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A Smart Meeting Room Scheduling and Management System with Utilization Control and Ad-hoc Support Based on Real-Time Occupancy Detection

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Abstract - At In most meeting room scheduling or management system, the availability of meeting rooms are mainly based on pre-determined schedules. However, since the meeting duration is not always exact as it is scheduled, there are some situations that a meeting room is underutilized. Therefore, in this paper, we present a smart meeting room scheduling and management system which detect occupancy status of meeting rooms in real- time and integrate this information into the scheduling application to support ad-hoc meetings and increase room utilization. Our system is a simple, ease-of-implementation solution based on PIR sensor fusion devices and Ethernet connectivity. Occupancy data is sent to a central application server by UDP over IP protocols. On this server, a web application is developed and hosted to not only allow people book rooms for their meetings, but also check the utilization of these rooms based on predefined policies. The system also supports ad- hoc meetings by providing real-time availability of meeting rooms to users.

***Key Words*:** meeting scheduling; room management; real-time occupancy detection; utilization control; ad-hoc meetings

1. INTRODUCTION

Meetings are indispensable events in every organization where people can simply share knowledge and information or discuss for important decisions. To facilitate those activities, most of researches concentrate on improving scheduling software to help participant's select optimal meeting time [1] [2] or building smart meeting rooms where audio–visual content are automatically recorded for future viewing [3] [4] [5]. There are very limited number of systems that can manage meeting rooms in term of real-time availability and utilization. This study is aimed to target this area and address existing issues.

First of all, since a meeting room can only be reserved for a meeting appointment at a time, there are some circumstances that those resources are underutilized [6]. For example, a meeting may be over before scheduled time or even not happen at all but still reserves a room in scheduling software and prevent others from using. In addition, conventional meeting scheduling/booking software cannot support ad-hoc/ drop-in meetings because the real-time availability of meeting rooms are unavailable. For this type of meetings, people may take a lot of time to find an unoccupied room to use, especially when these rooms are located in different buildings. To resolve these problems above, in this paper, we propose a smart meeting room management and scheduling system with real-time occupancy detection to support ad-hoc meetings and maximize utilization.

Most related work is presented in [6]. However, this system has many limitations:

- The occupancy detection module must use both PIR sensor and microphone to detect attendee presence
- The setup is too costly and complex to implement. In each building, wireless sensors are connected as a mesh network with many coordinator and gateway devices before connecting to a PC. Then this PC must process raw data and send them to a central application server through local area network (LAN).
- The occupancy status is not integrated into the booking/ scheduling application, which is simply Microsoft Outlook software in this project. As a result, the system cannot support ad-hoc meetings. Furthermore, the system is mainly based on manual actions to resolve underutilization. If a scheduled meeting does not take place, the organizer is alerted with an SMS and he/ she must manually cancel the reservation in the Outlook to free the room for other meeting requests.

Another related system is described in [7]. However, in this system, occupancy information is used in HVAC systems to control energy consumption rather than for meeting purposes. Furthermore, this system is also based on wireless sensor devices which require many local base stations to transmit data and bring up concerns relating to radio signal interference.

Our system is an integrated and ease-of-implementation solution. We use PIR sensor fusion devices for occupancy detection instead of single PIR sensors to get desirable detection range with cost efficiency. Especially, these PIR devices could be simply mounted on the ceiling of meeting rooms without large-scale modifications in existing buildings. Moreover, in our system, we use embedded modules to connect the PIR sensor devices directly to LAN through existing Ethernet cable rather than through a complex wireless network. Occupancy data is transmitted to a central application server by UDP over IP protocols. On that central server, the real-time occupancy data in integrated into a meeting scheduling application to control utilization. The system also supports ad-hoc meetings by providing real-time availability of meeting rooms to users.

