Internet Of Things (Iot) For Smart Agriculture And Farming In Developing Nations

Shiva Pujan Jaiswal, Vikas Singh Bhadoria*, Amit Agrawal, Hemant Ahuja

Abstract: Agriculture has been primary economic activity for the people of developing nations. The green-house based agriculture system enhanced by IoT for monitoring and controlling would provide better yield as well as quality as per required by the market. The use of Wireless Sensor Nodes (WSN), actuators, remote database server/cloud computing, remote access through user application integrated as part of IoT, will enable the efficient utilization of resources available. This paper aims to design the IoT based system for operation of agricultural activities which is scalable and cost effective so that developing countries and rural areas within the available infrastructure like internet, renewable resources maximize their throughput. The data collected can be further analyzed for environmental and climatic conditions and the economically productive crop to be cultivated throughout the year can be planned.

Index Terms: Internet of Things, Smart Agriculture, Wireless Sensor Nodes, Green-house, monitoring and control, cloud services

1. INTRODUCTION

The developing nations have majority of their GDP dependent on agriculture [1]. Agricultural activity extends from crop cultivation (farming), timber to livestock rearing for domestic consumption or economic purposes as raw materials to other activities. It has been the primary precursor for human evolution. The ever-increasing population has put on immense pressure on agriculture sector to meet the demands of growing population and technology. The estimated world population is expected to reach 8.5 billion by 2030 and 9.7 billion in 2050 [2]. China and India represent the two most populated countries in the world with more than 1billion people, with 19% and 18% of the world population. The population of India is expected to surpass that of China by 2022 [2]. These countries are also heavily dependent on agriculture to sustain the availability of livelihood of their growing population. The major challenges in agriculture in developing nations and rural areas can be stated as follows:

i. Quality of crops and land available for farming and agriculture.
ii. Lack of availability of utilities like electricity, machines, irrigation.
iii. The low economic condition of farmers.
iv. The disparity between product prices from farmers to customers. Involvement of third party has increased the gap between what farmers are paid and what customers buy for [3].
v. Climatic change has unpredicted adverse effect on the farming process and outcomes.
vi. Lack of technology in agriculture either due to lack of access, high cost of commissioning and operation or due to knowledge.

IoT is a system of interrelated computing devices, mechanical & digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction [5]. As field is distributed over a large area in agriculture for farming or animal gazing, the use of WSN finds the best option [6]. The low power consumption makes it able to work on batteries or solar for stationary node. The actuator nodes are connected to personal area network (PAN) as they require high power and their numbers are not as much as sensor nodes. This overall system can be integrated into IoT based system using existing local area network (LAN) and internet [8]. This hardware system is supported by cloud-based data analytic software which helps in remote monitoring and controlling of field nodes. So, IoT can play vital role in uplifting the role and functions of every component of agriculture and farming. From cultivation to livestock rising, IoT can integrate overall system into cloud-based system. Each animal and field area can be a node in IoT system and their status, performance parameter can be recorded into system. This information can be used for real time monitoring and control of various performance parameters like field moisture, nutrients, humidity and temperature of the field and crop. Furthermore, the tags on animals and livestock help to track their mobility pattern, feeding time table and health conditions. The resources in the field can be managed for maximum utilization of available resources. In developing nations, the main advantages of the IoT in agriculture and farming is the economical technology for development of agriculture process and system. The main advantages of integration of IoT in agriculture are listed:

i. It empowers farmers through knowledge about agricultural condition and maximizes their productivity, quality and profit through efficient use of available resources [4].
ii. The real time data about crop, environment and cattle help to act immediately improving yield [4].
iii. Proper crop breed or proper cash crop.
iv. Timely application of fertilizers and incorrect quantity.
v. Controlled irrigation when and where required, drip irrigation for optimal use of water resource.
vi. Detection diseases and malfunction at early state so that problem can be isolated and resolved.
vii. The climatic change record can help to maintain condition of green house.
viii. The recorded data can be reassessed for selection of breeds, crops and animals which yield optimal benefit in available environment and resources. It can track and audit the raw materials and resources used which can further be optimized.

