Implementation of Long Range Wireless IoT Device for Agriculture Using Multi-Hop Topology Design

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Abstract: ***This paper presents a proof of concept for self powered Internet of Things (IoT) device, which is maintenance free and completely self-sustainable through energy harvesting. The Wireless Sensor Networks (WSNs) consists of sensor nodes (SNs) that are distributed randomly or pre planned form and have restricted capacity. Because SNs are energy limited and battery change is difficult, energy consumption is one of the most vital factors affecting the WSN design. There is a lot of energy efficiency studies done because of the effect on network life time. These IoT devices can be deployed in large scale and placed anywhere as long as they are in range of a gateway, and as long as there is sufficient light levels for the solar panel, such as indoor lights. The IoT device can potentially last for more than 7 months (transmission interval of 30 seconds). The preferred topologies and protocols in multi-hop WSNs have a significant impact on energy consumption. In this study, the effect of different WSN topologies on energy consumption under the same conditions was examined comparatively. For this purpose, a multi-hop WSN application was made in different scenarios in the simulation environment and the total energy consumption amounts of SNs were scrutinized for different topologies.***

Keywords: Multi-hop WSN, Topology, Sensor Node, IoT, Temperature, Humidity

1. Introduction

Today's world demands improved methods as compared to the old ones to carry out processes faster and the world is moving towards automation of every process. Recent developments in semiconductor technology, integrated circuit (IC) technology and advancements in wireless technology enables the development of several applications related to wireless embedded systems and Internet of Things (IoT) devices. Wireless embedded systems such as wireless sensor networks (WSNs) have several applications, such as health care applications [1] and monitoring of industrial processes [2]. Internet of things (IoT) is actually networking of smart embedded electronic devices which sense and exchange data without human intervention, with applications starting from smart homes to industrial automation.

IoT devices are usually equipped with a transceiver, a microcontroller unit (MCU) or a processor, a set of sensors and actuators which require power for seamless operation. These devices are usually powered by batteries if they are ultra-low powered devices. The batteries lifetime depends on transmission intervals, wireless technology and range coverage. The batteries need to be replaced at some point of time if they are non- rechargeable. Rechargeable batteries are an alternative solution as compared to non rechargeable batteries but still requires maintenance and is not a viable solution for the devices deployed in remote and harsh weather conditions.

a) Photovoltaic energy harvesting

Harvesting electricity from light is usually through with Photovoltaic (PV) Cells. Most PV cells are designed to be most effective in natural light, with the sun because the source. Sunlight has higher intensity and provides a wider spectrum than what's found in artificial lightning, as shown in Fig. 1. Fluorescent light, illustrated as blue, covers a really narrow spectrum, while LED light covers a broader spectrum, but peaks at a shorter wavelength.

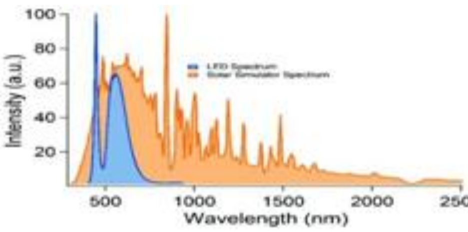

Figure 1: Spectrum of different light source

Switching from conventional fossil-based energy to renewable energy sources was always hurdle by the high cost barrier. In recent years, this is no longer the case, especially for PV-based solar energy modules that are expected to revolutionize the electricity systems.

2. Literature Review

The literature associated with analysis has been reviewed for last twenty years so as to search out work distribute by numerous researchers. There are many systems for monitoring remotely and control designed as commercial products or experimental research platforms.

For development of machine-controlled irrigation system, soil moisture content is more important parameter as compared to others as it has crucial role in plant growth mechanism and availability of water for irrigation is major

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concern for the farmers specially those who square measure enthusiastic about rain. Hence water management has high priority while designing automated irrigation system as seen in most of the literature.

R Jaichandran [12]: Water is one of nature's most important gifts to mankind, because of the increase in population food requirement for human being is also increasing. Over the past few decade usage of water for irrigation has redoubled hysterically. Water is polluted because of wastage and contaminants within the industries. Saving water is more important. This final aim can be achieved by mistreatment the exiting ANN system. It will give how to save lot of flood water within the fields for future irrigation purpose.

Anjum Awasthi et al, [13]: The proposed system in this paper is designed by considering the requirement of a sugarcane crop for Indian climatic conditions. The WSN in agriculture is new technology for info acquisition and process in sugarcane field. It is a lot of advantageous than the standard agriculture techniques. This work structured the exactitude agriculture observance system by wireless device nodes and base station to record the information of device nodes. This is low value system wherever the recorded info is transmitted to remote location employing a GSM network via a SMS. The farmer might use the received info to manage the parameters. This kind of wireless detection and management improves the effectiveness and potency of resources used, which leads to the improved production. The drawback of system is its dependency on the GSM network.

