IoT: Protocols, challenges, and opportunities with agriculture perspective

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Abstract

The rustic regions in Pakistan face numerous and similar concerns in the fields of agriculture, connectivity, water, transport and others. The present work provides a roadmap to solve these issues potentially and pave a way for similar results to be focused and headed for explaining these concerns. In this regard, an extensive variety of industrial IoT applications specific to agriculture is evaluated and presented in this work. This study analyses the contemporary enquiries of IoT, significant and supporting technologies, key IoT protocols in agriculture and classifies research tendencies and experiments in Pakistan. A simulation of the state of the art IoT protocols was conducted for their evaluation.

Keywords: IoT, Agriculture, Protocols, Pakistan.

1 Introduction

IoT in its basic form can be explained as a network of physical devices connected to internet without requiring any human interaction for them to function. As per CISCO's predictions, over 50 billion devices will be connected to the internet by 2020. The impact and numbers are such which cannot be ignored; IoT will affect our lives in every aspect hence, making it worthwhile, in agriculture, just as in any other industry. Being the second largest sector of Pakistan's economy, it engages about 42.3% of the labor force.

Our country, Pakistan, has been blessed with abundant natural resources such as arable-land and water making agriculture as one of the most important part of its gross domestic product i.e. 19.8%. Roughly 60% of the country's population resides in rural areas which is directly or indirectly related to agriculture. Punjab, being the most cultivatable of all provinces, yields cotton and wheat in every year. Despite the considerable importance of the industry, it is suffering from an unstoppable decline. From 5.1% growth performance in 1960's, it has seen a steep drop to 3.2% in the 2000's. This can only be attributed to low investments and absence of advancements in conventional technologies or farming techniques to which the concept IoT can play a vital role in agriculture[1].

Not only does meeting the ever-growing local and international demands for food and other edible resources is becoming an up-hill task, the drying up water resources is worsening the situation as well, eventually, putting an immense burden on the agriculture sector. The rapid population increase and urban migration contributes mainly to that.

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In order to tackle the challenges that we face today, we need to understand that there lies a strong connection between agriculture and climate. Factors such as temperature, moisture, precipitation and other aspects affect the agricultural production and eventually, our economy.

2 IoT in Agriculture

In smart farming [2]–[4] variety of things that you may connect like weather forecasting. You have to connect devices like drone [5] with mobile phone that forecast and signal to spray water on those days in which sun is hot and temperature is above the threshold value. Different monitoring and sensory equipment are the key precision in agriculture technology. Smart mapping is very essential where the drones move and give direction to them automatically. Crop monitor by taking the pictures randomly and find the growing rate. Figure 1 describes this process visually how smart farming connects with those features.

A Human Factor

The 21st century world favors automation over labor force. Farmers do the tiresome job of spraying their corps which at times badly affects their respiratory system, hence affecting their health. This can be done by a remotely controlled drone or robot which would perform the spraying task instead of the human. These drones could well be equipped with various agricultural sensors such as NDVI crop sensors to full spectrum and near infrared cameras. Drones can be useful in a way that they cover large areas of land in short time interval with:

- No safety risks
- Attached sensor data and real time imagery data that can't be retrieved quickly on foot or by vehicle
- Low cost and low human efforts

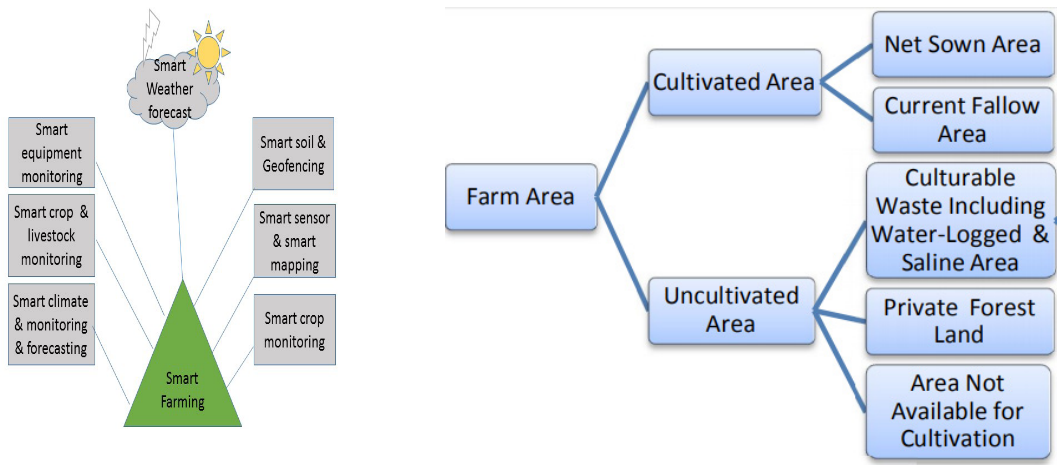
This can be categorized as Precision agriculture which requires real time data and the capability of UAV's to glide over crops and speedily gather its data. The improvements and developments in drone's batteries, guidance systems and control systems have enabled them to be both reasonable and practical. It is also important to note here that the center of those crops which are of considerable height and/or are dense are difficulty assessed on foot or by land vehicle. They get damaged in the assessment process which can be avoided by the usage of light weight drones.

