An Architecture model for Smart Farming

Anna Triantafyllou
Dep. of Informatics and Telecommunications Engineering
University of Western Macedonia
Kozani, Greece
atriantafyllou@uowm.gr

Dimosthenis C. Tsouros
Dep. of Informatics and Telecommunications Engineering
University of Western Macedonia
Kozani, Greece
dtsouros@uowm.gr

Panagiotis Sarigiannidis
Dep. of Informatics and Telecommunications Engineering
University of Western Macedonia
Kozani, Greece
psarigiannidis@uowm.gr

Stamatia Bibi
Dep. of Informatics and Telecommunications Engineering
University of Western Macedonia
Kozani, Greece
sbibi@uowm.gr

***Abstract*—Smart Farming is a development that emphasizes on the use of modern technologies in the cyber-physical field management cycle. Technologies such as the Internet of Things (IoT) and Cloud Computing have accelerated the digital transformation of the conventional agricultural practices promising increased production rate and product quality. The adoption of smart farming though is hampered because of the lack of models providing guidance to practitioners regarding the necessary components that constitute IoT based monitoring systems. To guide the process of designing and implementing *Smart farming monitoring systems* , in this paper we propose a generic reference architecture model, taking also into consideration a very important non-functional requirement, *the energy consumption* restriction. Moreover, we present and discuss the technologies that incorporate the four layers of the architecture model that are the Sensor Layer, the Network Layer, the Service Layer and the Application Layer. A discussion is also conducted upon the challenges that smart farming monitoring systems face.**

***Index Terms*—Wireless Sensor Networks, Internet of Things, Precision Agriculture, Smart Farming, Communication technologies, Cloud Computing**

I. Introduction

Nowadays, the digital transformation of the agricultural sector is considered a priority in order to face the numerous challenges presented in the fields. Environmental monitoring and remote controlling in agriculture is rapidly growing towards developing more productive and competitive agricultural systems and tools. Precision Agriculture and Smart Farming can lead to this direction. These two terms refer to the integration of advanced technologies into existing agricultural practices so as to achieve fine-grid crops management. Smart farming systems can provide to farmers meaningful real-time environmental data from the cultivation fields aiming to boost competitiveness and profit. Almost every aspect of the agricultural field can benefit from these kind of technological advances ranging from planting and irrigation processes to plant protection and harvesting methods. Most of the current and forthcoming agricultural technologies under Precision Agriculture fall into the following three categories that are expected to become the pillars in each Smart Farm:

- The *Internet of Things (IoT)* is a large communication network involving a vast number of distributed devices around the network, so as to recognize and notify users instantly about real-time events. These devices, having basic computational skills, are called smart objects. Smart objects are characterized by a unique identifier, i.e., a name tag for device description and an address for communication. In most cases IoT devices have constrained resources in terms of power, processing, memory and bandwidth.
- *The Unmanned Aerial Vehicles (UAV)* are flying vehicles that do not have a pilot on their spindle, but make flights either autonomously or by means of remote control. Unmanned aircrafts that can be used for remote sensing are part of Unmanned Aerial Systems (UASs), which include all necessary devices and procedures to operate an UAV, while managing the kind of data it collects.
- *Sensors* are measuring devices that convert an external stimulus, input signal, into an appropriately measurable output signal. A sensor is a device that will convert a macroscopic size (light, power, pressure, etc.) to an electrically measurable size, and then, after processing this electrical signal, it will convert it into a standardized signal with certain characteristics. Exposure to a particular analyzer or change in environmental conditions alters one or more of the sensor properties in a measurable manner, either directly or indirectly.

