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EMPOWERING AGRICULTURE: A COMPREHENSIVE REVIEW OF WIRELESS NETWORKS IN FARMING

C. Rajalakshmi, Research Scholar, Sri Krishna Adithya College of Arts and Science, Coimbatore, Tamilnadu, India.
Dr. Sreejith Vignesh B P Assistant Professor, Sri Krishna Adithya College of Arts and Science, Coimbatore, Tamilnadu, India.

ABSTRACT

Agriculture is entering a new emerging field that aims to develop integration between wireless networks and agricultural practices. The agricultural sector needs to adapt to the digital era and its requirements. Farmers face the growing challenge of feeding a growing population, and they are forced to expand resources and improve their production through agricultural practices. However, the impact of environmental changes has created a gap between production and food supply for the population. Farmers still struggle with observing crop diseases, weather condition, irrigation, and other factors in a timely and cost effective manner. As current technology has improved every aspect of the agriculture sector and its industries, among the many technologies, wireless networks and their applications are focused on enhancing productivity, sustainability, and revolutionizing farming practices. This review considers the research status of the last 15 years and addresses the various tools, techniques, and algorithms used to improve the agriculture sector.

Keywords: Wireless Networks, Precision agriculture, Smart irrigation systems, Crop and Livestock Monitoring, Market Access and Information Sharing, Disaster Management.

INTRODUCTION

Agriculture stands at a center point of the economy and in all the ways it's continuously get affected by food demand, low productivity, changes in bio environment and destruction of natural resources. In olden days farmers used manual labour for cultivation, disease identification, transportation which results failure in crop protection, more labour, cost and prolong the process. As a result farmer's life was in danger and they struggle to proceed their day today life which affects the nations economical status.Traditional farming practices has no awareness and technological support to overcome above stated problem. This 21st century needs more support from technology.

At the same time there is no technology to identify natural disasters, climatic variations, smart irrigation system. To fill this gap wireless networks and its adaptive natures of technologies come into play. The application of wireless networks strategically positioned as follows.

Precision Agriculture :

These days, it's among the most widely used technologies that anyone with a rudimentary understanding of gadget operation may use. It offers information on a number of variables, including temperature, humidity, soil nutrient levels, soil moisture, soil pH, and crop development conditions. By taking pictures of farm areas, crops, and animal activities, drones are a valuable tool for determining crop health. They are also capable of evaluating crop yield, soil quality, and the general environment, all of which support the profitability, efficiency, and sustainability of agriculture.

Smart Irrigation Systems:

Considered a notable technological advancement in wireless networks is the smart irrigation system. By tracking soil moisture content and detecting meteorological conditions, a variety of sensors help with water management. This makes it possible for wireless networks to simply monitor how water is distributed across farm fields and to adjust water flow without the need for human involvement. The main resource for vegetation and agriculture is water. Effective water management boosts production and conserves water resources in many nations.

Crop and Livestock Monitoring:

The proliferation of the Internet of Things has made wireless sensor networks necessary for farmers. Today's technologies make it possible for anybody to conduct study on the benefits of vegetation, environmental elements, animal behavior, and improved livestock management. These systems offer useful functions like insect identification and pesticide monitoring, and they monitor every stage of crop development.

Market Access and Information Sharing:

Technology empowers the information sharing and shorten the world by online business monitoring, marketing makes the world by easy sharing and quick communication to farmer and customer .Through increased openness, wireless networks facilitate better distribution, crop health monitoring, and product quality assurance..

Disaster Management:

IoT devices are capable of identifying and disseminating early warning signals regarding abrupt hazards including animal infestations, insect outbreaks, and high temperatures, in addition to natural disasters like floods, droughts, and wildfires. This makes it possible for farmers to use websites and mobile apps to communicate and keep informed.

From above listed applications of wireless networks guaranteed the Sustainable farming methods, intelligent irrigation systems, accurate water management, efficient use of resources, and support the creation of high-quality products are all made possible by wireless network technology. This research analyzes and presents the numerous problems and challenges faced by agricultural production, transportation, marketing, and information sharing, along with the solutions offered by wireless network technology. Using wireless networks in agriculture is arranged in this paper's following manner: In Section 2, precision agriculture is outlined; in Section 3, the smart irrigation system is presented; in Section 4, crop and livestock monitoring is examined; in Section 5, market access and information sharing are covered; and in Section 6, the paper's scope is condensed for future development.

II. PRECISION AGRICULTURE

Morais (1996) et al. implemented a wireless data acquisition network based on the Intel 87C592 and Microchip PIC16C71 micro controller for agricultural applications. A base station (BS) and many solar-powered wireless data-acquisition stations(SPWAS) connected via radio frequency make up the system. The primary duties of the base station include managing the data-acquisition stations and storing the information they gathered.[87]

Louise (2007) et al. investigated a low power, low complexity, low data rate sensor network that is appropriate for agricultural monitoring and is looked into for its physical layer specification. An aggregate data rate of two bytes per minute and a node population of about 1000 can be supported at distances up to a few kilometers from the central node, with less than 0.2% chance of failure due to multiple access interference, according to the investigated scenario and specification. The interference arising from each node is calculated.[117]

Amar (2008) et al. developed a competent decision support system that enhances agricultural practice and decision making. An ongoing initiative to supply agricultural intelligence is the focus, which draws lessons from that experience. Worked a framework for constructing wireless sensor networks for agricultural monitoring in poor countries, taking into consideration all the unique characteristics of such locations, by generalizing the research issues encountered.[76]

Sonal (2010) et al. designed and constructed a wireless sensor network that can track the ambient light intensity, humidity and air temperatures in a crop field. Farmers and other end users may find this to be helpful in better understanding the agricultural practices that should be used for crop management. A plant fire detection mechanism has also been integrated into the system because it is impressive to detect plant fires early in order to avert significant crop damages. The system is made up of nodes, each of which has radio frequency modules and tiny application-specific sensors installed.[106]

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Zhang (2010) et al. Presented a novel adaptive forward error correction mechanism was introduced, which dynamically chooses the most suitable error-correction code by considering the packet error rate within wireless sensor networks. This approach stemmed from the empirical observation that environmental conditions affect packet errors.Proposed research demonstrated that when compared to conventional forward error correction techniques, adaptive forward error correction delivers enhanced recovery performance. It achieve this with reduced acknowledgment frequency, improved efficiency, and lower power consumption. The feasibility and effectiveness of this mechanism were successfully verified in a wireless sensor network. [5]

Xihai (2010) et al. offered an improved hardware platform for future studies on wireless sensor network communication protocols. Nodes have been communicated effectively over a distance of 80m, and the error ratio is roughly 1%, satisfying the criteria for gathered agricultural data. The designed node has a small volume, a consistent performance and a compact structure. Information on the temperature of the soil can be gathered by the nodes and sent to higher network nodes.[20]

