A Bicycle-Borne Sensor Node for Monitoring Air Pollution Based on NB-IoT

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Abstract. Nowadays, everybody knows that shared bicycles have become a new type of green transportation in the city. The impact on people's health caused by air pollutants exposed near roads has become a concern in recent years. This paper introduces a device which consists of a particulate detector, temperature and humidity sensor, micro-SD card, GPS receiver and the NB-IoT communication module. The device can be installed as a sensor node on a shared bike, and a mobile sensor network has been set up on a shared bike to monitor air quality throughout the city, which is of great significance for urban air quality testing.

Keywords: Air pollution · Environmental monitoring · NB-IoT · Shared bicycle

1 Introduction

1.1 Concepts

With the continuous progress of urbanization, intelligent transportation system has been popularized and developed in many cities. Intelligent transportation systems improve the mobility and safety of traffic and effectively reduce the environmental pollution [1]. In China, the shared bicycles has been developing rapidly since mid-2016. Since this way of travel is green, healthy and environmentally friendly, it has become an important tool for people. We can see it in many public fields, such as subway stations, bus stops, large shopping malls, residential neighborhoods and university campuses.

Narrowband Internet of Things (NB-IoT) is a new cellular technology introduced in 3GPP Release 13 for providing wide-area coverage for the Internet of Things (IoT). It is a new 3GPP radio-access technology in the sense that it is not fully backward compatible with existing 3GPP devices. However, it is

designed to achieve excellent coexistence performance with legacy GSM, General Packet Radio Service (GPRS) and LTE technologies. NB-IoT requires 180 kHz minimum system bandwidth for both downlink and uplink, respectively [2].

1.2   Motivations

Due to the rapid growth of urban population, environmental pollution, traffic congestion, energy consumption and other problems. They are attracted the attention of all sectors of society, almost all cities of the country must face this problem [3]. With the development of intelligent transportation system in the city, shared bicycles as a new way of green travel play an increasingly important role. A survey report showed that 76.56% people used shared bicycles, and only a small number of people used public bicycles, mainly because the use of shared bicycles was more convenient and could be parked at any time [4]. The health issue of air pollutants near roads have become a concern in recent years, and shared bicycles has become an important part of urban transport. Therefore, the device can be installed as a sensor node on a shared bike, and a mobile sensor network has been established on the shared bicycles to monitor air quality throughout the city, which is of great significance for air quality inspection and management.

The rest of this paper is organized as follows. It is discussed related research in Sect. 2. Section 3 introduces the essential workflow and frame structure of the device. The test result and data collection are illustrated in Sect. 4. Section 5 has a prospect about NB-IoT. Section 6 concludes the paper.

2   Related Work

Liu et al. introduced the installation of similar nodes on public bicycles using the communication of Bluetooth [5]. Aguiari et al. also proposed the idea was used for electric bikes, based on WiFi transmission [6]. Compared with public bicycles, shared bicycles solve the problem of bicycle location restrictions. It is more suitable for the deployment of wireless sensor networks in the city by improving the diversity of environmental data collection. It also can realize the urban environment detection and management. In February 2017, ofo signed a partnership agreement about NB-IoT shared bicycles applications with China Telecom and Huawei, which will provide wireless network solutions including NB-IoT chips. The tripartite management said that the "Little Yellow Car" will be able to access the latest NB-IoT technology to provide users with a better use experience by China Telecom's wireless network in the future [7]. Due to the current combination of NB-IoT technology and shared bicycles have become a trend, this paper uses NB-IoT technology. The common means of communication are compared, as in Table 1 [8].

Considering the power consumption problem of GSM communication and GPRS positioning module and the large number of shared bicycles, we can see the advantages to use of NB-IoT technology [9].

Table 1. The Comparation of communication.

Subject	Bluetooth	WiFi	Zigbee	NB-IoT
Networking	Bluetooth-based Mesh gateway	Based wireless router	Based on Zigbee gateway	Based on the existing cellular network
Network deployment	Node	Node + router	Node + Gateway	Node
Transmission distance	10 m	A short distance (50 m)	Short range (10–100 m)	Long-range (up to a dozen kilometers, under normal circumstances 10 km above)
Access nodes	Theoretically about 60000	About 50	More than 60,00 theoretically 200 to 500	About 200,000
Battery life	Days	Hours	Theory about 2 years/AA batteries	Theory about 10 years/AA batteries
Cost		Modul about $7–8	Module about $1–2	$5–10 modules, the next target down to $1
Bands	2.4G	2.4G and 5G	unlicense band 2.4G	License band, band operators
Transfer speed	1M	2.4G: 1M–11M 5G: 1M–500M	Theory 250 kps, generally less than actual 100 kbps, limited low speed communication interface UART	Theoretical 160 kbps–250 Kbps, the actual generally less than 100 kbps, limited low speed communication interface UART
Network latency	Less than 1 S	Less than 1S	Less than 1 S	6–10 S

