the connectivity of IoT systems in the SG, these solutions typically have a number of drawbacks, including high costs, limited scalability, poor battery life, high intricacy, and bad dependability. For example, if utilized in the smart grid, especially in urban areas, the restricted coverage of ZigBee and the weak dispersion capability of WiMAX constitute important barriers. LPWAN technology might offer a novel approach to better meet Singapore's communication needs.

The SG is a purpose system that requires excellent quality of service (QoS) and safe and dependable connections. Since license to drive LPWAN systems are very likely to experience disturbance in the congested uncontrolled band, it is challenging for them to meet these standards. NB-IoT is built on existing LTE functionality and operates on licensed airwaves. It can serve as the basis for lengthy service level contracts with a certain quality of service that is inaccessible to unlicensed technology. Additionally, NB-IoT works on the current cellular infrastructure rather than brand-new ones like LoRa and Sigfox do, reducing the need for investments in a convenience transmission infrastructure and the amount of time needed for app deployment.

The generation partnerships project (3GPP) has now standardized NB-IoT with long term evolution (LTE) version 13 [12], & Huawei, Ericsson, & Qualcomm have all been very supportive of the technology. The various NB-IoT functionalities have been examined in a large number of academic articles. In [14]–[16], a thorough explanation of the NB-IoT architecture and a summary of physically & higher level design were given. In addition to adjustments made to LTE standards to facilitate NB-IoT, the development of 3GPP specifications relevant to NBIoT was outlined in [8]. A NB-IoT deployment study was described in [17]. [18] Describes an experimental network including NB-IoT gadgets, an IoT public cloud, and a software server. The transmission of NB-IoT is the main topic of the investigations in [19] and [20]. [21] Looked closely at the suitability of NB-IoT for spontaneous experience some sort apps with aid from vehicle-mounted sensors. To the greatest of the writers' understanding, there is still lot of concerns that need to be looked into when using NB-IoT in the SG, this is what drove our research.

We present NB-IoT towards the SG in the paper and contrast it with the region's current representative CT. The effectiveness of NBIoT is assessed in relation to all of the overall needs of the SG through equally statistical and subjective viewpoints. This paper's contribution can be summed up as follows:

- We review the CT that is accessible in the SG, includes LPWAN standards like LoRa& NB-IoT as well as more established LPWAN solutions like WiMAX and ZigBee. In-depth research is done on the major performance metrics of various technologies, including such connection speed, latency, etc.
- We offer a thorough evaluation of the SG's connectivity needs from both numerical and qualitative angles, including data rate, dependability, security, and scalability. We carefully consider all of these needs to see if NB-IoT can meet them. Additionally, both potential and inappropriate NB-IoT SG implementations are thoroughly studied based on the examination of NB-IoT features and SG needs.
- Using simulations, we assess how well NBIoT operated with various installations performs in four common connectivity scenarios for the SG, namely rural areas, unfavorable urban areas, typical urban areas, and areas with steep terrain.

The remainder of the essay is structured as follows. A description of the available CT is given in Section II. The general parameters of Services and applications are described in Section III. Examples of NB-IoT-compatible applications are provided in Section IV. A signal - to - noise ratio efficiency of NB-IoT in various SG scenarios is displayed in Section V. The paper concludes in Section VI.

II. SGS CT AVAILABLE

For SGs, there are numerous CTs accessible. CT can be divided into two major groups: wired techniques & wireless technology. In terms of dependability, security, and bandwidth, wired technologies are typically seen as being superior to wireless ones.

Cordless telecommunications, on the other hand, guarantee low construction prices and variable deployments with little need for cabling, allowing for the provision of connectivity over large regions or in places where there is no existing communication infrastructure. Every of these methods so has advantages and disadvantages depending on the usage. We briefly describe the current CT inside the SGs in this part and contrast this with NBIoT in respect of efficiency parameters like data rates and delay. A. contains the findings in a logical order. Cabled CT

Integrated services digital line (DSL), optical fiber, & electricity line connections are examples of wired communication systems (PLC). Fiber optic technology delivers great dependability, ultra-low delay, and data rates up to 40 Gbps. It frequently serves as the foundation for lengthy data transfers of large or real-time amounts of data. However, fiber optic network installation and upkeep can be expensive.