Lei Xiao (2010) et al. developed a wireless sensor network based on agricultural environmental monitoring systems. Temperature, humidity and light intensity are just a few of the agricultural environmental data that the system can track in real time. Additionally, introduced a theory of the monitoring system. Covered network architecture network communication protocol, hardware and software design of component modules and current issues. Tests demonstrated that the node is capable of gathering and transmitting agricultural environmental data.[48]

Xihai (2010) et al. assessed the effectiveness of NMDS-RSSI localization algorithms using data from various farm conditions. Deduced that as the signal propagation coefficient increases, the average value of the localization error has decreased. And also demonstrated the NMDS algorithm's robustness in challenging environments. In addition, they discovered the connection between connectivity and localization error. According to the simulations, under identical simulation conditions, the NMDS-RSSI localization technique performed better than the MDS-MAP.[29]

Alfredo (2010) et al. offered a thorough approach that uses embedded controls and the UDP and TCP/IP protocols to establish a quasi-isochronous wireless communication system for machine synchronization. The long-range communication needs are met by the TCP/IP protocol and GPRS/GSM networks, but not the real-time communication requirements for the short-range communication.[131]

Bradford (2010) et al. worked on a trend towards a sense and control infrastructure which enables quick informed decisions regarding environmental factors will need to be initiated. Able to set up networks with more sensors that can communicate with less power and more dependability by using inexpensive motes. These characteristics make this type of system ideal for agricultural applications, where a high number of sensors is needed to give the requisite level of control granularity.[145]

Luca (2011) et al. determined whether RFID technology can be used to establish a comprehensive traceability system that encompasses the operations from the farm to the fork, the RFID Farm to Fork project was established. It described a system for wine traceability from the vineyard to the consumer glass, along with relevant electromagnetic and deployment concerns based on the joint use of RFID technology and WSN. After that, the current deployment progress is revealed and two distinct wineries that were chosen as pilot locations.[108]

Vijayakumar (2011) et al. suggested cutting-edge wireless sensor technologies for agriculture, which has helped rural farmers replace some of their outdated methods. The sensor motes in this paper are equipped with a number of external sensors, including sensors for soil pH, leaf wetness, soil moisture and air pressure. Based on the water shortage, the sprinkler is activated by the mote based on the value of the soil moisture sensor. This paper has used a wireless sensor network to automate the regulation of water sprinkling and ultimately provided farmers with information.[31]

Gerard (2011) et al. created a smart wireless sensor network for agriculture. They had been investigated into a wifi-based remote monitoring system whose wireless sensor nodes are built around WSN802G modules. These nodes have been wirelessly transmitted data to a central server, which gathers, stores and permits analysis before displaying it as needed. Unattended monitoring systems have been researched for this purpose because the capacity to record and described changes in parameters of interest.[16] Kehui (2011) et al. provided the hierarchical storage, hierarchical error control, and re transmission methods. Also presented the architecture of the wireless moisture sensor network and the structure of the moisture data packet. In particular, it has examined and modeled the error control mechanism in terms of time consumption and error correction capability. The simulation results indicated that BCH coding works better for wireless moisture sensor networks than RS coding.[14]

Tagarakis (2011) et al. aimed to install and calibrate WATERMARK sensors in a commercial vineyard in accordance with precision agriculture methods. The findings demonstrated that WATERMARK sensors had a high degree of accuracy when determining soil moisture (R 2=0.85). It assists farmers in determining how much irrigation water is appropriated for each growing season. In addition, an increase in the final production could result from the combination of management zones and soil moisture sensors. The amount of moisture in the soil can be determined.[70]

Mendez (2012) et al. presented the study centered on conceiving and crafting a smart wireless sensor network tailored to agricultural applications. It encompassed the monitoring of various agricultural parameters, including humidity and temperature, along with a focus on adapting to changing parameter conditions. The research specifically revolved around a Wi- Fi-based remote monitoring system featuring wireless sensor nodes constructed with WSN802G modules. These nodes wirelessly relay data to a central server that efficiently collects, stores, and facilitates on-demand data analysis and display.[3]

Amal (2012) et al. presented ideas for wireless sensors for agricultural applications, based on patch antennas around the resonance frequency of 2.45 GHz, including an RFID-enabled tag antenna and two other miniaturized antennas. The simulation tool CST MWS was utilized in the design and optimisation of these antennas. They make it possible to include not just a microprocessor but also a sensor that is frequently used in agriculture, like a temperature and humidity sensor.[36]

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Xufeng (2013) et al. presented a distributed heterogeneous wireless sensor network based on internet of things technologies in order to monitor environmental parameters like temperature and humidity in facility agriculture in real-time. Specifically ZigBee wireless sensor network technology is utilized. In an emergency, a GSM SMS will alert the user to take the necessary precautions against environmental regulations. The degree of facility agricultural management is raised by the real-time gathering and early warning from environmental parameters related to facility agriculture, which raises crop production.[46].

Ravi (2013) et al. proposed a lot of interest from the farming and agricultural sectors in an effort to increase profitability by improving yield consistency and productivity. Mango exports from India are among the top in the world, and profits can be multiplied many times over. Proposed a WSN model for the WSN application in mango production and provides a full report on various agricultural practices and statistics related to mango cultivation in India. The amount of moisture content in the soil is tracked using this model.[110]

Tsuneo (2014) et al. introduced the idea of a generative WSN framework that makes it possible to create semi-custom WSN systems that meet the needs and limitations of specific farmers while staying within predetermined parameters. It also covers the core technologies of these systems. The framework

