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Research paper

A survey on agriculture and greenhouse monitoring using IOT and WSN

M. Lavanya [1] *, Sujatha Srinivasan [2]

[1] Research Scholar School of Computing Sciences, VISTAS, Chennai, India
[2] Asst. Prof & Head, Dept. of Information technology School of Computing Sciences, VISTAS, Chennai, India
**Corresponding author E-mail: lavanyalalith1979@gmail.com*

Abstract

Internet of things (IoT) is connecting physical objects around us; those physical objects can be monitored with the help of sensors. A sensor is a device, which is used to sense physical property of an element, any events or any changes present in the environment and send the in-formation to other electronic device, frequently a computer. Many research are made on those sensor enabled IoT system to provide intelli-gent and smart services, towards smart greenhouse and smart agriculture .This paper will explore various existing IoT based agriculture and greenhouse system according to their deployment with an intension of identifying how it can be improved in future using IoT, WSN and a very recent scenario of using cloud computing.

Keywords: *Internet of Things; Sensors; WSN; Cloud Computing.*

1. Introduction

Due to the increase in population, demand for food to meet day-to-day requirements is also growing, on the other hand drastic changes of climate and water scarcity, availability of agricultural land is replaced mostly by corporate buildings and apartments particularly in metropolitan cities. Due to the increase of vehicles, the pollution level is increasing day by day. Many of these issues should not destroy the backbone of India which is nothing but agriculture. Apart from all the above issues the real challenge lies in cultivation of crops which gives more yield with the available space, some new practices, some new methods has to be followed. An ideal solution is to convert our home terrace or backyard in to a greenhouse.

A greenhouse is a framed structure with walls and roof made with transparent material such as glass or translucent plastic roof, in which plants will grow in a regulated climatic condition. The greenhouse materials like glass or plastic are designed to hold heat inside. It may be a cold weather, but the green house will provide a nice warm environment through which plants can grow
and flourish. It is noticed that the yield of greenhouse is considerably high due to the controlled environment. This does not happen in regular cultivating field. An added advantage of greenhouse is protection of plants from environmental pollution because of its closed structure.

Advantages of greenhouse monitoring and control

A moderate temperature and humidity can be maintained inside a greenhouse through which plant propagation is effective. It also helps to improve quality and quantity of production. Moreover, it reduces infestation of disease or pests. A major advantage is water conservation and fertilizer requirements as compared to open field cultivation. It also reduces the gestation period of the crop. IoT is an emerging trend, widely used to make objects to think wiser, and to provide prediction for an event based on its historical data, IoT device connected with sensors, the communication between those sensors requires wireless sensor network. Nowadays researchers are interested in developing many applications based on IoT and WSN, one such application is greenhouse cultivation. Section 2 of this paper will discuss overview of IoT and WSN. Section 3 discuss about related work done using IoT and WSN in agriculture and greenhouse. Section 4 explains about challenges and design issues of WSN. Section 5 describes about discussion and future challenges. Section 6 gives the conclusion.

2. An overview of IOT and wireless sensor network

2.1. Overview of IOT

IoT connects devices through networks and tracks performance of those devices from remote area. A large amount of communication devices in the IoT are embedded in to sensor devices in the real world. Sensor plays a vital role in IoT technologies. Five IoT techniques are widely used in IoT product and services.

Radio Frequency Identification

It is used for unique identification to track an object. A tag is associated with electromagnetic field through which the movement of any tagged objects are easily identified even from the remote places.

Wireless Sensor Network

Devices with sensor used to monitor physical conditions or environmental conditions, when it is combined with RFID systems to better track the status of such things, their location, temperature, and movements.

Middleware

Middleware is a software layer through which software developers perform communication to provide input and to receive output.

Cloud Computing

The data which is generated by many applications need to get stored and those data has to be processed in order to generate

meaningful information out of which better decision can be made for this purpose Cloud computing is used.
IoT Application
In IoT applications, device communicates with the human or with other device. The communication should happen in such a manner that sending and receiving of data or message is strictly based on time.

2.1.2. IOT components

By using wired and wireless network, components are tied together by standards and protocols which provide a strong connectivity. Sensors, actuators, people who control the environmental happenings via mobile phones, cloud services which is used for storing and to perform an analysis with the data collected from sensors are well known IoT components.

