

# LITERATURE SURVEY

## Abstract

Smart farming era has already begun and its societal and environmental implications are expected to be huge. In this context, the Internet of Things (IoT) technologies have become the major path forward towards novel farming practices. The unprecedented capability of data collection and management offered by IoT is based on several factors of the underlying communication network architecture and technology, one of the most important being the application level protocol that is used among IoT nodes, gateways, and application servers. This work offers an up-to-date survey of research efforts on the IoT application layer protocols, focusing on their basic characteristics, their performance as well as their recent use in agricultural applications. Furthermore, it provides a comparison among them, in terms of well-accepted key performance indicators and comments on their suitability in the framework of smart farming as well as the corresponding challenges that have to be faced towards their efficient implementation.

## Introduction

Emerging Internet of Things (IoT) technologies offer a great potential for novel solutions and smarter application development that can improve all aspects of the agricultural sector. Data collection has been made easier during the last decade due to recent advances of communication networks and protocols, mainly on the lower layers, i.e., the physical, link and network layers. However, in addition to these, the upper layer protocols are of major importance for efficient data collection and sharing. In the context of IoT, application layer protocols mainly refer to the lower part of the TCP/IP stack model's application layer that corresponds to the OSI session layer and they are also commonly referred as messaging protocols. The two main categories are the protocols that follow the request/response model, and those that follow the publish/subscribe model. They can either be used in parts only of the IoT communication architecture or in the whole of it, meaning that while an IoT application protocol can be used for communication between the IoT devices and an IoT gateway, other protocols may be used between the gateway and the cloud or the cloud and the end user. Similarly to all IoT application frameworks, smart farming applications are based on IoT application layer protocols for data transfer. Though, the nature and diversity of IoT agricultural applications which span a wide range of requirements both in the type of data and the environments that the IoT devices are installed raise major challenges related to the volume, variety, veracity and velocity of the data. In this context, this work is building upon recent research efforts and related] to include all the advancements and new evaluation results of testing IoT application protocols during the past three years, so that to provide a fresh and consistent basis that will allow comparison of the major ones among them: the Message Queue Telemetry Transport (MQTT) protocol, the Constrained Application Protocol (CoAP), the Extensible Messaging and Presence Protocol (XMPP), the Advanced Message Queuing Protocol (AMQP), the Data Distribution Service (DDS) protocol, the Representational State Transfer Hypertext Transfer Protocol (REST HTTP) and the WebSocket protocol. This comparison is based on key performance indicators [3] and is combined with the latest research efforts in IoT applications in agriculture, to derive the lessons learned as well as the issues and challenges that are still important and need to be considered for real-life agricultural applications.

While IoT in agriculture has already been in the center of smart farming research efforts for several years, the majority of works focus on the benefits and challenges of IoT in agriculture [15,16] or analyze IoT architectures, technologies and practices for smart agriculture ([7,17]), focusing on hardware, platforms, sensors and wireless communication protocols [18,19]. There are no studies focusing explicitly on the evaluation of IoT application layer protocols in agricultural applications. Building upon recent surveys on IoT application protocols and comparative evaluations, as well as recent IoT enabled agricultural applications' development, the contribution of this work is twofold: (i) to provide a general, up to date, survey of IoT application protocols, (ii) to focus on the use, requirements, evaluation and research challenges of IoT application protocols in smart farming based on suitable key performance indicators, i.e., latency, energy and bandwidth requirements, throughput, reliability, security as well as developers' preferences.

The next Section provides a description of the protocols under consideration and their main characteristics summarizing recent literature and the corresponding, per protocol, standards. Based on this description, a review of the recent literature and the work in [3], Section 3 provides a comparison of the protocols in terms of latency, bandwidth and energy requirements as well as throughput and reliability. Section 4 reviews the latest IoT applications in farming and Section 5 provides an evaluation and discussion on the use of IoT application protocols in agriculture while Section 6 concludes our work.

## Comparison of IoT application protocols

Several works have been published with comparative performance results of the IoT application protocols during the last years. These works usually compare two, three or more protocols via simulations, testbed implementations, close to real world realizations or a combination of the abovementioned methods in environments and applications with different requirements. In most cases, networking protocols and hardware/software implementations are significantly different.

## On the use of IoT application protocols in smart farming

IoT applications in agriculture have been in the forefront for several years. This Section reviews the most recent attempts (over the last two years) and the application protocols used or proposed. In this context, a categorization is made to discriminate between simple, small-scale applications and complete prototypes that have been implemented in medium or large-scale applications. Then, a discussion on the evaluation of IoT application layer protocols in smart farming implementations is.

## Discussion

On the basis of the above, the safest, at the moment, option seems to be the MQTT protocol, either when it is applied in an end-to-end network architecture, or when a gateway-server architecture is used to collect the measurements. This outcome is reinforced by the comparison of IoT application protocols analysed in Section 3, where the most important research works with comparative performance results during the past three years have been studied.

## Conclusion

This work provided a thorough and up-to-date survey of IoT messaging (application) protocols that are regarded as major options for IoT applications. Based on the most recent literature, seven protocols (MQTT, CoAP, XMPP, AMQP, DDS, REST-HTTP and WebSocket) were presented, analyzed and compared with respect to their performance, measured in terms of relevant key indicators, i.e., latency, energy and bandwidth requirements, throughput, reliability and security.