An Effective Novel IOT Framework For Water Irrigation System In Smart Precision Agriculture

P Suresh, S Koteeswaran

AbstractIn order to accommodate growing population, the call for more food will increase and new strategies should be designed to create more reliable agricultural production strategies. There is a need to create new agricultural manufacturing methods with the smarter water management point on productiveness and rational usage of environmental assets. Considering the need to collect new records about the rural cycle, that is the set of occasions happening at crop all through its lifetime, the scientific community started exploring new era that might be applied to fulfil the necessities of Precision Agriculture. The continuous research on inexpensive, smaller, extra energy-green community nodes will result in the need of Internet of Things. Water irrigation control is one of the typical usages of computer systems in Agriculture. In this paper, an effective novel IoT framework for water irrigation system is designed and evaluated. It is justified that the proposed methodology yields good results.

Keywords: Internet of Things; Smart Water management; Sensor cloud; Precision Agriculture.

1. Introduction

According to the latest United Nations projections, the population on the planet is expected to rise from 7:3 109 people, as of today, to 9:7 109 people in 2050. To accommodate a larger population, the demand for food will increase and new techniques need to be designed to create more efficient agricultural production methods [10]. Moreover, global climate is changing and the growing conditions of the agricultural goods are being affected as well, so there is a need to create new agricultural production models with the focus on productivity and rational usage of environmental resources. The growth of Internet of Things [26-29] for doing smart agriculture is becoming an emerging field. There are also farms with specialty crops (fruits, vegetables [13] and flowers) where there are no big machines involved on the activities being made and farmers need to use manual labor in the production process. In this type of crops, there is a lack of systems capable of automating the process of managing the worker behaviour which, as stated before, can be useful to provide better knowledge about the crop and the field when integrated with other sources of data. Ampatzidis et. al developed a wearable [3] module for recording the worker's positioning in orchards, emphasizing the importance of having such systems available to modern agriculture.

In order to overcome variability, one of the biggest challenges to agricultural productivity, farmers need a broader understanding about the characteristics of the field and the development of the crops [2, 8]. Precision Agriculture [1, 22] envisions a deeper agricultural data capturing, gathering data in each step from planning to final product, in the agricultural production process. Furthermore, Precision Agriculture systems can help farmers with decision making and resource management while integrating different information sources such as sensors, satellites and meteorological forecasts. Considering the need to collect new data about the agricultural cycle, which is the set of events occurring at a certain crop during its lifetime, the scientific community started exploring new technology that could be applied to satisfy the requirements of Precision Agriculture [25]. Nowadays, consumers want to know more information on the products they are eating and this creates a demand for new mechanisms of product identification such as Electronic Product Code (EPC) based on Radio Frequency Identification [19] (RFID). For large scale farms, technology was developed to solve the problem of automated data acquisition, using Global Positioning System [11] (GPS), satellite imagery, and advanced sensors. In this type of crop production there are solutions allowing the mapping between performed task in space/time to data about the task itself, such as crop's yield or amount of fertilizer applied.

1.1. Agricultural Production Models

Precision agriculture systems [14], being capable of gathering a deeply rooted data from the agricultural fields are the enablers to more sophisticated modeling. The Agricultural Production Model and the Production Process decomposition are presented in Fig. 1 which are the focus of this dissertation. To explore the full potential of agricultural models it needs to be captured a big set of information in each step of the production process. Planning market analysis, variety analysis, gather previous data about the crop [15], Production Preparation buy seeds/plants, buy pesticides/fertilizers, manage workers and machinery, Production Process from installing the crop to harvesting and getting the final product, Production Chain Management managing the events from the production process, Supply Chain integration with the product supply chain. The first layer of the model represents the procedures that farmers usually perform when they have an agricultural business. Agricultural

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business management is typically based on subsets or on the whole set represented in the first layer. Agricultural data is also moving across each model's step, with farmers having every piece of information at their entire disposal when it is needed. Having an iterative model can help those willing to find trends from crop seasons. For instance, if farmers find that a limited area in the field is identified to be less productive they might counter the problem with different fertilizers or irrigation systems [9].

