A Technical Assessment of IOT for Indian Agriculture Sector

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ABSTRACT
Agriculture is one of the most important aspects of human civilization. The usages of information and communication technologies (ICT) have significantly contributed in the area in last two decades. Internet of things (IOT) is a technology, where real life physical objects (e.g. sensor nodes) can work collaboratively to create an information based and technology driven system to maximize the benefits (e.g. improved agricultural production) with minimized risks (e.g. environmental impact). Implementation of IOT based solutions, at each phase of the area, could be a game changer for whole agricultural landscape, i.e. from seeding to selling and beyond. This article presents a technical review of IOT based application scenarios for agriculture sector. The article presents a brief introduction to IOT, IOT framework for agricultural applications and discusses various agriculture specific application scenarios, e.g. farming resource optimization, decision support system, environment monitoring and control systems. The article concludes with the future research directions in this area.

Keywords
IOT, ICT, WSN, Precision Agriculture, Cloud Computing

1. INTRODUCTION
Agriculture (including forestry and fishing) is one of the largest sectors of Indian Economy. While employment share in the sector declined from 64.8% in 1993-94 to 48.9% in 2011-12, almost half of the Indian workforce remains dependent on agriculture[1]. The Government of India (GOI) has taken many initiatives for upliftment of this sector, and the country has seen improved food production in last few decades. GOI is already disseminating the information and knowledge in the area to the stakeholders through various means, e.g. television, websites, radio, print media, call centers, etc. Under GOI, the Ministry of Agriculture and Farmers Welfare (formerly Ministry of Agriculture) is the apex body working in this area. Under the ministry, the Department of Agricultural Research and Education (DARE) coordinates and promotes agricultural research and education. The Indian Council of Agricultural Research (ICAR) is an autonomous organisation under the DARE, which is engaged in scientific and technological areas with approximately 100 of its institutes spread across the country.

Internet of things (IOT) is based on the recent advances in networking, computing andsensing technologies; and it connects digital and physical entities to enable a whole new class of applications and services. IOT envisions an "anytime, anyplace, anything" scenario, i.e. connectivity to anything (smart objects) at anytime and from anyplace. Gartner, world's leading IT research and advisory company, has forecasted use of 6.4 billion connected things worldwide in 2016, up 30 percent from 2015, and predicted the number will reach to 20.8 billion by 2020[2]. Some of the IOT application scenarios are: smart agriculture; environmental monitoring and forecasting; asset management and logistics; vehicular automation and smart transport; healthcare and wellness; home and building automation; industrial automation; smart metering and smart grid infrastructures; etc. IOT can provide a means to monitor, analyze and control every phase of agricultural ecosystem. This paper presents an introduction to IOT and its applications in agricultural landscape.

The remainder of this paper is organized as follows: In section 2, basics of IOT have been discussed. In section 3, an IOT framework for Agriculture applications is presented. In section 4, some case studies in the area have been discussed. The document has been concluded in section 5 with future research directions.

2. INTRODUCTION TO IOT
IOT is an integration of several technologies, e.g. sensors, actuators, embedded systems, networks, wireless communication, web technologies (Fig1). The IOT based smart objects should have unique identities, and they should have abilities to communicate and interact with each other, and with other entities in the network, along with the mobile and/or web based platforms[3].

Many technologies and standards have been proposed for realizing IOT vision, and interoperability of heterogeneous entities is a major challenge in the area. Some of the enabling technologies (sensor, communication and cloud computing) of IOT systems have been discussed in this section.

2.1 Sensors and Actuators

The choice of sensor and actuators generally depends on the application domain. A variety of sensors are available for a number of application areas, e.g. Gas sensors (CO, CO_2, CH_4, O_2, O_3, NO_2, SO_2, etc.) for monitoring pollution, forest fires, etc.; water quality monitoring sensors (pH, conductivity, dissolved oxygen, dissolved ions, etc.); cameras, microphones, and other general purpose sensors like temperature, humidity, pressure sensors, etc. Sensors foragricultural requirements[4] are widely available and utilized for monitoring of soil (temperature, moisture, rain/water flow, water level, dielectric permittivity, conductivity and salinity, etc.), leave/plant (photosynthesis, wetness, moisture, hydrogen, CO_2, temperature, etc.) and weather (e.g. wind speed, atmospheric pressure, wind direction),etc.

