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Review Article

INTERNET OF THINGS: APPLICATIONS TO DEVELOPING COUNTRY AGRICULTURE SECTOR

LALITHA A.*[1], SURESH BABU[2] and PURNIMA K.S.[3]
[1]Scientist (Extension), Agricultural Information & Communication Centre, Acharya N. G. Ranga Agricultural University, Lam, 522034, Andhra Pradesh, India
[2]Head of Capacity Strengthening, International Food Policy Research Institute, Washington, USA
[3]Scientist (Extension), Open and Distance Learning Centre, Acharya N. G. Ranga Agricultural University, Lam, 522034, Andhra Pradesh, India, India
*Corresponding Author: Email -lalithareddy6@gmail.com

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Abstract: The Internet of Things (IoT) is a novel paradigm shift in information technology (IT) sector. The sensor data visualization for agriculture has a great opportunity for mobile technology. Cloud computing offers several applications in the field of agriculture with limited infrastructure and costs. The IoT food supply chains can become self-adaptive systems in which smart objects operate, decide, and learn autonomously. This review paper discusses IoT application in agriculture in developed and developing countries and suggests a conceptual framework for IoT application in State Agricultural Universities of India. By 2020, the world will be having around five billion mobile subscribers and most of these will reside in China and India. Hence, there is a scope for IoT application in Indian agriculture. Any initiative that could move a part of the agriculture and food enterprise into the IoT platform/cloud at a cost-effective price would help the Indian agriculture and food sector.

Keywords: Internet of Things (IoT) architecture, Smart Agriculture, Sustainable Development Goals (SDGs), Sensors, Cloud Computing, Wireless Sensor Network

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Introduction

The Internet of Things is a novel paradigm shift in IT sector. Things can be both living and non-living and are real objects in the physical or material world. Each object will be tagged for identification, automation, monitoring, and controlling. With the spread of smart devices, mobile networks, cloud computing, big data analysis, innovative technologies related to sensors, and micro controllers have evolved the new era of the Internet of Things [1]. IoT can be realized in three paradigms – internet oriented (middleware), things oriented (sensors) and semantic oriented (knowledge) [2]. The IoT aims to unify everything in our world under a common infrastructure, giving us not only control of things around us, but also keeping us informed of their state [3]. IoT has application potential in every area since it can be context-aware and provide tailored services [4]. Compared with the Internet, IoT provides a wider platform to share more information. The information service in IoT is necessary to organize the process of getting and sharing information for the IoT user [5]. IoT can provide a means to monitor, analyse, and control every phase of Agricultural eco system [6]. Use of rapidly evolving IoT may lead to more efficient designs of ICT-extension services, avoiding the need for physical inspections. IoT stitches together diverse sources of information and support delivery of farmer specific information [7]. Cloud computing offers a number of applications in the field of agriculture with limited infrastructure and costs [8]. IoT has been looked upon as a hope to encourage innovation in agriculture with "connected farms" speculated to be the future of farming. Information and Communication Technologies (ICTs) have the power to enhance the opportunities for producers in global markets and in their own domestic markets by linking the stakeholders in the food supply chains through innovative technologies and facilitating communication for a superior system [9]. The applications of ICTs to tackle climate change impacts in various areas including agriculture has been reviewed by researchers [10]. By 2050, World's population will reach 9.1 billion - with an estimated requirement to increase food production by 70% globally to feed an additional 2.3 billion people. In order to exploit the potentiality of Internet, Food and Agriculture Organization (FAO) has formulated a conceptual model Virtual Extension and Research Communication Network (VERCON) that employs internet-based technologies and Communication for Development methodologies to facilitate networking, knowledge sharing and interaction among agricultural institutions, producer organization and other actors of the agricultural innovation system [11]. The sustainable development goals (SDGs) *viz*., 1) No Poverty 2) Zero hunger 3) Good health and well-being 4) Climate action address concerns for agricultural extension professionals. They can play a major role in enhancing food and nutritional security, sustainable livelihoods, resilience to climate change and peace and well-being of the farming community. The extension profession is already advocating the set targets of the SDGs. Further, the role of IoT can be providing back-up information and revolutionizing agriculture in developing countries with designs/prototypes/business models that combine smart agriculture and smart food supply chains from both producer/consumer perspective and logistics perspective. The CGIAR Platform for Big Data in Agriculture aims to close the digital divide between rich and poor farmers to achieve the United Nations' Sustainable Development Goals of increasing food production, reducing poverty and tackling climate change. The platform will focus on three areas-organize data on soils, climate and crops, foster new partnerships between the agriculture science and technology sectors and put the data and partnerships into practice with big data approaches at their core [12]. Smart agriculture includes agricultural practices with the adoption of IoT, sensors and others, in order to increase the productivity of the farm. Smart agriculture also addresses the interlinked challenges of food security and climate change and benefit smallholder farmers by increasing efficiency of inputs such as labour, seeds, and fertilizers, to increase food security. At this juncture, 'Smart' meaning can be automation, intelligent data aggregation and traceability in the IoT food supply chains can become self-adaptive systems in which smart objects operate, decide and learn autonomously [13]. There were around 173 million mobile internet users in India by the year 2014. The mobile internet market is growing at the rate of 12.38 percent [9].

