Soil Quality Management using Wireless Sensor Network

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***Abstract*— Wireless Sensor Networks are used to examine environmental conditions using a set of spatially distributed sensors. This is done by cooperatively exchanging data between nodes, until it reaches the Gateway node. One of the various applications of WSN is in monitoring soil parameters. Soil management can improve the yield by accurately monitoring the quality of soil according to the crop. Incorporating Wireless Sensor Network into the proposed Soil Quality Management System makes it possible to measure various qualities of soil like Electrical Conductivity, pH, temperature, NPK (Nitrogen Phosphate Potassium) content and light intensity. In the proposed system, a farmer can get real-time test results of significant soil parameters, which play a crucial role in increasing the yield. This system makes use of the hardware platforms, Arduino and Raspberry Pi which are open-source.**

Keywords—Wireless Sensor Network, Internet of Things, Soil Testing, Cloud.

I. INTRODUCTION

It is estimated that the human population will increase from 7.3 billion in 2015 to 9.1 billion by 2050 [1]. Correspondingly, there should be an increase in food production by 70% to feed this growing number. As of 2016, the cultivable land available in the world is 11.61%. This number is decreasing by the day. Traditional farming methods will soon be insufficient. The need of the hour is to improve farming methods so as to grow crops using a smaller portion of arable land to produce a higher yield.

There has been a massive growth in the consumption of fertilizers since the Green Revolution period in 1960s [2]. This is shown in Fig.1. India, China and the United States of America combined comprise more than 50% of fertilizer usage around the world. The fertilizer consumption in India is growing at the rate of 5% per year.

The impetuous use of fertilizers is one of the causes of declining productivity. Inadequate soil testing facilities and lack of guidance has led to a reckless usage of fertilizers. By knowing the nutrient requirement for a particular crop and measuring the current NPK readings of the soil, the appropriate amount of fertilizer to be used for that specific crop can be calculated. Using an optimum amount of fertilizer will result in higher yield. Some fertilizers are more acidifying than others, and should be used in sparingly low pH soils.

The Internet of Things (IoT) is transforming agricultural practices to meet the demands of growing population [3].

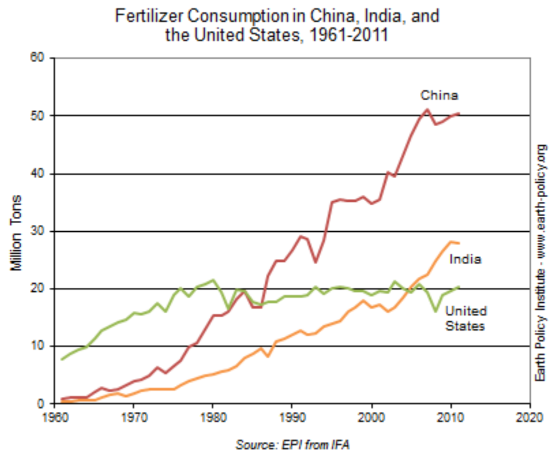


Fig. 1. Rate of Fertilizer Consumption

IoT is a system of interconnected objects, both living and non-living which interact with each other and the surroundings, without human intervention. If these objects are autonomous sensors which communicate with each other, then this arrangement of sensors forming a network is known as Wireless Sensor Network (WSN) [4]. A schematic diagram of a WSN is shown in Fig. 2. This type of network is sometimes referred to as Wireless Sensor and Actuator Network (WSAN).

The use of IoT in agriculture can result in judicious use of resources and hence combat the problem of decreasing cultivable land [3].

Experts have estimated that the number of connected devices in IoT is expected to increase from 500 million devices in 2003 to 50 billion devices in 2020. IoT allows objects to be remotely controlled from a distant network infrastructure, making it possible for the integration of the physical world into computer systems. Each object is identified uniquely in the network.

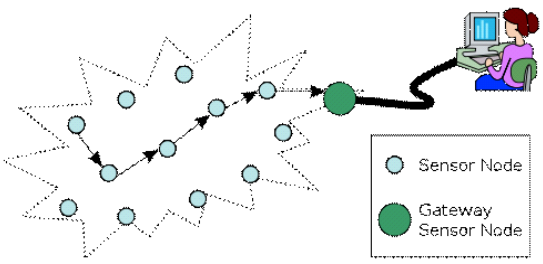


Fig. 2. Wireless Sensor Network

The main challenge in WSN is to use low cost, low power, miniscule sensor nodes [5]. In the field of agriculture, each node must be completely autonomous even with respect to the power source. These nodes must also withstand various weather conditions. In the proposed system, the sensor nodes are comprised of Arduino Uno microcontrollers that have sensors attached to it. Arduino Software (IDE) is used to program the board. An nRF module is connected to this microcontroller for communication in WSN.

