# Smart Agriculture Based on IoT and Cloud Computing

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***Abstract*—The improvement in new technologies in this mod- ern era has resulted to miniaturization of sensors and the attempts to utilize them in various areas are getting succeeded. Also, adoption of Internet of Things (IoT) and Cloud Computing in any area are leading them to a notion of "Smart" like Smart Health Care systems, Smart Cities, Smart Mobility, Smart Grid, Smart Home and Smart Metering etc. One such area of research that has also seen this adoption is agriculture and thus making it a Smart Agriculture. Agriculture is one of the major source for any of the largest population countries like India, China etc. to earn money and carry out the livelihood. Involvement of IoT and Cloud Computing in the agricultural sector would result in the better production of crops by controlling the cost, monitoring performance and maintenance, thereby benefiting the farmers and the overall nation. This paper focuses on introduction of a Smart Drone for crop management where the real-time Drone data coupled with IoT and Cloud Computing technologies help in building a sustainable Smart Agriculture.**

***Keywords-cloud computing; Internet of Things (IoT); smart agriculture; smart drone***

## I. INTRODUCTION

Agricultural techniques and practices play a major role in the largest population countries like India, China where the area of farmland, production value and the land yield per unit are lower than compared to the developed countries. So, food production plays a crucial role to satisfy the Nation's hunger. To face these challenges with limited natural resources available, we need to involve the emerging technologies like Internet of Things (IoT) and Cloud Computing into agricultural sector along with various machinery or devices. IoT will be beneficial to connect the devices, collect and distribute the data on Internet whereas the Cloud Computing adoption is expected to improve the cloud hosting facilities with faster internet speed and thereby provide new approaches to farmers and the producers to make smarter decisions, reduce costs, provide efficiency and boost the production.

Inspecting the health state of farming has been a growing interest from last years for which various autonomous techniques are under use. One such technique is Robotics, where it jumped into this field providing interesting and effective solutions to several phases like harvesting or the plowing [1]. The other is the satellite technology, where the health of the farms are being monitored and data is recorded, but are not effective when talked in a small scale. So, here comes the use of drones in agriculture which can provide the smart farming very effectively due to the fact that unmanned aerial vehicles (UAV) can give farmers a bird's eye view of their fields still remaining close to the terrain and thus providing more precise evaluations.

Drones are defined as Unmanned Aerial Vehicles (UAVs) [2]. In other words, drones are flying devices that are autonomously programmed or remotely controlled, either by a remote control or a ground station, and are categorized as networked robotic technologies [3]. Use of drones allows the opportunity to get an overall survey of the area and make a better use of farmer time rather than just making to walk blindly into the field. Drones with the combination of IoT and Cloud computing technologies, can help in a real-time data extraction, evaluation and solutions to the agricultural farming. This paper aims to introduction of a Smart Drone which is coupled with the complementary technologies, IoT and Cloud computing for agricultural farm inspection and crop screening by remote monitoring. The data acquired from drones gives the insights of the crop like plant health indices, plant counting, plant height measurement, field prediction, mapping of field water, drainage etc. and promote quick, reliable and cost-

effective service to farmers.

### *A. Concept of IOT*

Internet of Things (IoT), a popular term now-a-days, de- scribes a system where the world is connected to Internet with the help different kinds of sensors. It allows objects to be sensed or controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit in addition to reduced human intervention [4].

IOT is a vision where "things", especially everyday objects, such as all home appliances, furniture, clothes, vehicles, roads and smart materials, etc. are readable, recognizable, locatable, addressable and/or controllable via the Internet. It is a com- bination of ubiquitous communications, ambient intelligence and pervasive computing. Internet of Things will connect the world's objects in both a sensory and intelligent manner through combining technological developments in item

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identification (“tagging things”), sensors and wireless sensor networks (“feeling things”), embedded systems (“thinking things”) and nanotechnology (“shrinking things”) [5].

### B. Concept of Cloud Computing

Cloud Computing, a very common hearing buzzword in the Information Technology (IT) world today, describes a computing paradigm which provide on-demand access, either the application data or the storage space to large pool of systems which are connected to each other privately/publicly/hybridly. It describes a new way of adding, using and exchanging IT service based on the internet which involves providing dynamic, expandable and virtualized resources [6].

The reusability of IT capabilities, an important feature for cost effectiveness is the fundamental principal in innovating the idea of Cloud Computing. It broadens the horizons across the organizational boundaries by providing a practical approach to experience direct cost benefits in computation, application hosting, content delivery and storage. The word "cloud" can be referred as a blend of networks, hardware, storage and interfaces to deliver a service - Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) which can be deployed on Public, Private or Hybrid clouds.