The adoption of smart farming though is hampered because of the lack of models providing guidance to practitioners regarding the necessary components that constitute IoT based monitoring systems. The contribution of this paper lies upon the presentation of a simple reference architecture model for a smart farming monitoring system. This architecture model engages novel IoT technologies [1] and Wirelesse Sensor Networks (WSNs) capabilities so as to provide a sufficient view of precision agriculture. What is more, the proposed architecture enables a combination of modern remote sensing techniques such as UAV tracking, Global Positioning System (GPS) for location detection, Geographic Information Systems (GIS), real-time monitoring with different types of sensors and intelligent input control systems. These technologies have already been tested in various agricultural fields in different countries for the cultivation of rice, wheat, tomatoes, vegetables, potatoes, ornamental flowers, chilly, cacao, pepper, corn, olives, apples, lemons, grape and others. By incorporating new technologies into agricultural production growers will be able to manage their crops at a different and more advanced kind of level in detail that was not possible a few years ago.

The rest of the paper is organized as follows. In Section II, the proposed smart farming monitoring system architecture is introduced. In Section III, the sensor layer is presented, followed by the network layer and its suitable protocols and technologies in Section IV. Section V refers to the provided services of the proposed monitoring system, while Section VI focuses on IoT agricultural applications. Section VII presents energy saving technologies that be implemented in cooperation with networking technologies of the system. Existing challenges are mentioned and discussed in Section VIII. Finally, Section XI concludes this study.

II. The Architecture of a Smart Farming Monitoring System

A precision farming system consists mainly of the sensing agricultural parameters, the identification of sensing location and data gathering, the routing of data from crop field to control station for decision making, the actuation and control decision based on sensed data and the visualization of results to the grower through an application. According to these procedures four basic agricultural layers are defined in our model as presented in Fig.1:

- The **Sensor Layer** including all kinds of crops sensors and smart objects for data collection and monitoring. Sensors can be placed under ground(in the soil), on the crops or on UAVs [2]. Underground sensors are specially manufactured so as to be water resistant and usually refer to measurements of moisture, ph and soil chemical properties like sulfur. UAV sensors measure environmental parameters like humidity, temperature, wind speed, luminosity or solar radiation. However, the most popular kind of sensors to be placed on UAVs are thermal cameras. Thermal drones which use vision imaging cameras have so many positive uses by detecting heat coming from almost all objects and materials turning them into images and video.
- The **Network Layer** consisting of all available communication technologies between sensors and the Internet. In order deploy efficient crop and field management the IoT platform utilizes Wireless Sensor Networks (WSNs). The use of WSN in smart farming systems provides immediate monitoring and optimization of crop quality, while offering a potential for large area surveillance with high sampling densities. The constant monitoring of a great number of environmental parameters by distributed sensor nodes along the field help the grower supervise and maintain optimal conditions to achieve maximum productivity with remarkable energy savings.
- The **Service Layer** involving processing and analysis of the collected data. A significant number of studies focusing on precision agriculture discuss the most efficient data management and data mining techniques so as to avoid a low level of productivity in the fields via accurate predictions. Data processing is supported by Decision Support Systems (DSS) that take care of the overall management of available collected information from the fields towards optimizing crop yield, maintaining quality and saving resources. It is well known that farmers suffer great economic losses due to incorrect weather forecasting or incorrect irrigation methods. Data analysis is the most important component of IoT agricultural systems resulting to efficient pesticide use and protection against diseases.
- The **Application Layer** providing the visualization of information of the sensor network. The farmer is provided with the ability to inspect the results of the review produced by the services of the system and take action accordingly. The application software presents information in a user friendly way and may refer to different kind of field optimization deployments such as irrigation, pesticide drift control, cultivation process, crop disease prediction and protection.

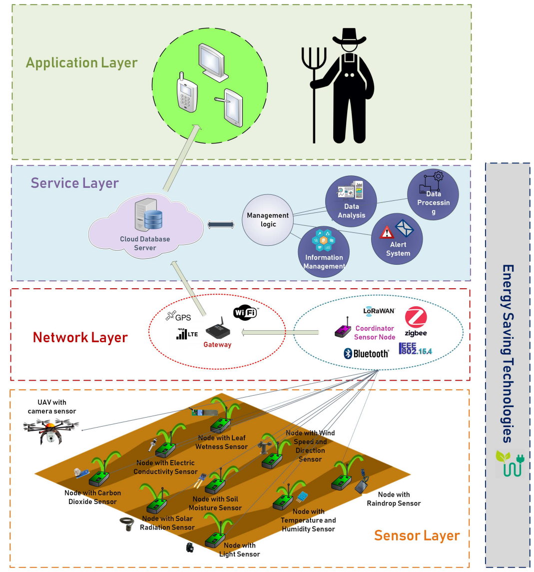

Fig. 1. Precision farming system architecture.