In generally, the term "DSL" refers to a group of CT that allow for the transfer of digital information over phone lines without the added expense of building out an electric utility's own connection network. However, DSL can only work over limited distances because its effectiveness decreases as the length rises. Furthermore, telecom companies have the right to charge utilities a lot of money to utilize their systems. PLC lowers the cost of installing the communication networks by using the power wires already in place for data transmission. Since the PLC's data transmission environment is dangerous and chaotic, it is challenging to simulate the channel, and data transmissions across power lines could not be trustworthy.

B Technologies for Wireless Transmission, based on the IEEE standard 802.15.4, ZigBee is a wirelessly network technology [22]. Because to its low electricity consumption and low implementation costs, it has been frequently used in applications for the smart grid. ISM bands without a license are used by ZigBee. The projected data rates for the 2.4 GHz frequency, the 915 MHz frequency, and the 868 MHz band being 250 kbps each channel, 40 kbps per stream, and 20 kbps each channel, respectively. Consumer devices, energy management systems, and home/building automation are among the in-home applications for which ZigBee is regarded as a viable choice [23]. In terms of practical use, ZigBee is constrained by factors including limited processor power, limited memory space, and minimal latency requirements. Additionally, ZigBee is much more susceptible to interference than other licensed systems because it uses the same license-free frequency as other equipment.

Wireless LAN Networking (WLAN), also referred to as Wi-Fi, is a rising wireless network and Internet transmission technique. WLAN enables fast, dependable, and secure connectivity. Data rates between 2 Mbps and 600 Mbps are available, and coverage extends up to 100 meters [24]. Apps requiring a reasonably high data rate, including those for video surveillance, are better suited for WLAN/Wi-Fi in the house and local area. However, many smart grid equipment may not be able to handle WLAN's high energy consumption.

Z-Wave is a trusted, inexpensive, low-power patented wireless network that runs in the 868 MHz ISM band in Europe and the 908 MHz ISM frequency in the United States. It has a low data speed of 9.6–40 kbps and typically has a range of 30–100 meters indoors and outside [25]. Because of its quick and 'reduced, Z-Wave is an excellent choice for applications of smart grids in home area networking.

Using the IEEE 802.16 collection of specifications as its foundation, WiMAX is a 4G wireless network. It offers data rates of up to 75 Mbps, coverage over a radius of 50 km, and latency times of 10 to 50 ms [26]. The real-time, high-data-rate, two-way WiMAX standard allows applications like remote monitoring, real-time pricing, etc. WiMAX is not extensively used as a cellular framework for intelligent grid applications because of the high cost of deployment due to the WiMAX towers' reliance on expensive communication equipment. Additionally, WiMAX's frequency above 10 GHz comes in a small wavelength, which makes it hard to pass past obstructions. What's worse is that inclement environment can actually impede WiMAX performance. WiMAX might not be the best option for communications in the smart grid as a result.

A mesh network system is a dynamic network made up of a number of nodes that each function as an autonomous router and allow for the addition of new nodes. The channel's reliability is significantly increased by this topology's identity and self-healing features. Mesh networks are able to do multi-hop routing, which results in a large coverage area and high capacity. Different wireless techniques, such as 802.11, 802.15, & 802.16, can be utilized to construct mesh networks. This topology is extremely challenging to put up and maintain, though. Due to the resilience offered by the network, it needs ongoing management. The mesh network system may therefore require management and upkeep from a third-party company.

The ISM bands of 433, 868, or 915 MHz are used by LoRa, a representative unlicensed LPWAN technology [27]. Semtech made the suggestion, and the LoRa Alliance supported it. Because developers may construct entire system options on top of LoRaand the description for the specification LoRaWAN is freely available, LoRa is appealing to them. The chirping spread spectral (CSS) modulation used by LoRa aids in the fight against severe multi-path fading.

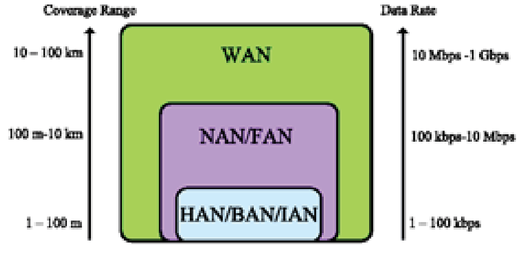

Fig. 2. Prerequisites for the hierarchy [47] of smart grid networks in terms of information rate and connection range.

