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Research and Application of GPRS, LoRa and NB-IoT in Environmental Monitoring

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Abstract. With the development of industry, the environmental issue has drawn more and more attention. Currently, in order to monitoring and managing environment issues, we use real-time online monitoring equipment that is the way of remote communication to achieve data exchange between equipment and server. At the present there have also emerged a variety of wireless local area network communications technology. This article is based on the application of environmental monitoring, then comprehensive analyzed and compared the three mainstream LPWAN (low power wide area network) communication technologies: GPRS, LoRa and NB-IoT. Through research we get the conclusion., among them, LoRa technology that belongs to unlicensed band has obvious advantages in power consumption and cost. GPRS and NB-IoT work in the licensed frequency band, both of which have advantages in quality of service (QoS), latency, reliability and distance.

Keywords: GPRS, LoRa, NB-IoT, environmental monitoring

1. Introduction

Environmental monitoring network is a coordinated system, according to a certain organization and interconnected procedures, that constituted by monitoring nodes these are different spatial distribution but function similar. It accomplished that upload the collected environmental parameters to the server for data analysis and release, such as fine particles PM2.5, water oxygen content, soil salt and so on. Most the data size of equipment is small, usually about 100 bytes. But monitoring objectives are mostly in the wild environment, as a result, application scenarios vary and are complex, requiring different the way of communication. For example, monitoring in the cities requires a higher penetration of communication, however, the low power consumption is usually more important in the field. The current typical architecture of the environmental monitoring system is shown in Figure 1. The system consists of collecting terminal, communication module, server-side and data display. The choice of communication determines the design of the telecommunication module and the data exchange between the server and the equipment. When selecting the way of communication, we consider the impact of the following parameters: communication distance, power consumption, communication latency and cost. Therefore, researching and analyzing different communication is great significance to the design of environmental monitoring system, and choosing the right communication means is the basis for ensuring long-term and stable work of the system.

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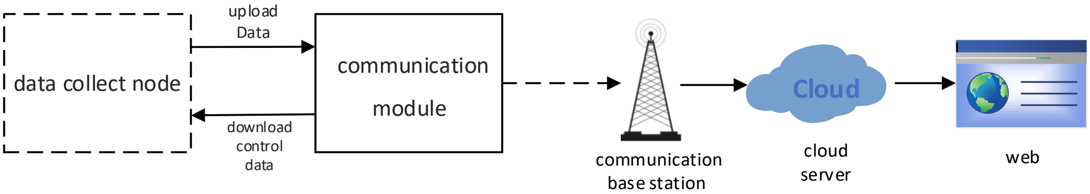

Fig. 1: Environmental monitoring system typical architecture.

LPWAN (Low Power Wide Area Network) is a common name for the rapidly growing means of communication in recent years, a communication technology capable of achieving long-distance at a lower node cost and power consumption [1]. It is very suitable for the current rapid development of Internet of Things(IoT), these IoT applications usually mean that a small amount of data needs to be transmitted in a long distance. Environmental monitoring network is a typical IoT application. Until 2013, the LPWAN did even not exist. But with the rapid expansion of the Internet of Things market, LPWAN has become one of the fastest growing areas in IoT till of 2018. As shown in Figure 2, LoRa and NB-IOT are in a leading position. GPRS technology belongs to cellular network technology, and evolved based on GSM. GPRS is mature and has a wide range of applications in electricity, agriculture, environment, transportation and so on [2]-[5].

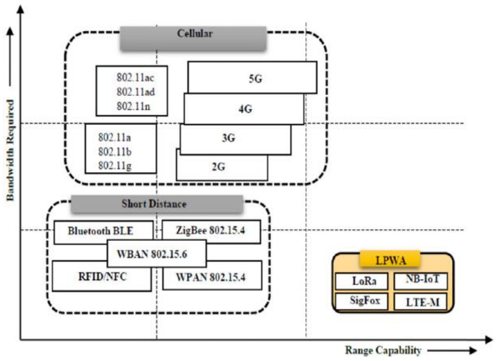

Fig. 2: Required bandwidth vs. range capacity of short distance, cellular, and LPWA.

