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A Robust Device Free Localization Based Occupancy Detection System for Campus Monitoring

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Abstract: *This paper proposes the implementation of wireless sensor network for campus monitoring using Device Free Localization Technology. The method exploits the known fact that human body contains 70% water which resonates with radio signals by causing shadowing effects. Introduced irregularities in the radio propagation pattern indicate possible presence of a human. As opposed to conventional solutions which utilize a complex set of sensors for human detection, the proposed approach achieves the same only by analyzing and quantifying radio signal strength variations incorporated in messages exchanged between 2.4 GHz(ZigBee) radio transceivers. One of the key benefits of the proposed solution is the integration of the powerful and accurate detection algorithm into the smart nodes to control appliances of a wide campus like schools and universities. Such an approach improves occupancy detection systems, enables intelligent power consumption and low installation cost..*

1. INTRODUCTION

Wireless Sensor Networks play an important role in detecting environmental changes in smart home applications. The human presence within the wireless network range produces significant impact on received signal strength (RSS). The variation in RSS due to human presence can be analyzed and quantified to control power outlets and energy saving in a campus based on human occupancy. The radio signal propagation are versatile across different environments where the signals can be absorbed, reflected, scattered or diffracted by many objects in its propagation path.[1] The shadowing effect caused by a human subject within the line of sight between transmitter and receiver creates molecular resonance[2]. Device free localization technique is an emerging technique for human occupancy detection. The major disadvantage of this technique is that it needs lots of wireless links travel through the deployment area to guarantee good performance[3]. Also, the RSS signals are very sensitive and evena slight change of the environment affects the RSS measurements leading to degradation of the localization performance. To overcome this problem, a robust DFL scheme based on differential RSS may be used [4].Nuzzer, a large-scale DFP (Device Free Passive) localization system is used to track entities in real environments, rich in multipath. Probabilistic techniques can be used for evaluating the performance both experimentally and analytically in campus buildings using this system [5].Inhnaea, an accurate, robust and low-overhead DFP localization which uses a lightweight, typically two minutes training period to learn the silence profile of an environment can also be used. It applies statistical anomaly detection techniques and particle filtering to provide localization techniques using standard Wi-Fi hardware [6]. ACE is a system that uses a probabilistic energy-minimization framework and combines a conditionalrandom field with a Markov model to capture the temporal and spatial relations between the entities' poses. A novel cross calibrationtechnique is used to reduce the calibration overhead of multiple entities to linear, regardless of the number ofhumans being tracked [7]. A lightweight robust Bayesian grid approach (BGA) which utilizes not only the observation information of the shadowed links, but also the prior information involved in the previous estimations and the constraint information involved in the non-shadowed links, which ensure its robust performance, may also be used [8]. Spotis an accurate and efficientsystem for multi-entity device-free (DF) detection and tracking. Itprovides a novelcross-calibration technique that reduces the overhead of multipleentities calibration from exponential to linear. It also capturesthe spatial relations between the entities' poses into a probabilisticenergy minimization framework via a conditional random fieldmodel. The designed energy minimization function is then solved by a binary graph-cut algorithm [9].

Background subtraction methods are adapted from the field of computer vision to estimate baseline RSS values from measurements taken while thesystem is online and obstructions may be present. This is done by forming an analogy between the intensity of a background pixel in animage and the baseline RSS value of a WSN link and then translating the concepts of temporal similarity, spatial similarity, and spatialergodicity, which underlie specific background subtraction algorithms to WSNs. Then, using experimental data, thesetechniques are capable of estimating baseline RSS values with enough accuracy that RF tomographic tracking can be carried out in avariety of different environments without the need for a calibration period [10]. A new approach where both the average path-loss and the fluctuations of the received signal strength induced by the moving target are jointly modelled based on the theory of diffraction through a novel stochasticModel which is derived and used for the evaluation of fundamental performance limits. The model is proved to be tight enough to be adopted for real-time estimation of the target location. The localization system is validated by extensive experimentalstudies in both indoor and outdoor environments [11].

