Survey of Internet of Things Applications in Smart Agriculture: A typical architecture

Salim Chikhi* — Badreddine Miles**

* MISC Laboratory
University Abdelhamid Mehri Constantine 2
salim.chikhi@univ-constantine2.dz

** MISC Laboratory
University Brother Mentouri Constantine 1
badr-eddine.miles@umc.edu.dz

ABSTRACT. The world will need to produce 70% more food in 2050 than it did in 2006 in order to feed the growing population of the Earth, according to the UN Food and Agriculture Organization. To meet this demand, farmers and agricultural companies are turning to the Internet of Things for analytics and greater production capabilities. The IoT is set to push the future of farming to the next level thanks to agricultural drones and sensors. In this article, we present a survey of the various technological advances used in the Internet of Things (IOT) for smart agriculture, and we end by raising the positive contribution of the use of IoT in the development of agriculture by projects and applications that have already been realized. At the same time, we are attracting the attention of African researchers to look into the possibilities of developing IoT-based systems to meet the challenges of agriculture on our continent by the proposition of a typical architecture.

RÉSUMÉ. Selon l'Organisation des Nations Unies pour l'alimentation et l'agriculture, le monde devra produire 70% de plus de nourriture en 2050 qu'en 2006 pour nourrir la population croissante de la planète. Pour répondre à cette demande, les agriculteurs et les entreprises agricoles se tournent vers l'Internet des objets pour des analyses et des capacités de production plus importantes. L'IoT devrait faire passer l'avenir de l'agriculture à un niveau supérieur grâce aux drones et aux capteurs agricoles. Dans cet article, nous présentons une étude des différentes avancées technologiques utilisées dans l'Internet des objets (IOT) pour l'agriculture intelligente, et nous concluons en soulignant la contribution positive de l'utilisation de l'IoT dans le développement de l'agriculture par des projets et des applications déjà réalisés. Dans le même temps, nous attirons l'attention des chercheurs africains sur les possibilités de développer des systèmes basés sur l'IoT pour relever les défis de l'agriculture sur notre continent par la proposition d'une architecture typique.

KEYWORDS : Internet of things, Applications of IoT, Smart agriculture, Sensors, LPWAN.

MOTS-CLÉS : Internet des objets, Applications de l'IoT, Agriculture intelligente, Capteurs, LPWAN.

1. Introduction

The applications of IoT are numerous and can improve the daily life of citizens. IoT has a good chance of succeeding in developing countries because of existence of means to overcome challenges for effective deployment of IoT solutions. The issues across Africa can be very different from other continents [1, 2].

IoT can be used, among others, to:

– help deliver clean water to thousands of people,

– better protect endangered species,

– diagnose and follow patients remotely ,

– make roads and streets safer for citizens,

– better inform farmers and increase crop production.

The application of IoT in Africa faces the barriers of the required investment and the weak existing infrastructure. However, Literature shows that many countries have started experimenting Iot based applications, such as:

– intelligent traffic lights in Nairobi are helping to ease traffic congestion,

– new smart city in the suburb of Algiers,

– smart meters to reduce the load and avoid power outages in south africa,

– unmanned aerial vehicles (UAVs) are used to protect some african national parks.

In the agricultural domain, Iot can play a crucial role in Africa because there are one billion farmers across the continent who contribute significantly to the economy of their countries.

Through this paper, we try to review some important works done in developed countries in the agricultural field to draw some lessons that encourage African researchers to invest in this area for the good of our continent. We give some recommendations for the application of IoT in the different agricultural applications.

The rest of the paper is organized as follows: Section 2 summarizes some well known IoT definitions and the nature of data involved in most corresponding systems. Section 3 is on the communication aspects which are the heart of any IoT system. In section 4 we present a brief overview of some interesting IoT solutions for intelligent agriculture. Section 5 is reserved for the proposition of a basic architecture to be used in any system dedicated to making farms intelligent. In section 6, we conclude the present study.