B Intelligent Greenhouses

Greenhouses are used to grow plants in a controlled environment. Arduino based intelligent greenhouses could well maintain the suitable temperature for plants with minimum human interaction. Greenhouse control system hardware refers to the hardware circuit based on single chip design; the part of the hardware mainly includes 5 elements:

- The Microprocessor Control Unit (MCU)
- The sensor of temperature and humidity detection system

- The Arduino UNO controller
- Input and display system
- Network controller. [2]



(a) (b)

Figure 1: IoT in Agriculture (a) Smart farming (b) Farming area classification

C Pesticides and disease detection

Pests and insects not only affect the quality of corps but the quantity as well. Forecasting plant diseases [6] or insecticides attacks have become much more important. Machine learning based on detection and recognition of plant diseases can provide an early insight for us to start its treatment accordingly and in early stages. With digital image analysis being a technology that is firmly-established, can be used in plant disease assessment and detection.

As discussed, RGB (red, green and blue) imaging and/or digital photographic images are vital in evaluating plant health. The simple source of RGB digital images for disease detection, identification and quantification are digital cameras which are easy to handle. The technical attributes that these digital cameras are comprised of such as light sensitivity, spatial resolution or/and digital focus have improved significantly over the course of time [7].

D Animal Intrusion

Animals do intrude into fields and affect the crops yields. The most common techniques used for this are such fences which when applied pressure on, automatically triggers an alarm to the concerned farmer and let him/her know that an intrusion is in process. The digital image analysis including RGB co lor images, as already discussed above, with the red, green and blue channels are also vital for its use in detect biotic stress detection in plants[6].

E. Weather Monitoring and Water Irrigation

A farmer could take care of his/her farm in a better way if he/she is aware of the weather conditions. Arduino can be used for weather monitoring which consists of 4 main sensors. These sensors detect and monitor the temperature, humidity, light and rain level. These readings are constantly sent to a web server where a farmer can login, inspect the reports and take actions accordingly. The same concept can be used for water irrigation purposes by detecting the soil moisture level and notifying the farmer when to stop the supply of water.

Implementing a change is not always as easy as it looks. In Pakistan's agriculture sector, the numbers of required professionals are low. The agriculture related jobs are not ample for the number of already limited professionals, making the introduction of IoT an issue amongst less educated farmers. Adoption of such devices that are connected is also a considerable issue. Machines that are commonly used in west would be hard to adopt in our scenario for which steps are needed on a broader level, farmers need to be made aware of the importance of these techniques and advancements.

While automaton farming is on the rise, it isn't seeing speedy progress. The main aspect behind it is the constraints of farm robots. Most robots are confined to do a single job and current technology is still away from developing robots that could run unmanned farms. As with all impending products, the costs are quite high due to limited global demand and technical expenditure. Once parts become inexpensive and are developed on a wider scale, the charges will drop and farm robots will see a much wider adoption.
Currently Pakistan has almost 80 million hectors of land out of which half is cultivable, yet we only have a mere 22 million hectors cultivated. With the use of IoT, the uncultivated land of can be brought to use. Considering the fast urbanization that is been in progress, the introduction can increase the current yield production using automation and machine learning.