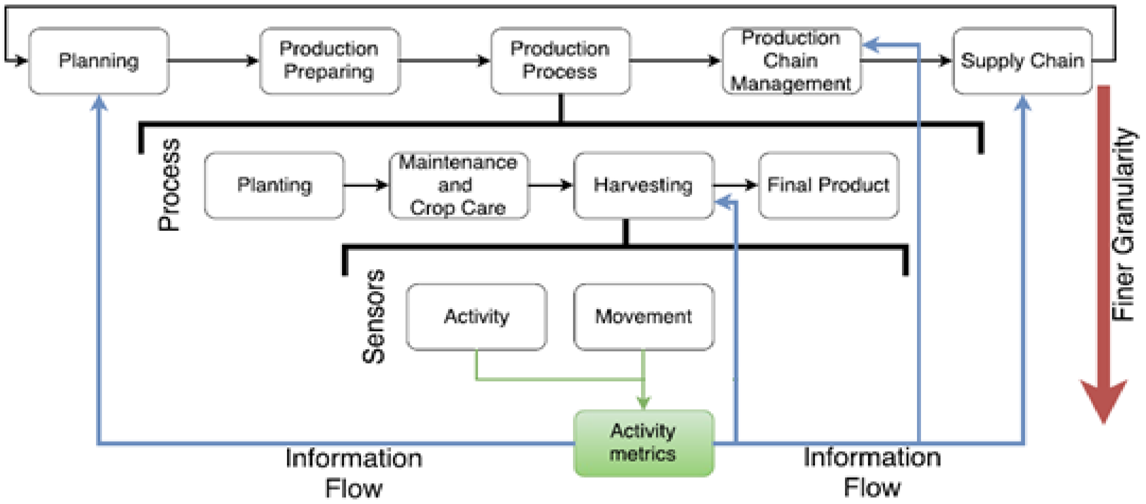

Fig. 1. Agricultural Production Model

where it is typically studied the market, with the focus on production costs analysis, installation costs analysis, choice of plant varieties and gathering of previous data about the crop. Following the planning step, farmers need to create an infrastructure to assist in the production phase. Production preparation is about buying seeds or plants, buying pesticides and fertilizers, hire and manage workers and to manage the farm's machinery, and other resources needed to produce agricultural goods.

1.2 Production Process

Farmers intend to monitor workers in order to obtain a more detailed view about what is being done in the field with agricultural activities. In farms that are more dependent on human labour, workforce monitoring [4] is deeply connected with the production process, enabling a data capturing mechanism that previously was only available at heavily mechanized farms. Every of those steps have human actions that need to be monitored, which is the main focus of workforce monitoring systems. Monitoring other activities such as manual fertilizing will also add value to the production management. In this case it can be possible to detect irregular applications of fertilizer which can be dangerous to crops by analyzing worker's location during the activity. As the whole production process is monitored, farmers can track and trace crop's growth and detect anomalies. Having all the activities monitored enables farmers to foresee problems in the crop and to overcome agricultural variability issues. The agricultural variability, besides from being associated with soil [12] and climate it is also tied with human decisions and behavior. In this way, to monitor worker activities allows a deeper control at crop affecting variations, a procedure considered in the Production Chain Management phase.

1.3 Irrigation Monitor and Control

Irrigation management systems are typically based on Wireless Sensor Networks (WSNs) and provide a user interface to show information about field water resources, to the agriculture expert. Many researchers developed water management solutions and studied the benefits they introduce to precision agriculture. An automated irrigation system (shown in Fig. 2) consists of a distributed WSN, a gateway and a remote web server. This system was intended to demonstrate how an automatic irrigation system can be used to reduce water consumption. Each network node was composed of both temperature and soil-moisture sensors, a radio modem ZigBee, rechargeable batteries, and a photovoltaic cell. These nodes were deployed at ground level, near the plant roots, in order to measure soil-moistureand temperature levels. A gateway is used to automate the activation of irrigation when the thresholds of moisture and temperature are reached. It is also used to communicate with the sensor nodes using ZigBee and with the remote server [23] using mobile cellular data network, based on GPRS and GSM. The authors of this article point out that in some rural places there might be weak mobile network signal.