2. Technology Features

This chapter will analyze and compare the physical features and network architecture of GPRS, LoRa and NB-IOT.

2.1 Physical Features

GPRS, LoRa and NB-IoT all belong to the wireless communication technology [6], The basic physical parameters shown in Table 1. In the frequency band, GPRS and NB-IoT are the same, LoRa work on a lower frequency that is unlicensed than NB-IoT and GPRS and its bandwidth is less than NB-IoT and GPRS. From the maximum data transfer rate, GPRS that provide network data services for mobile device is much higher than LoRa and NB-IoT. This is because GPRS technology achieves higher transmission speed through larger bandwidth, but increased transmission power consumption. It can be seen from Table 1 that the transmission rate is higher lead to higher transmission power. So LoRa and NB-IoT sacrifice a certain transmission rate to reduce transmission power consumption, therefore they are more suitable for applications such as environmental monitoring that require less data but consume less power.

Table 1: Physical features

	GPRS	LoRa	NB-IOT
Spectrum	Licensed (700-900)MHz	Unlicensed (433-915)MHz	Licensed (700-900)MHz
Bandwidth[KHz]	200	125	180
Max. data rate*	<500kbps (DL/UL)	<50kbps (DL/UL)	< 170kbps (DL) < 250kbps (UL)
Transmit power [dBm]	33/37	14	23/35
Max. coupling loss[dB]	144	157	164

2.2 Network Architecture

LoRa is a kind of ultra-long-range wireless transmission scheme based on spread spectrum technology adopted and popularized by American Semtech Company [7]. This solution changed the previous trade-off between transmission distance and power consumption, to provide users with a simple system to achieve long-distance, long battery life, high-capacity, and then expand the sensor network. According to the LoRa Alliance's January 2018 report, there are currently 65 publicly-deployed networks worldwide. LoRaWAN network is a standard networking protocol for LoRa technology. It is a typical star-star topology. The gateway is responsible for data exchange between the terminal equipment and the back-end central network server. Its network architect shown in Figure 3. The connection between Gateway and server is through a standard IP. They can be connected via ethernet, GPRS and wifi. The terminal equipment connects to a single gateway or multiple gateways through one-hop LoRaWAN protocol or FSK communication.

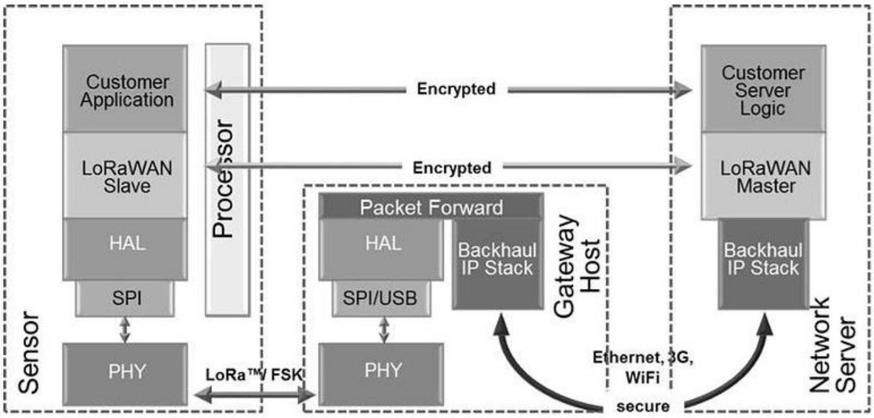

Fig. 3: LoRaWAN network architect.

NB-IoT core network is based on EPS (Envolved Packet System), Its network architect is shown in Figure 4, which belongs to the cellular internet of things technology. In order to send IoT data to applications, CIoT has defined two optimization scenarios in EPS. The user plane function optimization, as shown in the dashed part of Figure 4; and control surface function optimization, as shown in Figure 4 solid line part. Optimized for CIoT EPS control plane functions is that the uplink data is transmitted from the eNB (CIoT RAN) to the MME, the transmission path is divided into two branches in here: transmitted to the PGW through the SGW and then transmitted to the application server, or connected to the application server (CIoT Services) through the SCEF (Service Capabilities),and the second only supports non-IP data transfer. Downlink data transmission path is same as upload, just the opposite direction. This scheme does not need to establish a data radio bearer, and the data packet is sent directly on the signaling radio bearer. Therefore, this scheme is very suitable for infrequent small packet transmission.