## II. Literature Review

We conducted a literature review on Smart Agriculture using research papers, journals, articles. One paper [7] discussed about the Fuzzy Control System for irrigation and water conservation in agricultural field if given the information on the crop and site characteristics. It describes a protocol for the field implementation of a fully automated irrigation system. Another paper [8] proposed a greenhouse Monitoring System based on agriculture IoT with a cloud where sensors are installed in the farm to periodically collect information of agriculture field area and store the information online. The other few papers [9] [10] [11] proposed an agricultural application of wireless sensor network for crop field monitoring where the systems are equipped with two type sensor nodes, one to measure different parameters like humidity, temperature etc. and the other, an image sensing node for taking the images of the crops.

Most of the papers are focusing mainly on irrigation in the agricultural land. One such paper [12] discussed about the Neural Computing modeling of the reference crop evapotranspiration to better manage the limited water resources in arid regions and importance of accurately determining the plant water requirements. Another paper [13] proposed Automatic Smart Irrigation Decision Support System (SIDSS) to manage irrigation in agriculture where the system estimates the weekly irrigation needs of a plantation, based on both soil measurements and climatic variables gathered by several autonomous nodes deployed in field. Few other papers [14] [15] [16] proposed smart irrigation systems using Internet of Things, where sensed data is sent to a smart gateway through a network and then to a web service. GSM (Global System for Mobile Communications) also proposed a system for monitoring Pest Insect Traps using image sensors & Aspic. They used distributed imaging devices which are operated using wireless sensor networks. This method only detects pests, but does not suggest any method to control the pests.

Few articles on smart agriculture says that, Precision agriculture is being followed in many countries now. Precision agriculture is a satellite farming or Site-Specific Crop Management (SSCM) based on observing, measuring and responding to inter and intra-filed variability of crops [17]. Fujitsu in Japan has developed a model for using Cloud Computing in agriculture which can also be used in other sectors such as environment, medicine and maintenance sectors [18] [19] where the model consists of a sequence of steps, Inputs-Data Storage-Visualization-Analysis-Instruction.

Most papers report the results of explorative studies or they present IoT systems that are designed or implemented in prototypes and pilots. The literature reviewed focuses on sensing and monitoring, while actuation and remote control is much less addressed and more advanced solutions are in an experimental stage of development. This paper discusses about a new technique of monitoring the crop field with the help of Smart Drones by remotely controlling it and monitoring all the required parameters of the agricultural land which help in the field prediction and data analysis.

## III. Project Narrative

Drones has been under use for many commercial applications due to their ability to fly without an on-board pilot and act as an eye-in-the-sky. But these drones have limited capability and is used in the area permitted. To extend their capabilities and make use of data collected by drones in large scale, we combine it with smart technologies. The proposed model is involvement of IoT and Cloud Computing in Drones, give them a notion of “Smart”. The aim of this proposed model is to provide an intelligent cultivation control for the farmers. Smart Drones is a more modern term, inferring that sensors within these UAVs feed into a network infrastructure where drones are connected to other devices via Internet technologies, which enables communication and thus, makes them smart i.e., these devices now have real time properties making them multi-dimensional.

### A. Architecture of Smart Drone

The drone technology used for the model is Sky Drone FPV2 (First Person View) and compresses of a camera module, a data module and a 4G / LTE modem. The smart drone would be a Fixed wing aerial vehicle which can carry many sensors, achieve greater speeds, have longer flight time and cover large areas. It will have an embedded software for flight planning and control based on GPS (Global Positioning System) navigation, as well as Google maps and is furnished with the

complete ICT (Information and Communication Technologies) equipment for data processing from sensor devices, which means that the processing results are available immediately after the flight to authorized users. The proposed model consists of 3 modules – Sensing, Communication and Coordination.

*1) Sensing:* Synchronous type of sensors - flight and navigation sensor and camera sensor are installed in the Smart Drones for exclusive useful/user data collection. The flight and navigation sensors like vision sensor, gyroscope, tilt and current sensors, GPS are controlled by the drone status, flight parameters, the sensors also aid the navigation and monitor the immediate or farther environment of the drone in order to detect and avoid unexpected obstacles. Cameras used in the Smart Drone should have at least a 12-megapixel resolution with different frequency ranges, as they present the basic useful load of drones used for monitoring in agriculture like

- Identify pests, weeds and diseases which help in optimizing pesticide usage and crop sprays.
- Estimate the crop yield, i.e., provides the plant counting.
- Provide data on soil fertility by detecting nutrient deficiencies.
- Measure irrigation and control crop by identifying areas where water stress is suspected.

