Comparison of UNB-based LPWAN Networks

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Abstract. Internet of things (IoT) technology has been a hot research direction in recent years. Low Power Wide Area Network (LPWAN) is an important part of IoT. It helps realize smart cities, guarantees logistics security, and food security. It has important applications in both industrial and agricultural fields. Ultra narrow band (UNB) are systems that have very high spectrum efficiency but with restricted communication rate. It has become a popular choice for LPWAN due to its high anti-interference ability and low energy consumption. Therefore, in recent years, many LPWANs based on UNB technology have been developed. This paper introduces UNB, LPWAN, and IOT technologies in detail, and explains how LPWAN and UNB are used in IoT technologies. Then three UNB-based LPWAN networks, Sigfox, Telensa, Weightless-N, are introduced. Finally, we will compare these three technologies in terms of system composition, performance and application to find out their advantages and disadvantages in different aspects.

Keywords: UNB, LPWAN, IoT, Sigfox, Telensa.

1. Introduction

With the modern communication technologies growing rapidely, the era of 5G has arrived. In the global unlicense band of 60 GHz, the available bandwidth has reached of 7 GHz - a very wide bandwidth [1], which enables high-speed transmission of information. However, frequency resources are always limited, and reducing the bandwidth and improving the band utilization has become a popular research direction. From the invention of variable phase-shift keying (VPSK) modulation by Walker in the 1990s [2] to the invention of extended binary phase-shift keying (EBPSK) modulation by Professor LeNan Wu of Southeast University in the early 21st century [3], a variety of Ultra Narrowband (UNB) modulation techniques have been created, among which EBPSK-based modulation methods such as continuous extended binary phase-shift keying (cp-EBPSK) have been optimized to achieve a very high spectrum utilization [4]. Despite the efforts to improve the spectrum utilization of UNB, the rate of UNB has never been able to get a big breakthrough due to the bandwidth limitation, and it cannot adapt to the demand for Gbps-level transmission rate due to the propagation of audio images, and UNB gradually becomes faded from people's view.

In recent years, the Internet of Things (IoT) has become a hot topic, and since the machines to machines(M2M) technology, does not require high rates, Low Power Wide Area Network (LPWAN) has become the most central topic of IoT. At this time, UNB and Spread Spectrum (SS) become two possible technologies to realize LPWAN, where UNB is widely developed and re-emerges as a popular technology due to its advantages in energy saving, transmission distance and channel capacity [5-7]. The Sigfox [8] developed by the French company Sigfox, Telensa [9] in the US and Weightless-N [10] in the UK are LPWAN technologies developed based on UNB, which are widely used in the IoT field such as smart metering services [11], street lighting systems (based on Telensa) [12]. Different studies have used different technologies, each with different modulation, code rate, channel capacity, target, etc. Therefore, it is very helpful to compare and analyze these UNB-based LPWAN technologies and extract their respective advantages and disadvantages for further IoT development.

This paper will introduce UNB technology, IoT technology, LPWAN technology, explain why IoT needs LPWAN technology, and introduce three UNB-based communication technologies for IoT: Sigfox, LPWAN, Telensa, then compare their transmission speed by code rate, channel capacity, compare their transmission coverage, usage time, anti-interference ability, analyze their advantages and disadvantages, find out their respective suitable application scenarios, provide more application ideas for UNB, and enrich and improve IoT technology.

2. Principle

2.1. Ultra Narrowband(UNB)

UNB is a communication technology with a bandwidth below 1 KHz [7], usually around 100 Hz. It has extremely high spectrum utilization, requiring more than 30bps/Hz (-60dB bandwidth) [3]. In a decade since Walker's invention of VPSK, a large number of UNB modulation methods have emerged, such as VMSK, 3PRK, MCM, etc. [3].The spectrum utilization of VMSK techniques first exceeded 50bps/Hz, while later BPSK-based EBPSK and its derivatives such as CP-EBPSK have been able to increase the spectrum utilization to 235.3bps/ Hz [4].

Three focuses of UNB modulation.