NB-IoT is a brand-new 3GPP transmission technique that was developed using the LTE infrastructure already in place. With legacy GSM, generalized packet radio services (GPRS), and LTE technology, it offers good coexistence performance and is easy to plug through into LTE core network. The dynamic spectrum divisions multiplex (OFDM) type of transmission in the downlink and single channel frequencies division multiple input multiple output in the uplift are two examples of how the LTE design is heavily reused in NB-IoT. NB-IoT may reach peak data speeds of up to 250 kbps again for uplink and 230 kbps again for downstream [14].

In comparison to unregulated NAN technology, NB-IoT can offer high QoS and dependable service for grids application that are mission-critical. the same data speed as NB-IoT similarly to Wi-Fi mesh systems, and latencies. Wi-Fi mesh systems are able to offer range that is comparable to that of NB-IoT. All of them have numerous smart network applications, including meters monitoring & house monitoring. But when used in real-world scenarios, Wi-Fi mesh systems encounter numerous difficulties. While data packets are being routed via numerous nodes in mesh systems, loop problems may arise. Redundancy increases overhead costs in the data route and would waste resources. The fact that metering data is transmitted over each access point makes the mesh network's safety issue particularly significant. While smart grid applications are thought to be better suited for NB-IoT. Because it was built on top of the cellphone networks already in place, it can provide wide-scale, affordable connectivity. Additionally, the cellular network's data transfers are subject to rigorous security checks, while its availability has nearly reached 100%, ensuring stable and secure interactions with equipment including both urban & rural locations. Further, NBIoT uses SC-FDMA for the uplink and OFDMA for the downlink. As a result of their inherent multi-user arrangements, which permit continuous data transmission from a sizable number of users, these architectures greatly increase the network's throughput. Additionally, NB-IoT is a suitable option for widespread implementation and commercialization inside the power grid because to its extremely reduced cost ($5).

III. General Requirements For Smart Grid Services

The key specifications for intelligent grid connections are described in the following in two categories: There are two types of requirements: I numerical demands, which describe in quantifiable terms the goal signal quality required by the intelligent grid apps, and (ii) qualitatively criteria, which characterize the abilities that the information networks must provide.

A. *Quantitative Prerequisites*

The following is a list of the main quantitative information needs that should be met by communications for the smart grid:

- Latency: Varied smart grid apps have different latency needs. Some mission-critical systems, including automation systems installed in substations and wide-area special awareness devices, have strict delay limitations and call for speedy data transmission.
- Frequency range: To get around line-of-sight problems and offer high and reasonably priced connectivity so over utilities provider network, smart gird apps may be required to run towards to the low end of the scale of the frequency band (below 2 GHz).
- Stability: The smart grid has reliability difficulties due to a variety of connectivity issues scenarios, such as link/node outages, inconsistent routing, overcrowding, etc.

One of the top priorities for electrical utilities today is resulting.

- Data rate: For every unique smart grid operation, different data rates are needed. Applications like wider-area special awareness devices, which require high data-rate values to achieve successful data transfer, are used to convey audio and video data.

B. Subjective Criteria

Following is a summary of the critical capabilities required for smart grid correspondence:

- Security: The smart grid is a crucial infrastructure that must be resistant to errors and assaults. The greatest objective for practically all smart grid projects is to provide end-to-end safety [30]. Safety should be offered on a communication system, especially for purpose applications like invoicing and grid control, to safeguard the vital components of the electricity network against any weaknesses.
- Expanding: A smart grid may include millions of smart meters, embedded sensors nodes, efficient data collection, renewable power sources, etc. Flexibility is therefore considered to be one of the most obvious criteria for the smart grids interaction system.
- Versatility: Since diverse applications can run on top of the same communications networks, highly flexible communication solutions are required. In order to enable diverse smart energy services with various data speeds and reliability standards, the smart grid must be flexible. The versatility implies the capacity to offer several communication skills.

IV. Apps And Information Management Systems

Numerous apps have been created or are currently being created for such smart grid network. Communications requirements vary significantly depending on the activity. As a result, each individual scenario should be taken into consideration when deciding if NB-IoT may be employed for a certain smart grid system. NB-IoT is a dependable, adaptable, and affordable technology with great security & manageability, as shown by the study in the preceding sections. With an unresponsive latency, it allows low data rate transfer. AMI, demands responsive management (DRM), electrical vehicles (EV) recharging, and other customer-based systems are examples of NAN systems with fewer strict needs for latency that might benefit from NB-inherent IoT's coverage, delay, and data rate. While distributed energy resources (DER) and distribution automation (DA), which need transmitting major operational and controlling info of utility in real-time, are mission-critical NAN technologies that cannot be handled by NB-IoT. (DERs). Following are examples of both NB-IoT-compatible and incompatible technologies.