In order to support the efficiency and effectiveness of a smart farming monitoring system energy consumption should be kept under control. Due to the limited battery life and constrained resources of sensor nodes, **energy saving techniques** must be applied across the sensor and network layer accordingly. Energy saving techniques deal with the active and inactive operational time in each sensor node, the scheduling of information transmission and the routing process of data packets.

III. The Sensor Layer

The Sensor Layer is in charge of acquiring the data of the different climatic and soil variables involved in the growth and production of the crops. In the Sensor Layer each sensor sends the acquired data in the cloud through a WSN. The WSN (see more in Section IV) is made up of sensor nodes that operate under a mesh topology, a coordinator node and a gateway. Each node in such a network is connected to one or more sensors [3]. In precision agriculture the most important types of sensors for measuring the different types of corps attributes are:

Optical Sensors: Optical sensors are usually embedded in aerial vehicles and use light reflection information to measure the varying properties of soil and vegetation. In that case the sensors acquire image data, that are further analysed with photogrammetry techniques. Object detectors and pattern recognition form the basic building block for extracting information from the images. Such information may involve the vegetation and soil color, the moisture content and temperature of soil and vegetation, the position, height, size and shape of vegetation along with the level of chlorophyll. In this category we find ***visible light sensors, multispectral sensors, hyperspectral sensors and thermal sensors.***

Electrochemical Sensors: These types of sensors acquire data regarding the the nutrient contents of soil and its associated pH. Electrodes in these sensors work by detecting specific ions in the soil. Different families of electrochemical sensors can be recognized depending on the electrical magnitude used for transduction of the recognition event: ***potentiometric*** , that indicates change of membrane potential); ***conductometric***, that indicates change of conductance; ***impedimetric*** , that indicates change of impedance; and ***voltammetric*** or ***amperometric*** that indicates change of current for an electrochemical reaction with the applied voltage in the first case, or with time at a fixed applied potential in the latter.

Location Sensors: Location sensors provide spatial information regarding the positioning of an element. These types of sensors use signals from GPS satellites to determine ***latitude, longitude, and altitude*** to within feet. Three satellites minimum are required to triangulate a position. Precise positioning is the cornerstone of precision agriculture. GPS integrated circuits like the NJR NJG1157PCD-TE1 are a good example of location sensors.

Weather Stations: Weather stations are free-standing units situated at different locations throughout the cultivating fields. These stations measure various data for precision agriculture such as ***airflow, seasonal rainfall, leaf moisture, speed of wind, humidity level, direction of wind, atmospheric pressure and solar radiation***, etc.

Summarizing the above the most frequently acquired data from sensors in the agricultural domain are:

- Soil moisture and temperature
- Environmental humidity and temperature
- Leaf wetness
- Electric conductivity
- Wind speed and direction
- Barometric pressure
- Carbon dioxide
- Ph value
- Light intensity
- Solar radiation
- Rainfall

A sensor node consists of a radio transceiver with an internal antenna or a connection to an external antenna, a micro-controller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or a built-in energy harvested form. There are numerous commercial models of micro-controllers to be used in precision agriculture applications. The most popular ones are the Arduino, the Raspberry Pi, the Atmega328 and the LPC2148 boards. Accordingly, commonly used wireless communication modules used are the XBee module, the WSN802G module and the NRF24L01 module. A sensor node can vary in size and cost, depending on the complexity of its capabilities. Size and cost constraints result in corresponding limitations on resources such as energy, memory, computing speed, and bandwidth of communications. The types of sensors that are mostly used in Smart farming monitoring systems are summarized in Table I.