A Raspberry Pi acts as a gateway node in the WSN. It basically uses Raspbian, which is a debian based Linux operating system. Other operating systems including Ubuntu and Windows can also run on it.

II. Design

A. System Architecture

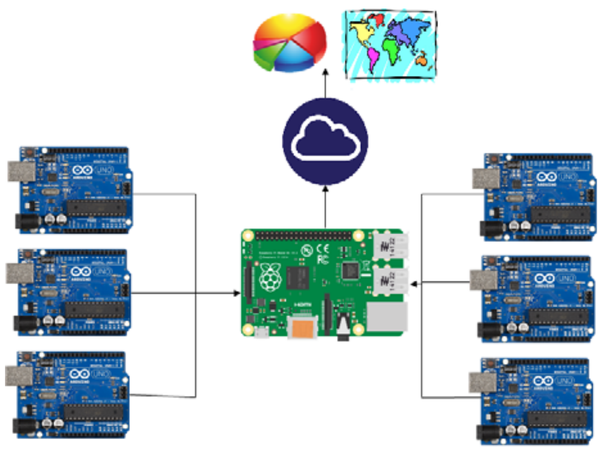


Fig. 3. System Architecture of the Soil Quality Management System

Fig. 3 shows the basic architecture of the proposed system. It consists of several Arduino UNO boards as sensor nodes which communicate with a Raspberry Pi that acts as a gateway node. This gateway node sends data to the cloud. The cloud platform which has been used is Amazon Web Services. On the cloud, data analysis is performed. Graphs and maps that show this information are generated as results.

B. Sensor Node Architecture

Arduino is a widely used open-source single-board microcontroller development platform with flexible, easy-to-use software and hardware components. Arduino Uno is based on Atmel Atmega328 microcontroller and has a clock speed of 16 MHz. It has 6 analog inputs with a built in analog to digital converter and 14 digital I/O pins. Hence making it possible to connect a number of sensors to a single Arduino board.

Sensor nodes in the network are individual units which are capable of collecting data from their environment and sending it to the gateway node. These Sensor nodes forming WSNs consist of an Arduino UNO connected to various sensors, a GPS module, a transceiver and a solar panel with battery pack as shown in Fig. 4. The sensors used include temperature, moisture (EC), pH and NPK sensors. These are connected to the analog ports of Arduino. A Boost converter is connected between the Arduino and the Battery.

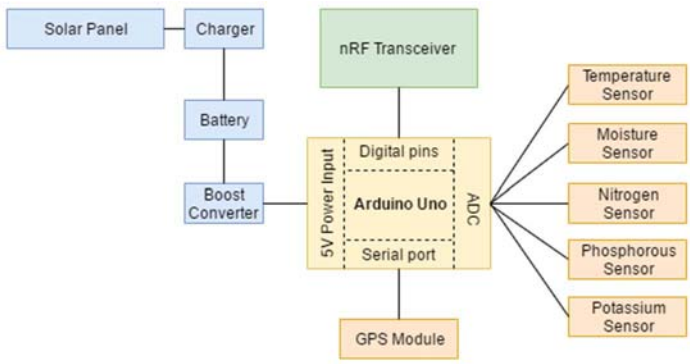


Fig. 4 Architecture of the Sensor Node

For measuring the temperature of soil, LM35 sensor is used. The amount of water present in the soil is measured by using a moisture sensor. From this, the water requirement of the crop can be monitored. Overwatering can hinder the plant's growth. Measuring the water content of the soil also helps in saving water as farmers can irrigate their lands only when required. pH sensors along with NPK sensors are used to maintain the quality of soil by recommending fertilizer usage.

For measuring NPK ions, sensors having selective electrodes are used. These sensors generate readings in analog form which are converted to their respective digital form by utilizing the Analog to Digital converter of Arduino. The readings are collected at regular intervals. The NPK sensors are covered by a mesh like structure with small sized pores so that only the water particles from the soil can come in contact with the membrane of the ion selective electrodes. This mesh like structure prevents the soil particles from touching the membrane as it may result in the membrane getting damaged.

