# NARROWBAND IoT AND ITS IMPLICATIONS IN DEVELOPING COUNTRIES

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**Abstract**— Internet of things (IoT) is asserting itself very rapidly as it gains much global attention due to its several sensor based applications. It utilizes minimal resources to provide wide coverage for services. It has been found to be very useful in providing sensing from basic systems like the digital ecosystem to more complex systems like modern systems of manufacturing, security, healthcare, agriculture, etc. Amongst the several types of IoTs proposed, the Narrowband IoT (NbIoT) is one of the most economical as it can provide coverage for a Low Power Wide Area (LPWA),thus, making it the most suitable for developing countries which are characterized by scarce resources and require every possible economical solution. In this article, we present the characteristics and capabilities of NbIoT that makes it suitable for developing countries and its implications on development based on sectors of its possible deployment.

**Index Terms**— Internet of things (IoT); Narrowband IoT (NbIoT); developing countries; Low Power Wide Area (LPWA), Wireless, Network

## 1 Introduction

THE internet of things, or IoT, is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.[1]

According to IERC, IoT is "A dynamic global infrastructure with self-configuring capabilities based on standard and interoperable communication protocol where physical and virtual things have identities, physical attributes, virtual personalities, and use intelligent interface and seamlessly integrated into information network" [2]

The definition of the Internet of things has evolved due to the convergence of multiple technologies, real-time analytics, machine learning, commodity sensors, and embedded systems[3]. Traditional fields of embedded systems, wireless sensor networks, control systems, automation (including home and building automation), and others all contribute to enabling the Internet of things. In the consumer market, IoT technology is most synonymous with products pertaining to the concept of the "smart home", covering devices and appliances (such as lighting fixtures, thermostats, home security systems and cameras, and other home appliances) that support one or more common ecosystems, and can be controlled through devices associated with that ecosystem, such as smartphones and smart speakers.

IoTs can be of various types relying on their capabilities. One of the standardized forms of IoT is narrowband IoT (NbIoT). As the name implies, this IoT needs narrow band frequencies for its operations. Due to the narrow band requirement, NbIoT has several advantages over other forms of IoTs. Green and sustainable technologies are in high demand due to their energy efficiency and environment friendly features. These low energy technologies are very popular in different forms of IoTs and sensor based applications. They become even more important in the developing countries due to the scarcity of resources and the need to optimize performance of various sectors in order to drive development [4]. In recent years, several works have been carried out on different types of IoTs to make them more energy efficient. [5],carried out a study on energy efficient and sustainable initiatives for IoT based smart world. This study provides several recent progressive trends and technologies which are able to make the entire IoT networks energy efficient. It also gives insight to the segment-wise greening processes in the framework of existing information and communication technologies (ICTs) across different application domains.In [6], the recent trends of consumer electronics driven data communication networks are provided. It shows the volume of the resources needed for the global communication networks. The data storage and communication infrastructure required for the current ICT sectors too have been presented in this article. [7], presents a comprehensive survey on the practical aspects of IoT. First, it deals with the enabling technologies that make IoT a reality, then shows the main protocols which are instrumental in the IoT operations. Second, it provides a long list of applications in which IoT can play a significant role. The authors pointed that the overall success of IoT is very much dependent on the efficiency of the entire IoT networks, their components and end devices.

More works have been done in this area, like [8], presents a detailed survey of the IoT marketplace of last few years. This study explains the recent industrial demands and applications of IoT and its associated technologies in different processes. It also elaborates through justified logic that manufacturing and automation will have a large share of industrial IoT. In [9], research and development initiatives of 5G and IoT are presented in which energy efficiency and overall network optimizations are analyzed. In [10], sustainability aspects of communication networks have been presented. It shows the carbon emission contributions of global communication sector. This work also provides outlooks for overall sustainability. In [11], the green radio communication technologies and emerging methods are highlighted with proper background information. It also provides insights for emerging networking technologies for energy efficiency. In [12], green technologies for clouds are analyzed. Cloud energy efficiency is essential for green IoTs as clouds are going to be their integral parts in the long term. IoT data management needs clouds for the efficient ICT activities. In [13], 5G energy efficiency related as-

pects are presented which discusses the general system characteristics and their overall effect on the system.your paper.