2. OCCUPANCY DETECTION

Fig. To realize the occupancy in real-time, many methods have been proposed. In a smart meeting room system, called Easy Meeting, researchers at the University of Maryland detect human presence through Bluetooth-enabled devices [5]. Each participant must have or be given a mobile device and asked to active the Bluetooth connection when arrives. Although this solution is appropriate to manage all participants, it is not realistic. If the system provides all Bluetooth devices for meeting participants, then the cost of this can become very expensive for a large number of participants. Otherwise, it is very inconvenient that attendees must bring a mobile device and activate Bluetooth connection before attending the meeting.

Most advanced systems use cameras and image processing techniques [8] [9] [10] [11] to detect human presence. However, this method has many drawbacks in concern of cost, deployment and privacy. Some other systems use ultrasonic sensors [12], however it is not a suitable solution for in-room presence detection. Ultrasonic sensor can only detect the human presence when people block the ultrasonic transmission line. Thus, each ultrasonic sensor module includes a transmitter and a receiver and in order to apply for a wide area, multiple sensor modules must be used together, which results in high cost and complex installation. A CO2-based solution was also examined [13] but it requires long processing time.

The most applicable solution for in-room occupancy detection is passive infrared sensor (PIR). PIR devices detect human presence by sensing the change in infrared heat radiation emitted from the human body. Detection system based on PIR sensors is very popular as being low cost, low power consumption and ease of installation [14] [15] [16]

[17] [18] . However, using merely a PIR sensor component is not effective as its detection range is very short. Most of the system above use multiple PIR sensors to enlarge sensing region. In our system, we use PIR fusion modules to resolve the issue. Each module is the combination of three or four PIR sensors. Because our main objective is not building a sensor fusion system, we choose to use off-the-shelf SLSCPS1000 PIR product from Schneider Electric. Its detection range is a cone whose height is about 2.7 m and base diameter is nearly

9.7 m (Figure 1)

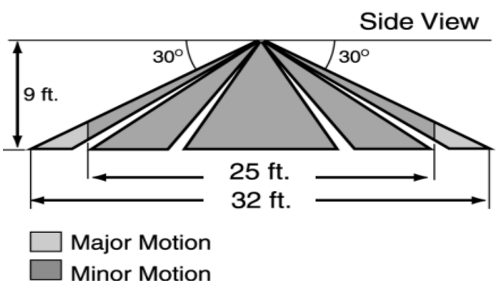

Figure 1: Occupancy detection range [19]

3. COMMUNICATION LINK

A. System overview

This system is a combination of both software and hardware components (Figure 2). In each meeting room, there will be a PIR sensor device mounted on the ceiling and an embedded module connected to Ethernet cable. The PIR sensor module is used to detect human presence in the room or in other words, whether people are using this room or not. Then, the signal from sensors will be connected to the embedded module, which contains a microprocessor with Ethernet connectivity. Those embedded modules will send the occupancy status over local area network to a local server via UDP protocols.

On this local server, a scheduling and management web application is developed and hosted to manage the whole system. Meeting organizers can use this application to book rooms for their meetings. However, unlike conventional meeting scheduling software, this application also manage real- time availability and utilization of these meeting rooms. To elaborate, based on the meeting schedule and real-time occupancy, whenever the application detects an underutilization case, it will automatically send out notification emails to meeting bookers and then may remove the corresponding room reservation from the system if the underutilization is not resolved. There are some circumstances that a meeting room may be underutilized since the duration that it is occupied is sometimes not exact as it is booked. For instance, a meeting may take place shorter than expected and still reserves a room in the scheduling system when it is over. The detailed policies in which how an underutilization is defined and how the system react is discussed in section D.

Together with utilization control, the system also supports ad-hoc meetings. The real-time occupancy status of meeting rooms is made available to users via the scheduling application. Therefore, via this application, people can easily find out an available room to drop in and occupy for their prompt meetings.