controls essential assets and presents a paradigm for software product lines, which form the foundation of the WSN system that will be created. In addition, technologies created to realize the generative WSN framework include integer programming based optimization of system setup, variation point mechanisms for hardware and two tiered feature modelling.[79]
Usha Rani (2014) et al. described the most effective fault-tolerant topology design for wireless sensor network development. Mesh topology is the most effective and ideal way to create a wireless sensor network that meets all the requirements for increasing efficiency and service quality, It is used to deploy sensors on agricultural fields. Used a cutting-edge algorithm to identify the problem and figure out how to fix it so that the network may be reconstructed without distortion.[82]
Xiang (2014) et al. addressed the practical requirements of agricultural wireless sensor networks, a soil moisture classification model based on Support Vector Machine (SVM) with low-cost sensors has been proposed in this research as a replacement for high-cost soil moisture sensors. Basic classification is suited for the requirements of routine agricultural uses. The suggested model offers good classification accuracy in the same soil environment, according to test findings.[34]
Jiajin (2014) et al. proposed a smart agriculture management platform was developed and implemented, consisting of three key layers: the application layer, perception layer, and network layer. The perception layer employs a multitude of ZigBee sensor nodes to establish ZigBee networks. Data collected from the perception layer is then transmitted to the application layer through the use of an unmanned aerial vehicle-borne mobile sink at the network layer. Additionally, a feature-rich web application was integrated into the application layer to offer a wide range of services to users.[2] Song Huang (2014) et al. presented a plan for designing and implementing a wireless sensor network system for tropical agriculture that can be used under high temperatures, multiple rainstorms and other conditions. A novel form of embedded architecture known as ERA employs reconfigurable architecture and a generalized fault-tolerant algorithm to enhance the software system’s hardware adequacy. Its robust security assurance mechanism and excellent performance allowed it to work reliably in system application activities.[148]
Tuan (2015) et al. covered the design, development and application of a wireless sensor network for precision agriculture. To support precision agriculture, a wireless sensor network was developed, allowing farmers to track and manage environmental and agricultural variables like pH, light, soil moisture, air temperature and air humidity. The implemented system has been operating as intended and has great promise for the agricultural industry. According to experimental findings, the data prediction module using a dynamic Bayesian network can forecast temperature and humidity with an average accuracy of 77.5% and 67.6%.[45]
Nengcheng (2015) et al. reviewed an integrated geospatial sensor web for China's agricultural soil moisture monitoring. First, sensor web-based cyber infrastructure connected satellite sensors, in-situ sensors, and wireless sensor networks. Afterwards, multi-sensor collaboration techniques were created to fully utilize these various monitoring capacities. Web processing services were also used to accomplish online mapping, fusing and estimation of soil moisture.[139]
Feiroz (2016) et al. A strategy was devised and implemented to manage the network's load effectively, improving its energy efficiency. Each node is assigned a load threshold, and when this threshold is exceeded due to an influx of data, it autonomously transmits an MC_REQ to the mobile collector (MC) for assistance. Among several static Wireless Sensor Networks (WSNs) deployed to oversee an agricultural region, the MC assesses the optimal relocation based on the requests from each node. The research successfully demonstrated the efficiency of the proposed MCER protocol.[8]
Jaisingh (2016) et al. determined whether employing a wireless sensor network in an agricultural area is feasible, four routing protocols with MAC 802.11 that are assessed in this paper. The best routing protocol has been determined by assessing the network’s performance using a number of

different metrics. To simulate this, has used NS-2.34. Simulation results have indicated that DSR is a more appropriate routing strategy for agricultural applications.[23]

Dragoş (2016) et al. described a wireless sensor node that was created for tracking fruit growth. A detailed description is given of the low cost diameter sensor, the data acquisition node, and the sensor's signals conditioning interface. Numerous benefits are associated with the suggested system, including low implementation costs, minimal human interaction, and fruit monitoring. The outcome of the laboratory measurements of the mode's energy consumption are given together with a multi-day collection of the air temperature, humidity, light intensity and rainfall.[141]

Stamenković (2016) et al. provided an overview of cutting-edge wireless sensor nodes, networks and precision agriculture applications. The characteristics of a number of commercial and experimental sensor node systems that are intended for use in agricultural applications have been detailed. The fundamentals of sensor network topologies and protocols have been examined along with a variety of applications. There has also been discussion of more sophisticated machine learning techniques in this area, particularly kernel methods, gaussian processes and deep neural networks.[69]

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Shankar (2017) et al. investigated a context-based precision agricultural system that reframes crop-related plans and policies as necessary in this regard. Planned to record temperature, relative humidity, soil moisture and rainfall in real time using a wireless sensor network deployed on the field. A notice on the disease and pest assault of sigatoka disease will be sent to the user. Also saw the actual scenario following the alert, confirming that a disease or pest attack was indeed occurring. The gathered information will be examined to determine the best pattern for banana cultivation based on context. The implementation findings demonstrated a 74% accuracy improvement over conventionally followed agriculture practises.[72]

Mohamed (2017) et al. proposed WSN and Cloud computing integrated architecture are covered. Applications for the agricultural environment have grown in importance as a field of control because they offer real-time system and physical world connection. Application for the agricultural environment using cloud computing and wireless sensor networks gathered and processed vast amounts of data from the start of the process to its conclusion.[73]

Tien Cao (2017) et al. developed a wireless sensor network based on internet of things system architecture for the application of agriculture. Using a web browser, a user of the system has monitored environmental data related to agriculture and transferred environmental data from sensor nodes to the linux-powered gateway, a wifi interface is set up. The data is managed and transferred by the gateway to a cloud where it is stored and graphed.[12]

Mohamed (2017) et al. proposed WSN and Cloud computing integrated architecture and also benefits and uses has also been covered in this paper. Applications for the agricultural environment using cloud computing and wireless sensor networks gathered and processed vast amounts of data from the start of the process to its conclusion. Applications for the agricultural environment have grown in importance as a field of control because they offer real-time system and physical world connection. The sheer demand for automation and precision agriculture is driven up the requirement for agricultural environment applications.[22]

Manish (2017) et al. presents a proposed method that distributes available water among different crops grown on farms and analyzes its impact on farm yield output. Using interpolation techniques, the wireless sensor network offers an extremely good option for water distribution. Wireless sensor

networks have explained the techniques for managing a variety of parameters, including temperature, humidity and soil moisture.[58]
Rajinder (2017) et al. suggested precision agriculture framework makes use of inexpensive environmental sensors, an Arduino Uno prototyping board, two wireless transceivers and an actuation circuit to automate crop monitoring and irrigation. The XBee protocol,which is built upon the IEEE 802.15.4 standard and is based on ZigBee technology, is used in the suggested prototype. Precision agriculture benefits greatly from ZigBee technology's low data rate, low power consumption and wider coverage area.[59]
Manish (2017) et al. presented a proposed method that distributes available water among different crops grown on farms and analyzes its impact on farm yield output. Using interpolation techniques, the wireless sensor network offers an extremely good option for water distribution. WSN explains the techniques for managing a variety of parameters, including temperature, humidity and soil moisture.[92]
Ponde (2018) et al. demonstrated an improved algorithm performance, the suggested algorithm is assessed and simulated using NS2, and the outcomes are examined. Purpose of the suggested algorithm by comparing the nodes energy levels with thresholds, the adaptive sleep scheduling algorithm determines when to put them into the sleep and active states. The node with the highest energy in each cluster, which makes up the entire network, is the cluster head. Whether the node is an active or sleep state is within the control of the cluster head.[74]
Gonçalo (2018) et al. described an automated method for monitoring farm surroundings in order to improve the productivity and caliber of the agricultural environment. Based on the Internet of Things, it makes use of an inexpensive wireless sensor network called Sun spot that is built in java. The Arduino platform is used for Internet connectivity and the Java virtual machine has been executed on the device itself. The information gathered is disseminated via Facebook's social network. Real- time monitoring is done for the brightness and temperature parameters. To monitor the problem for certain objectives, more sensors might be added. The findings has demonstrated that conditions inside greenhouses can occasionally deviated greatly from predictions.[24]
Ashish (2018) et al. offered a system that uses a single mobile sink in WSNs to monitor the agricultural field in real-time. Position the sensors in the agricultural field using the square deployment pattern. In addition, a prototype is created and evaluated using current agricultural field data. Temperature, humidity and soil moisture sensors coupled to a NodeMCU are used in the prototype. The data gathered from sensors is transferred by the system to the mobile wash basin via wifi.[88]