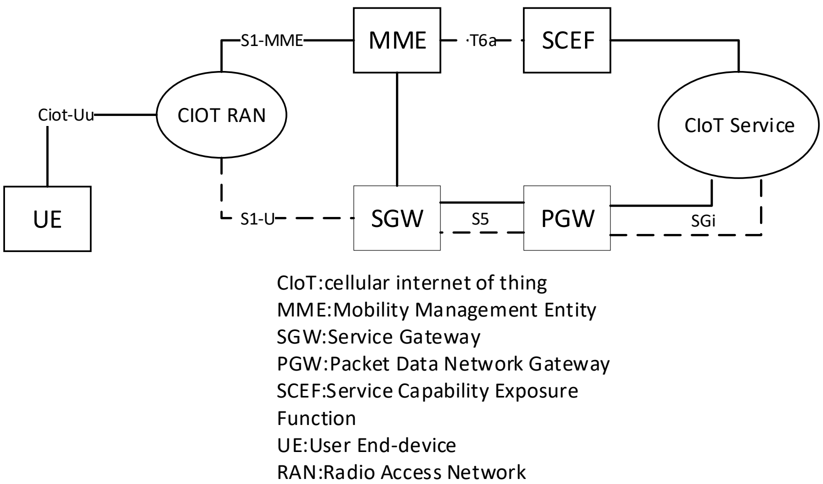

Fig. 4: NB-IOT network architect.

GPRS (General Packet Radio Service) is a technology developed on the basis of GSM (Global System for Mobile Communication). So it is the most mature technology, the most widely used in three technologies. Its network architectis is shown in Figure 5, The GPRS system adds PCU(Packet Control Unit), SGCN(Serving GPRS Support Node) and the Gateway GSN based on the GSM system.

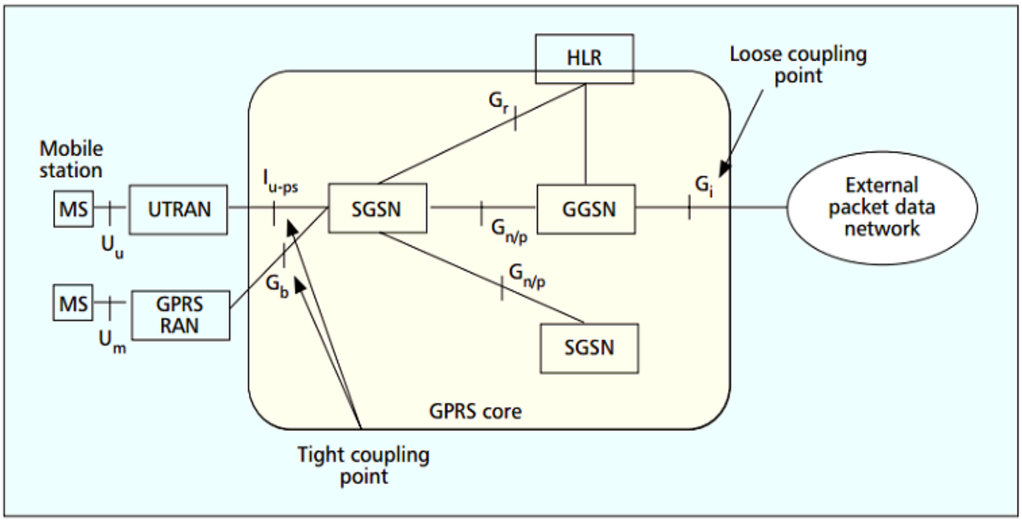

Fig. 5: GPRS network architect.