Rolf A. Kjelly, Linga R. Cenkeramaddi [19]: This text presents the prototype design and testing of a long-range, self-powered IoT devices for use in precision agriculture and aquaponics. The devices are designed using the ultra-low power nRF52840 microcontroller with Bluetooth 5 support and ambient energy harvesting. A power of 942_W is harvested in an indoor environment. The devices are therefore suitable for both indoor and outdoor use, as natural sunlight will provide far more energy compared to artificial indoor lights. However, the coverage area and range can be extended significantly by deploying the devices in multihop network topology. The custom multi-hop protocol provides energy efficient communication from any device in a wireless sensor network to a gateway while consuming an average of 267_W with a transmission interval of 5 minutes. The sensor data is transmitted to a gateway, which then forwards it to a local server or cloud service, where the data can be analyzed to optimize the assembly in agriculture.

3. Problem Identification

In multi-hop WSNs, the nodes can have different energy consumption rates. Since the nodes near the base station are routers for other nodes, the packet transmission ratio is significantly higher than the others are. This excessive packet traffic causes nodes to consume more energy. As a result, the node is disconnected from the network because of the energy is exhausted. Also all nodes that connected as relay type with the disconnected node is disconnected from the network. Efficient energy consumption methods make to achieve good performance from the WSN application in such situations. It needs to know the causes that increase the energy consumption for the development of the best methods.

4. Objective

The main goal of this paper is to understand the existing IoT device systems for agriculture implemented using various techniques and to propose a novel automated system with all the necessary requirements and very less human intervention with the system. The main technology used is IOT by which the authors have implemented various sensor node over a single control unit at a regular interval of time, automated water supply to the plants is done on basis of soil moisture sensor readings. We are making a system that need not be dependent on internet only to fetch important data related to field, we included Bluetooth module as well so that we can get all the reading even if internet is slow or down.

5. Proposed Work

- To provide a low cost solar power auto irrigation system that can be implemented in irrigation especially by the farmers of developing countries like India, using ESP32 Module.
- To develop and deploy a system that includes a bunch of different sensors to find real time status of the field over internet as well as without internet.
- To develop a system that needs minimum power to run node of WSN.
- To develop a methodology to use renewable source of energy and make our farmers not be dependent on electricity.

System input parameters are soil moisture. Data are collected at centre node and used for deciding control action based on settings feed earlier. The settings can be altered anytime later. At user end a temporary webpage is to be developed which will provide interface between the system and the user for further information and processing. Few parameter need to be monitored like:- temperature and humidity of atmosphere, soil moisture level, air pressure by the system to take required action. An extra parameter of battery level indication is also included so that we focus toward the energy harvesting as well.

Requirement of the System

- ESP32 Module
- DC Water Pump
- Solar Panel
- Soil Moisture Sensor
- Air Pressure Sensor
- Camera for live tracking

IRRIGATION control system

The ESP32 Module and sensor network are connected using UART (universal asynchronous receiver / transmitter). When the moisture sensor senses the low wetness content of the soil, it provides a symptom to the microcontroller. The Module then gives a signal to relay to switch on the pump and at the mean time other parameter like temperature, humidity, air pressure, visible light and battery level is also monitored and reading of each sensor get updated on a temporary webpage created with the of HTML coding.

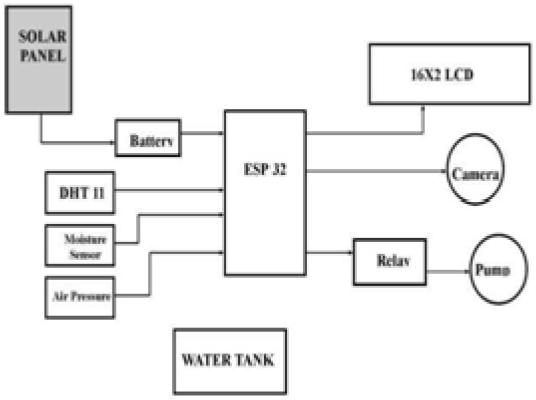

Figure 2: Block diagram of Irrigation control system

5.2.1 Atmospheric Pressure Sensor

BMP280 is one of sensor of BMP XXX series. They are all designed to measure Barometric Pressure or Atmospheric pressure. BMP280 is a high precision sensor designed for consumer applications. Barometric Pressure is nothing but weight of air applied on everything. The air has weight and wherever there is air its pressure is felt. BMP280 sensor senses that pressure and provides that information in digital output. Also the temperature affects the pressure and so we need temperature compensated pressure reading. To compensate, the BM280 also has good temperature sensor.