A. Apps for NB-IoT

1) AMI: AMI is a bi-directional telecommunications technology that combines a number of devices, including smart appliances, cutting-edge sensing, surveillance technologies, processing technology, programming, & data management systems, to enable the collection & distribution of input among consumer & services [32]. AMI has the capacity to offer providers with information on power usage for monitoring and billing, information on electricity, voltages and loading characteristics, etc. It also has the capacity to enable global meter control and interruption monitoring

2) Demand Response Management (DRM): DRM comprises the management of electricity demand &loading during crucial peak conditions to achieve an equilibrium between electric power generation with the goal of increasing the reliability and economy of the energy system. Variable pricing is the method most frequently suggested for putting DRM technologies into practice, and it has advantages for both businesses and end consumers [38][39].

3) Power system (G2V) and sometimes vehicle-to-grid (V2G) trying to charge: Because EVs have a substantial potential to reduce greenhouse gas emissions and fossil energy imports, they are commercially viable [41].

4) V2G is a novel electricity paradigm that allows EVs to be connected to the electrical grid and return some of the electrical energy they have stored there for grid stability. The dispersion of cars affects the V2G communication requirements. The quick wireless network is appropriate when a fleet of automobiles is gathered, like in carparks. Long-distance connections are preferred when cars are spread out over a vast area. V2G requires a data rate of 5 to 10 kbps and a max delay of 15 s.

B. NB-IoT-incompatible apps

1) DA: To automate and autonomously supervise, control, modify, and coordinate distributed systems in the electricity network, DA systems give accordance with project information of the meshed network, automation technology, network capacity, and data management [42]. Utilities can increase the effectiveness, dependability, and efficiency of their electric operations with the use of DA technologies.

2) Since DA offers real-time data on fault fixes, impacts, & outages period, DA systems have strict latency requirements. Communications including alarms and alerts must have a latency of less than one second. Some DA actions require a delay of 100 ms for data transfer between sites. Additionally, the power control signal' values obtained must not be longer than 15 ms [43]. WiMAX and optical fiber approaches are advised for DA applications rather than NB-IoT because to the demanding latency requirements.

3) DERs: Tiny power generating and/or storage arrays linked to the distribution network are referred to as DERs. Due to its ability to level out voltage instability by enhancing renewable electricity sources like solar and wind, distributed energy resources (DERs) are widely acknowledged as a crucial enabler of smart grids. Due to the intermittent, unpredictable, and inconsistent character of renewable energy sources, responsive and effective communication solutions are needed to communicate real-time data from various electricity producing sites. Yet, because sustainable energy supplies are inherently sporadic, unexpected, and inconsistent, responsive, efficient communication methods are needed to relay immediate information. Data from various electrical producing sources. The required latency ranges from 300 milliseconds to two seconds, while the bandwidth ranges from 9.6 to 56 kbps [44]. It is advised to employ LoRa, WiMAX, and fiber optic in DERs systems because to the low latency needs of DERs. The efficiency of NB-IoT will be assessed in the next part using simulations in urban, rural, & mountainous environments.

V. SIMUATIONS,

Because the network control is designed to be mission-critical, it is important to thoroughly assess NB-reliability IoT's while using it. A most exact and straightforward metric available is BER. describes how reliable data transfer across wireless links is. Consequently, in this part, we run Monte Carlo calculations to compare the BER efficiency to the sensor ratio. A common communications situation for the power system is taken into consideration, including rural & urban settings, and the route model selected is COST 207.At the connection level, the scenarios are run. Due to the NB-IoT requirements, all simulation settings were chosen. When used in LTE networks and in GSM networks, accordingly, the programming of NB-IoT is chosen to be QPSK and GMSK. In the interest of equality, we assume that all systems in our study have the similar spectral performance. The COST 207 network patterns [45] were standardized so that various communication developers may evaluate their networks using a shared set of channels types. There are identified four transmission models.

Rural Area (RA): An RA is often a level area devoid of many mountains & high structures. Rayleigh fade on the second route and Rician fading on the initial path are characteristics of RA systems. The three remaining routes. The longest route latency is 0.6 seconds. The K-factor for RA is typically -1.5 dB.

Bad Urban (BU): BU typically refers to a location with a lot of elevated structures and dense population, like Manhattan's central business district. Rayleigh fading from all pathways is a characteristic of BU models. A Rayleigh network item containing six taps is used to build the model. The longest path delay is 6.6 seconds.