- *Shiva Pujan Jaiswal, Department of Electrical & Electronics Engineering, Sharda University, G.Noida.*
- *Vikas Singh Bhadoria, Amit Agrawal and Hemant Ahuja, Department of Electrical & Electronics Engineering, ABES Engineering College, Ghaziabad* vikasbhadoria@gmail.com

ix. The system can be remotely monitored and controlled which enhances the farmers' ability to concentrate on business and market extension.
x. The system can be integrated with national and international agencies which work for farmer and agriculture so that they are updated with latest technology, system and programs implemented in agriculture.
xi. The cloud applications can be integrated with market so that farmers can have proper price to their products. It can help to farmers and customers to come together into single system.
xii. IoT provides cost effective and scalable technology for farmers to integrate onto their system according to their financial conditions i.e. number of WSN, extend of drip irrigation, number of tags for animals.

In this paper, IoT based system in agriculture and farming is reviewed through observation and study of published journals. This paper presents a design of scalable IoT system in agriculture and farming which can implemented in developing nations considering economic, technical and utility infrastructure available.

2. IOT SYSTEM COMPONENTS:

For wireless sensor network (WSN) application in monitoring & control of agriculture system, the Green House, open agriculture and farming, we consider variables to be monitored and variables to be controlled with their control mechanisms. IoT system consists of IoT hardware, communication system, data storage and central control units [24]. The architecture of wireless sensor node is shown in Figure 1.

A. IoT hardware & Software

It consists of sensor and actuator nodes for measurement and control of agriculture variables.

WS nodes and actuator nodes are embedded based system and programmable devices. WS nodes are the basic unit of any wireless sensor network (WSN). A number of sensor nodes distributed within the application area and communicating with each other using radio-frequency signals constitute a wireless sensor network. Functions of WS node are mentioned below.

i. Sensing
ii. Data acquisition (Sensor => Signal Conditioner => ADC)
iii. Data processing (Logical operation for sending data)
iv. Data storage (Store data before sending it to base station)
v. Wireless (radio-frequency) communication (Signal Transmission Medium)
vi. Data networking in local and internet

The typical design requirements or specifications of a wireless sensor node are Sensing capability, data processing capability, data storage capacity, Unlicensed radio-frequency-band communication capability, Low power consumption , Small size and Low cost. WS node consists of embedded hardware and software components.

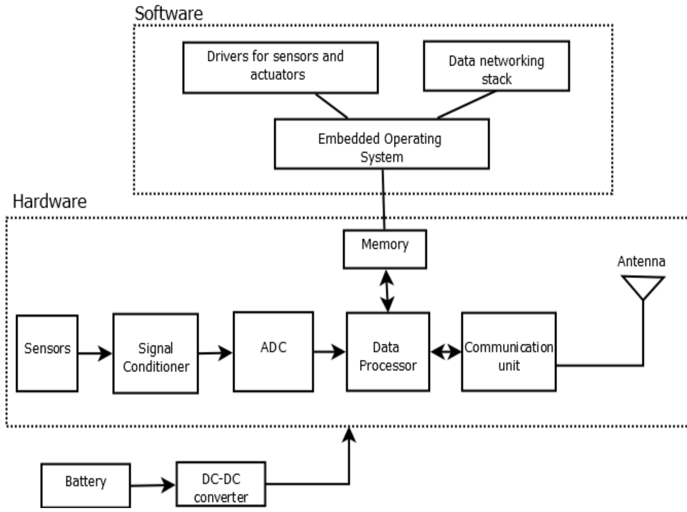

***Figure 1:** Architecture of Wireless Sensor Node*

The hardware comprises five units.

1. Sensors

Sensors form the front end of a WS node. They sense real time physical variables and produce analog electrical signals as the outputs. Generally, smart sensors (characterized by inbuilt signal conditioning circuits, small size, low power consumption and high reliability of operation) with standard analog/digital output are preferred over conventional sensors.

2. Data acquisition unit (DAQ unit)

DAQ unit is comprised of signal conditioner and analog to digital converter (ADC). Signal conditioner processes or conditions the analog electrical signals obtained from sensors to make them compatible with the ADC. The conditioned analog signals are then converted to equivalent digital signals by a multi-channel ADC. If a smart sensor (rather than a conventional sensor) with conditioned analog output is used, then further signal conditioning may not be required for that sensor. If a smart sensor with digital output is used, then even ADC will not be needed for that sensor.

