Parkurbike: An IoT-Based System for Bike Parking Occupation Checking

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***Abstract*—Smart campus are enabled by IoT, Big Data and data analytics. Particulary, IoT is used in smart campus to collect data from connected sensors, lights and meters. The collected data can be used to create value-added services that improve the quality of experience of users in a smart campus. Smart bike systems are a technological approach installed in cities or campus. This paper presents Parkurbike, an entire solution to automatically determine and present bike parking occupation. Parkurbike consists of a sensing system, an IoT Edge Platform, an IoT Platform Repository and a web application.**

***Index Terms*—Internet of Things, Smart Campus, Presence sensors, Bike parking.**

I. Introduction

The Internet of Things (IoT) is a new technological paradigm that enables advanced services by interconnecting physical devices, based on existing and evolving network technologies. Thus, applications leverage ubiquitous connectivity to provide new value added-services in various sectors (*e.g.* transport, energy, safety, retail, environment, health). In IoT, connected sensors allow to monitor, control and report behaviors to a centralized platform. According to the reported data, objects can have the ability to make decisions, automating processes that usually require human interaction [1].

Smart cities use IoT devices such as connected sensors and meters to collect and analyze data, in order to improve the quality of life of citizens and to impact on economic, social and environmental aspects. Meanwhile, a smart campus are small-size examples of smart cities and are focused on schools, universities, government entities an other building or group of buildings. Parkings are a critical part of a smart campus. Although, car parking technological approaches have been addressed in the literature [2], [3], [4], [5], bike parkings remains less studied.

This paper presents Parkurbike: an IoT-based system for bike parking occupation checking. This approach involves the deployment of sensors on bike rack slots that continuously monitors the slot's availability/occupation. The sensed data is uploaded to an IoT repository in the cloud through a gateway. A web application is used to present the bike rack slots utilization. The analysis of historical data allows to determine how a bike parking is used in order to fix opening hours or to plan bike parking expansion.

This paper is organized as follows. Section 2 presents previous works about smart bike systems. Parkurbike's architecture and implementation are presented in section 3 and 4, respectively. Section 5 presents the conclusion and futures works.

II. Smart bike systems

Technological approaches to bike systems include: algorithms, information systems and Bike Sharing Systems (BSS).

Huang, Y. *et. al* [6] propose a control algorithm for an IoT-based bicycle parking system. The control algorithm allows parking a bicycle in electrified locksets. The system sends notifications to users' mobile phones when the bicycle arrives or leaves the system. The algorithm has been deployed in the bike parkings of the school of electronics and information engineering, located in China. An algorithm to predict waiting times for shared bicycles and parking slots was proposed in [7]. While an algorithm to predict stations status of the BSS in Barcelona was presented in [8].

A mechanism to detect in real time fallen down bicycles in an automatic underground parking is proposed by Takeda, F. [9]. The implemented mechanism consists of a network of cameras for monitoring the sites of parking. Cameras capture different images and processes them to detect fallen bikes. Cameras incorporate also an optical flow method to motion detection to tackle the problems of brightness fluctuations [9]. In another study, an information system to improve the existent mechanisms for managing bike systems is described in [10]. This system presents the location of the bicycle rental sites, the numbers of available bikes and the available parking spots. This information system was implemented in Google Maps .

Regarding the BSS systems, in China a module was designed to track the bikes belonging to a public BSS. This module allows the monitoringo of each bicycle of the public system. The location of the bike is sent by using a mobile 3G network. The location is received by the network operators and also by government entities who take in charge anomalous actions, thus reducing the bike theft levels. As a value-added service for users, the system publishes on Internet the information related to the state of congestion in bike station

[11]. In other BSS work, Razzaque and Clark [12] presents a framework for a next generation IoT integrated BSS to offer real and non-real time services by analyzing the users information, and the trends of bike usage. Furthermore, the study mentions bike stations and bike parking availability check as a main important feature to manage the BSS. Security has also been taken into account in [13]. In that study, authors propose a secure BSS for multi-modal journey environment using a symmetric key encryption and digital signature. Consequently, IoT-based will inevitably be an aspect that enables BSS.

