Smart Irrigation Using Internet of Things

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***Abstract*—The Algerian economy is currently experiencing a significant deterioration because of its dependence on oil revenues, which drops in prices recently. Therefore, it is necessary to revive the Algerian economy with other important sectors, mainly agricultural sector especially in the south of Algeria. The southern Algeria Contain all necessary conditions for agriculture, which are the large agricultural areas, water resources and good illumination (sunlight).The mismanagement of irrigation water affects negatively the agricultural production of Algeria because of the shortage of irrigation water. Thus, with the benefit of the Internet of Things and the smart technologies, we will propose in this paper a new strategy for smart irrigation in southern Algeria regions, to optimize the water consumption, and to provide a remote control and monitoring for the irrigation system. Tests were realized to prove the validity of our proposed system by using Contiki-Cooja simulator.**

Keywords—Agriculture, smart irrigation, Internet of Things, Contiki-Cooja, Coap

I. Introduction

Recently, the Algerian economy starts to decline due to the drop in oil prices. The decline in oil prices shows the dependence and vulnerability of a system built on the only resource of the hydrocarbon sector. In this case, it is urgent to develop other sectors of the economy to reduce the dependence on hydrocarbons. Agriculture is a strategic and important sector for economic development, especially in southern Algeria. This Saharan and semi-arid region has all conditions required for agriculture; there are wide agricultural surfaces, sun light and large water resources.

Agricultural production, including livestock production, consumes more fresh water than any other activity in the world. Agricultural irrigation accounts for 85% of the consumed fresh water over the planet, and this percentage will continue to be dominant in water consumption due to population growth and the increasing of demand for food [1]. In general, poor irrigation management affects agricultural production, for this purpose it is necessary to develop strategies to optimize irrigation.

An automated irrigation system is designed to monitor and control the various factors derived from an agricultural field such as humidity, water level, temperature, and human interaction. This system is generally composed of controllers and a wireless sensor network using ZigBee as the transmission technology for detecting values of an agricultural field. The sensors gather the various agricultural factors in real time and transmit them using Internet of Thing (IoT) applications [2]. The control architecture of smart agriculture based on cloud computing and IOT is presented in [3].

The integration of modern technology in irrigation management system is one of the ways to improve the irrigation processes to optimize the use of water, electricity consumption and labor costs. In this regard, with the new technology and the development of the Internet and the Internet of Things, we will propose in this paper a strategy for smart irrigation in southern Algeria regions based on the use of the Internet of Things and new communication technologies. In this paper, this new scheme proposed for intelligent irrigation using IoT is an extension of our already attendant solution [4]. This new mechanism allows the farmer to monitor and manage agricultural area using smart phones via Internet.

The rest of paper is organized as follow: in section 2 we will present generality about basic notions of Internet of Things, the section 3 presents current state of information and communication technology (ICT) in Algeria, our proposed approach will be presented in section 4 and finally, a conclusion and proposed perspectives of this work will be presented in section 5.

II. GENERALITY

A. *Internet of Things (IoT)*

The term “Internet of Things” was first used by the Massachusetts Institute of Technology in the year 1999[5]. There are several definitions of the Internet of Things. Definitions focus on technical aspects of IoT when the other based on the applications and functionalities. Some definition defined IoT as "an extension of the current Internet to all objects that can communicate directly or indirectly with electronic equipment and connected to the Internet"[6]. Other defied as "a novel paradigm that is rapidly gaining ground in the scenario of modern wireless telecommunications. The basic idea of this concept is the pervasive presence around us of a variety of things or objects – such as Radio-Frequency IDentification (RFID) tags, sensors, actuators, mobile phones, etc. – which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals”[7].

B. *The application domains of IoT*

According to the definition of IoT, this technology can be applied in all domains possible but in reality IoT applied in specific domains. We categorize this application into four application domains:

1) Daily life: A Smartphone become a necessity in our life, several application for Apple iOS, Google Android and Windows Phone operating can be used for interfacing sensors measuring various parameters, which implies that facilitate the use of the concept of IoT in our daily life[8].

The use of IOT in daily live appear in several application such as control of home equipment such as air conditioners, refrigerators, washing machines, etc[8]. Sensors and actuators distributed in houses and offices can make our life more comfortable in several aspects, and domestic incidents can be avoided with appropriate monitoring and alarm systems, etc. [7]. Other application necessary of IoT like for losses, IoT can be helped to find objects that we don't remember where have been left. Or in thefts an application similar to the previous one may leave the user to know if some objects are moved from a restricted area which would indicate that the object is being stolen [7].

