Design of an Innovative Campus Remote Seat Booking System for Smart Learning Environment

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***Abstract*—This paper presents a project-based research study that tackles a real-world problem at the University of Nottingham Ningbo China. The project was performed by recruiting student interns from two different campuses. The project investigated how a remote seat booking system could be designed and used in the library or other study rooms across the campus. A wireless sensor network was created using Zigbee wireless standards. A prototype was implemented using a pressure sensor integrated into the CC2530-based wireless sensor node. A WeChat mini program was designed as a front-end for a student user to search and book the available seat. The proposed prototype in this paper aims at cost reduction and flexibility enhancement. The study recommends that a comprehensive system based on the proposed prototype could be part of the campus digital transformation in the future.**

Keywords*—*smart learning environment, campus management system, wireless sensor networks, internet of things, digital transformation.

I. INTRODUCTION

Project-based learning plays an essential role in the engineering education process. It helps engineering students to develop many skills required for their future careers, including critical thinking, teamworking, cognitive, and leadership on the one hand [1, 2]. On the other hand, project-based learning helps undergraduate engineering students better understand and practice the research process [3]. At the University of Nottingham Ningbo China (UNNC), where this project was developed, some innovative pedagogical learning approaches were introduced to cope with the recent engineering education disruption and improve the student experience [4]. Additionally, it is believed that student engagement in projects that solves real-world problems can assist in developing a wide range of future graduates with the academic and professional skills required for success in their prospective postgraduate study and future career [5].

This paper proposes an innovative smart learning environment solution to manage seat booking on campus. The proposed solution is an outcome of project-based extra-curriculum research that can be deployed in common study rooms or the library. In UNNC, during the final exam period, most students review their lessons in common study rooms, and due to the high demand, congestion happens in study areas. It was noticed that some students struggle to find a seat quickly. It was also noticed that other students maintained the seat in common study areas occupied even when they didn't use them or after they left. This was the motivation to design the proposed intelligent seat management system. The project is an application of an IoT smart campus that can be integrated into the campus digital transformation plan [6-8]. The paper proposes a prototype that includes designing and implementing a wireless sensor network for the actual university site. A user-friendly front-end user interface App was also designed to be integrated into the hardware prototype. The rest of this paper is structured as follows: Section 2 gives an architectural overview of the proposed campus seat management system. While the wireless sensor node design is explained in section 3, section 4 offers the front-end user interface design. The results and calculations are described in section 5, and section 6 concludes.

II. SEAT MANAGEMENT SYSTEM ARCHITECTURE OVERVIEW

The general overview of the proposed system is shown in Fig. 1. It represents a smart campus Internet of Things (IoT) application consisting of a wireless sensor network for seat availability monitoring and management at one end. The wireless sensor network consists of the wireless nodes connected to a network coordinator in each study room. A front-end user interface is an App running on a smartphone or tablet connected to the Internet. A protocol integrated controller is used to connect wireless networks of different protocols. Cost reduction and flexibility were considered for this proposed architecture. The system allows students to remotely monitor and book available seats in common study areas using their smartphones. Additionally, the proposed system can reduce multi-seat booking when a student reserves a seat and leave, especially during the high-demand season of final exams.

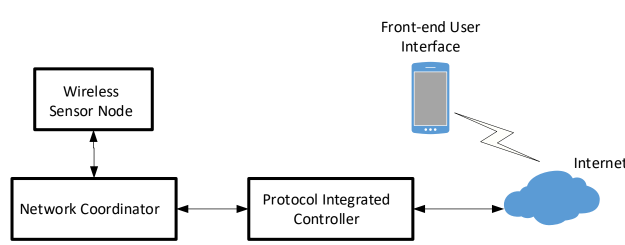

Fig. 1. Remote seat booking system architecture.

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III. WIRELESS SENSOR NETWORK

The wireless sensor node of the proposed system is based on Zigbee technology for many of its beneficial features for this project. Some of which include bidirectional wireless communication of low data rate, low cost, and low power consumption, which results in less node and battery maintenance [9]. Each available seat in the common study area is equipped with a sensor node. The node includes a Zigbee module and a sensor to detect the seat availability at the actual site. Sensor nodes in one study room are connected to a coordinator. As shown in Fig 2, the coordinator is connected to a gateway that simultaneously facilitates the interoperability of the Zigbee wireless sensor network to the Internet [10]. This will help end-users connect to the network remotely with any device connected to the Internet, such as from the student dorm, and not necessarily log in to the campus WiFi. Since Zigbee can use an ad-hoc network, the connection with the coordinator can always be restored in case of any node being disconnected, which enables a high level of flexibility.