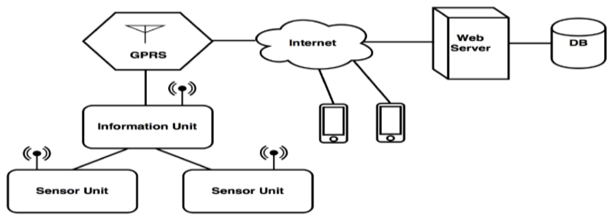

Fig. 2. System overview of automated irrigation system

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using a WSN and a GPRS module

The remote server is used to store all the information, providing as well a graphical application that enables sensor data monitoring and irrigation schemes programming. The implementation of the described system was deployed to a sage crop and allowed a water usage optimization with 60% and 90% savings compared to a traditional water irrigation system in the performed experiments. Kim et. al explored the feasibility of a fine grained irrigation system [24] using a WSN, to more precisely irrigate the field using water only where it is really needed, which is called site specific irrigation, also known as variable rate irrigation. When using this irrigation method, data about both soil and atmosphere parameters like moisture, temperature and humidity are needed. In order to do that, the authors mounted five in-field sensing stations across the field, periodically sending local sensed information a base station computer. With distance, data rate, compatibility and cost in mind it was decided to make use of the Bluetooth protocol to perform communications between the sensing stations and the base station machine, leaving behind ZigBee and other license-free radio frequency transmission protocols.

2. Smart Agriculture

2.1 Pest Control

To increase crop quality and productivity, farmers also are concerned about pest monitoring and control. To prevent the occurrence of pests in crops it is important to detect relevant climate events that can lead to pest development. One way to monitor climate data is through the use of WSNs with temperature, humidity and light sensors. In the presence of data that predicts favorable conditions to pest development, farmers have a better chance to prevent that occurrence, making use of pesticides and other pest control techniques. However, it is not always possible to prevent the occurrence of pests, so there are also systems to detect the presence of those organisms in the crop.

2.2 Harvesting

To further improve productivity, sensors are also applied to a diversity of agricultural machines, such as tractors, harvesters or spraying machines, collecting data about performed tasks and exchanging information with base stations or other machines. It is typical to have integrated GPS which can be associated with variable rate management technology and also yield measuring sensors that can associate harvested product with the area of the field where it was collected. Such systems improve management in large fields making use of several network nodes communicating between them to collect more valuable data. Robots [5] can be used to help with improving grape composition and wine quality. Toru Torii researched autonomous agriculture vehicles in Japan, and the sensors they use to get information from the field.

2.3 Integrated Precision Agriculture Systems

This system has a high-quality wine monitoring system aiming to help wine producers to gather the environment conditions in both the cellar and the vineyard. During the growing season it is important to monitor some parameters that are extremely valuable to the enologist. Measuring soil moisture, soil temperature and air humidity can lead to better decisions applied to the vineyard resulting in grapes with better quality for wine. To collect this information, a WSN was deployed to the vineyard and each node had light, temperature and relative humidity sensors.

3. Experimental Results

3.1 GPS Assessment

GPS is the most used technology to track people and object positioning outdoors, a feature supported by the portability and sturdiness of its receivers. Our goal is to use a Smartphone as a GPS receiver to monitor workers' positions in the field, and since GPS receivers embedded in Smartphones have low quality clocks, the average positioning error is high when compared to dedicated GPS receiving devices.

Fig. 3 (a) First Test - Traditional Olive Orchard - Image captured with Google Maps service

Fig. 3 (b) Second Test - Traditional Olive Orchard - Image captured with Google Maps service

GPS receivers have been used in the past in Precision Agriculture systems such as machinery control, worker guidance or registry of the events happening in the farm. However, the vast majority of those systems are used in open clear sky, where the receivers have optimal conditions to capture signals. In those circumstances the average location error usually varies in about 5 to 10 meters from the real position according to our tests.

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This system has the goal to locate workers in specialized crops such as olive orchards, consequently we have to take into account the problem of signal attenuation caused by the presence of trees. When farmers want to know the exact worker position where a single agricultural activity was performed (i.e. was this single tree pruned?), it is necessary to have an accuracy to detect workers that does not mislead farmers into thinking that the activity was done in a different tree in another row.

3.2 Tests

In the first test, presented in Fig. 3 (a), the smartphone operator walked along a row of 12 olive trees where it was verified that the number of available satellites dropped from 20 to 15 when the receiver got close to a tree. The path captured with the application was very similar to the real path taken by the operator. In this test there were no significant distortions on the captured data points. In the second test, Fig. 3(b) it was analyzed the GPS module capacity to capture GPS signals when the operator walks under the trees crowns simulating agricultural activities such as olive harvesting. When the smartphone operator started the harvesting simulation the GPS module started capturing erroneous positions, which sometimes were under trees in the same row.