The sensor nodes are powered by solar panels. They are also provided with a battery for backup. A GPS module is added to each node in order to obtain its current location. The location data is used for plotting the sensor nodes on a map. This gives a better idea of the placement of sensor nodes. The location of the sensor nodes may be varied for experimentation. The corresponding variations of the data readings can be studied to find the best locations for placing the sensor nodes. The GPS module is also necessary for security reasons to prevent theft.

C. *Gateway Node Architecture*

Raspberry Pi is a credit-card sized computer on a single board. It uses the system on a chip produced by Broadcom Corporation. It includes a CPU which is compatible to the ARM architecture. It also includes a GPU. The architecture of the gateway node is shown in Fig 5.

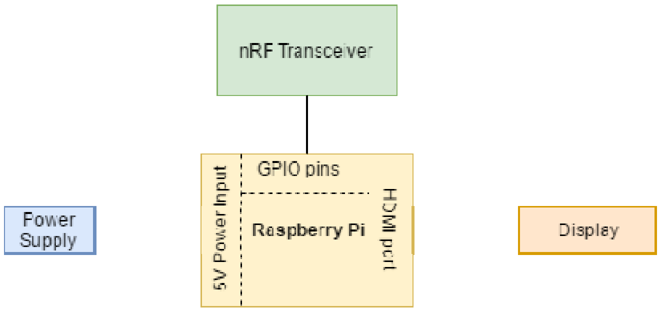


Fig. 5. Architecture of the Gateway Node

Data which is collected by sensor nodes is sent to Raspberry Pi by using an nRF transceiver. The Raspberry Pi acts as the gateway node of WSN. It collects data from all the sensor nodes in its network, at regular intervals. The serial data collected needs to be parsed to separate individual readings of the sensors. This parsing is done using Lex and Yacc code. This process is automated using a shell script. Parsed data is stored in a CSV file. This data will be analyzed in order to make predictions about the quality of soil.

D. *Uploading to Cloud*

A database on the cloud is used for storing historic soil quality readings. The database also contains the NPK rating of a list of fertilizers and NPK requirements of various crops. The newly collected soil test result data which is stored in the gateway node will be uploaded to this database on the cloud for analysis. This uploading process is also automated using shell scripting. The internet facility used by the Raspberry Pi for accessing cloud is provided by using a GSM module.

The formula used for calculating the amount of fertilizer, say, for Nitrogen required by a crop is as below in (1).

$$A_N = R_N \times \frac{100}{P_N} \qquad (1)$$

Where,

A_N= Amount of nitrogenous fertilizer per acre

R_N= Recommended Nitrogen for a crop per acre

P_N= Percentage of Nitrogen in that fertilizer

After calculating the amount of fertilizer required for NPK, this data is displayed on a dashboard for viewing. Other data like amount of water required by the crop is also displayed. All the data is sent to the farmer's mobile via Short Message Service (SMS).

III. RESULTS

This model for soil management is designed to provide an apparatus to make the process of soil quality measurement more convenient and automated. The time interval at which data is collected from the sensor nodes can be varied from one minute to one day based on the requirement. Depending on the frequency of data collection, the data is sent to the gateway node. A sample of the serial data which arrives at the Raspberry Pi (the gateway node) is show in Fig. 6. This serial data is parsed and individual readings are separated for storing in a CSV file. Fig. 7 shows what the CSV file looks like after this process of parsing.