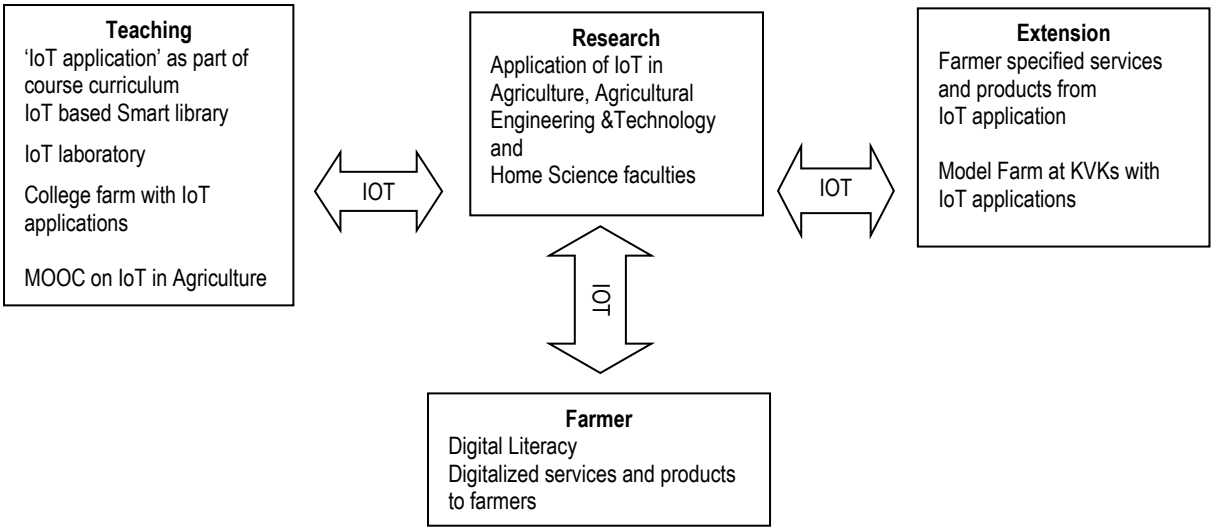

Fig-1 Conceptual framework of IoT for a SAU in India

Key initiative taken by Government of India is the formation of Centre of Excellence on IoT and CoE-IoT at Bangalore. The centre has started an initiative to consolidate the efforts, products and solutions in the Agri-Tech field in India [14]. This review paper is motivated by questions relevant to a developing country such as India–how important IoT is for information sharing and decision making? Can the present ICT applications can be upgraded as IoT technologies with minimum cost? How feasible IoT is under small farmer's field conditions? What are the potential areas in agriculture sector for IoT implementation? Can we focus on policy and program interventions with IoT from the public sector extension? What will be the public-private partnership in this effort? What are the institutional impediments for IoT to become reality in farmers' field? Will it stay in the books as Precision Agriculture or Smart Agriculture? Will it stay in the books as decision support systems that have been discussed? Do developing countries need to revisit agricultural extension strategies for enhancing food and nutritional security? Can IoT act as enabler in agriculture sector of developing countries? This study looks at the scope of IoT for Indian agriculture sector with a focus on small farm holdings and review IoT applications to agriculture sector in India.