3. Data processing unit (DPU)

DPU (data processing unit) comprises data processor and memory. Data processor is a device that processes the data and controls the operation of other components (DAQ unit, memory and communication unit) in the node. It acquires data from various sensors of the node, processes this data, receives data from other WS nodes, collaborates data and decides when and where to send it. It executes various programs ranging from time-critical digital signal processing, communication protocols to application programs. Data processing device is a microcontroller, programmable digital signal processor (DSP), field programmable gate array (FPGA) or an application-specific integrated circuit (ASIC), chosen on the basis of flexibility, performance, energy efficiency and cost. Small size (4kB) RAM is used to store the incoming data and intermediate results of computation. EEPROM or flash memory is used to store program code.

4. Communication Unit

Communication unit comprises radio-frequency (RF) transceiver and antenna. It is used to exchange data with other nodes and the station/gateway node. It converts the bit stream coming from the DPU to radio waves and vice versa. A low-cost, low-power, short-range, ISM-RF based transceiver with energy saving states operating in half-duplex mode is generally used. Issues related to the physical, medium access control and network layers are considered while designing the transceiver.

5. Power supply unit (PSU)

PSU (power supply unit) feeds power to all other units of the node. It is a crucial component of WS node as it decides the life time of the node. PSU is usually comprised of a battery followed by a DC-to-DC converter. Battery used should be of adequate capacity, high energy density, small weight and low self discharge. In some cases, rechargeable battery has been used along with photovoltaic (PV) solar cells. Converter is used for regulating voltage of the power supply. Software is an important architectural element of a WS node as it drives the node hardware. The node software carries out following functions: a. Data acquisition b. Signal processing c. In-network computation d. Data compression e. Error control f. Encryption g. Data communication h. Network routing. The software has several modules and their complexity can vary widely. The major ones have discussed below.

1. Operating system

The operating system is essential software as it provides the framework for developing any application and relieves the developer from the machine level functionality of the microprocessor. It is also used by all other software modules to support various functions. Desirable features of operating system are mentioned below.

- Should be small in itself
- Should enable rapid implementation
- Should ensure minimum application code size because of memory constraint in sensor nodes.

2. Drivers for sensors and actuators

This software module supports various functions of the on-board sensors and actuators. It facilitates configuring and setting on-board sensors and actuators. It insulates the application software from the machine level functionality of these peripherals.

3. Data networking stack

This software module implements data communication on the network. Typically the following five layers of the seven layer OSI model are included in the data networking stack of WS node. 1. Application Layer (L-7) 2. Transport Layer (L-4) 3. Network Layer (L-3) 4. Data Link Layer (L-2) 5. Physical Layer (L-1)

B. Communication System

For measurement and control of agriculture system, each node in the system must be connected in a communication network. This ensures data exchange between sensor/actuator nodes and the data storage and processing unit used for monitor and control. The sensor nodes are preferably wireless as it is advantageous in necessary application areas,

1. Where sensors are located at inaccessible or difficult-to-access places
2. Where sensors are either mobile or portable
3. Where quick deployment of sensor network is required
4. Where ad-hoc networking of sensor nodes is required.

So, for implementation of WSN, we consider special requirements as,

1. Low latency or small end-to-end delay
2. High data security
3. High network security
4. Low power consumption or long battery life
5. Operation in an ISM frequency band
6. Low bandwidth or data rate is adequate

For addressing the requirements of WSN, we can implement existing communication technology. Among the available technology options, we consider the following protocols.

1. Zigbee/IEEE 802.15.4
2. Wi-Fi/IEEE 802.11
3. Bluetooth/IEEE 802.15.1

Zigbee technology addresses needs of agriculture measurement and control (automation). Zigbee conforms to IEEE 802.15.4 standard “Low-Rate Wireless PAN Standard”. IEEE 802.15.4 defines only Physical and MAC layers. Zigbee supports networking of fixed, portable and moving devices (sensor nodes).

The special requirements of wireless sensor and actuator networks are Low latency, Low bandwidth, Long battery life and High data security. It is not attractive for business communication networks because of low data rate. Main Features of Zigbee are as below.

1. Data rates: 20, 40 & 250 Kbps
2. Topologies: Star and Mesh
3. MAC logic: CSMA/CA
4. Device addressing: Dynamic
5. Transmission technique: Direct Sequence Spread Spectrum (DSSS)
6. Transmitter power: 1 mW or more
7. Range: 10 m or more
8. Frequency bands:

ISM-900: Channel BW = 2MHz, Data rate = 20 & 40 kbps
ISM-2.4: Channel BW = 5MHz, Data rate = 250 kbps
Standard specifies 2 types of devices.