A finite-state machine (FSM), an on-line recalibration method that allows the system to adapt to the changes in the radio environment and provides accurate position estimates in the long run, defines when the person is located at specific areas-of-interest (AoI) inside the campus building (e.g. cabin, classroom, laboratory, etc.). The FSM allows extracting higher level information about the daily routine of the person being monitored, enabling interested parties (e.g. caretakers, subordinates) to check that everything is proceeding normally in his life [12].RF based human detection method is incorporated in the network of smart power outlets and light switches. The outlets and light switches are extended to detect human presence in order to increase user awareness and to improve human-computer interaction in smart homes. For certain applications in smart homes, this method is even more reliable and robust than other conventional sensor technologies. The RF based detection accuracy is not disturbed with the typical temperature changes. It successfully detects the presence even in such demanding cases. It is achieved by analysing and quantifying radio signal strength variations incorporated in messages exchanged between 2.4 GHz radio transceivers. One of the key benefits is the integration of the detection algorithm into the smart power outlets and smart light switches. This approach improves interactions in smart home systems, enables intelligent power consumption management and low installation costs [13].

The aim is to trackpeople just through their physical body interfering with a standard wireless network. The human body contains about 70% water whichattenuates the wireless signal reacting as an absorber. The changes in the signal along with prior fingerprinting of a physical location allow identification of a person's location. Naïve Bayes with Gaussian and kernel distributions, andTree Bagger classifiers can be used to process wirelesssignal strengths in order to detect motion [14].

To achieve omnidirectional coverage under link-centric architecture, the concept of omnidirectional passive human detection is used. PHY layer features to robustly capture the fine-grained multipath characteristics and virtually tune the shapeof the coverage of the monitoring unit, is previously prohibited with mere MAC layer RSSI. A fingerprinting scheme and a threshold-based scheme with off-the-shelf Wi-Fi infrastructure and evaluate both schemes in typical clustered indoor scenarios. Experimental results demonstrate an average false positive of 8 percent and an average false negative of 7 percent for fingerprinting in detecting human presence in 4 directions. And both average false positive and false negative remainaround 10 percent even with threshold-based methods [15]. This wireless sensor network provides real time data collection and analysis for temperature , humidity and motion and controlling of electrical appliance for e.g. lights, AC, Fans, Exhaust etc of the campus. This system also provides security and can detect presence of a person using PIR sensor. It operates appliances only after detecting a motion in a particular area of the campus. This automatic control system provides remarkable power saving. This paper has four sections. Section 2 explains hardware development. Section 3 explains working of hardware . Section 4 explains result and section 5 explains conclusion .

2. HARDWARE DEVELOPMENT

This section consists of hardware development of the system for campus monitoring. Hardware development is divided into two parts

A) Monitoring Point(MP)
B) Transmitter

The MP is aimed at detection occupancy using Device Free Localization technology. This technology uses Received signal strength Indication (RSSI) based method for detecting occupancy by measuring variance of a signal. The system is equipped to monitor the changes in the RSSI values as a result of human detection. It also consists of digital temperature and humidity sensors for sensing the environmental conditions. PIC microcontroller is used for analysing the received data from the sensors and controlling appliances in accordance to the sensed conditions. The transmitter is the Zigbee module and configured as an end device.

3. WORKING OF HARDWARE

This section explains the working of the circuit. RSS sensors sense the movement inside its remote area. Output of sensor is analog signal which is converted into digital by inbuilt ADC in the PIC16F877A. As motion is detected, corresponding lights are ON and other sensors are initialized. Temperature as well as humidity are sensed and analyzed by microcontroller. According to the conditions, the relays are activated and thus corresponding appliances are controlled .Relays remain inactive until movement is sensed.

4. TEST DEPLOYMENT AND RESULTS

We deployed our system across one of the wings of the Electronics and Communication Engineering(ECE) building and collected data for several offices over two weeks. Figure 1 shows the floor layout with the occupancy detection nodes marked.

Fig. 1: Deployment Scheme of RSSI Sensor

Detailed accurate occupancy information is critical in order to achieve any occupancy-driven control system. Over two days we constantly monitored the hallway to record the actual occupancy for each of the rooms. This gives us ground truth with which to compare our sensor readings. In order to compare our system with commonly deployed sensors based systems, we also monitor the room with a sensors based systems using a 10 minute timeout (the sensor will consider the room occupied up to 10 minutes after the last detected movement).Figure 2 compares the actual occupancy with our RSSI based system and the sensor based systems. We notice that our sensor node matches the actual occupancy well.