2. IoT Definition

According to the International Telecommunication Union, the Internet of Things (IoT) is a " global infrastructure for the information society, which provides advanced services by interconnecting objects (physical or virtual) with the technologies of the Internet. Ex-

isting and evolving interoperable information and communication.
According to [3] defines "the internet of things as a network of networks that allows, via standardized and unified electronic identification systems, and mobile wireless devices, to identify directly and unambiguously digital entities and objects physical and thus to be able to recover, store, transfer and process, without discontinuity between the physical and virtual worlds, the data related thereto".
According to [4] defines "IoT is a dynamic global network infrastructure with self- configuring capabilities based on standard and interoperable communication protocols where physical and virtual Things have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network".
The semantic meaning of the "Internet of Things" is presented as "a globally network of uniquely addressable interconnected objects based on standard communication protocols"
According to Gartner, 25 billion devices will be connected to the Internet by 2020 and these connections will make it easier to use data to analyze, plan, manage and make intelligent decisions independently. In this context, IoT can be used in several sectors, such as transportation, smart city, intelligent home automation, intelligent health, life support, logistics, automation, industry, and agriculture.
Although the data generated daily in agriculture continue to rise. BI Intelligence, Busi-

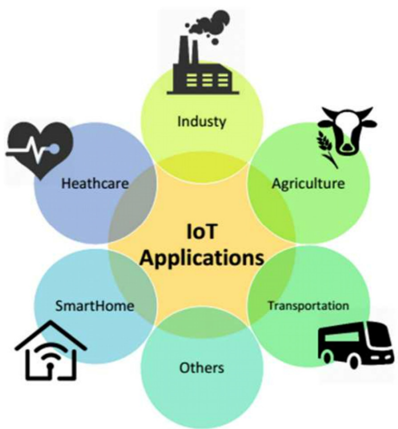

Figure 1. *different areas of IoT applications*

ness Insider's premium search service [5], predicts that IoT device installations in the agricultural world will grow from 30 million in 2015 to 75 million in 2020, for a compound annual growth rate of 20

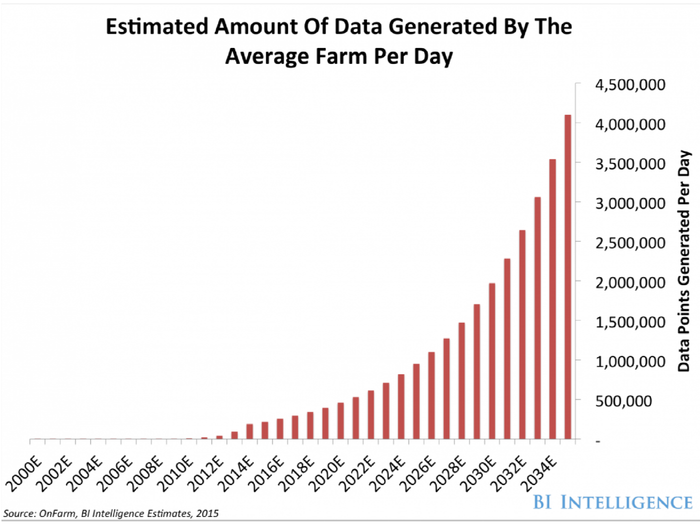

Figure 2. *Estimated Amount of data generated by the average farm per day [5]*

Precision agriculture is sometimes referred to as "smart farming", involving different types of technologies such as data analysis, sensing technologies, communication systems, and hardware and software systems. These technologies are needed to implement the computing system that gathers, analyzes, and then presents the data to initiate an appropriate response to the information received.

For farmers and producers, a wide variety of information regarding soil and crop behavior, animal behavior, condition of machinery, storage tank status from isolated sites is presented for farmers can make decisions and improve production.

