Scholars Journal of Agriculture and Veterinary Sciences **e-ISSN 2348–1854**
Sch J Agric Vet Sci 2017; 4(1):18-23 **p-ISSN 2348–8883**

(An International Publisher for Academic and Scientific Resources) DOI: 10.36347/sjavs.2017.v04i01.004

Low Power Wide Area Network (LPWAN) and Internet of Things Adaptation in Agricultural Machinery

Cagdas Civelek
Agricultural Machinery and Technologies Engineering Department, Faculty of Agriculture, Çukurova University, Adana, Turkey

***Corresponding Author**
Name: Cagdas Civelek
Email: cagdascivelek@gmail.com

Abstract: By the 20th century developments in electronics, computers, robotics and internet technology have accelerated more and now these disciplines are more cross related than ever before. Applications of these technologies have spread wide in different areas like transportation, construction, aviation, space, etc. Since agricultural areas are getting narrow, agricultural practices should be made more intensive and precisely where these technologies application to be penetrated into agriculture very fast. Also these new technologies have brought a term called information technology (IT) which makes these technologies usage meaningful. For making high yield production computers, electronics, internet and information technology should be used together. One of the new eras that internet technology has brought is Internet of Things (IoT) which is a useful tool for agriculture. Wireless communication systems are getting more important since a thing should have an ability to connect to internet and become an internet thing. There are lots of wireless communication systems still being used but, reliability, security, installation and operating costs are becoming more important now. As LPWAN (low power wide area network) has these capabilities and more, it has a potential and coming forward to be used in agriculture.
Keywords: Agriculture, Internet of Things, LoRaWAN, LPWAN, Tractor

INTRODUCTION

Today world population 7.3 billion and it is expected to reach 9.7 billion by the year of 2050 and 11.2 billion by the year of 2100 [1]. Producing food to feed that much of people is getting more difficult since agricultural areas getting very narrow and soil has restricted capacity for high amount of agricultural product and so many variables should be taken into account like weather and soil conditions, tractors and mechanization equipment, management, farm economics and so on. Each topic has so many sub variables inside in and from that point so as to achieve high yield agricultural production new technologies are needed to be implemented into agricultural production. Since the world population rise has been seen as a disadvantage on agricultural production, researches have started to find out solutions to make agricultural production more using remaining sources which brought us a term called "precision agriculture" or "precision farming" in 1980s.

At first it was understood that the precision agriculture was only about temporal and spatial variation so that the first real application of it was the on-the-go fertilizer which was used to fertilize soil in parts variably [2]. In 1990s with GPS' have become more common and integrated into precision agriculture very fast thus, with the usage of sensors precision agriculture has become more complicated than ever before. With the implementation of different types of sensors, the precision agriculture has become more information based system that the gathered data should be analysed and evaluated to make a decision. For that reason decision support systems (DSS) have been developed and become very popular by using computers [3-5]. At first these programs have been developed as an executable file [4, 5], but nowadays since development of internet technology and mobile devices, programs have been developing as web-based DSS [3]. For developing reliable and effective DSS', real information data should be collected and stored. Therefore sensors and data logging systems should be used to collect data, different types of data transfer systems should be used to transfer gathered data where it is going to be analysed in and different types of database systems and software interfaces should be used to analyse stored data. Today's internet technology is getting more based on cloud systems which means that can be accessible from any device and anywhere without carrying any data storing devices with you.

AGRICULTURE AND ITS SENSORS

Since today's agriculture is more based on data, several sensors are being used. Agricultural activities can be divided into several parts starting from soil preparing, seeding, fertilizing, harvesting, crop

processing, packaging and transferring. For these activities different types of machines are used in different periods of the production. As importance of the agricultural data has risen, researchers have started to develop and use different types of sensors to collect real data. These sensors have been used to measure soil parameters like soil moisture, soil temperature and conductivity, weather parameters like temperature, moisture and insolation and tractor data like speed, slip, torque and fuel consumption and etc.

