Study on known models of NB-IoT Applications in Iraqi environments

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Abstract. Internet of things (IoT) considerably changes connectivity requirements, in particular concerning longer battery life, lower device costs, lower deployment costs, increased support and coverage for a lot of devices. Starting from those necessities, numerous various cellular and non-cellular low power WAN which could be abbreviated to (LPWAN) solutions emerged lately and are challenging for business related to IoT and the general market of connectivity. Therefore, in this study, Narrowband IoT main characteristics are explained, as well as, the suitability for different IoT applications in smart cities industry. The Narrowband IoT, which could be abbreviated to (NB-IoT), is known as a LPWAN technology of radio criterion which was presented for enabling the connections of various services and devices with the use of cellular tele-communication bands. NB-IoT can be defined as a narrow band radio technology that was created for internet of things (IoT) which is considered as a wide area of Mobile internet of things (MiIoT) techniques which were published as a standard through 3GPP (third Generation Partnership Project), applications for NB-IoT could be very wide range and different topics, within this paper suggested NB-IoT applicable models for application in Iraqi environment to solve many problems (Smart white goods, Smart logistics, Smart electricity metering and Smart street lighting). These models based on NB-IoT technologies which are not yet provided by communications providers in Iraq (zain, Asia, korek).

1. Introduction

The mobile industry developed and standardized a novel category of technologies of LPWAN which are helpful for network operators in cost tailoring, power consumption and coverage of connectivity for certain IoT applications [1].

NB_IoT is considered as a LPWAN standard which was presented for enabling many different services and devices to be connected with the use of cellular telecommunication bands. NB_IoT can be defined as a narrowband radio technology that was created for IoT, also it is a range of Mobile IoT (MiIoT) technologies which were standardized via 3GPP [2].

It may be employed in 3 distinct modes of operation [3] individually in a form of a separate carrier, [4] in-band in the utilized bandwidth regarding the wide-band LTE carrier, [5] and in guard-band related to the available LTE carrier. Concerning individual utilization, Narrowband IoT could utilize a single channel of GSM (200 kilohertz) whereas for guard-band and in-band utilization, usually it is going to utilize only 1 physical resource block (PRB) related to Long-Term Evolution (180 kilohertz). NB_IoT plan targets comprise high-coverage (20dB enhancement over GPRS), inexpensive devices, battery long life (over ten years), and huge capacity (over (52,000) devices per channel per cell). Latency is basically relaxed even though a small amount of delay budget like ten sec. is the exception reports targets. As Narrowband IoT is anticipated to implement a design on the basis of the available functionalities of LTE, reusing the same devices is possible, in addition to sharing spectrum with no
problems of coexistence [6]. Moreover, Narrowband-IoT could easily plug into LTE’s core network. Allowing the entire services of network like tracking, policy, security, authentication, and charging of being entirely supported [7].

Scheme of Down-link transmission

The Narrowband IoT downlink is based on orthogonal-frequency-division-multiple access (OFDM) with the same sub-carrier space of 15 kHz as Long-Term Evolution (LTE). Duration of the slot, duration of the sub-frame, and duration of the frame = 0.5 millisecond, one minute, and ten millisecond, respectively, equal to the ones in LTE. In addition to that, slot format with respect to the phrase cyclic prefix (CP) number plus duration of orthogonal frequency-division multiple access (OFDM) symbols for each slot are congruent as well to the ones in Long-Term Evolution (LTE). Essentially, an NB_IoT carrier utilizes a single LTE PRB in the frequency domain, in other words, (12 of 15) kHz sub-carriers for totally 180 kHz. The reuse of the same numerology of OFDM as the Long-Term Evolution (LTE) guarantees the coexistence performance with LTE in the down-link. For instance, if the Narrowband IoT is used within a carrier of LTE, the orthogonality between the Narrowband IoT PRB and all the other Long-Term Evolution PRBs is maintained in the down-link [8].

