Classroom Automation Using RSSI

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***Abstract*—The surging energy costs has urged the need to minimize power consumption, especially in large education institutions where most of the power is consumed in providing well lit and air-conditioned classrooms, seminar halls, laboratories and corridors. A lot of power can be saved if we could control electrical appliances through automation, completely removing the possibility of a power loss, that is found to occur in cases where (i) classrooms are unoccupied, yet running with power, or (ii) occupancy of even a small part of the classroom involves all appliances to be turned on, due to a centralized power system. To overcome such cases of power losses, this paper pro-poses an efficient, cost effective and low-cost architecture model that consists of an occupancy monitoring system (subsystem I) integrated with a localized power system. To create such a low-cost system, the usage of Node MCU, a cheaply available microcontroller, as a wireless sensor network(WSN) node is experimented and tested for performing localization using the RSSI. The efficiency of NodeMCU as a sensor node, is measured by the accuracy of detection, which uses a mean algorithm, over a specified period of time. Additionally, to contribute to the automation of a classroom, a second subsystem is integrated with this model, which provides control over the door lock of every classroom. It also provides the means to indicate the status of occupancy in a room, to its clients, the teachers, and allots a free room if requested through an SMS message. Through repeated trials of experimentation, the proposed occupancy monitoring design is found to be successful in detecting the presence of a person(s) in Line of Sight(LOS), when limited up to 3 meters of detection region, with an accuracy of 95%(1 error every 20 min). Beyond this regions, the accuracy dips arbitrarily below an appreciable level due to multipath propagation. Secondly, results show that subsystem II functions smoothly with a maximum latency of 23s and an average latency of 14s before receiving the corresponding response action. Hence the proposed system is found to be a possible solution to save power and automate education institutions over certain limitations.**

***Keywords*—WSN, RSSI, Classroom Automation, Node MCU, WiFi, Occupancy Monitoring System, GSM**

I. INTRODUCTION

The widespread usage of technologies such as IOT and Wireless Sensor Networks (WSN) has veritably reached every facet of the modern civilization. The countless number of people involved in developing these fields, have paved the way to work on myriad number of innovative applications in areas such as marine, military, agriculture, mining and many more. However, this paper proposes a system model which focuses on contributing to the automation of classrooms in educational institutions. Educational institutions all over the world are a juggernaut of power consumers, also covering large areas of land. Witnessing an unprecedented increase in the worlds population, each year, while not being able to procure a completely replaceable renewable energy source to that of the fast-depleting non renewable energy, urges the need to take measures in conserving power. Lots of energy and time is wasted in large education institutions, due to lack of human effort and carelessness. By proposing to automate the classrooms with a system architecture that has low complexity, low-cost and easy maintenance, with flexibility depending on its purpose, we could save power by a large margin. Such a solution involves the replacement of a localised power system, in the place of a centralized power system. The efficiency of a localised power system in that case, directly depends on the accuracy of the integrated occupancy monitoring system. This, is the central focus of the paper.

Over the past few years, many localization algorithms have been introduced using WSN nodes which improves the accuracy of object tracking. Fortunately, in the application of a localised power system for classroom automation it is sufficient to acknowledge only the presence of an object within an area of interest, thus reducing computation complexity drastically. Our model, proposes to use the NodeMCU as a wireless sensor network node which uses the Received Signal Strength Indicator (RSSI) to detect the presence of a human being within an area of interest. NodeMCU being equipped with the ESP8266, a low cost WiFi microchip, can easily detect the RSSI of the WiFi signal. It also harbours enough input and output pins that can be used to control power to the localised electrical appliances.

The proposed system also includes the functionality of an automated door locking system. A single WSN node in each room is equipped with a door sensor that adds to the knowledge of the activity status of a classroom. Overall, each part of this proposed system is elaborately explained in section III of this essay.