2) Transportation and mobility: Transport domain is one of most important domains, and one of the most complicated domains. Urban traffic is the main contributor to traffic noise pollution and a major contributor to urban air quality degradation and greenhouse gas emissions. Traffic congestion directly imposes significant costs on economic and social activities in most cities [8].

Advanced cars, trains, buses as well as bicycles along with roads and/or rails are becoming more instrumented with sensors, actuators, and processing power. Roads themselves are also equipped with tags and sensors that send important information to traffic control sites to better route the traffic, provide the tourist with appropriate transportation information. In this domain exist several applications such us assisted driving offer collision avoidance systems and monitoring of transportation of hazardous materials, or mobile ticketing and augmented maps [7].

3) Work environment: In this domain they are several uses of IoT such us Industrial plants, enterprise, logistics, etc.

Sensors have always been a part of the factory setup for security, automation, climate control, etc. Which ultimately will be replaced by a wireless system giving the opportunity to make changes to the configuration whenever necessary? It is nothing but a subnet IoT dedicated to the maintenance of the plant [8].

In industrial plants, IoT also contribute to improving the automation of industrial plants with a massive deployment of RFID tags associated with production parts. An event is generated by the reader with all the necessary data, such as RFID number, and stored on the network. The machine / robot is notified by the event and picks up part of the production [7].

Logistics is a work domain but also attached to the transport domain including the management of transport offers good logistics management. With the application of IoT can improve these domains to offers the best customer services.

4) Others utilities: Other domains are necessary need the IoT as a Healthcare domain, military and smart environment, etc. In the military domain smart objects can protect the lives of people. In another side many benefits of IoT technologies in healthcare and resulting applications can be grouped essentially of: tracking objects and people, the identification and authentication of people, automatic data collection and sensing of sickness [7]. One of the major IoT application areas that are already drawing attention is Smart Environment IoT. There are several test beds being implemented and many more planned in the coming years. Other use of the IoT is Smart museum and gym and Monitoring environmental parameters. Smart museum and gym as to smart leisure environments, the museum and the gym are two representative examples where the IoT technologies can help in exploiting their facilities at the best. Monitoring environmental parameters perishable goods such as fruits, fresh-cut produce, meat, and dairy products are vital parts of our nutrition. From the production to the consumption sites thousands of kilometers or even more are covered and during the transportation the conservation status need to be monitored to avoid uncertainty in quality levels for distribution decisions. Pervasive computing and sensor technologies offer great potential for improving the efficiency of the food supply chain [3].

C. The protocols layer of the IoT

Protocols layer of the IoT consists of 4 main layers:

a) Physical and Data Link Layers: The most common physical layer protocols used (10, 100, 1G) WiFi (802.11b, g, n), GSM, 3G, LTE, 4G,IEEE 802.15.4,PLC,etc.

b) Network Layer: The protocols of this layer are IPv6, RPL.

- ***Routing Protocol for Low and Lossy networks (RPL):*** The Internet Engineering Task Force (IETF) formed a new Working Group called ROLL (Routing Over Low-power and Lossy networks) in 2008[6] which was defined a new protocol RPL to solve de problem of Low power and Lossy Networks (LLN). Algorithmic and protocolary foundations of RPL described in RFC 6550[10]. RPL was developed from four sets of requirements that represent the four main foreseen uses of WSN: Home Automation, Building Automation, Industrial and Urban environments [15].

RPL is a Distance Vector IPv6 routing protocol for LLNs that specifies how to build a Destination Oriented Directed Acyclic Graph (DoDAG) using an objective function and a set of metrics/constraints [9]. The objective functions to adapt the generic behavior to a particular environment and specify more precisely the rules of construction of DoDAG [11].

RPL is based on the topological concept of Directed Acyclic Graphs (DAGs). The DAG defines a tree-like structure that specifies the default routes between nodes in the LLN. However, a DAG structure is more than a typical tree in the sense that a node might associate to multiple parent nodes in the DAG, in contrast to classical trees where only one parent is allowed. More specifically, RPL organizes nodes as

Destination-Oriented DAGs (DODAGs), where most popular destination nodes (i.e. sinks) or those providing a default route to the Internet (i.e. gateways) act as the roots of the DAGs.

A network may consist of one or several DODAGs, which form together an RPL instance identified by a unique ID, called RPLInstanceID.