4. Methodology

Even though there are many applications which use internet of things [6, 7, 16, 17, 20, 21]; the main application of internet of things is smart agriculture. The world population is increasing and it reaches 9.6 billion by 2050. From this point, an issue arises. How this much population is going to be feed? IoT technologies are used to predict the weather conditions, climate change and environmental changes which can be helpful for the rising of crops. This can be named as smart farming which is a hi-tech system that can be used to grow crops. In the smart farming, a system which contains of sensors is built for monitoring the crop field. The sensors are used to predict the light, humidity, temperature and soil moisture. Very importantly, the sensors are used to automate the irrigation system. The farmers can monitor the crop field from anywhere. The smart agriculture is used to control the internal processes of crop field and avoids lower production risks. In agriculture, IoT monitors vehicle tracking, cattle monitoring, food storage and other farm operations (shown in Fig. 4). Precision farming using IoT helps to make the farming procedure more accurate and controlled for growing livestock and crops. Agriculture drones are used to monitor the crop health. Livestock monitoring using IoT is used to identify the health condition of the livestock. It can be used to identify whether any animals are sick and suffering from disease. So that other animals can be prevented from the disease. The main applications of IoT in agriculture are soil moisture sensing, controlled water usage for optimal plant growth, determine the fertilizer usage, finding the optimal time to plant/harvest and reporting the weather conditions.

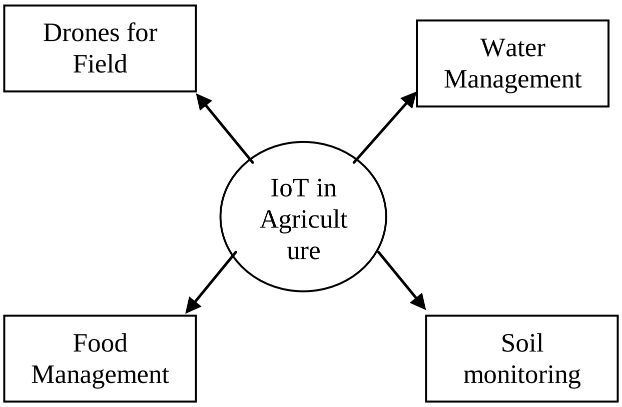

Fig. 4. Applications of IoT in Agriculture

4.1 Proposed Framework

The proposed framework is shown in Fig. 5 and performance evaluation of the proposed framework is given in Fig. 6 – Fig. 13. The Internet of Things (IoT) has the capability to transform the world we live in. Numerous sensor-based intelligent systems are constantly being developed and implemented in almost all industries to buildmore-efficient industries, connected cars, and smarter cities. However, the application of technology like IoT in agriculture could have the greatest impact. In this research work, the research methodology clearly outlines the proposed system to utilize the IoT sensor for input gathering from the fields. The sensors planted in the fields provide various attributes regarding the agriculture scenario such as humidity, soil type, temperature, mineral contents etc. These data are being collected in real-time and these are streamed and sent to the cloud in regular intervals of time. The streamed data follow a proposed pipeline including various data analytics operations. The research work promotes the use of IoT sensors to collect and reciprocate the results with the machine learning algorithm which is processed over the cloud. The real time input data is first processed in the local processing unit in which the stream processing is made and carries out the tasks such as data transformation such as construction and integration. The data transformation helps to convert the data into readable format in which data analytics can be performed. The proposed algorithm is run on the system which results in better accurate description of the soil and provides insights to the farmers with Interactive Computer based system that will suggest the farmers in making decisions such as waste reduction, enhancing the productivity and the type of fertilizer to be used. Thus making predictive decision making that will enhance the farming and support the agriculture in mass numbers. As a result of the decisions taken from the proposed algorithm, the IoT actuators can make necessary requirements that are required for the crops to grow healthy and make the soil fertile.

