Technologies and Applications of Narrowband Internet of Things

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Abstract. Narrowband Internet of Things (NB-IoT) is one kind of Low Power Wide Area Network (LPWAN) technologies to achieve the aims of deep coverage penetration, low power consumption, low cost and massive connections. NB-IoT aims at supporting small data and low rate applications. In this paper, we first introduce the general background of NB-IoT. Then we overview several performances of NB-IoT and make comparison between NB-IoT with other wireless communication technologies, including WiFi, ZigBee and etc. Finally, we design an environmental monitoring system based on NB-IoT. In this proposed system, NB-IoT module transmits the data of the sensor nodes to cloud platform.

Keywords: NB-IoT · Internet of Things · LPWAN

1 Introduction

Over the past 20 years, Internet of Things (IoT) technologies have developed significantly, and they have been incorporated in various fields. From the perspective of transmission rate, the communication services of IoT can be classified into two categories: high-data-rate services (such as video service) and low-datarate services (such as meter reading service) [1]. Unlike traditional cellular communications, IoT applications have special requirements that support massive connections, low cost, low terminal power consumption and superior coverage capabilities. Low Power Wide Area Network (LPWAN) aims at addressing these requirements. The features of LPWAN are battery-powered, low-rate, ultra-low-power and maximum coverage up to 100 km. LPWAN are suitable for the IoT applications that only need to transmit tiny amounts of information in the long range [2,3].

NB-IoT is a cellular network-based LPWAN solution. It supports large number connections, ultra-low power consumption and ultra-low cost [4]. In addition, it is well supported by cellular communication networks [5]. The NB-IoT can support coverage enhancement (20 dB coverage improvement), ultra-low power consumption (5W/h battery for 10 years), low latency (up to 10 s for uplink

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delay) and a huge number of connections (a single sector can support more than 50000 connections) at transmission bandwidth of 180 kHz.

Lots of research efforts have been devoted to studying NB-IoT. In [2], Xu *et al.* studied NB-IoT's evolutions, technologies and issues, spanned from performance analysis, design optimization, to implementation and application. In [5], Chen *et al.* reviewed the background and state-of-the-art of the NB-IoT. In [6], Shi *et al.* proposed a smart parking system in order to mitigate problems such as high power consumption of sensor node and high deployment costs of wireless network. In [7], Miao *et al.* studied construction of NB-IoT model based on OPNET and verification of its characteristics. In [8], Ratasuk *et al.* provided an overview of NB-IoT design and also provided illustrative results with respect to performance objectives. In [9], Yang *et al.* investigated the small-cell assisted traffic offloading for NB-IoT systems. In [10], Adhikary *et al.* provided a detailed evaluation of the coverage performance of NB-IoT. Driven by the growing demand for improving energy-efficiency and greening wireless networks [11–13], many studies investigated the energy management for NB-IoT [14–17]. In [11], Wu *et al.* studied traffic offloading in future heterogeneous cellular networks. In [12], Wu *et al.* studied the NOMA downlink relay-transmission to accommodate tremendous traffic growth in future cellular networks. In [13], Wu *et al.* investigated the cooperative traffic offloading among mobiles devices. In [14], Malik *et al.* proposed an efficient resource allocation for NB-IoT with cooperative approaches. In [15], Liu *et al.* proposed a new resource allocation method, which includes a new definition of paging resource set and corresponding resource selection method. In [16], Zhuang *et al.* proposed a method for the uplink resource scheduling of power wireless private network based on NB-IoT and LTE hybrid transmission. In [17], Kroll *et al.* studied hardware implementation of the maximum likelihood crosscorrelation detection for energy savings in NB-IoT devices.