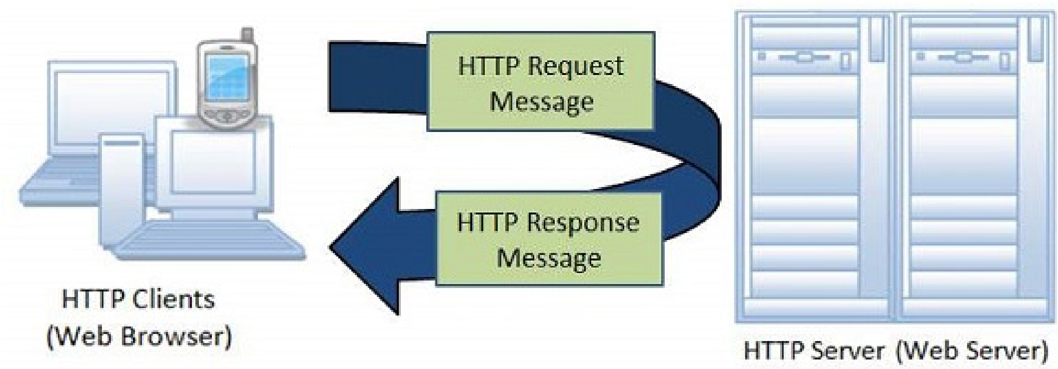


Figure 2: Hypertext transfer protocol (HTTP)

3 IoT Protocols

Common understandable communication is necessary for IoT implementation. Different devices communicate with each other to expedite a given problem. Traditional technologies such as HTTP, HTTP(S) and Web Services can be used for communication between devices. The communication payload can be represented as XML or JavaScript Object Notation (JSON). JSON provides a data representation and development of a stateful web application for persistent connection between clients and the web server.

A Hypertext transfer protocol (HTTP)

The widely used client/server model for web applications is the HTTP [8]. HTTP provides secure method when communication mainly initiated by the clients. Several security methods using private and public keys concept has been well matured in HTTP environment. For IoT, simply adding clients to the network initiates communication and secure transfer of data. Since HTTP works on client/server model, direct communication among clients is not possible. Architecture of HTTP is shown in Figure 2.

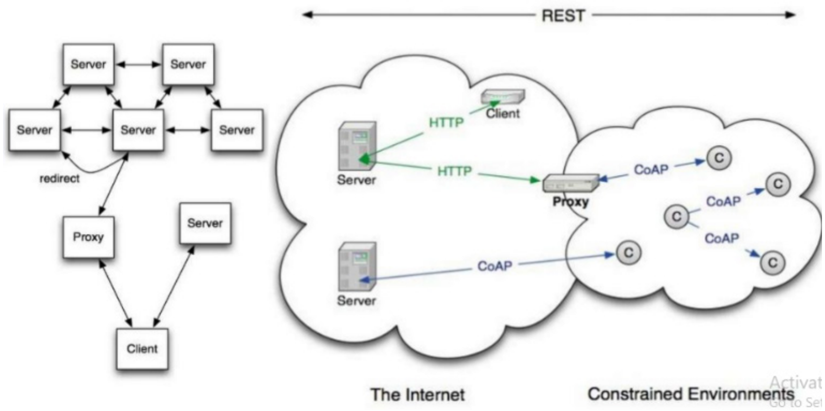


Figure 3: Constrained Application Protocol (CoAP)

B Constrained Application Protocol (CoAP)

Web protocols such as HTTP provide easy and secure solution for IoT devices. However, web protocols are resource intensive for many IoT applications. Internet Engineering Task Force (IETF) [9] has designed a protocol named Constrained Application Protocol (CoAP) for low-power devices working under constrained network. CoAP works over the traditional RESTful protocol. In addition, CoAP support one to one mapping with (to and from) HTTP. CoAP is preferred for devices using batteries as power supply or devices using energy harvesting strategies. The internal architecture of the CoAP works on UDP protocol with additional functions of the TCP as shown in Figure 3. These additional functions include acknowledgement for distinguishing messages. Furthermore, CoAP messages for request and response are communicated asynchronously. To reduce protocol overhead for making CoAP usable with low powered devices, the headers, status and underlying methods are encoded in binary representation. For caching, CoAP depend on response code similar to HTTP. In agriculture scenario, CoAP is a suitable choice as most of the IoT devices are lightweight and require a consistent connection. Implementing CoAP as a web service is a possible way for inducting it into agriculture IoT.