However collecting data from sensors are easier now, thanks to the microprocessors, there are still several obstacles to collect data from sensors. These obstacles can be concluded as;

- Uneasy to deploy sensors in agricultural areas,
- Most of the sensors are still human depended that one has to get to the sensor from its place and save data to a device (hard disc, flash memory),
- Most of the sensors do not have a memory itself to record data so, they should be connected to a special data logger,
- Sensors are generally electricity dependent to work on thus, batteries should be changed periodically,
- It is not possible to get data at the same time from different sensors which are far away from each other unless sensors have wireless connection capabilities,
- Wireless sensors are very complicated, limited communication range and expensive to set up and collect data.

WIRELESS COMMUNICATION TECHNOLOGIES FOR SENSORS

Today's precision agriculture is forcing farmers to use GPS and sensor technologies along with computer technology and systems. For making precision agriculture integrated into farm, multiple sensor nodes should be connected together and send acquired data to main database station where it should be saved on to the database and used in DSS. Wireless communication technologies can be divided as long range and short range communications. Not every communication method is suitable for agriculture thus, today mostly used communication technologies are Cellular Network, WiMAX and LPWAN (LoRaWAN) for long-range communications (Table 1); WiFi, Bluetooth and RFID for short-range communications (Table 2). However it is a short or long range, these technologies' energy consumption is still very high and transmission power gets lower in places where there are lots of buildings and structures except for LPWAN. Since LPWAN has very low energy consumption, higher transmission power, easy to set up and exception of other obstacles, it differs from other communication methods.

Cellular Network

Cellular network is a network type where at least one base station covers a cell and whole cells joining together becomes coverage area. Voice or data can be transmitted over the base station using compatible devices. Most known type of cellular network is mobile phone network that is mostly used one today. Four different types of frequencies 450, 950, 1800 and 1900 used for data transmitting and the coverage radius of each cell by frequency are 48.9, 26.9, 14 and 12 kilometers respectively. There are different types of cellular network standards 1G, 2G, 3G and 4G.

WiMAX

WiMAX is a wireless communication method based on IEE 802.16 standards. It can be used for data transferring, internet communications, portable mobile broadband connectivity, smart grids and metering. WiMAX can operate in licensed and unlicensed frequencies from 2 to 60 GHz, but using unlicensed frequencies may result in interference with other devices. Besides WiMAX has some advantages like long range coverage about 50 km, it is not very popular like Wi-Fi. For direct connections user end devices should be in the range of WiMAX access point unlike Wi-Fi. Since LTE has up to 100 Mbits download speeds whereas WiMAX has 30-40 Mbits, mobile phone producers left putting WiMAX technology into their phones.

LoRaWAN (LPWAN)

LoRaWAN is a new technology of wireless communication for long distances which uses low power wide area network technology [6]. With this technology it is possible to cover very long range area to send data. For this technology the coverage distance depends on topography of the area. This technology comes with the advantage of low power consumption, low cost, easy positioning and free of licence. It uses free communication band between 867-869 MHz in Europe, 902-928 MHz for America. As a result of using under gigahertz frequencies it is less unhealthy than other connection types. The data rates vary from 250 bps to 5.5 kbps and it has an unlimited message number per day. The biggest advantage that has been brought by this technology is that the devices sending data using uses very low power that can last in 10 years. That means with this technology it is possible to put a sensor and leave it without changing battery for a long time.

Table 1: Differences of long-range communication technologies for agricultural applications

	Cellular Network	WiMAX	LoRaWAN
Standard	3GPP	IEEE 802.16	IEEE 802.15.4
Frequency Band	850, 900, 1900, 2100 MHz	2-11 GHz 10-60 GHz	863-870 Mhz (EU) 902-928 MHz (US)
Range	Base station coverage area	50 km	Urban (3-6 km) Rural (15 km)
Energy Consumption	High	Medium-high	Low
Cost	High (100$)	High (80$)	Low (20$)

Short-range communication technologies are used for communication between a sensor and the long-range communication end node. Since long range communications' hardware is more expensive and hard to build up, short communication hardware devices have an advantage since they are cheaper, smaller and easier to set up.

WiFi

WiFi is a wireless Local Area Network using 2.4 GHz UHF and 5 GHz SHF ISM frequencies which enable electronic devices to connect to network. So many electronic devices like personal computers, tablets, mobile phones and etc. are using this connection type today. The main device creates local area network is called access point and it has a very small coverage area that is 70 meters for indoor operations and 230 meters for outdoor operations which is very limited for critical operations like gathering data from agricultural sensors on land.

