NB-IoT Applications in Smart Grid: Survey and Research Challenges

Shahram Javadi, Sharifeh Seifvand

Abstract—Narrow Band Internet of Things (NB-IoT) is a Low Power Wide Area (LPWA) technology standardized by 3GPP. It is a cellular technology with wide coverage, low power consumption, Low costs, and massive connections benefits. NB-IoT has the potential to improve the automation of processes and provide a better service in Smart Grid. Many attempts started to introduce the NB-IoT as enabling technology to the Smart Grid. In this paper, NB-IoT use cases and approaches in Smart Grid will be analyzed. Research works will be surveyed based on existing NB-IoT techniques, which address various benefits in Smart Grid networks. Solved problems and issues of these techniques will be summarized.

Keywords-Nb-IoT, Smart Grid, Smart Metering

I. INTRODUCTION

Smart Grid integrates energy generation, transmission and distribution network with control methods, integrated communications, real-time monitoring and two-way flow of electrical power and information. Smart Grid enables electricity companies and grid system operators to reduce capital expenditure, effective asset management, manage demand, increase renewable capacity, comply with regulations and enhance customer engagement. NB-IoT will be one of the largest and secure communications protocols in the Smart Grid. Smart grid communications are classified based on their functionality within network consist of home area network (HAN), neighborhood area network (NAN), access network, and core networks.

The Internet of Things (IoT) changes the requirements for connectivity significantly, mainly with regards to long battery life, low device costs, low deployment costs, extended coverage and support for a massive number of devices. Several different non-cellular LPWA connectivity solutions are emerging and are competing for IoT business and the overall connectivity market.

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In recent years, 3GPP has approved the specification of the narrow band (NB)-Internet of things (IoT) system to support low cost and power machine type devices through the narrow bandwidth (i.e. 180 kHz) which built from existing LTE functionalities [1]. NB- IoT supports massive connections related to IoT requirement and state-of-the-art 3GPP security, with authentication, signaling protection, and data encryption. Since it operates in licensed spectrum, it is secure and reliable providing guaranteed quality of service [2]. NB-IoT perfectly matches LPWA market requirements, enabling operators to enter this new field. It has been introduced for cellular IoT with the following advantages [3-7]:

- Improved wide area coverage(seven times greater than existing 3GPP technologies)
- Support of massive number of devices transferring small, intermittent blocks of data, which is common to a lot of IoT applications (50K devices per channel per cell- some vendors puts it up to 100K)
- Reduced complexity
- Low Latency
- Lower component costs
- Low-power consumption guaranteeing 10 year battery life
- Fast upgrade of existing network
- High reliability and carrier-class network security
- Optimized data transfer, supporting small, intermittent blocks of data
- Simplified network topology and deployment
- Ability to integrate into a unified IoT/MTC platform

NB-IoT was designed with three different deployment scenarios [6]:

A. Stand-alone

Standalone deployment is mainly utilizes new bandwidth as a dedicated carrier and can be used as a replacement of GSM carriers. it provides deployment flexibility based on available spectrum and use cases.

B. Guard-band

Guard-band operation is done using the bandwidth reserved in the existing LTE carrier's guard-band which can be used without taking capacity from the main LTE traffic carriers.

C. In-band .

In-band operation utilizes same Physical Resource Blocks (PRB), within the occupied bandwidth of a LTE carrier. For an LTE service provider; the in-band option

provides the most efficient NB-IoT deployment. This allows the base station scheduler to multiplex LTE and NB-IoT traffic in the same spectrum.

The Standalone and Guard band deployment options tend to offer the best performance in terms of improved indoor coverage. In stand-alone deployment, NB-IoT can occupy one GSM channel (200 kHz) while for in-band and guard-band deployment, it will use one physical resource block (PRB) of LTE (180 kHz).

The three operation modes for NB-IoT are shown in Figure 1 [8].

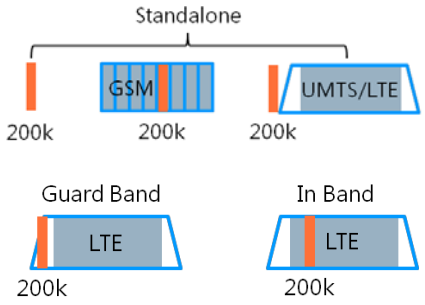

Figure 1. NB-IoT deployment modes [8]

Examples of service categories where NB-IoT is expected to transform business models include Smart metering (electricity, gas and water), Smart city infrastructure such as street lamps or dustbins, Connected industrial appliances , smart parking, building automation, asset tracking, and remote agriculture. Companies looking to deliver NB-IoT services via connected devices are increasingly seeing value in the ability to manage massive-scale device deployments in mixed connectivity environments [9].