Figure 3: BM280 Atmospheric Pressure Sensor

Thingspeak (An API)

The ThingSpeak API (application programming interface) is an open source interface which listens to incoming data, timestamps it, and outputs it for both human users (through visual graphs) and machines (through easily parse-able code). ThingSpeak is especially useful for smaller hardware projects where connectivity over the Internet is required but in which the maintenance of a dedicated communication server is not practical. Alternative IoT services exist but tend to require payment for some of their functionality and are consequently not open source [21].

MQTT Protocol

MQTT may be a machine-to-machine (M2M)/"Internet of Things" property protocol. MQTT may be a light-weight publish/subscribe electronic messaging protocol designed for M2M (machine to machine) measure in low information measure environments. The protocol, which uses a publish/subscribe communication pattern, is used for machine-to-machine (M2M) communication and plays an important role in the internet of things (IoT).

Table 1: MQTT protocol message

MQTT Message	Description
CONNECT	Client request to connect to server
CONNACK	Connect acknowledgement
PUBLISH	Publish Message
PUBACK	Publish acknowledgement
PUBREC	Publish Received
PUBCOMP	Publish complete
SUBSCRIBE	Client subscribe request
SUBACK	Subscribe acknowledgement
PINGREQ	PING Request
DISCONNECT	Client is disconnecting

TCP/IP (Transmission Control Protocol/ Internet Protocol)

TCP/IP, or the Transmission Control Protocol/Internet Protocol, is a suite of communication protocol won't to interconnect network devices on the web. TCP/IP also can be used as a protocol during a personal network (an computer network or an extranet).

The entire internet protocol suite -- a set of rules and procedures -- is commonly referred to as TCP/IP, though others are included in the suite. TCP/IP specifies how data is exchanged over the internet by providing end-to-end communications that identify how it should be broken into packets, addressed, transmitted, routed and received at the destination. TCP/IP needs very little central management, and it's designed to form networks reliable, with the ability to recover automatically from the failure of any device on the network.

UART Communication (Bluetooth)

In UART communication, two UARTs communicate directly with each other. The transmission UART converts parallel knowledge from a dominant device sort of a processor into serial type, transmits it in serial to the receiving UART, which then converts the serial data back to parallel knowledge for the receiving device. Only two wires are needed to transmit data between two UARTs. Data flows from the Texas pin of the transmission UART to the Rx pin of the receiving UART:

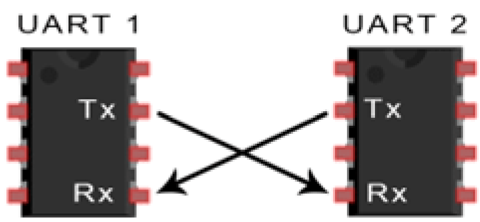

Figure 4: Way of Communication Between two UART devices

6. Result / Discussions

The System can works in two modes depending on availability on Internet source. Mode 1 include internet to update various sensor data on an API called ThingSpeak, so that data can be accessed from anywhere in world. And Mode 2 includes Bluetooth to update data on mobile parallel. Bluetooth facility is included so that even in absence of Internet we will get all the sensor data. The given below shows the graphical representation of the system designed.

Here we design the system for two modes which are:

MODE 1:- Internet Mode

Case 1: With the help of DHT 11 sensor we are taking field temperature in Degree Celsius and that data obtained by sensor isgiven to our control unit (ESP 32), so that it can be updated on ThingSpeak at regular interval.

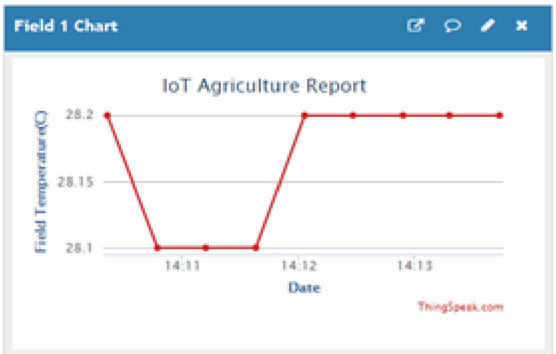

Figure 5: Field Temperature (deg C)

Case 2: With the help of DHT 11 sensor only we are taking field Humidity in percentage (%) and that data obtained by sensor is given to our control unit (ESP 32), so that it can be updated on ThingSpeak at regular interval.

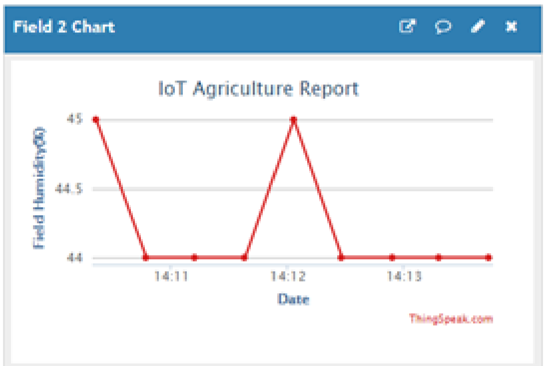

Figure 6: Field Humidity (%)

Case 3: Next parameter we included is atmospheric pressure and that can be obtained using BMP280 sensor. BMP280 uses I2C protocol. I2C protocol devices need only 2 pins i.e, SCL and SDA to fetch data to ESP32 unit. Standard unit of Pressure is Pascal, and we are updating that data on ThingSpeak.