In other works related to smart bike systems [14], the authors present a collaborative sensing monitoring system for urban air quality installed on public bicycles. The lessons from developing public bicycle system in Hangzhou are described in [15].

This paper proposes a new approach to manage the bike parking availability (occupation) through IoT technologies. On the contrary of the studies mentioned above, this system is focused on personal bicycles. Its purpose is to provide a value-added services to bicycle users. This system has a low maintenace cost since it does not involve mechanic locks or sensors activated by contact.

III. System Architecture

Parkurbike is a smart bike parking system that uses IoT technologies to capture, send/submit, store, processing and publish information related to the presence (or absence) of bikes in a given parking slot. Parkurbike's system architecture is inspired on the Gartner IoT architecture [16]. The system architecture consists of four layers: IoT Endpoints, IoT Edge Platform, IoT Platform Repository and application.

A. IoT Endpoints

An IoT Endpoint detects the occupation(or availability) of a bike rack slot. IoT Endpoints are devices that continuously monitor the presence of a bike. If a bike rack slot changes from occupied to available (or viceversa), the IoT Endpoint associated with the bike rack slot reports that change. These devices can be based on pressure, ultrasonic and capacitance sensors.

B. IoT Edge Platform

An IoT Edge Platform acts as a gateway between the IoT Endpoints and the IoT Edge Platform. An IoT Edge Platform collects, aggregates and processes the data sent by the IoT Endpoints in order to save it into the IoT Edge Platform. For this reason, and IoT Edge Platforms typically implements protocol and format translation functions. Specifically, in Parkurbike IoT Edge Platforms aggregate the data related to the availability of bike rack slots. Since it represents a single point of failure, IoT Edge Platforms have a more performance hardware than IoT Endpoints.

C. IoT Platform Repository

The IoT Platform Repository clearly defines methods of communications by implementing a multi-protocol API that supports the most common protocols for IoT, like MQTT and HTTP. An IoT Platform Repository stores the data sent by the IoT Edge Platforms. Data may be provided automatically to(or consumed regularly by) applications. Specifically, in Parkurbike the IoT Platform Repository centralizes the timestamped-data of all the IoT Endpoints. Generally it is deployed in a cloud in order to assure the highest resiliency.

D. Application

Applications consume the data stored into the IoT Platform Repository in order to provide value-added services. Specifically, in Parkurbike a web application presents the availability of bike rack slots and statistics related to the bike parking usage.

IV. Implementation

The current implementation of Parkurbike involves a sensing system, a gateway, an IoT platform repository and a web application (Fig. 1).

A. Sensing system

The sensing system consists of presence modules (IoT Endpoints) installed in each bike rack slot and attached in a bus network topology. Therefore, presence modules are linked to each other through a serial connection (Fig. 2). A collecting node, located in the gateway, is used to aggregate the data reported by the presence modules attached to the bus.

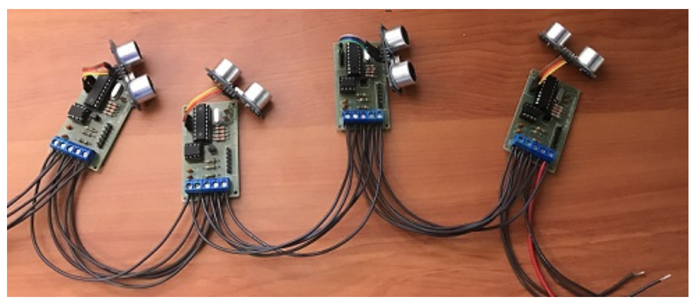

Figure 2: Bus with presence sensors.