1. Full-Function Device (FFD)
   a. Can talk to any other device
   b. Can perform job of Network (or PAN) Coordinator
   c. Can also function as a normal device
2. Reduced-Function Device (RFD) or Normal Device
   a. Can function only as an end device (terminal node)
   b. Can’t function as Network Coordinator
   c. Simpler in design than FFD Wireless Sensor Network

Network (PAN) Coordinator: There is only one node in a network functioning as the Network Coordinator (NC) or PAN Coordinator.NC can communicate directly with any other device. Main functions of network coordinator:

- Generally, it initiates all network communications
- Transmits beacon in beaconing system used for “periodic data transfers”

Advantages of Zigbee are as below.

- Small bandwidth
- Low latency
- Low power requirement
- Low complexity
- Low message overhead
- Low cost

Limitations of Zigbee:

- Low data rate
- Small range

C. Data Storage and Central Control Unit

In agriculture and farming, we have to monitor and measure large, dynamic, temporal and spatial data which have to be processed and stored in database [11]. The data processing in the WSN is limited formatting and time stamping of data which can be structured to non-structured [13], [12] and can be in the form of numbers, pictures, textual, audio and video. This is to restrain data processor to consume more battery power. The complex calculation and logical calculation are done in central control unit. Cloud based IoT platforms like Goggle Cloud IoT core integrate Influx Data [9], which allow timer series of data from sensors to be stored in the cloud. The monitoring system is shown in Figure 2.

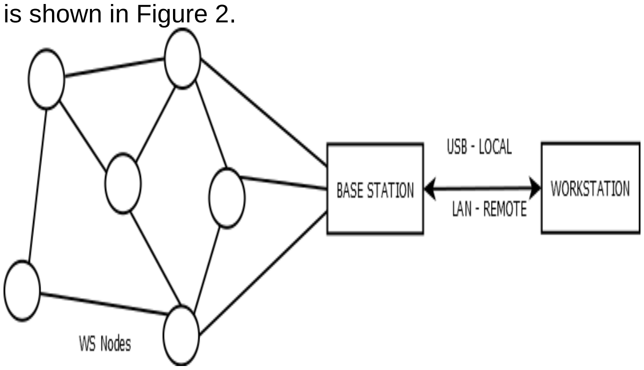

Figure 2: *Monitoring System*

This helps users to improve operational efficiency and real-time decision making from IoT sensor data. Influx Data provides the data services layer to Google Cloud IoT Core that allows users to collect time series data for instrumenting, observing, learning and automating any system [9]. WSN can directly update the cloud data or is passed to user application for further processing which in turn updates the cloud database. Node-red can be used as user interface as web service or standalone application in central control unit/PC. Web service provides remote access to the data visualization of the time series data. Edge or fog computing in the gateway/ base stations of every WSN enables data-stream acceleration, including real time data processing without latency for critical application. It allows smart applications and devices to respond to data almost instantaneously, as its being created, eliminating lag time [10]. The node-red application provides data visualization, analytics and control logic implementation.

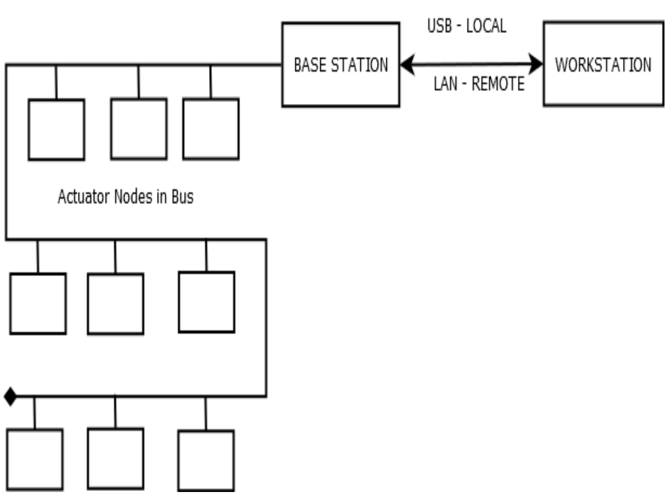

Figure 3: *Control System*

So, a single workstation is used to integrate monitoring as well as control system into Internet. The workstation PC maintains a local as well as internet-based database (Influx Data) as well as control system (node-red system). Remote access to the system is done through internet using standalone app in the smart phone. Cloud computing can be used to host Software as service in the cloud. The system software application integrates database for monitoring crop and animals in farm, control of respective variables in farm and field, climate and weather report analysis and market status trend to know which crop is viable and most profitable economically as well as in favor with climate and soil condition. The smart app using the data in database has following application. The overall system is shown by Figure 4.