II. RELATED WORK

Ever since IOT has been introduced [23], most classroom spaces are increasingly made up of highly smart and logical devices that imprints in the minds of its occupants, the aura of technological advancement today. Smart classrooms may in-clude cameras with image signal processing to take attendance [12], smart interactive boards and wireless projectors, that helps to enhance the quality of

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learning. In [5], a very creative application of AI in classrooms are made which involves the assessment of the quality of teaching using complex face detection algorithms. In [14], they have proposed a mobile application that is used to control and monitor the usage of a student's mobile during class hours, while also taking attendance automatically. For the cause of saving power, a lighting control system using light sensors can be designed to turn on electrical tube-lights only when day light is insufficient [24].

A. Occupancy Monitoring System

An occupancy monitoring system can be developed using many methods, the most prevalent being the camera [21], [1], [6], while other methods include a campus card [20], using PIR sensors, Live tags [4], RFID tags and many more. Sometimes more than one method is combined into a single architecture to improve accuracy [16]. The usage of RFID tags involves the requirement of the person to carry a device in order to be detected by RF signals. On the other hand, although the usage of Live tags is device-free, it requires a human touch for detection and a delicate procedure for the preparation of the tag. This leaves us with the usage of a Camera for human body detection. While it is easy to detect the presence of a human body, the process of localization will further increase computation complexity. In [21], a camera node is integrated with other sensor network nodes to count the number of people within a region. In [10], an entire classroom automation model using vision processing tools is proposed. However cameras are expensive and delicate while also increasing cost of computation, hence the usage of RSSI using WSN nodes is suggested for localization. The RSSI is a metric, normally used as a Quality of Service(QoS) for a WiFi signal. In [27] and [21], WSN nodes such as Micaz and Memsic are used for detecting the signal. Localization can generally be divided into range free(without the calculation of distance) and range based localization (involving the calculation of distances). Under the latter, a mapping based localization method is proposed in great detail in [13].

B. RSSI for localisation

RSSI has been widely used for localization purposes over the past 10 years using WSN architecture. In [11], the effects of the radio signal strength in the presence and absence of a human is explored in great detail. The values of RSSI is found to have a wide range of fluctuations in the presence of a human while compared to the small fluctuations of RSSI about a mean (threshold value of RSSI) in the absence of a human. This is the criteria used to detect the presence of a human body that comes between the electromagnetic spatial spectrum of the radio signal, as done in [2], [7] . In [22], a zone selection method is applied to detect a person within an enclosed area, using a well defined protocol that simplifies the process of communication between the nodes for detection. However, the model proposed includes 3 transmitters node and 1 receiver node which would involve greater power consumption and computation complexity as opposed to our proposed model, which has 3 receivers and 1 transmitter. This, improves accuracy as the threshold value for every zone or sector is likely to vary by a considerable margin, making it easier to compute the threshold value in each sector separately by each receiver node. The protocol used in [19], also includes an authorization function for each received packet by the base node, which can be avoided by using the system architecture of this essay, which requires only a one time authorization at each receiver node with the transmitter node. Additionally in [3], a detailed analysis is carried out on how the distance between the nodes affect the range of RSSI fluctuations for the same activity occurring in-between. As expected, the farthest node proves to have greater fluctuation and this type of analysis must be used to model the fixed sensor node locations within a classroom. Other works that use RSSI for localization, also includes live tracking of either a node or a human as in [17], [9]. The WKNN algorithm is predominantly used for localization with the triangulation method in these works. In [15], two types of training model is proposed for tracking, where one method involves estimating RSSI range model for a given set of anchor node locations and another which uses a camera to estimate the anchor node location. Interestingly, localization using RSSI also acts as an alarm system to detect a breach in security as discussed in [25], when a fake node replaces the original node or when an existing node is attacked or blocked from transmission within the network. In [13], a new algorithm is proposed for using WKNN, but it requires for us, to know the path loss exponent for propagation model, which cannot always be accurately determined for our purpose.

