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LoRa, Edge Computing and Blockchain Improving the IoT World

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Abstract

Long Range (LoRa) is a technology widely used to build Low-Power Wide-Area Networks (LPWANs) that enables bidirectional transmission of data packets over long distances. Most suitable for Internet of Things (IoTs) applications, it enables the broad-range communication and enables transmission of small data packets over long distances. This technology is perfect for covering remote areas where other data networks are not available. The small amount of data exchanged can be limiting if complex processing is required to understand specific events happening around the devices. An image elaboration or video processing is an example. As of today this tasks are mostly available in the cloud. Recent developments in the field of artificial intelligence hardware have led to the emergence of a new generation of low-power hardware capable of carrying out inference on pre-trained models with good performance on the edge for a few watts. In this paper we investigate the use of LoRa technology in combination with Edge Artificial Intelligence computing and Blockchain to build an architecture enabling vehicle surveillance and control of large and remote areas.

Keywords

LoRa, AI, Surveillance

1. Introduction

Over the past few years, interest in Low Power Wide Area Area (LPWA) technologies has grown so much that it has gained unprecedented momentum and strong commercial interest especially in the field of the Internet of Things (IoT) [1, 2, 3, 4]. Many candidates appeared on the LPWA scene (SigFox [5], LoRa [6], Wheighless [7], Ingenu [8]). In this paper we decided to use LoRa (Long Range), one of the most promising wide-area LPWA technologies proposed by Semtech and subsequently promoted by the LoRa Alliance [9]. The ability to accommodate multiple users in the same channel through spread spectrum multiple access techniques allows this technology to establish communication channels with low power consumption and low cost design. The LoRa Alliance has defined the upper layers and network architecture above the LoRa physical layers and called them LoRaWAN [9]. Together, these features make LoRa attractive to developers who can build complete system solutions on top of it for both geographic [10] and residential/industrial types of IoT networks [11], thus accelerating its market adoption. The ability to cover large areas with a low number of devices compared to other technologies makes it possible to approach problems that were previously difficult to solve. Imagine having to cover vast mountainous or wooded areas, or in any case areas that are difficult to reach and are poorly or not at all covered by other types of networks [12, 13]. The aim of this work is to apply state-of-the-art computer and artificial intelligence tools to optimise a remote surveillance system capable of understanding what is happening around the sensors by processing the information on site, transmitting with a few data the occurrence of an event and allowing an eventual supervisor to inspect the data once the alarm point is reached.

2. Long Range (LoRa)

Long Range (LoRa [6]) is a proprietary spread spectrum modulation technique by Semtech, derived from Chirp Spread Spectrum (CSS). Instead of modulating the message on a pseudorandom binary sequence, as is done in the well known Direct-Sequence Spread Spectrum (DSSS), LoRa uses a sweep tone that increases (upchirp) or decreases (downchirp) in frequency over time to encode the message. Spreading the signal over a wide bandwidth makes it less susceptible to noise and interference. CSS in particular is resistant to Doppler effects [14] (common in mobile applications) and multipath fading [15]. A LoRa receiver can decode transmissions 20 dB below the noise floor [16], making very long communication distances possible, while operating at a very low power. LoRa transceivers available today can operate between 137MHz to 1020MHz, and therefore can also operate in licensed bands. However, they are often deployed in ISM bands (EU: 868MHz and 433MHz, USA: 915MHz

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and 433MHz). The LoRa physical layer may be used with any MAC layer; however, Long Range Wide Area Network (LoRaWAN) is the currently proposed MAC. LoRaWAN operates in a simple star topology. A LoRa transceiver has five runtime-adjustable transmission parameters: Transmission Power (TP), Carrier Frequency (CF), Spreading Factor (SF), Bandwidth (BW), and Coding Rate (CR). These parameters have an influence on the transmission duration, energy consumption, robustness and range [17]. Transmission Power (TP). TP on a LoRa receiver can be adjusted between -4 dBm and 20 dBm in 1 dB steps. Because of regulatory and hardware limitations, however, this is often limited between 2 dBm and 14 dBm. TP has a direct influence on energy consumption and the range of the signal. Carrier Frequency (CF). CF is the centre frequency, which can be programmed in steps of 61Hz between 137MHz to 1020MHz. Spreading Factor (SF). SF determines how many bits are encoded in each symbol, and can be set between 6 and 12. A higher spreading factor increases the Signal to Noise Ratio (SNR) and therefore receiver sensitivity and range of the signal. However, it lowers the transmission rate and thus increases the transmission duration and energy consumption. The SFs in LoRa are orthogonal. Consequently, concurrent transmissions with different SF do not interfere with each other, and can be successfully decoded (assuming a receiver with multiple receive paths). Bandwidth (BW). BW can be set from (a fairly narrow) 7.8 kHz up to 500 kHz. In a typical LoRa deployment, only 125 kHz, 250 kHz and 500 kHz are considered. A wider bandwidth means a more spread-out and therefore more interference-resilient link. In addition, it increases the data rate, as the chips are sent out at a rate equivalent to the bandwidth. The downside of a higher bandwidth is a less sensitive reception, caused by the integration of additional noise. Coding Rate (CR). CR is the amount of Forward Error Correction (FEC) that is applied to the message to protect it against burst interference. Higher CR makes the message longer and therefore increases the time on air. LoRa transceivers with different CR, and operating in ‘explicit header mode’, can still communicate with each other, as the CR is encoded in the header.