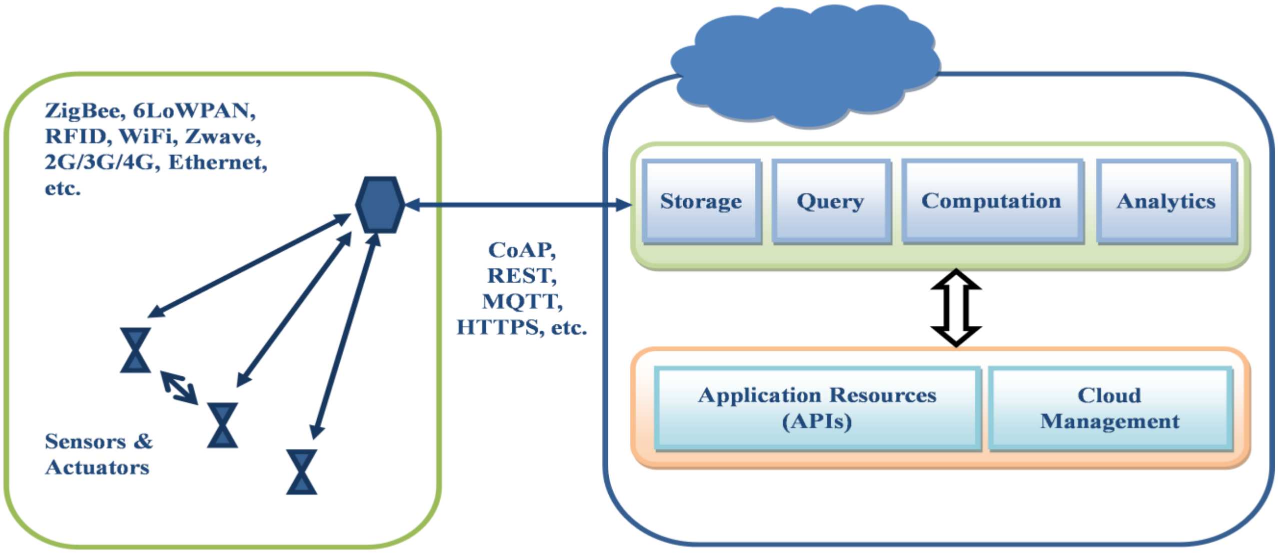

Fig 1: IOT deployment scenario

2.2 Communication Technologies

To achieve communication abilities many technologies and standards have been proposed, e.g. ZigBee, 6LoWPAN, RFID (Radio Frequency Identification), Wi-Fi, Zwave, Near Field Communication (NFC), Bluetooth Low Energy, WirelessHART, Mobile-phone technologies (2G/3G/4G), Ethernet, etc. RFIDs are inexpensive microchips with unique identities and wireless communication capabilities. Passive RFIDs do not require external power source (battery), and they are powered by the RFID reader's RF interrogation signal to communicate their information to RFID reader. Active RFIDs are battery powered devices, with improved computation and communication (signal range) capabilities. RFIDs have many application areas, e.g. access control, transportation, retail and supply chain management. Wireless sensor network (WSN) consists of spatially distributed sensors nodes (with sensing, computation and communication capabilities) to monitor physical or environmental conditions. IEEE 802.15.4 standard specifies the physical layer and media access control layer functionality for low-rate wireless personal area networks. Various WSN solutions have been proposed based on IEEE 802.15.4 standards, e.g. ZigBee, 6LoWPAN,etc.Ojha et al.[5]presented a comparison of various communication technologies and a detailed review of WSN applications in agriculture including Indian scenario.

