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LORA SMART PARKING FOR PHUKET SMART CITY

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Abstract: *Phuket is a small beautiful province that is encouraged to be a smart city and received several funds to build the smart city. Smart Parking is one goal of Phuket smart city since the traffic congestion is a main problem in the most touristic cities. Many wireless technologies have been applied for creating machine to machine communication among IoT sensors and service applications. We investigate, in this paper, LoRaWAN technology for smart parking. We performed an experiment of successfully received packets through LoRa simulation before having the real implementation and deployment.*

Keywords: ***LoRaWAN / Smart Parking / Smart City***

1. INTRODUCTION

Smart innovation is the key to bring all great communication technologies, Internet of things (IoT) and the application together depending on the circumstances. M2M networking for sensors that link to a concentrator or a gateway that forwards real time information to end users. Smart Parking is one interesing system using IoT components to implement it. The aim to create this system is to make people live more conveniently especially in the small city that is so crowded in Phuket, to save energy and to have better management. Moreover, the system can gather and analyze information and offer greater opportunity for many businesses.

However, to deploy real implementation to the city is a big challenge since the user expects to have reliable services. Once a number of sensors are deployed, packet collision or many other reasons may cause unreliable services. This leads us to build the prove of concept of smart parking system and also simulate a number of sensor nodes with several gateways in order to have reliable and sustainable services.

The rest of this paper is organized as follows. The next section shows in a nutshell the available currently wireless technolgies. Section 3 presents LoRa architecture and its related work. Next, we give smart parking architecture and detail the proposed solution followed by Section 5 where we simulate the smart parking system. Eventually, conclusions and future work are presented in Section 6.

2. RELATED WORK

There are many wireless technologies, for instances, ZigBee, 6LoWPAN, Bluetooth LE, IEEE 802.11ah, and LoRa, which are enabling the Internet of Things (IoT). IoT has challenges in power consumption, coverage area, network topology, security, latency, and more to be overcome [1]. We summarized the comparison of some wireless technologies in various topics described above as shown in Table 1.

Table 1. *Comparison of Wireless Technologies*

Wireless Technology	Coverage Area	Data Rate	Energy Consumption	Topologies
IEEE 802.11ah	up to 1 km (sub GHz radio)	20 Mbps	100mW	Star
Bluetooth LE	100 m	2 Mbps	10mW	Scatternet
ZigBee	20 m	250 kbps	1 - 60mW	Mesh, Star, Tree
6LoWPAN	20 m	200 kbps	2 – 10 mW	Mesh, Star
LTE Advanced	depends on provider	up to 1 Gbps	1mW – 5 W	Mesh
LoRa	5 km in urban area (up to 15 km LOS)	up to 100 kbps	Adjustable	Star, Star-of-stars

Wireless LAN and LTE have an advantage in data rate compared to others as its transfer speed is up to 1.3 Gbps on IEEE 802.11ac and up to 1 Gbps on LTE Advanced. Zigbee has only up to 250 kbps data rate. However, ZigBee is capable to connect approximately 65,000 nodes. LoRa has lower data rate but capable to connect more end devices [1].

The LoRa radio module operates in the sub-GHz band. The network of LoRa consists of gateways, end-devices, and the NetServer. The NetServer is the root in the star-of-stars network topology [2]. According to the specification [7], the core of LoRa enabling the trade-off between throughputs for coverage area or power consumption is its modulation scheme, namely, chirp spread spectrum (CSS). The chirp spread spectrum is also immune to channel noise as it uses entire allocated bandwidth. The power consumption is regulated by bandwidth and the spreading factor, which are configurable on NetServer. The spreading factor (SF) value is varying from 7 to 12 defining the length of chirp symbol. Higher SF causes the receiver to be more sensitive and enable to establish in longer range. For example, if SF is set to 12, its range is 10 kilometers or farther while the receiver sensitivity is about -137 dBm [2].

In comparison between LPWAN radio technologies, there is a claim that LoRa is able to communicate up to 5 kilometers in urban area and 10 – 15 kms in rural area [3]. Moreover, the packet loss ratio is only averagely 33% in coverage range of 5 – 10 kilometers [4]. The end device is installed on a car using Planar-F type printed circuit board antenna while the gateway is deployed and connected to biconical D100-1000 antenna at 24 meters above sea-level.

In 2016, Orestis and Usman [2] found that LoRa performance is exponentially decayed up on the number of end devices. Thus, this means that LoRa is limited in scalability. However, it is interesting to gain the benefits of multiple gateways [2].

An intelligent car park management system based on wireless sensor networks was proposed by Tang, Zheng, and Cao [5]. The system prototype consists of sensor nodes using battery-powered Berkeley Mote with various sensors and a gateway connected using Crossbow's XMesh (IEEE 802.15.4 LR-WPAN compatible) network stack. Through system evaluation over scenarios checklist, they conclude that the prototype system can effectively satisfy the requirements of a WSN-based intelligent car park management.