3. Edge computing

Edge computing refers to applications, services, and processing performed outside of a central data center and closer to end users [18]. The definition of “closer” falls along a spectrum and depends highly on networking technologies used, the application characteristics, and the desired end user experience. While edge applications do not need to communicate with the cloud, they may still interact with servers and internet based applications. Many of the most common edge devices feature physical sensors (such as temperature, lights, speakers), and moving computing power closer to these sensors in the physical world makes sense. With collection and processing power now available on the edge, companies can significantly reduce the volumes of data that must be moved and stored in the cloud, saving themselves time and money in the process. Image recognition and video streaming are just the tip of the iceberg. Security camera companies, for example, struggle to use cloud-based solutions because real-time data and video streaming to the cloud is prohibitively expensive [19]. Autonomous cars need offline functionality on the road [20], while AR/VR gaming companies maintain their brand credibility by keeping their products resilient to lag using 5G networks or other technologies [21].

4. Blockchain

Blockchain technology was introduced by a single entity or group under the name of Satoshi Nakamoto in 2008 and the code of its implementation was published a year later in 2009 in the document ‘Bitcoin: A Peer-to-Peer Electronic Cash System’ [22]. The Blockchain is essentially a distributed and transactional database shared by the various nodes of the network. The validity and integrity of the data is maintained by chaining the transactions contained in the blocks using hash functions that prevent them from being modified without consent. Bitcoin uses the public key infrastructure (PKI) mechanism [23]. In PKI, the user has a couple formed by a public and a private key. The public key is used as the address of the user’s wallet, while the private key is used to sign transactions. A block is accepted by the network on average every 10 minutes through a consensus mechanism. The new chain with the new block on top will spread quickly in all the nodes of the network.

Inside each node there is a key-value database in which the blocks containing the transactions that have reached consensus will be written. Each node validates the new blocks. Although the search for the hash that satisfies the consensus called Proof of Work takes on average 10 minutes regardless of the network’s computational capacity, checking the correctness of these hashes is extremely fast. This method creates a linear chain of blocks on which all nodes agree (Figure 1). This chain of blocks is the public ledger technique of Bitcoin, called Blockchain.

5. Application Scenarios

In this section, we discuss several recent IoT applications based on LoRa and LPWAN and analyze possible areas for improvement. The studies will be broken down by application type.

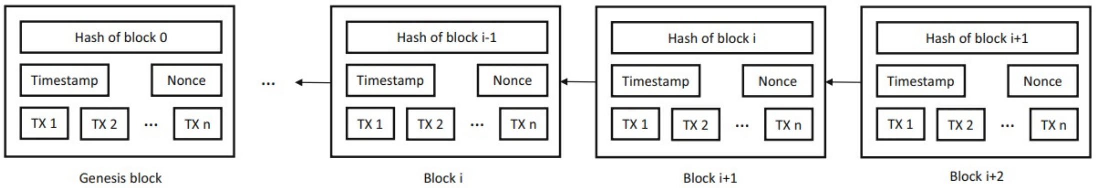

Figure 1: Blockchain structure. (Zheng et al. 2016 [24])