i. Data visualization of plant and soil conditions, temperature of environment and green house, cattle health and habits and other monitoring parameters.
ii. Remote control of variables to be controlled.
iii. Notify farmers about market condition to maintain demand and supply.
iv. Notify weather forecast for contingency planning.
v. Notify farmers if animals in the farm are ill, irregular movement pattern, feeding schedule, health checkup schedule.
vi. Notify users about availability of products in respective farmer's depot.
vii. Users can do online shopping with the farmers or demand certain crops for them to be grown.

The comparative analysis is shown in Table 1.

So, for execution of IoT system in agriculture, we consider a WSN with Zigbee protocol, node-red based user application and InfuxData time series database. The actuator system is based on PAN with low latency and Master Slave configuration as simple MAC protocol. This system considered the requirement of IoT based agriculture. The control system is shown by Figure 3.

i. Mobile sensor node, compact and low power consumption for battery operation.
ii. Ad-hoc network with easy addition and removal of sensor nodes.
iii. High data security and network security
iv. As actuators are high powered, they have wired power supply lines, so we consider wired network for actuator networks, RS-485, Foundation Field bus.

3 IoT System Design

IoT application in agriculture and farming system can be described as one monitoring system and other as control system for automation of overall system. Main areas are monitoring, tracking and tracing, agricultural machinery, precision agriculture, and greenhouse farming.

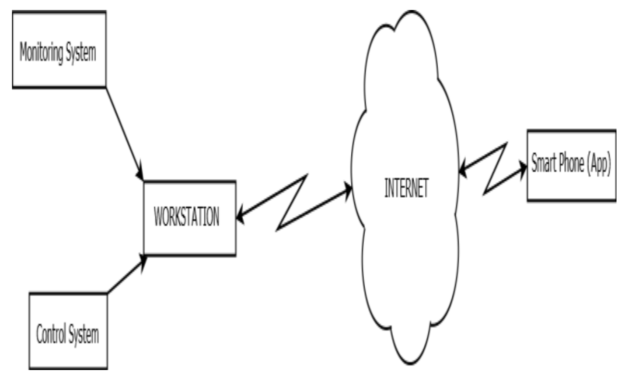

Figure 2: *Overall System*

SN	Feature	Zigbee	Wifi	Bluetooth
1	Data rates	20, 40 and 250 kbps	2, 11 and 54 Mbps	1 Mbps
2	Range	50-100 m	200-500 m	1-10 m
3	Network size	Personal Area Network	Local Area Network	Pico-net
4	Topologies supported	Start Mesh	Star	Mesh
5	ISM Frequency bands	900 MHz 2.4 GHz	2.4 GHz 5 GHz	2.4 GHz
6	MAC	CSMA/CA Ad-hoc Peer-to-peer	CSMA Point-to-hub	Ad-hoc
7	Routing	Multi-hop	Single-hop	Single-hop
8	Modulation Techniques	DSSS	DSSS FHSS OFDM	FHSS
9	Latency	Very Low (30 ms)	High (3-5 s)	Very High (10 s)
10	Network Scalability	Very High (65,000 nodes)	Good (255 nodes)	Poor (7 nodes)
11	Power Consumption	Very Low	High	Medium
12	Battery Life	Long	Very Short	Short
13	Reliability	Very High	High	High
14	Market trend	Establishing	Established	Established

Table 1: *Comparison of Zigbee, WiFi & Bluetooth*

4 ANALYSIS OF DATA IN IOT

In Monitoring and Control system, usually the control is based on real-time data, manual or scheduled operations. The accurate analysis of the stored data is vital for increasing the overall operation and production efficiency of the farming system. Data Analysis has been divided into different classes based on IoT application needs [14]. They include real-time, off-line, memory-level, business intelligence level and massive analytics. The data analysis includes statistical reading of data through trends, maximum and minimum values of data, mean and standard deviation of different sensors data. Image processing has been implemented in data analysis where data are collected as image through vision systems (camera). The application of image processing is extensively done to detect any abnormalities of plants like dead leaves, stem or fruit [16], fruit quality [17], weed detection and irrigation [15],[16]. The use of drones has increased the possibilities of the image processing for prior detection of crops failure, animal status and environmental mapping. The data analysis includes various methods like statistical analysis, classification, and clustering and trend analysis. Using these results from the analysis, it can help farmers in insurance, prediction, decision making, tool operation, store management and overall farming operation.

