BASA: Building Automation and Security on Android

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***Abstract*—Systems capable of reducing energy consumption are needed in order to reduce monetary energy costs for companies. At the same time, studies show that temperature can influence human productivity, thus simply removing Heating, ventilation and air conditioning (HVAC) systems could impact negatively a company's employees work productivity.**

Nowadays Building Automation Systems (BAS) are used to manage a building, however traditional systems face a big problem, they have high monetary costs associated with installation and hardware. At the same time, the market is flooded with cheaper tablet devices with built-in sensors, connectivity and visual display.

In this document, we propose a system that utilizes an Android tablet, mounted in the room wall, running an application to achieve building automation. Our solution addresses the energy consumption problem, increases occupant comfort and offers security, including intrusion detection notification and video monitoring, to the user. The proposed system differs from traditional centralized BAS by offering a distributed architecture with nodes deployed in every office and a user mobile application capable of interacting with the system.

I. Introduction

Buildings represent a large portion of the total energy consumed. According to the International Energy Agency, buildings represent 32% of total final energy consumption [1]. One way to contribute to reducing the energy consumption is to use of BAS to improve their efficiency. Unfortunately, not all buildings are equipped with such systems. Most times, these systems offer limited functionality and can only be controlled by the building manager.

Human behavior influences the amount of energy a building requires. Depending on the occupant behavior, the building's energy cost can increase or decrease by one-third of its design performance [2]. Simple actions such as leaving the lighting system always on, even after the occupant has gone home, has an impact on the wasted energy used by the building. The lack of occupant detection systems in buildings prevents further energy savings, as by knowing when a room is unoccupied it is possible to shutdown unnecessary electric systems.

Nowadays, consumer smart home systems are becoming more popular. The ability to remote control the house lighting and electric devices is very appealing to consumers. At the same time smart phones and tablets flood the market at very accessible price ranges.

In this thesis, we preset a BASA (Building Automation and Security on Android) a system that uses existing Android devices to provide a BAS capable of managing a room. Our system consists in using a wall mounted Android tablet, called Hub, to control other devices. It also allows the user's phone to interact with the Hub using a mobile application.

We designed BASA with a set of requirements in mind: The system must offer remote control of the room's lighting and HVAC systems, allow users to automate tasks, it must be user and motion aware, it must have a affordable cost and offer good usability.

Our system is user aware and is capable of adjusting the lighting and HVAC systems in a energy efficient way. At the same time it offers the user a If This Then That (IFTTT) system (trigger actions based on events) including voice recognition, for a personalized smart office experience. Finally, it provides the user with a security system. The Android camera is used to detect motion, when movement is detected and no registered person is present in the room a notification is sent to the user and a 30 second video is recorded to the cloud for latter viewing.

By using a tablet as a BAS we are able to reduce the monetary cost of our system in comparison to traditional alternatives. The tablet offers several sensors, access to Wireless fidelity (WiFi) and Bluetooth (BT) networks, microphone, sound speaker and a touch screen. We are able to leverage the tablet sensors including illuminance, temperature and camera sensor for automation. If the tablet does not have a temperature sensor it is possible to interact with external sensors to overcome the lack of the sensor.

The below listed examples represent some automation actions possible with our IFTTT system that contribute to decrease energy consumption and increase user comfort:

- If no user is present in the office then turn off the lights.
- If user arrives at building then set temperature to 24 ^{o}C (pre-heating).
- If lights are turned on and illuminance is above 120 lux then turn off the lights. (If there is sunshine and the lights are on, we turn them off).
- If no user is present in office and motion is detected then say "Hi! You are being recorded, smile!".

The above examples are not hard-coded into the system. They are created by the user. This ability offers great flexibility to our system to provide a personalized feel to the room.

Our system can be seen as a framework that provides a modern User Interface (UI), a IFTTT and security system. In the future other controllable devices, triggers and actions can be added to improve the system.

II. Background and related work

BAS are distributed control systems capable of monitoring and controlling a multitude of individual systems in a building. Usually they are used to control a building's HVAC, lighting, security and access control system (SAC). The objectives of building automation are the reduction in energy consumption, operating cost, improvement of occupant comfort, and efficient operation of building systems.