Modulation Method - RF channel – Bandpass Filter

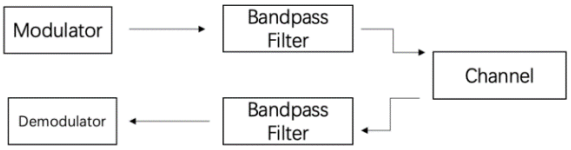


Figure 1. UNB system

Efficient modulation techniques and filters are the key to UNB technology, which usually uses PSK as the modulation method in order to shrink the bandwidth and increase the spectral small rate.

The following are some of the commonly used modulation methods.

EBPSK :

The basic formula of EBPSK :

$$S_0(t) = A\cos(2\pi f_c t)\ 0 \le t \le T. \tag{1}$$

$$S_1(t) = \begin{cases} B\cos(2\pi f_c t + \theta)\ 0 \le t \le \tau, 0 \le \theta \\ A\cos(2\pi f_c t)\ \tau \le t \le T \end{cases} \tag{2}$$

DBPSK:

Principle of DBPSK:

The phase difference of two adjacent code elements is used to transfer information.

$$\Delta\varphi = \varphi_n - \varphi_{n-1} = \begin{cases} 0 \\ \pi \end{cases} \tag{3}$$

0 means digital information 0, π means digital information 1.

In the following simulation we transmit a set of data 1,0,1,0,1,1,1,0,1. The initial phase of St1 is 0 and the initial phase of St2 is π

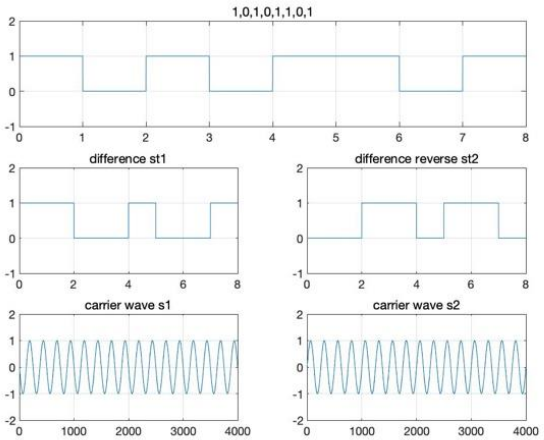


Figure 2. DBPSK Simulation

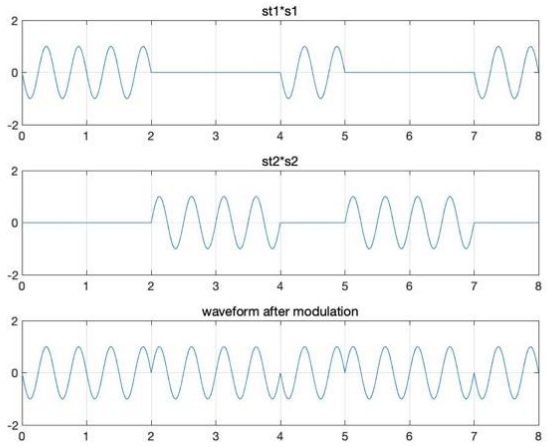


Figure 3. DBPSK Waveform

UNB uses RF channels with adjacent subcarriers orthogonal to avoid subcarrier interference, which, along with its ultra-high PSD (power spectral density), improves the interference immunity of UNB systems. In addition, because the power of UNB is concentrated in its very narrow bandwidth and most of its noise is filtered out by the receiver filter, it has an excellent link budget, which gives the ability to have UNB support long-range communication [7]. the low power of UNB has a high battery life. All these features make UNB an excellent choice for LPWAN technology.

2.2. Internet of Things(IoT)

IoT, or Internet of Things, is a direct object-to-object communication in the context of more objects connected to the Internet, and M2M (Machine to Machine) gives machines the ability to talk to each other. The goal of IoT is to interconnect billions or trillions of objects through the Internet [13]. Among the many models of IoT the most adopted is the three-layer architecture - application layer, network layer, and sensing layer [14]. The communication of things belongs to the network layer, and IoT communication technology is a technology that connects things to things to provide intelligent services. A noisy and functionally lossy channel is the environment in which IoT nodes exist. IoT should operate at low power in this environment [13]. This requires a high link budget and low power for IoT communication technologies and one needs LPWAN to achieve the requirements of IoT communication. At this point, UNB is the key technology of interest for IoT communication because of its various features.