TABLE I
PRECISION AGRICULTURE SENSOR MODELS

Sensor Type	Sensor Model
Soil moisture sensor	10-HS,SY-HS-220, FC-28
Temperature sensor	LM35, SHT15, DS18B20
Humidity sensor	DHT22, DHT11
Electric conductivity sensor	DFR0300
Wind speed and direction sensor	SEN0170
Barometric pressure sensor	BMP180
Carbon dioxide sensor	CDM4161A, MHZ16
Ph sensor	MCP1525
Light sensor	TSL2561, BH1750
Solar radiation sensor	6450 TSR
Thermal sensors	ThermoMAP

IV. The Network Layer

In precision agriculture WSN communication protocols and technologies are used to support the connection between sensor nodes in the network and also to provide a channel for communication between the coordinator node and the gateway. According to the type of application, such as precision farming, field irrigation management or greenhouse crop management, the sensor network topology may also differ. Each node utilizes a routing protocol [4] in the view of transferring the data collected to the coordinator node. The kind of communication technology to be used between the nodes depends on the type of application and the characteristics of the hardware and software selected.

Based on a large number of experimental studies on agricultural fields, there is not an ideal combination of a specific communication technology and a routing protocol. The basic goal is to build each smart monitoring system upon application appropriate networking technologies in order to operate efficiently with minimum energy consumption. Once the coordinator node obtains the data it forwards the flow of information to the gateway so as to reach the main server, where the database is located. However, in some cases the coordinator node can be substituted by a base station to obtain the collected data by the use of a WiFi connection as presented in [5], or another cellular communication technology.

A. Precision agriculture communication protocols

There is a wide variety of networking technologies suitable for the deployment of smart farming applications.The most popular are the following:

- The **IEEE 802.15.4** standard is a widely used networking technology in precision agriculture and defines the physical layer and the Media Access Control (MAC) technique in Low-Rate Wireless Personal Area Networks (LR-WPANs).
- **ZigBee** is another suitable technology for short range radio communication in the fields utilizing low-power devices capable of transmitting data over long distances using intermediate stations.
- **LoRa** is a type of wireless configuration that has been created to achieve long-range connections for Low - power Wide Area Networks (LPWANs). LoRAWAN is a protocol for managing communication between LPWAN gateways and nodes.
- **6LoWPAN** (IPv6 over Low-Power Wireless Personal Area Networks) is defined for devices that are IEEE 802.15.4 compatible and efficiently encapsulate IPv6 long headers in IEEE 802.15.4 small frames.
- **Bluetooth Low Energy** is a global personal area network protocol built for transmitting small data pieces infrequently at low rates with significantly low power consumption per bit.
- **RFID** (Radio Frequency Identification) is a different technology that utilizes radio signals to monitor and identify in real-time objects without requiring line-of-sight communication. An RFID system includes a reader, a tag, and a host and is presented as ideal for field monitoring in multiple studies.

Moreover, the communication between sensor nodes and a base station can be supported by:

- the **WiFi protocol**, based on the IEEE 802.11 standard. This standard specifies the set of media access control (MAC) and physical layer (PHY) protocols for implementing wireless local area network (WLAN) Wi-Fi computer communication in various frequencies.
- the **GSM** (Global System for Mobile Communications), a standard developed by the European Telecommunications Standards Institute (ETSI) to describe the protocols for second-generation (2G) digital cellular networks used by mobile devices such as mobile phones and tablets.
- the **GPRS** (General Packet Radio Service) technology standard that provides rapid sending and receiving of data over the GSM mobile networks based on packet switching, a well known network transmission process.
- the **2G, 3G and 4G (LTE)** are respectively the 2nd, 3rd and 4th generation of GSM technology aiming at higher speeds.

Table 2 summarizes the communication technologies adopted in smart farming systems according to literature.

