Journal of Informatics and Mathematical Sciences
Vol. 9, No. 1, pp. 129–136, 2017
ISSN 0975-5748 (online); 0974-875X (print)
Published by RGN Publications

http://www.rgnpublications.com

Research Article

A Novel Cognitive Radio Enabled IoT System for Smart Irrigation

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Abstract. A novel architecture is proposed, presented andanalyzed for Internet of Things (IoT) driven smart agriculture setup. This smart setup integrates Cognitive Radio technology to result in a ubiquitous connected system.The proposed system will optimize the use of natural resource i.e. water. Typically, the flow of water for irrigation of crop fields is not uniform due to many reasons including non-uniform terrain, availability of resources at different sites and etc. This non-uniformity produces lesser product from the available farms. This results in economically challenging for third world countries with limited resources. The proposed system uses two data types to model the different conditions of crop filed. Based on these assumptions, the proposed system is analyzed. The simulation results for the proposed scenario are also presented.

Keywords. Smart Irrigation; IoT; Cognitive Radio

MSC. 97C30

Received: July 1, 2017 **Accepted:** July 21, 2017

1. Introduction

The IoT (Internet of Things) refers to the connection or network of devices or nodes (of every-day life) to provide efficiency in different areas of interest [10, 24, 8]. Things refer to all the objects with radio identification that can be sensed and communicated. Thus, all the available devices will be connected to produce ubiquitous connectivity. The statistics show that presently 9 billion devices are interconnected and available on the planet that will rise to 24 billion devices by 2020 [6]. Additionally, US National Intelligence Council (NIC) expects that by 2025 IoT may be the part of all the everyday things like food packing, utilities, furniture etc. Besides, it is also included IoT into the list of six technologies that would have a significant impact on national power [15, 1]. In addition to the many benefits offered by this exciting technology, there are also many challenges faced by it. These include discovery, scalability, interoperability, technological standardization, wireless ubiquitous connectivity, security and privacy issues [1]. The IoT is bringing a new direction of thought towards areas of electrical power generation through introducing smart patrol system in addition to improve power distribution and transmission [13]. Furthermore, this evolving technology also finds applications into predication of natural disasters, industry applications, water scarcity monitoring and data analysis, smart homes, medical applications such as autonomous healthcare monitoring systems, smart infrastructure. Futuristic that include robot taxi, city information models, smart museums, gymnasiums, smart industrial parks and smart cities [1, 21].

Cognitive Radio is attributed as a principal technology for implementation of 5G wireless communications [2]. Cognitive Radio exploits the RF spectrum an intelligent manner. It searches for the unutilized bandwidth and transmits the data over those bands in opportunistic method. Thus, the radio can provide ubiquitous connectivity to the proposed IoT platform for smart irrigation [7]. These radios are already allowed to operate in vacant broadcast bands in USA and UK with low power constraint [14]. Thus, it is a practical idea to implement cognitive radio on the back of the IoT platform. Besides, RF spectrum allocated to licensed users in villages is also scarcely utilized. Thus, using proposed platform the RF spectrum will also be fairly utilized. This radio can work in both underlay and overlay schemes. Overlay schemes refer to the communication setup where opportunistic radio (cognitive radio) uses licensed spectrum bands when there is absence of a legitimate user or it transmits in an orthogonal manner. This technique produces limited interference to the legitimate or cellular user; however, the opportunities are limited for such kind of communication Underlay communication refers to the technique when cognitive radio operates in presence of a legacy user or cellular user. Under this scheme, enormous opportunities are available for transmission however the network architecture becomes much more complex [4, 12]. Cognitive Radio is also implemented into available broadcast bands (i.e. TV and microphone) in USA. This transmission is followed on the rules set into first IEEE standard for Wireless Regional Area Network i.e. IEEE 802.22 [3].

The ability to collect transmitted data from micro sources that can monitor physical and natural quantities i.e. environment can help in identifying several phenomenon based on the collected data. These networks are evolving out of advancements in very large scale integration (VLSI) technologies and improved embedded system design. Furthermore, the need to create longer, lasting and self-healing networks has caused great advancements in the network design algorithm especially on the layer 3 i.e. Network Layer. These algorithms have also a direct impact on energy conservation of independent nodes.Thus, having large clusters of wireless sensors transmitting data towards a central source have given the Internet of Things (IoT) a wide scope in monitoring and mass control networks. In mass control networks, such sensors are being used to control and activate relays that involve a transducer system to interact with the physical quantity in question. However, such networks cannot be directly applied to a scenario and need to be configured with specific settings. The configuration that is efficient for one network might not be efficient enough for another network because it depends upon the following parameters:

- Sampling and transmit interval for the sensors to sample and send the data
- Transmission rate – high throughput is undesired for a simple true/false detection
- Channel coding – due to the dynamic behavior of wireless channel
- Modulation Type – Under random error channels a spectrally efficient modulation can be used while under Bursty channel conditions, BPSK may be the only choice [19]

Hence, for a given scenario, a framework for modeling and implementing a cognitive radio enabled IoT network is a necessary step so that the effective utilization of resources such as bandwidth, power, time and frequency could be achieved. In our paper, we present a cognitive radio driven IoT based system to monitor water level into crop-field, as shown in Figure 1. The proposed framework will provide a reference to the researchers going for implementation of such a task.