Typical Urban (TU): The suburbs of large towns or more typical towns with less towering structures are typically represented as TU. Rayleigh fading, with a 16-s total route delay, characterizes TU systems on all 5 routes. Mountainous Terrain: A region with hills & undulating mountains is designated as having HT. Rayleigh fading across most pathways is a characteristic of HT models. Twelve taps make up the channel's construction. 20 seconds is the greatest route latency. Due to the fact that the majority of smart network systems remain immobile, this version is built with zero moving speed & Dispersion scatter.

The prologue, which comes before every data symbol and is a whole sign that is recognized to both the broadcaster and the receivers, is used in our simulations to conduct the channel model. The leveling and demultiplexing of the information symbol follow, using the channel predictions as a base. A zero-forcing method is used for channel estimation. We compare the SNR—which is calculated as the product of the variance of the AWGN and the energy per bit, or Eb=N0—and the BER obtained by the maximal likely (ML) sensor when channel estimation is not used. For the sake of convenience, we'll suppose that each consumer computer and base stations have a single channel. Performance will be similar because total power for in-band & defender operating condition is split between LTE and NB-IoT. The efficiency of in-band operations inside LTE networks & that of stand-alone operations inside GSM systems are the main ones we assess in this area.

A. LTE Systems' In-Band

The downstream functionality of NB-IoT is displayed in Figure 3. It is obvious that AWGN channels efficiency is significantly better then COST 207 channel quality. Since the COST 207 wireless channel incorporates frequency selected withering as a result of the spread spectrum effects, this is a readily understandable situation. The efficiency of the RA is greater than those of other situations, as shown in Fig. 3, where we can observe that the byte errors rate (BER) of the RA drops smoothly with Eb=N0. This occurs as a result of the flat, hillless, and tall building-free environment in RA; as a result, a LOS route connecting the broadcaster & reception occurs, delivering the primary informational piece. Rayleigh fading is present in the remaining three cases. The ICI brought on by the delayed spreading becoming the restricting issue as the SNR rises, causing these three graphs to have mistaken floors. In comparison to TU and HT, it is clear that BU performs better. There're many thick & abrasive materials in the Because there are so many barriers in BU, including tall towers, its total route delay is less than that of TU & HT. Consequently, BU's coherence frequency is greater than theirs, creating the upstream capability of NB-IoT is depicted in Fig. 4 for various scenarios. As can be observed, the curves associated with various circumstances follow similar guidelines to Fig. 3. To the SCFDMA, Localized FDMA (LFDMA) & interlaced FDMA are the two methods for mapping subcarriers.

In Figure 4, we may observe that the IFDMA works better than the LFDMA in practically every case we evaluated. This may be understood by the fact that interspersed mappings places equal emphasis on each subcarrier inside a group, allowing them to statistically undergo separate fading over distances typically larger than the coherent frequency. In the future, IFDMA will be able to achieve a frequencies diversification gain to increase the system's resistance against frequency-selective fading.

B. GSM Devices that Are Stand-Alone

The efficiency of NB-IoT used in GSM networks is displayed in Fig. 5. The modulating format used by GSM is called Gaussian Minimize Shifter Keying (GMSK). The Gaussian filter's bandwidth-time combination (BT) for the GSM system is 0.3. The efficiency curves show identical laws to those in Figs. 3-4 when Eb=N0 rises. Remarks: NBIoT is shown to function well in all common connection situations in the power system depending on the models discussed above. Furthermore, NB-IoT is anticipated to allow interactions with about 100% coverage because of the current mobile telecommunications infrastructure's extensive coverage [46]. So, it stands to reason that NBIoT should be the primary technology used to execute geographic wide micro grid apps like meter readings and DRM. Because of this, using NB-IoT can remove the need for workers to go on field excursions for meter readings, manually interruption notification, and the majority of restoration activities, particularly in hostile regions that are challenging for persons to reach. There are several ways to improve efficiency. Compared to the other situations, the likelihood of deep withering is rather low. However, it is clear that HT outperforms TU while having a comparable coherence capacity. Due to the presence of peaks and sloping hillsides, HT has more dispersion & reflection routes than TU; as a result, the diversification advantage over separate fading routes is brought about by the additional transmitting routes. Because to the comparable phy layer structure, that employed in OFDM/SC-FDMA could be transferred to NB-IoT.