2 Overview of NB-IOT

2.1 NB-IOT in 3GPP

3GPP is promoting the related technology of Machine Type Communication (MTC), mainly in two directions. Because the challenges of non-3GPP technologies, the first direction carries out the further evolution of GSM and new access technologies to fulfill characteristics such as lower complexity, lower cost, lower power consumption, and stronger coverage [18]. And the second direction researches new technologies to replace 2G/3G IoT module. 3GPP defines the terminal types for many scenarios of different service requirements. R-8 has defined terminal types of cat 1–5 at different rates [19]. While newly defined terminal types supporting high-bandwidth, high-speed cat 6, cat 9, etc., it also newly defined cat 0 (R-12) terminal types that are lower in cost and support lower power consumption [18].

At present, 3GPP mainly focuses on NB-IoT, eMTC and EC-GSM. Among them, EC-GSM adds Power Saving Mode (PSM) and Enhanced Discontinuous Reception (eDRX) base on GSM. This is the technology that 3GPP researches in the first direction; And NB-IoT is a new radio access system built from existing LTE functionalities with essential simplifications and optimizations [7]. This is the technology that 3GPP researches in the second direction.

2.2 NB-IOT vs. Other Wireless Solutions

Nowadays common used wireless communication technologies are 4.0 Bluetooth, WiFi, ZigBee and etc. These solutions have their own advantages, disadvantages and applicable scenarios. The main differences are summarized as follows: transmission rate, transmission distance, terminal cost, terminal power consumption and signal penetration. For low-rate IoT applications, they have high requirements for low power consumption, large connections and wide coverage and not very sensitive to delay. NB-IoT has an excellent performance in terms of coverage, power consumption, cost and connection number. Comparison of wireless technologies as shown in Fig. 1 [5].

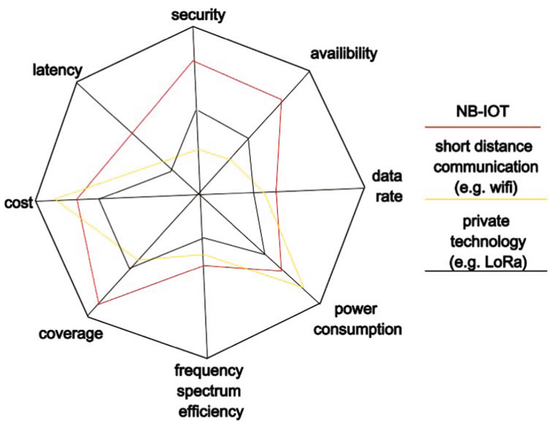

Fig. 1. Performance comparison of different wireless technologies

2.3 Features of NB-IOT

NB-IoT has lots of advantages. In this section, we briefly introduce the main advantages and features of NB-IoT.

Massive connection: By increasing the power spectral density and optimizing the base station and core network. The theoretical supported number of connection can reach 52547 per cell site sector.

Low power consumption: This feature is achieved mainly by two technologies: power saving mode (PSM) and extended discontinuous reception (eDRX) which provides 10 years battery life.

Super coverage: Due to NB-IoT's narrowband design and the increase in power spectral density and retransmission, the gain is increased by 20dB The transmission power of NB-IOT has increased by 100 times.

Low cost: NB-IOT's narrowband design and low complexity directly reduces the cost of the device unit.

3 Protocol of NB-IOT

The commonly used IoT application layer protocols include MQTT, XMPP, CoAP, LwM2M and so on. For IoT terminal nodes, simple protocols should be used as much as possible because of the limited resources they can use. And in NB-IOT, Lightweight protocols CoAP and LwM2M are used.

3.1 Coap Protocol

The Constrained Application Protocol (CoAP) is a lightweight protocol defined for resource-constrained conditions (power, storage space, etc.). CoAP is based on the REST architecture and adopts similar features as HTTP. It's core content is resource abstraction, RESTful interaction and extensible header options. In order to overcome the disadvantages of HTTP for constrained environments, CoAP considers both the optimization of the data length and reliable communications. Protocol stack of CoAP as shown in Fig. 2.