Cognitive Radio is a natural enabler technology for IoT framework [18, 23]. IoT for smart agriculture system can also play an important role in the efficient utilization of natural resource such as water. Algeria is a recent example, whose economy after getting a hit from lower oil prices can utilize this exercise for providing better agricultural resources [9]. In this direction several researchers have designed smart agricultural system based on IoT that exploit cellular bands for transmission purpose. In [20], researchers use gun method to sprinkle water on the agricultural plot wherever necessary. This setup uses GSM connection to control the smart agricultural setup that is microcontroller enabled. Similarly, authors [16] use GSM setup to monitor the crop monitoring, and authors [11] use GSM to control the use of water and power resources for smart agricultural setup. Additionally, authors [5] introduce a novel system that uses wireless technologies and IoT framework for efficient distribution of water to agriculture land. In [22] authors present a system that incorporates temperature adjustment in addition to fair distribution of water through cloud based computing and IoT. In [17], authors propose a framework that can be utilized by the researchers for the efficient usage of water. Furthermore, authors in [6] also gives a comprehensive summary of the IoT and cloud computing architectures for future wireless systems.

In this paper, a novel system is proposed, investigated and analyzed for smart irrigation system that incorporates two evolving technologies i.e. IoT and cognitive radio.

Rest of the paper is organized as follows: Section 2 presents the proposed system model and simulation framework. Section 3 presents conclusion of the paper.

2. System Model

We first model the farming setup in the context of a physical environment with similar conditions as a typical farm field with continuously changing natural and physical climatic properties.

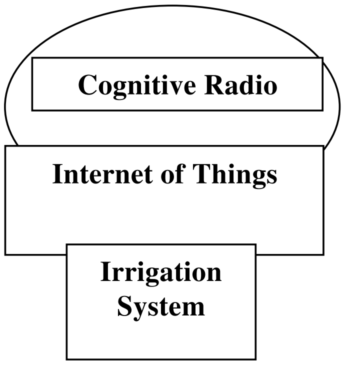

Figure 1. Proposed System

A typical crop field with sensors placed near crops over a defined area acts as a field of simultaneously data emitting sources that can be thought of as either delta source or threshold source. These can be defined as follow.

- *Delta source:* emits data only on change in the value of a physical property that is being monitored.
- *Threshold source:* emits data only when a certain threshold has been reached for the physical property that is being monitored.

The performance of these sources is evaluated using typical crop field that is being:

- Irrigated
- Experiences a temperature change of 3 degrees over a 5 hour time scale

In this paper, evaluation of irrigation scenario is presented.

2.1 Crop Field as Delta Source in an Irrigation Scenario

In this case, physical process that is being observed will be of irrigation through small channels that are drawn out in the crops so that the water can flow steadily and with equal volume in all channels. Such an irrigation technique is the oldest technique in use and has been used all over the world even till today as shown in Figure 2.

The data source is assumed a tiny humidity sensor that is placed in the middle of a crop row that is being irrigated by a small irrigation channel. The reason to place this sensor in the middle of the crop row is to check whether more than 50% crops in a given crop-row receive the desired volume of water. This sensor can also be placed at the end of the row to check whether all the crops that are 100% receive the desired volume of water. Consequently, three sensors can be used within a crop row as well to check water availability at 0% , 50% and 100% of the crops in a given crop row and hence the chances of a blockage within an irrigation channel can be found out by monitoring the difference in the 3 values provided the water flow is constant.

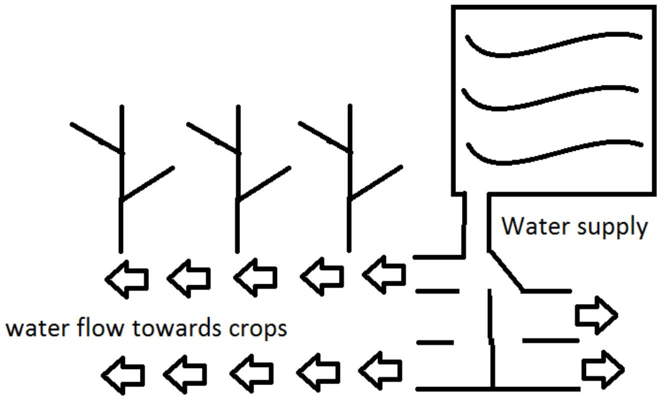

Figure 2. Shows a Typical Water Channel Irrigation Method Illustration

As the water flows through the channel, the crops within a given row consume it and the flow volume decreases and when the water flow reaches the middle of the crop row, delta sensor detects a change in moisture and emits that data change through a tiny radio sensor with low payload. The steadily flow of water that is feeding the water channel causes more water to flow through all sections of the channel and moisture levels increase which are detected by the sensor and emit as data packets. With time the sensor reaches a state where maximum moisture is detected and the change in moisture that was emit by the sensor will be zero. If a graph of values vs. time is drawn out for the given scenario, it would look like as shown in Figure 3.