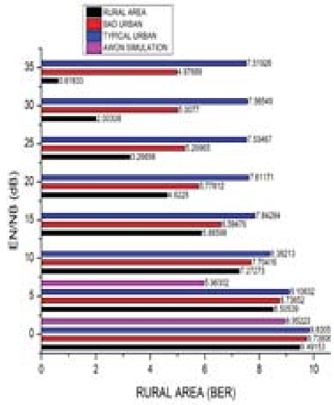

Fig. 3. shows the BER efficiency obtained by the NB-IoT downlink using in installation under various conditions.

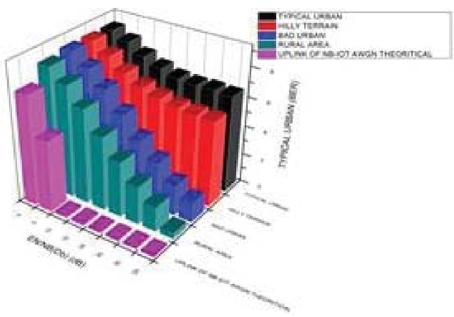

Fig. 4. shows the BER effectiveness obtained by the NB-IoT uplink with in-band installation under various conditions.

VI. Summary

In the study, NB-IoT is suggested for the power city to enable safe and dependable connections across various parts of the electrical system. We firstly looked at the available communications technology; include LPWANs like LoRa & NB-IoT as well as more conventional ones like WiMAX and ZigBee, to confirm that NB-IoT is indeed the best option for the power grid. It has been demonstrated that the NB-IoT can deliver communication services with extended range, adequate information rate, and highly reliable all at once. Then, a thorough study of the smart grid's demands was given. Each of them is examined, and it is shown that NB-IoT fully satisfies the majority of the numerical and subjective standards, including dependability, security, and adaptability. The NB-IoT standard is only appropriate for delayed tolerant systems like AMI, DRM, G2V, & V2G because it is delay sensitive. According to models of how well NB-IoT performed in common smart grid communication scenarios, the technology is effective for smart grid applications. Additionally, simulations show that it operates better with LOS pathways present and that the sub band involves the division can boost performance.

References

[1] L. Atzori, A. Iera, and G. Morabito, "The internet of things: A survey," Comput. Netw., vol. 54, no. 15, pp. 2787C2805, 2010.

[2] E. Soltanmohammadi, K. Ghavami and M. Naraghi-Pour, "A Survey of Traffic Issues in Machine-to-Machine Communications Over LTE," IEEE Internet of Things Journal, vol. 3, no. 6, pp. 865-884, Dec. 2016.

[3] Rebbeck, T., Mackenzie, M., Afonso, N., "Low-powered wireless solutions have the potential to increase the M2M market by over 3 billion connections," Analysys Mason, September 2014.

[4] M. Centenaro, L. Vangelista, A. Zanella and M. Zorzi, "Long-range communications in unlicensed bands: the rising stars in the IoT and smart city scenarios," IEEE Wireless Communications, vol. 23, no. 5, pp. 60-67, October 2016.

[5] Cisco, "Visual networking index: Global mobile data traffic forecast update, 2015 - 2020," White paper, 2016.

[6] LoRa Alliance, "LoRaWAN Specification Version V1.0," Jan. 2015 [Online]. Available: https://www.rs-online.com/designspark/rel-assets/dsassets/ uploads/knowledge-items/application-notes-for-the-internet-ofthings/ LoRaWAN%20Specification%201R0.pdf

[7] Zuniga, J. and B. PONSARD, "SIGFOX System Description", draftzuniga- lpwan-sigfox-system-description-03 (work in progress), June 2017.

[8] A. D. Zayas and P. Merino, "The 3GPP NB-IoT system architecture for the Internet of Things," in Proc. 2017 IEEE International Conference on Communications Workshops (ICC Workshops), Paris, 2017, pp. 277-282.

[9] M. Centenaro, L. Vangelista, A. Zanella and M. Zorzi, "Long-range communications in unlicensed bands: the rising stars in the IoT and smart city scenarios," IEEE Wireless Communications, vol. 23, no. 5, pp. 60-67, October 2016.

[10] S. H. Shah and I. Yaqoob, "A survey: Internet of Things (IOT) technologies, applications and challenges," in Proc. 2016 IEEE Smart Energy Grid Engineering (SEGE), Oshawa, ON, 2016, pp. 381-385.

[11] Mahmood A, Javaid N, Razzaq S., "A review of wireless communications for smart grid," Renewable and sustainable energy reviews, vol. 41, pp. 248-260, 2015.