NB-IoT connectivity will offer different smart grid services with sensor containing NB-IoT module. One of the NB-IoT LTE Cat. NB1 compliant module is u-blox's SARA-N2. It is optimized for poor coverage applications, even underground. It provides secure, private communications over licensed spectrum with guaranteed quality of service. Peak download data rates of up to 27.2 kb/s can be achieved, while the peak upload data rate is 62.5 kb/s. Also the Sequans Communications company introduced the Monarch, a single-chip NB-IoT solution designed specifically for narrowband IoT applications, including sensors, wearable, and other low data, low power IoT devices [10].

The rest of the paper is organized as follows. In Section II, NB-IoT applications in Smart Grid are presented. NB-IoT lunched solutions and current state of the art techniques and research works by vendors are provided in section III and section IV introduces the open issues and challenges for NB-IoT application in the Smart Grid. Finally, the paper conclusions are drawn in Section V.

II. NB-IoT Application In Smart Grid

Different business case analytics were designed to evaluate the NB-IoT business for Smart Grid based on social and demographic data evaluation in countries or regions. For example Huawei has modeled the adoption rates for different NB-IoT applications during the next five years based on use cases in more than one industry. In this section, the main scenarios NB-IoT application in Smart Grid will be introduced. The use of NB-IoT, a cellular IoT connectivity protocol, reduces power consumption while providing wide coverage, it added.

A. Smart Metering

Smart metering enables the automated collection of utility meter data and plays a significant role in smart grid. It will consequently reduce the cost generated from manual meter reading. NB-IoT supports the automatic collecting and processing power consumption information intelligently, via regular and small data transmissions.

Probably the main requirement for smart metering is network coverage. NB-IoT has excellent coverage and penetration to address this issue. Behavior of using electricity can be adjusted by customers to save money according to the statistics and analysis of power consumption as well as the implemented price ladder. NB-IoT would greatly enhance the stability and accuracy of traditional AMR system and achieves power consumption statistics, analysis and state of use via advanced communication technologies, computing technologies and electric energy metering technologies. Figure 2 shows a typical smart energy meter based on NB-IoT.

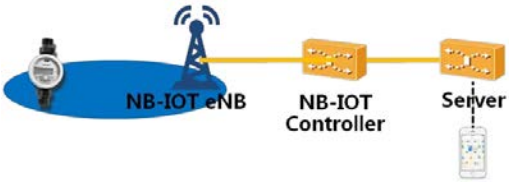

Figure 2. NB-IoT Smart Meter [8]

B. Real-Time Monitoring(Alarms & Events)

Security is a very important aspect in smart grid. Network monitoring with alarms and event detections will help to rapidly inform a detected grid intrusion. This system will not only offer intelligent protection from intrusion but will also offer intelligence action for detected.

Alarms and events detectors will make use of sensors that constantly communicates with the NB-IoT network. It can be used for unit, distributed power plant, energy consumption, plant, energy storage, transmission line, condition and energy efficiency monitoring and management. Moreover, the system also enables functions such as information release, distributed energy monitoring and information exchange between smart power devices. High-voltage power transmission line monitoring system is one of the most important applications of NB-IoT in smart grid.

C. Smart EV Charging

Interconnection and high interaction of EVs, batteries and charging stations will be realized with NB-IoT communication technology. This enables customers to know

the availability and usage of resources, examine nearby charging stations, and thus realize unified distribution of resources and quality services. Smart charging provides related information to citizens in real time to enable better charging management.

Operator expects millions of devices to be connected with this smart charging service. Sensors that are placed under cars will communicate with the charging server through the NB-IoT network to gain information. Meanwhile, an overall management of charging process, billing and integrated services will be achieved.

D. Smart Home

Smart home enhances the capacity of integrated services of the grid, meeting the demand of interactive marketing and improving the quality of service. It is widely used in daily power consumption.

NB-IoT connected sensors can be used in general home sensor LAN protocol. It also provides smart appliances control, multi-meter reading, power consumption and sends alerts about building maintenance issues and perform automated tasks, such as light and heat control. Consequently, the goals of saving energy and using various resources effectively will be met.

III. NB-IoT lunched Solutions In Smart Grid

Different Mobile Telecommunication companies and vendors have launched the NB-IoT technology for Smart Grid solutions on commercial network and manage related devices across multiple network types. Some of them are listed as below [11-21]:

- Chinese vendor Huawei
- Germany's Deutsche Telekom
- Vodafone in the Spanish network
- Cisco Jasper and its service provider partners
- Nokia
- Ericsson

Nokia, Ericsson and Intel have been used in band method for NB-IoT implementation into existing 4G networks. The alternative approach, led by Huawei and Vodafone is a solution which could be a guard band, specifically reserved for IoT traffic.

