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## Internet of Things (IoT): Applications, Implications & Green IoT in Agriculture

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### Abstract

Existence of Internet of Things (IoT) is due to spread of smart devices throughout world. Enormous amount of data from IoT enabled devices are getting generated in real time. Real time data originates from IoT enabled devices build knowledge database and magnifies the wisdom in the society. Application of IoT is in areas like homes, agriculture, transport, health, security & safety. Green IoT based agriculture makes life easy for farmers. It is being used in controlled environment farming like greenhouse farming, open field farming, livestock breeding, aquaculture & in aquaponics. Use of IoT technology will certainly enrich the quality of human life.

**Keywords:** Internet of Things; IoT, Smart home, Smart transport, Smart health, Green IoT, Security & safety, Big Data.

### 1 Introduction

The title Internet of Things (IoT) was first conceived by Kevin Ashton in 1999 [1]. But in the recent year, annotation of IoT has become more comprehensive in terms of agriculture, health, transport, security & safety, smart homes etc. Over a period of time objects or things are connected to Internet as compared to human being [2].

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### 1.1 Trend of Connected Devices Across Globe

Internet of Things (IoT) was came into existence in 2009. Connected devices on internet has increased compare to no of people. Till 2020 number of expected connected devices will be more than 50 billion compare to population of 7.6 billion. As an average each person will be having 6.58 devices. Figure 1 shows Connected Devices by 2020.

World Population	6.3 Billion	6.8 Billion	7.2 Billion	7.6 Billion
Connected Devices	500 Million	12.5 Billion	25 Billion	50 Billion
Connected Device Per Person	0.08	1.84	3.47	6.58
Year	2003	2010	2015	2020

Figure 1 Connected Devices by 2020

### 1.2 IoT Platform Evolution

Emerging technologies like are redefining, how companies see and use IOT platform. While technologies continue to evolve towards connectivity and ecosystem enabling platform, business must understand and redefine strategies to exploit these opportunities. IoT technology are facilitating highly obstreperous models & encouraging organization to innovate in digital arena. As per Gartner report on Hype cycle for emerging technologies, IOT platform is one of emerging platform and will be into existence for 5 to 10 years of time. Figure 2 shows Hype Curve for Emerging Tehnologies, 2018.

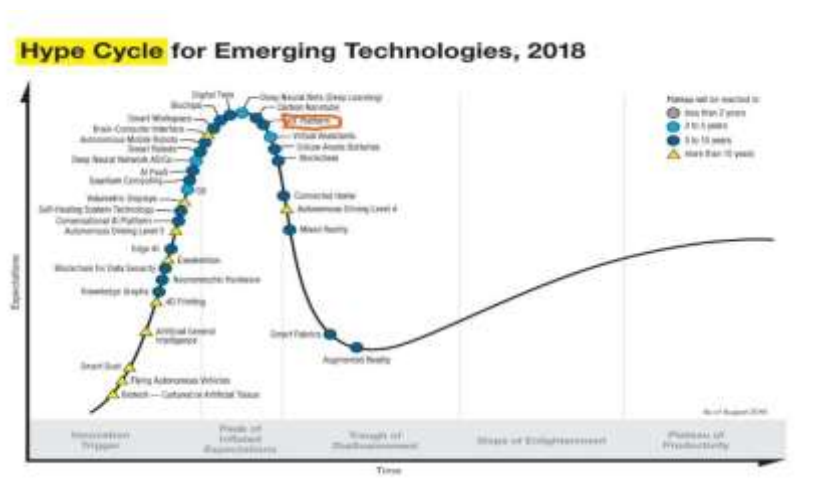


Figure 2 Hype Curve for Emerging Tehnologies, 2018 [2]

### **1.3 Green IoT in Agriculture**

#### **1.3.1 Need of IoT**

With the ever-growing increase in world's population, there is skyrocketing demand for food. Parallely, with global warming and climate change there is fastened depletion of natural resources and increased weather uncertainty. This altogether poses a huge challenge to match food production with its demand. Not only this, there is a huge disparity in availability of food in different parts of the world due to uneven distribution of natural resources and income inequalities. This is evident through Global hunger index that millions are suffering from hunger and malnutrition particularly in the continents of Africa and Asia. One of the many factors behind this massive problem includes unavailability of food at affordable prices. This calls for a sustainable solution to provide food security in all the parts of the world.