2.1.3. Applications

IoT can be used in many real world applications; some of the most prominent field of applications is;
Smart City
Smart city is one of the powerful application of IoT through which automatic transportation, water management , pollution control, traffic route updates , smart parking for vehicles , smart surveillance ,identifying water leakages , saving necessary resources such as electricity and water. Overall people can enjoy a complete and secured environment.
Smart Retail and Efficient Energy Utilization
IoT provides good opportunity for the retailers to communicate with the customer, through which they can enhance their experience of shopping. It is executed through the product preference by the customer.
IoT in Agriculture and Greenhouse
The demand of food products is a big challenge; IoT gives a solution to farmers to get better productivity in their agricultural land, shares knowledge to farmers about climate, soil and water level to get good yield in their crop.
IoT in patient care
IoT plays a vital role in health care industry, by tracking patient's health each and every second, RFID technique plays an important role in collecting patient's information even though if he/she resides in the remote place from where hospital is situated, their health data can be maintained and any issues can be attended then and there. Elderly pupil can also be taken care through this.
IoT in Farm animals monitoring
The behavior and health conditions of farm animals can be monitored and tracked even from the remote places with the help of IoT.
IoT in Industries
Industries with devices were the major source of producing large amount of data, termed as big data in order to utilize the data efficiently and effectively and to make efficient decision which is useful for business; those data need to be analyzed called as big data analytics.

2.2. Wireless sensor networks

Wireless Sensor Networks (WSN) are networks that consist of sensors which are dispersed in random manner. These sensors coordinate with each other to record the physical or environment parameters , the gathered information will get processed to extract required result, WSN protocols and algorithms has the capacity of self-organizing themselves.

2.2.1. Components of WSN

It is usually a mixture of hardware and software packages. Four components of WSN usually exists they are,
Sensors
This is connected with every node
Nodes
This is used collect from sensors and used to transmit the data to base station. The communication may either be in single direction or bi-directional, for only monitoring, single direction communication is used for monitoring and control bidirectional is used.
Base station
It is nothing but a web based connected to internet. Collected data from nodes are transmitted to the base station, irrespective of the location. It can be viewed in any system connected with internet.
Graphical user interface
A Web based software, which is used to view the data collected from the sensor.

2.2.2. Characteristics of WSN

It uses low power, less memory, limited energy because of its small size. It can be utilized effectively in harsh environment condition for example in too hot/ in too cold. It does not follow any specific structure. It is constantly reconfigured. Power consumption is the only constraints; due to the usage of batteries it can be saved. Heterogeneity of nodes gives the ability to cope with node failure and easy usage.

2.2.3. Applications of WSN

WSN is practiced in many places, predominantly in establishing smart home or smart office where sensors are used to control appliances and electrical devices, for example automatically switching off / switching on the lights, it pays the way for saving the source of electrical energy. In Biomedical / Medical it is used for monitoring glucose , heart rate , cancer detection any chronic diseases can also be implemented for hospital sensors For monitoring vital signs, record anomalies, also used in agricultural crop for inventory tracking , automated problem reporting., better plant maintenance. RFID is also used for theft detection. Monitoring over a region seems to be a common application of WSN. For example military is an example where the enemy's intrusion can be monitored and alarm can be raised as a sign of emergency However it can be used to monitor climate both in indoor and outdoor It also helps to monitor the animals habitat. It also helps to track our asset, It can be used in disaster management, health monitoring and soon.

2.3. Overview of greenhouse monitoring and control

Systems using IoT and WSN
IoT and WSN based green house, can be monitored and controlled from anywhere for example from office, while in meeting , during trip , the plant parameters such as soil temperature, soil humidity, environment temperature , humidity, pH value of soil, level of CO_2 and other pollutants like carbon monoxide, Ammonia , sulphur, can simply remote monitored. Automation of green house also implemented by connecting actuators like fan for providing ventilation , pump and motor for automatic watering , connecting lights also provides necessary heat for plants during winter season. Based on the data collected from sensors the controller unit will switch on or off the necessary actuators. It is known that IoT is interconnection of objects, with internet infrastructure, through which objects are allowed to transfer and receive data using the internet and those data gets transferred to other device within the internet infrastructure utilized by device which is connected to it for further evaluation.

3. Related work

This section will discuss about the research which was carried out using IoT and WSN in greenhouse or agriculture. Each paper has its own problem for discussion. Much type of sensors has been used for the research purpose. Some of the sensors like temperature and humidity sensors have been utilized almost by every researcher, through which the basic soil parameters can be acquired. The above two sensors can be considered as the basic sensors

which is required for agriculture and greenhouse for cultivating plants which give good yield.

BoselinPrabhu, et al. (2014) uses wireless transmission, sensor network instead of WSN with for periodic monitoring green house in an enhanced manner. A future development is to provide an energy efficiency algorithm for distributed and clustering mechanism (HEED). To monitor vital signs, temperature inside the animal cage. Shakthipriya (2014) discusses about precision agriculture, for efficient utilization of agro-ecological resources has been monitored with WSN, Mica2 Mote, and soil PH value along with leaf wetness.

