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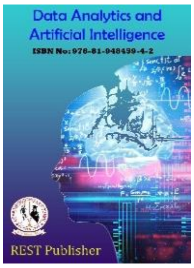

Constructing an IoT-Based Human-CentricAgricultural Model

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Abstract: *As a direct result of the growing human population, the current state of agriculture is insufficiently efficient and organized, particularly indeveloping nations, to meet the growing demand for food. When combined, the internet of things and cloud computing offer a promising way to address the issues raised by this growing demand on a global scale. Agricultural production, storage, and transportation can be made much more efficient and of higher quality by utilizing IoT and cloud services along with precision farming techniques.The architecture of a multilayered enabling platform for integrating IoT technologies in agriculture is presented in this paper. By putting forth a workable human-centric IoT model for agriculture with a focus on developing countries,this work significantly advances the field.*

Keywords: *Internet of Things (IoT), human- centeredness, cloud computing, service-oriented architecture (SoA), and smart agriculture*

1. INTRODUCTION

The recently developed frontier in the fields of communications and IT is the Internet of Things. Large-scale digitization of the physical world is occurring thanks to IoT. Every single object in the perfect Internet of things has networking, computing, and sensing embedded in it. All of these connected items—whether they are wearable accessories, lights, thermostats, or household appliances—have one thing in common: they gather data created by or about people in order to provide value-added services [1]. IoT development and adoption in the agriculture sector have been sluggish, particularly in developing countries. Global food demand is rising, necessitating the use of productive and successful farming techniques. Cloud computing and the Internet of Things must be actively involved for such strategies to be implemented. Given that farmers in developing countries typically have low literacy and education levels, there is a pressing need to develop an IoT platform and cloud services that are centered around the needs of people. A bottom-up approach has been proposed in a recent work that is similar and targets the Indian agricultural sector [3]. However, because farmers in India lack self- sufficiency, a strictly bottom-up approach is impractical in the country's agricultural scenario. Once self-sufficiency has been established in terms of education, infrastructure, and finances, such an approach would be advantageous. Thus, a model that lessens the manual workload while also empowering the farming community is required. In an important study, Wark, T., et al. created an outdoor pervasive computing system on a large scale that measures the condition of a complex system made up of pasture, animals, climate, and soil using both stationary and animal-borne nodes [6]. This system's reliance on farm animal movement to obtain spatially variable data is a drawback, despite the fact that it effectively uses animal mobility for farm hold monitoring. Using this system on a farm where the primary purpose is crop growth would therefore be counterproductive. In a different research study, a suggestion was made for the use of CCTV for both image and GPS monitoring of agricultural holdings [4]. Even though this method makes the farm land more visible and manageable, it has minimal impact.We have developed a strategy for integrating IoT and cloud computing into the agricultural sector that is aimed primarily at developing nations, keeping these crucial considerations in mind. Agricultural issues stem from ineffectiveness and poor management. With the widespread use of cloud computing and IoT, we have tried to offer a solution to this issue.The structure of this paper is as follows. The status of agriculture in India is covered in Section II, along with some of the drawbacks of the current system that is in place. The design challenges encountered when deploying IoT solutions in agriculture are discussed in section III, along with the actions we have taken to address them. In section IV, we go on to provide a detailed description of the layers of the suggested architecture. The services provided by the suggested architecture both cloud and basic data analytics services—are covered in Section V. Section VI provide research challenges and future trends. In section VII, we finally present our conclusion

