LoRa IoT WSN for E-Agriculture

Tea Osmëni(✉) and Maaruf Ali

Epoka University, Rruga Tiranë-Rinas, Km 12, 1032 Vorë, Tiranë, Albania
maaruf@ieee.org

Abstract. This paper presents the research carried out in the application of wireless sensor networks to aid agriculture and cultivation using Albania as an example. Utilisation of artificial intelligence, machine learning to aid agriculture are presented. For a primarily agricultural-based economy with rugged terrain, power availability is the biggest problem along with security. The research presents various technologies that may be applied to aid the farmer. The conclusion of the research finds that Internet-of-Things (IoT) using Long Range (LoRa) Wireless Sensor Networks (WSNs) is the most secure solution for productive and economic farming in semi-developed countries.

Keywords: LoRa · IoT · E-Agriculture · WSN · Wireless Sensor Network

1 Introduction

1.1 Background

Three issues were taken into consideration regarding WSNs (Wireless Sensor Networks) at the onset of this research, these being:

1. The effective radio coverage field (network field) by the sensors. This is related to the sensor receiver sensitivity. The sensitivity of the other types of sensors will also affect the domain of the area or volume being monitored, for example, the IR (infrared) radiation of intruders in the farmer's area.
2. Prolonging the operational life of the network when the number of sensors is greater than operational necessity. This could be required for the simple case to ensure network redundancy and fault tolerance. Some of them could then be scheduled to have their power turned off to save energy.
3. The network needs to be secured against intrusion, spoofing and data theft for protection against hacking.

1.2 Purpose

The purpose of this project was to present several issues regarding wireless connectivity, more specifically related to farming. The research questions to be answered were:

- How could a farmer best make use of the radio network coverage map?
- What issues do we face in using WSNs (Wireless Sensor Networks)?
- Which is the best solution to mitigate against security attacks in agriculture?

M. H. Miraz et al. (Eds.): iCETiC 2021, LNICST 395, pp. 85–93, 2021.
https://doi.org/10.1007/978-3-030-90016-8_6

1.3 Approach

The starting point was a feasibility study where the focus lay on different reference literature study. This would result in a number of hypotheses, which were analysed after the case study. This consisted of implementing the WSN and a skeleton of the coverage map of Tirana, the capital city of Albania, which was performed in Matlab®. After the case study was completed, an evaluation of the issues regarding energy, power consumption and security in agriculture was performed. In the evaluation, the hypotheses were to be confirmed or denied, based on the empirical findings from the case study.

1.4 Literature Review

Based on the literature review, agriculture can be considered a complex dynamic biological production system affected by many parameters: human behaviour, machines used, nature, chemicals, biology, weather and the climate.

Data fusion is necessary to increase the effectiveness of decision making from the myriad of sensors. Maintaining the security of the information flow has become paramount for data integrity, security and privacy with the rise in cybercrime. WSNs and IoTs have now become essential for enabling remote real-time information gathering, analysis and decision making applicable to agriculture using the least amount of labour.

2 IoT (Internet of Things) Domain Model Concepts

This section presents the application of IoT in Albania and other developing countries for a sustainable future.

In general, IoT as the acronym represents, are Internet (connected) of things (objects, devices). These devices come in all sizes and communicate with one another using the Internet, unattended and autonomously.

2.1 IoT Utilisation in Albanian Agriculture

Developed countries continue to extend its network of IoT investing time in research and money to convert the abstract into material reality all with the goal of a sustainable future.

IoT sensors continue to be deployed from the microscopic level to an industrial scale, from underground, overground, in the sea, in humans and animals to space. Applications of IoTs in agriculture is also accelerating, for monitoring and controlling ground water, irrigation, crop growth, harvesting and crop health. All the vast amount of data generated can be saved in the cloud, processed by it and made easily accessible to the farmers and by institutions [1].

How can IoT help in the evolution of a country, currently speaking, the evolving of agriculture in Albania (or any developing country)? Well, in a lot of ways actually, such as:

- Weather monitoring, pest control, nutrient and greenhouse gases emission management [2, 3].
- Information to aid governments and farmers to design business models fusing smart agriculture and optimising the smart food supply chains by making them smarter [1, 4].
- Water supply control and management of irrigation to prevent wastage and thus help prevent flooding or drought - a common problem in Albania [1]. Smart water monitoring using IoTs can help agriculture use 30%–50% less energy and water. Currently many places lack adequate water resources and suffer from poor management leaving many without access to potable water.