Summarized above, LoRaWAN network architecture is the simplest of the three technologies. And it is working in the unlicensed band, Users can be set up through personal network gateway to meet the application requirements. NB-IoT is based on LTE technology, the main application is currently CIoT. The user can select an existing LTE base station as a gateway, thereby reducing the cost of hardware. Since the beginning of GPRS design is not for the application of Internet of things, but for mobile phones and other mobile devices, GPRS is the most complicated network structure in the three technologies and its network structure has a perfect traffic accounting and gateway management functions.

3. Application Comparison

From the application of environment monitoring, we compared the following difference: the quality of service (QOS), battery life, network latency, network coverage, development mode and cost analysis.

3.1 Distance and Coverage

The MCL(Maximum Coupling Loss) of communication and transmission power usually have a direct impact on the transmission distance. GPRS has a theoretical maximum communication distance, The actual application examination found that the largest base station of GPRS coverage can reach 35 km; LoRa's communication distance is generally 1-20 km; NB-IoT is 20dB higher than GPRS in uplink power spectral density, so in theory NB-IoT has higher communication distance than GPRS. According to the literature [8], the results show that NB-IoT is the best over the coverage. GPRS's communication distance and coverage capability is between NB-IoT and LoRa both. LoRa can communicate up to 20 kilometers in open spaces outdoors, but only 2-3 kilometers in the urban buildings, so LoRa coverage is small in urban areas.

3.2 Power Consumption and Latency

The design of cellular network is the optimal frequency band utilization, it also sacrifice the node costs and battery life. In contrast, LoRaWAN nodes are born for low cost and long battery life, with some limitations in frequency band utilization. There are two important factors in battery life that need to be considered, the node's current consumption (peak current and average current), and protocol content. LoRaWAN is an asynchronous protocol based on ALOHA. In another way, nodes can sleep for a longer or shorter period according to specific application scenarios, while nodes such as cellular synchronization protocols must be regularly networked. For example, mobile phones on the market now have to synchronize with the network every 1.5s. In NB-IoT, this synchronization becomes less frequent but still timed, which in turn consumes extra battery power.

Therefore, NB-IoT may be a better choice for applications that require frequent communications, shorter latency, or larger data, and it is better to use LoRa for the scenarios that require lower cost, higher battery life, and less frequent communications.

3.3 Development Efficiency and Cost

LoRa works in an unlicensed band below 1GHz, so there is no extra charge for the application. NB-IoT and GPRS use the licensed band which belows 1GHz. LoRaWAN uses a free, unlicensed band. Meanwhile, the essential requirement for node work is network coverage. One obvious advantage for NB-IoT is that it provides network deployment by upgrading existing network infrastructure, but this upgrade is limited to some specific 4G / LTE base stations and spend more.

LoRa technology has been relatively mature and many countries are in progress or have completed a nationwide network deployment. A prominent advantage of LoRa is that each link has its own autonomy, but also through hybrid communications to achieve a larger network. The NB-IoT and GPRS will be limited by band, operators and other restrictions.

3.4 Quality of Service (QoS) and Data Rate

LoRa is an asynchronous communication protocol which causes the transmission data rate is lower than GPRS and NB-IoT. LoRaWAN protocol provides QOS functions such as network management, adaptive rate, reliable communication, fast delivery and frame loss detection. It has unique features in handling interference, network overlap and scalability but can not provide the same features as cellular protocols Quality of Service (QoS). the price of authorized sub-GHz frequency band auction for per MHz is more than 500 million US dollars [9]. GPRS and NB-IoT do not provide the same battery life as LoRa because of the considerations for Quality of Service (QoS), but both of them are based on the quality of service (QoS) and data rate offered by cellular networks which is better than LoRa. The NB-IoT decreased power consumption and increased communication coverage for GPRS by optimizing the expense of a certain communication bandwidth and speed.