The scheme of uplink transmission

The Narrowband IoT up-link support each of the multi- and single-tone transmission types. The former is modeled on the basis of SC-FDMA with identical (15 kilohertz) spacing of subcarrier, 0.5 millisecond slot, and one millisecond subframe to Long-Term Evolution. Single tone transmission support (15 and 3.75 kilohertz) , 2 numerologies. The 15 kilohertz numerology equals the LTE and therefore reaches the optimal efficiency of the co-existence with the up-link LTE. The (3.75 kilohertz) single-tone numerology utilizes two millisecond duration of slot. Similar to the down-link, an up-link NB_IoT carrier utilizes an overall system band-width of 180 kHz [9].

Options of Deployment

NB_IoT could be utilized as a separate carrier with the use of any of the available spectrums which exceed 180 kHz. It could be used as well within the allocation of the LTE spectrum, either within a carrier of LTE or in the guard-band. Those various situations of utilization are depicted in Figure 1 [10]. The scenario of usage, guard-band, in-band or stand-alone, nevertheless have to be transparent to a user equipment (UE) in the case of initial turn on and looks for a carrier of Narrowband IoT. Like existing LTE user equipment, a Narrowband IoT user equipment is merely needed for searching for a carrier on a raster of 100 kHz. Anchor carrier is the Narrowband IoT carrier characterized to facilitate initial synchronization of UE [11]. The (100 kilohertz) user equipment search raster suggests that to utilize in-band type, an anchor carrier could just be located in specific Population Reference Bureau (PRBs). As an example, in an LTE carrier of ten MHz, the PRBs’ indexes which are optimally aligned with (100 kilohertz) grid and may be utilized as an NB_IoT anchor carrier are (4,9,14,19,30,35,40,45). The indexing of PRB start indexing zero position in Population Reference Bureau (PRBs) that occupies the lower frequency in the bandwidth of the LTE system [12].

Figure 1. guard-band utilizations in the down-link.
Figure 1 shows similar to the utilization inside in-band, the guard-band utilization in a NB_IoT anchor carrier requires having center frequency which is a maximum of (7.5 kilohertz) from the (100 kilohertz) raster. Cell of NB_IoT search and first acquisition (initial acquisition) are modeled in user equipment for being capable of synchronizing to network with the existence of a raster offset of about 7.5 kilohertz. Multicarrier Narrowband IoT process is supported [13]. Due to the fact that it is sufficient to have a single Narrowband IoT anchor carrier to facilitate an early synchronization of UE, the extra carriers don’t necessarily require being close to the 100 kilohertz raster grid. Those extra carriers are known as secondary carriers [14].

**Physical Channels**
The physical channels of NB_IoT have been designed mostly according to legacy LTE. In this part, summary of them is provided focusing on characteristics which differ from legacy LTE [15].

**Downlink**
- NB_IoT offers down-link next physical channels and signals.
- NB-Physical Broadcast Channel (NPBCH)
- NB-Primary Synchronization Signal (NPSS)
- NB-Physical Downlink Control Channel (NPDCCH)
- NB-Secondary Synchronization Signal (NSSS)
- NB-Physical Downlink Shared Channel (NPDSCH)

With contrast to the LTE, those NB_IoT signals and physical channels are mainly time multiplexed. Figure 2 depicts the way NB_IoT sub-frames are distributed to various physical signals and channels. Every Narrowband IoT sub-frame spans over a single PRB (12 sub-carriers) in the domain of frequency and one millisecond in the time domain [16].

**Uplink**
NB_IoT comprises the next channels in up-link [17].
- NB-Physical Uplink Shared Channel (NPUSCH)
- NB-Physical Random-Access Channel (NPRACH)

**Device Complexity**
NB_IoT gives the ability of low-complexity UE implementation via the following designs [18].
- Supporting a single version of redundancy in the down-link
- Considerably reducing sizes of transport blocks for each of the down-link and up-link.
- A UE needs one antenna only.
- Supporting single-stream transmissions only in each of the down-link and the up-link.
- requires no turbo decoder at the UE due to the fact that TBCC alone is utilized to downlink channels
- Supporting single HARQ process only in each of the down-link and the up-link
- Low sampling rate because of lower UE bandwidths
- Does not require connected mode mobility measurement. A UE merely requires performing mobility measurement throughout the Idle mode.
- Does not require any parallel processing. All the processes of the physical layer, reception and transmission related to the physical channels happens sequentially.
- Allowing the operation of half-duplex frequency-division duplexing (FDD) only.