2.2 IoT Domain Model Requirements

The six primary requirements for IoT deployment are next explained.

Physical Entity User Interaction, Mediated or Physically via IoT.

I. Application
A agrarian IoT system using WSNs actively monitors its farming environment taking measurements of the temperature, humidity, rainfall, air pressure, light intensity, soil moisture. These are some physical attributes essential for helping to achieve high yield and high cultivation products. These parameters can be displayed on a mobile application on the farmer's phone, tablet or desktop computer. For modelling purposes, the farm is the Physical Entity and the application is the user.

The Physical Entity is an Identifiable Component of the Physical Realm that is for the User's Goal Completion Interest.

II. Environment
Optical sensors may be used for smoke, sand, fog, haze, pollen, precipitation measurements to determine air visibility. The information may used to provide safety information for traffic or air traffic management systems.

III. Living Being
Crop growth monitoring systems allied to WSNs are also being used to determine the rate of growth of plants, fruits, vegetables and crops and the effect of crop spraying of liquid fertilisers. Growth monitors, such as that shown in Fig. 1, below are deployed. These have vegetable/fruit growth sensors. In such a scenario, the fruits are Physical Entities.

Software Components are the Resources that Send Information or Data for Actuation of the Physical Entities.

IV. Resources.
It comes in two contexts: Network Resource and On-Device Resource. We are interested in the Network Resources, as we will see below that we need a wireless connection for the transmission to be done (actually by using WSN). For example, HBase2 is a distributed,

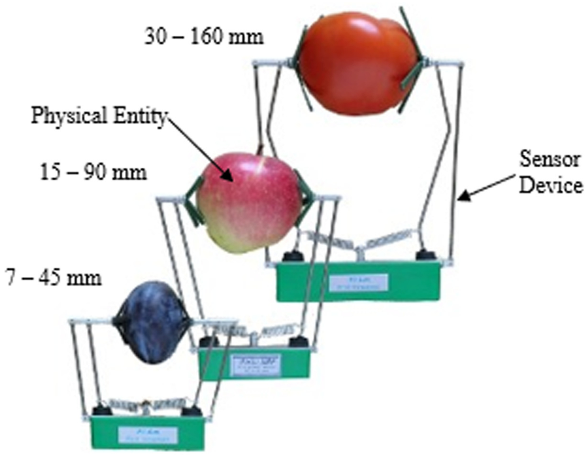

Fig. 1. Physical Entity as part of the physical environment. Adapted from [5].

open-source, column-oriented database offering distributed information management. The Network Resources here are the libraries and components of the HBase software.

A Service Offers a Standardised and Unambiguous Interface with the Functionalities for Interacting with the Related Processes of the Physical Entities.

V. Interacting Services

A resource hungry service that requires high CPU utilisation, memory and storage requirements may be divided as smaller tasks running across multiple machines in a distributed manner, invoking each other for convenient and scalable processing. These subservices in themselves will require smaller resources and less power. A balance and trade-off will need to be established taking into account the increased networking overhead of inter-communication and possible combined increase in the total power of all the host machines.

Devices are Defined as Real-World Technical Artefacts for Bridging the Digital World Internet with the Physical Entities.

VI. Devices

Typical devices needed in our case are both simple sensors that will measure sound, possibly seismic activity, light, thermal, acoustic or lux sensors, but also complex ones like IR or UV cameras. A device can be unitary as well as a conglomerate of devices. The Domain Model for IoT does not define this granularity due to the application dependence of the sensor.

Figure 2, shows that the sensors to be utilised in e-agriculture are at Stage 1 of the four stage IoT Solutions Architecture. Figure 2 also shows the complexity of the end-to-end solution that must be thought out for a seamless fault free solution to the deployment of IoTs in any application and not just in e-agriculture. A clear overview of Fig. 2 is given in [7], which also proposes a final fifth stage with the goal of "initiating a user's control over the structure".