Bluetooth

Bluetooth is a wireless communication standard for data transmission in short distances. It uses UHF radio waves in the ISM band from 2.4 to 2.485 GHz. Bluetooth equipped devices are mostly consumer electronic devices like mobile phones, tablets, PCs and so on. From the beginning of the Bluetooth technology it has been changed from Version 1 to 5. Today mostly used version of Bluetooth is 4, also known as Bluetooth-LE, since its power consumption is very low. Bluetooth data transmission range is from 1 to 100 meters based on power class type which is from 1 to 4.

RFID (Radio frequency identification)

RFID is a tag that uses electromagnetic fields to be identified based on assigned information to it. It can be active which has a battery on it and sends signals from meters away from tag reader or passive that has to be come close with tag reader. RFID can be attached in anywhere like clothes, cars, drugs, passports, transportation payments and in agriculture even on cows to measure milk production. RFID's has two main components, one of them is a circuit to store and process information, modulate signal that is sent from reader and an antenna for receiving and transmitting signal. RFID tags uses frequencies from 120 kHz to 10 GHz but, there are regulations an RFID in which regulation should be used in different types of applications. Based on used frequency, RFID's data speed and communication range changes from 10 cm to 200 meters.

Table 2: Main differences in short-range communication technologies for agriculture

	WiFi	Bluetooth	RFID
Standard	IEEE 802.11n-2009	IEEE 802.15.1	ISO/IEC 15693
Frequency Band	2.4 GHz 5 GHz	2.4-2.485 GHz	2.45-5.8 GHz
Range	70 meters (indoor) 230 meters (outdoor)	5-10 meters	1-2 meters
Data Speed	72 Mbit/s	54 Mbit/s	640 kbit/s
Maximum Connection Nodes	11 (Hardware depended)	7	(Hardware Depended)
Energy Consumption	High	Low	Low
Cost	High	Medium	Low

Rising importance of the precision agriculture has been forcing to get GPS data to match sensor data so as to collected data is to be meaningful and make decisions. Communication technologies along with proper sensor and GPS can be used in agricultural activities listed below;

- Precision irrigation
- Variable-rate fertilization
- Machinery management
- Greenhouse control
- Traceability systems
- Animal identification
- Food packaging
- Transportation

INTERNET OF THINGS AND CONNECTED AGRICULTURE

Internet of things is a pool of biologic or non-biologic things which have ability to connect internet to

send, receive data and execute functions and communicate with other things. That means even if a living thing is equipped with a hardware which connects it to the internet and makes it possible to send and receive data is capable of being an internet thing. Although IoT is a new era, it is spreading wide very fast and it is estimated that there will be 50 billion internet objects in 2020 [7].

There are still lots of things are still waiting to be connected to the internet. With the development of devices to enable this, the number of internet of things will be much more. Application areas of the IoT are very wide from health to transportation, from energy to security and from environment to agriculture. In cities it can be used for smart parking, waste management and traffic management; in health it can be used for patient monitoring in hospitals or hearth attack monitoring for risky people. Besides these, IoT has a very huge application area in agriculture and it is predicted that agriculture will be the biggest area for IoT. IoT device installations in agriculture is expected to increase from 30 million in 2015 to 75 million in 2020 [8]. In agriculture IoT can be used in tractor performance and machinery monitoring, farm area, soil and weather monitoring, food tracking, animal health monitoring and so on. Since importance of precision farming is growing and there are some technological obstacles to enable precision farming, IoT technology seems to be the best one for getting over these obstacles.

Since IoT technology is still developing, there are some obstacles for it, too. These can be concluded as unique name availability for IoT devices, wireless communication types, sensor energy and security. Today devices that connect to the internet use a special number called IP (Internet Protocol) addresses version 4 which uses 32-bit addresses. But, because of the growing of internet IPv4 numbers have ended up in 2011. IPv6 which is the 6th version of IP address system will be the solution for this situation which has uses 128-bit addresses. Also IPv6 enables devices smart objects assign own IP addresses.

Other difficulty in enabling IoT is the wireless communication technologies to be used. Since smart devices has to communicate with other devices in short range or long range to send and receive data, there has to be one type of communication technology to be used. The most common obstacles in long range communication technologies are high initial investment costs, limited number of connections and high prices for end-users.