Gomes et al. (2015) proposes a greenhouse with WSN and Zigbee, to monitor the parameter such as air temperature, humidity, pressure, soil temperature and moisture. The author discusses about his future research will be in tracking the greenhouse gases such as CO2, CO and O2. His goal is to automate greenhouse using actuators.

Ahmet Murat Turk et al. (2015) monitored two parameters such as temperature and humidity of greenhouse, he used Arduino, Raspberry Pi, sql for database operation and photovoltaic batteries for providing electricity. Result shows that from acquired data, prediction is possible for future. Data mining is also used for recording past data.

Keerthi et al. (2015) Implements of an electronic system basedGSM (Global System for Mobile communication), cloud computing and IoT for sensing climatic parameters of green house. A real-time environmental information for crop growth,focused ondeveloping a system that can automatically measure and monitor changes of temperature,light, humidity, moisture level in green house. Parameters collected for every 30 seconds. The complete module is of low cost, low power operation, more over easily available to everyone. Parameters are stored and retrieved for real time processing using cloud IoT.

ZhenfengXu, et al. (2016) uses, ACK mechanisms & LPL technology. To continuously run with low power for monitoring microclimate factors of greenhouse remotely. Energy saving methods and control strategies were the considerations for future research.

Jayashri Gajanan Hagaone et al. (2016) proposes a model in which Irrigation was monitored with ARM 9, Raspberry Pi controller, Embedded Linux board, with Zigbee protocol, and developed using Embedded C for watering crop algorithm along with CO_2 content is also measured. With the future application of system concluded that uniform watering of crop by analyzing soil parameters, which helps in reducing the fresh water consumption, also a plan to minimize human intervention in the agricultural land.

TomoPopovic et al., (2017) designed a model for enabled platform for precision agriculture and ecological monitoring solar radiation, leaf wetness is considered as parameters apart from temperature and humidity monitoring. The authors discusses that data analytics will be his future enhancement.Mustafa AlperAkkasa et al., (2017) said that Data analysis which also includes data even from actuation is his future goal. YuthikaShekhar et al. (2017) has analyzed soil moisture and temperature, with KNN machine learning algorithm for the prediction towards irrigating the soil with water. He used four data sets of soil such as dry soil, little dry, little wet, wet for identifying moisture level of soil.

Revathy et al. (2017) developed a system with Fuzzy logic along with Arduino controller has been effectively utilized for data collection.Here the author used sensors like temperature and humidity along with the actuators fan and fogger unit which is used for reducing temperature inside green house and water sprayer respectively. The author says that small scale agriculturists, rural farmers and remote green house can get benefit through her research work.

Juanjuan.(2017) Carried his complete implementation work inside laboratory , data acquisition, remote monitoring has been effectively carried with the data from indoor greenhouse as well as from outdoor rirrigation land , he has got the expected result as output.

Dan JericArcegaRustia et al. (2017) developed pest monitoring system for agricultural farm, and it has been tested in National Taiwan university where cabbage found to be major crop .Image processing is used to identify insects with the image obtained from Raspberry pi camera along with machine learning algorithm, K-means color clustering for real time update of the insects, pest count and environmental conditional data plots. The author discussed that finding pest by deploying more nodes in different locations will be his future findings. Aiello et al. (2017) detected Temperature of leaves with Data fusion algorithm. Implements an Effective Decision support system on the basis of simple rule based system like IF<Condition> then <Action> to suggest solution for the problem on the basis of the data gathered , with that available end solution monitoring climatic condition , potential risk of pest and how venting greenhouse prevent the spread of disease were discussed by the author.

Peerapak et al. (2017) said about minimizing energy power at the sensor node, by using an energy-efficient transmission algorithm. He used Greedy method for Data driven algorithm for monitoring light intensity , humidity , temperature in agricultural field .Performance of proposed energy-efficient algorithm is compared with two transmission protocol such as SPIN and ESPIN. The author says that the proposed algorithm seems to be an effective one. SrideviNavalur et al. (2017) discussed that PH value is one of the important parameter for growth of plants. PH value is acquired through sensors along with humidity for determining condition of soil. Apart from the above, water level in the field is monitored before watering the crops. She also discussed about the common issue that arise in agriculture land is power failure, has to effectively handled by placing solar rechargeable batteries.