## 2 Perculiar Issues Of Developing Countries

Developing countries are faced with a myriad of challenges such as environmental degradation due to poor monitoring, low and poor state of existing infrastructure, low standard of education, poor quality of healthcare and complete lack of provision of healthcare in some communities and poor access to portable water, gas, electricity. Also, high rate of insecurity due to communal, ethnic and religious conflicts, poor and unstable economy due to political instability and unrests, poor equipped security personnel, poor agricultural and agro-allied yield due to unavailability of mechanized and industrial alternatives, e.t.c.

All these issues lead to a general lack of resources that are instrumental to the adoption of technology which can help to fast-track development. In order to mitigate its imminent spiral to morbidity due to its self-destructive pattern of unconsciously creating an unsustainable environment for an ever increasing population, it is therefore necessary to explore every possible and available economic solution.

## 3 Characteristics Of NbIoT That Makes It An Appropriate Solution For Developing Countries

NbIoT is the low energy and low bandwidth version of IoT which is designed for the massive machine-to-machine communications. As the name suggests, it uses narrow bands for its different functions and operations. It needs a bandwidth of just 180 kHz to 200 kHz for its designated processes. In LTE Release 13 and 14, 180 kHz has been proposed as the operating bandwidth for NbIoT. It is a low power wide area (LPWA) technology which can save a lot of power when compared with other forms of IoTs. It is good for large scale economical deployment of IoT for different applications. In true sense, it is leaner, thinner and greener than other IoTs proposed in the recent years. It can be deployed in both the cellular and non-cellular forms. However, cellular forms are popular as they can use the existing cellular architectures for its operations. In LTE Release 13 and 14, it has been standardized according to the compatible LTE provisions and also proposed for connected living environments [14].

### A. Low Power Characteristics of NbIoT

The major attraction of NbIoT is its LPWA nature. It is an energy efficient version of IoT. It can save a large amount of energy and bandwidth of a network.It is the latest technology that has been identified and standardized in a little time span, in response to customer requirements and pressure to tussle with non-3GPP proprietary technologies. (https://www.gsma.com/iot/wpcontent/uploads/2018/04/NBIoT_Deployment_Guide_v2_5Apr2018.Pdf). Its architecture and protocols have been standardized in the recent releases of LTE for different environments. Deployment bandwidths of NbIoT have been agreed by the standardization committee in Release 13. Depending on the situation, different spectral bands can be used by different operators. According to Release 13 of 3GPP LTE, the maximum usable bandwidth of an end device is 200 kHz. In fact, for the communication purpose 180 kHz is used [16]. At this bandwidth, the upper limits of the uplink and downlink data rates are set at 150 kbps. Half duplex mode has been recommended for NbIoT communications [17]. In Release 14, these specifications have been further enhanced for advanced applications. The power from the transmitter is kept quite small so that a single battery can supply power to the NbIoT devices or nodes for more than 10 years. In fact, in the recent NbIoT standards, two power levels have been specified: 20 dBm and 23 dBm [1]. The sensitivities of the NbIoT sensors are really good. They can receive the signal at a power level as low as 64 dBm. These are the exclusive features of NbIoT which is not found in other versions of IoTs proposed so far.