(1) Wide depth coverage: compared with GSM, NB-IoT can achieve more than a 20 db enhanced coverage. To a certain extent, it can effectively solve the problem that the shared bicycles cant be accurately positioned in the indoor, stairwell, basement and other deep coverage areas. Thus, use of NB-IoT technology can avoid the shared bicycle was private occupied and disorderly parked this problem. This can help the enterprise to carry out vehicle maintenance and other daily management.
(2) Oversized connection: In the rush hour, there are many shared cycles dense unlock to access network in the vicinity of the subway port and other business hotspot areas. The wireless access network capacity has put forward higher requirements. NB-IoT's low power consumption, massive connectivity capabilities can better meet the needs of user-intensive access.
(3) Ultra low power consumption: The protocol of the bicycles based on the NB-IoT modules is more simplified, and the centralization of the communication chips and modules are more higher. Besides, the power consumption will be significantly reduced compared with the original GSM modules.

3   Design Scheme

3.1   Frame Structure

The device consists of a particulate detector, a temperature and humidity sensor, a micro-SD card, a GPS receiver and the NB-IoT communication module, as shown in Fig. 1.
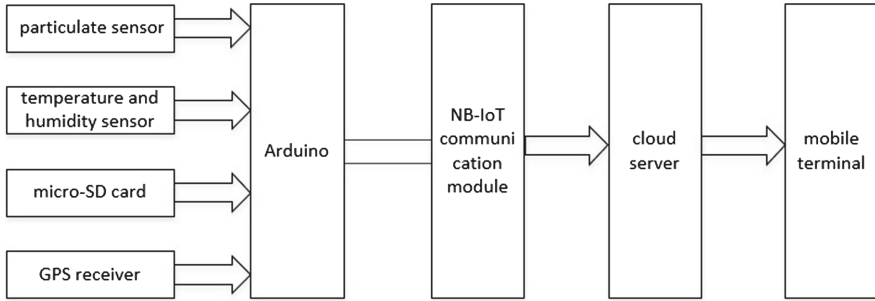

Fig. 1. Frame structure

3.2   Module Function

Particulate detector can be used to detect respirable particulate matter in the air. Temperature and humidity sensor can detect air temperature and humidity. A GPS receiver is for the acquisition of geographic information, and the micro-SD card can be stored data. These can be connected with Arduino, and through the NB-IoT communication module upload cloud server. Eventually, we can see the relevant data at the mobile terminal. If a bike is at rest, the geographical location remains the same and the environmental parameters fluctuate less. So GPS data can be uploaded once in a while, and the frequency of environmental acquisition can be reduced. When the bike is borrowed, the geographical location has been changing, then the GPS data upload frequency and the frequency of environmental collection should be improved.

Particulate Detector. PM 2.5/PM 10 laser sensor: It uses the laser scattering principle, so it can obtain the 0.3–10 μ suspended particulate matter concentration in the air. Using the imported laser and the photosensitive component, we can obtain the stable and reliable data. This detector has a fan in it and the output form is digital. Besides, it has a high integration.

Arduino Plartform. Arduino can sense the environment through a wide variety of sensors, feedback and influence the environment by controlling lights, motors and other devices. The microcontroller on the board can write programs through Arduino's programming language, and compile into binary files. Then the binary files are recorded in microcontrollers. The programming of Arduino is achieved through the Arduino programming language and the Arduino development environment [10].