A. Insurance

i. The weather is unpredictable so using IoT, the collected weather data can be analyzed, and farmers can be notified about potential hazardous event through mail or text. Then farmers can take either contingency plan or protect their crops from potential harm.

ii. The footprint of animals can be tracked so this data can be used to know if cattle are active and within the legit area. Farms can be notified if any abnormal movement of animal is observed.

iii. If farmers have insured their system, this data can be used to make insurance clams and it will reduce the processing time as real-time data is readily available in the internet/cloud.

B. Prediction

i. The statistical data, trend of data can be used to estimate environmental conditions.

ii. Using machine learning algorithms, future conditions can be predicted.

iii. The choice of crops for consecutive year can be predicted using market and environment data.

iv. Dynamic irrigation implementation for effective use of water resource.

v. Fire, disease and drought can be predicted before and during cultivation of crops which would help farmers in disaster management.

C. Decision Making

i. For making decision, we require accurate and adequate data that is available through sensors and updated in time series database

ii. The decision taken in agriculture can be short, medium- or long-term basis.

iii. Use of drip irrigation when soil moisture is below threshold is immediate and short-term decision. To alert farmers immediately when cattle roam off their boundary, applying of nutrient, lighting systems are based on concurrent situation and are short term solutions.

iv. Analysis of dead leaves pattern, mobility of animals to find condition of plants as well as animals to know if they are ill or dead help to decide on accurate action plan. To reduce the risk of disease spread, the plants and animals are removed from the farm and area is neutralized.

v. In green house, machine learning can be used to find optimal condition for proper growth of plant and appropriate temperature, humidity and luminosity level can be decided with correct amount of nutrients.

vi. Data analysis of the demand and supply chain helps farmers which crop to priories. The crop knowledge, pests and disease recognition can help farmers decide the crop choice and contingency planning. The system is integrated with government agencies working for agriculture, so the information of governmental plans and subsides can be put into action for crop and animal choice [18] in farm.

D. Tool operation

i. Use of correct tools and its effective use is both important to increase yield and quality of product. They reduce effective man hour on the field but increase fuel and maintenance cost if not utilized when in need.

ii. Data analysis of the soil conditions like moisture, nutrient level with regards to required crop to be planted, it helps to decide which operating machines and tools to be used in the fields.

iii. We can even keep track of the tools and machines used and proper and timely maintenance of the operational tools.

iv. Selective control of nutrients, moisture, weed and pest control can be done which optimizes the use of tools.

E. Store Management

i. In agriculture different products to be stored. This ranges from initial raw materials like seedlings, nutrient packages, medical supplies, animal foods, agricultural tools and spares parts, and finished or harvested products.
ii. Temperature and environmental conditions severely effect the quality of the food products as well as the rodents, micro-organism can contaminate the food products [19]. So, use of IoT can improve store management of all the products especially the finished food products [20].
iii. WSN to track condition of the warehouse and stores can help to maintain the condition of the same. The temperature regulators, rodent and micro-organism control system can be operated according to the condition of the store.
iv. The quantity of products, tools and spares can be balanced according to demand and supply. Data analysis of work operation in the field, parts tracking in the system, market demand, and environmental condition facilitates farmers to maintain effective and efficient store.
v. Security system integrated with the IoT helps to insure products from being misused or stolen.

F. Farming Management

i. Overall farm management system includes monitoring and control of farm. The software level of integration of system where farm data are collected in database and operational as well as preventive actions are carried out using software.
ii. Market trends, customer ecommerce, governmental policies are all integrated in the software which together with farm parameters can be analyzed for optimal farm operation maximizing yield and revenue.
iii. Risk management, cost and productivity yield need to be managed with real time information and properly optimized to maximize productivity [21].
iv. Many farms can be integrated in Farm Management system (Software level integration), which helps to maintain the farming community need. The system can help government in policy making regrading agriculture.
v. These data can be asset for research which can further increase technology in agriculture sector.