Visual cameras are used for capturing images during day- light, while a thermal camera may be used for night vision, seeing through smoke or fog, vegetation monitoring, fire and heat detection using infrared patterns, etc.

*2) Communication:* The communication and networking block is responsible for the information flow and needs to be robust against uncertainties in the environment and quickly adapt to changes in the network topology. The Smart Drone will have an antenna with nearly isotropic radiation intensity patterns and has 4G/LTE modem with embedded IoT wireless technologies like Wi-Fi, ZigBee that are tested for aerial net- works which help in the wireless communication to remotely control the drone and receive the data acquired from the drone. The drone proposed will include a WiFi communication module plus a computation, storage and/or actuation capabilities that characterize the IoT. The IoT devices can be any of the smart devices like mobiles, laptop, iPad etc. which act as a gateway and provide the internet access when required and available. These communication devices connect to the drone from anywhere on any device. The data to be collected from the drone is controlled by the smart device at the remote location. Since the proposed drone is embedded with WiFi, the information collected can be sent on to the cloud at real time and can be viewed across internet. The data collected is stored in the application cloud and used for data analysis, evaluation and provide best practices and techniques for a certain situation to the farmers.

*3) Coordination:* The coordination block focusses on adapting to the needs of the application of interest. It contains 3 main components - Mission Control, Mission Planning and Sensor Data Analysis. We would develop a distributed and centralized coordination strategies to handle both the static and dynamic environments. The mission control unit takes the users input and dispatches it to the desired components, mission planning breaks down the high-level tasks to flight routes that are to be visited and certain actions for each waypoint. Finally, the sensor data analysis mosaics the images

taken by different sensors, combine them to a single large overview image and is presented to the user.

Process Flow:

The phases that will be performed in the proposed model are

- Pre-planning: The pre-planned path is to be calculated first and define the search engine for the drone.
- Searching: The drone takes off and follows the assigned path while images are captured and analyzed on-board.
- Detection: Depending on the required application of the drone, we adapt the detection algorithm to detect any uncertainties in the field by the sensors embedded in the drone.
- Streaming: The captured images or any data is collected on the IoT device at real time. The streaming is also con- trolled accordingly by the devices and the data collected is transferred to the cloud system.
- Data Analysis: As per the requirement and the question under concern, the data is taken from the cloud system for analysis and evaluated by the concerned researchers and possible solutions are made which will help the farmers to practice in their fields.
- Cultivation Control: The information received from the drones can help in the control of the cultivation, like the drone embedded sensors detect the soil, humidity, health of the plants which help farmers predict their fields and the next steps to be performed.

Intelligent cultivation control is possible by makes use of this smart drone where the problem is just not restricted to small group and controlling mechanisms are also offered by the researchers with the data obtained in the cloud.

Agricultural informationization has very much importance these days for the development of worlds agriculture. By using cloud computing database, information and records of specific processes in plant production can be maintained, thus help in analysis of

productivity, property based on production curve. The advantage of using the cloud computing storage server is that the cost of data as a service is reduced, as now the user is provided with the extra facility to request only the required service for the required time from the server. The information gathered also helps in addressing the key problems that occur in such specific processes of production, analyze the potential management defects, measurement, make production plans etc. All this information relevant to the agricultural need can be stored in a centralized location i.e., a single location and thereby data availability can be achieved. This data can be accessed by the end users such as farmers, experts, researchers etc. easily any time from any location through the devices that are connected to them, where IoT comes to play. Based on Cloud Computing, Agricultural Information Cloud is to be constructed and thus Smart Agriculture can be obtained using

Smart Drones, Smart Irrigation etc.

The Smart Drone proposed is coupled with these technologies, used to fly on an agricultural land to detect all the required parameters with the help of the sensors built in it and the cameras to get the images or live streaming which help in building a sustainable smart agricultural practice by preventing the outcomes of any disasters, predictions of the field and best practices to be followed in the farm land.

## IV. Conclusion and Future Work

The goal of smart agriculture with the advent of IoT is to provide latest technology in agriculture and farming for better crop production by gathering the existing real-time status of crop and make the farmers understand the advancement in agriculture, with lot of added features and benefits in order to improve the farming practices. The paper discussed about a proposed model of Smart Drone, an eye-in-the-sky for the crop land which is more effective than the satellite technologies to build a Smart Agriculture. Importance of public cloud in agriculture is discussed as it can promote resource sharing, cost-saving and data storage.