In [8], RSSI values are detected using the XBee pro S1 and S2, to find the best of the two nodes for localization. Based on the results, XBP2 proves to be a very good sensor network model for distance estimation in indoor environments. However the range of RSSI values for detection within a radius of 5m is not appreciable enough for detection within most classroom dimensions. In [19], a comparison model on the different modes of wireless technology for RSSI detection is conducted and they have shown that WiFi signals, have been more accurate for Indoor localization, than BLE 4.0, Zigbee or LoRaWen. Thus the proposed model uses the WiFi protocol to act as the communication link between the sensor nodes.

III. Proposed System

Many different types of WSN nodes have been used to detect RSSI [26]. This paper proposes the usage of Node MCU to act as a WSN node. The novelty of this essay is the usage of Node MCU as a possible fit to act as a sensor node for localization. Being equipped with a ESP8255 [18], a microchip WiFi module, it can easily detect the strength of any WiFi server. It is also cheap enough to be found appropriate in the goal of making a low-cost system. This essay also aims in integrating this WSN model with the door locking automation model, overall, acting as a central control system for classroom automation. The proposed system architecture consists of two subsystems, i) WSN module with 4 nodes that detects the presence of a human in each sector and ii) A GSM module with Arduino as a central processor to talk to authorized controllers using SMS.

A. Methodology

1) Subsystem 1: The WSN module contains 4 nodes to cover the classroom, by separating it into 3 zones or sectors. The number of nodes used in a classroom directly

depends on the size of the classroom and range of the sensor node used. The 4 nodes consist of one transmitter node, acting as server or an Access Point (AP) and the remaining 3 nodes acting as a receiver station for each zone. The following Fig. 1 shows the node locations in a classroom. Each station node first connects to the WiFi server of the AP and then starts receiving RSSI values of the WiFi server signal. The node is then run by a code that contains the threshold value of RSSI (when there is no human in the AOI of the node), after proper calibration. Thus the mean algorithm is incorporated for higher accuracy in detection, as it removes errors caused by sudden arbitrary fluctuation in RSSI values. Thus, only whenever the average RSSI value of 7 iterations, dips below the threshold, it acknowledges the presence of a person by switching on the relay which turns on all the electrical appliances of that area. After 7 iterations, the condition of threshold is checked, and code resets RSSI to 0. The central AP node, is also connected to an Arduino which works for subsystem 2. Alternatively, the AP node can also be replaced by a mobile hotspot or a WiFi router, to act as a stand alone system. While coding every receiver node, the RSSI value is scaled with an addition of 400 so the range of values observed comes around 340dB instead of -40dB.