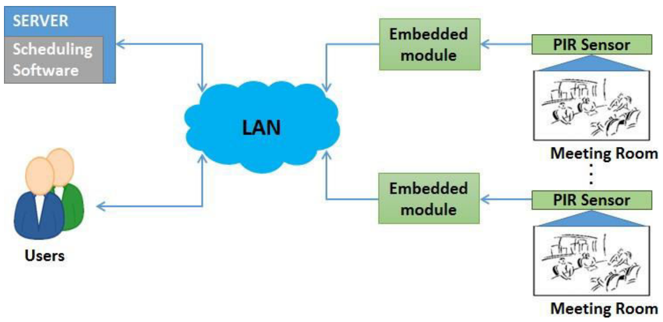

Figure 2: System overview

B. Sensor installation

In each meeting room, the PIR sensor fusion device is mounted on the ceiling at an effective height of about 2.7 m as in Figure 3. As mentioned early, it can cover a room with up to nearly 10 m in diameter, which is suitable for most of normal- sized meeting rooms.

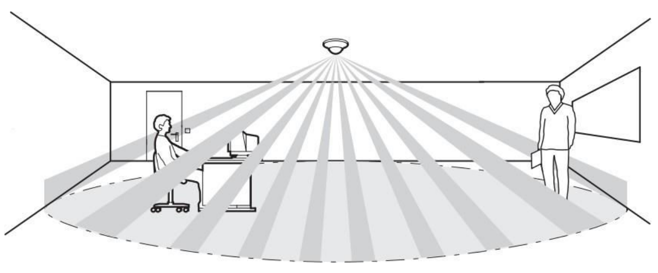

Figure 3: Sensor installation (adapted from [20])

C. Data transmission over Ethernet

A room management system must be real-time data acquisition and processing system. Among customary approaches, a solution based on embedded devices is the most suitable due to its low cost, reliability and ease of installation. Therefore, embedded programming modules are used in our system as the data acquisition and processing unit. In detail, STM32F107VC microcontrollers are used to process signals from PIR devices and send the room status to scheduling application through local area network.

Generally, in meeting rooms, Ethernet cables are usually available for network connection. Therefore, instead of developing a complex wireless system, which usually suffer from complexity and cost, we install the PIR modules on the ceiling of rooms and then connect them directly to local area network through existing Ethernet ports.

In detail, to transmit data on the Ethernet link, we use DP83848C PHY (Figure 4) and open-source LWIP TCP/IP stack. LWIP provides all necessary functions and APIs for TCP/IP protocols, such as IP, ICMP, UDP, TCP, IGMP, ARP and can run independently without operating system. In our system, we use UDP over IP to transmit occupancy status to the scheduling server. All of the microcontrollers are UDP clients while the server with scheduling software is a UDP server.

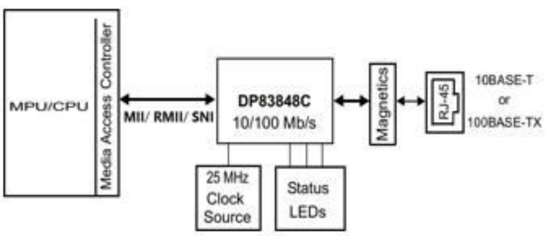

Figure 4: Ethernet connection [21]

Generally, in the transportation layer, there are two types of protocols: TCP and UDP. Both of them can carry data from programs to programs which are identified within hosts by port numbers (end-to-end transport protocols) [22]. However, compared to TCP, UDP protocol is more suitable for this project. UDP is simply an extension of the best-effort datagram service [22]. By using UDP, the microcontroller can send data to the scheduling server without prior communication to set up data paths. In addition, in terms of message size, UDP message is quite small. In this project, for simplicity, occupancy status will be sent continuously from the microcontroller, thus the small size of data is required to avoid overload on network traffic. Therefore, UDP is the suitable solution for communication through Ethernet network.

In detail, the network communication is based on socket programming techniques (Figure 5). A socket is an interface which application processes can send and receive messages to/from another application process [23]. A socket enables applications to communicate with others in the same network. “Information written to the socket by an application on one machine can be read by an application on a different machine and vice versa” [22]. With UDP, sockets do not require to be connected before being used. It means that microcontrollers and the scheduling application on the local server do not have to establish a connection before sending and receiving data. In our system, all microcontrollers use dynamic IP address while the scheduling server has a static IP address. Therefore, the microcontrollers can continuously send room status to the scheduling server with predefined IP and UDP socket port.

