IoT Based Energy-Efficient Data Aggregation Wireless Sensor Network in Agriculture: A Review

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ABSTRACT:
Sensor nodes generate Wireless Sensor Networks (WSNs), these networks have considerable application in the areas of habitat safety, disaster management, surveillance in defense, security & many more areas. WSNs are compact in size, with short battery power & additionally their processing capabilities are low. This restriction of battery power makes them vulnerably faulty. In order to save this limited power, redundant data must be stored inside the sensor node during aggregation which will result in a reduction power dissipation associated with the sending of unnecessary data. By aggregating data, we can control energy consumption by reducing redundancy. Data aggregation is a really effective technique for WSN. In this paper we discuss the aggregation of data and their complex energy-efficient approach used for data aggregation in WSN. This paper highlights the latest innovations in WSNs vital for the research in agricultural domain, further we present their classification & did a comparative analysis of the discussed protocols, the nomenclature of energy saving & harvesting strategies used in agricultural monitoring. Further it discuss the difficulties and drawbacks of WSNs in context of agriculture, The presented comparative study will helpful in increasing number of data processing opportunities available through the Internet of Things (IoT).

Keywords:
Wireless Communication Technology; WSN; Energy-Efficient, Data Aggregation; IoT.
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1. Introduction

The WSN emerged in 1998, from the dream of the Smartdust project which needed sensing and communication skills in the cubic millimeter order. The Sensor Node, which is a basic component of the WSN, consists of the device Sensing, Computing and Wireless Communication. These have been extended to different fields, such as Smart Cities, Smart Buildings and monitoring systems for the climate. Environmental surveillance systems deploy either small-scale nodes or large-scale networks to track natural phenomena in remote areas. This offers solutions which are economically sustainable and effective for a wide range of applications as health tracking, environmental & animal tracking as well as tracking of various defense activities. WSN is a state of the art technology that combines sensor awareness, automation control digital network transmission data storage and information processing. It also uses different protocols to make it possible for IoT to grow faster [1]. The significant technological advancement in field of communication, computing and sensing leads to the development of small, efficient & less power consuming sensor nodes. This led to the realization that in the present times it can cater for several applications of extreme importance leading to a safe and more comfortable life which requires the automation and optimization of different processes based on intelligent physical phenomenon sensing. There are various sensors, processors and RF modules (Radio frequency) for battery-powered WSNs which help them to track a plethora of environments in order of achieving reliable data of the field [2]. Sensor nodes ' capabilities for sensing, storage, processing, and communication have therefore continuously increased. WSNs were used in various applications, including defense forces, agriculture, sports, pharmacy and other industries. The WSN's implementations in agriculture are very advantageous in improving agricultural productivity which in result reduces the farmer's burden to a great extent [3]. Many of the farming practices can be done precisely with the aid of WSNs, resulting in yield production and minimize the agricultural costs. The sensor nodes can be deployed for calculating various soil and atmospheric parameters.

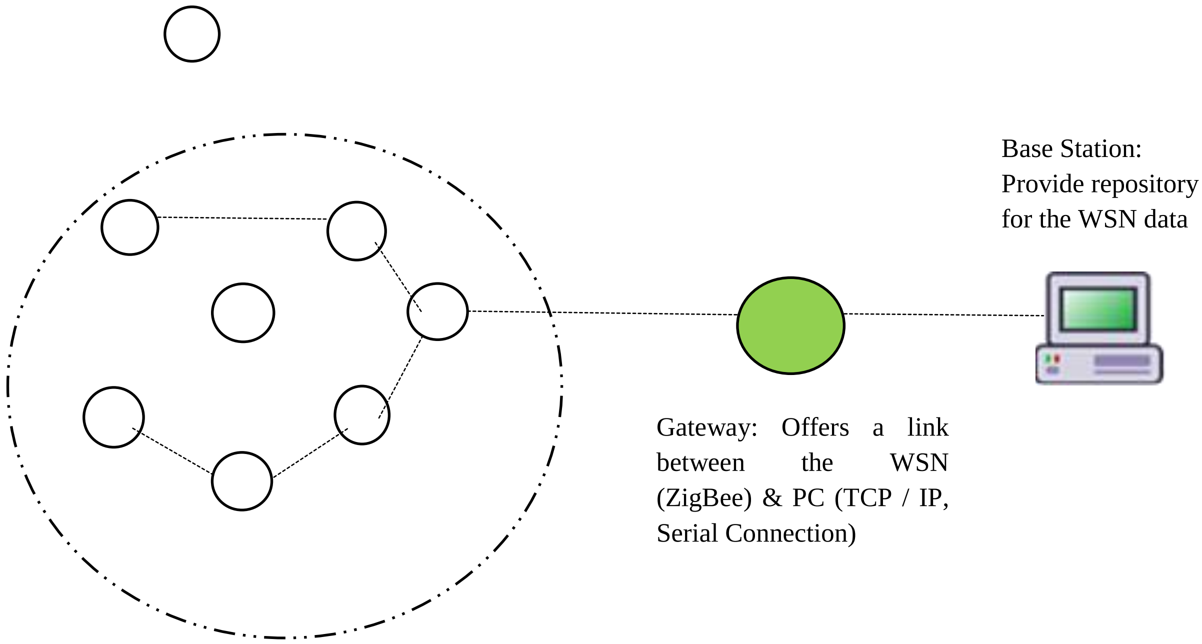

Fig. 1. A Wireless Sensor Network [2].

Precision farming refers to identifying, gathering and transmitting data for decision making at a control station and activating it according to the decision. The distribution of each crop is determined by climatic conditions, soil fertility. Agriculture is difficult, because they are not deterministic. The authors have therefore combined wireless sensor networks (WSN) with modern agro ideas to tackle node failure with a suggested routing mechanism. However, the agricultural implementation of WSNs has been hampered by some challenges, such as deciding optimal deployment [5] schemes, routing protocols, measurement times, energy efficiency, expense, scalability, fault tolerance and communication range. Scattered installation of sensor nodes with a long data collection time, for example, will help extend the life of the network.

Some considerations, however, can challenge the distribution area selection. When the agricultural field encounters several obstacles, as a result of signal attenuation, the contact connection may be compromised or lost. The sensor nodes are supplied from the battery in WSNs and thus prevent the deployment position from connecting to the main supply. In view of their limited battery capacity, it is important for WSNs to [6, 7] reduce power depletion and extend battery life. Although there has been a steady increase in the application of WSNs over the years, battery production not gets advanced at the same rate as a result these networks are primarily constrained due to their battery life. This paper is directed towards energy management among the aforementioned problems and highlights techniques for energy-efficient production that can be used in agriculture.