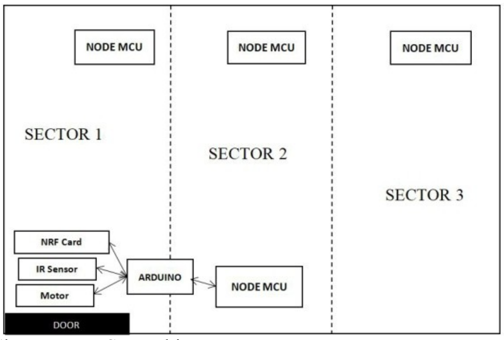


Fig. 1 Classroom WSN architecture

2) Subsystem 2: It consists of a single GSM placed at the center of a floor or building, connected to an Arduino and an NRF card. This setup will communicate with the NRF card and Arduino that is present in each classroom. The GSM is also attached to an RTC which is used as a timer. For example, we implement the case of 6 classrooms in each floor as show in Fig 2, a single GSM with NRF 4201L is sufficient to connect to a range of radius 520m with 2Mb/s speed of data transfer, approximately covering 5 floors of a building. If the module of NRF is joined with an antenna it can reach up to 1Km radius, which is enough to cover an entire building. Within each classroom an NRF card is used to listen to radio signals from the central NRF card (connected to GSM). Each Arduino in a classroom has the function of processing every forwarded message from the GSM after checking the authorization of the sender. It is connected to a motor, that actuates a door lock and an IR sensor that detects if the room door is open or closed. The fig2 depicts the representation of a floor plan model. The following functions are operated in this subsystem by coding in the Arduino IDE software framework. i) At 7am and 5pm all classrooms must be closed automatically. ii)During emergencies an admin can send a single message to the GSM to open or close all doors irrespective of any other concurrent processes. iii) Each registered client number, which includes the list of all authorized teachers can send a message seeking permission to open for a particular classroom, to the GSM. The GSM first checks the occupancy of the specified classroom and then allots the room by sending a command to open the door after seeking permission from admin. This facility is also extended to work after 5pm. If a request has been queued to keep a classroom open after 5pm, it carries out a similar process after RTC sends the signal command for the function (i). Sample message format request by a client: C:5:B (C is used for the purpose of message extraction in the software, 5 denotes floor number, B denotes the class number within each floor), Sample message format request by admin for a successful allotment of classroom: C:OK (OK to denote permission granted), Sample message format for emergency commands: C:E:O and C:E:C (represents emergency open and close).

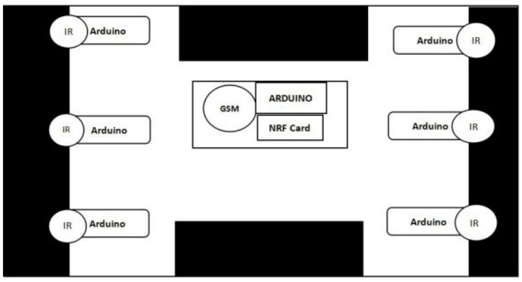


Fig. 2 Floor plan of door lock automation

The overall system is given as a flow process diagram in Fig 3. It starts with the RTC sending a command to the

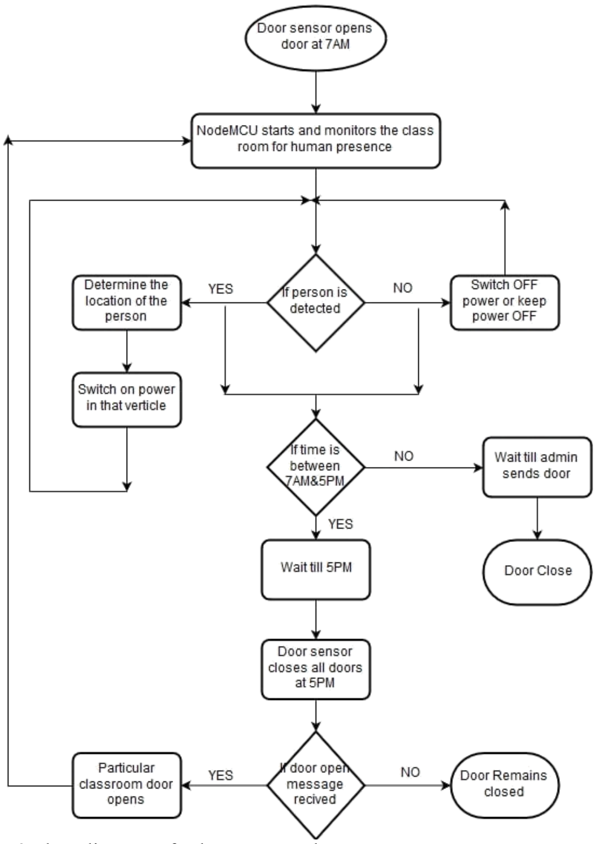


Fig. 3 Flow diagram of subsystem I and II processes

GSM and central Arduino to open all doors at 7am. The occupancy monitoring system operates continuously till 5pm and accordingly controls the electrical appliance. If a request has been made to keep a classroom open after 5pm, the motor is switched ON to actuate the unlocking of the door.