An ultrasonic sensor connected to a serial communications card was used as a presence module. The bike rack slot occupation is detected by the ultrasonic sensor. The serial communication card is composed of a slave multiplexer which has a unique identification code for each slot. Therefore, every time that a bike arrives or leaves a given slot, the presence module sends an event to collecting node by using the serial communications card. The presence module incorporates also an alarm system that activates a noisy speaker when a user tries to occupy a bike rack slot with a different element other than a bike or tries to interpose physical elements to simulate that the slot is occupied. The alarm is triggered when the slot status is undefined. A slot may have three different status:

- Occupied: a slot is considered occupied if the distance between the bike and the presence module is between 10 to 18 cm.

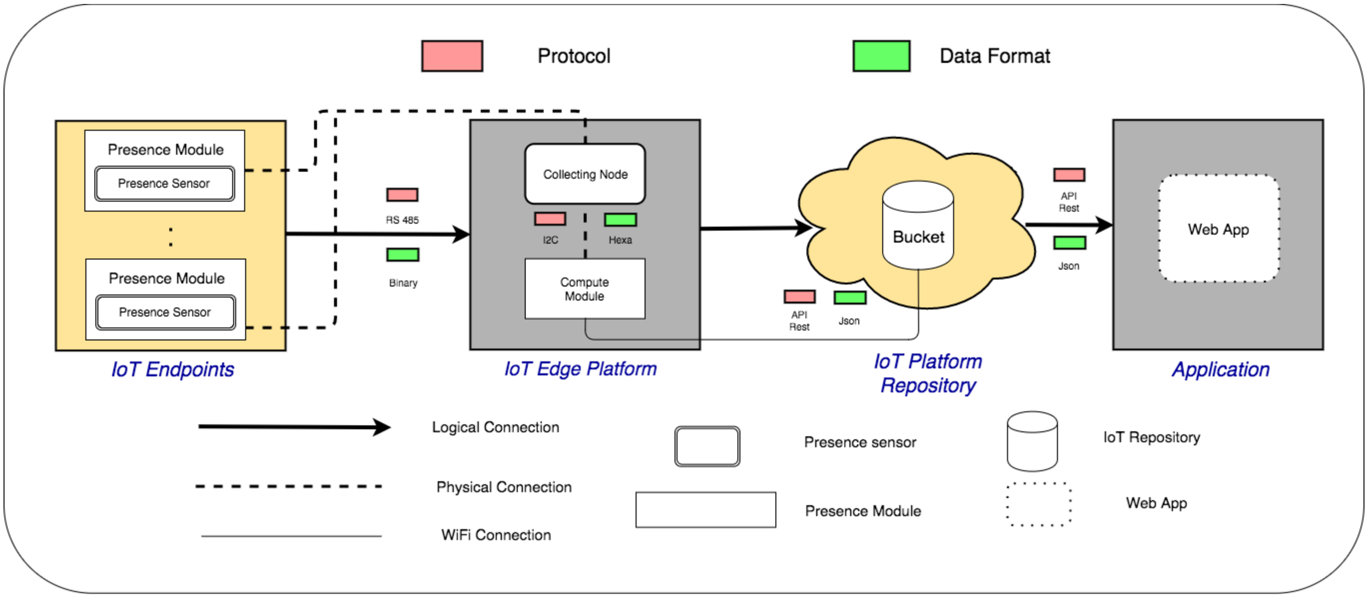

Figure 1: Parkurbike's block diagram.

- Available: a slot is considered available if there is no any bike detection. In other words, the presence module does not detect any object in a range of 18 to 40 cm.
- Undefined: a slot is considered with an undefined status when the presence module detects an object within a distance of 10 cm or less.

The distance used to determine the status of a given slot were obtained by testing several times the presence module in a real bike rack slot. They may be set up in order to be adapted to other bike parking slots. Once an object is detected, the presence module triggers a timer before reporting the change of status. If the object is retired before the timer expires, the timer is restarted. This is done in order to avoid that temporary detected objects trigger a change of status. Once the timer expires a change of status in the slot is produced, this change is reported to a collecting node.