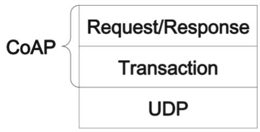

Fig. 2. Protocol stack of CoAP

CoAP is an application layer protocol and Based on the UDP protocol. CoAP complies with the UDP data packet format and transmits according to the CoAP format. With retransmission mechanism, protocol supports IP multicast, small protocol header only 4 bytes and low power consumption, CoAP is suitable for low-power IoT scenarios.

3.2 LwM2M Protocol

Lightweight Machine to Machine (LwM2M) is a lightweight IoT protocol, it can be applied to various scenarios such as NB-IoT. Because M2M devices are usually terminals with limited resources, the computing power and communication capabilities are limited. Therefore, OMA defines a lightweight protocol based on the traditional OMA-DM protocol for IoT devices, which are mainly used in devices with limited resources (including storage, power consumption, etc.). Protocol stack of LwM2M shown in Fig. 3.

LwM2M is an application layer protocol and above the CoAP protocol. LwM2M can do DTLS encryption processing and transmit it through UDP or SMS.

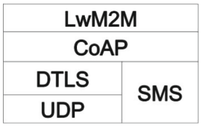

Fig. 3. Protocol stack of LwM2M

4 Cloud Platform OneNET

In this section, we introduce the cloud platform and the configuration of the cloud platform. In the environmental monitoring system, the cloud platform is used to store and process the data reported by the NB-IOT module. Using the cloud platform provided by the operator as the data receiving platform has multiple advantages: data security storage, rich API support, high concurrent availability and so on. Huawei's OceanConnect is an open ecosystem based on the IoT, cloud computing and big data. OceanConnect provides ecological API and serialized Agent software to achieve product connection, and supports the rapid access of various types of smart devices. OneNET is a PaaS IoT open platform created by China Mobile. The platform can implement device access and device connection, quickly complete product development and deployment. It provides comprehensive IoT solutions for smart hardware and smart home products. The NB-IOT based on the LwM2M protocol and the CoAP protocol implements communication between the UE and the OneNET platform. The transport layer protocol is CoAP and the application layer protocol is LwM2M. The architecture of the OneNET platform is shown in Fig. 4.

OneNET platform development process: North registration is required before the NB-IOT module interacts with the cloud platform. Each device needs to register through its International Mobile Equipment Identity (IMEI) and selects the appropriate transport protocol. After successful configuration, the device needs to report the data by using the encoded password. The password includes the IMEI numbers and the reported data. After the cloud platform receives the data, it will return a response. Configuration of Cloud platform as illustrated in Fig. 5.

5 Typical Application Scenario

NB-IOT's data rate is small and slow, high delay and poor real-time performance. And it is low data service frequency, poor mobility but the coverage is deep and wide. From these characteristics we consider deploying NB-IOT in the following application scenarios: Smart City [20]: NB-IOT can cope with the ever-growing information data and more and more IOT devices generated in smart cities. Smart Factory: The industry is moving toward intelligent, information-based production, resource-saving and high-efficiency. Smart factories require collect and transmit various data generated during plant operations. Smart agriculture: NB-IOT can effectively solve problems in the agricultural environment.