Sensor energy consumption is also a major problem for IoT. While IoT covering more area of the world, there will be much more sensors will be used to sense and get data. For agricultural activities some of these sensors will have to be left in farm area, for example to measure soil temperature and humidity, and there will be some difficulties in finding these sensors and changing batteries. For that reason, sensors that will be used in harsh conditions and with difficulties in replacing batteries should have to be designed to use solar energy or with low-power consumption. For long range communications, LoRaWAN like technologies with low operating costs should be used. For short range communications data transmission periods should be longer and sensors with Bluetooth 4.0 or higher hardware which has low-power consumption should be developed.

Internet is a huge network whereas web is a tool for accessing information from internet. With the development IoT, a new era Web of Things came along of which internet things and their services are addressed through URLs and queried using HTTP (Hyper-Text Transfer Protocol). Thus, servers and internet of things can communicate using web services like XML (Extensible Markup Language) or JSON (Java Script Object Notation) which can be understood not only by machines but also by human. These ways of communication make storing data on servers and showing stored data in any visual type or on any device is very easy.

SAMPLE APPLICATION OF LORAWAN IN AGRICULTURAL MACHINERY

One of a sample application of tractor data acquisition system using LoRaWAN technology has been developed (Fig. 1).

The acquisition system shown in Fig.1 is consisted of 3 main hardware system;

1. Tractor performance monitoring system: This system has been built up for metering tractor performance. There are 5 main components of this system.
   a. Torque meter
   b. Pull gauges
   c. Fuel flow meter
   d. Radar speed sensor
   e. Data logger
2. Beacon reader: The main task of this component is to detect if there is a machine attached to or detached from the tractor and this component detects beacons which are small tags that are using Bluetooth-LE that has the information according to the connected machine. This component has been placed at the back of the tractor cabin over the mudguard and it is connected to the SkySens [9] modem to send machinery detection data.
3. SkySens Modem: The main purpose of this modem is to send data coming from different components which are defined in no 1 and 2 and transmit them to the base station of LPWAN. This modem also has several sensors and components such as GPS, temperature, air pressure, humidity, light sensor and accelerometer to measure different types of data. Data that is coming from

tractor acquisition system, beacon reader and internal sensors of the modem are combined, converted to a data package and send to the SkySens base station (Fig. 2).

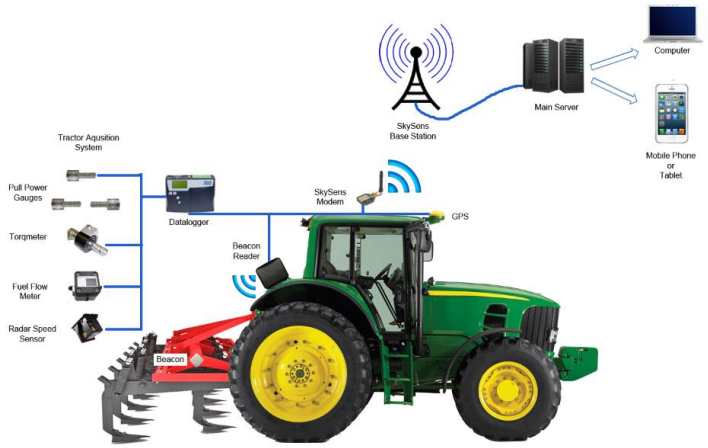

Fig-1: Developed tractor performance measurement and transfer system using LoRaWAN technology

Fig-2: SkySens modem used for transmitting tractor performance data to base station

Other main component of the system is the SkySens base station (Fig. 3) which is using LoRaWAN communication technology. The main purpose of this component is to get data from SkySens modem and send it to the main server by using internet connection which is provided by a small computer that is connected to the internet. After data has been sent by using SkySens base station, it is saved on a database using XML (Extensible Markup Language) which is specially created for this purpose. Using XML enables developers to develop special software, application or web site where any kind of query that is going to be made is independent from database. For the project going on, the developing software is web-based where tractors' position on the ground can be seen on a map and by clicking any of the tractor, its performance data will be able to seen as gauges or scales and also the data will be available to be downloaded. Moreover, developed software will be able to be used on tablets and mobile phones.