Another major issue in the field of agriculture relates to the poor return on investment to the farmers, particularly small and marginal farmers, which discourages them to continue with farming. It also results in disguised unemployment, poor productivity, and poor income of the farming community.

In a country like India, where agriculture is the primary source of livelihood for around 58% of the population, it contributes only 17-18% to the country's GDP. This clearly shows the underlying problem of poor economic returns to the farmers.

However, there is an increasing shift of workforce from agriculture to other sectors due to dismal future of opportunities and poor income in the field. This is creating huge supply-demand gap in manpower in the field of agriculture in many parts of the world.

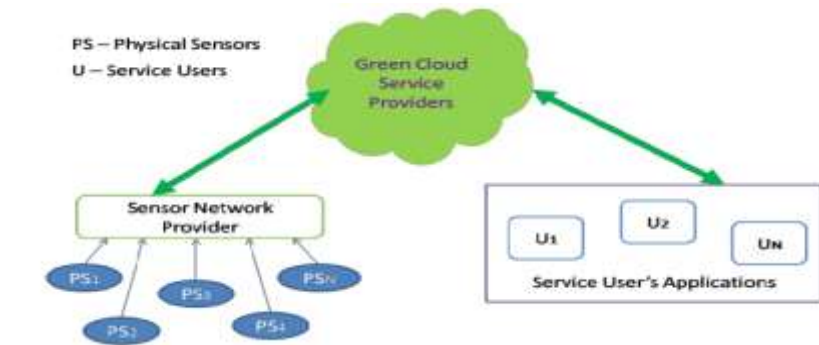
To sustain agricultural growth and ensure food security, it is therefore, of utmost importance to improve efficiency in agriculture by deploying latest technologies and providing incentives to farmers by improving return on investments. IoT enabled smart farming brings solutions to these problems by enhancing productivity, increasing returns, and reducing wastage.

#### **1.3.2 Green IoT Architecture**

Sensor networks are used in agriculture, health, transport, securities, homes, industries related applications. In agriculture entire life cycle starting from ingredient supply, growth, packaging, distribution & consumption can be monitored & controlled by green IoT framework [3]. Growth of the plants can be monitored by using temperature, humidity, pressure etc sensors. IoT frame work can be used in controlled & open environment planting, livestock breeding, aquaculture and aquaponics. Similarly, human health parameters like blood pressure, heart rate, blood sugar, sleep pattern etc can be

monitored by using IoT enabled sensors. Data collected through sensor network is utilised by hospitals for recommending appropriate treatment for the patient remotely. However, this paper cover green IoT in agriculture.

Sensor network collects the data from IoT enabled devices through physical sensors and share the data centrally on cloud computing infrastructure. After processing of voluminous of data, user will be able to see the results on the application user interface (UI). As per Mark Hachman [4], in 2012 all world data centre consumes 30 billion watts of electricity which is equivalent to output of 30 nuclear plants. Electricity required for data centres for cooling of servers & data centres for one year, can power 5 million houses for one year. Therefore, there is ned to optimize the power consumption & build energy efficiency enabled IoT network.



**Figure 3** Green IoT Application Architecture in Agriculture [4]

Following point to be considered for saving power consumption during deployment of Green IoT architecture [4]: -

- Sensors or cloud computing infrastructure should be enabled, if it is required otherwise, it should go on sleep mode.
- Data transmission consumes lot of power. Hence sensor should send data, which is actually required.
- Data transmission should be through optimal wireless path in wireless communication network.
- By using renewable resources (water, solar, timber, biomass etc). Therefore, utilizing renewable energy resources to reduce the dependency on oil & emission of CO<sub>2</sub>.

## 2 Literature Review

Green IoT is being used in managing life cycle in agriculture starting from inventory management of ingredients and ordering based on requirement. Checking temperature, humidity & growth of plants. Post harvesting, IoT technology is used in processing, packaging, distribution & storages [3].

