Comparative Analysis of Communication Protocols in Agricultural IoT

Sumanta Das
Computer Sc. and Technology.

Dr. B.C.Roy Polytechnic,

Durgapur, India

Email: sumanta.das@bcrec.ac.in

Abstract— **In today's data driven technical world, decisions are made by proper analysis of the real time data obtained from different sensors attached in the premises. The field of agriculture is also not an exception. To process these huge data, they need to be transferred to respective data processing units situated in the same premises or at remote end. In both of the cases, data transfer mechanism is performed by wirelessly interconnected specialized nodes having integrated sensors, controllers, wireless connectivity modules and portable energy sources. These nodes are popularly known as sensor nodes and the arrangement of wirelessly interconnected nodes is called Wireless Sensor Network (WSN). When WSN nodes are connected with processing units and other WSNs at remote end through internet, they constitute a networked ecosystem called Internet of Things (IoT). In this paper, we have attempted to survey the wireless protocols for IoT and their challenges while used in the field of Agriculture. Also a comparative analysis of the protocols has been provided to facilitate the researchers and farmers to choose suitable protocols for their application.**

Keywords—Agricultural IoT, Energy, IoT, protocols, WSN

I. Introduction

In today's data driven world, data obtained from various sensors employed at industrial premises influence the production of food, clothing and shelter for human being. Information obtained from different sources is analyzed to extract the required inference to take decisions. In present day, the decision making job has been made easy by the help machine learning algorithm and artificial intelligence. But gathering of the required data and transmit them without any error over a medium is also a challenging task due to unavailability of suitable network at the remote places. Here, Internet of Things brings the solution to transfer the information from remote areas to the processing hubs situated at well communicated areas. Like all other industrial applications, the internet of things for agriculture is comprised of the tools and components which are to be connected with internet for proper operation. Inclusions of internet of things in agriculture help to monitor control and manage the entire system smoothly. It helps in handling agricultural emergency decisions produced due to climate change and any type of pest attack. In this paper, the present scenario of IoT based agricultural advancement is discussed on the context of communication technologies and the research status on the very topic has been projected. This paper also tries to indicate the gaps in implementing communication protocols that can be attempted to minimize in future attempts.

II. Protocol Surveys

Under the present context of IoT, precise information gathering and transmission of the data has become utmost important to extract the features for decision making. To get the precise data, the sensor technology has been improving day by day by miniaturization in the physical appearance. Whereas wireless sensor network is employed as the most important information transmission technique. The characteristics of different sensor networks makes them suitable based on data rate, distance covered, bandwidth, number of wireless nodes supported, consumption of power, security issues etc. Therefore, the transmission technology must be selected depending upon the requirement and characteristics of farm area.

A. Cellular Communication

Data communication is the backbone of any IoT architecture. Unlike the image data, the data obtained from sensor could be of several bytes in size. Therefore, conventional 2G or 4G communication technology to transmit the sensor data of small size may lead to spend large cost and wastage of bandwidth. The energy consumption of these technologies is also large. It suffers from reliable connectivity issues if the farmland is in a remote place. The satellite communication could be costlier than the previous technology to be implemented in small and medium size farms. Low Power Wide Area Network (LPWA) [1] has showed better prospects as an alternative to existing cellular technology with better energy efficiency. It provides better network coverage than Bluetooth and Zigbee communication and low implementation charge for creating a mesh topology for devices that generates small size data. LPWA suffers significantly due to its cheap hardware design and connectivity issues. Cross technology interference issues have been observed which is hampering beyond the threshold level in quality of service in ISM band. Despite of these limitations, LPWA is good for low bandwidth applications.