It is true that for smart agriculture we need sensors that measure the temperature, the humidity, the climate, and the acidity of the soil. and also the sensors placed in the fields to allow farmers to obtain detailed maps of the topography and resources of the area. This data must be sent to the server for storage and analysis. Therefore, communication is very important in precision farming. There is a lot of recent technology for communication in IoT, for example Zigbee, z-wave, Bluetooth Low Power, Wifi, and LPWAN communication networks (SigFox, LoRa, NB-IoT). These proves very useful and practical in intelligent agriculture, because communication is used for a great distance up to 40 Km and inexpensive in energy, a battery can emit some messages a day for 10 years.

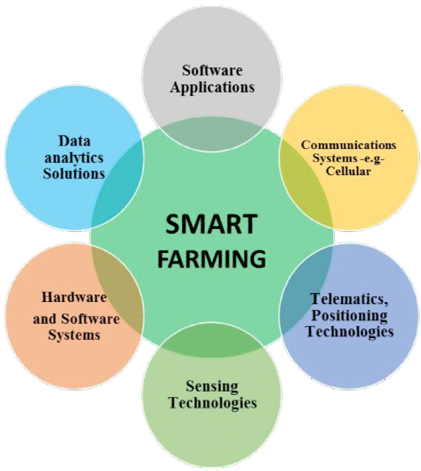

Figure 3. *The different types of technologies involved in smart farming*

3. LPWAN

Recently, a new generation of low power wide area network (LPWAN) has emerged to bridge the gap between wireless and mobile network technologies. This LPWAN network is still little known, but behind it hides more high-profile technologies such as LoRaWan, SigFox, and NB-IoT. These LPWAN networks have several features that make them particularly attractive for devices and applications that require low mobility and low levels of data transfer. This makes it possible to send and receive messages of very small size over very long periods of time. range (from 5km to 40km), with a major advantage to issue messages very inexpensive and very low energy (it is possible with a single battery, to issue a few messages per day for 10 years). To see the benefits of these LPWAN networks, Figure 4 shows a comparison of this network with two other commonly used communicating technologies, GSM (3G, 4G, and 5G) and ZigBee.

3.1. SigFox

The Sigfox technology was developed in 2010 by the start-up Sigfox (in Toulouse, France), both company and network operator LPWAN. Sigfox operates and markets its own IoT solution in 31 countries around the world, including two in Africa (South Africa and Tunisia), and is still being rolled out worldwide through partnership with various network operators [6].
Sigfox uses unlicensed ISM bands, for example, 868 MHz in Europe, 915 MHz in North America and 433 MHz in Asia. Using the ultra-narrow band, Sigfox uses bandwidth effectively and experiences very low noise levels, resulting in very low power consumption, high receiver sensitivity and economical antenna design at the cost of a maximum speed

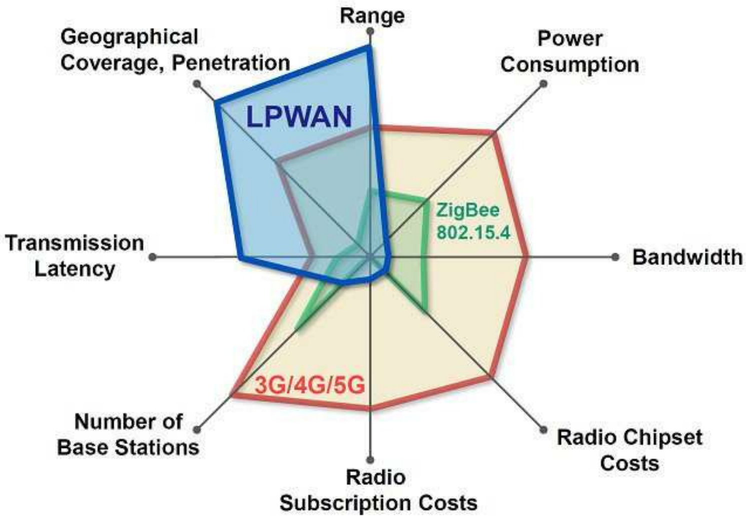

Figure 4. *comparative communicating technology*

of 100 bps.

The number of messages on the uplink is limited to 140 messages per day. The maximum payload length for each uplink message is 12 bytes.