2. CURRENT PHASE

In developing countries, one of the main industries for employment is agriculture. For example, in India, the agricultural sector employs 47% of the workforce and accounts for roughly 18% of the country's GDP as of 2012 [5]. Despite being enormous, the advances in agriculture over the last ten years have only affected the industrial side of the industry. During the busiest harvesting season, machinery such as threshers, winnowers, chaff cutters, de-huskers, and decorticators are designed to minimize labor and time consumption. Nonetheless, a system that improves farming practices overall, tracks crop health from birth to death, and gives a typical farmer in a developing country the tools they need to prevent significant yield waste is required. Large-scale crop spoilage incidents are frequent problems in developing nations. According to a recent report, at least 40% of India's total produce, including fruits and vegetables, is wasted, and each year, roughly 21 million tons of grain are lost as a result of inadequate storage facilities, a lack of refrigerated transportation options, corruption, etc. [5]. Thus, real-time storage unit condition monitoring is crucial for these kinds of infrastructures. A lack of technical knowledge about farming equipment, low income for small-scale farmers, illiteracy, and an inadequate resource base are all exacerbated by a number of other issues, such as corrupt practices involving the distribution of tainted fertilizers, we decides, and pesticides. The lack of the subsequently discussed electronic human-centric technologies in modern farms leaves farmers defenseless against crop ruination from contaminated pesticides, unfavorable storage conditions, and other numerous mishaps. Irrigation is the key to agriculture in developing nations. Humans currently use around 3.8 trillion m3 of water annually. The global agriculture sector uses about 70% of this [5]. Since irrigation covers just 36.3% of India's agricultural land, water is the most valuable resource for farmers. Monitoring the flow of water and the moisture content of agricultural soil can serve as important indicators of how well water resources are being used. Paddy crops need extremely careful irrigation techniques, so it's critical that the crop be completely submerged in water for the first 15 to 20 days after planting. Periodically, this water is removed to monitor the temperature rise caused by sunlight. This is a crucial element on Selective exhaustion of the soil is a problem in the current agricultural scenario arising from the injudicious use of fertilizers. Growing one kind of crop repetitively depletes crop specific nutrients in the soil. The need is to ascertain the nutrients which the soil lacks in. The amount of soil exhaustion also has spatial dependence i.e. different areas of the farm will have different nutrient content. To reap maximum yield, it is essential to know the area-wise nutrient profile of the farm hold. The required fertilizers can accordingly be distributed around the farm in optimum quantities

3. DECISIONS AND DIFFICULTIES IN DESIGN

Creating an IoT-based human-centric agricultural model that targets developing nations in particular presents a number of intricate, multifaceted challenges. Some of these challenges are covered in the subsections that follow in the context of this paper. Our system design choices are based on these design limitations.* Scalability Each owner's agricultural holding is different in size. The average farm size in China and India is approximately 1 hectare, but in the US, this number jumps dramatically to approximately 170 hectares [7]. In India, farm holdings vary in size from less than one hectare to larger plantations spanning tens or even hundreds of hectares. The kind of wireless communication technology and protocol to be used depends on the size of an agricultural holding. A typical Indian farm holding, for example, would need one Wi- Fi access point so that all of the sensors could easily communicate with each other across the entire land. However, a single Wi-Fi or Zig Bee access point won't be sufficient in the case of plantations dispersed over vast areas. Inconsistency in data those engaged in agricultural practices have notably low literacy rates in developing countries. It is therefore inappropriate to directly present data obtained from sensors, data analytics, and cloud services to illiterate farmers. A human-centric approach to agricultural automation is necessary in this situation. With the data incoherence in mind, the authors of this paper have created a Statement of Agricultural Practices (SoA) that makes this information easily comprehensible and available to farmers. This has been achieved by adding a data simplification service and a language translation service above the local server layer. This gives real-time data in the preferred language format to the farm owner's PDA. The purpose of the data simplification service is to streamline incoming data before it is processed by data analytics and cloud services. Constraints of the Current ICT Infrastructure. The adoption of IoT in any industry is heavily dependent on pervasive ICT infrastructure, but this is especially true in the agricultural sector due to the intricacies involved. But as is generally acknowledged, developing countries' ICT scenarios lag behind in this aspect. When IoT is implemented in the agriculture sector, a highly skilled ICT platform is necessary. If this platform is absent, the followingunfavorable factors occur: Limited knowledge of computer and communication technologies Expensive ICT equipment Problems with connectivity in rural areas Exorbitant prices for mobile data services We have made the following design choices in orderto get around the restrictions brought on by an inadequate ICT platform: Reduced front-end software and hardware infrastructure by fully utilizing cloud-based back-end services via a So A Self-supporting architecture that enables

