Telemedicine by NB-IOT

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Abstract:
NB-IOT (Narrow-Band Internet of things) is a low-power protocol that is required for various application areas such as healthcare, automotive, aerospace, etc. It provides a wide service coverage area using a very small amount of resources. It is useful in a wide range from normal scenarios like hospital automation to real-time telemedicine. Remote medical monitoring of the patient in real-time is built on the continuous monitoring of the important vital parameters of the patients, which indicate the health status of the patients. Monitoring and control of important signs are required in various scenarios. In case of critical health problems, vital parameters should be continuously measured. Let's imagine a scenario where a patient lives in a rural area far from a hospital. This kind of environment requires the involvement of new and emerging technologies such as real-time telemedicine, a massive machine-type communication that helps to avoid problems in the delivery of medical care. Due to technological challenges and limitations, in several remote regions that do not have hospital services, we have come up with a new technology (NB-IOT) that supports the provision of medical services to patients who reside in a remote area that is far from a hospital. This newly designed technology uses NB-IOT as a communication method to transmit the patient's vital signs. It is an excellent new technology that offers long-range real-time communication for different sensors with low temporal latency at a low baud rate, less device processing complexity and very good device battery life. The goal of the study is to examine the real performance of NB-IOT in terms of effective data throughput and the number of patients served per cell in a stand-alone and in-band NB-IOT health care monitoring system in a rural location. IoT systems have been developed for emerging applications. One of the best and most affordable IOT implementations is NB-IOT. It is an energy-efficient wide-angle network technology and is therefore suitable for resource-constrained scenarios. Therefore, NB-IOT is a relatively attractive solution for real-time telemedicine. In this article, we have presented the features and functions of NB-IOT that make it a good and suitable technology for telemedicine.

DOI: 10.24297/j.cims.2023.2.13

1. Introduction

The IOT (Internet of Things) is a crucial component of the contemporary digital world. It may be used in a wide range of sensor-based application situations and has several sub-divisions. Initially, it was only a basic value-added solution for WCNs. They now come in a variety of cellular and non-cellular configurations due to advancements in technology, including autonomous networks, wireless sensor networks, and wireless control networks. IOT may be categorized into many types based on its characteristics. Narrowband IoT is one of the specified IOT configurations. As the name implies, this IOT needs a certain frequency range to function. As its requirement is narrowband, it has several advantages over other forms of IOT.

In many rural areas and slums in large cities, access to health care is limited especially for large populations, especially in developing and developed countries. The health sector faces many challenges such as a lack of skills, a lack of health professionals and a lack of health centers. There are many such issues in remote locations. For the residents of this area, it includes the continuity, availability and provision of healthcare and other services. As a consequence of a lack of or improper allocation of human and financial resources, as well as a lack of specialized medical services, the majority of the population in these regions receives insufficient healthcare. A sparsely populated and distant area cannot support a medical professional with enough patients to make their practice profitable. Patients suffering from certain conditions or the elderly may find the situation more challenging. E-health and telemedicine are examples of information and communication technology solutions that may be used to solve rural health issues and the digital gap between urban and rural health facilities [5]. The primary outcomes and contributions are:

• Develop an NB-IOT system using a wireless sensor network to manage patient monitoring in a remote area.

• Real-time remote monitoring of patients in severe condition

• Enable the automated collection of multimodal data from several sensors, and then store and analyze it with a single system.

• Improve the ability of the nursing staff to respond to the patient's vital signs.

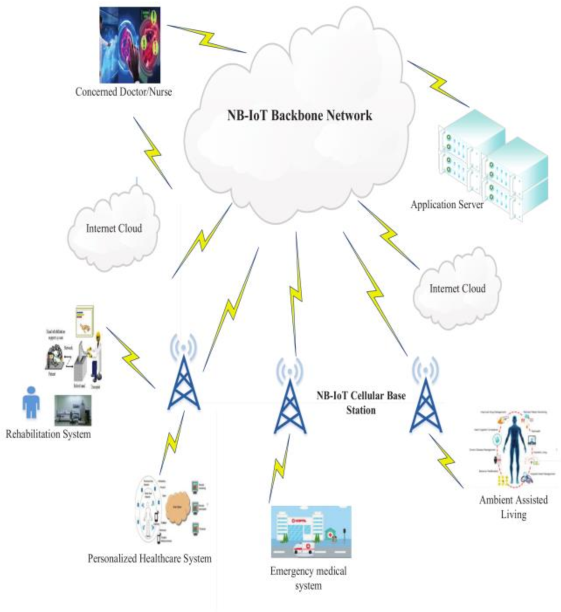

Figure 1: NB-IOT Telemedicine architecture.