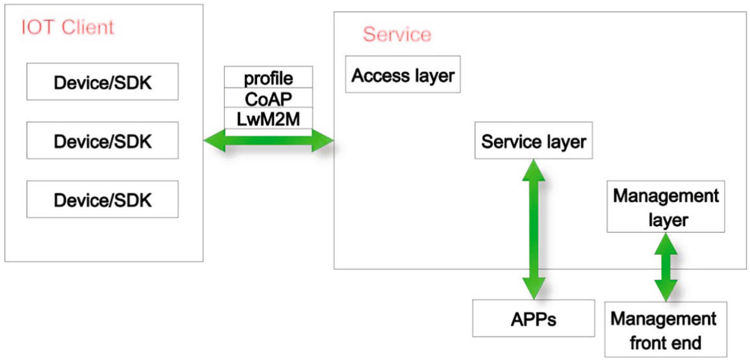

Fig. 4. Cloud platform communication framework

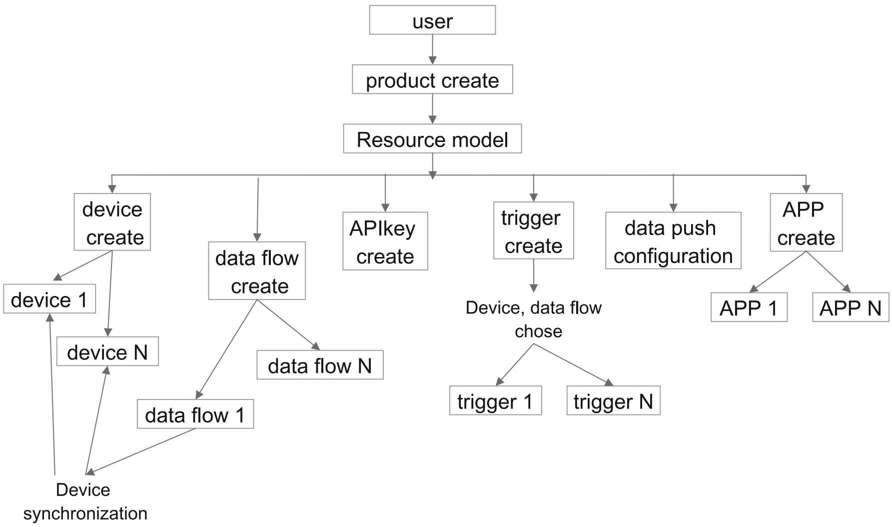

Fig. 5. Cloud platform configuration process

The cellular network basically achieves full coverage, and the power consumption of the terminal nodes is relatively ideal. Therefor, NB-IoT can resolve some pain points in smart agriculture.

6 Application System Test

In this section, we design an environmental monitoring system which includes NB-IoT devices, cloud platform and sensors. System as illustrated in Fig. 6. Through this system, we can monitor the environmental status in real time.

Specifically, the environmental monitoring system is mainly composed of data collection, data processing part, data transmission part and cloud platform part.

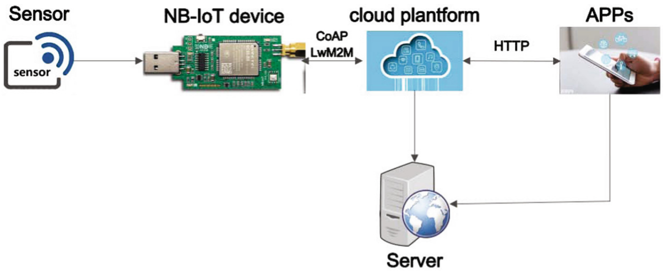

Fig. 6. System design

The first part is the sensors obtain environment data; the second part is the MCU processes data and the third part is the data transmitted by the NB-IOT module; the fourth part is configure the cloud platform. For the NB-IOT module, we chose Quectel's BC95-B8 and China Mobile's M5310. The operator is China Mobile. The IoT platform can use commercial platform, such as Huawei's OceanConnect and China Mobile's OneNet, and it can also use private platform. The system structure as illustrated in Fig. 7.

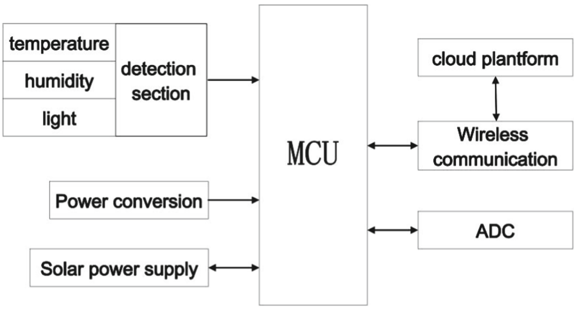

Fig. 7. System structure

The environmental monitoring system works as follow: system uses sensors to collect environmental data. The MCU processes data and uses the NB-IOT module to transmit data to the cloud platform. After the cloud platform is configured, it stores and displays data. The data flow as follows: (Fig. 8).