Gourab (2018) et al. worked on a wireless sensor network for indoor agricultural applications. The router, gateway, sensor node make up the system. The sensor nodes gathered data from multiple sensors and transmitted over a router to the gateway. The gateway receives the sensor data, which the user can view on a laptop or personal computer. The actuator responded when the sensor data exceeded a predetermined threshold, performed the necessary actions to normalize the nodes and created a closed loop control system.[95]
Yi-Wei (2018) et al. suggested a wireless sensor network and LoRa communication technology based intelligent agricultural service platform. In order to address the issue of communication failure and conserve energy, it makes use of LoRa as a network transmission interface. It enhanced farm management efficiency and facilitate environmental monitoring, an agricultural intelligent agriculture service platform is created.[98]
Zoran (2018) et al. provided a decision support system that preserved or treated plants and crops while accounting for the temporal and spatial variability of agricultural, environmental and physical characteristics. It is predicted on the most advanced machine learning methods, including deep neural networks and gaussian processes as well as remote sensing. In addition, a sample of knowledge extraction and the specification of an actionable rule have been provided.[134]

Carlo (2018) et al. evaluated power consumption as one of the primary issues in the creation of an effective wireless sensor network. Wireless sensor nodes based on Raspberry Pis were tested for power consumption in a variety of operating conditions, including idle, sensing, processing and sending. With a root mean square error of 9.02 hours, the power consumption model obtained an accuracy of more than 80%.[138]

Dong-Hee (2019) et al. suggested a low-density parity-check codes scheme based on patterns to use logical XOR to reduce the decoding complexity. Ir presented new methods for describing pattern-based encoders that use logical XOR operations. In the process of decoding operations, the suggested strategy can lower complexity, iteration and packet mistakes. It can achieve improved throughput as well as multiple signal to noise ratio levels at the receiver side. The suggested approach enhanced wireless sensor network throughput and transmission delay, according to simulation results.[102]

Rao (2019) et al. introduced a smart agriculture management platform consisting of three layers: the application layer, the perception layer, and the network layer. In the perception layer, ZigBee sensor nodes are deployed to establish ZigBee networks. Data collected at the perception layer is transmitted to the application layer via an unmanned aerial vehicle-borne mobile sink in the network layer. Additionally, a feature-rich web application has been developed in the application layer to offer users a range of services.[1]

Dahane (2019) et al. developed a precision agriculture platform that enables the collection of basic physical phenomena that is air, temperature, humidity, water level, water flow and light density needed for precision agriculture. These phenomena are then processed to determine the amount of water required for the best irrigation. Our platform is made up of a gateway switches relay, a desktop application and a sensor/actuator node that regulates a water pump based on requirements.[127]

Liya (2020) et al. focused a low power wide area network device for the smart agriculture industry that has long-range, low-cost and low-power communication. It presented a comparison of the fundamentals LPWAN strategies utilized in the agriculture monitoring network to gather real-time agricultural field data. Farmers in India would be able to address their main issue with food security with the aid of LPWAN technology.[140]

Alansari (2020) et al. introduced one of the nodes from the current period of wireless sensor networks and explained the activities performed by each sensor node to support agriculture. The intended node circuit is made up of several sensors that measure light, humidity and heat. And used a wireless sensor network to send the data it collects to a different node. The circuit at a frequency of 915 MHz was constructed using a transmitter and receiver. An AVR microcontroller serves as the node's central CPU and handles all processing and monitoring duties.[41]

Abhishek (2020) et al. provided an overview of the several agricultural sensors that are now on the market. After that, it will recommend a framework that calculates the precise amount of fertilizer needed by the field based on a number of related parameters. After assessing a number of variables, including soil moisture, soil temperature, soil humidity, volumetric water content and electrical conductivity. The study suggested the requirement is based on a decision support system. According to the experiment's dindings, fertilizer consumption has decreased by 24.68%.[104]

Abhishek (2020) et al. suggested the requirement-based-decision support system (R b DSS) after assessing a number of variables including soil moisture (Sm), soil temperature (St), volumetric water content (VWC) and electrical conductivity (EC). According to the experiment's findings fertilizer consumption has decreased by 24.68%.[60]

Chuan (2020) et al. suggested a design for an embedded IWSN system that uses UAVs as data relay and charging devices, with IWSN functioning as the data sensing or gathering component. Addressed the energy-optimal charging path planning problems with length constraints for the UAV-assisted IWSN based agricultural monitoring system, where all residual energy for the network is considered simultaneously with the charging path's length.[91]

Nilanjana (2020) et al. proposed an energy efficient, low cost, long-range wide-area network based on internet of things architecture with two LoRa end nodes designed to monitor body temperature and pulse rate and to collect metrics from agricultural fields. Following communication to a single gateway, the readings from these two nodes are subsequently sent to the network server. Everyday, the gathered data can be seen on a web-based dashboard.[116]
Supachai (2021) et al. worked a curve-fitting for LoRa WSN in a banana garden that was used to develop path loss models. Furthermore, deterministic large-scale models that were based on 433MHz measurement effort were available. The received signal strength indicator readings were used to model and calculate the route loss between the transmitter and receiver nodes. By comparing the suggested models with the traditional path loss models, it was traditional path loss models, it was discovered that the models offered the lowest MAE for banana trees.[109]
Shaowei (2022) et al. addressed the monitoring requirements of an intelligent greenhouse through the development of an intelligent greenhouse visualization system based on wireless sensor network technology. The Zigbee wireless network and PLC served as the system's primary controllers and data collection tools for the intelligent greenhouse environment. It automatically configured the light control, fertilization, watering and other activities in agricultural intelligent greenhouse, combined resources and extended agricultural activities.[15]
Lin (2022) et al. advocated the utilization of a refined wireless ad-hoc network that amplifies automation and rectifies the previously mentioned shortcomings. The paper succinctly highlights critical concerns by elucidating the operation of an improved ad-hoc routing protocol introduced within this research. Discouraging manual task reassignment is underscored, particularly in situations where the number of operational robots experiences fluctuations, thereby advocating a higher degree of automation..[6]
Naoki (2022) et al. created a novel sensor network system in which the sensor nodes are able to choose the best wireless channel based on the kind of communication. Furthermore, It presented a novel approach for precisely determining the plant's growing status by the examination of many image formats of the intended plants. In order to stabilize and boost harvest efficiency, a system that reliably estimates plant growth from the data gathered is also required.[128]
Héctor (2022) et al. offered the basic technical specifications of wireless network protocols. As a result, it will be feasible to develop a worldwide technical vision that will enable the requirements based on selection of devices and /or sensors for the purpose of implementing a WSN applied to smart agriculture. In addition, it lists each wireless communication protocol's specifications which are categorized based on coverage.[130]
Subhashree (2023) et al. presented a novel precision farming technique ans =d shows how sensor data can be used efficiently. The sensor-generated data is fed into the crop yield prediction model in real time. The tactic helps to obtain more precise outcomes. Proposed a mobile application that feeds a crop production forecast model with data from wireless sensors used in precision farming once every second. These sensed properties from various users can also be utilized as a training dataset.[97]