RPL defines three types of nodes:

- Low Power and Lossy Border Routers (LBRs): it refers to the root of a DODAG that represents a collection point in the network and has the ability to construct a DAG. The LBR also acts as a gateway (or edge router) between the Internet and the LLN.
- Router: it refers to a device that can forward and generate traffic. Such a router does not have the ability to create a new DAG, but associate to an existing one.
- Host: it refers to an end-device that is capable of generating data traffic, but is not able to forward traffic [14].

c) Transport Layer: There are two protocols: TCP, UDP.

d) Application layer: There are several protocols in this layer but the most important protocols are: HTTP (TCP), CoAP (UDP). Appear of IoT and the limits of IP architecture obliged to define new protocols and an adaptive layer.

- **Constrained Application Protocol CoAP:** The IETF Constrained Application Protocol (CoAP) is an application-layer protocol designed to provide a REST-like interface [16].The CoAP protocol can remove HTTP limitations constrained environment while ensuring high compatibility with existing. It is relatively easy to turn HTTP requests in CoAP queries. A old device connected to an IPv4 network may well request access to a resource on a connected server to an IPv6 network and gateway translates between the two worlds [11]. Thus the side of a sensor network, we can use the protocol stack CoAP / UDP / 6LoWPAN for IPv6 auto configuration properties and the small size of the battery, and it will keep the Internet side HTTP stack / TCP / IPv4 which is present on all devices. If, for example, an iPhone wants to know the temperature measured by a sensor, it will send its HTTP request, it will be transformed into CoAP by a bridge, and the answer may be stored for a period specified by the sensor in the gateway. If another device on the Internet requires the same value during this time interval, it will not be necessary to propagate the query to the sensor [11].
- **CoAP vs HTTP:** CoAP is network-oriented protocol, using similar features to HTTP but also allows for low overhead, multicast, etc. As HTTP protocol is a long-term successful standard, it can use small script to integrate various resources and services. Interoperation provided by HTTP is the key point of IoT, for this, http is employed in application level. However, HTTP is based on TCP protocol using point to point (p2p) communication model that not suitable for notification push services. Also, for constrained devices, HTTP is too complex.

Unlike HTTP based protocols, CoAP operates over UDP instead of using complex congestion control as in TCP [12]. CoAP is based on REST architecture, which is a general design for accessing Internet resources. In order to overcome disadvantage in constrained resource, CoAP need to optimize the length of datagram and provide reliable communication. On one side, CoAP provides URI, REST method such as GET, POST, PUT, and DELETE. On the other side, based on lightweight UDP protocol, CoAP allows IP multicast, which satisfies group communication for IoT. To compensate for the unreliability of UDP protocol, CoAP defines a retransmission mechanism and provides resource discovery mechanism with resource description [13].

e) A version of IPv6 adapted to constrained networks 6LoWPAN: In 2005, the IETF chartered the IPv6 over Low Power, Wireless Networks (6LoWPAN) working group to standardize adaptations of IPv6 over mesh networks composed of low-power, wireless links[9]. The difference in size of the package IPv6 and datagram of IEEE 802.15.4 obliged 6LoWPAN group to define encapsulation and header compression mechanisms that allow IPv6 packets to be sent to and received from over IEEE 802.15.4 based networks.

III. Information and communication technology (ICT) in Algeria

Algeria wants to position itself as one of the strongholds of the wireless Internet in the Maghreb. The development of Wi-Fi (Wireless Fidelity), WiMax (Worldwide Interoperability for Microwave Access) is a wireless data transmission standard, with a theoretical speed of 70 megabits per second, the equivalent of hundreds of ADSL (Asymmetric Digital Subscriber Line) connections with range of 50 kilometers. This wireless radio technology that aims to connect any wireless equipment: access points Wi-Fi, IP phone, mobile phone.

The commercialization of wireless telephony in fixed mode (4G LTE) has just started through all the capitals of the 48 provinces of the country with a gradual roll in each province. This new generation of wireless technology used in the majority of developed countries to provid users a remote and speed access to the Internet that not depend on fixed phone lines as ADSL and with a higher performance, as the incumbent Algeria Telecom has launched this technology. Choosing the 4G LTE was motivated to its flexibility, easy to deploy and competitiveness.

IV. Our approach

A. The System design

The communications technologies in the Internet of Things is developing rapidly in recent years so it can meet the demands of the connections between the physical world "things" and "human". Thus, the use of smartphones helps to handle remote objects via Internet.