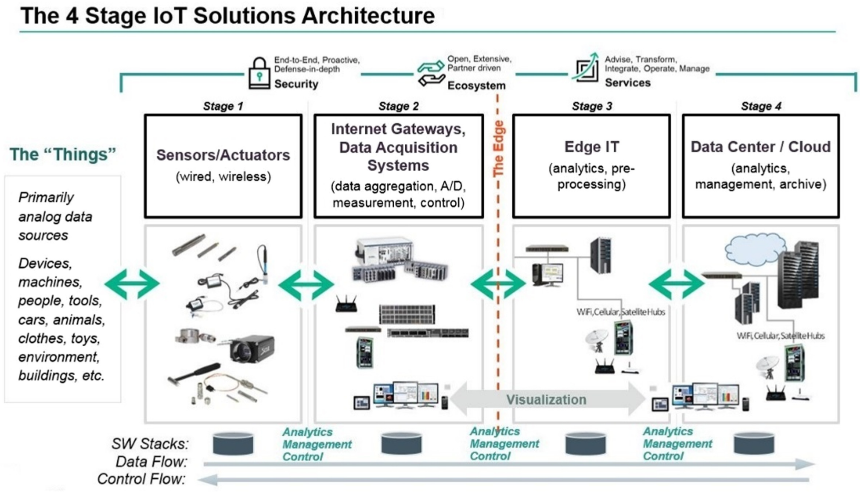

Fig. 2. The four stage IoT solutions architecture [6].

3 Methodology and Steps

3.1 Coverage Map Regarding Albanian Farms

Ensuring full network coverage via radio in WSNs is a major problem due to the varying and harsh RF propagation environment. Radio coverage planning and monitoring is essential, just like in a mobile cellular network. Three models to deal with this coverage issue are [8]:

- Binary model – each sensor's RF (radio frequency) coverage area is modelled by a circle of a predefined radius.
- Probabilistic model – a stochastic process to describe an event taken place in the coverage of a sensor is either not detected or detected based on a probability distribution measure.
- The third model deals with the coverage problem by considering the trajectory (and velocity) of how the targets are travelling through the sensor's sensing field.

The Matlab® code obtained from [9] takes into consideration the visualisation of the coverage map, communication links and directional antenna. The simulation does include directional and bi-directional antennae, but in this scenario, we only discuss in terms of the directional antenna, because we want the transmission to be done to a specific location. The specific locations here are Tirana with its longitude and latitude, as well as some urban areas not so far from Tirana, in terms of agricultural urban areas. Site Viewer is part of Matlab® which is not free to use. So the main problem, the coverage area and how we can be adapt it in terms of the IoT systems, as an advantage for the agricultural sector of Albania was focussed upon.

3.2 Running a WSN (Wireless Sensor Network) in Matlab®

WSN deployment is ubiquitous including for agriculture monitoring to increase productivity and the quality of the produce.

- So, one main problem was the lifetime of our network. What do we want? We want to improve the energy efficiency to extend the lifetime of our network.

In the Matlab® code obtained from [10], the parameter for defining the number of nodes are included. Then, we define the position of two nodes, which is actually fixed, because one node is transmitting the data to another node using the nodes between them.

The position of the nodes is contained in a one square kilometre area. This area is sufficient taking into consideration the typical cultivation area of the average Albanian freehold farmer in our case. Then the range of the nodes are defined, as the WSN has a range of the signal that it can connect to the node if it is inside the range of the node.

Afterwards the range of each node is defined, along with the minimum and maximum energy, energy consumption per cycle (every time a node forwards a packet or a data).

It is a basic scenario as the range of all the nodes need to be checked to ensure connectivity. In this simulation, 20 nodes were chosen, which is a large number of nodes. Some typical farms were taken into consideration with wireless connectivity for assessment of surveillance and safety.

WSNs still have several shortcomings in terms of poor energy efficiency, routing overhead, limited onboard or embedded computational capability, secure packet delivery and many more. However, efficient power utilisation and access is still a major problem [11, 12]. The number of the sensor nodes are high and they are densely deployed in the farm to offer and ensure network redundancy in case of faulty nodes. The density is the number of the neighbouring nodes that it can interact with. The algorithms should be self-organising and scalable for the large number of entities comprising the IOTs. After executing the code, the results shown in Figs. 3 and 4 were obtained, as shown below.

As the process runs, it is shown which are the dead nodes and the routing nodes that the transmission proceeds. To conserve power, unused and redundant path sensors may be turned off.

3.3 LoRa WSN as the Best Solution

As soon as the code is executed, it starts to send data. As soon as a dead node is obtained, the transmitting node will change its path by itself.