NB-IOT FEATURES

A low-power and narrowband form of IOT is known as NB-IOT. It is developed for massive communication between machines. As its name implies, it operates and performs its functions using narrow bands. Only 180-200 kHz of bandwidth is needed for its operations. The operating bandwidth for NB-IOT was set at 180 kHz in LTE Releases 13 and 14. In comparison to other IOT kinds, it is an LPWA (low power wide area) which saves a significant amount of power. It is the best option for efficient and extensive IOT implementation across a range of uses. Compared to the proposed IOTs, it is slimmer, thinner and greener. It can be used in cellular or non-cellular form depending on the application. However, since they can perform all of their operations using already-existing cellular structures, cellular forms are more often used. It was standardized under compatible LTE specifications and created for associated home environments for LTE Releases 13 and 14 [15].

The following three operating modes [12] in which NB-IOT may be implemented are:

- Standalone mode as a dedicated carrier.
- In-band mode within the allocated bandwidth of the broadband LTE carrier;
- Within the protection band of the current LTE operator.

One 200kHz GSM channel may be used by NB-IOT in the stand-alone mode of operation, while one LTE physical resource block (PRB) will be used in in-band and guard-band modes (180kHz). This NB-IOT concept aims to provide low-cost, low-power-consumption devices with great coverage (20dB better than GPRS), extended battery life (over 15 years), and huge capacity. Although a 10-second delay is intended for exception reporting, latency is eased [8]. Essential and fundamental LTE functions are used in the NB-IOT design. However, NB-IOT has only added signaling and control channels. Additionally, although classic LTE also offers full-duplex mode, FDD (frequency division duplex) half-duplex type B is the best option for NB-IoT. FDD Half duplex means that up-downlink are frequency separated. Messages are transmitted in both operations (transmission and reception) simultaneously [9]. Extracted from 3GPP specifications, the control channels and both down-uplinks' brief frame structures are as follows: The downlink frame structure of the NB-IOT is 10ms in duration, which is the same as an LTE frame. Each of the 10 sub frames in a frame, each lasting one millisecond, is made up of two slots, each holding seven OFDM symbols. It has one physical source block (PRB) in the frequency domain, with 12 subcarriers separated at 15 kHz and a typical cyclic prefix (CP) [11]. The smallest transmission unit is a resource element (RE), which consists of one subcarrier and one symbol. In contrast to LTE, NB-IOT has 3 physical channels and 2 physical signals, as indicated below.

- Narrowband primary and secondary synchronization signals
- Narrowband reference signal
- Narrowband physical shared download channel
- Narrowband physical downlink control channel

Both single-tone as well as multi-tone broadcasts are supported by NB-IOT in the uplink direction. The SCFDMA technique is used for multi-tone transmission, and a 15 kHz subcarrier spacing is used. Monotone transmission may use either a 3.75 kHz or a 15 kHz subcarrier spacing. The numerology of LTE and the frequency of 15 KHz are comparable. A slot length of 2ms is produced by the subcarrier spacing, which is 4 times greater than the symbol duration of 3.5 kHz compared to 15 kHz. Additionally, a new form of resource mapping unit known as Resource Unit is developed for the NB-IOT uplink (RU). In the frequency domain, the number of slots and subcarriers together make up the RU (in the time domain). The following diagram illustrates the one physical signal and two physical channels that NB-IOT has for uplink.

- Narrowband physical channel with random access.
- Demodulation reference signal.
- Narrowband shared channel uplink.

The 3GPP organization created the low-power radio WAN (LPWAN) standard known as NB-IOT to support a variety of mobile services and devices [10]. Smart meters, smart grids, smart cities, logistics, personal IOT applications, agricultural, and industrial monitoring, and many more applications are among the key target applications. In this study, we use NB-IOT as part of a wireless remote monitoring system (WBAN). These devices are wireless sensors that exchange information over a long-distance wireless network.