[12] Dino Flore, "3GPP Standards for the Internet-of-Things," 2016 [Online]. Available: http://www.3gpp.org/images/presentations/3GPP-Standardsfor- IoT.pdf

[13] TR 45.820, "Cellular system support for ultra low complexity and low throughput Internet of Things," V2.1.0, Aug., 2015.

[14] Y. P. E. Wang et al., "A Primer on 3GPP Narrowband Internet of Things," IEEE Communications Magazine, vol. 55, no. 3, pp. 117-123, March 2017.

[15] R. Ratasuk, B. Vejlgaard, N. Mangalvedhe and A. Ghosh, "NB-IoT system for M2M communication," in Proc. 2016 IEEE Wireless Communications and Networking Conference, Doha, 2016, pp. 1-5.

[16] R. Ratasuk, N. Mangalvedhe, Y. Zhang, M. Robert and J. P. Koskinen, "Overview of narrowband IoT in LTE Rel-13," in Proc. 2016 IEEE Conference on Standards for Communications and Networking (CSCN), Berlin, 2016, pp. 1-7.

[17] Mangalvedhe, R. Ratasuk and A. Ghosh, "NB-IoT deployment study for low power wide area cellular IoT," in Proc. 2016 IEEE 27th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC), Valencia, 2016, pp. 1-6.

[18] J. Chen, K. Hu, Q. Wang, Y. Sun, Z. Shi and S. He, "Narrow-Band Internet of Things: Implementations and Applications," IEEE Internet of Things Journal, vol. PP, no. 99, pp. 1-1.

[19] A. Adhikary, X. Lin and Y. P. E. Wang, "Performance Evaluation of NB-IoT Coverage," in Proc. 2016 IEEE 84th Vehicular Technology Conference (VTC-Fall), Montr´eal, QC, 2016, pp. 1-5.

[20] M. Lauridsen, I. Z. Kovacs, P. Mogensen, M. Sorensen and S. Holst, "Coverage and Capacity Analysis of LTE-M and NB-IoT in a Rural Area," in Proc. 2016 IEEE 84th Vehicular Technology Conference (VTC-Fall), Montr´eal, QC, 2016, pp. 1-5.

[21] V. Petrov et al., "Vehicle-Based Relay Assistance for Opportunistic Crowdsensing over Narrowband IoT (NB-IoT)," IEEE Internet of Things Journal, vol. PP, no. 99, pp. 1-1.

[22] Ambikapathy, A., & Singh, G. (2017). Multi-level (13) inverter for Grid connected PV system with PID controller. International journal of control theory and Applications, 10(6), 215-222.

[23] X. Cao, D. M. Shila, Y. Cheng, Z. Yang, Y. Zhou and J. Chen, "Ghost-in- ZigBee: Energy Depletion Attack on ZigBee-Based Wireless

Networks," IEEE Internet of Things Journal, vol. 3, no. 5, pp. 816-829, Oct. 2016.

[24] L. Li, H. Xiaoguang, C. Ke and H. Ketai, "The applications of WiFibased Wireless Sensor Network in Internet of Things and Smart Grid," in Proc. 2011 6th IEEE Conference on Industrial Electronics and Applications, Beijing, 2011, pp. 789-793.

[25] C. Gomez and J. Paradells, "Wireless home automation networks: A survey of architectures and technologies," IEEE Communications Magazine, vol. 48, no. 6, pp. 92-101, June 2010.

[26] P. Rengaraju, C. H. Lung and A. Srinivasan, "Communication requirements and analysis of distribution networks using WiMAX technology for smart grids," in Proc. 2012 8th International Wireless Communications and Mobile Computing Conference (IWCMC), Limassol, 2012, pp. 666- 670.

[27] O. Georgiou and U. Raza, "Low Power Wide Area Network Analysis: Can LoRa Scale?," IEEE Wireless Communications Letters, vol. 6, no. 2, pp. 162-165, April 2017.

[28] Murat Kuzlu, ManisaPipattanasomporn, SaifurRahman, "Communication network requirements for major smart grid applications in HAN, NAN and WAN," Computer Networks, vol. 67, pp. 74-88, 2014.

[29] C. Yu, L. Yu, Y. Wu, Y. He and Q. Lu, "Uplink Scheduling and Link Adaptation for Narrowband Internet of Things Systems," IEEE Access, vol. 5, pp. 1724-1734, 2017.