B. Precision agriculture routing protocols

Data routing algorithms play an important role in WSNs by establishing the path of communication for data exchange between sensor nodes and base stations on a network. A variety of routing techniques have been proposed until now, aiming to achieve higher performance with minimal power consumption.

IoT and WSN routing protocols can be categorized according to network structure and the way information will be disseminated through the network. A routing protocol can belong to more than one categories, aiming to satisfy as many performance metrics as possible.

According to the the way by which routing protocols make the routing decisions the following categorization can be applied:

- **Proactive routing (table-driven)**: The basic feature of protocols that belong in this category is the periodic renewal and updating of the routes and destinations that are formed between the nodes throughout the network. This provides for great performance in terms of latency, but decreases battery lifetime. Popular routing protocols for precision agriculture applications in this category are:
  - the **RPL** (Routing over Low Power and Lossy Networks) based on distance-vector routing. It constructs a Destination Oriented Acyclic Graph (DODAG) whose root is the sink node so as to direct all traffic towards the sink node. RPL is the ideal routing protocol for wireless network applications based on 6LoWPAN communication technology.
  - the **DSVD** (Destination-Sequenced Distance-Vector) protocol based on distance-vector routing. It can be efficiently used to monitor soil parameters, as it provides route availability to all network destinations with minimal delay in the route setup process.
  - the **LEPS** (Link Estimation Parent Selection) protocol based on a different technique regarding the maintenance of routing tables. The basic idea of link-state routing is that each node builds a map of the network in the form of a graph regarding the interconnection of nodes.
- **Reactive routing (on-demand)**: Routing protocols based on this technique discover routes on demand based on the transmission of route request packets. In this case, the

TABLE II
SMART FARMING NETWORKING TECHNOLOGIES

Communication technology	Data rate	Frequency band	Range	References
IEEE 802.15.4	20-250 Kbps	2400/915/868z	10m	[6]
IEEE 802.15.4 - ZigBee	20-250 Kbps	2400/915/868z	10-100m	[7]
IEEE 802.15.4 - 6LoWPAN	20-250 Kbps	2.4 GHz	10-30m	[8], [6]
Wi-Fi - IEEE 802.11	450 Mbps	2.4GHz 5GHz	100m	[9], [5]
GPRS-2G GSM	64Kbps	900MHz-1800MHz	100m	[10]
3G	14.4Kbps-2Mbps	1.6-2GHz	100m	[10]
4G - LTE	100Mbps-1Gps	2-8GHz	100m	[11]
LoRa	0.3 50 Kbps	433,868,780,915MHz	2-5km	[12], [13]
Bluetooth LE	1 Mbps	2.4 GHz 2.485GHz	$>$ 100m	[14]
RFID	400Kbps	125KHz-915MHz	3m	[15]

routes are discovered only when data transfer is declared. The basic advantage of this technique is decreasing traffic load, in case the network changes. The downside to reactive protocols is their latency, since transmissions over unknown or expired routes face delays, for which either the application or the routing protocol has to account by buffering or dropping data. Popular routing protocols for precision agriculture applications in this category are:

  - the **TinyLunar** (Tiny Lightweight UNderlay Adhoc Routing) [16] able to monitor agro-cultivation. TinyLUNAR provides clearly defined interfaces that allow the upper layers to from the route characteristics and work with the IEEE 802.15.4 communication standard.
  - the **AODV** (Ad-hoc On-Demand Distance Vector) protocol is suitable for use by the ZigBee communication protocol for interconnection of sensor nodes.
  - the **DSR** (Dynamic Source Routing) forms a route on demand when a transmission node requests it. However, routing is determined by the source node to the final destination and is not based on the routing table of each intermediate node.