4. SYSTEM DESCRIPTION

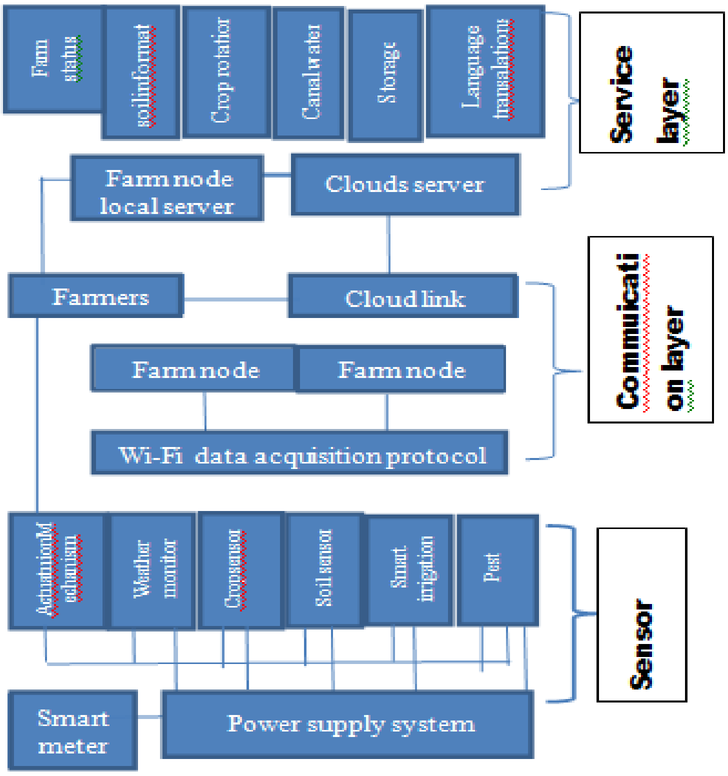

FIGURE 1. Layers of the proposed architecture

4.1. Sensing and Actuation Layer: The sensors and actuators that serve as the framework for the overall system are located in thislayer. Accurate and consistent data is provided by sensors. With wireless sensor networking, variables that the farmer first personally saw can be organizedvisualized through data analytics, resulting in a reduced workload for the farmer. Use cases for remote actuation include operating a tube well, activating an emergency mechanism, andmisting insecticides or pesticides in a contaminated region. Farmers can further minimize their responsibilities and concentrate on productive learning processes to advance their knowledge and abilities by remotely operating a variety of farming tools. In agricultural applications, sensors and actuatorsare typically powered by solar energy or batteries. Inthe latter scenario, effective power management is essential. A more sustainable method is to power sensor nodes using solar energy. An intriguing element that has been included is the connection between the farm's smart meter and water and power usage. Future system enhancements andmodifications can be implemented through ongoing resource usage monitoring.

4.2. Communication and Networking Layer: We have only employed the most popular technologies for communication in line with our minimal cost approach. Based on parameters relevant to context, Table I contrasts different wireless technologies [2].

TABLE 1. Comparison of Wireless Standards

Metrics	Wi-Fi	Bluetoot h	ZigBee
Range	200m	20m	20m-200m
DataRate	55 Mbps	1Mbps	255 Kbps
Nodes	2007	8	65000
NominalTx Power	20-25dbm	0-10 dbm	(-30)-0 dbm
Frequency Band	2.4 GHz,5GHz	2.4 GHz	900 MHz,2.4 GHz
Channel Bandwidth	22 MHz	1 MHz	0.3 MHz-2MHz