Review of Applications

Agriculture sector

The literature review on Internet of Things (IoT) in agriculture and food provides an overview of existing applications, enabling technologies and main challenges ahead. The review in this section pays close attention to the literature and designs of computer architecture that can be applied to IoT in agriculture. In a developing country such as India, IoT interventions and applications are mostly confined to sectors other than agriculture [13]. Sensors such as temperature sensor, soil moisture sensor and relative humidity sensors are the most important for the agriculture production and for measurement of such parameter's microcontroller can be used and digital data is transmitted to cloud through esp8266 which acts as an internet gateway. The use of microcontroller and esp8266 is proposed in the system for low cost and re-programmability according to different environmental conditions [15]. Sensors have been able to gather data from remote village sites on meteorology, moisture and soil nutrient management [16]. Many built-in sensors in smart phones have yet to be explored in the context of agriculture [17]. The sensor data visualization for agriculture has great opportunity for mobile technology [18]. IoT devices communicate using a range of different communication protocols, which may include: short-range radio protocols (ZigBee, Bluetooth and Wi-Fi), mobile networks, or longer-range radio protocols (LoRa). These technologies can be segmented based on wireless versus wireline, and the wireless technologies can be grouped by personal area network (WPAN), wireless local area network (WLAN) or wide area network (WWAN) technologies [16]. There is a need to provide better technological solutions to the farmers for the precision agriculture since agriculture is the base of Indian economy [19]. IoT architecture contains four layers such as sensor layer, gateway and network layer, management service layer and application layer. Sensor layer is the lowest layer and application layer is the topmost layer. IoT uses multiple sensors that are embedded in the fields, which collect real-time information regarding weather, temperature, humidity, rain fall, soil moisture, soil composition, wind speed, wind direction, soil temperature, leaf wetness, air quality, predicting pests, crops, water level, which in turn, this predictive statistical data provides information to the farmer to make smarter decisions. The information helps farmer in crop selection, crop monitoring, crop maturity, crop yield, fertilizers, pesticides, soil erosion, crop yield, diagnosis of crop diseases [20]. Future PhenoApps will address additional data bottlenecks in plant breeding programs including managing crossing blocks, collecting specific geospatial data, analysing root phenotypes, and further ensuring data integrity [21]. IoT based 'Smart Library' system provides the luxury of fetching a book from its place with the assistance of an IoT based interconnected system using a Wi-Fi based Local Positioning System (LPS) and Near Field Communication (NFC) tags. With much ease, the user can interact with the library server to check whether the book is available and if available to locate it right to its position [22]. Smart warehouse management includes temperature maintenance, humidity maintenance and theft detection in the warehouse [23]. The IoT can be applied to monitor and control the microclimate factors of greenhouse remotely [24]. Application of wireless sensor network (WSN) in tea plantation management opened a new dimension for online data acquisition, and automated irrigation/fertilizer spreading decreases the human dependency and maintains the optimum soil conditions for plant growth [25].

Case Studies of IoT

Developing Countries

IoT is not much used in the field of agriculture in India [20]. This section presents few IoT applications initiated in the agriculture sector in India and other developing countries.

KISAN Project and android app

Indian Space Research Organisation (ISRO) has developed (Crop insurance using space technology and geo informatics - KISAN) project that envisages use of Space Technology and geoinformatics (GIS, GPS and Smartphone) technology along with high resolution data from UAV/ drone-based imaging to advance yield estimation and enhance planning of Crop Cutting Experiments (CCEs), needed for crop insurance programme. This android based app can also collect real-time information to assess the damage to agricultural crops due to hailstorm. The app can be used through smartphones for collection of hailstorm data along with photographs and geographical coordinates (longitude and latitude). This app aids to process faster claims to crop insurance during crop damage by accessing real-time data for farmers.

Farm irrigation through mobile motor controller
In many cases, farmers need to travel long distances and/or through difficult conditions to access pumps from their households. Mobile Motor Controller is a device (invented and manufactured by Vinfinet Technologies Pvt. Ltd.) that allows farmers to remotely control the agricultural motor using their mobile or landline. A text message or missed call (GSM) or an IVRS (Interactive Voice Response System) in local language helps in making selections for switching the motor on or off. Farmers also receive voice alerts for faulty power supply, motor not starting, lack of water in the well/bore, and attempt of device/motor theft. The company also introduced Multi Motor Controller that can control up to five motors.

Near real time data collection and management reports by SUVIDHA, NGO
The Society for Upliftment of Villagers and Development of Himalayan Areas (SUVIDHA) which works with small and marginal farmers to help improve their socio-economic conditions has collected near real time data and information on the area of cultivation (both season wise and crop wise mapping) from farmers' field and generated management reports. The software solution significantly reduced farmer data collection costs in remote locations with existing mobile and wireless data networks.

Enterprise Resource Planning (ERP) based solutions for farmers
Cropin geotags farmers plots and provides farm scores. It provides farmers with mobile apps which enable them to do connected and data driven farming. It allows farmers to take advantage of real time data and insights from farms and improves financial, operational and agronomical aspects. Cropin has products such as Smart farm, Smart sales, M warehouse, advisory and extension activities, crop analytics, smart pulse, weather-based analysis and satellite-based geo spatial analysis of plot.