5 CHALLENGES FOR IMPLEMENTATION OF IOT IN AGRICULTURE FOR DEVELOPING NATIONS

The implementation of IoT in agriculture is very welcoming but includes challenges for effective implementation of the system. The system includes integration of monitoring and control system to internet and software level implantation of market, customer and governmental policy integration. The challenges mainly are derivative of economic and technical issues. These factors have contributed to slow adaptation of IoT based system in agriculture. Economical issues are discussed as below.

i. The implementation of IoT system requires capital cost as well as operation cost. The cost includes the hardware cost (IoT devices, cables, sensors and actuators, base stations, PC and power supply system), software cost (design and implementation of cloud-based system for monitoring and control), operation cost for spares, internet and cloud service, energy and maintenance cost.
ii. So, farmers should be satisfied with breakeven point, period after which they can actually generate revenue from the system implemented.
iii. According to Turgut and Boloni, [22] the success of IoT has to satisfy two conditions. First the customers are persuaded that the IoT devices provide a value that exceeds their physical and privacy costs. Second, the businesses involved in IoT will successfully make money.
iv. Addition of more sensor and actuator nodes will add more cost.
v. Addition of functionality and services to the software will also increase the cost of system.
vi. Though the IoT cloud service providers include free limited subscription model for small system, large system and data privacy incur larger fee that are controlled by service providers.
vii. The internet service required may be of limited bandwidth or too costly for higher bandwidth.
viii. Internet banking facility may not be developed for fast and easy transactions between farmers and customers or vendors.

Technical Issues (especially in developing nations) are discussed as below.

i. The availability of internet service is not spread through the country.
ii. The alternate services like mobile internet services are bandwidth limited or too costly.
iii. The governmental software system in developing nations is not timely or adequately updated with the latest information.
iv. Farmers in developing nations are usually uneducated. Hence, they find it difficult to integrate and operate IoT based system.
v. Lack of technical manpower has also hindered operation of IoT as solutions provides are not available and all devices has to be imported.
vi. There is threat of theft, damage and vandalization of IoT devices [23].
vii. The internet-based system is prone to cyber-attack to steal critical farming data.
viii. There are many technologies available in market and no service providers follow a definite system setup. So, it can be hard for system implementation, expansion and up gradation.
ix. Lack of available system for ecommerce, internet-based market system, online payment facility for customers, geographical mapping system.

6 CONCLUSION

This paper discusses IoT based system in agriculture and its system design implementation. The importance of IoT and data analysis has been presented for effective and efficient farming practices. The WSN nodes and their connection with the internet is designed and presented. The effective use of available systems in control system is also presented. This paper suggests the use of cloud-based services especially for database of the data from different sensors and actuator nodes. On software side, this paper proposes the implementation of time series-based database and as control and visualization software, node-red based application. This paper identifies the importance of data and its analysis for optimal operation of the farming, the importance of customer and farmer relationship to eliminate middle man and maximize the profitability for farmers. However, there are number of issues to be addressed regarding its effective implementation in developing nations where the whole country's economy is dependent on agriculture. The IoT system has bright future in agriculture sector as it is perfect match for it. For better ease of integration and maximization of system usage, the government must upgrade their policy. The government should facilitate farmers by developing basic infrastructure of internet, availability of governmental plan and policy regarding agriculture. The main limitation is cost and system knowledge. The government should realize importance of the information that can be generated from IoT system and hence encourage farmers for the same providing cheaper loans and ease of access to IoT devices and services. The farmers should be educated, and vocational training programs should be developed for better use of system. In developing nations, the concept of online payment and ecommerce is increasing rapidly so will benefit IoT system integration in farming. There is increased research in IoT system which will provide optimal IoT solutions in agriculture sector.

REFERENCES

[1] World atlas, "Countries Most Dependent On Agriculture." Accessed on: 4th Feb. 2019. [Online]. Available: https://www.worldatlas.com/articles/countries-most-dependent-on-agriculture.html

[2] United Nations, Department of Economic and Social Affairs DESA, "World population projected to reach 9.7 billion by 2050," New York, USA, 29 July, 2015. Accessed on: 4thFeb. 2019. [Online]. Available: http://www.un.org/en/development/desa/news/population/2015-report.html

[3] Schafer, HB. Inter economics (1987) 22: 129. [Online]. Available: https://doi.org/10.1007/BF02932234

[4] Elijah, Olakunle& Abd Rahman, Tharek&Orikumhi, Igbafe&Leow, Chee Yen &Hindia, Mohammad. (2018). An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits and Challenges. IEEE Internet of Things Journal. PP. 1-1. 10.1109/JIOT.2018.2844296.