According to S. Popli et al. (2019), NBIoT has the following features as outlined;

- NbIoT can support massive connections (more than52K/channel)
- NbIoT uses a bandwidth of 180 KHz and operates in HD-FDD
- NbIoT design objective is to provide prolonged battery life
- NbIoT provides extend coverage range of 20dB as compared to GPRS (especially deep indoor penetration)
- NbIoT offers operating mode flexibility
- NbIoT supports Low-Data-Rate applications
- NbIoT operates in Licensed Band
- NbIoT achieves signalling optimization

### B. NbIoT Network Architecture

A systematic NbIoT architecture is required for its planning, dimensioning, cost estimation, design and final deployment. It does not have a legacy to follow as it is one of the earliest IoTs of its type. However, it is similar to the Wireless Sensor Network(WSN) and the WSNs have been there for several years. The existing WSN architecture and topologies can be helpful in its further advancement. It is noteworthy that WSNs does not have a structured and well defined architecture like the cellular systems such as the LTE networks which will form the backbone of NbIoT. Therefore, an LTE cellular framework for NbIoT is the right choice at the moment [17]. The layered structure of NbIoT is helpful in its planning and deployment. In Release 13, several specifications for different layers have been mentioned. NbIoT can be separated into 6 layers. The physical layer is at the bottom and it is normally the air interface. Physical layer does the similar functions as other WSNs and some added functions as defined in Release 13. Above it is the medium access control (MAC) layer. This has the similar functions like the MAC layer of other networks. It incorporates the protocols for medium access and multiple access techniques. There is a radio link control layer in between the MAC and the upper layers. This layer makes the adaptation of the MAC layer information for radio links. Above it is the packet data convergence protocol layer which provides routing, traffic scheduling, networking and other related tasks. Then above it is the radio resource control layer which takes

care of the radio resources of the packets in the channels. NbIoT uses user datagram protocol (UDP) and other cellular mechanism to carry out this function [19]. UDP is effective in the wireless networks and thus suitable for NbIoT as well. The topmost layer is the Non-Access Stratum (NAS) which establishes the communication between the user equipment (UE) and the main server of the NbIoT also known as NbIoT central node. The six (6) layers of the NbIoT architecture are shown in figure 1.

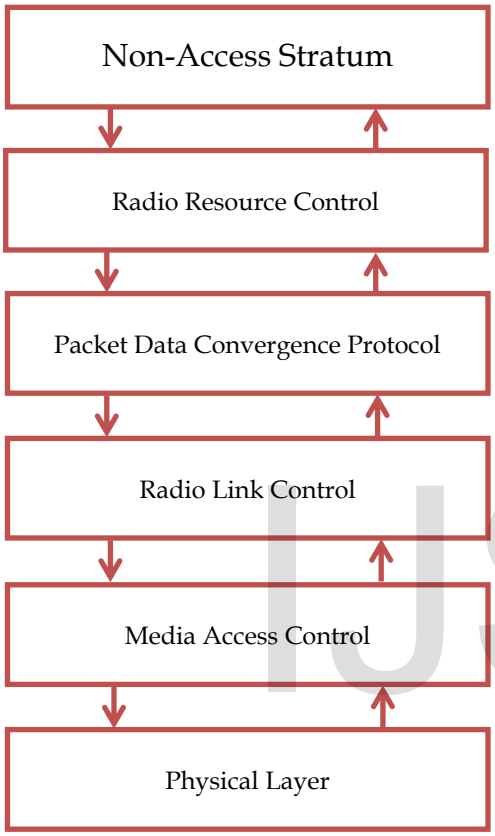


**FIGURE 1:LAYERED STRUCTURE OF THE NBIOT NETWORK ARCHITECTURE**

## C. MODES OF OPERATION OF NBIOT

NbIoT carrier can be deployed in three modes standalone,in-band, and guard band.

- Standalone Operation: In this mode, a separate spectrumis either reserved for radio access technology likeGSM/UMTS or a dedicated spectrum is used for deploymentof NbIoT carrier. However, this will escalate the implementationcost as software and hardware upgrade will berequired for spectrum reframing.
- In-Band Operation: In this mode NbIoT carrier isdeployed within LTE carrier. Sharing of resource blockwould definitely result in the more efficient use of spectrum whichin turn will increase the capacity. The LTE bands not utilized to carry system information block 1 are used for in-banddeployment of NbIoT.In single tone transmission mode in uplink, there will beinterference between NbIoT and LTE (3.75 kHz subcarrierspacing). Although this interference could be minimized byscheduling users with similar SNR requirements in NB-IoTand nearby LTE PRBs. It's also a cost effective way as no hardware modifications are required.
- Guard-Band Operation: In this mode NbIoT carrierwill be located within guard band of LTE carrier to avoidinterference. This mode delivers better downlink throughputin comparison to in-band as more downlink resource is available [20].