Low Power WAN (LPWAN) NB-IOT Features

An energy-efficient variation of traditional IoT is NB-IOT. The LPWA character of NB-IOT is its key feature. In addition to network bandwidth, it may save a lot of energy. Recent LTE releases have standardized its architecture and protocols for varying operating conditions. The 3GPP standards committee has accepted the NB-IOT deployment bandwidths in version 13. Different operators may employ various spectrum bands depending on the conditions. The highest acceptable bandwidth for an end device is 200 kHz, as stated by Release 13 of the 3GPP LTE standard. A bandwidth of 180 kHz is used for communication purposes [16] – [20]. The maximum uplink and downlink data rates are limited to 150kbps at this bandwidth. It was advised to use half-duplex mode for NB-IOT communication [17]. These standards have been improved for more sophisticated applications in version 14. One battery may run NB-IOT nodes or devices for more than 15 years since the power output of the transmitter is relatively low. 2 power levels have been specified in the recent NB-IOT standards, namely 20dBm and 23dBm [1]. The NB-IOT sensors have excellent sensitivity. In any condition, they are capable of receiving signals with up to 64dBm of power. These are specific NB-IOT features that have not been included in any other IOT versions to date.

NB-IOT Layer-wise Architecture

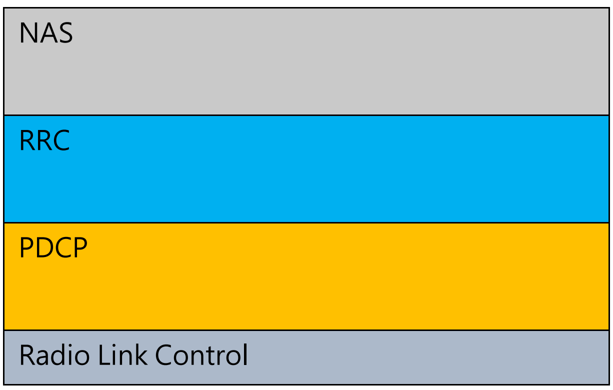

Figure 2: NB-IOT Layer wise architecture.

For its dimensioning, planning, design, cost estimation, and ultimate implementation, a formal NB-IOT architecture is necessary. However, it is comparable to wireless sensor networks (WSNs), which have existed for a long time. The current WSN topology and design may be helpful for future advancements. Unlike cellular systems, including LTE networks, which will serve as the foundation of NB-IOT, WSNs didn’t have an organized and well-defined design. LTE cellular architecture for NB-IOT [17] is the best option in this situation. Real-time planning and deployment are made possible by the layered architecture of NB-IOT. Version 13 included several requirements for different layers. As seen in Fig. 1, NB-IOT may be categorized into 6 layers. The air interface often makes up the bottom physical layer. Similar to previous WSNs, the physical layer also carries out several additional tasks that were introduced in version 13. Similar tasks are performed by Layer 2 and the MAC layer in other networks. Includes multiple access modes and media access protocols. The radio link control layer is between the upper and MAC layers. For radio links, this layer matches the MAC layer information. The Packet Data Convergence Protocol (PDCP) layer, which is located above it, performs several related tasks, including routing and traffic scheduling. The Radio Resource Control (RRC) layer lies above it and manages the radio resources used by the packets in the channels. UDP (User Datagram Protocol) and other cellular mechanisms are used by NB-IOT to carry out this task [18]. Since UDP works well in wireless networks, it is also appropriate for NB-IOT. The NAS (Non-Access Stratum), which is the top layer, helps to communicate between the UE (user equipment) and the NB-IOT central node, also called the NB-IOT main server.

2. Deployment options for NB-IOT

NB-IOT deployment options were agreed upon in version 13. According to version 13, NB-IOT may be used in 3 different forms. In the first case, an independent microwave band in the region of 700MHz or 800MHz is made available for its implementation. The second form is guard band deployment, in which spectrum is a new IOT application. In-band deployment is the third type. These 3 deployment conditions are shown in Figure 3. Depending on the bands' accessibility and appropriateness for the purpose, any of these may be employed in practice. In certain application-specific situations, it may be necessary to employ even two or all three methods.