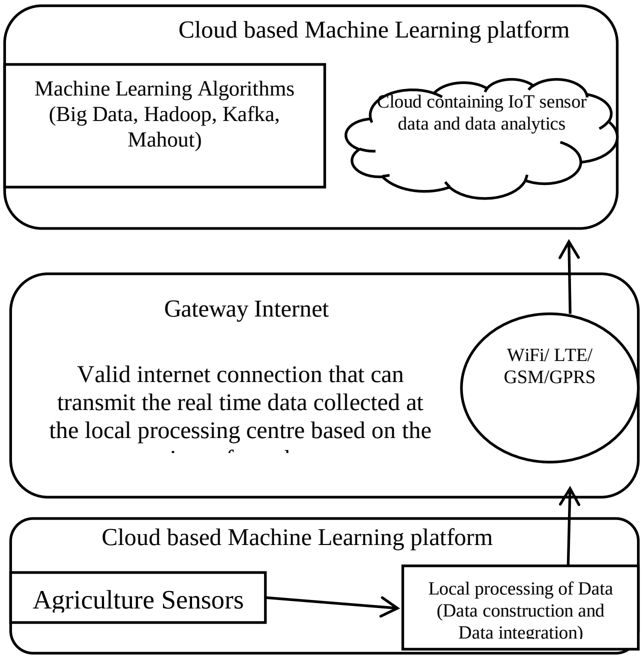

Fig. 5. Proposed Framework for Smart Precision Agriculture

4.2 Performance Analysis

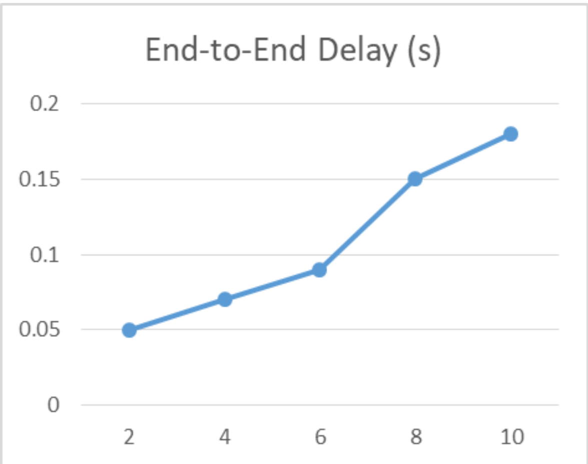

Fig. 6. Traffic Load (pkts/s) vs End-to-End Delay

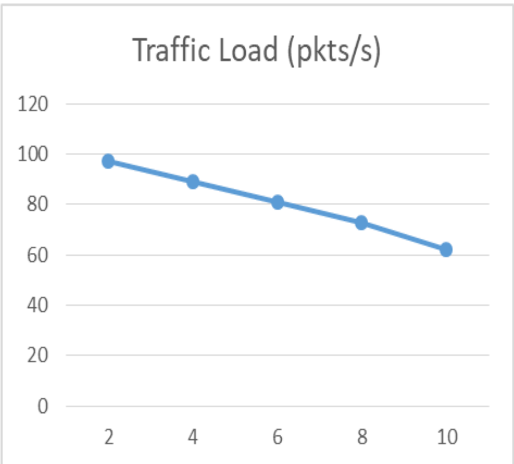

Fig. 7. Packet Delivery Ratio (%) vs Traffic Load

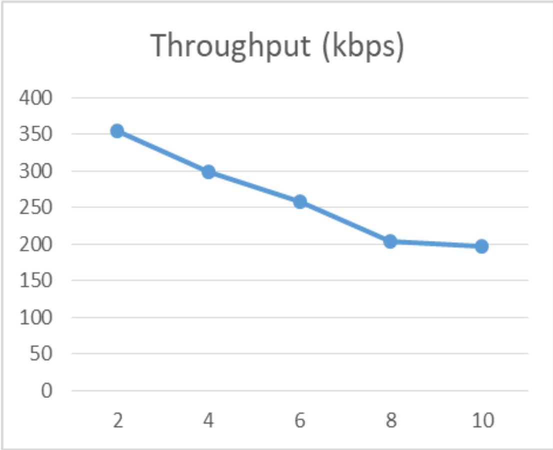

Fig. 8. Traffic Load (pkts/s) vs Throughput

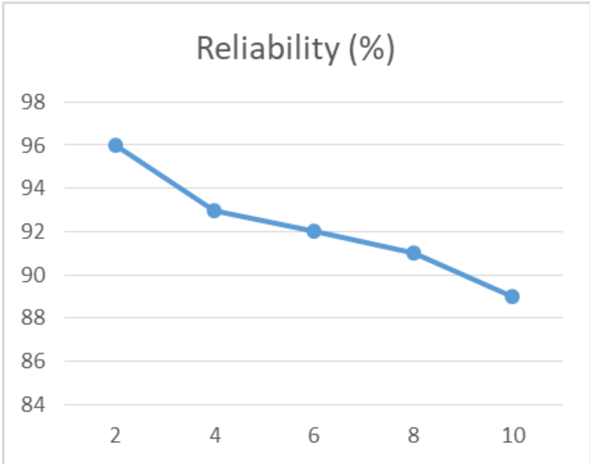

Fig. 9. Traffic Load (pkts/s) vs Reliability

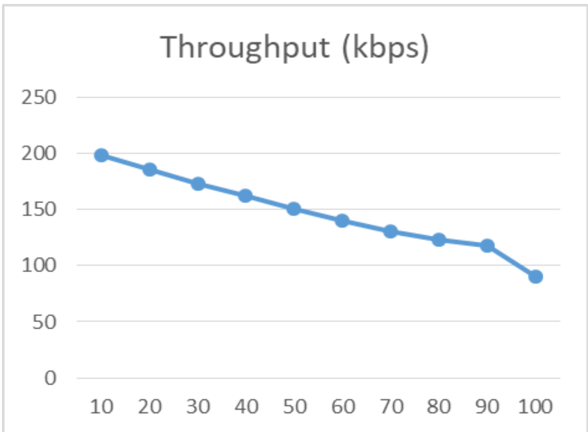

Fig. 10. Number of Nodes vs Throughput (kbps)

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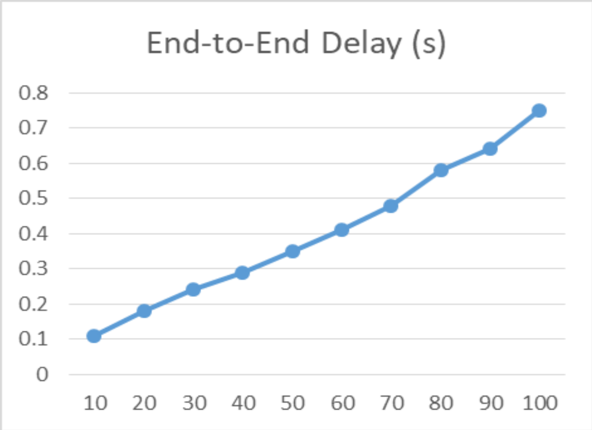

Fig. 11. Number of Nodes vs End-to-End Delay (s)

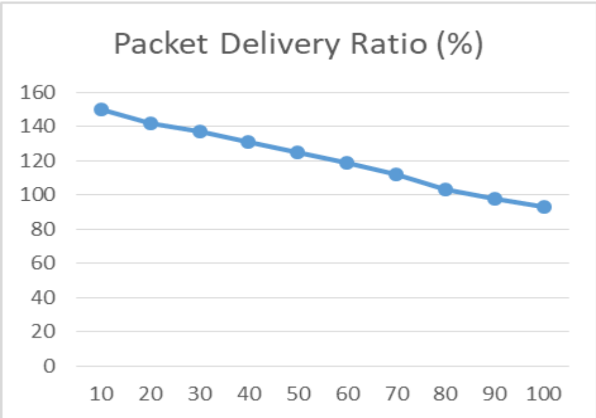

Fig. 12. Number of Nodes vs Packet Delivery Ratio (%)

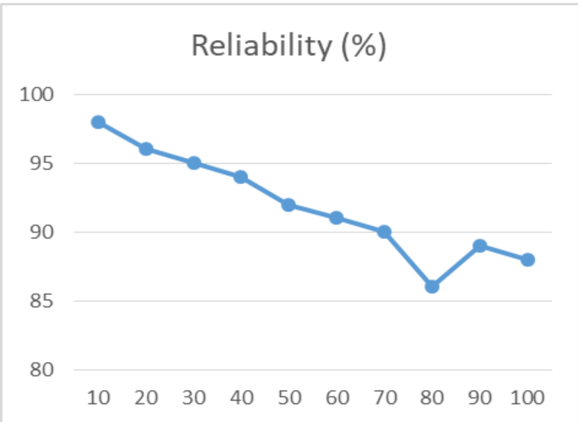

Fig. 13. Number of Nodes vs Reliability (%)

5. Conclusion

The agricultural business is evolving with a focus on productivity and efficiency and farmers want to have a deeper control on the quality of their products. This led to the creation of Agricultural Production Models that use data captured in the farm to reduce costs and maximize productivity while forecasting the future of agricultural businesses. To feed the agricultural models, new data needs to be captured in all the agricultural production process steps, including the activities that in smaller or less mechanized farms need to be done by hand. The need for a global understating about what is happening with the crop at every moment led farmers to install new technology in their fields that monitor soil, weather and pests during crop's life cycle. Other farmers have the activities held in the field monitored by capturing machinery location and productivity data. The available solutions are usually not adapted to smaller farms or those with specialty crops where a large percentage of the work is done by hand. The proposed system in this paper produces good results in terms of end-to-end delay, reliability and packet delivery ratio.

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