The aim of coverage is accomplished with (20 or 23 dBm PA), which makes it possible using an integrated PA inside the UE [19]

**Battery Lifetime and Latency**
NB_IoT aims at applications known as latency insensitive. On the other hand, for applications such as sending alarm signals, narrow IoT has been designed for allowing a maximum of ten seconds latency [20]. NB_IoT has the aim of supporting long period life for battery. This lifetime for battery calculated
for device that has (164 Db) losses coupled, and the hope ten-year battery-life may be achieved only if the transmit average of UE is 200-B, daily data [21].

**Capacity**

Narrowband IoT supports huge capacity of Internet of Things with the use of a single PRB in both up-link and down-link. Sub-PRB UE scheduled bandwidth has been summarized in the up-link, which includes one sub-carrier NPUSCH. It is worth noting that for coverage limited UE, the allocation of bigger bandwidth is spectrally inefficient due to the fact that the UE is not capable of benefitting from it for being capable of transmitting at greater data rate. According to the traffic scheme in [22], Narrowband IoT with a single PRB support over 52500 UE for each cell [23]. In addition to that, Narrowband IoT support numerous carrier operation. Therefore, more Internet of Things capacity may be added via the addition of more NB_IoT carriers.

![Figure 2. The architecture of NB-IoT Network [23].](image)

**Architecture of NB-IoT Network**

Core network of NB_IoT depends on the evolved-packet-system (EPS) and 2 optimizations made for cellular IoT (CIoT) have been needed, the cellular IoT user plane evolved packet system enhancement and the cellular IoT control plane evolved enhancement for the packet system. Each one of the planes chooses the optimal route for user data packets as well as control, for up-link and down-link data. Flexible path of optimizing for the chosen plane is provided for the data packet that has been produced by sets of mobile. User access to a cell in a NB_IoT is just like to the one of LTE. On the control plane CIoT EPS optimizing, the enhanced UMTS terrestrial radio access network (E-UTRAN) is responsible for handling the communications between the MME and UE, which may include the base stations (B.S) evolved referred to as the e-NodeB or e-NB. After that, data has been transmitted to the packet data network gateway (PGW) through the serving gateway (SGW). For data that is considered as non-IP data, which will be transmitted to new defined node, service capability exposure function (SCEF) that can make the delivery for data in the machine type data in the control plane and give abstract interface to the services. With the user plane CIoT EPS optimizing, each of the non-IP and IP data may transferred via radio bearers through (PGW and SGW) to the application server [24] as shown in figure 2.

**Suggested NB-IoT applications in Iraqi environments to apply smart cities:**

1. **Smart street lighting:**

   one of the most important applications in smart cities is Smart Street Lighting. The street lighting is a large energy expense for any city. Smart system for street lighting might minimize the costs of municipal street lighting for about 50% to 70%. An intelligent system of street lighting is the one adjusting light output according to occupancy and usage, which means the automated pedestrian vs.
cyclist, vs. automotive classification. An intelligent street lighting control suggests installing a wireless based system for remotely tracking and controlling the precise street lights energy consumption and take the suitable measures for reducing energy consumption via power conditioning and control.

The controller of street lights must be installed on the pole lights consisting of micro-controller in addition to different wireless module and sensors. The LED street lights will be controlled via pole where the controller is installed which will control in accordance with the traffic flow, and the communication between each street light. The information from the road light controller can be exchanged to a base station using Wireless technology to screen the framework the framework activity method can be led utilizing manual mode and auto mode. The framework responsible for control will turn on-off the lights at predefined timing and required timings and can likewise shift power of the road light as per prerequisite. The traditional smart street light solution suffers several challenges: network instability, and multi-hop network operation. The smart Street Lighting system based on NB-IoT technology is composed of street lamp monitoring terminal equipment, NB-IoT network connectivity, IoT management platform and operation management cloud platform. The network structure is clear. The application protocol is simple. And it does not require any gateways greatly improving both the stability and the reliability of the system. At the same time, it can bring down operation costs by approximately 50% while allowing the control and status monitoring of each individual lamp, which makes the energy-saving configuration simpler and much more flexible as shown in figure 3.