The base station is connected by unmanned aerial vehicles or drones to meet PA requirements; a mobile data link service may be created for solving the problems such as the elongated distances between the farm& base stations. This link enables the sensor nodes for transmitting data within wide area of agricultural field to the base station. This approach, however, is constrained by WSN's quality of service. For efficient agricultural monitoring, the criteria to be met by implementing a WSN apply to each system's [5] level issues (i.e. unattended service, overall network existence, adaptability or even self-configurability of functionalities and protocols) and end-user needs (i.e. reliability and robustness of communication, user-friendly, scalable and efficient graphical user interfaces). PA (Precision Agriculture) varies in the sense that this method correctly defines differences for traditional farming and relates [4] spatial data for managerial operations. PA includes five phases: (i) compilation of data, (ii) evaluation, (iii) analysis of data, (iv) field precise operation, and (v) evaluation. These may help to make decisions on applications for irrigation, fertilizer, and pesticides. The WSNs can also be used for applications such as detection of intruders, insect detection, prediction of plant disease, fire detection, automation of irrigation, etc. Some of India's current and past agricultural ventures are Agrisens, mKRISHI, Agrosense etc. Certain important issues that can be addressed using WSNs include planting mushrooms and monitoring cattle.

The review is framed as: Section 2 discuss about the WSN protocols, Section 3 provides Performance comparison of protocols for wireless communication. The section 4 highlights the WSN protocols on energy conservation data aggregation, further it deals with the detailed study and comparisons of structured & structure free WSN protocols. Later in section 5 we did a comparative study of precise farming techniques in WSN. The Section 6 offers a review of literature associated with WSN protocols & techniques for agriculture, next section highlights the research gap and lastly in Section 8 we concluded the paper with future prospect of the domain.

2 .The Protocols in Wireless Sensor Network

This segment of our study first discuss about the various protocols and standards used in WSN and later compares them to determine the most suitable system as consumption of power, range of contact [8] & various other parameters, all columns provides these protocol's challenges & solution proposed for them.

Wireless ZigBee protocol

This is counted among the most suited protocols used in various agriculture applications. This protocol is found very suitable for the PA (Precision Agriculture) applications as irrigation control, managing water quality due to its low duty cycle [9], and regulate fertilizers and pesticides control, all requiring cyclic information update. When using XBee Series 2 the Agricultural sensor nodes which communicate with a long distanced (Hundred meter) router or coordinator node based on this technology for indoor (Greenhouses) conditions. Furthermore, ZigBee can reduce contact distance to a maximum of 30 meters. The number of sensor nodes & routers deployed under monitoring will be broadened by covering the whole area of the field. For PA, ZigBee was used in some research such as; ZigBee was used at the base station to study the impact strength of signal on antenna height, node size, and density of the leaf [10, 11]. Even used in a grazing field was focused on cattle location ZigBee WSN. Rather than necessity of additional hardware, for measuring distance, ZigBee depends on the indication of connection quality. At low power consumption and minimum cost, the ZigBee protocol achieves cattle location [31, 32, 34]. The greenhouse climate's key parameters (temperature, humidity, solar radiation andCO_2) are assumed to provide healthy energy-saving plant growth [12] of 22% and water consumption is 33 per cent. The ZigBee and General Packet Radio Service (GPRS)/ Global System Mobile Communication (GSM) systems have been implemented for tracking and regulating greenhouse environment.

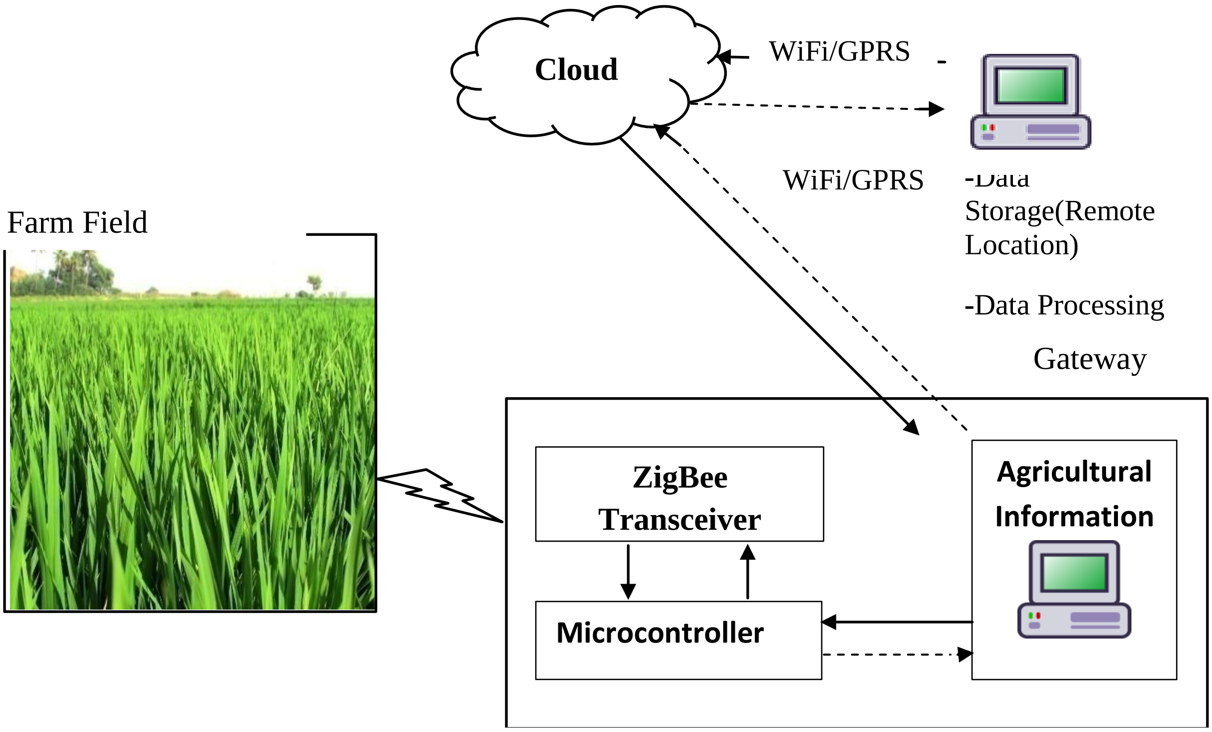

Fig. 2. A general setup of ZigBee protocol in agriculture [10]

Furthermore, the ZigBee wireless protocol was used for animal behavior control (e.g. walking, to sleep, to lie and to stand). It has also been implemented to address the issues of unreliability& high power efficiency of ad-hoc WSN cells [13] which are implemented to save energy by alternating between the active and sleeping states. This allows minimizing consumption of power and boosting the battery life of sensor nodes. Actually this is used in pastures and barns for smart beehives, orange orchards, cow dairy protection surveillance systems, irrigation control, greenhouse and livestock tracking. The ZigBee protocol has been used as a universal standard for WSNs in many agricultural applications due to its [14] reduced consumption of power, cost, self-forming features & a decent contact range.