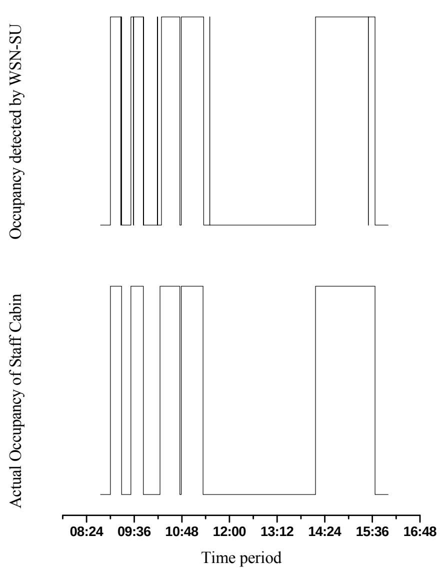

Fig. 2: Accuracy of occupancy detection

4.1 Energy Savings

One working day means Eight to Nine hours. In one cabin light consumes .030 KWH, fan consumes .075KWH, air conditioner consumes 2KWH .Total consumed power is 2.105KWH per hour. Without application of this circuit, the total consumed power for Nine hours is 18.945KWH. After application of this circuit, the total consumed power for Nine hours is 11.525KWH. Electricity is saved for approximately 7.42KWH. By this approach around 40% electric power can be saved without applying manpower in one day. But the same power saving cannot be estimated for each day. The observation of faculty cabin for 20 days without and with application of occupancy based control system has been taken to show the cumulative power saving and the fig. 3 shows tremendous power savings.

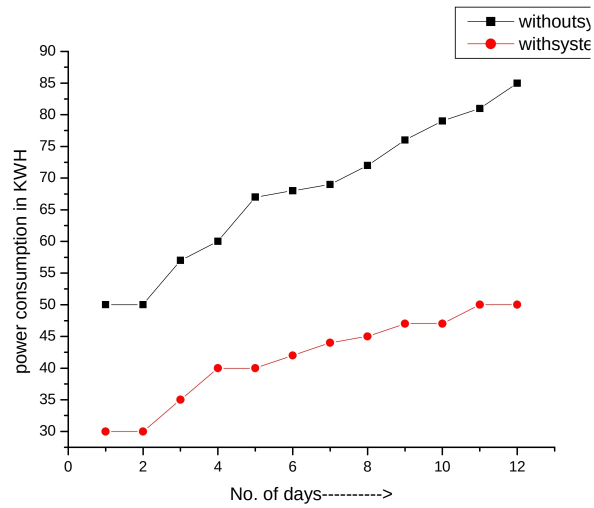

Fig. 3: Power Saving with and without system

4.2 Simulation

The impact of occupancy system on appliances energy cost was studied using energy plus building energy simulation program developed by US department of energy. The building model was simulated for one year including two modes: i) all appliances were turned ON during entire working hours at 25^0 C and ii) with occupancy controlled sysytems which turns ON appliances only when there was occupancy Fig. 4 shows that the monthly savings using our occupancy systems is between approximately 23%.

5. CONCLUSION

Wireless sensor network has been developed and implemented in one of rooms of Sharda University campus by monitoring system and integrating it with ZigBee to save energy. Due to irregular appearance of the staffs of university in their rooms, appliances remain working and consume power without any use, which result in wastage of power. Since this system is controlled by wireless sensor network, no man power is required to control the appliances and at least 18-19% power can be saved per year.

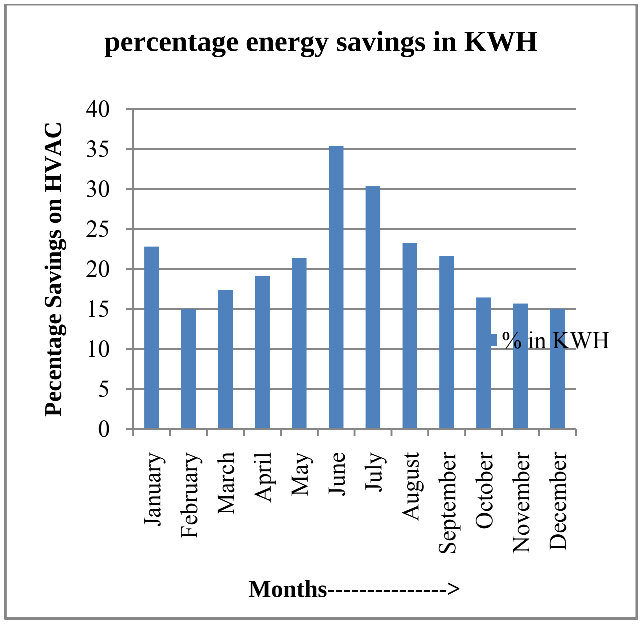

Fig. 4: Power Saving annually by simulation

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