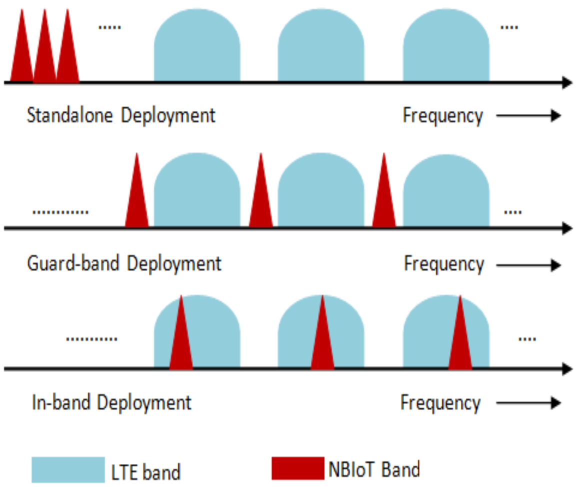

Figure 3: NB-IOT deployment for different frequency bands.

NB-IOT Applications

NB-IOT is an attractive technology in LPWA mode. It has a huge capability to work in resource-constrained conditions. Here we can look at some typical sectors where its deployment is being considered. Every month, new applications appear in several sectors. NB-IOT offers potential applications across a wide range of new industries. Both indoor and outdoor uses may be made of these applications. NB-IOT technology is essential for creating smart cities and smart homes [16]. Both healthcare and public place security surveillance may benefit from it. In Figure 4, we presented real-time healthcare monitoring. The monitoring and management of smart cities, smart home applications, mass production, pet and child monitoring, and real-time healthcare monitoring are all areas where NB-IOT may be very useful.

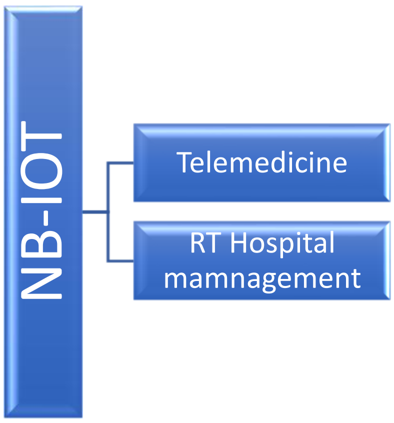

Figure 4: NB-IOT Applications in the medical domain

NB-IOT for Healthcare

In each nation, one of the fundamental services needed is the provision and monitoring of health care. The healthcare system is a multi-layered architecture and requires proper cooperation between individual layers. In several healthcare processes, NB-IOT is playing a game-changing role. For instance, it may assist patients in receiving the proper care when travelling from their house to the hospital in an emergency. Biomedical sensors can provide critical patient data to medical professionals, who may then respond appropriately until the patient arrives at the hospital.

In hospitals, the patient's vital signs must be constantly monitored, which is usually done by a hospital doctor. The doctor constantly observes and records the vital signs of the patient's body and informs the medical staff to act according to the patient's condition. A significant breakthrough due to its cutting-edge technology is the remote patient monitoring system. The patient's vital signs are measured automatically by a wireless real-time health monitoring system employing embedded technology. NB-IOT uses an already deployed cellular base station to offer real-time telemedicine. It monitors breathing rate, sweating, body temperature, blood pressure and pulse. It offers a transfer rate of up to 2Kbps/sensor. We take into account a single sensor node while designing our healthcare monitoring system. Each sensor node in this implementation, including temperature and respiration rate sensors, is seen as a distinct node with its transmission module. As a result, each node uses an eNB with optimized latency and data rate needs to communicate data to the central processing unit [4]. In this embodiment, multiple transmission links to the base station are required for each patient. The functioning of the health monitoring system is based on several sensors, each of which has a varied information packet size as well as a different time and crucial patient data. We assume in our study that the patient is critical and needs continuous observation. For each patient, all sensors communicate directly with the NB-IOT base station. In this instance, sensors worn by patients communicate all patient data to the treatment facility through a base station. This data is processed and sent to medical personnel such as general practitioners, specialists, and nurses so that the medical personnel can act on the received patient data. Figure 5 shows the proposed model.