2.2 Bluetooth (BT) Wireless Protocol

This protocol was used for a small distance up to 10 m to connect mobile and portable devices, such as laptops, for communication. The BT has been used to satisfy multilevel agricultural requirements thanks to its omnipresence and incorporation in most mobile devices. The proposed model for irrigation practices was designed for production boost of the field & to conserve water [15, 16]. The framework for irrigation proposed to collect real-time field information using BT's Wireless Communications Protocol. For BT-based greenhouses many software and hardware have been developed for controlling relative humidity and temperature. Using an integrated control method [17], in greenhouses, the BT module controlled the irrigation system. The outcome of the calculation for water usage & energy based on an optimized control method using BT technology was improved by 90 percent was compared to the conventional (i.e. timer control approach) system. BT based smartphones was used in various agricultural applications [18], for example, Irrigation systems supervision, soil monitoring, weather conditions & fertilizer & pesticide management.

2.3 WiFi Wireless Protocol

This is a wireless technology widely used in compact appliances where tablets, desktops and laptops are included. For indoor and outdoor settings, WiFi has an acceptable contact gap of about 20 m and 100 m respectively [19]. The WiFi expands the various PA framework architectures by linking several system types to ad hoc network.

The wireless technologies like 3G & WiFi were used for estimating agricultural mobile phone applications. It also uses distant accessible services &brief messages to monitor and control secured crops. For agricultural monitoring, a smart WSN with Wi-Fi (IEEE 802.11 g) is suggested, which comprises of three nodes: router, sensor and server [20]. The greenhouse or agricultural field climate conditions are monitored; these include air pressure, water, humidity, soil moisture, light and temperature. WiFi needs a lot of power, communication delay and huge data payload [21,46]. Despite the reality that Wi-Fi protocol avoid data loss by adopting techniques for data redundancy; thus for agricultural applications WiFi technology is not preferable. Therefore, this can’t be used for multi-hope applications & is determined byuser statistics& strength of the signal, rendering it undesirable for WSNs in agriculture [22, 44]. In fact, the WiFi nodes are listening all the time, thereby increasing the power consumption.

2.4 GPRS Based Network

The GPRS (General Packet Radio Service) services for mobiles are based on GSM driven data transmission. It often encounters throughputs, variable delays& the number of users using the same communication channels and facilities is based on this framework. Gutiérrez et al. [23] developed an automated knowledge based crop irrigation network gathered from soil moisture& temperature sensors mounted in the plant root zone using the GPRS module and WSN, and this system was considered cheap and realistic solution to improve quality of water at PA. Soil moisture measurement tested a form of drip irrigation. It also developed a server managing data based prototype along with WSN-GPRS gateway [24]. The interface of WSN-GPRS is used as a WSN-GPRS bridge from which data is forwarded to a data center; Hellín-Navarro et al. [25] it is installed with GPRS for calculating and transmitting various parameters’ information as of soil, plants and atmospheres of different wireless nodes. Wireless nodes have full flexibility, thanks to their independence and use of solar energy. For further research, various sensors can transmit information via tablets, mobile phones or computers via a GPRS network to a remote location. All agricultural sensors interfaced with sensor board to collect information on agriculture. This information is forwarded via the GPRS monitor that is based on a mobile GSM / GPRS network, to the remote server for further revision.

2.5 LoRa (Long Range Radio) Protocol

The LoRa Alliance introduces LoRa protocol as a stack of low-power protocol indoor transmission and broad networking technologies related to the Internet of Things (IoT)[33].The basic architecture of a LoRa network, WAN is composed of end devices of LoRa protocol [26], The gateways of this protocol& a server for its network. The end node of LoRa links to gateways using LoRa for LoRa WAN. LoRa end user gateways send raw LoRa WAN packets, typically 3G or Ethernet, for a high backhaul-based LoRa network server. While LoRa gateways operate with the LoRa network server as bidirectional Adapter or Protocol [36]. It is the role of a server of LoRa network in this situation to interpret the packets of data disseminated by LoRa apps& to generate frames which are returned to the devices. It provides a two-way streak approach which suits machine-to-machine (M2 M) WiFi [38] protocol. It provides a cheap approach for connecting mobile devices or batteries operating on a network or server. This protocol has been used for bee colonies surveillance in rural areas & for establishing remote contact point of bee node with a central server [27]. Soil humidity, temperature and light intensity were also controlled in greenhouses using various sensors, the LoRa wireless protocol and microcontrollers. To create a star network topology, LoRa gateway collects LoRa node's data& can connect the long communication spectrum and high scalability to a cloud server [37].

This is now a days has been used at agricultural projects created by Libelium Company (Zaragoza, Spain),e.g. improvement of production of kiwi using a system for smart irrigation (Italy), climatic controlled tobacco crop production (Italy), conservation of water by smart irrigation methods (Barcelona), controlling vineyards (Spain) and tracking vineyard affecting diseases (Switzerland).

2.6 SigFox Protocol

For applications with low data rates, it is ultra-narrowband cellular wireless network which makes it suitable for IoT communication systems. The SigFox has been used in a range of apps include telecommunications, defense, the Internet, broadband and television [28]. During the summer, this network is used to create a geolocation device for animals in mountain pastures. It suggests a program for assisting farmers to track & increase their cattle production. The value of an energy consumption analysis [29] was particularly outlined when animal herds located at high mountainous areas.

3. Performance based comparative study for WSN protocols

The comparison & discussion of these protocols & technologies on various factors as communication range, complexity of the network, power consumption, cost, data, and other factors were done in table 1. With selecting deployment range the problems posed in agricultural applications may be defined. For example, the transmitted sensor node signal is ameliorated by dividing the region of [30] agriculture with Barriers. Consumption in power with agricultural applications found as further restriction in WSN architecture.

This protocol was designed to work at low power & within proper communication range as well. Consequently, the comparison of power consumption & communication distance in above listed technologies was pictorially shown below in fig. 1 & fig. 2 respectively.