A. *Wireless Node Controller*

The Zigbee wireless sensor node controller is realized using Texas Instrument CC2530 chip [11]. This true System-on-Chip (SoC) that implements the IEEE 802.15.4 protocol (Z-Stack) has been extensively used in home automation and Industrial Internet of Things IIoT [12]. The controller has an 8051-based processor, program, and data memories with an RF transceiver. It could cover an actual range of more than 100 meters and supports different modes of operation, which makes it an excellent choice for extra power-saving and battery maintenance reduction. Running in the interrupt node, the CC2530 chip can sense the event occurrence, wake up, handle the event, and go back into a sleep mode, maximizing efficiency and minimizing power consumption. If the node works as a coordinator, not as controlling the seat sensor, it will be included in the network layer management [13].

B. *Seat Sensor*

The proposed prototype uses a car seat sensor in this paper, as shown in Fig. 3 [14]. The hip range is considered for the pressure sensor used to distinguish between a student sitting on the seat, from another object used to reserve the seat, such as a book, laptop, bag… etc. The hip width range is assumed to be between 31 and 40.5 cm. This range is considered the minimum allowable distance between neighboring pressure sensors to ensure all sensors can be activated for different body types [15].

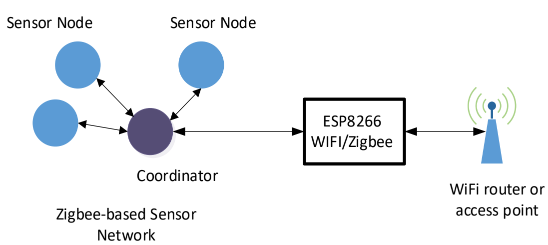

Fig. 2. CC2530-based Wireless Sensor Network

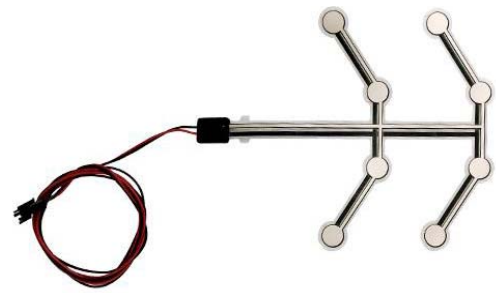

Fig. 3. Seat pressure sensor [16].

In the proposed prototype, the sensor has been installed in the core position of a flat seat cushion to make the sensing point feel pressure from above the seat. The triggering weight is around 30 Kg. Additionally, the shape and size of the pressure sensor used are consistent with the seat cushion. This kept the human in a sitting position that didn't interfere with their detection.

C. *Gateway Controller*

ESP8266 module was used in this prototype to facilitate the interoperability between the Zigbee wireless sensor network and the Internet. This module implements the 802.11 b/g/n standards with integrated TCP/IP protocol. Working in the 2.4 GHz band, it is considered a highly-integrated solution for numerous IoT applications and supports Bluetooth standards. The module is designed to achieve minimum power consumption, making it suitable for the proposed project to reduce battery maintenance. Only when specific conditions are detected can this module wake up periodically.

The trade-off between the power consumption and other factors like communication range and data rate can also be optimized by adjusting the power amplifier output [16]. The gateway layer provides an interface between the wireless sensor network and the application layer.

IV. FRONT-END USER INTERFACE

A user-friendly interface is required at the front-end side to display the seat availability in the common self-study rooms and valuable user information such as the latest booking and notifications. One option for this user interface is to make it web-based [17]. Another option is to develop an App that can run on the users' smartphones [18, 19]. We prefer the second option in this proposed prototype since smartphones are already connected to the Internet, increasing flexibility. In this way, students can monitor and book the available seat from anywhere as long as they can download, install and run the App on their smartphones. Fig. 4 shows the software architectural design diagram required for this project.

The gateway is considered the control hub of the seat management system. The gateway acts as a client for the cloud server. It is responsible for the communication between the internal and the external networks on the one hand. On the other hand, the gateway receives information from all the sensor nodes. It processes them via another control terminal that could be a PC running another Graphical User Interface (GUI) to monitor and control the seat management system. The smartphone is used as a control terminal that will use a remote communication link to the cloud server, the seat management system gateway, and the seat sensor node [20].

In this paper, we focus more on the front-end user interface rather than the gateway interface. Since this project aims to reduce the cost and increase flexibility, the WeChat platform is used as the application interface for its various advantages for both developers and users, which were found suitable for this design. One of the advantages is that this project is proposed for a campus in China, and the popularity of the software platform plays an essential role in enhancing flexibility. WeChat is quickly becoming a vital part of Chinese people's daily lives, as the most prominent social networking app capable of cloud payment and numerous user functions. WeChat supports the mini-program feature (mini App) released in 2017 as a brand-new applet feature added to the existing system and has already developed more than 0.3 billion active users out of the total 1.151 billion for WeChat in 2019 [21].

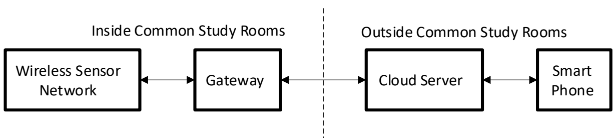

Fig. 4. Software architecture

V. Calculations and Results

A. Power Consumption Estimation

The power estimation for the CC2530-based sensor node is calculated in two modes of operations. The active mode is done first, and then the power reduction is calculated for the sleep mode operation.