Deutsche Telekom (DT) became the first operator to launch an NB-IoT network. It was launched in Germany and the Netherlands, initially for application developers to trial their solutions on commercial networks. DT is deploying NB-IoT network across Europe, following in the footsteps of Vodafone. The NB-IoT rollout will take place in eight countries in which the German-based telecommunication operates, including Germany, the Netherlands, Greece, Poland, Hungary, Austria, Slovakia and Croatia. Germany is already running several pilots with large customers in the areas of smart metering, smart parking and asset tracking. The NB-IoT end-to-end system and smart parking application deployed by DT in Bonn.

ZTE launched a smart EV charging system powered by NB-IoT in Shenzhen and Nanjing in China that it says reduces congestion and boosts charging revenues. It combines an IoT data unit and operations platform with a mobile app to link drivers with available charging spaces in a city. The user can search in real time and reserve them through the app. The app is then able to guide the user to the related charging space. Payment is offered through the app, through the on-board unit or manually. The system is designed to be compact and easy to install, and can be remotely maintained and upgraded through wireless connectivity. The vendor claimed that parking congestion rates had been reduced by 12 percent and time spent searching for parking spots reduced 43 percent, while parking management revenue had gone up 30 percent.

Telia Norway unveiled smart parking trials that use NB-IoT technology.

Vodafone is in the process of switching on its own NB-IoT network in Madrid and Valencia in Spain and other European markets (Netherlands, Germany, and Ireland) after upgrading existing 4G base stations. It will now offer smart metering, smart parking and other services. NB-IoT coverage will be extended to Barcelona, Bilbao, Malaga and Seville and more than 1,000 of its mobile sites will support NB-IoT, with each site capable of supporting more than 100,000 devices.

Powered by the NB-IoT technology by Huawei, MTN is succeeded in the commercial trial of smart metering, the first NB-IoT service in Africa and looking forward lots of services for example wildlife tracking, smart farm, and smart parking, etc. The Smart metering solution enables the automated collection of utility meter data, through sensors installed in energy meters. Household energy meters will automatically report data on a regular basis, reducing fault probabilities and the operating expense. The data gathered can be used to control electricity flows from each property, identify faults across the network and improve health and safety outcomes.

Telkomsel has partnered with Nokia to conduct NB-IoT trial on a commercial 4G network in Indonesia to support life applications such as smart home, smart metering, remote healthcare, traffic safety and control on the vehicles in reliable and secure network, deep indoor penetration, providing coverage with very low power consumption capabilities of devices. Testing was conducted using the method in Band Frequency 200 KHz at a frequency of 1800MHz.

Nokia and Sonera recently announced their work on a NB-IoT trial running on the carrier's Helsinki network in Finland to track their mobile assets by communicating such information as air pressure, humidity, and temperature.

M1 and Nokia have teamed up to roll out the commercial NB-IoT network in Singapore to deliver improved network performance for Smart Grid communications and smart city's machine-to-machine type of applications and services while delivering the benefits of licensed spectrum such as network reliability and security.

IV. Open Issues and Chalenges

NB-IoT standard was finalized in June 2016 for low-power applications related to the Internet of Things. It delays all of the important things like developing test equipment

and compliance programs which are vital to develop a robust network; So there are not required and sufficient researches in NB-IoT application in Smart Gris.

Although the enabling technologies described in previous sections make the NB-IoT concept feasible, a large research effort is still required for Smart Grid domain.

Some Smart Grid protocols such as Wi-Fi, ZigBee or Bluetooth, require the use of a gateway and several of LPWA technologies like Telensa and SigFox need a new network to connect to the IoT; therefore that large scale roll-out of NB-IoT will not happen for at least two to three years. In such a scenario, there may be less market adoption of NB-IoT. So don't expect too much of NB-IoT usage in Smart Grid.

Another challenge is that a lot of the in use device in Smart Grid need to be upgraded, which need tremendous volume of works. Also the corresponding hardware costs of power system are also enormous.

NB-IoT needs massive data processing and storage to meet higher and stricter requirements. The NB-IoT will generate data traffic with patterns that are expected to be significantly different from those observed in the current Internet. Accordingly, it will also be necessary to de fine new QoS requirements and support schemes.

Security issues like Authentication, Data integrity and Privacy supported by NB-IoT technology were not discussed in most cases.

A further challenge is the ability to ensure that the network can actually cope with the anticipated volume of attached devices, potentially exceeding that of current networks by an order of magnitude or more. Generally, the global IoT market is expected to be worth trillions of dollars by 2020.

V. Conclusion

NB-IoT aims to meet the stringent targets for both low device modem cost and long battery life, which are likely to make it much more successful. NB-IoT provides an immediate solution for mobile operators to create successful IoT businesses in the Smart Grid. NB-IoT applications focus on low speed, robust data transfer, and an appropriate level of reliability. In this paper, some applications of NB-IoT in smart grid have been discussed. However these are far more than what has been mentioned in this paper. A survey around the lunched smart grid projects, with emphasis on the role of NB-IoT applications is performed. In addition, some challenge the technological solutions adopted by several in terms of NB-IoT roll-out is referred.

VI. Acknowledgment

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