ICRISAT's Big Data analysis to guide farmers
In the year 2016, ICRISAT selected 175 farmers in Telangana state and advised them to delay sowing operations till they gave a go ahead. By monitoring weather data and analysis of big data, ICRISAT sent an SMS to farmers in the third week of June to sow the seeds. It helped the farmers as climate change made the rains unpredictable and their crop yields increased by 30 to 40 percent as they sowed closer to the time of rains.

Smart Greenhouse
Yuktix of Bengaluru, India has developed a device with a compatible sensor catalogue that can monitor environment variables in a greenhouse such as temperature, humidity, lux, soil temperature and moisture, CO_2, leaf wetness and soil pH, *etc.*

Tracking of dairy animals by Chitale Dairy, Maharashtra, India
Chitale Dairy maintains a database of 10,000 animals of dairy farmers, along with a complete progeny and medical history. Chitale Dairy deployed a "cows-to-cloud" strategy to increase the milk yield. Farmers access the data in a cloud portal and use the data. To monitor the cows, Chitale Dairy places RFID tags in cow's ears to receive information on whether the animals are in heat or need to be vaccinated or dewormed. This information is transmitted via the cloud to farmers' mobile devices. Farmers call the Chitale Dairy call centre, which sends the data to a mobile app, with the RFID number matching up with a cow. The cloud then sends a to-do list to farmers in their local language each morning on what each cow needs based on the data collected from the RFID signals. From the data received by RFID tags, Chitale Dairy performs mineral mapping and blood profiling. Monitoring the data allowed Chitale Dairy to increase milk production by more than five litres per animal.

Kenya
Beginning in 2009 with a pilot project offering index insurance to 200 farmers in Kenya, the Syngenta Foundation's Kilimo Salama ("Safe Farming") weather index insurance programme has helped over 51,000 farmers in Kenya. The program's solar-powered weather stations collect weather data every 15 minutes, which are then aggregated and compared to historical weather data at the end of each growing season. Any pay-out owed is calculated and sent to farmers via mobile phone. The premiums charged to consumers are calculated based on simple assumptions of the frequency of drought in Kenya.

Ghana
TradeNet, a single window trading platform via mobile networks and internet in Accra, Ghana allows traders and farmers to sign up for Short Message Service (SMS) alerts for commodities and markets of their choice and receive instant alerts for offers to buy or sell as soon as anyone else on the network has submitted an offer on their mobile phone. Farmers can also request and receive real-time prices on their mobile phones for more than 80 commodities from 400 markets across West Africa.

Conceptual framework of IoT application for State Agriculture University (SAU) in India
The SAUs in India have a mandate of training the man power in various faculties (teaching), constantly generate and improve technologies for increasing production (research) and assist in dissemination of the improved technologies to the farmers of the state (extension). The conceptual framework of IoT [Fig-1] for SAU is deliberated to connect the SAU with the farmers for high quality and large quantity of crops, thus, increasing crop production and productivity.

Teaching
Introductory course on 'IoT applications in agriculture' as a part of course curriculum in undergraduate, post graduate and doctoral courses can build a dynamic human resource for smart agriculture.

Research
Agriculture research shall focus on IoT smart applications that can bring 365/7/24 visibility and outputs in the areas of soil health, crop health, level of energy consumption and produce storage conditions at farm level and farmers' level.

Extension
Availability of real time data for monitoring of development programs can benefit the government. Further, teaching, research and extension can also be connected through IoT applications for real-time feedback, early decisions and move the SAU'S aggregated data into the cloud [Fig-1].

Conclusion and ways forward
The world will be having around five billion mobile subscribers and most these will reside in China and India by 2020. Hence, there is a scope for IoT application in Indian agriculture. However, the challenges are bigger such as identification of research areas where IoT projects can be successful and sustainable at farmers' level, availability of internet at farmer level, more IoT services and products to farmers at low cost and simplifying real time cloud data into farmer specified product and information. A push towards higher agricultural productivity in India will require an information-based, decision-making agricultural system [26]. Any initiative that could move a part of the agriculture and food sector into the IoT platform/cloud at a cost-effective price would help the Indian agriculture and food sector.

Application of research: Study shows current scenario of Agriculture Information Technology

Review Category: Agriculture Information Technology

Abbreviations:
IVRS: Interactive Voice Response System

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