Our approach proposed in this paper is mainly based on our system for irrigation shown in [4]. The difference is that here we have used the technologies of the Internet of things for smart irrigation management in southern Algeria via the Internet, and using smart phones.

As shown in figure 1, this system consists of: wireless sensor network system, the 6LoWPAN smart gateway that connects the Zigbee network with the internet via mobile communication network (4G LTE).

The sensors placed in the agricultural field, measure continuously the soil moisture values, the water tank level and the water well level , then send these values through a ZigBee mesh network to a smart gateway (Generic IoT Border Router Wireless Br 1000), those information are then sent via a mobile data communication 4G LTE network to a web service that uses intelligent software application to automatically analyze the data and act according to the obtained results, by selective activation of controllers as needed.

The routing protocol used in this proposed design is the RPL protocol. The outputs results and irrigation recommendations are presented to the user on a smart phone web application using CoAP or HTTPs interfaces.

Our system focuses on the following performance objectives to ensure its widespread adoption by farmers:

- The system is easy to deploy, to use, and facilitates planning of irrigation tasks.
- The system is modular and flexible, making it easy to maintain
- The system design is robust and reliable.

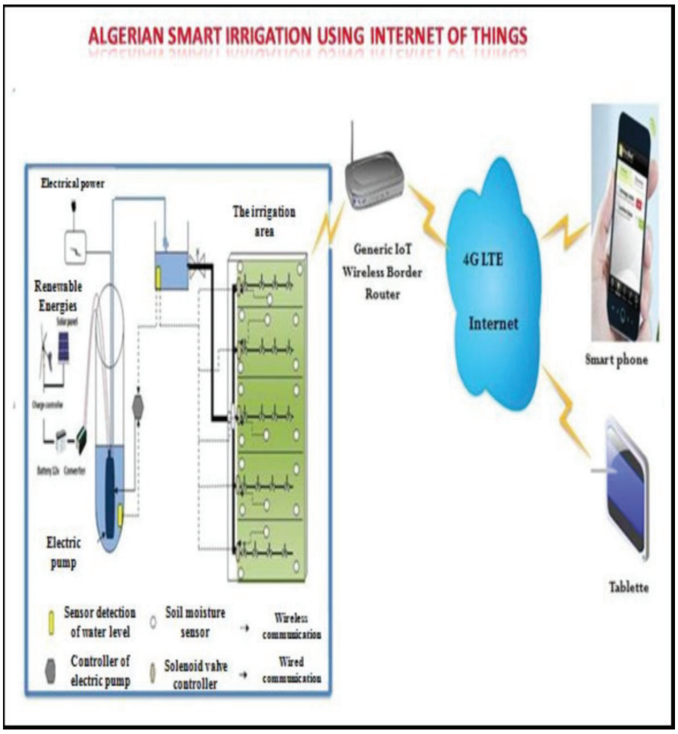

Fig. 1. The system design.

The Smart gateway connects the two parts of our system (the first part: the wireless sensor networks and controllers, the second parts: is the internet and smartphones), it is the 6LoWPAN Border Router translates between the two standardized protocol stacks. In addition it is an application level gateway for other IoT protocols such as Bluetooth Low Energy, Thread, and ZigBee. WLAN or LTE may be used for the uplink to the Internet [17].

B. Communication in our system

The network of our system consists of several tiny devices (sensors, microcontrollers, smart gateway) that communicate with themselves via a Low and Lossy networks (LLNs), using the routing protocol dedicated to this type of network called RPL (Routing protocol for Low and Lossy networks). This LLN network is connected to the internet by a smart 6lowpan gateway that represents the root of the RPL, as it shown in figure 2.

The construction of DODAG involves two phases.

- **Phase 1.** Creating the up paths (from the root to the nodes): The smart gateway sends a DIO message (DAG Information Object) to its neighbors which are (coordinators nodes, sensors detection of the water level and the controller of the electric pump) for the construction of DODAG. Each one of these neighbors in turn send a DIO message to its neighbors in each irrigation area for the creation of the DAGs (Directed Acyclic Graph).
- **Phase 2.** Creating the down paths (from the nodes to the root): Each node in the network when receiving the DIO Message send a DAO message (Destination Advertisement Object) to its root for creating paths to the root and filling tables routing.