B. Gateway

The gateway acts as a intermediary between the sensing system and Bucket (an IoT Platform Repository). For this, it isolates local communications carried out in the sensing system and provides long-range communications to reach the IoT Platform Repository. The gateway consists of:

- one or many collecting nodes and
- a compute module.

As described above, a collecting node aggregates the changes of status reported by the presence modules that are attached to the same bus of the collecting node. The presence modules are located at a distance of 10 to 20 meters of the collecting node. Due to these distance values, the RS-485 Communication Protocol was chosen to report changes of status of bike rack slots. Other advantages of this protocol are: a maximum data transmission speed of 10 Mbps, a good noise immunity and the connection of up to 256 transceivers. This protocol has a master-slave architecture that allows to connect one master and several slaves. For this implementation, the master and the slaves correspond to the collecting node and the presence modules, respectively. Both master and slaves were implemented using PICs and configured with C programming language.

The collecting nodes are also connected to a compute module. The I2C communication protocol was chosen to communicate the collecting nodes and the compute module, since, this protocol works with synchronous communication functional for short distances. Other reasons behind this choice are that I2C: guarantees that data sent is received by the slave device, supports multi-master and multi-slave communication and requires only two wires to establish communication among multiple devices.

The compute module processes the data sent by the collecting nodes. Once the data is received from the collecting node, it is sent to the IoT Platform Repository through the compute module. For this implementation, the Intel Edison development card was chosen as the compute module. This development card allows to send data through Wi-Fi or Ethernet networks.

C. Bucket

Bucket[17] is an IoT Platform Repository that provides a set of REST (Representational state transfer) services that allow sending the capture data of a sensor id and the value read by the device[18]. A sample request body is shown bellow:

{
"sensorId":"58e66b50d107ae3c6a91bb94",
"captureTypeName":"Busy",
"value":"1",

"captureDate": "2017-04-06 16:29:00"
}

The capture data is saved by Bucket using a data base management system, and is set up in the following way (Fig.3):

- Solution holds a set of devices.
- Device holds a set of sensors.
- Sensor holds a set of captures.

Bucket includes an administrative tool for creating the hierarchy that contains the captures. In addition, it allows to configure alerts that will be triggered when the capture values are equal to a given number. These alerts are configured to trigger a POST request to the Parkurbike web application notifying a slot status change. In Bucket there is a virtual representation of every presence module and gateway. Thus, Bucket enables the storage of historical slots status.

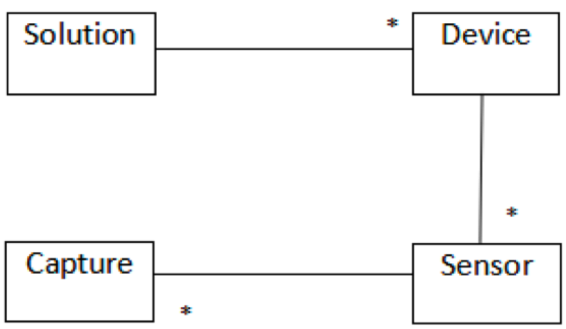

Figure 3: Bucket data representation.

D. Parkurbike web application

Nowadays, the Parkurbike web application allows bike users (or anyone interested) to consult online the availability of bike rack slots (Fig. 4). The web application includes the adaptation of different device resolutions by means of bootstrap mechanism (Fig. 5). Futures features of Parkurbike web application are the generation of reports with statistics of bike rack usage (*e.g. usage history, days and hours of highest number of bikes*). This information can be used as an input to plan ahead the installation of new bike racks or the bike parking opening.

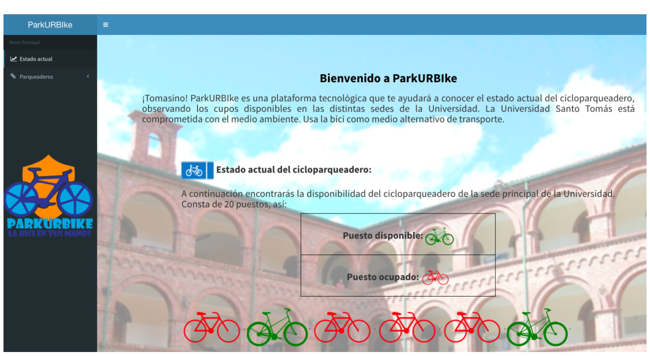

Figure 4: Web Application. Availability of bike parking.