4. Conclusion

Comparison of the necessary characteristics of the three communication technologies in terms of when applied to environmental monitoring. As shown in Figure 6, we can see that LoRa has advantages in power consumption, cost and communication distance. NB-IoT has more advantages than LoRa in latency, QoS, data rate and coverage, GPRS has advantages over both QoS, latency, data rate and distance, but has disadvantages in power consumption, cost and development. So for the need for a large number of deployment monitoring nodes in the environmental monitoring, cost and battery capacity requirements of GPRS will greatly increase the node cost, it is better to choose the LoRa or NB-IoT. Compared to LoRa and NB-IoT, the performance of NB-IoT in terms of communication speed, quality of service and latency makes it more suitable for applications with more data but less power consumption. LoRa is more cost-effective, lower power consumption and longer communication distance makes it more suitable for high power consumption and lots of node device.

In environmental monitoring, Users can choose to use combination of LoRa and GPRS to achieve environmental monitoring where some remote or base station signals are not covered, such as the concentration of carbon monoxide monitoring in the mine where GPRS and NB-IoT are not coveraged by base station. In urban with complex buildings and other similar places, such as monitoring air pollution in urban areas, LoRa signal is easily blocked, that lead to a serious decline in communication distance, selecting NB-IoT can guarantee a certain coverage. Therefore, in practical application, the appropriate communication module needs to be selected according to different application environments with the advantages and disadvantages of the three technologies, and sometimes a combination of multiple communication modes can be implemented to achieve the optimal communication solution.

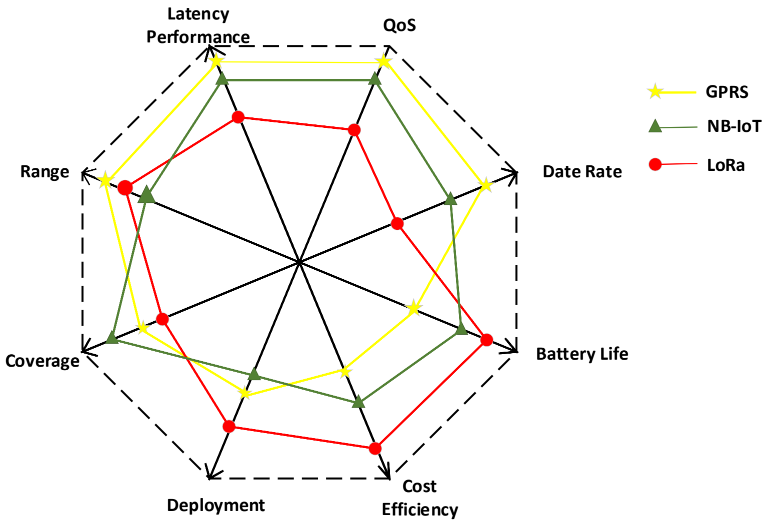

Fig. 6: Comparison in terms of various factors.

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6. References

[1] LoRa Alliance, LPWA Technologies Unlock New IoT Market Potential,Machina Research, Nov, 2015.

[2] Link Labs, Inc., A Comprehensive Look at Low Power, Wide Area Networks [Internet]. Available: http://cdn2.hubspot.net/hubfs/427771/LPWAN-Brochure-Interactive.pdf.

[3] Yongtao Wang,Yanying Wu.2013: Application and Research of Intelligent Control System of Agricultural Irrigation and Fertilization Based on. China Rural Water and Hydropower,12,93-95.

[4] Feng Piao，Chuanjiang Li.2014: Design and Realization of Bus Remote Monitoring System Based on GPS / GPRS. Computer Measurement and Control.22(1),79-80.

[5] Yaohua Guo.2014: Wireless Substation Equipment Temperature Monitoring System Based on ZigBee and GPRS Network. Instrumentation Technology and Sensor.1,80-82.

[6] Nokia, "LTE-M Optimizing LTE for the Internet of Things," White paper, 2015.

[7] LoRa Alliance, https://lora-alliance.org.

[8] Lauridsen M, Nguyen H, Vejlgaard B, et al. Coverage Comparison of GPRS, NB-IoT, LoRa, and SigFox in a 7800 km ^{2}Area[C]// Vehicular Technology Conference. IEEE, 2017:1-5.

[9] LoRa Alliance, NB-IoT VS LoRa^{TM} Technology, Sep., 2016. Available: https://docs.wixstatic.com/ugd/eccc1a_fb4ea35d44a5492b8c7c58c3b64cdc3d.pdf