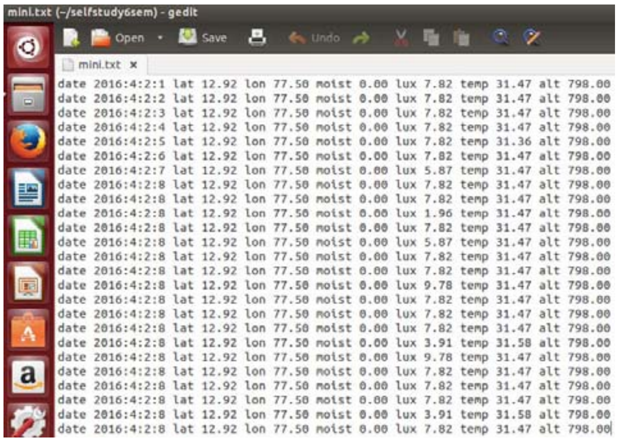
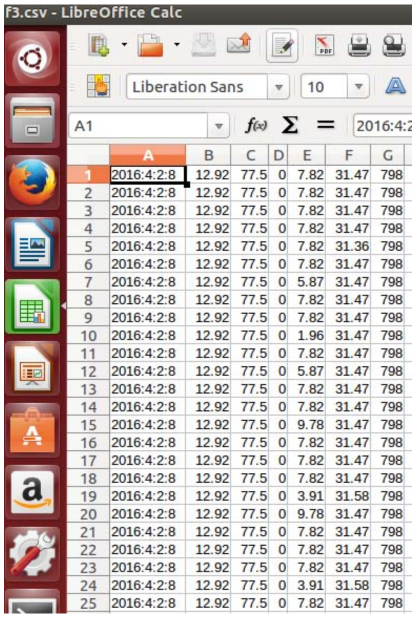


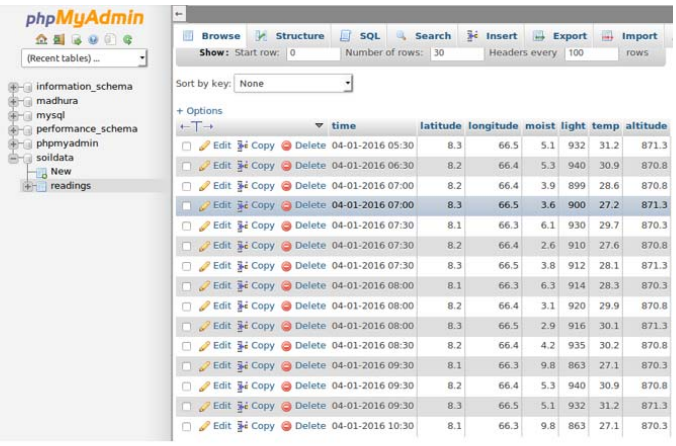
Fig. 6. Serial data collected by the Raspberry Pi



	A	B	C	D	E	F	G
1	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
2	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
3	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
4	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
5	2016:4:2:8	12.92	77.5	0	7.82	31.36	798
6	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
7	2016:4:2:8	12.92	77.5	0	5.87	31.47	798
8	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
9	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
10	2016:4:2:8	12.92	77.5	0	1.96	31.47	798
11	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
12	2016:4:2:8	12.92	77.5	0	5.87	31.47	798
13	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
14	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
15	2016:4:2:8	12.92	77.5	0	9.78	31.47	798
16	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
17	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
18	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
19	2016:4:2:8	12.92	77.5	0	3.91	31.58	798
20	2016:4:2:8	12.92	77.5	0	9.78	31.47	798
21	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
22	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
23	2016:4:2:8	12.92	77.5	0	7.82	31.47	798
24	2016:4:2:8	12.92	77.5	0	3.91	31.58	798
25	2016:4:2:8	12.92	77.5	0	7.82	31.47	798

Fig. 7. CSV file containing the data after parsing

The gateway node uploads the data from the CSV file to a database on the cloud. Fig. 8 shows a glimpse of the cloud database. The upload process is carried out as soon as new data arrives to the gateway node. In this way, even a small change in the condition of the soil and the atmosphere of the crop can be monitored.



	time	latitude	longitude	moist	light	temp	altitude
Edit Copy Delete	04-01-2016 05:30	8.3	66.5	5.1	932	31.2	871.3
Edit Copy Delete	04-01-2016 06:30	8.2	66.4	5.3	940	30.9	870.8
Edit Copy Delete	04-01-2016 07:00	8.2	66.4	3.9	899	28.6	870.8
Edit Copy Delete	04-01-2016 07:00	8.3	66.5	3.6	900	27.2	871.3
Edit Copy Delete	04-01-2016 07:30	8.1	66.3	6.1	930	29.7	870.3
Edit Copy Delete	04-01-2016 07:30	8.2	66.4	2.6	910	27.6	870.8
Edit Copy Delete	04-01-2016 07:30	8.3	66.5	3.8	912	28.1	871.3
Edit Copy Delete	04-01-2016 08:00	8.1	66.3	6.3	914	28.3	870.3
Edit Copy Delete	04-01-2016 08:00	8.2	66.4	3.1	920	29.9	870.8
Edit Copy Delete	04-01-2016 08:00	8.3	66.5	2.9	916	30.1	871.3
Edit Copy Delete	04-01-2016 08:30	8.2	66.4	4.2	935	30.2	870.8
Edit Copy Delete	04-01-2016 09:30	8.1	66.3	9.8	863	27.1	870.3
Edit Copy Delete	04-01-2016 09:30	8.2	66.4	5.3	940	30.9	870.8
Edit Copy Delete	04-01-2016 09:30	8.3	66.5	5.1	932	31.2	871.3
Edit Copy Delete	04-01-2016 10:30	8.1	66.3	9.8	863	27.1	870.3