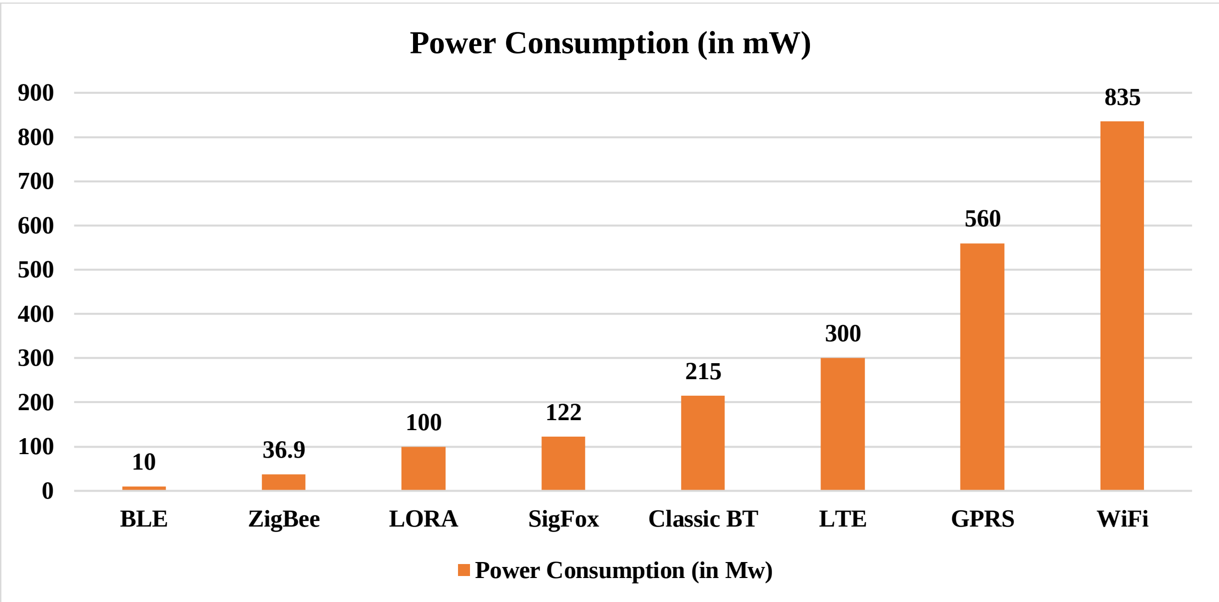

Fig. 3. Comparison of power consumption [68]

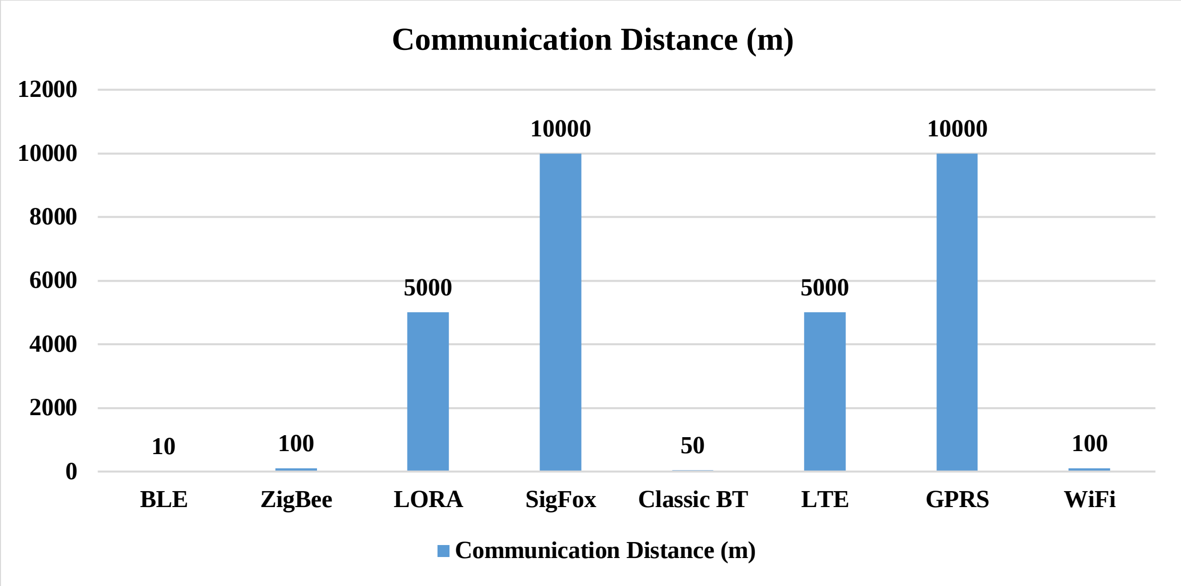

Fig. 4. Comparison of communication Distance [68]

The wireless protocols considered for the case of agricultural applications improve the agricultural area in terms of precision. Using sensors, actuators, processors, wireless transceivers and other information technology, PA will allow manufacturers computerize site-specific Automated Agriculture Management. Precision irrigation is often considered to maximize the efficiency of irrigation because of its potential to control optimal water and irrigation period. In testing, water savings was found 50% & 90% (Using Bluetooth), and of 33% & 90% (Using ZigBee) were obtained for precision systems for irrigation as compared with conventional systems for irrigation [50,51], respectively. By using the wireless protocol ZigBee, animal activities such as lying, standing, feeding, walking and other forms have been tracked. The authors found that compared to results from similar studies, laying down and grazing could be enhanced by 83.5 percent. In a further study which adopted a proposed wireless protocol-dependent algorithm [39, 40], the proposed algorithm for monitoring honey bee and the environmental and agricultural aspects was expected to have an accuracy rate of 95.4 percent. With energy efficiencies of 2.05 to 8.21 per cent & energy savings between 0.71 and 6.46 per cent, ZigBee-based irrigation system automation saved system costs between 1.24 per cent and 6.72 per cent compared to total water user association's costs. The three types of irrigation systems were enabled by the proposed model used in [35] Smartphone interface (GSM & Bluetooth-based). Factors of effectiveness improved by 90 percent in the form of underground drip, and by 85 percent and 75 percent in the forms of high and low pressure overhead sprinklers. Water droplets were penetrated to measure drift and evaporation before surface. The 3 G technology used by Libelium was introduced using Wireless sensor waspmote devices to track Northwest Spain vineyards [57]. Phytosanitary materials, such as fertilizers and fungicides; improved yields increased by 15% & decreased 20% with PA. LoRa deemed to control 90% power output in agricultural environments [8]. The pumping and water costs of the common irrigation systems were cut by 30 per cent in green areas with SigFox [58].