Krishna Mohan et al. (2017) discusses about greenhouse which monitors plant parameters within plant premises and automation is also provided. Xueyan Zhang et al. (2017) found a solution for monitoring the production of citrus using zigbee protocol, Artificial intelligence, Decision support technology. The experiment result shows reduction in labour cost, pollution control which is caused by chemical fertilizer is major highlight of his work. A future enhancement of this research work is to optimize the high cost.

Shirsath et al. (2017) developed a prototype of Greenhouse with temperature, humidity and soil moisture sensors. Three mode of operations such as time based, sensor based and user based has been implemented with the prototype. Decision for future development is to handle the issue in providing data security for data.

4. Challenges of WSN

More and more applications can be integrated using IoT and WSN. This section highlights design and operational issues in WSN. In order to better utilize WSN for IoT applications, fallowing challenges to be sorted out.

4.1. Design challenges of WSN

Heterogeneous devices need to get connected and collaborated with each other. Centralized algorithm is needed as the processing is going to get carried on different nodes.Data should get transferred efficiently between sensors because sensor uses low bandwidth for communication. In order to get required results coordination among the sensor nodes is very much essential. Sensor should be utilized correctly to maximize the performance and to use less energy. Real time computation should be done quickly as soon as the new data get generated.

4.2. Operational challenges of WSN

The challenges of WSN are to utilize the available energy efficiently, another known and important constraint is only limited storage and computation has to carry out successfully. Low bandwidth and high error rates is another major challenge. The occurrences of errors are common will be in Wireless communication, Noisy measurements, Node failure are expected. One of most important challenge is providing scalability to a large number of

sensor nodes, Survivability of sensor nodes in harsh environments, apart from all challenges are experiments are time- and space-intensive.

5. Discussion and future challenges

This section is going to analyze previous work that has been carried in agriculture farms and greenhouse using IoT and WSN.

5.1. Discussion

It is gathered from the above research that some of the research gaps were identified, they are as follows, According to TomoPopovic et al. (2017) his work supports cloud technology, he is insisting about data analysis as future work. YuthikaShekhar et al. (2017) say a solution is required for spraying appropriate chemicals for proper growth of crop. And to look in to water level of tank before irrigating the field, DanJeric Arcega Rustia et al. (2017)
discusses a future development of his work is to deploy more nodes in different locations for insect monitoring. Aiello et al. (2017) discusses a future prediction to use predictive time series method for proactive decision making in his work.
SrideviNavalur, et al. (2017) raises more opportunities for future, to make decisions for watering schedules for plants, Plants and seed selection and protection of crop from seasonal attacks of animals and insects. Which part of plant is having dead cells and which part is healthy. Amount of chemicals required for plant growth. Xueyan Zhang et al. (2017) discusses about Silo solution and to optimize the high cost as his future work. Shirsath, et al. (2017) his suggestion for future development to handle the issue in providing data security for data. Mustafa Alper Akkasa , et al. (2017) said that Data analysis which also includes data even from actuation is his future goal.. Krishna Mohan, et al. (2017) came out with more future research suggestions such as to check which part of

5.2. Future challenges

Given below are areas that need a solution, which can also be considered as research gap.

i) Maintenance of necessary nutrition among plants is one of the critical aspects of greenhouse crops. Fertilizers are necessary to supply nutrients for plants. Three major nutrients for plants such as nitrogen, phosphorus and potassium are important for plants growth and healthiness. Monitoring these three nutrients to feed the plants whenever required, this has to analyze with IoT and cloud.
ii) Pest's management is an approach for managing diseases, insects and, weeds. Prediction of pests, to prevent from damages occurs in crops. Identifying pests accurately, identifying or measuring pest populations, assessing damage levels.
iii) Prior identification of the pest's location, controlling pests and disease in crops need a solution.
iv) Pesticides are often used according to the type of pests Decision support system is required for pesticide selection. Greenhouse sensors can be combined with cloud to predict the same.
v) A solution for seed selection based on the soil parameter, using, machine learning algorithm and cloud is required.
vi) It is necessary to monitor water level in tank before and after watering plants. In addition, to monitor water requirements of plants in a sunny day and in a wet day requires solution using machine learning algorithm and cloud.
vii) A solution is required to protect greenhouses from bird's entry and other flies.
viii) Remote tracking of all greenhouse belongings have to be carried out.
ix) Remote monitoring and counting number of fruits, vegetables and flower that are ready for use in all greenhouses requires a solution by using cloud.