According to WSN structure, routing algorithms perform in terms of one of the following three categories:

- **Flat routing**: Flat routing protocols depend on neighbour nodes to broadcast the collected information. Sensor nodes near the sink node (sink) have a high demand on energy because they handle all the information within the network.
  - **OLSR** (Optimized Link State Routing Protocol) is a proactive protocol based on flat routing that utilizes information about the status of the nodes to select the appropriate path for packet forwarding. OLSR can be effectively used to route information packets in a video sensing system so as to program irrigation in a field using unmanned aerial vehicles (UAVs).
  - **ProtoSense** is a another routing protocol based on the reliable retransmission of information using confirmation messages. This request-confirmation pattern not only reduces the extra transmission packets but additionally improves the packet delivery rate, resulting in a reduction in packet collision rate and power consumption.
- **Hierarchical routing**: The hierarchical approach divides the network into clusters. Each cluster depends on a cluster head node to manage the routing of information between other clusters or base stations. Hierarchical routing is the most popular routing method in smart farming monitoring systems and soil parameter monitoring [15], [17].
  - **APTEEN** (Periodic Threshold-Sensitive Energy-Efficient Sensor Network) is considered one of the most efficient routing protocols for crop monitoring cultivation in this category, taking into account energy saving and network lifetime [17].
- **Location-based routing**: Protocols in this category use the location of the node broadcasting information to relay data to specific areas instead of the entire network.
  - **LORA-CBF** (Location Routing Algorithm with Cluster-Based Flooding) [18] is a location-based algorithm which uses the flood method in a hierarchical network structure to route data packets. Based on flood method, each incoming packet is sent through every link except the one it arrives from. The advantages of this protocol include the good management of network scalability, taking into account the battery life of sensor nodes.

According to operating procedures, routing protocols can also be divided into three more categories:

- **Multi-path routing protocols**: Routing protocols of this category use more than one route to send data. A multi-path routing protocol can be used to implement a smart farm monitoring system so as to balance the data transfer load and conserved energy.
- **Metric routing protocols**: Metric routing protocols take into account various control parameters related to network performance, such as power consumption, number of successful transmissions, latency, etc. An enhanced version of RPL, included in this category, is **RPAL** [8]. This routing model combines network power meter metrics and link quality metrics to select the appropriate routes.
- **Quality of Service (QoS) routing protocols**: Routing protocols in this category aim to maintain the quality

of services and to control power consumption, during data transmission. Based on this kind of protocols, the source node can construct an efficient routing path while avoiding the carrier sense range effect on transmission channel.

V. The Service Layer

In a smart farming monitoring system, the basic component of intelligence is considered to be the study and filtering of the collected data. These processes enable the advance of cultivation procedures and increase productivity. A large percentage of smart agriculture applications are based on simulators, commercial programs and specific programming languages for implementing and controlling the data system. The service layer utilizes modern software tools in order to efficiently satisfy multiple tasks, presented in Table 3.

Information management is deployed so the farmer can consult, record and modify the information collected by the WSN in tables, statistical graphs and interactive maps. In addition can download daily, monthly and annual reports of historical data. However, the farmer can mainly see the current data of the monitored variables of one or all the WSN nodes and also consult the history. The interaction with the network and services layer is achieved using an intermediate layer of management logic [19]. WSN data will be stored in an online database [20].

The system also enables **big data** analytics in agriculture monitoring by utilizing tools such as Mahout and and various IoT platforms [21]. The collected data are recorded in a specific format, so as to correct errors, eliminate duplicate and inconsistencies and also to solve noise problems. **Data processing** techniques based on new models - algorithms for data classification [22], [23] are also utilized to minimize the size of redundant data and fasten the analysis.

Moreover, the system performs **data mining processes** based on Hadoop or Apache Spark Framework to identify and discover hidden patterns in the collected data, once they are processed, in the form of reviews.

What is more, all these services are hosted in the cloud to be able to access them remotely from any geographical location.

VI. The Application Layer

Based on the proposed precision agriculture monitoring system architecture, the farmer has the ability to interact with the IoT applications of the system to remotely manage the cultivation process. Such applications may concern any aspect of the agricultural field ranging from planting and irrigation processes to plant protection and harvesting methods [24]. The applications that can be adopted may involve the fertilizer application, the weed mapping, the spraying process, the irrigation of the field and the alert system.