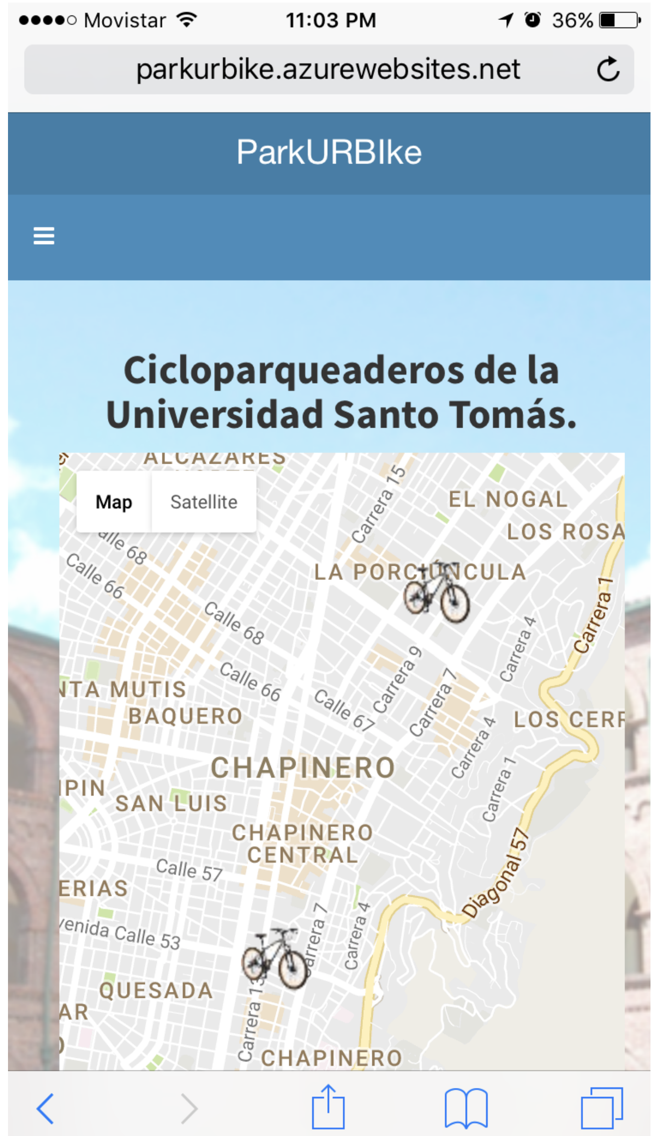

Figure 5: Parkurbike Smartphone view.

V. Conclusion

IoT enables the deployment of smart bike systems. By using capacitance, pressure or ultrasonic sensors, it is possible to determine the precise utilization of bike rack slots. Parkurbike is an entire IoT-based solution to automatically check bike parking availability. This solution consist of four main parts: a sensing system, a gateway, an IoT Repository Platform and a web application. The historical data produced by presence sensors and stored in the IoT Repository Platform allows to model bike parking users behavior.

Future works will be oriented to study the power consumption of the sensing system.

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REFERENCES

[1] Charith Perera, Chi Harold Liu, Srimal Jayawardena, and Min Chen. A survey on internet of things from industrial market perspective. *IEEE Access*, 2:1660–1679, 2014.

[2] Vaibhav Hans, Parminder Singh Sethi, and Jatin Kinra. An approach to iot based car parking and reservation system on cloud. In *Green Computing and Internet of Things (ICGCIoT), 2015 International Conference on*, pages 352–354. IEEE, 2015.