Car-Park management system using WSN is designed and evaluated again using CC2420 Zigbee compliant transceivers [6]. The experiments were conducted in many aspects, which are sensor, connectivity and routing tests. From the observations, communication reliability is good in 5 meters range. In the range of 5 to 10 meters, the communication becomes spatially and temporally unstable. It is nearly impossible to communicate beyond 10 meters and if a parked car covers the transmitter or receiver, it is impossible to establish a communication.

In order to solve the communication range problem, we introduce the LoRaWAN which effectively operates at least 10 kilometers of coverage area. Furthermore, LoRa is also suitable for low power and low data rate applications. In the Section 3, we summarized the LoRa architecture, which is rudimentary for further studies and experiments.

3. LORA ARCHITECTURE

LoRa is developed by Semtech to be a wireless modulation for long-range communications. In addition, it operates using low power consumption and suits for low data rate applications. LoRa utilizes frequency in regional ISM bands based, such as EU 868 MHz, 433 MHz, or US 915 MHz.

LoRa network discriminates the basic LoRaWAN (Class A) from the optional features. Currently, LoRaWAN defines three classes which are Class A, B, and C.

Class A is the lowest power end-device. It allow bi-directional communications. Class A end-device only wakes at scheduled time or when a data is ready to transmit. So it spends most of time in sleep mode and that makes the class A end-device energy efficient.

Class B allows schedule receive slots in addition to Class A. This is possible by receiving a time synchronized beacon from the LoRa gateway. Thus, the server can determine when the end-device is listening.

Class C end-device nearly continuously listening. This means that end-devices of Class C consumes more power than Class A or Class B. However, its latency is superior to others.

According to LoRa specifications [7], all LoRaWAN devices implement at least Class A functionality. Class B and C are optional.

Frame payload of LoRa, if carried in a data frame, must be encrypted. The encryption scheme used in LoRa is AES with 128 bits key as also described in LR-WPAN IEEE 802.15.4/2006 Annex B. The message integrity code is then calculated using AES-CMAC algorithm (RFC4493) after encrypts the payload.

The LoRa end-device can join a LoRaWAN network by a method called Over The Air Activation (OTAA). The end-device is activated when deployed or reset by sending a join-request message. The join-request message consists of an application identifier, an end-device identifier and a device's nonce. The network server will respond with a join-accept message. The join-accept message contains application's nonce, a network identifier, a device address, and some transceiver configurations. After that, the end-device computes and stores a network session key and an application session key for further secured communication.

We propose using LoRa to improve smart car parking system. This is becuase smart car parking system requires low-power, secured and stable long-range wireless communication. Also high data rate connection is not necessary. According to comparison in Table 1, this leads to an inference that LoRa is specifically superior to other communication methods for this situation.

4. SMART PARKING ARCHITECTURE

Presently, smart parking services are proposed with various wireless networking techniques, e.g., ZigBee and WiFi in the commercial production. However, they have some limitations at the communication range, capcity, enegy consumption and security comparing to LoRa technology.

Our proposed smart parking architecture consists of several components such as sensor nodes (SX127x series) and gateways (SX1301) [10] which are based on LoRa technology as shown in Fig 1. In addition, another important component is the cloud service platform. It connects between a LoRa gateway and mobile users in order to provide real-time information to users.

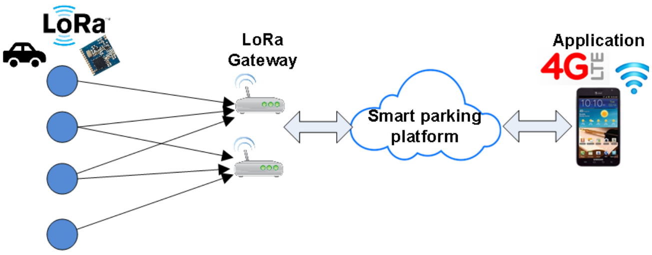

Fig 1. *General Smart Parking System with LoRa*

Parking slot status, read from a sensor node, is sent to a gateway and then it is forwarded to the application server which provides open parking spaces to drivers via mobile devices or PCs. Moreover, parking garage owners are able to gain profits their parking slot by offering them to drivers from the system effectively.

Parking status is handled from LoRa sensors and gateways. Currently, there are some ready products available today using the original Semtech LoRa chip. Another competition is focused on application service platform. Open parking slots must be provided as a main function basically and other features are interesting such as navigation system to the parking slot, notification via famous social networking (e.g., Line, Facebook), online payment for parking slot and link a customer (e.g., a driver) to parking slot owners to increase their revenues or create promotion. All collected data can be used to analyze people behavior for marking strategy or plan for the city.