Until recently, there was no standard industry network protocol for building automation. BAS manufacturers developed unique, proprietary communication protocols and users had to choose between many different systems. Today, we have reached a place where there are a few major platforms used for BAS to choose from: BACnet[3], [4], [5], [6], LonWorks[6], [3] and few other. They were designed for specialized tasks, which limits the possibilities and capabilities of every node. The automation control is usually performed on a centralized server, commonly specified to as the Gateway. Installation may be a very complex task, requiring personalized hardware and/or software to be configured.

More recently other standards for building automation were created: ZigBee [7] and Z-wave [8][9]. The new protocols vary from the previous ones by being designed to use wireless communication networks with mesh networks and allowing different manufacturers to produce products designed to to operate with these protocols. Nowadays many home automation products use ZigBee or Z-wave as their wireless communication standard allowing interoperability between products from different manufacturers.

Modern Home Automation

The popularity of home automation has been increasing in recent years due to higher affordability and simplicity. Home automation may include centralized control of lighting, HVAC, appliances, security locks of gates and doors and other systems. Vendor solutions often rely in wireless technologies to connect the various devices, thus eliminating the need to rewire the house.

Some companies like Philips have developed smart lighting products that allow remote control over the lighting system without the use of conventional light switches. The Philips hue[1] is a wireless lighting system. This system is quite simple, you replace existing lights with Hue light bulbs and use a device called Hue bridge to communicate with the lights using a mobile application. Both Philips hue and similar smart lights for a problem: the user cannot use a regular light switch to switch them off. By doing that the lights become disabled, the user won't be able to use the mobile application to turned them back on, requiring the user to flip the light switch back up.

One other popular product is the Nest[2] Learning Thermostat. It is an electronic, programmable, and self-learning WiFi thermostat. It uses machine learning algorithm to optimize heating and cooling of homes. Studies[10] show this thermostat is capable providing savings equal to about 10%-12% of heating usage and electric savings equal to about 15% of cooling usage in homes with central air conditioning.

Amazon Echo[3] is a smart speaker developed by Amazon[4]. The device is capable of voice interaction, music playback, making to-do lists and other useful features. It can also control several smart devices using itself as a home automation hub. The main characteristic of Echo is it's voice interaction capability, any automation system would benefit by having such functionality.

Finally there are companies that provide web-based services that allows users to create simple conditional statements, which are triggered based on changes to other web. One such company is IFTTT, it allows user to trigger actions based on services such as Weather channel, Facebook, Gmail, Amazon Echo and Nest thermostat. This service allows user for example to automate their Philips Hue lights, Nest thermostat and many other services.

There are many products for home automation in the market, in this paper we merely discussed some that contribute to our final solution. We learned smart lights have some setbacks. The Nest thermostat offers a good solution to control a HVAC system. The only problem is it has a high monetary cost so it won't be used in our solution. Echo increases user comfort by allowing it to serve as an automation hub and allow voice interaction.We choose to implement a simple voice interaction in our final solution, as it offer many advantages. Finally we decided to implement a similar feature to the service provided by IFTTT. We allow the user to create conditional statements that trigger actions based on events in the office.

Occupancy detection

Human behavior influences the amount of energy a building requires. Depending on the occupant behavior, the building's energy cost can increase or decrease by one-third of its design performance [2]. By knowing and tracking when a room is occupied, we can provide the system with relevant information that in turn my help in taking important actions such as switching off the lights if no one is present.

There are several different methods to determine if a person is in the room, they range from Radio Frequency Identification (RFID), Passive Infrared (PIR), Vision-based, WiFi and Bluetooth, among other [11].

Yuvraj Agarwal and his co-authors proposed using a mixture of PIR sensor and a simple magnetic contact switch to track when the door opens and closes, this solution provides better result in regard to a PIR only solution[12].

Using WiFi it is possible to estimate the number of occupants in the area. Occupants usually have mobile devices connected to the building's WiFi, by knowing the devices currently connected to the AP it is possible to estimate their relative location. Furthermore since it does not require additional equipment, it is an economic solution. Bluetooth

[1] www2.meethue.com, last accessed on January 6^{th}, 2016

[2] https://nest.com/

[3] https://www.amazon.com/Amazon-Echo-Bluetooth-Speaker-with-WiFi-Alexa/dp/B00X4WHP5E, accessed 10/10/2016

[4] https://www.amazon.com/

Low Energy (BLE) technology is also an available solution for room user detection, leveraging the user's phone to do the detection, or asking the user to carry a BLE beacon and have a system listening for the signals.

A camera and image analysis software are able to identify movement between video frames. Noise detection could also provide valuable input to determine occupation, yet it is less reliable as external sounds could induce false positive occupant detection.