The **Variable Rate Fertilizer** (VRF) application has as a target to optimize the usage of nutrients by defining the amount of fertilizer applied based on the health of the plant. Variable rate fertilizer in precision agriculture is an area of technology that focuses on the automated application of fertilizer to a given landscape. The way in which the materials are applied is based on data that is collected by sensors, maps, and gps. VRF applications bring a number of benefits related to savings on fertilizers and chemicals, potential yield increase and environmental protection. In the same context is the **Variable Spraying application**. These types of applications implement controllers that turn the herbicide sprayers on and off. Usually variable spraying applications take into consideration information coming from the weed mapping tools such as the weed locations. In that case the appropriate volume of herbicide is estimated and applied in the field based on the weed intensity.

The **Weed Mapping application** focuses on the visualization of the weed occurrences within a certain crop field with the help of mappings. The GPS receiver with an aerial vehicle generates maps which show the weed occurrences. These weed maps can be combined with fertilizer maps and yield maps. The **IoT-based irrigation system** use a microcontroller that serves as information gateway receiving real-time information from soil moisture and temperature sensors placed on the fields. Generally, a moisture/temperature threshold is specified based on which the microcontroller automatically switches on the water pump. The microcontroller also has servo motors to ensure that the area is uniformly irregated. The entire system can be managed remotely by the end-user through the dedicated application.

Alert/ notification applications are also very popular in IoT based precision agriculture. Producers and agriculture companies implement IoT solutions for instantly tracking their crop fields. In this case, the data coming from IoT devices is processed and transformed into knowledge properly visualized for offering information regarding the health of the vegetation and the soil, the behavior patterns of the plants, detect signs of disease on time, identify insects and harmful animals and instantly alert producers about potential difficulties. This type of applications serves for storing and analyzing data, providing producers with relevant recommendations.

The aforementioned applications aim at the efficient field and crop management so as to:

- increase production efficiency
- improve product quality
- provide more efficient use of chemicals in cultivation
- manage pesticide amounts
- reduce energy consumption
- protect the soil
- control water consumption and underground water amounts

The IoT-based agriculture applications can be implemented for an Android or Windows smart-phone, a tablet or as a web application. The applications of IoT-based smart farming apart from conventional, large farming operations, targets also other growing or common trends in agricultural like organic farming, family farming (complex or small spaces, particular cattle and/or cultures, preservation of particular or high quality varieties etc.), and enhance highly transparent farming. Our precision agriculture monitoring system can also benefit *the*

TABLE III
SMART FARMING MONITORING SYSTEM SERVICES

Service Type	Tools	Description
Information management	MySQL Database, management logic	The process of collecting, storing, managing and maintaining information in all its forms.
Big Data analytics	Mahoot, IoT platforms	Extracting, cleaning, transforming, modeling and visualization of data with an intention to uncover meaningful and useful information that can help in deriving conclusion and take decisions.
Data processing	Classification algorithms	Classification of data so as to decrease the size of redundant information.
Data mining	Hadoop, Apache Spark Framework	Systematic and sequential process of identifying hidden patterns and information in a large dataset.

dry farming technique that encompass specific agricultural techniques for the non-irrigated cultivation of crops. Furthermore, greenhouses can utilize our architectural model to intelligently monitor as well as control the climate, eliminating the need for manual intervention.

VII. ENERGY SAVING TECHNOLOGIES

In precision farming applications sensor nodes are usually powered by low-energy batteries that are difficult or impossible to recharge or replace. This is considered as a major disadvantage so as to maintain a real time monitoring system. Energy saving techniques is vital so as to maintain the system′s efficiency in smart farming. This kind of techniques can provide battery life extension by reducing the amount of communication between the nodes and the base station, while minimizing the redundant data in the network. Energy preservation techniques for precision agriculture systems are presented as a separate architectural level covering the sensing and networking procedures of smart farming.