III. SMART IRRIGATION SYSTEMS

Katsalis (2007) et al. proposed a novel approach to wireless sensor network construction, avoiding the traditional network grid implementation and relying instead on field electrical conductivity measurements. Additionally, the operation of a standard WSN is described along with its benefits and drawbacks, technical specifications and how electrical conductivity may affect the choice of WSN topology and why this technique is superior to others.[61]
Fausto (2012) et al. provided an unnamed aerial vehicle based on architecture that will be used to build a control loop in agricultural applications, where the UAVs are in charge of applying chemical sprays to the crops. The wireless sensor network installed on the crop field provides feedback that controls the chemical application procedure. Assessed an algorithm to adapt the UAV route to variations in wind direction and strength. In addition, assessed the influence of the quantity of messages exchanged

between the UAV and the WSN. The findings have indicated that the modified path according to the sensor's feedback information may reduce the amount of pesticide waste.[32]
Nandurkar (2014) et al. suggested using moisture and temperature sensors in strategic places to monitor crops. Based on the current temperature and moisture levels, the sensing system's feedback control mechanism, which is centralized in a control unit, controls the water flow onto the field in real time. After the sensor data was gathered, it was processed further by a central processing unit. Therefore, by giving the farm the proper amount of water, may improve its productivity.[126]
Usha Rani (2014) et al. created a smart wireless sensor network for use in agricultural settings. Water level management has become more important as environmental elements are monitored in order to raise the undersea level. In an agricultural setting, haven taken into account a number of variables, including temperature, the quantity of soil moisture that determines how much water flow will be permitted, the range of water flow, and the pressure that needs to be recovered.[83]
Luejun (2015) et al. introduced a multi-radius ring based multi-hop clustering routing algorithm for agricultural monitoring systems in wireless sensor networks in this research. To divide the entire area into several subareas many concentric rings with varying radii are formed. Each ring's radius is thoughtfully chosen to balance power usage. It is necessary for every cluster head to choose its subsequent hoo within the inner subarea.[147]
Romeo (2015) et al. employed sweet potato (Ipomoea batatas) as the crop. Two identical setups with sweet potatoes under observation are being planted. One setup is situated in a controlled setting, while the other is left to its natural elements. The controlled environment is housed in a tiny greenhouse and an Arduino Uno microcontroller is used to regulate the temperature, relative humidity and soil moisture in accordance with the typical growing conditions of sweet potatoes.[63]
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Sunil (2016) et al. suggested an agro device system for the pomegranate field in this regard. A wireless sensor network is set up in the field to continually monitor crop-specific, soil, hydrological and environmental data in real time. They are critical to agricultural growth, productivity and quality. Farmers will receive an agro advisory via email and SMS based on current field conditions. The suggested system's examination of the experimental results demonstrates an improvement over the conventionally used approaches.[71]
Santiago (2016) et al. presented the design and construction of a set of prototype nodes with ad hoc mode communication link establishment capabilities are explained in this paper. Low-cost single-board computers with embedded Linux (Raspberry Pi devices) were used to implement the prototypes. The installed stations seek to establish a wireless sensor network for the purpose of gathering data related to agricultural settings. Specifically, a node has been equipped with a GPS module to record geolocation data and a camera module to enable remote video surveillance of farming areas.[40]
Spyridon (2017) et al. introduced a unique leaf temperature sensor for agricultural monitoring. The sensor has used backscatter bi static standards to communicate remotely with a reader. It is built around an RF front-end for communication, a low power microprocessor and a sensor board. The communication component has used an 868 MHz carrier emitter signal to take advantage of backscatter Morse code modulation.[33]
Maksudjon (2017) et al. worked on a more straightforward and economical methodology created especially for drip irrigation systems. It describes the development of a graphical user interface application for controlling drip irrigation systems, as well as the implementation results of hardware and software for the wireless nodes. It included an analysis and studied the network

protocol which is based on LoRa modulation. Taking into account the expense and difficulty of establishing LoRaWAN.[124]
Yousef (2017) et al. described the design and development of a greenhouse smart management system that employs wireless sensor networks to autonomously control, manage and monitor agricultural factors and activities inside the greenhouse. Sensor nodes are used to measure the temperature and relative humidity in the greenhouse. The fan and water pump components are used to initiate the irrigation and cooling processes when the measured parameters above the threshold.[75]
Spyridon (2017) et al. introduced a unique leaf temperature sensor for agricultural monitoring. The sensor has used backscatter bi static standards to communicate remotely with a reader. It is built around an RF front-end for communication, a low power microprocessor and a sensor board. The communication component has used an 868 MHz carrier emitter signal to take advantage of backscatter Morse code modulation.[33]
Rajinder (2017) et al. suggested precision agricultural framework makes use of inexpensive environmental sensors, an arduino Uno prototyping board, two wireless transceivers and an actuation circuit to automate crop monitoring and irrigation. The XBee protocol, which is built upon the IEEE 802.15.4 standard and is based on ZigBee technology, is used in the suggested prototype. Precision agriculture benefits greatly from ZigBee technology's low data rate, low power consumption and wider coverage area. As a result of the aforementioned qualities, ZigBee technology is the preferred option for executing precision agriculture.[93]
James (2017) et al. examined the relationship between the height of the logger's wifi antenna above the crop and the range of dependable data transfer in each setting. The results showed that crop growth status had a far greater impact on signal strength than weather, with signal strength in a cotton field decreasing by 8dB and in a rice field by 20dB throughout the course of the season. Ranges exceeding one kilometer were measured in rice and cotton fields, as long as the radios were kept 20 cm above the crop canopy.[84]
Volodymyr (2019) et al. established a network that is currently being tested in both smart greenhouses and open agricultural areas. They contributed primarily to the design and rapid prototyping of WSN, considering the application task requirements related to field usage, extended autonomous operation and environmental parameter measurement. This led to the constructed network's parameters being estimated through modeling before it was put into operation.[47]
Andre (2019) et al. achieved a better efficiency in the process and potentially saved the end user money as well as natural resources like water and energy. Presented a novel approach to maintaining a sustainable irrigation system, applied to gardens or agricultural fields. Wireless Sensor Networks will replace human intervention in these systems, resulting in a more sustainable environment.[118]
Pablo (2019) et al. detailed the design and implementation of a wireless sensor network used in Arenillas Canton, Province of EI Oro, Ecuador, for conventional agriculture. The system will also be connected to an automatic sprinkler irrigation system, which operates primarily by comparing the data collected by each sensor located throughout the crop to achieve greater efficiency and less waste of water and supplies.[149]
Avinash (2020) et al. sensed a wireless sensor network to monitor agricultural land and presented the characteristics. Integrated technology into agriculture has to understand how agriculture operates. Proposed a ZBee technology to remotely monitor the agricultural area. Linked a number of sensors to monitor the field and take the appropriate action based on the sensor results. The primary benefit of the suggested work is that it will require far less power to communicate than previous wireless communication technologies.[85]
Yu Han (2020) et al. enhanced agricultural intelligence, optimized irrigation mode, increased farmland irrigation efficiency and convenience and advanced wireless sensor network technology for the purpose of agricultural intelligent irrigation system based on wireless sensor network. The system implemented the irrigation using a fuzzy PID control approach with STM32 microprocessors as the