Sensor application in Automation Systems: Sensors can have important contributes to BAS, they can provide higher comfort to the occupants of the building as well as save on energy costs. Comfort can be improved using temperature sensors by regulating the building temperature to maximize occupant productivity while at the same time only spending energy when required.

Luminosity Sensors can be used to determine if lights need to be turned on or if there is enough natural light to turn off the lights, or at the very least dim the light intensity.

III. Architecture

Nowadays it is affordable to built a device to provide BAS functionality to a small area. This allows the room to be personalized to the occupants needs and habits.

We designed a system, named BASA, capable of controlling the lighting/HVAC systems and offer room security. The system is described in Figure 1 and consists of two mobile applications, one is the Hub app that runs in a tablet mounted in a wall in the room, the other is the User app that the occupant of the room can install on his personal smartphone.

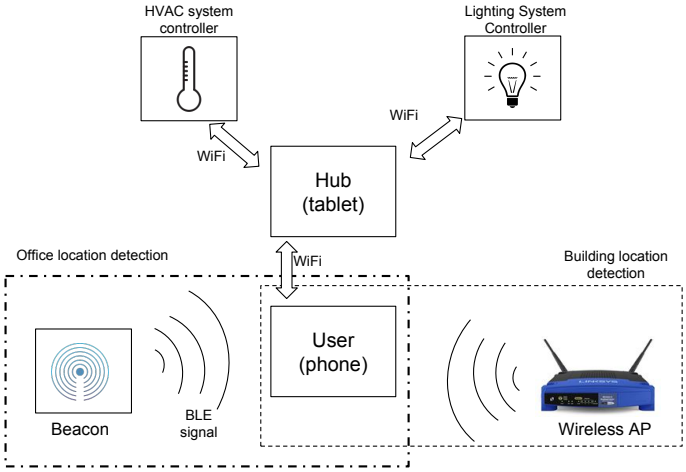

Fig. 1. Overview architecture of the system

The Hub app is responsible for controlling the HVAC and lighting systems in the office, enforcing energy saving policies, improving occupant comfort and providing security monitoring when the user is away from the office.

The main visual features of the Hub application are: a simple graphical user interface (GUI) to control the lights and heating/cooling system, an IFTTT automation system that allows the user to create personalize trigger/actions rules. In the background it also provides motion detection and video recording for occasions when the user left the room but movement is detected.

The User app runs in the user's mobile device and offers remote control of the lighting, HVAC and security systems provided by the Hub. Besides improving user comfort by allowing remote access to the Hub, the user app also helps the Hub with user detection, allowing the system to know when an authorized user is inside the building or room.

A. Hardware Architecture

To achieve building automation, our solution requires a tablet to act as a central control unit, a beacon device used for user detection inside the room and two other devices capable of interacting with the lighting and HVAC systems. In Figure 2 we describe the man hardware components of our system and the communication protocols used.

The tablet is where the Hub app is executed. It provides the sensors, the connectivity, the storage as well as a camera, microphone, speaker and a touch screen.

The beacon is used for user detection, this will be explained latter in Section **??**.

To control the lighting and HVAC systems we require devices capable of interacting with existing systems that offer a way to remotely control these existing systems. These devices can be for example microcontrollers. A microcontroller allows the digital world to interact with the real world through the use of actuators that convert electric signal into mechanical actions. The microcontroller is connected to the actuators (relay) and is able to switch on/off the lights as well as controlling the HVAC. This component is needed because typically, lighting and HVAC systems do not have any type of connectivity other than the electric wires.

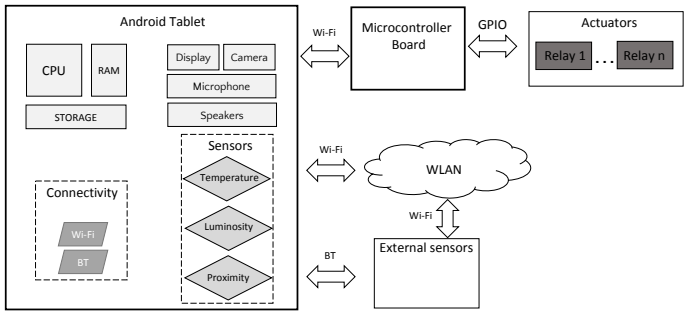

Fig. 2. Hardware architecture of the Hub

IV. Implementation

V. Evaluation

Conclusion

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