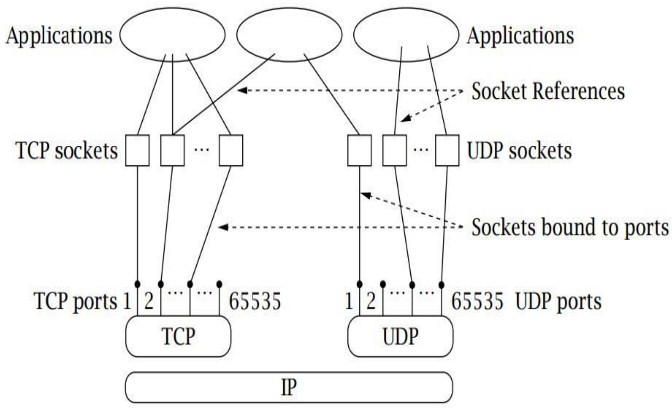

Figure 5: Network communication via UDP/TCP sockets [22]

In details of message frame, besides UDP header, we only use 16 bits to encode room ID and status. The detailed data frame is given in Figure 6. In the application data field, both Room ID and Room status are one byte ASCII encoded. Room ID is one character from “A” to “Z”, whereas Room Status is “0” (free) or “1” (occupied). For example, if data is 0x4131 in hexadecimal or “A1” in ASCII code, it means that the status of the room A is free (no one in this room). In the scheduling software, a lookup table is built to convert room name (in ASCII code) to real room name, for instance, room “A” is This is more compressed than Binary coded decimal

Source Port (16 bits)		Destination Port (16 bits)
Length (16 bits)		Checksum (16 bits)
Room ID (8 bits)	Room Status (8 bits)	*Reserve*

Figure 6: UDP message

D. User policy

The occupancy status itself does not indicate the meeting status. An unoccupied room doesn’t mean that the meeting is canceled or ended. For example, attendees may come late and thus let the room empty for early minutes, but the meeting still happens later. Similarly, although the meeting is not ended, all people may leave the room for a break. Therefore, it is necessary to create a mechanism to link between occupancy status and meeting status. In particular, this mechanism is implemented as policies for users on how they should use a room that they reserve for their meeting. There are two policies for occupancy of booked rooms: initial occupancy and continuous occupancy

1) Initial occupancy

If people do not occupy the room in first 15 minutes of the meetings, an email will be sent to the meeting organizer to remind. If he/she wants to delay the meeting, he/she can reschedule it in the scheduling application. Otherwise, in the

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next 10 minutes, if the room is still left empty, then the meeting reservation will be canceled and removed from scheduling application. An administrative penalty may be applied.

2) Continuous occupancy

Unless the meeting organizer specifies a break time with longer duration, if the meeting room is left unoccupied in 20 minutes, a notification email will be sent to the meeting organizer. He/she may access to the scheduling application to specify that the meeting is in break time with particular duration, or he/she can remove the meeting from the scheduling application if it is already over. Otherwise, in the next 10 minutes, if the room is still unoccupied, the meeting is assumed to be ended. Then, the corresponding room will be freed for other meeting requests. Of course, another email will be sent to the meeting organizer to notify this change.

E. Scheduling application

The scheduling software is developed as a responsive web application on the local server. It can be accessed from smartphones, tablets and PCs. Like other conventional scheduling software, meeting organizers can use this application to schedule their meetings. However, as discussed above, this application also manage meeting rooms in terms of real-time availability and utilization based on the meeting schedule and real-time occupancy status from PIR sensor devices.

The scheduling application uses a database to store all meeting requests. Each booking entry has a room number, room booker, start time and end time as shown in Table I.