controller. It measures environmental data using wireless sensor networks and monitoring technologies, enabling intelligent irrigation.[90]
Shikha (2020) et al. offered a thorough analysis of the use of sensor networks in agriculture, where data is stirred in microcontrollers and sent via ZigBee technology. In addition, it provides details on how farmers use the data gathered and how sensors are positioned in the field. In addition, the architecture if WSN is examined, providing details on how each OSI model layer operates.[81]
Alansari (2020) et al. introduced one of the nodes from the current period of wireless sensor networks and explained the activities performed by each sensor node to support agriculture. The intended node circuit is made up of several sensors that measure light, humidity and heat. And used a wireless sensor network to send the data it collects to a different node. The circuit at a frequency of 915 MHz was constructed using a transmitter and receiver. An AVR microcontroller serves as the node’s central CPU and handles all processing and monitoring duties.[41]
Shuai (2022) et al. looked at how wind affects signal-to-noise ratios and how different crop development stages affect the diffuse dispersion of electromagnetic waves caused by near-canopy propagation. It is demonstrated that in the absence of irrigation and rain, the effects of humidity and water vapour on the mmWave channel are negligible. Essential qualities developed sophisticated signal processing and channel estimation algorithms for cutting-edge agricultural Internet of Things systems.[35]
Lixia (2022) et al. focussed on the examination of the hardware and software architecture of the system, the node routing protocol of the sensor network, and how the intelligent sensor network is made up of different types of sensors, thereby enhancing the automation and monitoring capacity of the system as a whole. Lastly, it examined how the network based farming precision irrigation control system is implemented in order to save water. With the use of embedded control technology, the system completeness intelligent irrigation, increasing the rate at which agricultural irrigation water is utilized and achieving a water-saving effectiveness of 96.3%.[112]
Jakirul (2022) et al. presented an architecture of an Iot enabled sustainable cow farm monitoring system with dependable communications. Wireless Sensor Networks are used in the proposed system to exchange data between the farm and the owner/monitoring person. This Nobel Prize-winning research created a more reliable and adaptable smart idea for the agricultural industry, specifically for sustainable smart cattle ranches. In addition, farmers will be able to maintain the nutritional status of their cattle with the support of the planned work.[122]
Pallabi(2023) et al. overviewed the main components of WSN in precision agriculture including sensor networks, targeted irrigation, crop protection, crop monitoring, soil monitoring, predictive analytics, lower labor costs, and higher productivity. Farmers can use predictive analytics to analyze the data and make well-informed decisions about crop yield optimisation, fertilizer application, pest control and irrigation.[86]

IV. CROP AND LIVESTOCK MONITORING

Louise (2007) et al. worked on a low power, low complexity, low data rate sensor network that is appropriate for agricultural monitoring and is looked into for its physical layer specification. High processing gain code division multiple access enables transmission powers that meet the ultra wide band spectral mask, allowing physically tiny nodes with constrained energy storage capacity. With less than 0.2% likelihood of failure owing to multiple access interference, an aggregate data rate of 2 bytes per minute and a node population of about 1000 can be handled at distances up to a few kilometeres from the central node.[66]
Xiliang (2008) et al. examined a wireless monitoring and control system’s three-level network model, which is based on the multi-span in a greenhouse. The GPRS Module and Zigbee Module CC2430 are used in the design of the cluster head nodes in networks that have wireless sensor network and wireless motion network characteristics. Employed an updated LEACH clustering method to examine the impact of the number of cluster head nodes on latency and

energy usage using a single multi-span greenhouse as an example. Compared to a single clustered network, the network's lifetime and real-time performance have greatly improved with the deployment of optimized cluster head nodes.[10]
Xihai (2010) et al. assessed the effectiveness of NMDS-RSSI localization algorithms using data from various farm conditions. Deduced that as the signal propagation coefficient increases, the average value of the localization error has decreased. And also demonstrated the NMDS algorithm's robustness in challenging environments. In addition, they discovered the connection between connectivity and localization error. According to the simulations, under identical simulation conditions, the NMDS-RSSI localization technique performed better than the MDS-MAP.[29]
Sonal (2010) et al. designed and constructed a wireless sensor network that can track the ambient light intensity, humidity and air temperatures in a crop field. Farmers and other end users may find this to be helpful in better understanding the agricultural practices that should be used for crop management. A plant fire detection mechanism has also been integrated into the system because it is impressive to detect plant fires early in order to avert significant crop damages. The system is made up of nodes, each of which has radio frequency modules and tiny application-specific sensors installed.[106]
Bradford (2010) et al. deployed networks with more sensors that can communicate with less electricity and with more dependability. These characteristics make this type of system ideal for agricultural applications, where a high number of sensors is needed to give the requisite level of control granularity. The trend towards a sense and control infrastructure, which enables quick, informed decisions regarding environmental factors will need to be maintained by utilizing inexpensive motes.[42]
Ying (2011) et al. introduced the architecture and core technologies of a particular type of wireless sensor network node system, including the protocol used for node-to-node communication and the way in which sensor networks are used in digital agriculture. A novel approach to gathered, analysis and applied information is put forth and it is real-time, independent and flexible enough to be tailored to agricultural production management.A novel approach to gathering, processing, and applying information is suggested.[28].
Shinng (2011) et al. addressed the research and engineering issues in implementation and deployments, explained practical experience and presented the design of a WSN for PAMS. By controlling and keeping an eye on the growth period, these systems aimed to increase crop yields. PAMS is based on the wireless sensor network method and has gained more attention. The precision agriculture monitor system or PAMS is an intelligent system that may serve farmers and kept an eye on crop environments[94]
Luca (2011) et al. determined whether RFID technology can be used to establish a comprehensive traceability system that encompasses the operations from the farm to the fork, the RFID Farm to Fork was established. It describes a system for wine traceability from the vineyard to the consumer glass, along with relevant electromagnetic and deployment concerns based on the joint use of RFID technology and WSN. After that, the current deployment progress is revealed and two distinct wineries that were chosen as pilot locations.[64]
Zhenyu (2012) et al. explained a wireless agricultural and environmental sensing system for crop monitoring, based on research and applications in precision agriculture. TinyOS is used to build up the smart crop monitoring system, and historical and real-time agricultural data are used to conduct system tests. The application scenarios are accurate and reasonable, according to the results, allowing users to correctly get information from their surroundings.[44]
Jianfeng (2012) et al. employed RFID sensor network technology alongside Zigbee wireless sensor network technology to monitor the quality of agricultural products, effectively addressing the integration challenges between these two technologies. The application of RFID and Zigbee wireless sensor network technology for creating cost- effective electronic labels for the Internet of Things is a promising endeavor.[7]