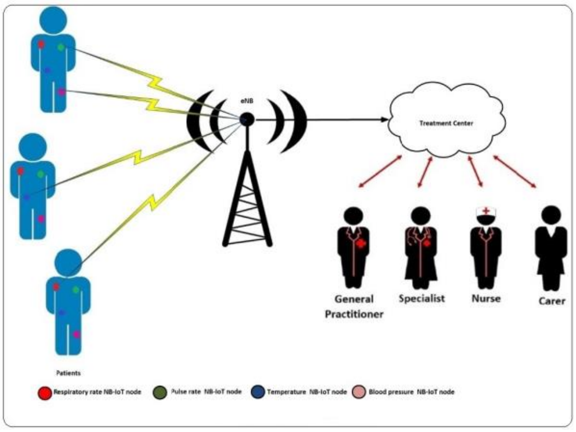

Figure 5: Telemedicine System

METHODOLOGY AND NB-IOT SYSTEM MODEL

We took into account both in-band and stand-alone NB-IOT implementations with 180 kHz bandwidth in a standard LTE system to undertake a system performance study. A typical three-sector site network with a 1732m site-to-site distance is used in the scenario. When mobile services are available and NB-IOT is enabled by an LTE operator sharing LTE resources, for instance, an in-band mode may be used. As it doesn't need any modifications to the RAN (Radio Access Network) hardware and effectively utilizes spectrum resources for LTE or NB-IOT services dependent on mobile user demand or equipment, this mode of operation is more economical and easy for mobile operators. Operators may guarantee a seamless switch to LTE mode for communications between several machines by re-framing one or more GSM operators to transmit NB-IOT traffic. Figure 6 shows Stand Alone and in-band deployments.

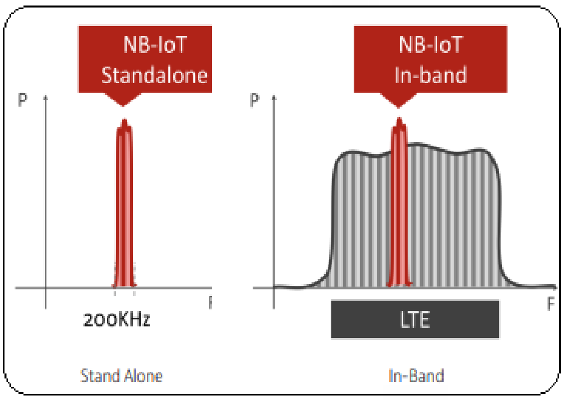

Figure 6: In-band and Stand Alone deployments

When the nth PRB is allocated, the following equation gives the transmission rate R_{in} for node i

Rin = B log 2(1 + SINRin) (1)

Where B is the allotted transmission bandwidth and SINRin is the SINR (signal-to-interference-plus-noise) for node i on the nth PRB and is provided by:

SINRin =Pnhinlin + N0 (2)

The channel gain between the base station and node i at the nth PRB is represented by h_{in}, and P_n is the transmit power. In our study, we will suppose that node interference, I_{in}, is minimal. Noise power spectral density is represented by N0. The corresponding MCL is determined based on the SINR. The following table outlines the link between MCL and SINR:

Target SINR = TX power + 174- Noise figure- 10 log 10(B)-MCL (3)

The path loss is represented by:

Path Loss = I + 37:6log10(R) (4)

R in kilometers with I=120.9 for 900 MHz

The CDF with interference and without interference for NB-IOT is shown in Figure 7.

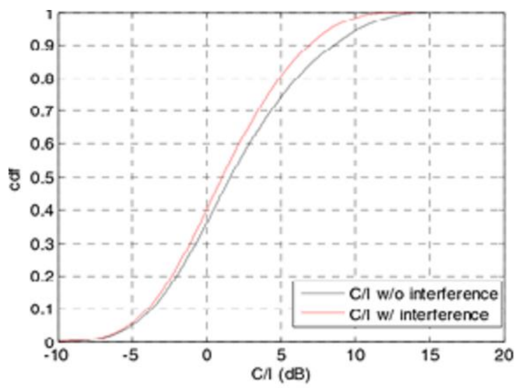

Figure 7: CDF vs C/I

3. Conclusions

Low-power IOT mode uniquely uses narrowband IOT. Additionally, it is a unique technology with broad application and affordable implementation. We discussed the key components of NB-IOT in this paper, including its layered architecture, which is necessary for its design and implementation. For underdeveloped nations and rural regions, NB-IOT is well suited. It is the best available option for real-time telemedicine because of its affordable cost and extensive coverage. NB-IOT is very effective in healthcare. The overall efficiency of NB-IOT in real-time telemedicine has been shown. The healthcare industry will use NB-IOT extensively in the future.

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