2.3 Cloud Computing Technologies

Cloud computing facilitates an on-demand network access to a shared pool of configurable computing resources (servers, storage, networks, applications, services, etc.). Based on services, clouds can be classified as Infrastructureas a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). Based on ownership, clouds can be classified as Private (single organization ownership), Public (open for public use), Community (exclusive use by a group of consumers), etc[6]. The cloud platforms receive the ubiquitous sensors' data; store, analyze and interpret the data; and provide user friendly decision support visualization [7].

In Table 1,some enabling technologies for three basic subcomponents of an IOT system(viz. sensors and actuators, communication and cloud computing technologies) have been listed.

Table 1.AgriculturalIOT subsystems

Subsystem	Enabling Technologies
Sensors and Actuators	Sensors for temperature, moisture, rain/water flow, water level, dielectric permittivity, conductivity, salinity, photosynthesis, hydrogen, wetness, CO_2, wind speed, wind direction, atmospheric pressure, etc.
Communication Technologies	ZigBee, 6LoWPAN, RFID (Radio Frequency Identification), Wi-Fi, Zwave, Near Field Communication (NFC), Bluetooth Low Energy (BLE), WirelessHART, Mobile-phone technologies (2G/3G/4G), Ethernet, etc
Cloud Computing Technologies	Infrastructureas a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS)

3. IOT FRAMEWORK FOR AGRICULTURE APPLICATIONS

IOT application areas are ubiquitous across the life cycle of agriculture sector, viz. cultivation, water management,harvest, storage, processing, transportation, and sales. Along with the commonly available sensors, a variety of specialized sensors are available for agricultural applications, e.g. Soil Moisture, Humidity, Leaf Wetness, Solar Radiations, Ultraviolet Radiations, Pluviometer (Rain Gauge), Wind Vanes, etc.

In a typical IOT scenario, sensors can be deployed in fields, green houses, seed storages, cold storages, agriculture machineries, transportation system, and livestock; and their data can be stored in a cloud for monitoring and control (Fig 2). The research and analysis of the data can guide the ways to improve production with optimized use of resources, and can bridge the demand and supply gap of the agricultural produce. Processing, correlating, analyzing and inferring correct information from the data, which is coming from a variety of sensors, is the most challenging task in any IOT system. Leeet al. [8] presented an IOTbased agricultural production system, based on correlation analysis between the crop statistical information and agricultural environment information, to enhance the ability to analyze current conditions and predict future harvest. Further, Semantic heterogeneity of multiple information resources is a challenge for integrating different agricultural IT system. Many researchers are working in this direction, e.g. Hu et al. [9] proposed an ontology-based approach (AgOnt) to solve the semantic interoperation problem for a seamless access of the distributed agriculture products' information system. Phenonet[10], a large scale experimentation built on an open semantic IOT platform, was developed by CSIRO Australia to study the impact of environmental variations (light, temperature and soil moisture) on plant growth. The Phenonet-OpenIoT architecture minimizes the programming efforts and handles the challenges like heterogeneous nature of data.

4. IOT APPLICATIONS IN AGRICULTURE

As discussed in earlier sections, IOT can be helpful during all the phases of the agricultural ecosystem (Fig 2). It can be applied for real time monitoring and control of controlled environment in greenhouses, and can be used for real time monitoring and decision support systems for fieldparameters, e.g. soil parameters (moisture, conductivity,etc.), environmental parameters (e.g. temperature, humidity, light, wind). The data received from remote sensing satellites and aerial imageries (through satellite/drones) can further complement the decision making process. Some application areas are discussed in brief in this section and some implementation examples are listed in Table 2.