The soil moisture sensors measure soil moisture, these values must be sent to the root nodes of sub-DAGs (coordinators nodes). Each soil moisture sensor sends the measured values to his favorite parent until the reception of these values by the coordinator node, this latter calculates the average of the received values and send them to the smart gateway.

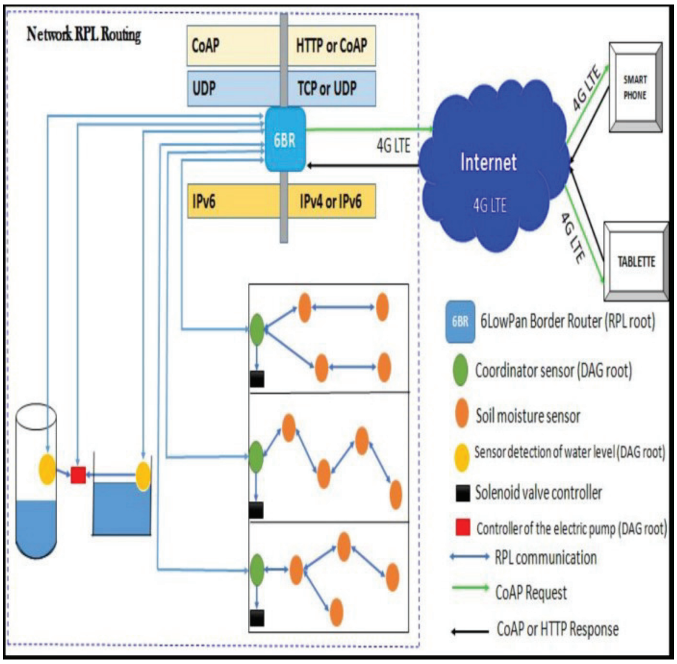

Fig. 2. The system communication.

The sensors detection of the water level measure the water level in the well and in the tank, also send these measured values to the smart gateway.

The smart gateway sends the received values (soil moisture values and water level values) via a mobile communication network (4G LTE) to the farmer.

The farmer can check the soil moisture values, and also water level in the tank and in the well with smart phone application that connect directly to the smart gateway using http or CoAP protocols. Therefore, the farmer may decide either the irrigation of dry areas or filling the tank by sending a response to the gateway, which represent an intermediate that send this response to the coordinator node in order to control the opening and closing of the solenoid valves or to electric pump controller in order to activate or deactivate the electric pump in the well according to the specific needs.

In the case where the values of soil moisture or the values of the water level in the tank are critical which means that areas are dry or the water level in the tank is minimum, our system will automatically pass to standalone mode (our proposed system in [4]), which makes our system tolerant to faults.

V. SIMULATION AND DISCUSSION OF RESULT

In order to validate the Performance of our approach by simulation, we use Cooja simulator provided by Contiki, which unlike most simulators also allows real hardware platforms to be emulated [18].

This simulation is about how the network converged and stabilized using the RPL protocol and OF0 implementation of ContikiRPL. The simulation scripts consists of RPL sender nodes and LLN Border Router (LBR) programs which are emulated as Tmote sky nodes and derived from Cooja and uIPv6 module including UDP, ICMPv6, IPv6, SICSLoWPAN and Rime of the Contiki kernel [19][20].

With the help of the CollectView tool [21] provided by Cooja, the following metrics could be observed: The time taken to find the first source-destination pair in the whole network; The time taken for the network to fully converge when all nodes join the network tree; The time taken for the network to fully stabilize after convergence, the time taken for the Estimated Transmission Count (ETX) value for each node.

As shown in figure 3, our network consists of 15 RPL nodes; deployed in an irrigation land which composed of 3 areas,

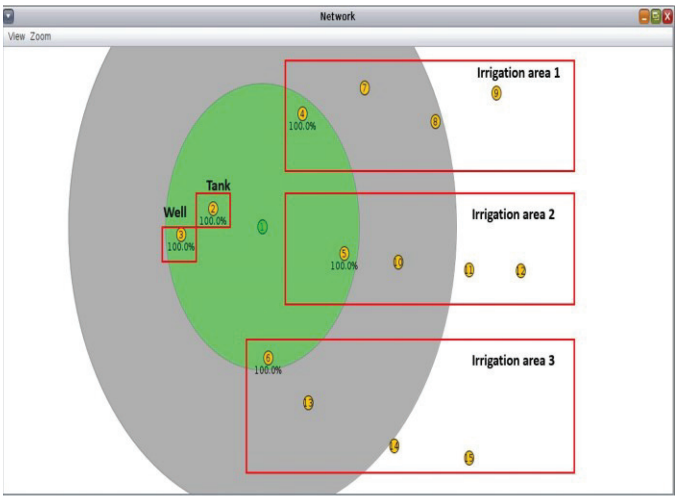

Fig. 3. The network simulation in cooja.

where each area consist of 4 RPL sender nodes, and the RPL sender nodes in the tank and in the well, all these nodes are connected to The RPL border router, and this router is used in order to interface a regular IP network with an RPL 6LoWPAN network.