2.3. Low Power Wide Area Network(LPWAN)

LPWAN is a wireless network for IoT applications that use low bit rate for long range communication connecting devices that have low power such as controllers and sensors in IoT and machine to machine communication. LPWAN usually has several features, which are: long battery life; low device cost; wide communication coverage; the ability to provide simultaneous connection to a large number of devices; and easy installation. LPWAN usually consists of four parts: LPWAN device, base station, cloud and application server. the link budget of LPWAN is kept at 150dB or less. There are two types of LPWAN operating on licensed or unlicensed spectrum. two technologies, UNB technology and Spread Spectrum (SS), are the two main LPWAN communication technologies.

3. Comparison of UNB-based LPWAN Technologies

3.1. Sigfox

Sigfox is an LPWAN technology for the IoT provided by the French company Sigfox. Sigfox uses UNB technology.

The basic operation of Sigfox is that a Sigfox protocol packet with application information is sent, then it is received by a nearby Sigfox base station and sent back by the base station to a Sigfox cloud server. the Sigfox cloud distributes it to a designated client server. The core technology used by Sigfox is UNB, which transmits signals with a total bandwidth of 192 kHz in the common band of 868-868.2 MHz (Europe) and 902-928 MHz (USA). Its UNB implementation benefits from two modulation methods, DBPSK for uplink and GFSK for downlink. although Sigfox can theoretically achieve bi-directional communication, its low receiver endpoint sensitivity causes it to basically not support downlink communication. Due to the ultra-narrowband modulation, the transmission width of each message is 100 Hz. the transmission bit rate is 100 or 600 bps, and its base station capacity is large enough to accommodate 1,000,000 terminal devices.

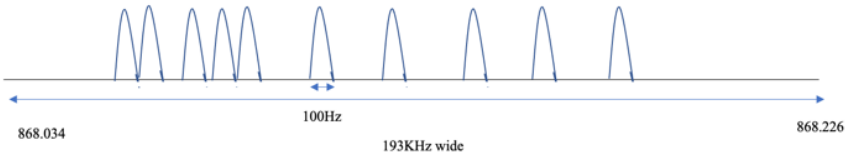


Figure 4. Sigfox Channel

The multiple access control protocol (MAC) used by Sigfox is R-FDMA. multiple access protocol is for collision between messages when multiple devices are connected to send messages at the same time. Sigfox works better when 1000 messages are accessed at the same time, but does not maintain good performance at 10000.

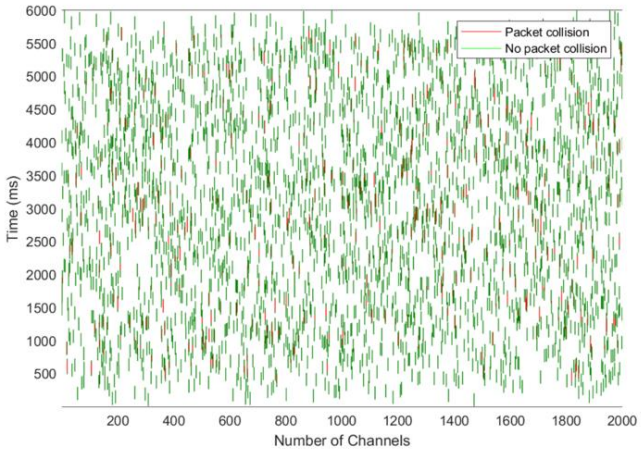


Figure 5. Sigfox Spectrum for 1000 devices[15]

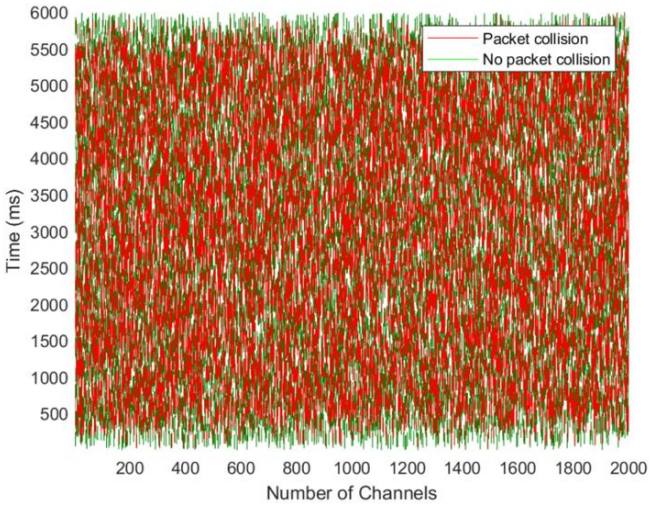


Figure 6. Sigfox Spectrum for 10000 Devices [15]