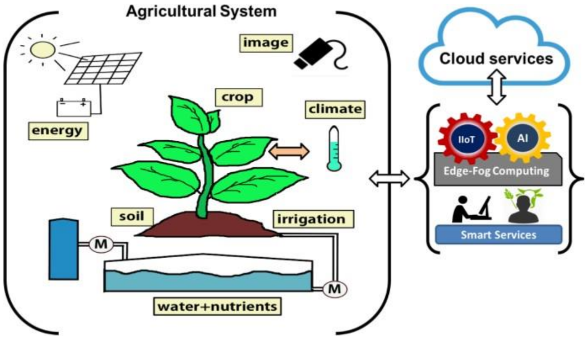

FIGURE 2. Management Scenario

For internal networking, Wi-Fi has been used, and forexternal networking, 3G. Wi-Fi is used by the sensor nodes to connect to the farm node, which serves as a local server by classifying and organizing raw sensor data. 3G cellular networking is then used by the farm node to send the information to a cellular gateway close to the agricultural land. We have used 3G cellulardata networks in our architecture due to the high expense of 4G networks. When an agricultural hold's size grows beyond the reach of a single Wi-Fi access point, a significant case occurs. The farm is set up in this scenario into a number of "zones," each of which has a single Wi-Fi access point for the sensors locatedthere. Every WiFi hotspot additionally

TABLE 2 . Wireless Station Requirement

Farm Area (hectares)	Farm Holding (%)	numberof Wi-Fistations
0.01 to 2.00	64.8	2
2.01 to 3.00	18.8	3
3.00 to 5.00	14.0	6
5.01 to 10.00	6.1	10
Above 10	1.4	>10

The foundation of inter-farm networks is the star topology, in which every farm node has direct communication with the cellular gateway. A 3G network is used by the cellular gateway to send data to the cloud server. A cloud-based forum service facilitates communication amongst farm owners. Farmers can also use a PDA with an applicationloaded on it to access cloud services. Using cellular 3G, this application pushes and pulls data to and fromthe cloud server.

5.1. Service layers: This work presents an architecture that offersfarm owners two main categories of services: cloudservices and basic data analytics. The data producedby sensors directly leads to basic data analytics. An application that is installed on the local farm server performs this analysis. A selection of the many services that can be provided via cloud computing areincluded here. For this use case, we discovered that the Software as a

Service (SaaS) cloud computing model is the best fit. The section that follows provides a detailed description of these services.

6. USENETWORK AND SERVICES

For farm owners, the suggested architecture allows fortwo main categories of services. Additionally, it generates opportunities and services for government survey committees, industry, researchers, and agronomists, among others [10]. They are further explained as follows:

6.1 Data Analytics:

This class comprises of the services that are directly enabled based on sensor data, out of the two types of services. Among them are: Current agricultural weather data, Real-time tracking of soil temperature and moisture, Crop condition in real time, Current usage of water and electricity, The water tube well, pesticide pivot spray, andemergency mechanism are all operational. Water availability in canals, Humidity and temperature in real-time storage.