6. Conclusion

IoT with WSN has been utilized for doing research in agriculture and greenhouse, many papers have been analyzed. The following were the three broad categories they were fall in to such as monitoring , prediction or to controlling the parameters like weather, soil , pest , CO2 , water level , crop yield, weather , and pest count and control. Some researchers have utilized machine learning

Table 1:. Iot Based Remote Agriculture and Greenhouse Monitoring Techniques

Reference	Application /Location used	SensorsUsed	IoT usage	Supports Cloud	Technology Used	Web based based/ App based/both	Limitations/ future research directions proposed
TomoPopovic, et al.,(2017)	Agriculture /outdoor	Temperature, Humidity, Leaf wetness.	Yes	Yes	Aurdino, Raspberry PI and Web based	Web based	Data analysis has been proposed as future work.
Mustafa AlperAkkasa, et al., (2017)	Agriculture /outdoor	Temperature , Light, Pressure & Humidity	Yes	No	Mica2 ,Zigbee Tiny OS , Nesc , Ado.Net	Both	Future work to collect data from actuators
YuthikaShekhar, et al. (2017)	Agriculture /indoor	Soil Moisture & Temperatue	Yes	Yes	Arduino, Raspberry Pi 3	Both	Spraying appropriate chemicals, water level of tank for irrigating.
Revathy. S, et al. (2017)	Green house /indoor	Temperature, Humidity, Fan, Fogger unit	Yes	Yes	Arduino, Fuzzy logic, Matlab	Web based	Crop growth is reliable degree of success has been increased in greenhouse.
Dan JericArcegaRustia, et al. (2017)	Agriculture /indoor	Atmospheric pressure , light intensity	Yes	No	Raspberry Pi 3, camera, PHP,WSN, Image processing , K-means algorithm	Web based	TO deploy more nodes in different locations for insect monitoring.
Aiello, et al. (2017)	Agriculture /indoor	Humidity , temperature	Yes	No	Data fusion algorithm,Dss for decision making	Web based	To use predictive time series method for proactive decision making
SrideviNavalur, et al. (2017)	Agriculture / outdoor	PH of soil, water level monitoring , humidity	Yes	No	WSN, Raspberry Pi , Data logger, python , Grove pi Solar rechargeable batteries	Mobile app	Watering schedules for plants. Plants and seed selection. Protection of crop from seasonal attacks of animals and insects.

Krishna Mohan, et al. (2017)	Greenhouse /indoor & outdoor	Illumination, Temperature, Moisture and Humidity	Yes	Server	ARM 7 ,Max 232 , Wi-Fi	Both	Future research to find which part of plant is having dead cells and healthy. Amount of chemicals required for plant growth.
Xueyan Zhang, et al. (2017)	Citrus crop /outdoor	Air and soil temperature and, humidity	Yes	No	ZIGBEE, AI , decision support technology	Both	Future work for Silo solution and to optimize the high cost.
Shirsath,et al. (2017)	Greenhouse Prototype	Temperature, soil moisture, humidity	Yes	Yes	Arduino, cloud	Both	To provide security toIoT data.
ZhenfengXu, et al. (2016)	Greenhouse /indoor	Air Temperature &Relative Humidity	Yes	Yes	Ack mechanism, LPL Technology,Mica 2 mote , Tiny Os	Energy efficiency	Energy saving methods of control strategies where the parameters for future research.
Gomes , et al. (2015)	Greenhouse /indoor	Air temperature, humidity, Pressure , Soil temperature and soil moisture	Yes	No	WSN , ZIGBEE	Both	Future research monitor parameters Co2, CO and O2. Using Actuation fora fully Automated greenhouse
Ahmet Murat Turk, et al. (2015)	Greenhouse /indoor and outdoor	Temperature, Humidity	Yes	No	Arduino& Raspberry pi , Sql , embedded c , photovoltaic batteries	Both	Result says from acquired data, prediction forfuture.
BoselinPrabhu, et al. (2014)	Green house/indoor	Temperature, Light , Humidity,CO_2, Vibration	Yes	No	Wireless network, Zigbee	Web based	Future development is to monitor animals in zoo. An energy efficient distributed clustering mechanism (HEED)

Algorithm in their work to make the system intelligent, Machine learning is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed. The primary aim is to allow the computers learn automatically without human intervention or assistance and adjust actions accordingly. Data analytics is the objective for the researchers with the data derived from IoT applications. The number of sensor is directly proportional to that of the data generated. Those data need to be analyzed in order to retrieve meaningful and useful information. The collected data is sent to the servers, where it is compared with previously collected data from similar machines. Changes are reported to the user, before any development of malfunction of the system. This analysis is done in real-time and the results are displayed on to the user's smart phone within seconds. Much research is possible by combining IoT, WSN, cloud and machine learning algorithm.

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