But a problem may be encountered, due to cyberattacks. So security of the farming data generated and dissemination need to be ensured to prevent network disruption and other types of attacks. [13] discusses a security model to ensure against such attacks.

We do know that in order for a wireless communication to be conducted, we need three elements: wireless hosts (laptops, mobile), wireless link (to link the communication from the source to the destination) as well as the base station or access point. So, in such a case, LoRa WSN will behave as the access point.

The server will act as the wireless host and if we look carefully in Fig. 5, the wireless link that will be used is LoRaWAN-59, which in general is used to provide coverage on demand for IoT projects.

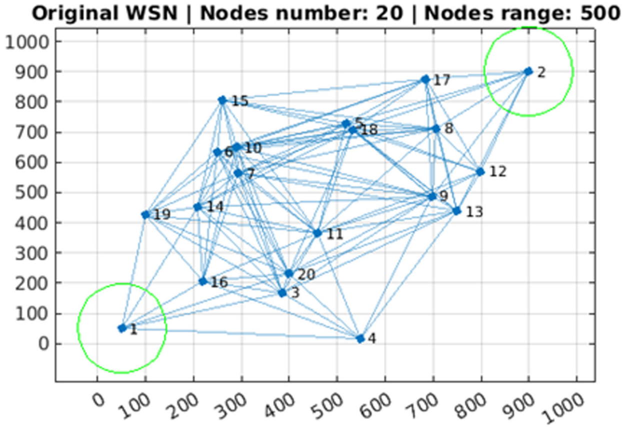

Fig. 3. Scene 2 with 4 hops, 3 dead nodes and routing nodes 1, 3, 9, 2 with 5844 packets sent.

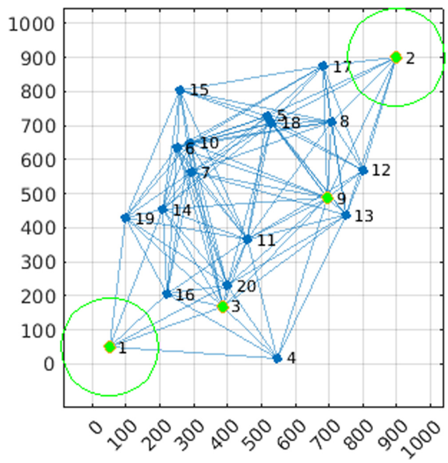

Fig. 4. Scene 3 with 4 hops, 9 dead nodes and routing nodes 1, 3, 9, 2 with 6595 packets sent.

LoRa WSN is the proposed solution by Girard et al. [14], which involves a third trusted party to avoid the problems of cryptographic key sharing.

The end node usually must use secret keys for a lifetime without updating. In the scheme proposed in [14], the end node can update the keys anytime. Chirp spread spectrum methodology modulation of LoRa technology is implemented. Figure 5 below shows the scheme using LoRa WSN.

Fig. 5. The topology of WSN for monitoring of agriculture conditions [11].

4 Conclusions

An explanation of the Domain Model for the IoT concepts was given to see how connections of different devices was done and as well as the requirements needed for an IoT system. The last step is necessary in order to determine the interactivity of the different configurations between the services and the users. This step will help farmers and governments design business models applicable to smart agriculture or e-agriculture.

The three main problems that might occur in future implementations, regarding coverage map, where we have adapted a Matlab® simulation in terms of the longitude and latitude of Tiranë and urban zones around it was described adapting it to our case.

Afterwards, we introduce WSN (Wireless Sensor Network) as a need in agriculture for monitoring, in order to improve farming quality and productivity. We evaluated the WSN issues by illustration with a Matlab® simulation, to justify our explanations to prove our point in terms of nodes, where nodes work as base stations (access points). As the process runs, it is shown which are the dead nodes and the routing nodes that the transmission proceeds. If extra sensors are deployed, these may be turned off to conserve power.

Finally, we have shown that in terms of security, LoRa WSN would be the best choice, after reviewing several publications. We do know that in order for a wireless communication to be conducted, we need three elements: wireless hosts (laptops, mobile), wireless link (to link the communication from source to destination) as well as the base station or access point. So, in such a case LoRa WSN will behave as the access point.

The server will act as the wireless host and specifically the wireless link will be LoRaWAN-59, which in general is used to provide coverage on demand for IoT projects.

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