6.2 Cloud service: The majority of the services in the suggestedarchitecture are cloud-based. Each farm owner receives these services in a unique way depending on avariety of factors, including land area, crop preference, location, literacy level, and education level. The services that are significant from a human-centric standpoint are listed below:1)Language translation: By translating information into the language of farm owners, this service eliminates the possibility of inconsistent data. Data simplification: Data can be made more valuable and comprehensible by being reduced to easily understood figures and numbers. Realtime weather forecast: Weather forecasting systems that are updated on a regular basis are crucial to farmers. If timely access to precise weather forecasts is possible, a significant quantity of agricultural produce can be preserved. Through the In-DG portal, CDAC, and DeitY, the Indian government offers accurate weather forecasts in real time. It includes the majority of weather metrics required to guarantee crop safety-learning portal: Focusing on the development of knowledge and skills can greatly boost a farm's growth. Farmers can access essential information, in-depth theory, and best practices regarding the crops of interest. through the e-learning portal. Researcher-farmer discussion platform: This is a new service that helps close the growing divide between academics and farmers. Through this service, both parties can benefit from each other's expertise and knowledge and aid in the advancement of the country as a whole. Market prices up dation system: For people engaged in farming practices, especially in remote areas, knowledge about the most recent prices of different crops can be extremely valuable. Advanced long term data analytics: The elementary data analytics service's long-term equivalent is this one. Important insights regarding the optimal yield parameters for a particular farmland, weather condition, and altitude can be gained by tracking and analyzing farm data over extended periods of time. Automatic water and electricity billing service: Farmers invest a significant portion of their input capital on electricity and water. Farmers can be released from this burden through strategies for waste minimization and careful monitoring of resource utilization. The following characteristics of a SaaS cloud server built on a community deployment model are proposed for the best possible implementation of these services: A PDA's installed application is used to access services. Accessing services will always require internet connectivity because the service model in use is Software as a Service. Network latency is introduced when using a SaaS model. Services that need to be monitored in real time are therefore accessed through the farm node server rather than being deployed in the cloud. Each cloud user subscribes to a monthly or annual plan, and the cost of the subscription is determined by a number of factors including the amount of data stored, the amount of bandwidth needed, the duration of the subscription, and the number of applications that are running on the cloud. Using cloud services is generally less expensive than setting up custom hardware, software, and networking infrastructure. Since data security is not a concern in this use case, standard SSL security measures are adequate.

7. FUTURE RESEARCH

Future research opportunities abound in the field of agricultural IoT, which is still in its infancy. If the true vision of smart farming is to be realized, a significant amount of work is needed. Among the possible study topics are:

7.1. Enhancements in sensing technologies: The development of sensors specifically for agriculture has not accelerated recently. Modern sensors are primarily made for use in automotive, industrial, electronic, and medical fields. It is necessary to use sensors that adhere to the standards for deployment on agricultural farmlands. They should be built as self-sufficient and self-sustaining nodes and should be able to withstand the harsh weather found in open farm holdings.

7.2. Low power wireless protocols and standards integration: In order to deploy sensors on agricultural holds that are remote, precautions must be taken to operate in environments with limited energy. 6LoWPAN is a newly developed wireless standard designed with Internet of Things applications in mind. With lower data rates, it has the same range as Wi-Fi or ZigBee and consumes less power. The viability, applicability, and scalability of using this recently created standard can be investigated further. Using an event-driven protocol for sensor layer communications is another way to save power.

7.3. Agricultural applications using underground WSNs: UWSN is a recently developed field of study. Underwater sensor networks are also referred to by the acronym, but not in our instance. The use of underground sensors is encouraged by the agricultural UWSN approach. Its primary application in agriculture is the monitoring of soil moisture, temperature, and nutrient profile. But new power and communication strategies are needed for these sensors. There may be room for more study in this area.

7.4. Detecting pests through image processing: With the use of image processing algorithms, plant diseases can be identified. A database on the chromatic characteristics of pests is compared with images captured by UAVs or cameras installed at the farm using spectral analysis. Pest detection in rice crops has been the subject of a thorough investigation in . It is a feasible research direction to integrate the outcomes of such analysis techniques with the Internet of Things infrastructure.

7.5. Solar-powered nodes for sensors: Indoor IoT infrastructures use battery-operated sensors. Solar-powered sensor nodes, on the other hand, offer a more practical, efficient, and sustainable option for agricultural applications. Solar energy has been used to power the sensors in a deployment conducted by researchers in the Chinese province of Shaanxi [8]. The development of solar-powered sensors that can be used in smart farming is necessary.

8. CONCLUSION

We have presented a methodical vision for the development of cloud computing and IoT technologies for agriculture in this paper. We have concentrated on developing countries in our research. Our approach to the system architecture and its features is balanced, in contrast to previous works in this field. After much discussion, we have developed services that take into account the importance of a human-centric approach for developing countries. Instead, attention has been drawn to the entire designas opposed to the system's intricate details. Lastly, by illustrating how cloud computing and IoT can be used in tandem to create an enabling platform for the next generation of smart agriculture, this work makes significant contributions.

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