Sigfox has several features such as low power consumption, small message size, ease of use, long transmission distance, high interference immunity and low cost. With a transmission bit rate of 100 or 600bps and a large base station capacity of 1,000,000 end devices. Sigfox has a more than 10 years battery life. Due to its 100 to 600bps transmission rate, Sigfox user devices are only allowed to send up to 12 bytes of messages, 140 messages a day.

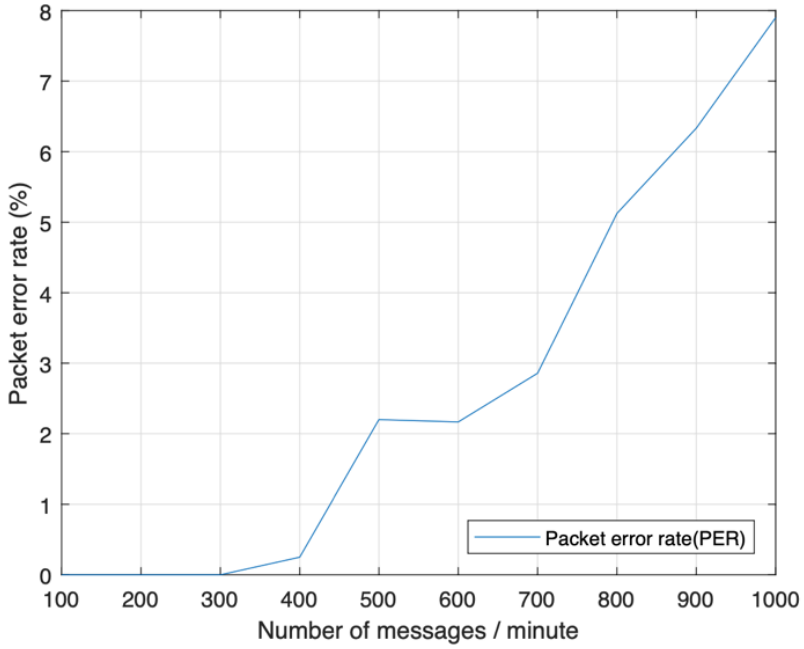


Figure 7. Sigfox PER for 1000 devices [15]

Sigfox, due to the use of ultra-narrowband technology, the bandwidth of 100Hz per message gives it extreme anti-interference and can communicate up to 10km in urban and 50km in rural areas.

Sigfox was the first to apply UNB system for LPWAN. The technology is mature and is the most widely used LPWAN technology. Sigfox's has more application scenarios. In smart city alone, there are smart real-time parking monitoring system, smart bicycle sharing, increasing the detection of air quality and urban heat island effect, etc. In the case of smart real-time parking, for example, easy-to-install ground sensors are installed on the ground, and the parking information is sent to the base station, which sends the information to the Sigfox cloud, which then sends the information to the customer server, and finally, the customer will know the real-time parking information and find a suitable parking location. food safety and other applications. In addition, Sigfox has a wide range of applications in the manufacturing and transportation industries.

3.2. Telensa

Telensa is the LPWAN technology provided by Telensa. It is the same LPWAN network as Sigfox that uses ultra-narrowband technology.

Telensa's message bandwidth of 100 kHz communicates on the ISM subGHz band in the common frequency band of 868 MHz and 915 MHz. Telensa uses the Frequency Shift-Keying modulation. Uplink and downlink both use FSK as modulator. This is different from the PSK method used by most UNB technologies.