Sensors are deployed in agricultural fields, which collect the data and send to cloud service provider. Service user application fetch the data from the cloud and farmers/ researchers get the relevant information for use [4].

Smart or intelligent transportation is developed by either transport department in government or transportation authorities. Proactive traffic information, on line traffic control, promoting electric vehicles etc are the some of the examples of smart transportation [5].

Smart home application exists since decade, however there are still constraint for adoption of technology due to impractical ideas, lack of industry standards and cost [5].

Trust, security & privacy are vital issues in real-world. Security can be deployed either at physical level or logical level [5].

IoT provide smart solutions for screening passengers & their bags, online fare collection through smart toll systems. Transportation for people & goods are more efficient by using smart transportation. Automated managing & tracking of luggage at airport will reduce manual operation of airlines and will enhance security [6].

Smart transportation system can be deployed by using smart phones, RFID, sensors & bus navigation systems. Application connected to IoT systems will produce smart transportation system [7]

Home domain can be formed by connecting home appliances, smart meters, security system, healthcare system & community entertainments with home gateway. It empowers a variety of services like monitoring health proactively and keep eye on neighborhood activities for safety & security [8]. Home gateway (Arduino Ethernet server, router, firewall) establish connectivity between Android smart phone & home appliances to control the devices like power plug, light switches, temperature & current sensor [9].

For safety & security in society, city, apartments, public places, IOT enabled sensors are used, which internally process the information and share to relevant centers like control centers, police stations, fire brigade stations, surveillance control centers [10].

Privacy & security are vital challenges while implementing IOT enabled solutions. Implementation of robust security system is important to safeguard security & privacy in various areas like businesses, transport & personal life along with adherence of data privacy law [11].

Real time data helps in either serving the customer or for individuals to monitoring & control IOT enabled devices. The case study on Omani banks by the author demonstrate that IoT along with Big Data analytics helps in to address current issues as well as in forecasting. Patrons can be provided with better services [12].

IoT provides chance to retail stores to mature their system so that mobile phones, store shelves, shopping basket and products will become smart and provide data for further analysis. It will also increase on-line interaction with end customers, which in turn helps in future planning [13].

IoT solutions provide proactive monitoring medical parameters of individuals and taking preventive actions to control any disease before it become chronic in nature also IOT enabled solutions ensures timely delivery of drugs [6].

Real time benefit of disruptive technologies like artificial intelligence, IoT comes after amalgamation with big data to manage plethora of complex data [14].

Smart technologies long with computation will lead to efficacious business operations. However, to achieve that, there are constraints like high investment, resistance in change, lack of effective model [15].

IOT technology enables agriculture industry to remotely monitor environment humidity, environment temperature & ground humanity by using temperature and humidity sensors [16].

IoT enabled smart agriculture refers to the concept of using modern information and communication technologies like Internet of Things, Artificial Intelligence, Robotics, and drones in agricultural farms to increase the quantity and quality of agricultural output with reduced human intervention [3]. It is an integrated approach to transform and reorient agricultural systems to ensure food security in the current times of climate change, boost agricultural income, reduce vulnerabilities to environmental uncertainties like extreme droughts, rainfall, pests attack etc.

In IoT based smart agriculture, a system is built to monitor the farm field with the help of sensors. These sensors act as data points thereby providing real time data to take decisions. Such data are further analyzed for predictive analysis and to automate decision making [17]. Automation reduces chances of human error in decision making since manual procedures are replaced by smart system-driven procedures.

One of the major challenges for farmers includes lack of right information for decision making. This is a major challenge considering the weather uncertainties and, in this light, smart agriculture provides the farmers with the necessary information to take correct and timely decisions. This reduces risk of economic losses to the farmers and gives them the chance to cultivate the right type of crops depending on the environmental conditions in their area, timely harvest the crops, protect crops against pest attacks etc. This is possible only because of the real time data delivery via sensors embedded devices.

Based on the combined application of modern Information and Communication Technologies in agriculture [17], it can lead to Third Green Revolution which has the potential to deliver highly productive and sustainable agricultural production based on a precise and resource efficient approach and methodologies.