Table 1 Comparative Chart of Various Technologies for Wireless Communication [68]

Parameters	LORA	BLE	ZigBee	GPRS	Wi-Fi	SigFox	Classic BT

Standard	IEEE 802.15.4g	IEEE 802.15.1	IEEE 802.15.4	N / A	IEEE 802.15.4	IEEE 802.15.4 g	IEEE 802.15.1
Spreading	CSSS	FHSS	DSSS	TDMA, DSSS	MC-DSSS , CCK	N/A	FHSS
Channel Bandwidth	<500 KHZ	1 MHZ	2 MHZ	200 KHZ	22 MHZ	<100 HZ	1 MHZ
No. of RF channel	10 in Eu, 8 in US	40	1, 10 & 16	124	11	360	79
Data Rate	50 kbps	1 mbps	20, 40 & 250 kbps	Up to 170 kbps	11-54 & 150 mbps	100 bps	1-3 mbps
Latency	N/A	6 ms	20-30 ms	<1 s	50 ms	N/A	100 ms
Frequency Band	869/ 915 MHZ	2.4 GHZ	869/ 915 MHZ& 2.4 GHZ	900- 1800 MHZ	2.4 GHZ	868/915 MHZ	2.4 GHZ
Modulation Type	GFSK	GMSK	OQPSK / BPSK	8PSK / GMSK	OQPSK / BPSK	GFSK (DL), DBPSK (UL)	DQPSK , DPSK & GPSK
Power consumption in Tx mode	Low 100 mW	Ultra Low 10 Mw	Low 36.9 mW	Medium 560 mW	High 835 mW	Low 122 mW	Medium 215 mW
Communication Range	5 km	10 m	100 m	1-10 km	100 m	10 km	10-50 m
Network Size (nodes per BS)	10,000	Limited by Application	6500	1000	32	1000,000	8
Cost	Low	Low	Low	Medium	High	Low	Low
Security Capability	AES 128 b	64 or 128 bits AES	128 bits AES	GEA, MS SGSN MS HOST	128 bits AES	Encryption not supported	64 or 128 bits AES
Application	Agriculture, Smart grid, Environment & lighting control	WPANs	WPANs, WSNs, Agriculture	AMI, HAN, Demand Response	WLANs	Agriculture, Automotive, buildings &Consumer Electronics	WPANs
Network Topologies	Star or Stars	Star, Bus	P2P, Tree, Star. Mesh	Cellular system	Point to hub	Star	Scatter net
Limitations	Network size (Scalibilit	Short communication	Line of sight (LOS)	Power consumption	High power consumpt	Low data rates	Short communication

	y), Data rate & Message capacity	range	between the sensor node & the coordinator node must be available	problem	ion & long acess time (13.74 s)		range

As per the discussion and the empirical findings provided in Table 1. Small size, low latency (for ZigBee), quick network deployment, accessibility, scalability, reduced power use, network capacity, communication range, LoRa & ZigBee wireless protocols were suited best wireless protocols in applications for agriculture.

The previous survey of various agrarian technologies showed The PA can be accomplished for various wireless protocols in Water saving conditions, animal behavior, performance, power efficiency and system cost reduction [42, 43]. Agriculture can therefore be constructed on the basis of compared with the traditional agricultural systems, agricultural automation systems.

4. WSN Protocols on Energy Conservation Data Aggregation

The WSNs are used primarily for the collecting and analysis of data. The collection of data is characterized as organized integration of sensed multi-sensor data that is eventually sent to base station for processing. Nevertheless, the data produced by adjoining sensor nodes remains superfluous & very interrelated. In these situations, sensor nodes may send data to local collector or specified head, combining all sensor nodes' data residing in its contact & transmitting the succinct packet accessible at base station, reduces all packet transfers and hence saves bandwidth & money which may achieved by aggregating the data. Data aggregation [53] is described as governing concept for integrating data sensed from various sensor nodes with decreased redundancy, &facilitates base station with the aggregate data. The Protocols for data aggregation can be divided in two groups as mentioned in the literature: structured & structure-free [54] as shown in the Fig. below,

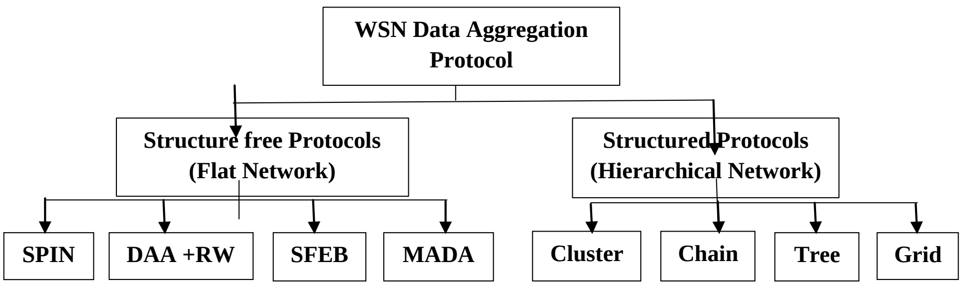

Fig. 5 Energy conservation data aggregation protocols of WSN

WSN Structure Free Protocols for data aggregation

Each sensor node deployed in a particular region for structure-free networks has identical responsibilities & carries the type of battery is almost identical. The data centric routing is used for achieving Data aggregation in such type of networks, where sensor nodes continuously receiving a question message from base station. We define these protocols in Table 3, and outline their key features, pros and cons.

SPIN (Sensor protocol for information via negotiation)

The SPIN protocol family relies on the two basic ideas. Firstly, sensor systems need to communicate with each other on the data they already have and on the data they are planning to obtain for successful operation and energy conservation. Switching sensor data can be a costly network operation, but there is no need to share sensor data. Secondly, network nodes need to monitor and adjust changes in their own energy resources to extend the operating life of the system [55]. SPIN is a structured protocol for disseminating information that is appropriate for WSN based on metadata.

DAA + RW (Data-aware anycast & randomized waiting)

Fan et al suggested a structurally free event-driven reporting scheme (DAA+RW) for data aggregation in WSN. An event detected by sensor node first sends any cast RTS to the base station for determining the next hop node for the transmission of event data. The sensor node that collects this RTS will be the candidate for hop next time. To achieve greater aggregation performance, sensor nodes which have the similar Responding to CTS is given priority for event data for transmission or lies near the base station. Additionally, a randomized waiting scheme is set up for reducing overall transmission counts, such that every sensor node is required to report the event data will begin transmission after random wait & possible aggregation is triggered if a node near to base station is waiting for long.