3.2. LoRa

LoRa technology, developed by Semtech, is a physical layer technology that modulates signals in the sub-GHZ ISM band. It is the most widely used technology for LP-WAN in the sub-GHz unlicensed band [7].Due to the use of unauthorized tapes; the LoRa network is open to customers who do not have the authorization of radio frequency regulators. As a result, the LoRa network is easy to deploy for a distance of more than several kilometers and serves customers with minimal investment and maintenance costs.

LoRa technology has been tested in 56 countries and in different areas, for example, traffic tracking, intelligent health car [8]. LoRa uses unlicensed ISM bands, namely 868 MHz in Europe, 433 MHz in Asia and 915 MHz in North America.

LoRa technology provides two-way communication through spectrum modulation. The maximum payload length for each message is 243 bytes. The communication protocol based on LoRa technology was standardized by LoRA-Alliance in 2015, this protocol is called LoRaWAN. To improve the success rate for receiving messages sent by the end device, the end device sends the message to all stations near that device. The resulting duplicate receptions from this operation are filtered in the backend system (network server) which also has the intelligence to check security, send acknowledgments to the end de-

vice, and send the message to the corresponding application server.
In addition, LoRaWAN provides various classes of terminal devices to meet the different requirements of a wide range of IoT applications. Class A, Class B and Class C bidirectional terminal devices. Class A uses less power, while Class C uses the maximum amount of energy.

3.3. NB-IoT

NB-IoT is an LPWAN technology based on narrow-band radio technology and standardized by the 3rd Generation Partnership Project (3GPP). Its specifications were published in version 13 of the 3GPP in June 2016.
IoT NB is still in test in Europe. In December 2016, Vodafone and Huawei integrated NB-IoT into the Spanish Vodafone network and sent the first NB-IoT compliant message to a water meter. Huawei is currently expanding partnerships to deploy this technology around the world. In May 2017, the Ministry of Industry and Information Technology of China announced its decision to accelerate the commercial use of Io-NB for utilities and smart city applications.
NB-IoT can coexist with GSM (Global System for Mobile Communications) and LTE (Long Term Evolution) under licensed frequency bands (eg MHz, 800 MHz and 900 MHz).
The NB-IoT communication protocol is based on the LTE protocol. In fact, NB-IoT reduces the functionality of the LTE protocol to a minimum and improves it as required for IoT applications.
The improvement of NB-IoT continues with version 15 of 3GPP. Under the current 3GPP plan, the Io-NB will be extended to include location methods, multicast services (eg, terminal and message software update for a variety of devices), mobility and data storage. Other technical details applications of NB-IoT technology.

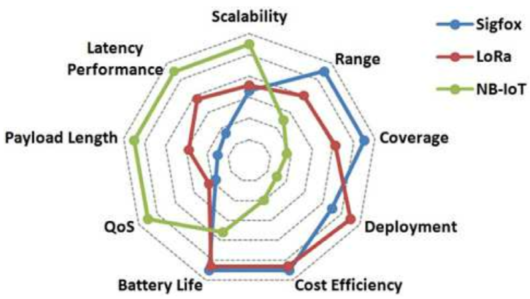

Figure 5. *Respective advantages of Sigfox, LoRa, and NB- IoT in terms of IoT factors [7]*

4. Smart agriculture applications projects

For farmers and producers, the Internet of Things has opened up extremely productive ways to grow crops and raise livestock, thanks to the use of cheap sensors. Intelligent agricultural applications are gaining ground with the promise of ubiquitous visibility on soil and crop health, machinery used, storage conditions, animal behavior and energy consumption. In this section, we discuss some IoT projects developed in intelligent agriculture.

4.1. CROPX SOIL MONITORING SYSTEM

Cropx produces hardware and software systems that measure moisture, temperature, and electrical conductivity in the soil (figure 6). The sensor reads measurements of humidity and temperature in different areas of the farmer's field, and sends this data over the internet to the server. The Cropx system analyzes and customizes irrigation plans for different areas of the field, this for better agricultural productivity and savings in water and energy.