Smart Agriculture is based on technologies like LPWAN, robotics, GPS, data analytics, Artificial Intelligence etc. However, it is the Internet of Things which is the backbone of smart agriculture since it connects the entire agricultural field using sensors enabled smart devices and machines [18].

This makes the agricultural processes data driven and data enabled. Armed with such smart devices, farmers can now monitor the fields and make strategic decisions for the entire field or only the problem points from a remote location itself. It has enabled farmers to gain better control over the processes of not only growing crops but also raising livestock.

### 3 Applications & Implications of IOT

IOT has implications in day today life of human being. Every human being uses transport to commute from one place to another place, cautious about his or family health issues, concerns about safety & security at home, trying to monitor & control the things remotely for comfort & security reasons. Enabling IOT in transport, health, home automation, safety & security makes them smart in nature. Therefore, human being knowingly or unknowingly will be using either IOT enabled products of services. It will enormously increase the quality of life of individuals, save time & money, proactive monitoring & controlling based on information generated from IOT enabled products & services. Table 1 provides Implications of IOT.

**Table 1:** Implications of IOT

Sr. No	Implications Areas	Discussion Point	Authors
1	Smart Transport	Real Time Information & Intelligent traffic control are resultant of smart transportation.	[5]
		Vehicle to vehicle & vehicle to infrastructure communications will lead to intelligent transportation & hence traffic management will be fully integrated with IoT infrastructure.	[6]
		Solution to traffic congestion problem is by deploying Intelligent transportation system.	[7]
		Automated toll collection is done using RFID or smart devices to solve problem of traffic congestion, fuel wastage, air pollution etc	[19]
2	Smart Homes	Door control, gas/smoke detectors, emergency button, are monitored & controlled remotely in smart homes. Similarly controlling of home appliance like air-conditioned, bulbs, washing machine, refrigerators etc are part of smart home application.	[5]



		Smart homes are connected through wireless technologies and provide home automation, security & surveillance.	[21]
		By using sensors in in smart homes, we can make elderly people independent for living alone in home.	[24]
		Google's Nest is learning thermostat for intelligent homes and can be connected to smart doors, bulbs, wearables etc for making smart homes	[28]
3	Real Time Information	It is challenge for IoT system to minimize the data from sensor gateway and send data to user only when it is required on real time basis.	[5]
		IoT technologies and big data generated real time data and hence it will help in generating prediction and sentimental analysis.	[12]
		IoT technologies will disrupt the retail industry by providing the real time interactions between customer either in physical or virtual stores.	[13]
		IoT technologies provide real time information's and contribute in building good relationship with peers in meeting common objectives.	[25]
4	Privacy & Security	IoT contributes majorly in providing the home security & community security	[5]
		By using motion sensors, if any activity is noticed in house or apartment, camera is automatically turned on and information can be send to nearest police station and owner of house.	[10]
		Security is critical and has threat at device, communications, network & application layer.	[11]
		Assurance of privacy & security in IoT enabled services will increase the people trust to use digital services.	[20]
		IoT security is enabled by protecting communication network, protecting devices, detect misbehaviour of devices & know what to trust.	[27]
		By using RFID health parameters & drug delivery can be monitored efficiently.	[6]



5	Smart Health	IoT based solution shifts reactive monitoring of health to proactive monitoring. [22]
		Real time information coming from IoT solution will helps physicians to monitor health remotely. [23]
		Smart Homes helping elderly to monitor their health and online assisting leads to live independent life. [24]
		IoT is used by clinical care by getting data through sensors and sending analysed data to processing centres for actions. [26]
		With wearable sensors & three-dimensional accelerometers, health of livestock can be monitored proactively. [3]
6	Green Agriculture	IoT solutions are used in controlled plant farming, livestock breeding, open field farming & aquaculture and aquaponics. [3]
		Sensor network collects temperature, pressure, humidity etc data from fields and send centrally for monitoring. To save energy IoT devices must if turned on, as an when they are required to send data and only required data to be shared. Renewable energy to be used [4]
		Using IoT Green technology, ground humidity, environment humidity & temperature can be monitored remotely. [16]
		IoT enabled solution predict crop yield seeing current soil nutrients information. [17]
		Blue tooth & LPWAN enabled network consumes less power and more suitable in agriculture sector for collecting field data. [18]

### **3.1 Smart Homes**

#### **3.1.1 Home Security & Monitoring**

IOT will help in enabling the window/door control, detecting gas/smoke at early stage by using sensors. This helps in looking after elderly & children.