4.1 Monitoring and Control Systems

Various IOT based systems have been proposed for monitoring and control of environmental conditions in greenhouses [11], and monitoring and decision support systems for agriculture field application [12], etc. WSN based precision agriculture architecture was proposed for sensing vital parameters of soil (pH, electrical conductivity, soil temperature and soil moisture) [13]. A ubiquitous sensor network based IOT solution was presented for a greenhouse with hydroponic crop production[14]. The experimental set-uputilized coco coir as Hydroponic Media (soil), ubiquitous sensor network (based on WIFI, Bluetooth Low Energy (BLE) and serial bus protocol), low cost sensors/actuators (temperature, moisture, pH, pumps, etc.), and open source hardware-software paradigm with web services protocols like REST, HTTP,MQTT,etc.WSN based solutions have also been proposed for environmental monitoring, precision agriculture, machines and process control, etc [15].To bridge the information gaps between the farmers and the agriculture scientists/experts through ICT initiatives, Jhunjhunwala et al. [16] presented an Agricultural Advisory System using a call center approach and a PUSH based voice messaging system. They implemented the system in Tamil Nadu (India) to address farming issues related to many crops, e.g. groundnut, paddy, sugarcane, redgram, black gram, maize.To expand the services offered by the Agricultural Advisory System,Sarangi et al. [17] presented a distributed Automated Crop-disease Advisory Service (ACAS) based on Wisekar, an Internet-of-Things repository.They presented a system to detect the crop diseases based on the cloud based processing and analyzing of crops' images received from the farmers.

Table 2.Examples of IOT applications in Agriculture

IOT applications in Agriculture	Description
E-kakashi project (Japan) [12]	***Phase:*** Pre-harvesting and monitoring ***Technology:*** sensor gadgets, cloud database system ***Area:***Farming productivity improvement and reduction of vermin damage
AGRO-SENSE (India) [13]	***Phase:*** Pre-harvesting ***Technology:*** Wireless Sensor Network, LR-WPAN technology ***Area:*** Control decision making
Precision agriculture irrigation system (China) [18]	***Phase:*** Pre-harvesting (Irrigation) ***Technology:*** WSN, Fine valve tube switches andirrigation pipes (site irrigation module), GPRS ***Area:*** Reduction in water consumption for irrigation
Agricultural Machinery Intelligent Scheduling in Cross-regional Work (China) [19]	***Phase:*** Post-harvesting ***Technology:*** Cloud computing, GPS, etc. ***Area:*** Agri-resource management
Automated Crop-disease Advisory Service (India) [17]	***Phase:*** Pre-harvesting ***Technology:*** Wisekar, an Internet-of-Things repository, Image processing ***Area:*** Crop-disease advisory system