B. Wi-Fi

It is a very well known standard and a member of IEEE 802.11 family and mostly used to create wireless local area networks (WLAN). Wi-Fi uses 2.4GHz ultra high frequency for commercial purpose. Some other variants of Wi-Fi uses 5 GHz super high frequency radio band which is again divided into multiple channels and distributed to operate multiple transmitters and receivers[2]. Wi-Fi technology is not suitable to operate in outdoor environment because of loss in signal strength due to absorption. Even in indoor conditions, less number of obstacles, like pillars, walls, home appliances, may produce better signal quality. Line of sight communication range for Wi-Fi under indoor situation is about 20m and in outdoor is nearly 150m. But researchers have found poor longevity of portable sensor nodes using Wi-Fi due to its power hungry nature. Even compared to LoRa node, a Wi-Fi enabled node consumes twice power under same configuration, same environment and same data rate [3]. Although Wi-Fi can be considered as one of the secured protocols that uses Wi-Fi Protected Access (WPA), Wi-Fi protected Access 2 (WPA 2) and Wi-Fi protected Access 3 (WPA 3) [4] security protocols. Maximum number of nodes that can be connected to Wi-Fi network is theoretically 255 [5].

C. Bluetooth Network

A very popular communication standard is used household, known as Bluetooth. It is an IEEE 802.15.1 standard that uses radio waves of 2.4 GHz ISM band to communicate with other Bluetooth devices [6]. The communication range between two Bluetooth devices is quite smaller. It is about 8m-10m. That is why it is sometimes called a personal area network communication protocol. Since the IoT devices mostly runs on limited energy sources, Bluetooth low Energy (BLE) variant or Bluetooth Smart can be used to create and IoT network. This technology uses adaptive frequency hopping technology to reduce energy consumption by minimizing interference with nearby devices [7-8]. Researchers have also successfully implemented a Bluetooth network to monitor ambient light and temperature [9] which and transferred the data for processing at remote end. But the limitation of BLE is it can work with limited number of devices only with star network. Present research work is going on to create a mesh network with a beacon facility to reduce the delay of connection establishment. The delay in connection establishment is found to be more than several hundred mili seconds in real time. Also the data transfer speed for BLE is below 1Mbps [10-11]. In normal Bluetooth protocol the consecutive packet transmission must have 20ms delay to reduce packet loss due to collision and interference which the researchers are trying reduce by implementing Time Division Multiple Access (TDMA) with optimized transmission allocation in BLE [12].

D. ZigBee Network

ZigBee [13] is a global wireless standard for low data rate communication for wireless personal area network. It comes under the IEEE standard 802.15.4 created by ZigBee alliance. The ZigBee standard is proved to be better than BLE in terms of number of nodes to be attached, topology support and distance covered. ZigBee platform supports star, tree, cluster and mesh topology and can be configured into ZigBee coordinator, router or end device. But ZigBee suffers from data loss and lower data rate in harsh weather conditions and during change in operating frequency [14]. Performance quality degrades when link quality in a ZigBee mesh network degrades because of multipath propagation, shadowing and attenuation. Under high density foliage, sensor nodes of a ZigBee network poorly perform. That is why the number of nodes required to be increased in ZigBee network for a dense agricultural filed. The data transfer rate also dependent upon battery voltage when the nodes are running with such limited power sources. The decrease in data rate becomes significant when the node voltage falls below 0.9 volts. Also, it has been observed that the data loss significantly increases when the battery temperature falls below 20 degree Celsius [15].

E. LoRa Network

Long Range WAN also named as LoRa is a new addition in the list of communication protocol used for long range connectivity of nodes and low power consumption. Experiments reveal that the energy consumption of LoRa network is dependent on payload size, transmission interval and spreading factor [16]. Among three variants of LoRa, Class A can reduce energy consumption up to 14 dBm or approximately 25 mW with a fixed payload and minimum spreading factor. LoRa is has gained its popularity because of its ability to penetrate thick wall and better reliability than Bluetooth and Wi-Fi [17]. Because of low data rate ranging from 300 bits per second to 37.5 kilo bits per second, LoRa has limited use in image or video transmission for intrusion detection in agricultural field [18]. Although, experiments have shown that, LoRa can be used for image transmission if the image variation is infrequent over the time to support low bandwidth of the channel [19]. LoRa can be used to create a network with maximum 1000 nodes with minimum interference [20] which makes this protocol to cover very large area without the internet connectivity requirement.