### **3.1.2 Appliance Control & Monitoring**

By using sensors, Wi-Fi & smart phones home appliance like air conditioner & washing machines, lighting etc can be controlled & monitor remotely.

## **3.2 Smart Transport**

For better safety & accuracy in navigation, IoT components like smart phones, sensors, actuators etc can be deployed in transport vehicles like cars, buses, trains.

### **3.2.1 Proactive Road Planning**

Government can plan better by using real time and accurate information received from IoT platforms. Climate changes information can be provided by using smart roads.

### **3.2.2 Fare Collection & Toll System**

IoT enabled solutions provide automatic fare collection at tolls. Fastag is designed as smart toll collection system in India. RFID (radio frequency identification) technology is used to collect the payment. By implementing the Fastag, it reduces the time taking to collect the fare, reduce the wastage of fuel consumption & reduce traffic jam from high to average. Online recharge facility also saves time & fuel wastage.

## **3.3 Smart Security & Safety**

Security & safety of every individuals should be utmost priority. Therefore, to enable smart security & safety mechanism, IOT enabled devices, sensors, actuators are being used to send the alerts to respective centers.

### **3.3.1 Information to Control Centers**

RFID cards are being used to monitor the information of any individual residing in the city or apartment or companies etc. Devices automatically stores the information into central database. Centralized database helps government or society authorities or companies to plan or improve services.

### **3.3.2 Information to Police Control Centers**

Police can monitor and take actions based on the information received through IOT enabled devices. Sensors like ESP-8266 can be connected to

Arduino server for processing information (Location, Name, contact number) and share with police control centers

### **3.3.3 Information to Fire Control Centers**

Heat & Fire control sensors detect the fire & smoke, sends information to server. Which further process the information and share with fire control center.

### **3.3.4 Emergency Information to Health Centers**

IOT enabled emergency switch can be deployed in apartments or homes, where individuals or elderly people are living alone to send the information to nearby Health centers or hospitals for immediate support.

### **3.3.5 Surveillance**

Smart cameras are connected to Wi-Fi to share apartment or home video footage online to the owner. Therefore, owner can surveillance, as and when required.

## **3.4 Real Time Information**

IOT enabled devices sends real time data to centralized server, which can be used for “nowcasting” or “forecasting”. It will help in time management. Anywhere, Anytime Access to Information Since IOT enabled devices sends real time data over the internet, therefore information can be extracted & used from anywhere and anytime. Resulting into saving of time.

### **3.4.1 Real Time Interaction with Customer**

Purchasing using smart phones, increase real time interaction between customer & entrepreneur. Customer’s choices on product & feedback mechanism give fare idea on demand management. Therefore, accordingly supply can be managed.

### **3.4.2 Better Service to Customer**

Real time information, will help entrepreneur or business man to analysis, plan and provide better services to the customer. Customer behavior can be easily predicted.

### **3.5 Smart Health**

#### **3.5.1 Preventive Monitoring**

Wireless sensors can be deployed to save patient's life in critical diseases like heart malfunctioning, cancer, diabetes, stroke, Alzheimer etc.

#### **3.5.2 Independent Living**

IoT solutions will help in proactive monitoring of disease by using wearables, sensors etc. Smart applications connected to IoT components will trigger the alerts and notifications in case of any variations.

#### **3.5.3 Timely Supply of Drugs**

IoT solutions will significantly reduce time to reach the drugs at customer's premises by using IoT components. Helps in monitoring timely supply of drugs.

#### **3.5.4 Medical Actions based on Information**

Temperature of drugs can be monitored using temperature sensors and drugs can be discarded if temperature exceed its threshold level. Smart labels can benefit patients by knowing information about dosages, expiry date etc.