The basic formula of FSK

$$s_m(t) = Ae^{i2\pi m\Delta ft} \tag{4}$$

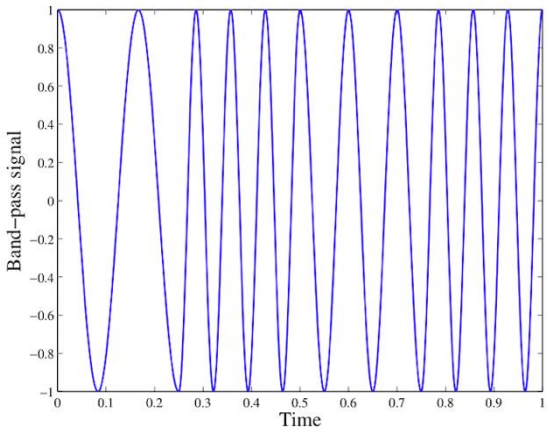


Figure 8. FSK Signal

The use of ultra-narrowband with FSK may lead to a reduction in spectrum utilization compared to PSK, however this may be for better use of frequency division duplexing. Unlike the unidirectional communication of Sigfox (which hardly supports downlink communication), Telensa supports full duplex communication, which means, it supports bidirectional propagation of information between systems [16].

The Telensa uplink has a maximum speed of 62.5 bps and the downlink has a maximum speed of 500 bps, while the Telensa consumes very little power. the Telensa terminals have a battery life of 8 years and a link budget of 160 dB allows it to communicate over long distances. the Telensa supports communication within one kilometer in urban areas and four kilometers in rural areas. rural areas within 4 kilometers. Its base station capacity of 5,000 is far inferior to Sigfox, but Telensa is still widely used due to its own characteristics. For example, the street lighting system PLANet.

PLANet is the most successful smart streetlights system in the market, with a network of more than 50 cities and regions in eight countries, a program covering more than 1,000,000 streetlights. Telensa also plans to use LED-based streetlights to improve energy savings by thirty percent. The localized customization of the lighting level is achieved and a low-cost sensor application for city-wide platform is provided.

The main components of PLANet are the telecell nodes, the ultra-narrow band network and the central management system.

The central management system uses a map-based control program to manage the millions of lights in the area. The management system sends commands to designated base stations, which in turn send them to the telematics control nodes. Each base station uses the UNB network, an ultra-narrowband technology with a longer communication range and lower data costs. Each base station, as mentioned in the previous introduction, can connect 5000 remote control nodes, and each node operates at a very low power of 0.7W. PLANet is an example of LPWAN technology application with UNB technology as the core, and is an important example of IoT to achieve urban intelligence.

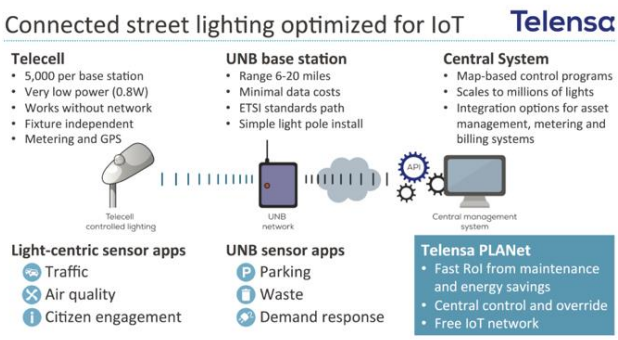


Figure 9. PLANet System

3.3. Weightless-N

Weightless-N is an ultra-narrow LPWAN based technology developed by Weightless, a UK company.The target application of Weightless-N is a low-cost application with one-way communication, so it only provides full uplink transmission.

Weightless-N and SigFox, like Telensa, operate in the Sub-GHz band between the 868 or 915 MHz unlicensed band, with a bandwidth of 200 Hz. Like Sigfox, they both use DBPSK as the modulation method. Slotted-ALOHA improves on the pure ALOHA algorithm by making a number of identical time slices in the same time frame, and if a collision occurs between messages transmitted at the same time, it waits until the next time slice before sending. This method reduces collisions between data, improves channel utilization, and is suitable for the case where multiple commands are sent at the same time [17].