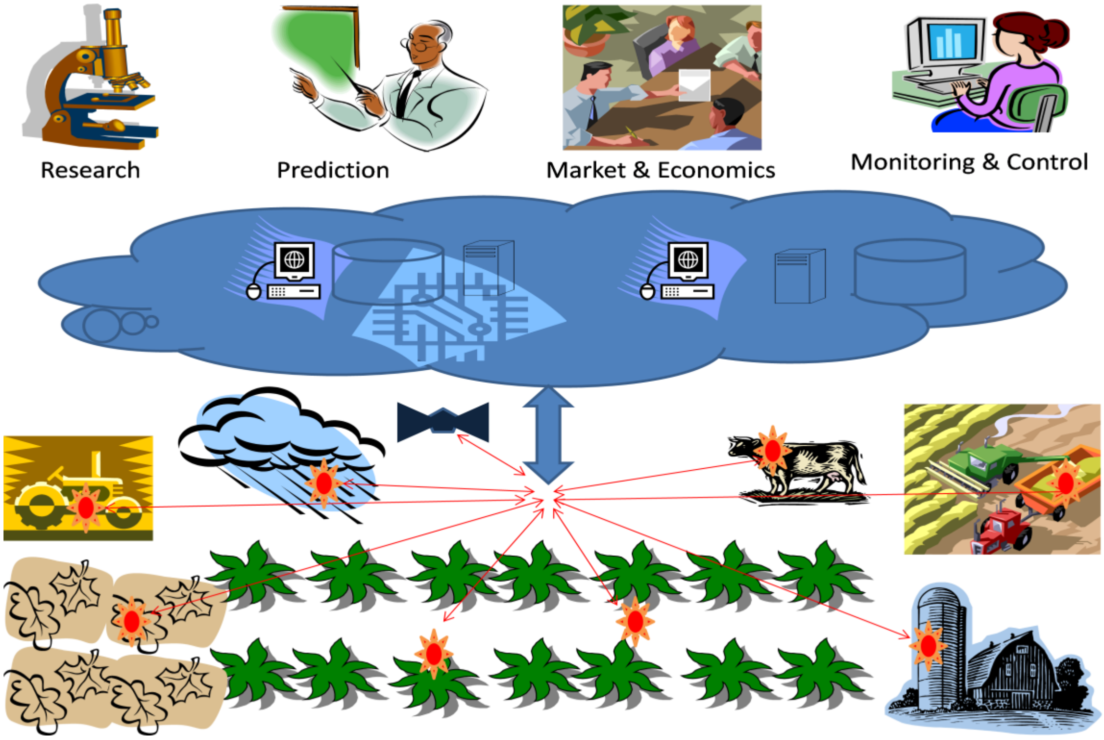

Fig 2: IOT framework for agriculture applications

4.2 Smart Irrigation System

Water is a critical input for agriculture yield in nearly all its aspects. Without optimal water, even good seeds and fertilizerfail to achieve their full potential. India has about 4% of theworld fresh water resources with about 17 % of the world'spopulation[1]. But in terms of water use efficiency, India uses 2-3 times the water used in countries like China, Brazil andUSA to produce one tone of grain. IOT based solution can be utilized to improve the water use efficiency, e.g. S. Li et al. [18] proposed an IOT based precision agriculture irrigation system for optimum water usage. Ojha et al.[5] discussed about a lab scale Irrigation Management project at IIT Kharagpur, India. In this project, they deployed WSN nodes in the field to monitor the irrigation requirement and to inform farmers through SMS viaa GPRS module. Panchard et al.[20] also proposed a sensor network based water management system with sensor nodes to sense various parameters related to environment and crops, and a GPRS based module to communicate the sensor network information to remote server.

4.3 Agri- produce and Agri-resource Management

In a typical IOT scenario, RFID tags (electronics barcode) or sensor node can be attached to the agricultural produce (e.g. grain/seeds bags with RFID tags) and the agriculture resources (e.g. expensive machineries) for effective tracking and management. Uses of RFIDs have been proposed for identification and tracking of livestock, Agro-produce, farm machinery, etc [21].A Cloud and IOT based conceptual framework was presented for efficient monitoring and analytics of grain warehouses[22]. Similarly, real time monitoring of products stored or transported under controlled environment is also a possible scenario. Further, IOT and cloud based platforms can be helpful in intelligent scheduling of expensive agricultural machinery [19].

4.4 Agri Business Management

IOT based integrated information environment, with information from farms, storage houses, transportation systems, processing units, markets and export houses available at single platform, can help in achieving resource optimization, quality improvement, cost reduction, improved profit, competitive sale prices, etc.

5. CONCLUSION

Information and Communication Technologies (ICT) are already ubiquitous in our lives, and the young generation has crossed the era of personal computers and living in the age of smart phones and internet. Technological advancements in the area are the best solution for improving agricultural yields and for uplifting the lives of workforce employed in this sector. IOT based system in agriculture,although proven successful in developed countries,arein a very primitive stage of implementation in India. The major challenge is to spread the knowledge and awareness about such systems to the various stakeholders, particularly the farmers. Further the cost of infrastructure modernization and maintenance is another challenge. Some of the research direction in the area are development of need specific and more effective sensors; algorithms and systems for energy efficient and secure communication; development of agriculture specific standards for IOT and cloud platforms; development of effective visualization and decision support systems; automation of agricultural processes; data analysis for planning, management, agricultural bio-informatics, and for finding the new and improving the existing process, methods and systems. Today, the mobile networks, internet and smart phones have already started their penetration towards villages, and building I-ways (ICT infrastructure) are considered as important as highways; this is a right time to seed the IOT knowledge and infrastructure in the agriculture sector for realizing a technology driven precision agriculture vision.

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