### **3.6 Green IoT Agriculture**

#### **3.6.1 Controlled Environment Planting**

Green house farming is done in controlled environment. Temperature, humidity & pressure sensors can be deployed to monitor the greenhouse environment. Can also be adjusted by using pumps, heaters & fans. This reduces labor costs by avoiding human intervention and prevents energy and production loss by maintaining favorable environment.

#### **3.6.2 Open Field Planting**

By using drone, data can be collected in open field agriculture. It is possible to detect disease and requirement of irrigation based on data collected through sensors. Sensors enabled devices known as weather stations are installed across the agricultural fields. These devices collect relevant data about the environment which area analyzed to map weather conditions. This enables deciding the types of crops suitable to the environmental conditions. Such smart devices measure various elements of weather like temperature, humidity, atmospheric pressure, wind,

precipitation etc. A better understanding of the environment enables improved decision making and therefore, better results in agriculture.

### 3.6.3 Livestock Breeding

Livestock growth in expected environment can be monitored by using temperature & humidity sensors. Feeding details can also be recorded by using sensors. This enables monitoring their nutritional needs, health monitoring, location monitoring, disease prevention etc. Sick animals can be easily identified and can be separated to prevent mass outbreak of infectious diseases.

### 3.6.4 Monitoring & controlling Aquaculture

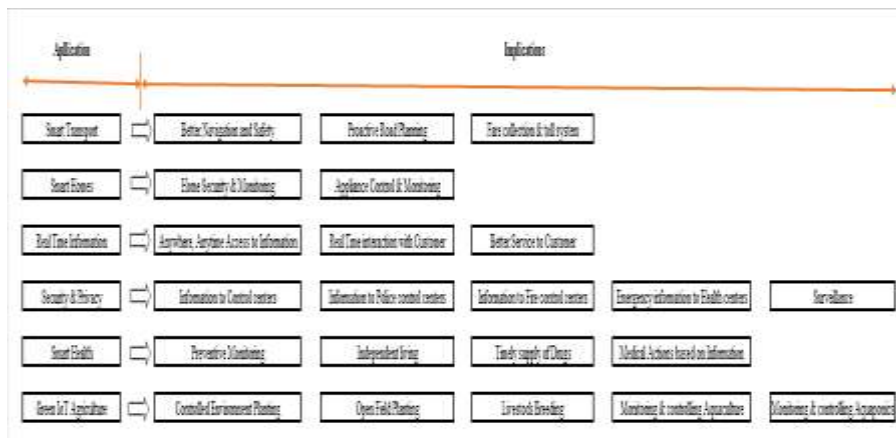
IoT sensors can be used in fish farming and monitor water quality, temperature, oxygen & pH etc

### 3.6.5 Monitoring & Controlling Aquaponic

IoT sensors helps in monitoring the growth of aquatic creatures & hydroponic plants

## 3.7 Implication Matrix

IoT enabled solutions provide smart transport, smart homes, smart health monitoring, real time information to address security & safety concerns. Each IoT applications has its own implications in society, which will have larger impact on day to day life. Day today problems in society, can be addressed to a large extend by implementing IoT technology and ameliorate quality of life. Figure 4 shows Applications Vs Implications.



**Figure 4** Applications Vs Implications

## 4 Conclusion

IOT enabled solutions prompt user to proactively monitor health, facilitate independent living being by sending alerts or notifications. Rule based information to control centers, police stations, fire stations & health care centers can be sent. Remotely monitoring elderly or children for safety & security. Real time information helps better plan & services to end customer. IoT enables users to access information from anyway & anytime. Home appliances can be remotely controlled & monitor. Smart solutions like Fastag helps in saving time, reduces wastage of fuel & avoid traffic jams. Green IoT in agriculture helps in remotely monitoring & controlling agriculture by using sensors data, improve efficiency, increase agility, increase revenue. Therefore, IoT implementations ameliorate quality of life in the society. This paper has established the findings based on the literature review, which has further contributed in forming the implication matrix. In future research, IoT implications can be established by doing empirical analysis.

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## Biographies



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**Teena Bagga**, has around 20 + years of experience. Her area of specialization is in the field of Information Systems, and her research interests are Technology Management, Data Analytics, Business Intelligence, Strategic HR, Quality & governance. She has published several research papers & case studies in various indexed national & international journals.