Fig. 8. phpMyAdmin console showing the data uploaded to the database

Various graphs are generated using the data on the cloud. These are displayed on the dashboard for viewing. Sample graphs showing light, moisture and temperature readings are shown in Fig. 9,10 and 11 respectively.

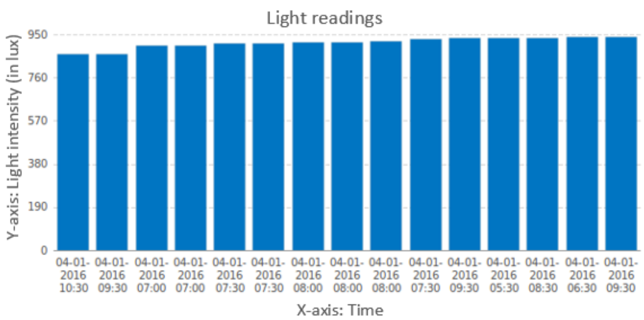


Fig. 9. Graph showing a range of light intensity readings

The data uploaded on the cloud is compared with historic and ideal data. The soil data is combined with the weather data for the particular location obtained from the Meteorological Department. Based on the crop grown in the field and the weather forecast, data analysis is carried out and farmers are suggested measures that are to be taken to improve the yield of their crops. Farmers also get frequent updates about the soil quality.

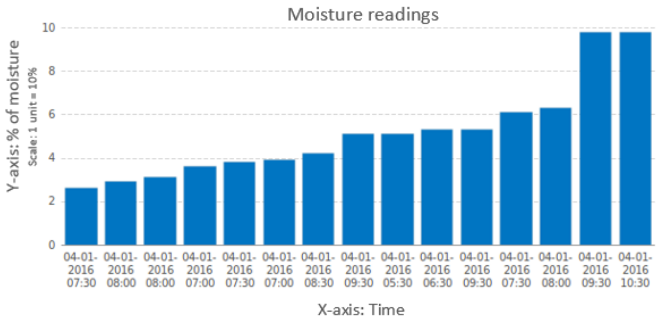


Fig. 10. Graph showing a range of moisture readings

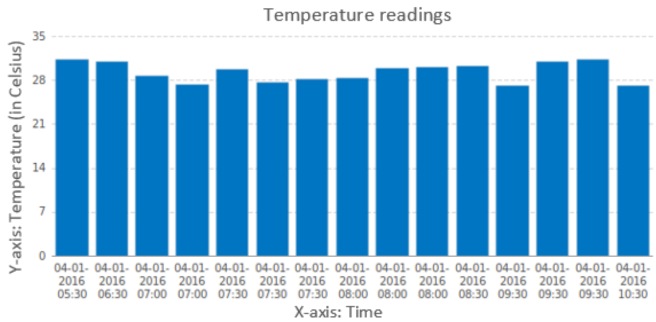


Fig. 11. Graph showing a range of temperature readings

To calculate the amount of Urea required for a yield goal of 3.85 tons/acre of Corn,

Where,

Recommended Nitrogen level = 170 lbs/acre

Reading of Nitrogen in the soil = 42 lbs/acre

R_N = Required Nitrogen for Corn crop

= (170 - 42) lbs/acre = 128 lbs/acre

P_N = Percentage of Nitrogen in Urea = 46%

$$A_N = R_N \times \frac{100}{P_N} = 128 \times \frac{100}{46} = 278.26$$

The amount of Urea required per acre (A_N) is 278.26 lbs. The farmer will be suggested to use this quantity.

IV. Conclusion

The applications of IoT in various fields are being explored all over the world. Seeing how the contribution of agriculture to economy is sinking, the proposed system is devised to improve the returns from the agricultural sector.