In the sensor layer, the proposed energy-saving approach is an on/off process which is based on the selection of a subset of nodes that will remain active for a certain period of time, while others remain inactive. Following this assumption, *SWORD* (sleep/wake on redundant data) is an energy preserving scheme that can be used to collect data on soil moisture [7]. The SWORD algorithm performs data control by removing redundant data so as to minimize energy consumption and increase the life of sensor nodes in the network.

In the network layer, data transmissions and receptions can also be scheduled based on the sleep/awake periods of sensor nodes at predetermined intervals. For this purpose, A^2S, an automated agricultural precision tracking system can be utilized [25]. Based on this energy saving technology, whenever the sensing period is set by the application server, the sink node keeps the schedule and it spreads the sleep order message over its network every sensing period. Each time a node receives the sleep message, it sets the sleep timer's end time to the value of the duration field included in the message. When the meter time ends, the node detects the environment and battery voltage level and sends the data to the source. Then, he expects the next sleep request message.

Moreover, another energy saving scheduling technique that can be deployed in the network layer involves the use of unmanned flying vehicles in an agricultural crop monitoring system. Based on this scheme, the node on the unmanned flying vehicle wakes the ground nodes to retrieve the measured data. To perform this function, a coded radio signal is sent via a transmitter to the ground nodes. The nodes are in an inactive state, except for a small receiver waiting to receive the trigger signal.

What is more, taking advantage of *APTEEN* hierarchical routing protocol, a time division multiple access technique can be implemented as a scheduling method. Based on this technique, messages are sent to put some nodes in sleep mode so as to avoid packet collisions between sensor nodes belonging to different clusters. In addition, carrier sense multiple access technique is another alternative method, which is equally effective for avoiding collisions.

VIII. CHALLENGES

The implementation and maintenance of a monitoring system in precision agriculture faces several challenges. The greatest challenge in the sensor layer is for sensor nodes to achieve efficient and continuous operation for a long time in a natural environment, while taking into account the climate change and wildlife interventions. The *battery life* of sensor nodes is not considered satisfactory, and it is necessary to design and implement energy-saving protocols with the highest possible system performance amongst other precautions. In addition, depending on the type of application, the supported agricultural work and the implementation technologies, the problems that arise can be differentiated. For instance, the use of sensors and controllers from *different manufacturers* prevents communication between them and makes it more difficult to interconnect with other agricultural components. Also, the sensor inertia phenomenon has been observed in a high speed WSN due to non-steep changes in humidity and soil temperature.

In the network layer, the basic challenges regarding the operation of a crop monitoring system with WSN and IoT technologies include the limited computational capabilities of sensor nodes. The restricted memory of the nodes disables them to handle large amounts of communication data and cluster based interconnection procedures. Due to this fact, long data queues are created in each node, leading to greater delay in transmissions. The same outcome can be triggered by the long *communication distance* of sensor nodes. One major issue routing algorithms have to deal with in such cases is the *high level of energy consumption*, which leads to a reduction in the overall viability of the network. In precision agriculture monitoring systems routing protocols should offer minimum delay, be able to provide efficient services in a large number of sensor nodes, while taking into account the limited resources. They should also be capable to accept all sorts of environments including severe and loss environments, while providing information security and privacy. Most routing protocols use some localization technique to obtain knowledge concerning their locations. The performance of the routing protocol is a function of network size and transmission media. So, transmission media of good quality enhances the network performance directly.

However, in many cases the failure of such advanced monitoring system may be due to the geographic, cultural or socio-economic distance between system designers and the intended user community. *Cost* is an important limiting factor in the implementation of such systems. The cost depends to a great extent on the quality of the materials and the topology of the network.

IX. Conclusion

This paper proposes the architectural components of a smart farming monitoring system, based on modern IoT communication technologies and WSN capabilities, in cooperation with energy saving protocol schemes. The IoT agricultural applications enable farmers to collect and analyze meaningful data. Large landowners and small farmers should welcome the potential of IoT market for agriculture by installing smart technologies to increase competitiveness and sustainability in their productions. The rapid growth of population forces farmers to meet the demand by implementing agricultural IoT solutions in a prosperous manner.

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