SFEBDA (Structure-free and energy- balanced data aggregation)

Chih-Min et al suggested that this is a two-phase protocol for WSN [56]. The first phase deals with an event to occur, such sensor nodes are selected on the basis of their role as primary and secondary aggregators (PA, SA respectively) & for the next phase, assumed a pair as PA / SA pair, where sensor node close to the base station is referred as aggregator & second as forwarding node for the early aggregation & selection of the forwarding nodes. Those aggregators return the received packets to base station in the second phase.

MADA (Multi-agent data aggregation)

The protocol that operates randomly when a sensor node senses important information; must include its neighbors in the aggregation of the most relevant details to be sent to the base station was introduced by Sardouk et al [57]. In this every sensor node determines whether to be the part of data aggregation process or not based on the specific factor of participation decided by the different parameters as distance, position, criticality, information and energy.

Table 2. Tabular Review of structure free aggregation data protocols

Protocol	Selection of Aggregation Head	Advantage	Disadvantage
SPIN [73]	Based on descriptors	Each sensor node needs their individual hop neighbors to be aware of only topological changes.	Inability of data delivery guarantee.
DAA + RW [74]	Aggregation depends on the detection of event	Every node with similar reporting event data or closer to the base station can start transmission with higher priority.	Poor aggregation efficiency due to short randomized waiting time chosen by the sensor nodes near the base station
SFEBDA [75]	Primary and secondary aggregator (PA/SA) pair based on their location	Efficient collection of data and efficient energy using aggregation process in two phases with dynamic	Overhead computation when choosing dynamic aggregator Built network holes

		aggregator selection method	
MADA [76]	Multi agent- structure free	Cooperating agents remove the inter- repetition of sensor nodes and merge the collected information from a processing session into one message	Aggregator node selected using event detection

WSN Structured Protocols of data aggregation

Cluster

The network is split into subgroups in a cluster-based system, and each subgroup is called a cluster. There are several sensor nodes in each cluster where one node is called CH (Cluster Center). They are allocated to forward data to the sink from their cluster nodes and typically regard the masters & sensor nodes as slaves, this structure (master/slave) allows a close traffic control, as no node may be transmitted beyond the cluster and no communication with the slaves is permitted but via the master.

Chain

Lindsey et al. suggested a chain-based information aggregation protocol for Sensor Information Systems (PEGASIS)[58]. The PEGASIS nodes are organized into a linear data aggregation chain. The nodes can form a chain by using a greedy algorithm, or the sink will centrally evaluate the chain. Creation of the Greedy chain means that all the nodes have the skills of a global network. The creation of a chain is chosen as its counterpart in the sequence, starting with the furthest node from the sink and, at each stage, the closest neighbor of the node. A node collects data from one of its neighbors, uses its own data in every data collection round, and transmits the fused data along the chain to its neighbor. Basically the leader node near the head of the cluster transmits the aggregated data to the sink.

Tree

The sensor nodes are grouped in a tree-like structure, and the data are aggregated at intermediate nodes along the chain. Aggregation is accomplished in a tree-based system by constructing an aggregation tree which may be a minimum spanning tree, embedded in the sink, and the leaves are considered root nodes. Every node has a parent node with which to forward data. The data flow continues from the leaves ' nodes to the drain and in the parent's nodes.

Grid

A two data aggregation schemes have been suggested by Vaidhyanathan et al. [59]: Aggregation of grid-based data and aggregation of data in the network, as per area partitioning. Through grid-based data aggregation a group of sensor nodes through fixed regions of the wireless sensor network is allocated as data aggregators. In a specific grid the sensor nodes relay the data directly to that grid's data aggregator. In a specific grid the sensor nodes relay the data directly to that grid's data aggregator therefore, inside a grid the sensor nodes do not interact among one another. Aggregation of grid-based data is consistent with the nomadic settings as surveillance in defense & forecasting of weather, in which adaptation of dynamic and mobile transition of events is required.

Table 3 Tabular Review of structured aggregation data protocols

Basic framework	**Protocol**	**Core Traits**	**Pros**	**Cons**
Cluster	LEACH [69]	Chooses sensor nodes as cluster heads (CHs) at random.	Every node has the same probability of becoming the head of the cluster.	There's a strong possibility that a very low powered node

		Adjusts this feature to distribute the energy charge in the network evenly between the sensors.	Using TDMA prevents CHs safe from unwanted collisions	will be picked as a CH. Unable to guarantee good distribution of CHs. In their set, those nodes have no CH.
Chain	PEGASIS [70]	The Nodes are distributed along a Greedy linear chain method.	The Energy charge is evenly distributed, Reduce overhead due to dynamic cluster formation, Reduces data transmission numbers	No problems of surplus data. Needs global experience in which all the nodes are at the sink. There is delay due to formation of long chains
Tree	EADAT [71]	Node selected with shorter sink path & higher residual power.	Sensor nodes with large residual power are more likely to become a node of the non-leaf tree. The mean residual energy of all live sensor nodes gradually decreases. Lifetime of a network increases linearly with density of the network..	Network density not considered at base station. Load balancing deficit. If a child node receives no message for support or can't switch to a new parent, the node will enter a danger state.
Grid	Grid [72]	A data aggregator collection per system. Adding data for each grid.	Adapting dynamic transition, and versatility of events	Nodes in the same system would not interact among themselves. Data redundancy
	In-network [72]	Data aggregator based on the signal strength by chosen grid.	That sensor node within the grid interacts with the nodes adjacent to it.	Overhead in Aggregation head selection

5. Comparative Precise Farming Techniques Using Wireless Sensor Networks

Farmers, academics, & technology manufacturers are working together to find more efficient solutions to complex agricultural problems to boost existing production and processes. Precision Agriculture is primarily based on tracking, measuring and responding to variability of crops intra- & inter- field where agriculture acts as the India's backbone & approximately 70 per cent of the population of India relies on agriculture. Precision farming [45] is used to resolve numerous issues that arise in traditional farming, such as insufficient real-time data collection, limited spectrum of monitoring coverage, unrealistic standards of human resources etc. Precision farming that helped to drive agriculture into the world of computer based information using range of technologies developed for supporting farmers to gain control over farm operational management. Precision farming uses WSN in the management of soil moisture, temperature sensing, humidity monitoring, pressure sensing, CO_2 sensing etc [47].

WSN-based precision farming infrastructure consists of monitoring nodes for the environment, communication systems, base stations, and internet connections & hardware-software application control networks. A WSN is an autonomous spatially distributed sensor which transmits its data to a main location over network [49]. The sensing circuits measure and convert the environmental conditions that surround the sensor into electrical signals that provide information about the detected objects or events that occur due to the proximity of the sensor when processed. While other types (ZigBee technology, HSCSD phone, GSM technology, HSCSD phone, GPRS phone, GPRS card phone, etc.) are capable of relaying these sensors' information to farmers.