[3] Suraj Choudhari, Tejas Rasal, Shubham Suryawanshi, and Mayur Mane. Intelligent car parking system. *International Journal of Engineering Science*, 3481, 2016.

[4] Muftah Fraifer and Mikael Fernström. Smart car parking system prototype utilizing cctv nodes: A proof of concept prototype of a novel approach towards iot-concept based smart parking. In *Internet of Things (WF-IoT), 2016 IEEE 3rd World Forum on*, pages 649–654. IEEE, 2016.

[5] Abhirup Khanna and Rishi Anand. Iot based smart parking system. In *Internet of Things and Applications (IOTA), International Conference on*, pages 266–270. IEEE, 2016.

[6] Yujia Huang, Zhongliang Yang, and Shuhua Xiong. The research on the control algorithm of iot based bicycle parking system. In *Cloud Computing and Intelligent Systems (CCIS), 2012 IEEE 2nd International Conference on*, volume 3, pages 1221–1225. IEEE, 2012.

[7] Bei Chen, Fabio Pinelli, Mathieu Sinn, Adi Botea, and Francesco Calabrese. Uncertainty in urban mobility: Predicting waiting times for shared bicycles and parking lots. In *Intelligent Transportation Systems-(ITSC), 2013 16th International IEEE Conference on*, pages 53–58. IEEE, 2013.

[8] Gabriel Martins Dias, Boris Bellalta, and Simon Oechsner. Predicting occupancy trends in barcelona's bicycle service stations using open data. In *SAI Intelligent Systems Conference (IntelliSys), 2015*, pages 439–445. IEEE, 2015.

[9] Fumiaki Takeda. Automatic detection system of the fallen down for the parked bicycle in the underground parking garage using optical flow method. In *Control Conference (ASCC), 2015 10th Asian*, pages 1–5. IEEE, 2015.

[10] Rongliang Luo and Yunru Shen. The design and implementation of public bike information system based on google maps. In *Environmental Science and Information Application Technology, 2009. ESIAT 2009. International Conference on*, volume 2, pages 156–159. IEEE, 2009.

[11] Kai-way Chun, Zih-Hong Chen, and Chi-Chia Sun. Iot solution for public bicycle system. In *Consumer Electronics-Taiwan (ICCE-TW), 2016 IEEE International Conference on*, pages 1–2. IEEE, 2016.

[12] MA Razzaque and Siobhan Clarke. Smart management of next generation bike sharing systems using internet of things. In *Smart Cities Conference (ISC2), 2015 IEEE First International*, pages 1–8. IEEE, 2015.

[13] Mohammad Shahriar Rahman and Shinsaku Kiyomoto. Secure bike sharing system for multi-modal journey. In *Big Data and Cloud Computing (BDCloud), Social Computing and Networking (SocialCom), Sustainable Computing and Communications (SustainCom)(BDCloud-SocialCom-SustainCom), 2016 IEEE International Conferences on*, pages 437–444. IEEE, 2016.

[14] Xiaofeng Liu, Chaosheng Xiang, Bin Li, and Aimin Jiang. Collaborative bicycle sensing for air pollution on roadway. In *Ubiquitous Intelligence and Computing and 2015 IEEE 12th Intl Conf on Autonomic and Trusted Computing and 2015 IEEE 15th Intl Conf on Scalable Computing and Communications and Its Associated Workshops (UIC-ATC-ScalCom), 2015 IEEE 12th Intl Conf on*, pages 316–319. IEEE, 2015.

[15] Li Kang and Chen Biao. Lessons from developing public bicycle system in hangzhou. In *Remote Sensing, Environment and Transportation Engineering (RSETE), 2012 2nd International Conference on*, pages 1–4. IEEE, 2012.

[16] Gartner. Inc. End to end iot business solution, 2016.

[17] CEA-IoT USTA. Bucket. urlhttps://bucket.usantotomas.edu.co, 2017. Accessed 11-May-2017.

[18] Roy Thomas Fielding. Architectural styles and the design of network based software architectures. USTA, 2000.