Main advantage of the suggested NB-IoT prototype will make the installation and control much easier and simple if the smart street lighting which will lead to reduce the energy required and make the lights themselves adapt to the environment and surroundings and they are simply report irregularities provide alerts and maintenance scheduling.

2- Smart electricity metering:
NB-IoT based smart electricity meter provides utilities with the most dependable and usable wireless communications system. By using smart meters in the narrowband IoT, utilities can collect power consumption information specifically directly, and support different qualities hourly, with handling wide range of energy measurements and events.

Narrowband IoT has outstanding performance in terms of coverage, capacity and power utilization. Narrowband IoT is a wireless access technology with low power wide area (LPWA), that provide a wide range of preferences, such as a battery life, coverage gain over conventional GSM networks, see figure 4.
Figure 4. Smart electricity metering

Some smart metering apps can offer some cloud solution data like (management of meter data, device management, automatic reading for meters, meter data analysis and meter data reporting).

System model:
With the government direction to the privatization of the electricity field in Iraq, the system model for NB-IoT is very simple. NB-IoT module suppliers will provide NB-IoT modules to metering manufacturers. Meter vendors can provide not only meters but also the complete AMI solution including MDM/HES systems, via the NB-IoT communication network from telecom companies. The smart meters' data will be received by the utilities' data center.

In the smart electricity metering system, normally the mobile operator only needs to provide SIM cards, and charges for connectivity. Some mobile operators can provide cloud services to utility for application server hosting.

3- Smart logistics:
In oil industry as well as in military supplements logistics is important for operations to proceed and to overcome any lack in supplies. A Smart logistics model is suggested.

The solution uses the carrier network without requiring a gateway or a concentrator. NB-IoT based sensors can straightforwardly connect with the system connect to the network, resulting in a basic network structure. It is consequently more helpful to install devices and data can be obtained more easily. Vendors and owners need to focus solely on their services, without paying attention to network preservation.

In addition, the NB-IoT sensors have low power and are powered by batteries. Plug & play. Without the requirement for wires, the sensors can screen the whole coordination process in real time.

When working with GPS, the system can provide positioning accuracy to the closest distance, which meets the positioning necessities of co-ordinations, as shown in figure 5.

System model:

Figure 5. Smart logistics system model

These systems usually face many problems that need to be solved:
• Maintenance of vehicle-mounted terminal.
• Sensors and vehicle interface and compatibility which may differ from one to another.
• Sensors in such system usually will connect via wires which may troublesome.
• It is hard for third party to add monitoring sensors and to obtain data like (location, temperature of moving container).

4- **Smart white goods**

This application is very useful for good delivers which may sport the startups and new companies in the Iraqi markets which is newly discover the e-business and online markets.

The NB-IoT-based Smart White Goods Solution is available upon network access, bringing high online availability of equipped household appliances. Featuring inherent high mobility, the solution can prevent unauthorized cross-regional transshipment. Therefore, sellers cannot earn profits by setting different prices in different regions and bring economic losses to household appliance vendors.

This offers wide indoor coverage and high online availability to household appliances. It can remotely monitor the usage and status of white goods and help vendors offer predictive maintenance.

Which can utilize the usage data of white goods for Big Data analysis, provide household appliance vendors with value-added services, and allow to explore new business opportunities.

**System model:**

![System Model](image)

**Figure 6.** system model

The business model is traditional B2B2C. The mobile operators provide SIM cards to white goods providers, and white goods manufacturers produce the smart white goods and sell them to the end customers.

The white goods providers pay the first 3 years of communication data traffic fees to the operators when they sell these products. Three years later if the end customers still want to use the NB-IoT connectivity service then they can easily pay the data traffic fees via a Smartphone application, as shown in figure 6.

Almost all goods are placed indoors which may lead to connectivity problems, so we need a network with wide coverage performance which cover all the white goods locations, the first consideration in such system when build is terminal activation rate and second is the online rate of appliances, number of white goods connected require real-time processing capability of connections, network also should be secure to provide protecting and prevent unauthorized access.

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