SIM7000C Arduino NB-IoT/LTE/GPRS Expansion Board. SIM7000C Arduino NB-IOT/LTE/GPRS expansion board is a wireless communication module designed by DFRobot based on SIMCOM SIM7000C. This is the first product in China to introduce NB-IoT technology into the field of open source hardware. Whether for prototyping or for small batch production, the SIM7000C Arduino NB-IOT/LTE/GPRS expansion board is the best solution for low-power, low-latency, medium-throughput applications. In addition, SIM7000C GNSS Global Navigation Satellite System which supports GPS in the United States, GLONASS in Russia, Galileo in Europe, QZSS in Japan and Beidou navigation system developed independently by China. It is suitable for some IoT applications, such as remote control, mobile tracking, remote meter reading, and shared bicycles. SIM7000C NB-IOT/LTE/GPRS expansion board also supports ordinary SIM card and NB-IoT special card. It can be plugged into the ordinary SIM card for telephone calls, texting and other traditional GSM applications. It also can be plugged into NB-IoT dedicated card to use the NB-IoT Network for data transmission. In addition, the expansion board also provides BME280 environmental sensors, which can be developed as prototypes of the NB-IoT project to monitor temperature, humidity and air pressure values [11].

4   Data Presentation

We collect the data in 5 locations. And we record data every half an hour. Tables 2, 3, 4 and 5 presents the results of temperature, humidity, PM2.5, and PM10. We can see the numerical changes in all aspects.

Table 2. Temperature change (°C).

Time/h	Location 1	Location 2	Location 3	Location 4	Location 5
0	22.11	18.52	12.31	9.35	7.59
0.5	23.37	18.36	19.08	9.26	7.67
1	23.5	18.76	18.74	9.39	7.72
1.5	14.13	18.93	18.2	9.05	7.76
2	13.12	19.18	19.12	10.57	7.79

Table 3. Humidity change (%).

Time/h	Location 1	Location 2	Location 3	Location 4	Location 5
0	12.58	11.08	15.75	16.8	16.82
0.5	9.56	10.63	10.47	16.68	16.77
1	9.15	11.13	11.2	17.21	16.77
1.5	12.84	10.47	11.08	18.17	16.74
2	13.85	10.51	10.51	16.22	16.71

Table 4. PM2.5 change (ug/m^3).

Time/h	Location 1	Location 2	Location 3	Location 4	Location 5
0	9	22	19	7	2
0.5	10	23	19	7	2
1	8	23	19	8	2
1.5	6	21	21	8	3
2	6	21	22	22	2

Table 5. PM10 change (ug/m^3).

Time/h	Location 1	Location 2	Location 3	Location 4	Location 5
0	22	4	2	18	2
0.5	24	1	19	22	21
1	20	26	21	23	17
1.5	23	22	25	25	17
2	18	25	24	15	4

5   Prospect on NB-IoT

Cellular IoT is a low-power WAN IoT technology based on 2/3/4G technology, it mainly for large-scale IoT connection applications, and the design objectives are: low cost, low complexity, coverage enhancement, low power consumption, high capacity.

With the "Comprehensive promotion of mobile Internet of Things (NB-IoT) development notice" issued by the Ministry of Industry and Information of Industry in June 2017, NB-IoT technology has developed vigorously in China, the whole industry from chip, module, terminal to operator network, cloud computing platform, application and other fields have an all-round development. At present, China Telecom has completed a full network coverage of the NB-IoT network in China, China Mobile and Unicom will also improve the corresponding network construction in the near future, which makes China become the largest country in the global NB-IoT market [12].

The horn of the 5G era has begun. With the development of modern society, the 5G era is bound to come. 5G brings more than just faster network speed, but the intelligent interconnection of all things. Among them, NB-IoT is the prelude and foundation of 5G commercial, and it is the only way to realize the interconnection of everything in 5G, and it is also the best touchstone for 5G network operation capability in the future. Therefore, the evolution of NB-IoT is more important, such as support the multicast, continuous mobility, new power levels and so on. Only complete the NB-IoT infrastructure, 5G is possible to truly achieve [13]. Nowadays, NB-IoT has been used in many Internet of Things fields in China, for instance, smart water meters, intelligent parking and so on. With the continuous advancement of science and technology, we can see that the IoT industry will be get a great development, I believe that NB-IoT will play a key role.

6   Conclusion

This paper proposes a device, which consists of a particulate detector, temperature and humidity sensor, micro-SD card, GPS receiver and the NB-IoT communication module. The device can be installed as a sensor node on a shared bike, and a mobile sensor network has been set up on a shared bike to monitor air quality throughout the city. In the fourth part of this article, we present the collected data at intervals of half an hour. We can see that in a static environment, the difference of the data changes is small. Using this device will facilitate the detection that all parts of the city environment, in addition to, introduce the NB-IoT technology is better for this work. With the development of science and technology, I believe that NB-IoT technology will enter our life and become the key to connect all things.

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