Table I: Database fields

Database Field	Description
Room number	▪ Number of the booking room or name of the room. ▪ Format: VARCHAR (maximum 45 characters) ▪ Example: 1.3.45 or Yarrow
Room booker	▪ Name or ID of booker ▪ Format : VARCHAR (maximum 45 characters) ▪ Example: John Smith or s3369856
Start time	▪ Start time the booking session ▪ Format: TIME (hour:minute:second) ▪ Example: 14:30:00
End time	▪ End time of the booking session ▪ Format: TIME (hour:minute:second) ▪ Example: 16:30:00

From the booking database, the scheduling application will check the occupancy status of all reserved rooms in two policies: initial occupancy and continuous occupancy, as mentioned early. The detailed algorithm is shown in Figure 7. Whenever a scheduled meeting violates these policies, this application will automatically send emails with a predefined template to meeting organizers. Further actions of the application are already declared in detail in section D.

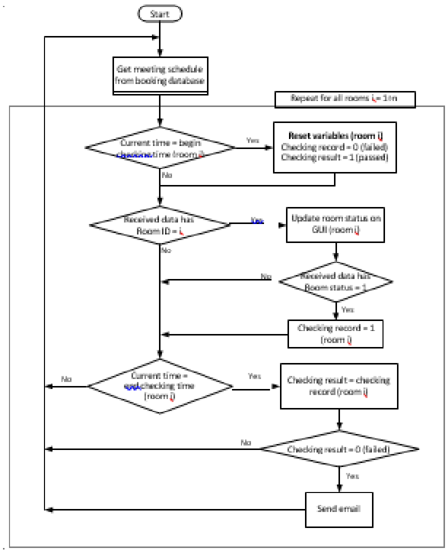

Figure 7: Software flowchart of utilization check

F. Ad-hoc meetings

Ad-hoc meetings are usually taken place with few participants when small groups drop in a room to discuss. Therefore, in our system, we reserve some small rooms only for ad-hoc meetings. The occupancy status of these rooms is checked in real-time with PIR sensor devices and shown on the meeting scheduling application. Therefore, through the web application, people can easily find out an available room for their drop-in meetings.

4. SYSTEM EVALUATION

The Several tests were carefully performed to test the system.

Those tests are described below.

1) Sensor test

Purpose: As one of the most important components, the main duty of the PIR sensor devices is to detect human presence. This test is to check the accuracy of these devices.

Test setup: In this test, the PIR sensor devices are only connected to embedded microprocessors. The microprocessors either turn on/ off LEDs to indicate whether the sensor devices detect human presence or not.

Test result: The PIR sensor fusion devices provide accurate occupancy status of the rooms. When a person walks into a room and when all people leave the room, the PIR sensor device changes the output level after a small delay time.

2) Network test

Purpose: This test is used to check the data transmission over Ethernet protocols between embedded microprocessors and scheduling application on the local server.

Test setup: the scheduling application is installed on a local server with static IP address, whereas the microprocessors use dynamic IP addresses. We connect multiple microprocessors to the local area network at the same time to continuously send occupancy data to scheduling application every minute through UDP over IP protocols.

Test result: on the scheduling application, the occupancy status was correctly extracted from received UDP packets.

3) System test

Purpose: This test is aimed to evaluate the whole system. All functions are tested together, such as, occupancy detection, meeting booking and email API.

Test setup: a whole system with both hardware (PIR sensor devices, embedded modules, local web server) and software (scheduling application).

Test result: the system work correctly as expected. All booking requests via the web application are stored in the database. Whenever a reserved room is underutilized, emails are successfully sent to bookers. For ad-hoc meeting purpose, the occupancy status of all dedicated meetings rooms is accurately displayed.

CONCLUSIONS

In this paper, we have presented the design and implementation of a smart meeting room scheduling and management system. This system does not only support room booking but also manage those rooms in terms of real-time occupancy. Therefore, it can be used to maximize utilization as well as to support ad-hoc meetings. Based on PIR sensor fusion devices, the system is cost-efficient and easy to implement. In addition, unlike other wireless sensor network based systems which often require many coordinators and gateway devices, this system is a simple solution based on Ethernet protocols.

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