NbIoT deployment modes offer high flexibility as carrier deployed in one mode can continue working through either of the other modes if spectrum migrates to LTE.

## 4 IMPLICATIONS OF NBIOT IN DEVELOPING COUNTRIES BASED ON POSSIBLE SECTORS OF DEPLOYMENT

With the prevailing challenges of developing countries as highlighted in section 2, there is no doubt a compelling need, if development must be driven, to seek out, first; technologically-based solutions, which have proven to be efficient as reflected by the state of the developed countries, and second; such solutions as would offer great economic potential when compared to their alternatives. NbIoT with its characteristics as outlined in section 3 proves to be a good option for developing countries. Another important point to note about NbIoT is that it is compatible with GSM as well as the recent versions of the LTE such as 4G and 4.5G. However, other forms of IoT are only compatible with the recent versions of LTE, and with GSM being prevalent in developing countries, hence, NbIoT is a necessary option. NBIoT being a promising technology could support a wide range of applications with increased efficiency. Some of the important applications sectors of NbIoT with notable market perspective are utility-meter, industry automation, smart logistics, smart cities,smart home applications(16),waste management, environmental monitoring, agriculture, e.t.c. Applications with public perspectives such as; automobile and vehicular management,policing and law enforcement assistance, e.tc.In personal sectors like wearable, pet tracking, kids monitoring, white goods monitoring, which provide convenience to remote access of water, gas, electricity, and heat readings even whenthey are located in weak coverage areas like basements, and several other LPWA applications. As a matter of fact, for rural areas there is currently no better alternative to NbIoT due to its economical features. Figure 2 shows a typical grid of some possible applications of NbIoT.

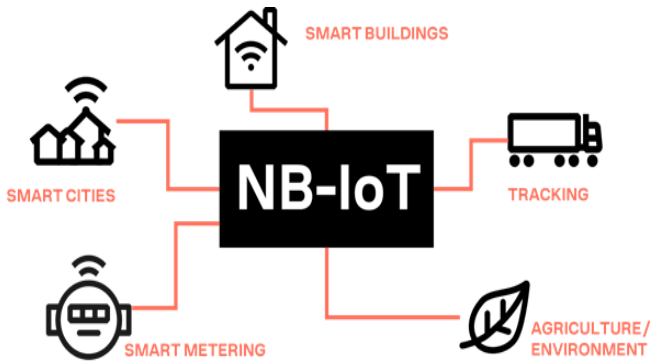


**FIGURE 2: APPLICATIONS OF NBIOT**

## 5 SECTORS WHERE NBIOT IS DEPLOYED

This section discusses a few critical sectors where NbIoT can be deployed and its implication in developing countries.

**i. Manufacturing**

Manufacturing is an important economic sector for developing countries. Recently, manufacturing companies in the developing countries are experiencing extreme competition, mainly due to the increasing pressures from technological changes and global business challenges. These pressures result in the globalization of manufacturing, characterized by faster transfers of materials, complex payment systems and the compression of products' life cycles, which drives the integration of technologies with increasingly sophisticated customers' needs [22]. To be successful, companies try to anticipate future trends by developing ideas, products or services to rapidly and effectively meet future demands. In addition to that they are responding to their current customers' or organizational needs to sustain competitive advantage. Among all the sets of pressures of a technological nature, the advent of the Internet has deeply affected companies' approach to production and has strongly reshaped organizational and operational structures. However, the role of the Internet in manufacturing is still understudied as it is for the IoT phenomenon. Advanced manufacturing technologies strongly rely on various ICT technologies to achieve higher productivity, higher quality and lower production costs. Such an effect is especially focused on processes of manufacturing automation, and of information systems. Indeed, the advent of Internet-based technologies has led to the emergence of new manufacturing philosophies and new forms of organization, such as virtual organizations, remote manufacturing, computer-integrated manufacturing systems, and Internet-based manufacturing, i.e. wireless milling machines, coordinated measuring machines, networked sensor arrays and surveillance systems. For example, "design anywhere, manufacture anywhere" is a new approach to production which shares design and manufacturing data across multiple platforms and infrastructures [23]. Recent studies have confirmed such trends, indicating that the future of manufacturing firms will be mostly information-oriented and knowledge-driven, leading to a much more flexible and an abundance of automated operations systems.