Tripathy (2013) et al. worked for better understand the relationships between crops, weather, environments and pests and diseases, an experiment was carried out using wireless sensor and field level surveillance data on the closely related and interdependent pest and disease dynamics of groundnut crop over the course of four consecutive agricultural seasons in a semi-arid region of india. In order to transform the data into meaningful information, knowledge, relationships and trends to understand the crop-weather-environment- pest/disease continuum, association rule mining and multivariate regression mining approaches and algorithms were conceived, developed and tailored.[114]

Abouzar (2014) et al. highlighted the growing significance of wireless sensor and actuator networks for farmers and orchardists seeking enhanced methods in pest control, precision irrigation, fertilizer application, frost and fire detection, crop maturation tracking, silage monitoring, and livestock management. Notably, the challenges posed by signal disruption caused by vegetation along the transmission path significantly hinder wireless propagation in agricultural settings. These discoveries are poised to exert a substantial influence on the future design of wireless networks for agriculture.[4]

Manlio (2014) et al. discussed the UAVs radio propagation model when they function as mobile modes in a wireless sensor network on the ground. As a result, more precise radio propagation models are required in order to assess the viability and efficacy of using UAVs in a variety of scenarios. This work’s primary contributions is to show that, when employing an unmanned aerial vehicle to operate and communicate with a ground wireless sensor network, there may be too many variables to account for in the traditional two-ray route loss model.[68]

Abel (2015) et al. presented a novel approach to the development of wireless sensor networks that are appropriate for describing the microclimatic behavior of agricultural areas. Sensing modules have been installed on the nodes to measure various physical properties. Their purposeful designs to consume as little power as possible, allowing them to function without an energy harvester for an entire season. The trial conducted in Montepulciano, Italy has shown that package permeability to moisture and humidity was the first source of issues. Reliability has reached 99% after the problem has been resolved.[26]

Hirofumi (2015) et al. provided a wireless control system for tomato nutriculture even under harsh circumstances. Utilized the 429MHz spectrum and two channel access techniques, were able to implement a highly dependable wireless control system and archive wireless communication without experiencing packet loss. Wireless sensor networks are unable to collect environmental data or control devices, though because of metal pipes or leaves.[121]

Mohamed (2016) et al. suggested employing CCTV cameras and WSN sensors to gather and track data about the growing conditions of crops both inside and outside of greenhouses. Both the temperature and humidity sensors are highly dependable and then created internally. Moreover, the technology enhances crop output by enabling remote, automated control of the greenhouse climate. The hardware, software and process control architecture for the agriculture environment monitoring system are presented in this paper.[30]

Elisa (2016) et al. presented an alternate approach that can be included into microwave sensor nodes. Typically, electronic instruments are used to assess leaf wetness. These devices monitor the electrical resistance or the dielectric constant of the leaves’ upper surface to determine whether water is present on the leaves. The reflection coefficient of microwave aperture antennas coated with plastic porous film is used to measure the presence of dampness. A few initial lab measures validate the solutions’s viability.[54]

Sunil (2016) et al. suggested an agro advice system for the pomegranate field in this regard. A wireless sensor network is set up in the field to continually monitor crop-specific, soil, hydrological and environmental data in real time. It’s a thread to agricultural growth, productivity and quality. Farmers received an agro advisory via email and SMS based on current field conditions. The

suggested system's examination of the experimental results demonstrated an improvement over the conventionally used approaches.[101]
Kristoffer (2016) et al. presented the data using a graphical user interface and the primary goals are to install a low-cost sensor system, collecting field data. Data was acquired using sensors for temperature, wetness, brightness, electrical conductivity, pH, and humidity. The Raspberry Pi served as a local server for data processing and transport. SQL was used to organize and store the sent data in a main server. Visualized the collected data, a graphical user interface was designed.[120]
Aruul (2017) et al. explained the smart agricultural system's primary goal is to increase field yield. Two primary streams were used in this paper, selecting the best crop to plant for the upcoming crop rotation, modifying the field's irrigation system through selective irrigation. The objective accomplished by routinely checking the field. The procedure of monitoring entails gathering data regarding the field's soil properties. The purpose of establishing a wireless sensor network is to gather data and periodically upload it to the cloud for retrospective analysis.[62]
Lijun (2017) et al. described the design of wireless sensor networks based on greenhouse environment monitoring systems. The system has used temperature and humidity sensors SHT11 and light intensity sensors BH1750 for data monitoring, a CC2530 microprocessor, and LabVIEW software to realize the man-machine interface. The system integrates detection, wireless communication, alarm, display, control and other functions into one.[123]
Aruul (2017) et al. worked on two primary streams, selecting the best crop to plant for the upcoming crop rotation and the other one is modifying the field's irrigation system through selective irrigation. The aforementioned objective is accomplished by routinely checking the field. The procedure of monitoring entails gathering data regarding the field's soil properties. The purpose of establishing a wireless sensor network is to gather data and periodically upload it to the cloud for retrospective analysis. The metrics are based uploaded data.[107]
Sachin (2017) et al. described the development of an agricultural support system for the management of large-scale commercial agriculture using WSAN and information technology. Agricultural characteristics and climate conditions are automatically monitored in real-time. It has the potential to increase crop yields while lowering waste and labor costs. A WSAN test-bed implementation for the FARMNET agricultural assistance system is established. The network is communicated with the master station, a central repository, in real time, detecting the agronomic and meteorological factors affecting crop outputs.[49]
Mohamed (2017) et al. established fundamentals of WSN and mobile computing technologies in order to present a smart system for shiitake mushroom cultivation in a greenhouse environment. This application uses wireless temperature, humidity and CO_2 sensors to gather data. The system employs a feedback cycle to monitor sensor data, with control devices activating in response to predetermined threshold values. By implementing SSSM, the mushroom production will be maximized and human resource utilization will be optimized.[53]
Carlo (2017) et al. pioneered the use of the network system for agricultural environment monitoring. Wireless Sensor Networks are frequently employed for effective farming management in the agricultural sector. The three key environmental parameters, that is, light, temperature and the humidity were measured using a variety of integrated sensors inside the lettuce growth chambers. The utilized raspberry pi as the primary component in the sensor node architecture provides an ideal foundation for a dependable, yet reasonably priced, wireless sensor network monitoring system.[13]
Jobish (2019) et al. researched a multi-hop tree based wireless sensor network for agricultural monitoring applications is designed and put into operation. In the actual network, the built data collecting tree's maximum depth was found to be five hops. The difference between the measured soil moisture and the commercial time domain reflectometry is observed to be ±3%. The performance of the in-house designed soil moisture sensors is tested using the installed WSN.[78]