5.1. Environmental Monitoring

The study and monitoring of the environment are essential for the preservation and prevention of all natural environments. Within precision agriculture (PA) practices, proximity data collection is often accomplished by IoT devices that act as collectors of environmental information. Many studies are present about environmental monitoring platforms realized by exploiting LORA technology. Ali et al. [25] built an environmental monitoring platform by combining the features of LORA and ZigBee. Leveraging the best wireless features of ZigBee and LoRa, they proposed a diversified communication system with smart features in a single loT system. Wang et al. [26] presented a wireless sensor network system dedicated for meteorological monitoring based on Long Range (LoRa) for real-time services such as agricultural production demand. Very interesting the study conducted by Chen et al. to monitor air quality by using a UAV (Unmanned Aerial Vehicle) and LoRa communication system [27]. Authors in [28] proposed a system for automated oil spill detection by remote sensing. Nordin et al. implemented a narrowband IoT-based hydrological monitoring system in a lagoon environment [29]. The authors studied network performance predictability, limitations, and reliability by comparing 2G and LoRa systems. They concluded that GSM-based data communication is unreliable in rural areas due to uneven terrain and non-line-of-sight of view and concluded that LoRa is a better alternative in terms of RSSI as long as the antenna is placed at high altitude.

5.2. Smart City

The smart city concept has become definitively consolidated with the emergence of IoT devices. These two areas have now become closely related concepts. Many fields of urban monitoring can be covered by IoT and LORA technology. Del Campo et al. [30] proposed the LoRa technology to monitor the power distribution on suburban area. Many studies address public lighting in a smart city context [31, 32, 33, 34]. One of the most interesting is presented by Pasolini et al [35]. They studied how to implement smart street lighting by comparing IEEE 802.15.4 short-range communication technology with a low-bandwith but long-range technology such as LoRa. The results show that correct parameters allow large urban areas to be covered while keeping the transmission time low enough to keep packet losses at satisfactory levels using LoRa. Interesting continous real-time testbed was conducted by Loriot et al. [36] analyzing the different receptions within an urban context by making connectivity maps and following the measurements through a custom made Web application for realtime data visualization.

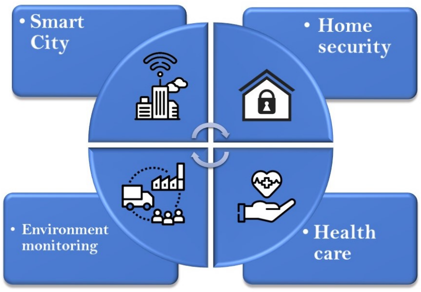

Figure 2: Blockchain, IoT and LoRA main use cases

5.3. Health monitoring

A new emerging technology called WHDs (Wearable Health Devices) has gained traction. This technology enables continuous health monitoring of human vital signs in everyday life, even 24h per day. Clinical environments can also benefit from the innovative advantages of this technology minimizing interference and discomfort with patients' daily lives. A low-cost LoRa health monitoring system was proposed by Lousado et al. [37]. The system is able to track different environment data to monitoring the health conditions of the elderly in their homes using LoRa technology and The Things Network cloud framework. The LoRa node was developed using an ESP32/LoRa microcontroller and collect various environmental sensors data on temperature, humidity, carbon monoxide, gas, and smoke. The results seem encouraging, succeeding in closed places to reach a communication range of 1.2 km. Dimitrievski et al. [38] address the digital device issue in rural areas that could create further disparity in the use of smart helth devices using a LoRa-IoT oriented architecture. However the constraints of low network bandwidth and the need to reduce the active time of the IoT nodes limit the capabilities of the overall system.

5.4. Securing LoRa comunications

Security and resistance to data tampering became critical issues during the development of the LoRa system for the Internet of Things. The LoRa system is a centralized system, where data is stored in the central cloud. This approach makes the system vulnerable to security risks such as data forgery or loss. To solve this problem, many researchers are using various types of Blockchain to increase the level of data consistency and achieve a more secure long-range communication system. LU et al. [39] introduced HyperLoRa, a blockchain-enabled LoRa system by using the open-source Hyperledge Fabric blockchain. Ozyılmaz et al. [40] have investigated the possibility of using a decentralized storage called SWARM for secure data storage, using Ethereum's blockchain infrastructure. Unfortunately, the system throughput is low due to the choice of consensus type. Using in the Ethereum private network the PoS instead of the PoW the number of transactions per second would have been much greater [41, 42].

5.5. Conclusion

This paper provides a brief introduction to Blockchain, Edge Computing and LoRa technologies and how they can together be used to improve both performance and security of IoT devices. As a result of this combination of technologies, the number of use cases and real-world applications will undoubtedly tend to increase, bringing an ever-increasing level of maturity to the IoT environment.

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