Figures 4 and 5, presents the network tree and the communication between DAGs roots (node 2.2, node 3.3, node 4.4, node 5.5, node 6.6) and DODAG root (RPL border router node 1.1).

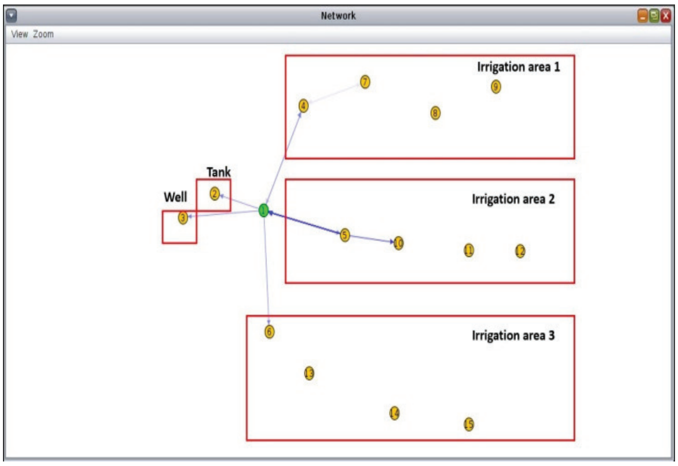

Fig. 4. Communication between nodes.

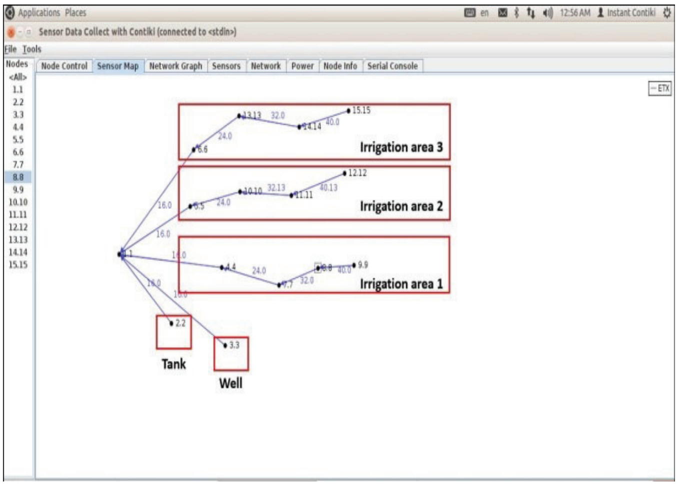

Fig. 5. The network tree.

All data collected by the wireless sensor network are used by the system to handle an intelligent, automated irrigation of vegetation (by saving water and energy use) and can be accessed in real time via a web application in smartphones, which can also send alerts and commands when the ground is too dry or a lack of water in the basin and offer suggestions to maximize plant health.

These first results obtained by simulation using the Cooja simulator are satisfactory, especially in routing information by RPL and COAP protocols. This will encourage us to go further towards creating a web application in smartphones to complete all the proposed system and facilitate the tasks of the farmers for a good monitoring of their agriculture.

Also, we hope that this approach will be very beneficial if we can experiment it in the fields of agriculture especially in Saharan and arid areas such as the south of Algeria.

VI. CONCLUSION

The intelligent technologies play a very important role for an effective management of irrigation, we have proposed in this article a smart irrigation system for a Saharan area like the south of Algeria. This proposed system is based on ICT and IoT technologies.

Using these technologies, the control of irrigation will be ensured at low cost and high accuracy. Our proposed system facilitates the irrigation tasks and optimizes the costs in term of minimizing the water consummation and reducing the cost of the working force.

The validation of the proposed approach by simulation showed us the value and the importance of the adoption of WSN and IoT technologies in precision farming.

As a perspective we plan to complete the implementation of our system using the CoAP protocol and web application for monitoring the irrigation via the internet using IoT, and also to apply this system in real world.

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