F. SigFox Network

Another variant of LPWAN protocol which is currently getting noticed for creating a long distance and cost effective communication environment is SigFox protocol. This is developed by a group from Labège, France, named as SigFox. This protocol uses a Ultra Narrow Band technology to transfer data at a low data rate. It is found that 40 packets can be sent at a time with a power of budget of maximum 14 dBm. It signifies the energy efficiency of this protocol and hence increases longevity of network by increasing battery life [21]. SigFox can send a packet to three different base locations at a time. It gives this protocol a spatial diversity. The network which is using this protocol is quite interference free and can simultaneously use three channels. SigFox can provide a 30Km – 50Km connectivity range in rural areas, 3Km – 10 Km in urban areas and more than 1000 Km for line of sight communication. SigFox bears a bandwidth of 192 kHz containing a 1920 number of channels [22]. SigFox uses 868 MHz and 902 MHz - 928 MHz bandwidth [23]. But SigFox is found to produce reliable communication with less data loss in static conditions only. In moving conditions of the sensor nodes, the quality of communication becomes poor due to data loss.

We have summarized the discussion and analyzed all these technologies through a comparison table shown in

Table 1.

Table 1: Comparison among different communication technologies

Technology	Channel Bandwidth	Operating frequency band	Max. Data Rate	Topology Support	Security	Energy consumed	Max. No. Of Nodes in a network	Distance range
Wi-Fi	22 MHz	2.4GHz & 5 GHz ISM	11 Mbps	Infrastructure, Ad-Hoc	WEP, WPA, WPA 2, WPA 3	2-20 watts	255 (theoretically)	Indoor 20m, outdoor 150m
Bluetooth	1MHz	2.4GHz ISM	2Mbps	star	AES	10 mW	7-8	10m (approx)
ZigBee	2MHz	2.4GHz (ISM), 902 to 928 MHz, 868 to 868.6 MHz	250kbps	star, mesh, tree & cluster	128-bit AES encryption	10mW-100mW	65000	10-100m (approx)
LoRa	125 kHz, 250 kHz or 500 kHz	169 MHz, 433 MHz, 868 MHz (Europe) and 915 MHz (North America).	37.5 kbps	star	128 bit AES two layer cryptography	25 mW (Approx)	1000 (over single channel)	10 miles (approx.) in rural area
SigFox .	100 Hz	868 MHz (Europe) and 915 MHz (USA)	From 10 to 1000 bps	star	AES	12.6 mW (approx for bidirectional data transfer)	100 (over 360 channel)	30 to 50 km in rural areas and 3 to 10 km in urban areas

III. CONCLUSION AND FUTURE SCOPE

The communication layer which is implemented to prepare an IoT network plays an important role to convey the field data to the data processing layer. The analysis of the data helps to make decisions and generate commands for other layers. Communication layer receives the data from field sensors and interconnects to the data processing units situated far end, through single or multiple communication protocols. Sensor nodes used in WSN propagates the data through routing protocols to multiple nodes connected with the data processing units. During this time, various parameters need to be monitored to transfer the data un-interruptedly. These are Signal-to-Noise ratio (SNR) of the communication channel, interference from other devices, throughput and energy consumption. The nodes in WSN mostly run on limited power sources and the topology of arranging sensor nodes over the terrain of agricultural field must be investigated to minimize the interference and energy consumption. Solar energy could be a better option for powering up the nodes, but the installation cost could be larger. Commercial powering of the nodes will introduce more underground wires and increase complexity of the network. Therefore, to increase the longevity of the network, as well as reduce the cost, a wise selection of network topology based on the terrain is necessary. It will help the farmers to find the number of sensor nodes required in the farm field. Selection of communication protocol with better energy efficiency must be a key factor for increasing the life time of the network. In the present day scenario, IoT have raised the threat level of unauthorized access of nodes. Therefore, secured protocol must be selected to provide a balance among number of nodes in the field, energy consumption, signal to noise ratio to sustain a WSN controlled from remote end. At the present scenario, inclusion of artificial intelligence and machine learning in the network shall be helpful to overcome the forthcoming challenges without human intervention and increase productivity using agricultural IoT.

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