Figure 6. *CROPX Soil Monitoring System*

4.2. MONITORING THE TEMPUTECH WIRELESS SENSOR

TempuTech offers an IoT solution for silo safety and monitoring and grain elevators. TempuTech has implemented an IoT system that allows farmers to understand their silo data with the wireless sensors installed at the silo level (figure 7). The platform enables manufacturers to establish benchmark performance standards and set alert and alarm conditions related to temperature, vibration, humidity and other conditions.

Figure 7. *TempuTech*

4.3. INTELLIGENT CLAAS EQUIPMENT

CLAAS is one of the world's leading manufacturers of agricultural engineering equipment. Their equipment can be controlled automatically. Their system provides advice to the farmer that minimizes grain loss and improves the flow of crops (figure 8). The system collects and makes good use of data through field mapping, fertilization planning, nutrient balance, and scheduling and planning programs.

Figure 8. *Intelligent CLAAS Equipment*

4.4. PRECISIONHAWK DRONE DATA PLATFORM

PrecisionHawk has created an autonomous UAV that collects high quality data through a series of sensors used for surveying, mapping and imaging farmland. The drone makes observations and a follow-up flight (figure 9). Using artificial intelligence, the drone can change course depending on the wind speed or the air pressure taken by sensors. During the flight, the drone collects visual, thermal and multispectral images. In this section,

Figure 9. *PRECISIONHAWK Drone Data Platform*

we have presented some projects in smart agriculture, these applications provide higher agricultural productivity and savings of water and energy and money to farmers. Other projects exist, such as Mb North America's connected cows, precision planting's corn maze, and Teamdev's Libelium network for tobacco crop quality.

5. Proposed architecture

In agriculture, the long life of the sensor battery is of great importance. Temperature, humidity and alkalinity sensors could significantly reduce water consumption and improve efficiency. The devices update the detected data only a few times a day because environmental conditions do not change dramatically. Thus, LPWAN technologies are ideal for smart agriculture applications. In Figure 10 we propose a typical IoT architecture for agricultural applications based on LPWAN networks. They represent the communication system that is the heart of the architecture. This system can be realized by three different technologies: Sigfox, LoRa and NB-IoT. We suggest the use of SigFox or LoRa because they use free frequency bands while NB-IoT requires LTE cellular coverage, which is not the case for most farms. The gateway receives data from different farm sensors installed in remote locations of the antennas, then, it transmits them to the server through an Internet access network. It stores them, analyzes them and makes them available to applications.

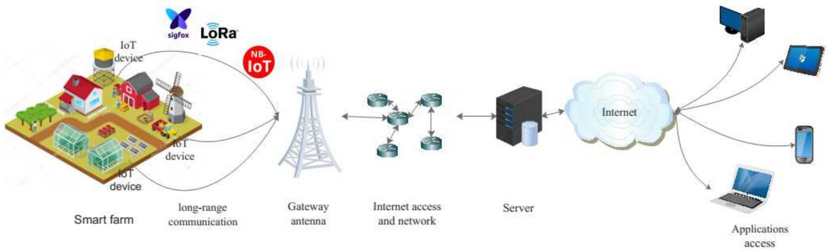

Figure 10. *Proposed architecture for smart farm*

6. Conclusion

Although vital, African agriculture is in difficulty, the sub-Sahara is made up of 95% of arable land which depend on the rain. This means that agricultural productivity is often low, making food insecurity a permanent danger. It is in this context that this paper is trying to sound the alarm to encourage researchers and governments to opt for a massive use of IoT through the design of appropriate architectures to help African agriculture in Africa. to get up. This paper provides basic architecture and communication system recommendations for efficient designs of intelligent farming systems based on connected components. We present particularly, a study of the different IoT technologies used in intelligent agriculture. This study shows the importance of LPWAN networks in the field of intelligent agriculture given the long range of communication (up to 40 KM) and low

energy consumption (one year of autonomy).
Finally, note that the success of IoT in Africa depends on close collaboration between companies, telecom providers, device suppliers and developers.

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