The proposed system takes into account the existing nutrient content of the soil, performs analysis on the data collected and gives suitable suggestions with respect to the needs of the crop.

Soil testing is done to measure the nutrient potential of the soil. Data analysis is performed in order to arrive at an optimum application rate of fertilizers for the tested soil. Over-fertilization can cause damage to the crops as well as the environment. The system acts as a tool in making informed ecological and economic land use decisions. It supports better management of available soil nutrients.

The system proposed by us can be built easily, maintained without much effort and has the advantage of being low-cost and easily scalable. The system is directed for use by not just farmers, but also researchers and others who are interested to know more about soil quality management.

As future work, the system can be enhanced to automate irrigation and fertilizer application based on the results generated by the system after analysis.

REFERENCES

[1] Rahman, M.M., Mostafiz, S.B. and Wahid, M.A., “Widespread production of bioenergy: land and water availability factors,” *Biofuels*, pp.1-10, 2016.

[2] Jaga, P.K. and Patel, Y., “An overview of fertilizers consumption in India: determinants and outlook for 2020-a review,” *International Journal of Science, Engineering and Technology*, Vol. 1, no. 6, pp.285-291, 2012.

[3] Zhao, J.C., Zhang, J.F., Feng, Y. and Guo, J.X., “The study and application of the IOT technology in agriculture,” In proceedings of *3rd IEEE International Conference on Computer Science and Information Technology (ICCSIT),* Vol. 2, pp. 462-465, July 2010.

[4] Alkhatib, A.A.A. and Baicher, G.S., “Wireless sensor network architecture,” In proceedings of *International Conference on Computer Networks and Communication Systems (CNCS)*, 2012.

[5] Sonavane, S.S., Kumar, V. and Patil, B.P., “Designing wireless sensor network with low cost and low power,” In proceedings of *16th IEEE International Conference on Networks (ICON),* pp. 1-5, December 2008.

[6] Chandra, A.A., Lee, Y., Kim, B.M., Maeng, S.Y., Park, S.H. and Lee, S.R., “Review on sensor cloud and its integration with arduino based sensor network,” In proceedings of *International Conference on IT Convergence and Security (ICITCS),* pp. 1-4, December 2013.

[7] Vujovic, V. and Maksimovic, M., “Raspberry Pi as a wireless sensor node: performances and constraints,” In proceedings of *37th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO),* pp. 1013-1018, May 2014.

[8] Bell, Charles., “Beginning sensor networks with Arduino and Raspberry Pi,” Apress, 2014.

[9] Suradhaniwar, S., Sawant, S.A., Badnakhe, M., Durbha, S.S. and Adinarayana, J., “An interoperable wireless sensor network platform for spatio-temporal soil moisture and soil temperature estimation,” In proceedings of *5th International Conference on Agro-Geoinformatics,* pp. 1-6, July 2016.

[10] Ferdoush, S. and Li, X., “Wireless sensor network system design using Raspberry Pi and Arduino for environmental monitoring applications,” *Procedia Computer Science*, Vol. 34, pp.103-110, 2014.

[11] Priyanka Rawat, Kamal Deep Singh, Hakima Chaouchi and Jean Marie Bonnin, “Wireless sensor networks: a survey on recent developments and potential synergies,” *The Journal of Supercomputing,* Vol. 68, pp. 1-48, April 2014.

[12] Liqiang Z, Shouyi Y, Leibo L, Zhen Z and Shaojun W, “A crop monitoring system based on wireless sensor network,” *Procedia Environmental Sciences*, pp. 558-565, January 2011.

[13] Li L, Xiaoguang H, Ke C, and Ketai H, “The applications of wifi-based wireless sensor network in internet of things and smart grid,” In Proceedings of *6th IEEE Conference on Industrial Electronics and Applications,* pp. 789-793, June 2011.

[14] Gubbi J, Buyya R, Marusic S, and Palaniswami M, “Internet of Things (IoT): A vision, architectural elements, and future directions,” *Future generation computer systems*, pp. 1645-1660, September 2013.

[15] Vermesan O, Friess P, Guillemin P, Gusmeroli S, Sundmaeker H, Bassi A, Jubert IS, Mazura M, Harrison M, Eisenhauer M, and Doody P, “Internet of things strategic research roadmap,” *Internet of Things-Global Technological and Societal Trends*, pp. 9-52, June 2011.

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