Several features could be added to improve the functionality of Smart Drones. Additional features include extending the drone capability by introducing a pluggable scheduler, an intelligent analyzer in the drone which help in less human intervention when there is an odd detection in the crop. Security and risk features are to be added. Drones has to be embedded with reprogrammable software which helps to divert the drone, come home and land etc. The Application cloud as to provide Agriculture has a Service for all the users of this resource and data center of IoT based on Cloud Computing needs to provide more reliable virtualized platforms which will help in building a more sustainable smart agriculture.

## References


[1] C. W. Bac, E. J. van Henten, J. Hemming, and Y. Edan, "Harvesting robots for high-value crops: State-of-the-art review and challenges ahead," *Journal of Field Robotics*, vol. 31, no. 6, pp. 888–911, 2014.

[2] A. Bürkle, "Collaborating miniature drones for surveillance and recon- naissance," in *Unmanned/Unattended Sensors and Sensor* Networks *VI*, vol. 7480. International Society for Optics and Photonics, 2009, p. 74800H.

[3] J. Borenstein and K. Miller, "Robots and the internet: Causes for concern," *IEEE Technology and Society Magazine*, vol. 32, no. 1, pp. 60–65, 2013.

[4] F. Mattern and C. Floerkemeier, *From the Internet of Computers to the Internet of Things*, ser. From active data management to event-based systems and more. Springer, 2010, pp. 242–259.

[5] B. S. Swathi and H. S. Guruprasad, "Integration of wireless sensor networks and cloud computing," *International Journal of Computer Science*, vol. 2, no. 5, pp. 49–53, 2014.

[6] G. Pingli, S. Yanlei, C. Junliang, D. Miaoting, and L. Bojia, "Enterprise- oriented communication among multiple esbs based on wsnotification and cloud queue model," *International Journal of Advancements in Computing Technology*, vol. 3, no. 7, pp. 255–263, 2011.

[7] E. Giusti and S. Marsili-Libelli, "A fuzzy decision support system for irrigation and water conservation in agriculture," *Environmental Modelling & Software*, vol. 63, pp. 73–86, 2015.

[8] V. Keerthi and G. N. Kodandaramaiah, "Cloud iot based greenhouse monitoring system," *International Journal of Engineering Research and Applications*, vol. 5, no. 10, pp. 35–41, 2015.

[9] Z. Liqiang, Y. Shouyi, L. Leibo, Z. Zhen, and W. Shaojun, "A crop monitoring system based on wireless sensor network," *Procedia Envi- ronmental Sciences*, vol. 11, pp. 558–565, 2011.

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

[11] S. A. Jaishetty and R. Patil, "Iot sensor network based approach for agricultural field monitoring and control," *IJRET: International Journal of Research in Engineering and Technology*, vol. 5, no. 06, 2016.

[12] A. J. Adeloye, R. Rustum, and I. D. Kariyama, "Neural computing mod- eling of the reference crop evapotranspiration," *Environmental Modelling & Software*, vol. 29, no. 1, pp. 61–73, 2012.

[13] H. MANJUNATH, VASANGOUDA, M. CHAKRASALI, and P. MURAGOD, "Internet of things and cloud computing for smart agriculture," Ph.D. dissertation, 2017.

[14] G. Parameswaran and K. Sivaprasath, "Arduino based smart drip irriga- tion system using internet of things," *Int.J.Eng.Sci*, vol. 5518, 2016.

[15] B. Kumbar, B. Galagi, Bheemashankar, and N. Honnalli, "Smart irriga- tion system using internet of things," *Bonfring International Journal of Research in Communication Engineering*, vol. 6, no. November 2016, 2016.

[16] D. K. M. R.Hemalatha, G.Deepika, "Internet of things (iot) based smart irrigation," *International Journal Of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST)*, vol. 2, no. 2, pp. 128–132, February 2016. [Online]. Available: https: //www.ijarbest.com/journal/v2i2

[17] "Precision agriculture." [Online]. Available: https://en.wikipedia.org/ wiki/Precision_agriculture

[18] K. *Venkataramana* and M. Padmavathamma, "A design of framework for agri-cloud," *IOSR Journal of Computer Engineering*, vol. 4, no. 5, pp. 1–6, 2012.

[19] S. R. Rupanagudi, B. S. Ranjani, P. Nagaraj, V. G. Bhat, and G. *Thippeswamy*, "A novel cloud computing based smart farming system for early detection of borer insects in tomatoes," in *2015 International Conference on Communication, Information & Computing Technology (ICCICT)*. IEEE, 2015, pp. 1–6.