In all these changing scenarios, overall efficiency and automation can be provided by NbIoT [24]. Thus, the choice of NbIoTwill have positive implications on industrial automation in developing countries.

ii. **Healthcare**

Healthcare provision in any country is one of the basic services. It is also a large sector due to the very nature of the services provided by this system. Healthcare system is multi-tiered and need proper collaboration among each of the tiers. In several healthcare processes, NbIoT can play a role of game changer. For instance, in emergency proceedings it can help the patients to get appropriate treatments while coming to the hospital from their residence. Using the sensors, the vital information of the patients can be sent to the doctor who in return can provide the appropriate support through the sensors till the patient reaches the hospital. Similarly, the telemedicine applications too can be improved through the NbIoT based sensor assistance. Several works have been done in this area;[25] proposed an NbIoT-based system for glucose control. [26], also proposed an NbIoT-based system for diabetes monitoring. This shows that the choice of NbIoT will no doubt have positive implications in the health sector of developing countries.

iii. **Agriculture**

NbIoT can be deployed in the agricultural sector for several performance enhancements. In agriculture, several resources are used to increase the harvest. Many of those resources are underutilized due to the lack of facilities to monitor their utilities. For optimal use of the resources, NbIoT can be used which can sense the level of utilization and improve the utilization efficiency. For instance, water is an essential resource for agriculture. It is not available in sufficient amount in every part of the world. In the dry areas, water has to be utilized very efficiently. This utilization can be monitored in the agricultural farms through the water sensors deployed under the soil. Similarly, fertilizer concentration, pesticide intensity and humidity levels too can be monitored using different types of sensors as a part of NbIoT in agriculture. These resources can also be remotely controlled through the NbIoT. As the energy levels for these sensing operations are very low, the cost of this IoT based monitoring is very much economical for the farmers. On the other hand, the harvest can be maximized due to the efficient nutrition distribution to the plants. These initiatives are already being deployed in several countries and found to be very effective. Of course, it will be made even more efficient in the future. [27]

iv. **Resource Management**

Basic resources such as water, electricity, gas and other essential commodities are not properly managed in the developing countries. That leads to the poor resource utilization efficiency and loss of revenue for the government and associated public sectors. NbIoT based solutions already exist to improve the resource utilization efficiency in these areas. Smart metering and efficient resource distribution can be a game changer in these sectors. NbIoT based automation in the metering and resource distribution is quite cost effective and efficient. It can provide a real-time resource monitoring framework to the resource distributors. This is how the operators can directly

monitor the efficiency of resource utilization. Thus, NbIoT is being deployed in several countries for the public resource management and it promises to be the most reliable option for developing countries.

## 6 Conclusion

The ability of Narrowband IoT(NbIoT)to provide coverage in low power applications amongst the various other versions of IoT makes it unique. It is also special in the wide coverage and low cost of its deployment. This article, has presented the main characteristics/features of NbIoT, its layered architecture which is needed in its design and implementation, its different modes of operation and possible sectors of its application, all as touching the relevant role it can play in driving the development of developing countries which have perculiar issues has have also been highlighted. It has been established that theNbIoT is very much suitable for developing countries due to its low cost and wide coverage. NbIoT is very much effective in manufacturing, healthcare,agriculture, resource management and several other LPWA applications.

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