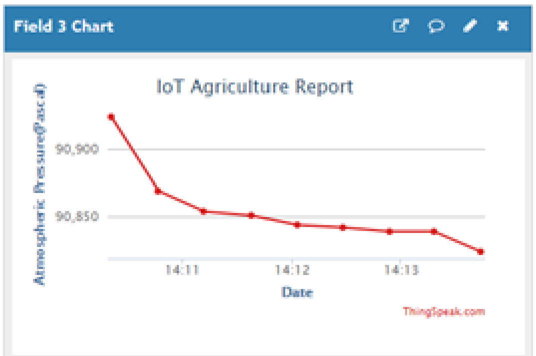

Figure 7: Atmospheric Pressure (Pascal)

Case 4: Next parameter we included is Visible Light Level and that can be obtained using Light Dependent Resistor (LDR) sensor. LDR provides analogue signal to fetch data to ESP32 unit. Standard unit of Light is LUX, and we are updating that data on ThingSpeak.

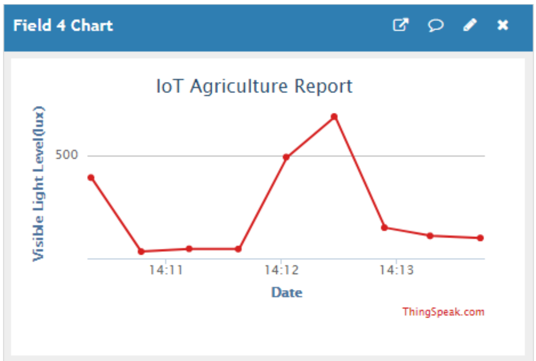

Figure 8: Visible Light Level (lux)

Hardware Simulation Operation

After making all the required connections with control unit, I initially tested all the necessary command to operate Wifi Module and Bluetooth Module. Then inserted soil moisture sensor into soil. On the dry state situation pump automatically to provide sufficient water to soil. I included BMP280 sensor, DHT11 sensor, LDR sensor to monitor various parameter of the field.

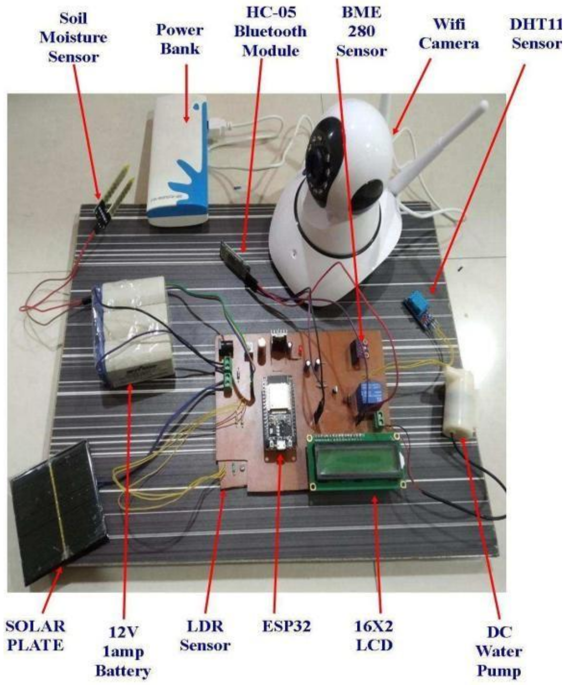

Figure 9: Hardware simulation of proposed system

7. Conclusion

A prototype IoT device has been developed supported modular approach and tested successfully. The IoT device can potentially last for more than 5 months (transmission interval of 15 seconds) on battery without any energy harvesting, sufficiently long for the dark seasons of the year.

IoT devices for agriculture have been designed and tested based on the ESP 32 with a multi- hop protocol. The nodes are embedded with environmental sensors. The multi-hop protocol is highly efficient and a maximum hop-by-hop delay of 0:15 s assuming successful transmissions. Additionally, due to its dynamic nature, nodes can be moved, added or removed from the topology without any issues, as the topology will quickly adapt to any changes.

8. Future Scope

We are using 2 different power sources for powering up the complete system. Currently we are using 12v 1amp battery as power source and we are using 5v 1amp power bank for camera. So in future we can use single power source for powering up both the section of the system. Apart from power supply section in future we can include another serial device named as GSM module so that even in absence of internet we will get alert in form of SMS. GSM module can provide us facility of SMS as well as internet using GPRS.

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