[5] "IoT analytics guide: Understanding Internet of Things data." [Online]. Available: https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT

[6] M. R. M. Kassim, I. Mat, and A. N. Harun, "Wireless Sensor Network in precision agriculture application," in International Conference on Computer, Information and Telecommunication Systems (CITS), pp. 1–5, IEEE, 2014.

[7] Y. Zhu, J. Song, and F. Dong, "Applications of wireless sensor network in the agriculture environment monitoring," Procedia Engineering, vol. 16, pp. 608–614, 2011.

[8] T. Ojha, S. Misra, and N. S. Raghuwanshi, "Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges," Computers and Electronics in Agriculture, vol. 118, pp. 66–84, 2015.

[9] Mark herring, "Press Release: Influx Data Integrates with Google Cloud IoT Core to Improve Users' IoT Environments with Expanded Data Collection and Analysis," OCT 10, 2018. Accessed on: 11th March, 2019. [Online] Available: https://www.influxdata.com/blog/influxdata-integrates with-google-cloud-iot-core-to-improve-users-iot-environments-with-expanded-data-collection-and-analysis/

[10] "Why edge computing?" [Online]. Available: https://www.hpe.com/in/en/what-is/edge-computing.html 3/11/2019

[11] D. Yan-e, "Design of intelligent agriculture management information system based on IoT," in 2011 Fourth International Conference on intelligent Computation Technology and Automation, vol. 1, March2011, pp. 1045–1049.

[12] M. R. Bendre, R. C. Thool, and V. R. Thool, "Big data in precision agriculture: Weather forecasting for future farming," in 2015 1stInternational Conference on Next Generation Computing Technologies(NGCT), Sept 2015, pp. 744–750.

[13] S. Wolfert, L. Ge, C. Verdouw, and M.-J. Bogaardt, "Big data in smart farming–a review," Agricultural Systems, vol. 153, pp. 69–80, 2017.

[14] C. P. Chen and C.-Y. Zhang, "Data-intensive applications, challenges, techniques and technologies: A survey on big data," Information Sciences, vol. 275, pp. 314–347, 2014.

[15] P. Tripicchio, M. Satler, G. Dabisias, E. Ruffaldi, and C. A. Avizzano, "Towards smart farming and sustainable agriculture with drones,"in Intelligent Environments (IE), 2015 International Conference on. IEEE, 2015, pp. 140–143.

[16] M. Jhuria, A. Kumar, and R. Borse, "Image processing for smart farming: Detection of disease and fruit grading," in 2013 IEEE Second International Conference on Image Information Processing (ICIIP-2013), Dec 2013, pp. 521–526.

[17] B. Suksawat and P. Komkum, "Pineapple quality grading using image processing and fuzzy logic based on Thai agriculture standards," in2015 International Conference on Control, Automation and Robotics,May 2015, pp. 218–222.

[18] Y. Zou and L. Quan, "A new service-oriented grid-based method foraiot application and implementation," Modern Physics Letters B, p.1740064, 2017.

[19] H. C. J. Godfray, J. R. Beddington, I. R. Crute, L. Haddad,D. Lawrence, J. F. Muir, J. Pretty, S. Robinson, S. M. Thomas, andC. Toulmin, "Food security: the challenge of feeding 9 billion people," science, vol. 327, no. 5967, pp. 812–818, 2010.

[20] C. Nelleman et al., "The environmental food crisis," The Environment'sRole in Averting Future Food Crises. A UNEP Rapid Response Assess-ment (United Nations Environment Program, GRID-Arendal, Arendal, Norway), 2009.

[21] N. Wang, N. Zhang, and M. Wang, "Wireless sensors in agriculture and food industry-recent development and future perspective," Computers and electronics in agriculture, vol. 50, no. 1, pp. 1–14, 2006

[22] D. Turgut and L. Boloni, "Value of information and cost of privacyin the internet of things," IEEE Communications Magazine, vol. 55,no. 9, pp. 62–66, 2017.

[23] P. Varga, S. Plosz, G. Soos, and C. Hegedus, "Security threats andissues in automation IoT," in 2017 IEEE 13th International Workshopon Factory Communication Systems (WFCS), May vaga2017, pp. 1–6.

[24] Dr H. K. Verma, “WIRELESS SENSOR NODE.” Accessed on: 10th Feb. 2019. [Online]. Available:http://profhkverma.info/wp/wp-content/uploads/2018/12/2018-Ch.-2-Wireless-Sensor-Node.pdf.