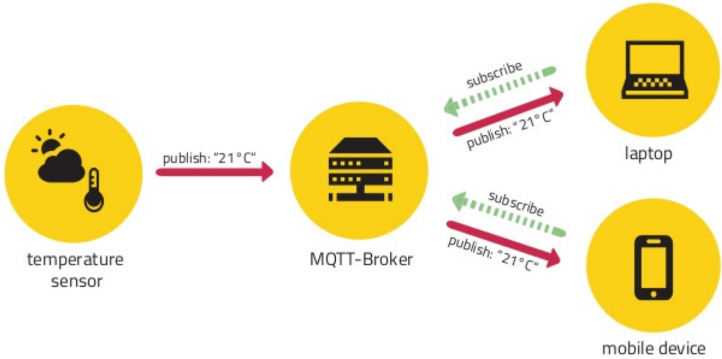


Figure 4: MQ Telemetry Transport (MQTT)

C MQ Telemetry Transport (MQTT)

Researchers at the IBM has invented the MQ Telemetry Transport (MQTT), an open source protocol [10]. Similar to CoAP, MQTT is designed for lightweight messaging among devices using publish/subscribe architecture. Figure 4 shows the architecture of the MQTT. MQTT main objectives are constrained and unreliable network with low-bandwidth communication. MQTT does not focus primarily on the security rather only assurance about successful message delivery between sender and the respondents. As compared to CoAP, MQTT provides a device to device communication, data agnostic and is suitable for mobile devices with low power and network requirements. However, MQTT does not support broadcast communication.

4 Evaluation and Results

Management of farming land, for the farmers and governments can play vital role in the economics and in the environment too. The application of IoT may incorporates decision support systems for entire farm administration with the objective of advancing profits for inputs while safeguarding assets, empowered by the across the board utilization of microcontrollers, GPS, various sensors, and the most importantly the communication infrastructure that supported by emerging protocols.

For these reasons, the performance of above mentioned protocols, i.e. HTTP [8], CoAP [9] and MQTT [10] is also evaluated in this work. First a test bed has been developed to perform performance measurement. A typical agriculture IoT network is realized. It is believed that in such network there will be thousands of sensing nodes spreading over the smart farm. These sensing nodes may have specific tasks or they might be useful for collective sensing.

Table 1: IoT Protocols Comparison

Protocol	Transport	Messaging	2G, 3G, 4G Suitability (10000s nodes)	LLN Suitability (10000s nodes)	Computational Resources	Data Format	Real Time Updates	Review
CoAP	UDP	Request / Response	Excellent	Excellent	10Ks RAM/Flash	Binary	With Observe Specifications	Field Area Networks
MQTT	TCP	Publish / Subscribe Request / Response	Excellent	Fair	10Ks RAM/Flash	Binary	Yes	Provision of enterprise level messaging between IoT applications
HTTP (RESTful)	TCP	Request / Response	Excellent	Fair	10Ks RAM/Flash	Text With Binary Support	With Custom protocol Over Websocket	Energy Management IoT Application

Since this is a preliminary work, it has some limitation, so in this study we have incorporated only few parameters. The sensing nodes that are considered in this simulation environment are assigned to measure temperature and humidity across the farm landscape. For which it is considered that the farm spread over hundreds of square meters. The sensors are installed densely to measure the farming-land more accurately. The various protocols that are compared in Table 1 are studied.

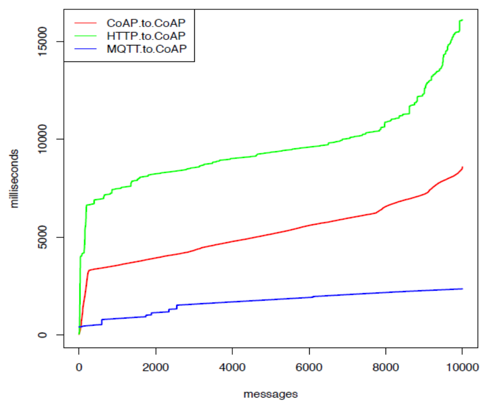


Figure 5: Messaging over the IoT system of multiple protocols

From the Figure 5, it is apparent that the behavior of HTTP-MQTT protocol is subject to higher latency and at second place CoAP is also facing similar problem. At both ends, when MQTT is implemented same gives some better results. Similar observation is found in Figure 6, where multiple clients are supported over the IoT system. However, MQTT based Mosquito is again at leading position with minimum latency. This provides a comparison of the evaluation of the IoT protocols with respect to agriculture domain. The comparison parameters are transport method, messaging, scalability, adaptability, suitability and computation resources required by a device under a given protocol. Transport methods describe the transport layer implementation of the IoT devices within the network. Messaging parameter deals with methods or models for message passing between clients and server or client to client. Since agriculture is mainly rural area, high speed internet connectivity is not possible or available at many areas; adaptability parameter provides indication about different speed internet network supported by an IoT protocol.