As LoRa has multiple significant advantages over sensor node capacity. A gateway is in charge for several thousand sensor nodes [10]. However, once sensors are deployed, packet may be undelivered to a destination from several reasons. Thus, LoRa simulation is conducted to reveal capcity of LoRa concentrators for real implementation and deployment plan in Phuket.

5. EXPERIMENTAL SETUP

We have built the smart parking model so as to prove the concept. Unfortunately, frequency band plan in Thailand, WiFi is used for sensor communciation instead of LoRa as shown in Fig 2. This is the first version before changing to LoRa after the frequency band plan is updated.

Thus, we simulate a number of sensor nodes in LoRaWAN. LoRaSim [8] has been used to evaluate unsuccessfully received packets in the network with the number of nodes and gateways. LoRaSim is developed as a discrete-event simulator based on SimPy[9]. Sensor nodes normally place at the smart parking slots as 2-dimensional space on random distribution. Moreover, the background LoRa traffic such as weather stations, home automation or other LoRa smart systems will be included in the experiment as shown in Fig 3.

Figure 2. *Smart parking PoC model*

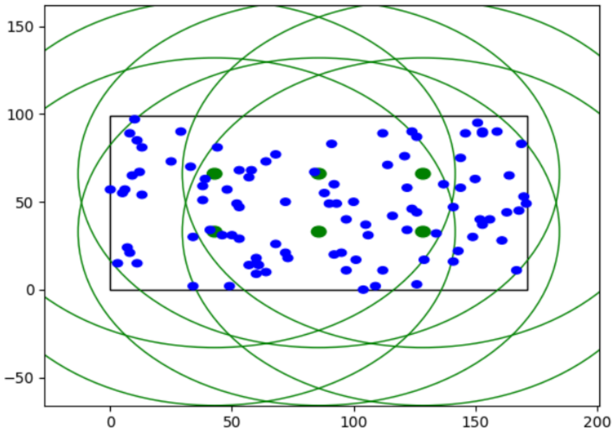

Figure 3. *LoRa nodes with 6 LoRa gateways simulation*

Typical LoRa setting parameters are described as follows: Spreading Factor (SF12: 4096 chirps/symbol), Bandwidth (BW125: 125 kHz), Coding Rate (CR4/5 FEC) and Packet transmission rate (λ) is 0.5 packet/sec as a typical updating status setting.

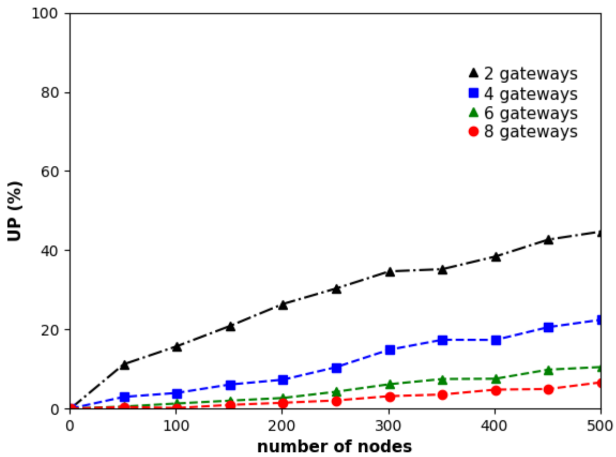

Figure 4. *Unreceived packet rate in LoRa Network*

Moreover, Several gateways have been tested with a number of LoRa nodes in order to examine the successfully received packet rate which is calcuated from equation (1).

$$\% \, UP = \left(1 - \frac{RP}{SP}\right) * 100 \qquad (1)$$

UP is referred as unreceived packet rate in a period of time. *RP* is denoted as successfully received packets and *SP* is denoted as sent packets.

The simulation results are shown in the Figure 4, it reveals that 200 LoRa sensor nodes may have collision or errors more than 20% for 2 gateways that will be the reliability problem for real deployment of LoRa smart parking. In addition, packet error rate is significantly decreased when a number of gateways are increased.

6. CONCLUSION AND FUTURE WORK

In this paper, we proposed the concept of smart parking using the LoRa technology. The proposed system is designed to manage available parking slots over LoRaWAN. The main benefit of the system is a way of managing parking slots for a number of vehicles more effectively. This system leads to many advantages (1) energy saving since there are rarely cases that cars freely run to find theirs parking slots, and (2) information of in charged slots can be used to analyze people behaviors. Furthermore, unreceived packet simulation is provided in order to examine that the deployment is practical or reliable enough. LoRa network is well scalable by providing many gateways. Eventually, the test result is used for a significant factor of the real smart parking implementation and deployment. In the future work, other LoRa modes with security parameters may be included to examine experimental results in more details.

7. ACKNOWLEDGEMENTS

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