B. Hardware Design

NodeMCU: The NodeMCU has been used for IOT applications in various fields. It has also been used for distance estimation by extracting the values of RSSI. The esp8266 library package in the Arduino IDE provides simple library functions required for the purpose of this paper. It also harbours 16 GPIO pins, that can be easily used to control all the localised electrical appliances.

nRF24: This 2.4Ghz operating transreceiver is used to provide a means of communication for the purpose of a centralised door locking control.

GSM: The usage of GSM for the purpose of a central unit of communication involves the usage of AT commands. Arduino The Arduino is used in every classroom as a processing unit for automation with the door locking system.

TABLE I HARDWARE SPECIFICATION

S.No.	Component	Quantity
1	NodeMCU	4
2	NodeMCU Base	4
3	Relays	4
4	IR sensor	1
5	GSM	1
6	Arduino	2
7	DC motor	3
8	Light Bulb	3
9	NRF 2401L	2
10	RTC	1
11	Transformer	3
12	SIM card	1

IV. RESULTS

Firstly, the table 2 represents the result of RSSI values sampled from the experiment that was conducted for 20 minutes and for varying distances. The Distance column in the table refers to the distance between the receiver node and transmitter node. While there are three receiver nodes in the experiment, the threshold RSSI value and recorded RSSI value for each node are independent of each other. The node 2, which is closer to the transmitter than the side nodes 1 and 3, have higher RSSI values, for the same distances. It is inferred that the system accurately and steadily determines the presence of a human(s). The errors or inaccurate interpretation is seen to take place, once in every 20 readings. This can however be corrected by keeping a time window before taking action(i.e. Switching On or Off the power supply to relay) to prevent wrong interpretations.

Secondly, depending on how far away the person stands from a transmitter or a receiver a greater range of readings are generated. For example, at 1.3m distance-333dB is generated, which is a very low dip and is caused because a person was standing very close to the transmitter, thus reducing the strength of the LOS signal. Thirdly, when a person walks perpendicular to the line of sight path, the sudden dip is recorded and easily detected. Hence, fast movements are found to be quickly detected in the experiment. On the other hand, a stationary human faces a time lag of 10s before he or she is detected. The figure below shows the recorded dip (350 to 345 at 1.3m) on the serial monitor.

Fourthly, the distance between the nodes, once changed, will not control the localized power system smoothly. Hence it is required to make sure that the node locations are fixed, otherwise the threshold value changes. For distances greater than 4m, we notice that the fluctuations are very random to be calibrated. This could be due to low power of the transmitted signal and many multipath interference terms. It drastically affects the efficiency of the model, as the sector in our classroom is not covered. In order to cover these blind spots an alternative model or additional nodes can be added.

The following are the screen-shots of the SMS in a teachers mobile interface and what happens when she asks for a class (ex:C:3:A-third floor, class A). When the teacher asks again for the same class the reply of ”Already opened indicates that the class is already taken. The second screenshot displays the admins interface.