[30] H. Li, L. Lai and W. Zhang, "Communication Requirement for Reliable and Secure State Estimation and Control in Smart Grid," IEEE Transactions on Smart Grid, vol. 2, no. 3, pp. 476-486, Sept. 2011.

[31] "NB-IoT: a sustainable technology for connecting billions of devices," 2016 [Online]. Available: https://www.ericsson.com/en/publications/ericsson-technologyreview/ archive/2016/nb-iot-a-sustainable-technology-for-connectingbillions- of-devices

[32] S. Galli, A. Scaglione and Z. Wang, "For the Grid and Through the Grid: The Role of Power Line Communications in the Smart Grid," in Proc. the IEEE, vol. 99, no. 6, pp. 998-1027, June 2011.

[33] Y. Cao, D. Duan, X. Cheng, L. Yang and J. Wei, "QoS-Oriented Wireless Routing for Smart Meter Data Collection: Stochastic Learning on Graph," IEEE Transactions on Wireless Communications, vol. 13, no. 8, pp. 4470- 4482, Aug. 2014.

[34] M. Dong, K. Ota and A. Liu, "RMER: Reliable and Energy-Efficient Data Collection for Large-Scale Wireless Sensor Networks," IEEE Internet of Things Journal, vol. 3, no. 4, pp. 511-519, Aug. 2016.

[35] NIST Priority Action Plan 2, "Guidelines for Assessing Wireless Standards for Smart Grid Applications," December 2010. [Online]. Available:http: www.nist.gov/smartgrid/twiki.cfm

[36] "Huawei and Janz CE Announce the First Smart Electrical Energy Meter Based on NB-IOT," 2016 [Ottp://www.huawei.com/en/news/2016/11/First-Smart-Electrical-Energy-Meter-NB-IOT

[37] "NOS, Huawei Support NB-IoT-based Smart Meter IoT Trial in Portugal," 2017 [Online]. Available: https://www.thefastmode.com/technology-solutions/10928-nos-huaweisupport-nb-iot-based-smart-meter-iot-trial-in-portugal

[38] Emilio Ancillotti, Raffaele Bruno, Marco Conti, "The role of communication systems in smart grids: Architectures, technical solutions and research challenges," Computer Communications, vol. 36, no. 17, pp. 1665-1697, 2013.

[39] Y. Cao, D. Duan, L. Yang, X. Cheng, X. Hu and J. Wei, "Closed-Form Pricing in Multiuser Access Networks With Incomplete Information," IEEE Transactions on Vehicular Technology, vol. 64, no. 11, pp. 5368-5373, Nov. 2015.

[40] K. Qian, C. Zhou, M. Allan and Y. Yuan, "Modeling of Load Demand Due to EV Battery Charging in Distribution Systems," IEEE Transactions on Power Systems, vol. 26, no. 2, pp. 802-810, May 2011.

[41] Khan R. H., Khan J. Y., "A comprehensive review of the application characteristics and traffic requirements of a smart grid communications network," Computer Networks, vol. 57, no. 3, pp. 825-845, 2013.

[42] H. Farhangi, "The path of the smart grid," IEEE Power and Energy Magazine, vol. 8, no. 1, pp. 18-28, Jan. 2010.

[43] Y. Wang, D. Ruan, D. Gu, J. Gao, D. Liu, J. Xu, F. Chen, F. Dai, and J. Yang, "Analysis of Smart Grid security standards," in Proc. 2011 IEEE International Conference on Computer Science and Automation Engineering, Shanghai, 2011, pp. 697-701.

[44] Communications Requirements of Smart Grid Technologies. Washington, DC: Dept. Energy, 2010.

[45] COST 207, "Digital land mobile radio communications," Office for Official Publications of the European Communities, Final report, Luxembourg, 1989.

[46] V. C. Gungor et al., "Smart Grid Technologies: Communication Technologies and Standards," IEEE Transactions on Industrial Informatics, vol. 7, no. 4, pp. 529-539, Nov. 2011.

[47] Idowu-Bismark, Bode & Idachaba, Francis & Atayero, Aderemi. (2017). A Survey on Traffic Evacuation Techniques in Internet of Things Network Environment. Indian Journal of Science and Technology. 10. 10.17485/ijst/2017/v10i33/112749.

[48] Kuzlu, Murat, Manisa Pipattanasomporn and Saifur Rahman. "Communication network requirements for major smart grid applications in HAN, NAN and WAN." *Comput. Networks* 67 (2014): 74-88.