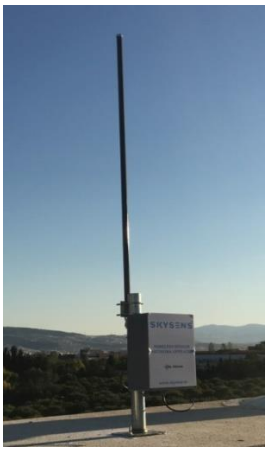

Fig-3: SkySens base station

In the developed system, energy used in data transfer is much less than GSM communication technology. If GSM technology was used, sensors' battery life would have been 1 week. But using LoRaWAN technology, sensors' battery lasts nearly in 5 years. On the other hand, LoRaWAN base station coverage area is 50 times more than a GSM base station (Fig. 4). In other words 50 GSM base stations needed for covering 1 LoRaWAN base station area.

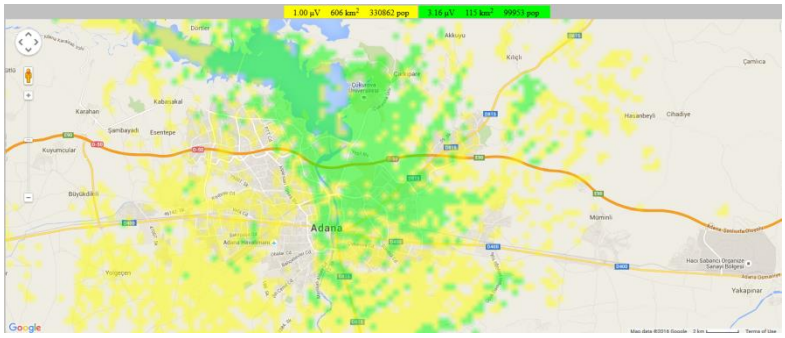

Fig-4: LoRaWAN base station coverage area

DISCUSSION

Internet of things and low power wide area networks are two emerging technologies coming forward as agricultural production has a very narrow way to success. Using internet oriented sensors over ballistic ones have advantages to gather data wirelessly, long-range communication and long-lasting battery advantages. However standard WiFi and GSM connection technologies are being used in agriculture (i.e. greenhouses), LoRaWAN technology coming forward since having long-range coverage, low energy consumption, low operating costs. Combining LoRaWAN and Internet of Things technologies has the potential to cover huge areas than ever before and gather operational data from tractors working in farms cheaper and easier.

CONCLUSION

IoT is getting very popular and lots of devices connecting to internet and getting data is becoming easier. Agriculture as an open factory has a big potential to use sensors and other devices to be connected to internet since it is always very difficult to get data for making decisions and tracking of products and machinery performance data. For IoT applications to be integrated in agriculture even short or long-range communication technology should be chosen properly to get data from long distances, save sensor energy and most important for making it in the cheapest way. In these circumstances LoRaWAN comes along as a new technology that enables IoT to be integrated in agriculture and minimizes obstacles in data transmission.

REFERENCES

1. United Nations, 2015. World Population Prospects: The 2015 Revision. The Department of Economic and Social Affairs of the United Nations. New York. https://esa.un.org/unpd/wpp/publications/files/key_findings_wpp_2015.pdf.
2. Stafford JV. Implementing Precision Agriculture in the 21st Century. Journal of Agricultural Engineering Researches. 2000;6:267-275.
3. Civelek Ç, Say SM. A Web-Based Decision Support System to Select Proper Machinery Size and Tractor Power. Turkish Journal of Agriculture and Forestry. 2016;40:512-525.
4. Zarini RL, Akram A, Alımardanı R, Tabatabaekoloor R. Development Of Decision Support Software For Matching Tractor-Implement System Used On Iranian Farms. American Journal of Engineering Research (AJER). 2013;2(7):86-98.
5. Sahu RK, Raheman H. A Decision Support System on Matching and Field Performance Prediction of Tractor-Implement System. Computers and Electronics in Agriculture. 2008;60:76-86.
6. LoRaWAN Technology. https://www.lora-alliance.org/What-Is-LoRa/Technology
7. Evans D. The Internet of Things. How the Next Evolution of the Internet is Changing Everything, 2011.
8. Meola A, Why IoT, Big Data & Smart Farming is the Future of Agriculture, 2016. http://www.businessinsider.com/internet-of-things-smart-agriculture-2016-10
9. Skysens Technology. http://www.skysens.io/en#technology