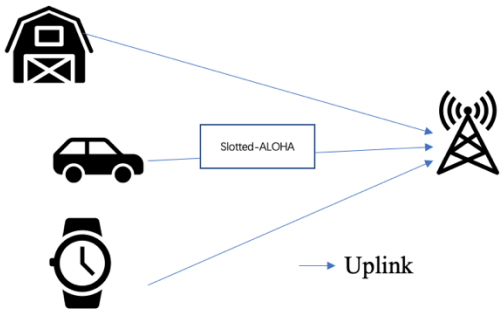


Figure 10. Weightless-N

Weightless-N has a similar communication range to Telensa at 5 km and a battery life of 10 years. It's one UNB base station can connect 50,000 devices. These elements are similar to the first two technologies. But as a UNB technology, Weightless-N's transmission speed is extremely outstanding. Its bit rate ranges from 30 kbps to 100 kbps, and the maximum payload length per message is 20 bytes. It is worth mentioning that Weightless can provide very low-cost base station equipment.

Weightless-N is widely used in the smart city construction in London.

The most special part of Weightless- N, as several current LPWAN networks based on UNB technology, is that it provides only single transmission, and this single transmission reduces the cost. Weightless-N is also the most advanced in terms of anti-collision algorithm and has the best anti-interference capability when multiple messages are sent at the same time. weightless-N also has the highest transmission speed.

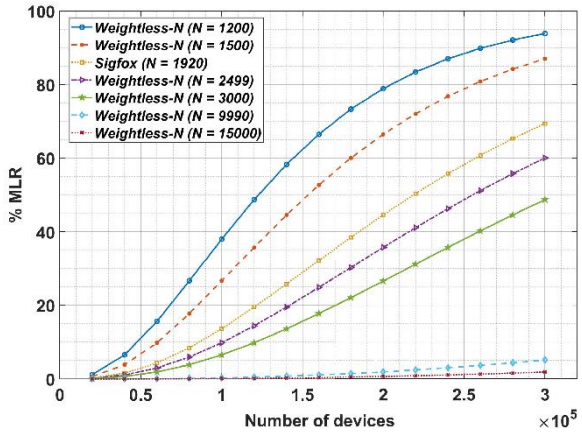


Figure 11. Weightless-N and Sigfox technologies' message lost rate with number of devices varying with all available bands included, where payload = 12 Bytes and *message copies* = 3[18].

3.4. Comparison

Sigfox, Telensa and Weightless-N are all LPWAN technologies based on UNB technology, and all three are implemented on the unlicensed band. Among them, Sigfox is the most mature technology due to its earliest appearance and strongest signal coverage and base station capacity. Telensa is the only one of the three technologies that uses FSK modulation and is the only one that supports full duplex communication. PLANet is the most successful smart city street lighting system. Weightless-N is characterized by its special MAC protocol, which is the best anti-interference. capability in both systems. However, since Weightless-N only provides a single communication, it is cheap, but it is only highly used in London area.

Table 1. Sigfox, Telensa and Weightless-N technologies

	Sigfox	Telensa	Weightless-N
Operating Frequencies	868 915MHz	868 915MHz	868 915MHz
Support for downlink communication	Limited	Yes	No
Bandwidth	100Hz	100kHz	200Hz
Multiple Access Scheme	R-FDMA	Unknown	Slotted-ALOHA
Uplink Modulation	DBPSK	2-FSK	DBPSK
Downlink Modulation	DBPSK	2-FSK	No
Data rates	100bps or 600bps	62.5bps Uplink 500bps Downlink	30kbps~100kbps
Base Station Capacity	Over 1,000,000	5,000	50,000
Travel Distance	10km (urban) 50km (rural)	1km (urban) 4km (rural)	5km
Battery Life	10 years	8 years	10 years
Network Deployment Cost	High	Medium	Low

4. Conlusion

This paper firstly introduces UNB technology and LPWAN technology, and then compares three LPWAN technologies based on UNB technology and finds different results for LPWAN systems due to UNB modulation, different MAC protocols. Among them, Sigfox base station has the largest capacity, the most mature technology, and the most widely used. Telensa is very successful in smart cities due to duplex communication, although it is less lacking in signal propagation speed and distance. Weightless-N has the highest transmission speed, and in addition to that, it performs the best when it comes to anti-interference because of using a special MAC protocol, but currently, it is less used.

In recent years, IoT has been a hot topic, and building a society where everything is connected is a common goal. The LPWAN network is an indispensable step.

Currently, LPWAN based on UNB technology has been widely used in smart cities, agriculture, and manufacturing industries. Comparing and analyzing different LPWAN networks with different performance and application objects will be of great help to clarify the direction of future LPWAN development.

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