Table 4 Comparison of Existing Technologies Used in Agriculture

Technology	Communication Technology	Efficiency	Cost	Application	Temperature Sensor	Moisture Sensor	Humidity Sensor	Soil Sensor
Wireless Monitoring[60]	ZigBee	Less	Low	Machine, Monitoring, Security etc.	No	Yes	Yes	No
Pervasive WSN [61]	GSM, RFID	Ltd	High	Communication etc.	No	No	No	Yes
Using WSN to manage PA [62]	RF	High	High	Communication, Greenhouse etc.	Yes	Yes	No	No
Irrigation Control [63]	ZigBee	Less	Low	Drip Irrigation etc.	No	No	No	Yes
Monitoring of WSN in PA [64]	ZigBee, GPRS	Less	Low	Communication etc.	Yes	Yes	No	Yes
ZigBee in PA[65]	ZigBee	Less	Low	ISM, Sensor etc.	Yes	No	Yes	No

The WSN's data obtained at the central base station is usually processed in numerical data form, which allows anyone to track or administer WSN via Web browser. Sensor is a type of transducer that provides different forms of information, depending on the type of sensor it conducts. We compared several sensors used in existing technologies in Table 2.

6. Related Work

Soledad Escolar Díaz et al. 2011 proposed an innovative approach for tracking farm production processes focused on wireless sensor networks. The approach consists of a sequence of well-defined phases covering the entire life cycle of WSN agricultural monitoring applications. This theory consists of seven steps, each of which identifies a function, generates an input, generates an output, and performs a group of users; the process gathers the generic activities to be performed in that step, but also includes specific actions to be considered in accordance with different scenario requirements. The seven stages of the methodology form the base for WSN agricultural monitoring applications, which provide a stable foundation on which systems with considerable production gains and maintenance facilities can be built. On the basis of these advantages, we assume that our solution will contribute to the implementation of the WSN program in the agricultural sector.

Tyler W. Daviset al. 2012 interpret power characteristics of wireless sensor networking systems for the sap flow, soil moisture and soil water potential sensors. We address the reasons for achieving an extended battery life for individual wireless nodes while safeguarding adequacy and reliability in accurate data transmission sampling. First, they analyze how specific sensor characteristics, such as various types of flow sensors, can affect the sampling and transmission rate of nodes. We then examine the effect of a sensing attenuation on sap flow, soil water and soil moisture measurements due to the low battery energy. A basic regression model was used to correct sampled data on underpowered nodes, for both the sap flow and the soil water potential sensors. This effectively increases the battery life of motes by working below maximum power levels to collect data from wireless sensor networks effectively.

Xiaoqing Yu et al. 2013 addressed hybrid wireless sensor network architecture. It develops the requisite applications for integration and operating a hybrid WSN. Experiments were carried out using 50 percent sandy soil, 35 percent silt and 15 percent clay; it had a density of 1.5 g / cm3 and a density of 2.6 cm−3.In addition, the deployment depth of the node influenced signal attenuation for the 433 MHz link. This decides the optimal installation depth of nodes to communicate securely into an underground wireless sensor network. The network architecture was developed for the wireless hybrid sensor networks, and the deployment plan for the hybrid sensor network was presented. A wireless underground sensor network is analyzed according to design of the network and methods of deployment.

Andrew J. Phillips et al. 2014 a series of primary soil moisture dynamics monitoring recommendations for remote sensing integration and models including advanced on-site sensing technologies to allow less restrictive soil moisture measurement. In addition, it involves incorporation of in situ networks on a field scale with regional remote sensing monitoring & this research is related to the creation of applications and web services to integrate multi-source data with model decision-support.

Tamoghna Ojha et al. 2015 presented a detailed review of State-of - the-art WSN delivery to specialized farming applications. Instead they introduced versions of the WSN — the terrestrial WSNs, and the underground WSNs. Then he stressed numerous WSN technologies and their ability to solve different agricultural problems. The consecutive parts of their paper described WSN's network and node architectures, the corresponding triggers, the classification by specific applications, the numerous wireless sensor nodes accessible and the various connectivity techniques followed by those nodes. Instead of using case studies, they discussed the latest WSN installations, globally and in India, for various agricultural applications. In the end, they explored the possibilities and issues of the current applications. They noted that low cost solution with features like autonomous operation needs little maintenance. Ultimately, innovative pre-planning is required specifically for the success of these applications to address the problems in both global as well as LMICs (Low & Middle Income Countries). Specifically, low cost solution requires low maintenance, with features such as autonomous operation. Ultimately, the performance of these applications includes creative pre-planning explicitly to overcome the problems in both global and LMICs.

Farzad Kiani 2016 concentrates on the topic of energy efficiency with various measures such as prolonging the network lifetime and rising the energy consumption of sensor nodes and increasing the durability of networks. Their suggested Procedure is composed of two stages. The sensors are placed into virtual layers during the first period (stage of network development). The second stage (data transmission) is linked to route exploration and data transfer, so that it is based on a virtual Classic-RBFS algorithm in energy-problem lake environments but in non-loadable environments, all nodes in each layer can be modeled as a random list, and then the task cycle process begins to handle them. This paper suggested an AR-RBFS-based routing protocol, to be implemented in two different scenarios on WSN. It is used to determine the power usage of the wireless sensor nodes and the efficiency of their packet transmission. The suggested technique can be extended to various applications, such as forestry, for both ecosystems.

James Gray et al. 2017 found the shortcomings of the existing framework for controlling the world and proposes a range of networking tools that can be utilized to enhance usability. Networking of environmental monitoring programs and the storage of recorded data is regarded. It also aims at designing and developing a software system to collect and archive collected environmental data from multiple farms. Simplified methods and methodologies for the software engineering were used to construct such a system. The main measures taken to complete the project included eliciting customer requests, updating the requirements, planning, executing the software and eventually checking it. The project results included a possible solution for enhancing the monitoring system for the environment, and an overview that indicated the application value. As suggested by this report, networking technologies are a viable option to reduce labor requirements and improve flexibility and efficiency by using networking, scripting, and database technology.