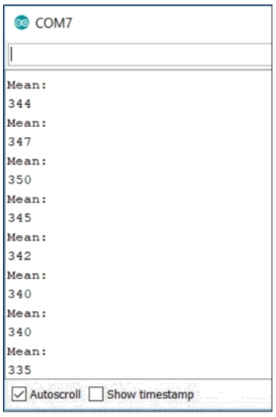


Fig. 4 Serial monitor output when a person walks by

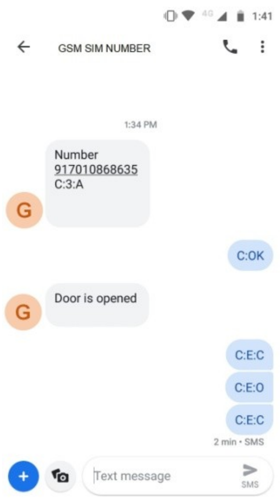
TABLE II SAMPLE RSSI OBSERVATIONS

Distance(m)	Occupancy	RSSI(dB)	Threshold (dB)	Detected?
0.5	Present	344	352	Yes
0.5	Present	347	352	Yes
0.5	Absent	353	352	Yes
0.5	Absent	359	352	Yes
1.3	Present	333	347	Yes
1.3	Present	342	347	Yes
1.3	Absent	348	347	Yes
1.3	Absent	350	347	Yes
2.2	Present	333	335	Yes
2.2	Absent	337	335	Yes
2.2	Absent	342	335	Yes
2.2	Present	338	335	No
4.0	Absent	325	315	Yes
4.0	Present	309	315	Yes
4.0	Present	304	315	Yes
4.0	Absent	328	315	Yes

When the C:E:O or C:E:C is sent, the motors used in our experiment to actuate the door lock, is turned by 90degrees. Both Communication links take place through the SIM card inserted into the GSM. The SIM card used must thus have enough credit to send the messages. Experimental observations also records a latency between request and a response message of 19 seconds, which could be due to the the GSMs' slower serial communication of decoding and forwarding each received message.

CONCLUSION AND FUTURE WORK

This paper proposes the usage of the NodeMCU as a WSN node for Indoor localization using RSSI using the mean algorithm. The purpose of this, is to automate a classroom to effectively save power. Hence a low-cost, simple and efficient WSN architecture is suggested to work as an occupancy monitoring system. After working on many trials of this model, we have found that, while NodeMCU performs a good job in detecting RSSI with appreciable accuracy, it only works in the region of Line of Sight(LOS) with a distance up to 3 meters. Hence, for NodeMCUs to be used as a WSN nodes, to cover the classroom as required in sectors, an antenna must be used to cover a wider area of the sector. Thus, future work in trying to improve this part of the subsystem, involves the usage of an antenna for greater area of detection. On the other hand, as a part of saving power, light sensors can be added to the model to switch of the light when daylight is sufficient to light up the classroom. This model is not only applicable to classrooms but also to any facility centers like shopping malls or hospitals, where such a system can be found useful to save power if implemented.



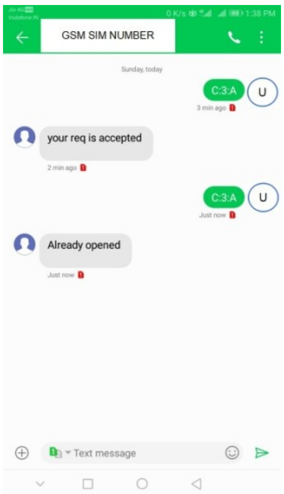


Fig. 5 Admin and GSM communication interface
Fig. 6 Client(teacher) and GSM Communication Interface

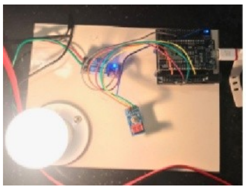


Fig. 7 Rx node1- control light

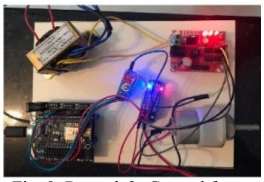


Fig. 8. Rx node2- Control fan

Fig. 9. Central Node

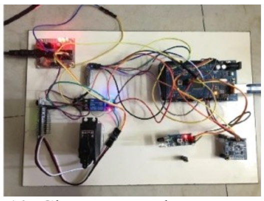


Fig. 10. Classroom node

In addition to this, the second subsystem is made of an automated door locking control which is implemented to contribute to the classroom automation. It successfully checks the occupancy of the classroom and grants permission to a faculty seeking an extra class, by opening the door. The proposed architecture is simple and found to be efficient in its working with a negligible average latency of 14 seconds. However this subsystem can further be made sophisticated and user friendly by creating an App Interface in place of sending an SMS. A cloud storage can be integrated with a graphical map of the room locations in a building or a floor, to save and display the status of vacant classrooms through this app. It can be further extended to provide functions such as taking attendance and hindering unwanted mobile usage by students during class hours as done in [14].

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