1) Active Mode

The power consumption estimation of different operations of the CC2530 chip is shown in Table 1 [11]. The normal operating current of the system is considered to be between 6.5 to 8.9 mA. The intermediate value of 7.7 mA is used for this calculation.

TABLE I. Estimated power consumption of different CC2530 operations [13]

Operation number	***Power consumption (mA*ms)***	***Operation description***
1 (OP_1)	100.5775	Polling
2 (OP_2)	388.4335	Ideal situation
3 (OP_3)	120.4175	TX
4 (OP_4)	245.669	RX

In this proposed prototype, an AA battery with a capacity of 650 mAh was used to power the sensor node. The power consumption of the CC2530 in the active mode per one day can be defined as:

$$CC_{active}=7.7mA\times1000ms\times60\times60\times24 = 665,280,000\ mAms \quad (1)$$

The frequency of the system polls the flag is assumed to be every 5 seconds and toggles the LED's light on the sensor module 12 times a day. Assuming there is no communication failure, this scenario has (60 × 60 × 24 / 5 – 12) = 17268 times of operation 1, 12 times of operation 3, and 12 times of operation 4. Therefore, the total power consumption per day can then be calculated as:

$$\begin{aligned} CC_{CHIP} &= CC_{active} + OP_1\times17268+OP_3\times12+OP_4\times12 \\ &=665,280,000+100.577517268+120.4175\times12+245.669\times12 \\ &=185.3mAh \quad (2) \end{aligned}$$

Therefore, the battery life = 650 ÷ 185.3 = 3.51 days (3)

2) Sleep Mode

The normal operating current of the system is considered to be 1 μA [13]. For one AA battery with a capacity of 650 mAh, the current consumption in the sleep mode per day is given by:

$$CC_{SLEEP} =0.001\ mA\times1000ms\times60\times60\times24=86400\ mAms \quad (4)$$

To compare the power consumption, the same condition as the active mode was adopted. The frequency of system polls the flag was assumed to happen every 5 seconds and toggles the light 12 times a day. Assuming there is no communication failure, this scenario has (60×60×24/5 – 12) = 17268 times of Operation1, 12 times of Operation3, and 12 times of Operation4. Therefore, the total power consumption per day can be calculated as:

$$\begin{aligned} CC_{CHIP} &= CC_{SLEEP} + OP_1\times17268+OP_3\times12+OP_4\times12 \\ &=86400+100.5775\times17268+120.4175\times12+245.669\times12 \\ &=1,827,565.308\ mAms \\ &=0.5077mAh \quad (5) \end{aligned}$$

Therefore, the battery life = 650 ÷ 0.5077 = 1280.3 days

= 3.5 years (6)

B. WeChat Mini App

WeChat mini App "*Find your Seat*" has been designed to provide the user interface for the proposed seat booking system. This mini App can implement some functions, including user login, seat booking, and booking cancelation. Users can make a reservation after logging in to their accounts by entering their username (student ID) and password. On a "*Library*" page, the availability of seats will be shown in different colors in a user-friendly design to help them distinguish the chosen seat quickly and easily. Red indicates a specific seat has been occupied, while white means the seat is available. Users can choose a vacant seat by clicking it; then, the appearance will turn green. After clicking the "confirm selection" button, the information will be stored. Fig. 5 shows the interface of seat selection and reservation.

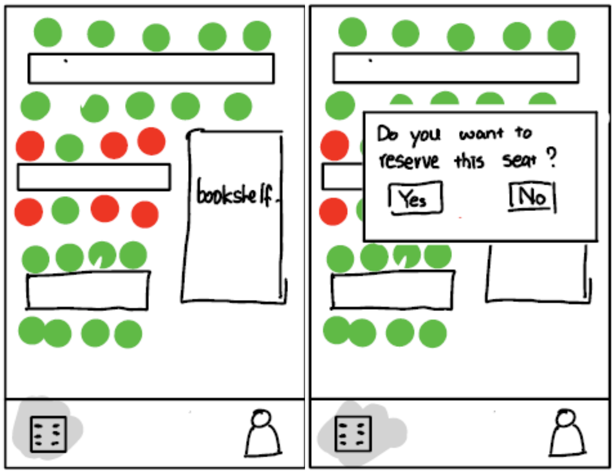

Fig. 5. WeChat mini App interface design.

VI. Conclusion

In this paper, an innovative smart learning management solution has been proposed. The IoT campus solution was developed to solve the real-world seat booking problem in common study rooms. A wireless sensor network prototype based on Zigbee standards was designed and implemented. A WeChat mini App was proposed as a student user interface. The proposed prototype has shown a notable cost reduction and flexibility enhancement at both the hardware and software levels and battery maintenance reduction at the hardware level. An extended project from this prototype can be deployed across the campus and be considered as one of the elements of the campus digital transformation in the future.

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