Maximilian Nicolae, Dan Popescu et al. (2018) They introduce in their paper a creative architecture for wireless sensor networks (WSNs) that can increase the performance of their precision farming (PA) systems. The authors argue that wider scale WSNs aren't automatically incorporated into PA. To this end, the paper explains the state of the art in WSNs that are used in PA, and proposes the proposed solution based on the conjectures established. The developed approach shows how small dimensional nodes can be without decreasing the communication range or the flexibility of the services. WSN is there to help and not to create overheads and issues. The communication protocol integrating the sleeping mechanism in simulation revealed that the proposed method might offer development in the WSN domain as WSNs would now qualify for widespread adoption in PA. On LoRa and LoRaWAN more and more of the WSN and IoT infrastructures are relying.

Devi Kala Rathinam. D et al. (2019) the wireless sensor nodes used for monitoring crops are mentioned in their paper, the instruments may be used for temperature detection, humidity and any other theft. This helps increase production in the agricultural sector. Automatic cycle decreases the human effort and allows the farmer to grow the agricultural land. The positioning of the fields may be transmitted using GPS. To render farming smart, other components such as sensor, Wi-Fi, camera and several other devices are used. All the captured information is stored in memory or cloud. WSN here is used to produce high yield and low cost crops. Nowadays, people do not know for agriculture. Human wireless sensor networks are used for effort reduction. The data is collected here by sensor nodes and sent to both farmers and field specialists. The smart phones are distributed using some additional information about the hardware and software. The farmer will run the cell phones from anywhere at any time. The initiative will also put together many producers, as well as the professional. This is best suited for agriculture-dependent countries such as India.

Table 5. Year-wise Distribution table of related work

Year	Area	Devices / Technologies used	Result
2015	Agricultural WSN: State-of - the-art in action and threats for the future[48]	Technologies for Wireless communication -Modules ZigBee, Wi-Max, Wi-Fi, GPRS/3G/4G, Bluetooth and Various Sensors (Soil Moisture Sensor, Temperature Sensor and other electronic devices).	Increased cost, need to improve scalability.
2016	Decision-making support scheme for rural irrigation management [25]	Machine learning methods used: ANFIS (Adaptive Neural Fuzzy Inference Systems) & PLSR (Partial Least Square Regression).	Good performance, accurate information prediction in the field.
2017	Architecture of an IoT-enabled agricultural precision platform and ecological surveillance [53]	Data gathering sensors, Web portal implementation using PHP and laravel platform, Paas cloud deployment, image capture drone.	Precise and frequent monitoring of the livestock, aquaculture and monitoring of different ecological factors.
2017	A temperature-compensated Smart Nitrate Monitor for Farming [54]	Together with a planar type interdigital sensor, spectrophotometric method is used for measuring soil nitrate levels; Arduino Yun was used for the development of sinusoidal volt, and the use of soil and temperature sensors.	Linear, portable through various nitrate levels, this approach improved performance.
2017	Stable user authentication and key agreement scheme for tracking agriculture using wireless sensor networks [66]	Wireless IoT and BAN (Burrows-Abadi-Needham) sensor networks and AVISPA methods are used to test protocols.	Highly safe, cost reduction
2017	Measuring Soil Macro Nutrients For Smart Agriculture In Coconut Growth [55]	Macro Nutrients including Nitrogen (N), Potassium (P) & phosphorous (K) are obtained using the data forwarding algorithm.	Enhanced Productivity, Cost and time are saved, as well.
2018	Wide WSN focused on Static nodes & mobile robots in precision agriculture [56]	Hybrid structure for WSN which includes both mobile & fixed nodes (mounted on UAVs or AVs)	Long range, cost of longer time for transmission

2019	An overview of energy efficiency implemented in smart agriculture in Wireless Sensor Networks (WSNs) [67]	WSN micro sensors are used with global positioning system (GPS) /sensor, Wi-Fi, cameras are used	High yield production with low cost

7. Research gap

WSN's development has ignited new trends in agrarian science. Microelectromechanical system (MEMS) technologies include manufacturing inexpensive & compact sensors. The device's omnipresent architecture along with cost-effective equipment, self-regulating sensor nodes & scalability imply WSNs should be used for the automation of agriculture [5]. Nonetheless; there remain a range of open problems and limitations about the provision of WSNs for observing various agricultural climates. In current WSN-based agricultural applications, several of these problems and weaknesses are highlighted below, along with suggestions for how to deal with these.

i. ***Battery life and power consumption:*** A WSN contains three main components: microcontrollers, RF transceivers & sensors. As sensor node battery has a small amount of energy, it is essential to ensure minimal power is consumed by the components of sensor node. This problem will be particularly mitigated by the energy consumption of the RF transceiver, which is more efficient than other sensor node components [67]. The first to deliver a smart energy efficient algorithm. To complete the second step, use the available energy collection techniques, such as solar cells.

ii. ***Range of communication:*** In spite of the wide variety of accessible agricultural habitats, WSNs are experiencing the effects of extreme environmental conditions [5]. The WSN protocol offers structures to tolerate the influence of environmental impacts induced by delays in the delivery of network data.

iii. ***Reliability:*** Agricultural monitoring systems based on various environmental sensors can also be used to track pollution, as well as climate conditions. Information on vital climatic conditions for advance investigations is obtained from remote locations by relevant agencies and farmers. Dangerous knowledge has to be answered quickly in the case of an emergency, which ensures that the high efficiency of data processing inside WSNs will be demonstrated [3].

iv. ***Security:*** Protection and safety of agricultural products are key issues. Protecting grain stores or fields from insects or rodent attacks is important. Such a question must be taken into account when preserving the standard of agricultural protection. Security and security may be accomplished without human intervention, relying on the study and processing of agricultural information in real time [59].

v. ***Heterogeneous sensors:*** The integration of heterogeneous wired and wireless sensors into interoperability of data knowledge databases raises problems within PA. Chen et al.[52] suggested a "web-service-enabled cyber-physical infrastructure" to address this issue. In the PA system, the conceptual network was able to integrate, store, capture and relay surveillance data from different physical sensors transmitted online.

8. Conclusion& Future Prospect

This paper addressed a study of farm applications based on WSN & various wireless protocols or technologies (Bluetooth, GPRS/3G/4G, WiFi, ZigBee, LoRa, and SigFox) have been compared. Also mentioned were the techniques or algorithms for energy efficiency. On the basis of the given classification and comparision, we demonstrate that important types of energy efficient and energy-harvesting techniques can be used in agriculture. Earlier research has also been investigated and contrasted with the study of current problems in farm applications based on the WSN and the research of optimum systems performance solutions. The state-of - the-art approaches to farm applications and the numerous controls, actuators, devices, IoT systems and technologies being studied are applied to the challenges and drawbacks to build requirements in future. The entire paper extends the scope of the study of precision farming. The successful use of the new crop yield technologies and the maximum benefit for farmers. This paper also provides a base for Precision Agriculture research for further work.

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