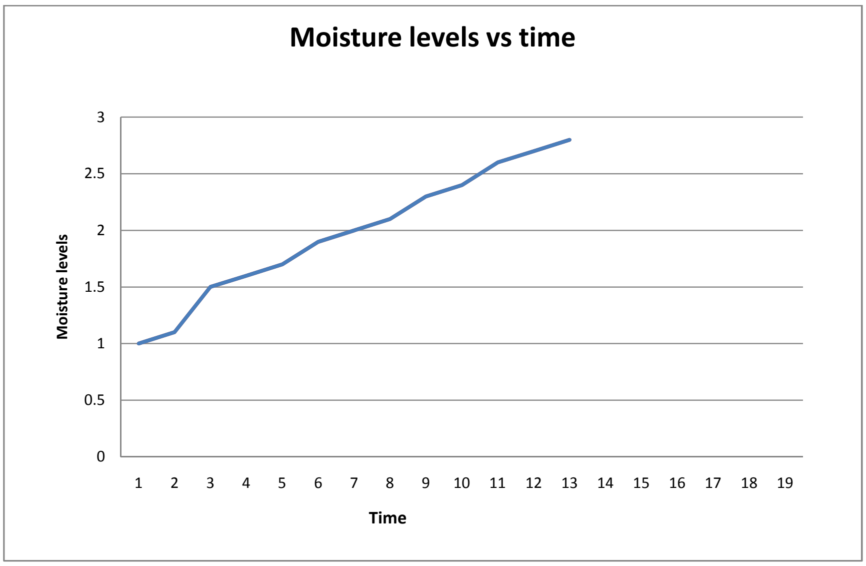

Figure 3. Shows Sensor Emissions in Delta Case

This data can be collected and manipulated over time to figure out optimizations that can be done to an existing irrigation system. Once this data is obtained, analytics and predictability can also be applied to this source of data.

2.2 Crop Field as a Threshold Source

The setup for this scenario is as same as the previous scenario but with a difference that our sensor will now transmit out data only when a specified threshold for moisture is reached for the crop or area of crop where the sensor is placed at.

In this situation, the water channel will irrigate the crop row and when the sensor placed at the crop will send out the following graph of values vs. time as shown in Figure 4. It is a step signal, modeling a onetime emission of data packets rather than continuous transmission of data packets for the source.

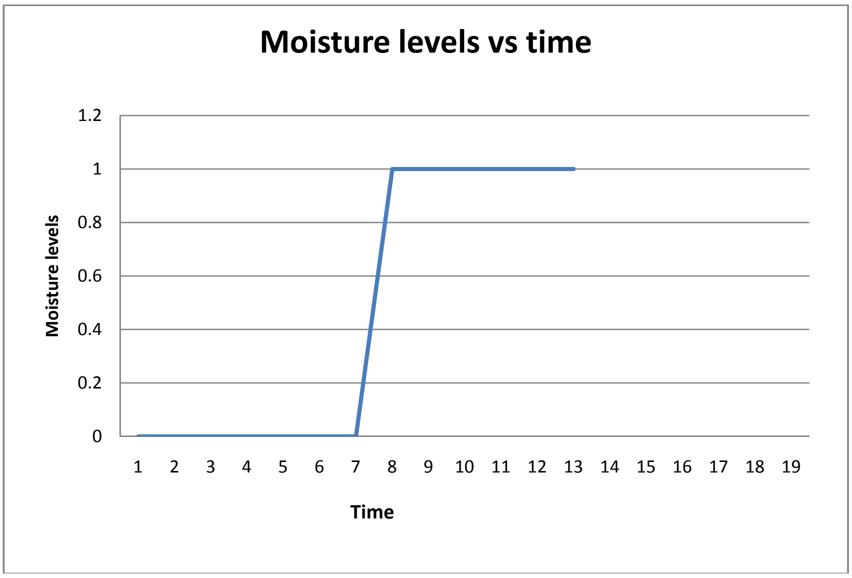

Figure 4. Shows Threshold Case Sensor Emissions

3. Conclusion

A novel architecture for IoT based smart irrigation system employing cognitive radio technology (for ubiquitous connectivity) is proposed, analyzed and presented. The proposed system not only efficiently utilizes natural resource such as water but also utilizes wireless and RF resources in an efficient manner. The simulation results demonstrate the possibility of the same. The proposed system will exploit RF spectrum in secondary fashion. Thus, for ubiquitous connectivity this system does not require any other network. This is beneficial because under extreme circumstances one cannot find the available connection of cellular and Wi-Fi.

Acknowledgements

The authors are highly thankful to the NED University of Engineering & Technology that provided all the required resources that were necessary for the successful completion of this paper.

Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

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