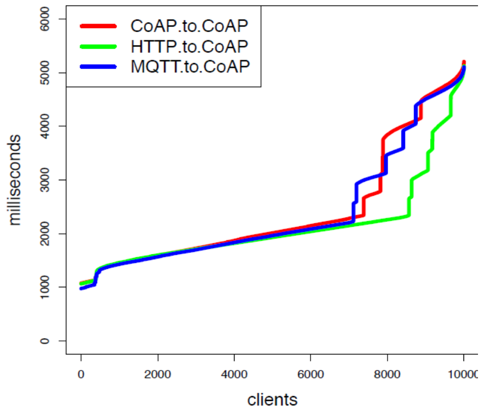


Figure 6: Multiple Clients support over the IoT system

For scalability the evaluation was carried out up to hundreds of nodes/devices. This can be increased to thousands in the future work. Even though ten thousand is sufficiently a big figure for agriculture domain, however the current evaluation was performed keeping in view a local IoT network rather than a global network. The sensors are installed densely to measure the farming-land more accurately. The various protocols that are compared in Table 1 are studied. Multiple Clients support over the IoT system.

Based on results, it can be concluded that MQTT is a viable solution for an environment where real time updates are not required. However, several tasks such as irrigation, spraying and animal intrusions require real time support that can be implemented using CoAP or HTTP. In addition, energy harvesting such as solar and wind powered techniques are required for implementing a real time solution. Latency of different evaluated IoT protocols remains same for number of clients less than 50K. However, it increases exponentially with increasing number of clients. The message communication provides a clear comparison among evaluated protocols. The communication between MQTT and CoAP shows a better performance over the other variants. MQTT and CoAP both use binary data format and support client's individual communication. However, HTTP variants work on client/server model that degrade the communication performance.

5 Conclusion

The application of IoT in the agriculture incorporates decision support systems for the entire farm administration with the objective of advancing profits for farmers while safeguarding assets, empowered by microcontrollers, GPS, various sensors, and the most importantly the communication infrastructure that is supported by emerging IoT protocols. This study develops the intuition smart agriculture systems that can help farmers and the regulating authorities to build and manage the farming activities more effectively. In this work various IoT protocols are discussed and also analyzed thoroughly. The HTTP, CoAP and MQTT are discussed and then compared. While for the development of smart farms a preliminary study work is also carried out in this paper. From the simulation work, it is find that the implementation of MQTT based Mosquito has far better performance than its counter parts. From these obvious reasons it has been proposed that the more suitable messaging protocol for the smart agriculture is the MQTT based Mosquito implementation. Results presented in the present work provide a comparison of the evaluation of the IoT protocols with respect to agriculture domain.

References

[1] R. Ni, "Design and implementation of intelligent greenhouses based on the internet of things," in Applied Mechanics and Materials, 2014, vol. 631, pp. 188–191.

[2] A. Abbas, M. T. Jilani, and M. K. Khan, "Comparative Analysis Of Wireless Technologies For Internet-Of-Things Based Smart Farm," Sci. Int., vol. 29, no. 2, pp. 373–378, 2017.

[3] S. Wolfert, L. Ge, C. Verdouw, and M.-J. Bogaardt, "Big Data in Smart Farming--A review," Agric. Syst., vol. 153, pp. 69–80, 2017.

[4] F. TongKe, "Smart agriculture based on cloud computing and IoT," J. Converg. Inf. Technol., vol. 8, no. 2, 2013.

[5] C. Malveaux, S. G. Hall, and R. Price, "Using Drones in Agriculture: Unmanned Aerial Systems for Agricultural Remote Sensing Applications," in 2014 Montreal, Quebec Canada July 13--July 16, 2014, 2014, p. 1.

[6] Y. Shi, Z. Wang, X. Wang, and S. Zhang, "Internet of Things Application to Monitoring Plant Disease and Insect Pests," in International Conference on Applied Science and Engineering Innovation (ASEI 2015), 2015, pp. 31–34.

[7] D. Georgakopoulos and P. P. Jayaraman, "Internet of things: from internet scale sensing to smart services," Computing, vol. 98, no. 10, pp. 1041–1058, 2016.

[8] Z. Shelby, "Embedded web services," IEEE Wirel. Commun., vol. 17, no. 6, 2010.

[9] C. Bormann, A. P. Castellani, and Z. Shelby, "Coap: An application protocol for billions of tiny internet nodes," IEEE Internet Comput., vol. 16, no. 2, pp. 62–67, 2012.

[10] M. Collina, G. E. Corazza, and A. Vanelli-Coralli, "Introducing the QEST broker: Scaling the IoT by bridging MQTT and REST," in Personal indoor and mobile radio communications (pimrc), 2012 ieee 23rd international symposium on, 2012, pp. 36–41.