The environment of experiment were indoor and outdoor environments of laboratory and no cover on the test system. In this environment, the signal of the base station received by the NB-IOT module was stable, which ensured stable transmission. To ensure the accuracy of the data, we used more than one node at the same time. The test time was 10:00 and 21:00. The sensor sampling time was half a minute and the data stored in the cloud platform. The system board as shown in Fig. 9. The test results as shown in Fig. 10. And the different lines in Fig. 11 mean different nodes.

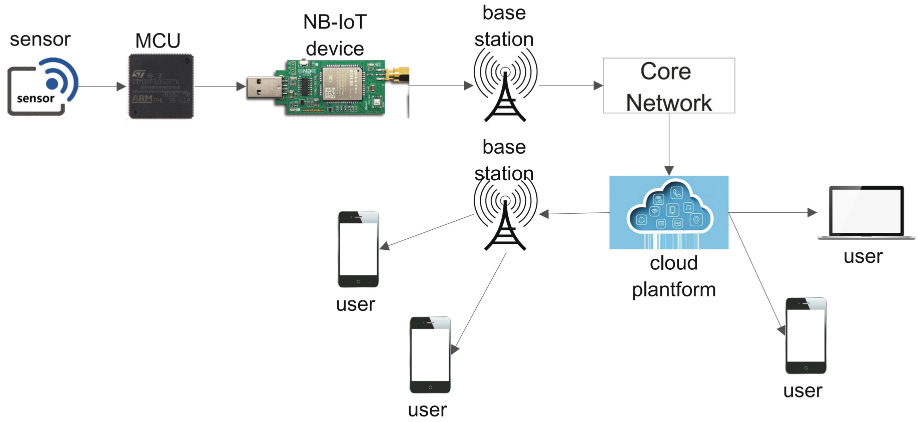

Fig. 8. Data transmission direction

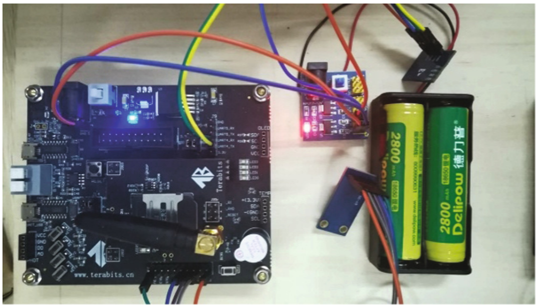

Fig. 9. System board

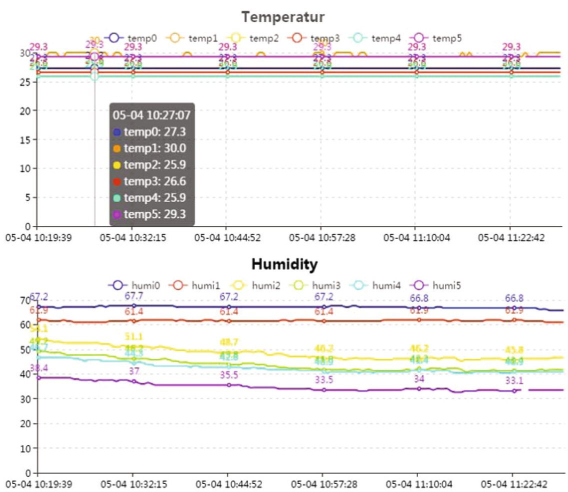

Fig. 10. Environmental parameter results

7 Conclusion

In this paper, we have introduced the general background of NB-IoT and gave a brief review of features. Then we have designed an environmental monitoring system that utilizes NB-IoT. The proposed system consists of three components: (1) the sensing part; (2) the transmission part; and (3) the cloud platform part. We have implemented this system by hardware and cloud platform. We have also shown some experiment results through this NB-IoT system.

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