Santosh (2019) et al. implemented and offers a way to distribute fertilizer that is needed for field crop production. The Newton Forward Difference (NFD) method of fertilizer distribution can be optimized with great efficiency by utilizing wireless sensor networks. Achmad (2020) et al. implemented wireless sensor networks and managed birds in rice fields. The primary sensors for identifying bird pests are PIR sensors, which have a wide field of view and cover the entirety of rice fields. Buzzers are used to deter bird pests. The system is constructed using mesh topology, which enables bidirectional communication between sensors and allows them to be aware of each other's situations.[80]

Maged (2019) et al. developed a system that uses LoRaWAN technology to assist farmers in remotely tracking their crops. The system's key characteristics that make it appropriate for a farming context are its extremely low power consumption and wide signal coverage area. Inaddition, the sensors assisted in providing farmers with vital information. The first step in the process was deciding which suitable and reasonably priced sensors to use.[133]

Xiaofan (2019) et al. discussed a fully customized hardware platform with a unique network structure made possible by LoRa and ANT radios in order to create a low-cost, low-power, long-range, wireless sensor network for smart farming. The LoRa component of the network was tested by placing four modules throughout an agricultural site, with data gathered over a six-month period and the hybrid network structure was demonstrated in the lab.[119]

Yu Han (2020) et al. implemented irrigation using a fuzzy PID control approach with STM32 microprocessors as the controller. It measures environmental data using wireless sensor networks and monitoring technologies, enabling intelligent irrigation. It can help to further realize the sustainable growth of the area's agricultural economy, enhance the level of farmland irrigation automation and address issues with weak stability and water resource waste.[56]

Chuan (2020) et al. utilized UAV as the wireless charging element to increase the agricultural monitoring systems based on IWSNs availability. Suggested a design for an embedded IWSN system that uses UAVs as dara relay and charging devices, with IWSN functioning as the data sensing or gathering component. Addressed the energy-optimal charging path planning problems with length constraints for the UAV assisted IWSN based agricultural monitoring system, where all residual energy for the network is considered simultaneously with the charging path's length. They have used the linear programming technique to define the problem and suggest an enhanced version of the max-min ant system (MMAS) algorithm, an adaptive optimization method for determining the UAVs charging path.[57]

Timothy (2021) et al. presented a novel strategy dubbed the Intellectual Agri-Data Processing Scheme that aims to effectively serve the agricultural field through the integration of cutting-edge technologies. With this method, it is possible to collect agricultural field data in real time and send it to the processing unit for modification. Farmers can use this service to check the crops' details at any time and form any location. The following section provides graphical evidence for the high degree of accuracy in anticipating the field details and associated monitoring ratio.[65]

Naveen (2021) et al. described a robot that sprays pesticides using a microcontroller. The primary phrases involved is dispersing seeds, identifying obstacles and applying pesticides. An automated arm will drill to precisely the right depth and space the seeds apart in order to plant the seedlings. The water syphon on the robot's bottom body will be adjusted, and water will be sprayed where needed. The seed will be covered with just the right amount of manure. The research presented a simplified machine that is manufactured and demonstrated to complete the duty of growing in the agribusiness industry.[137]

Aleksandr (2022) et al. presented the electromagnetic robustness of SmartMesh IP and IO-link Wireless for use on agricultural vehicles. For such wireless communication protocols, the reflective aspect of the agricultural vehicle poses particular challenges, particularly with regard to multipath fading. Both a real combine harvester and a double reverberation chamber were used to verify the electromagnetic robustness. The document contains comprehensive test setups and

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procedures. In order to confirm the environment produced in a harvester, the first steps were taken to dampen the RC with absorbers, yielding a comparable PER of 4.1%[51].

Anulekshmi (2022) et al. approached supervised multi-model data regression algorithm serves as the foundation of prior efforts. The suggested method makes use of an acoustic sensor as well as an insect pest detection sensor that tracks the noise level produced by the pest insects. These sensors significantly lessen crop loss by assisting in the early detection of infestations. In order to enable continuous network operation, energy harvesting-aware protocols and algorithms must be developed. Energy conservation and management are major challenges in EHWSNs.[55]

Mehmet (2022) et al. performed path loss analysis using the data from the control experiment and field measurements. Experiments with more than 6,860 data points gathered in three agricultural fields over a five-month period support findings that common crops like soybean and maize affect the mmWave channel. The insights offered crucial recommendations for the implementation of millimeter-wave wireless networks in agriculture.[135]

Malebo (2022) et al. researched an IoT based wireless sensor network solution for crop monitoring that includes an energy efficient sensor node as a crucial component. The energycontribution of a solar harvesting sub-system and the energy consumption of each component are examined through a survey of recent literature publications. This study can be used to the design of an energy-efficient wireless sensor node in an effective manner using a generic model.[115]

Jiang (2023) et al. designed and developed the control circuit of ES8H698, a 32-bit general purpose microcontroller based on the ARM Cortex-M0 CPU core and investigated the wireless communication method of LoRa. And achieved remote wireless information transmission and control, it has been tested and implemented to a caterpillar spray machine with satisfactory results.[17]

V MARKET ACCESS AND INFORMATION SHARING

Amar (20 08) et al. developed a competent decision support system that enhances agricultural practise and decision making. An initiative to supply agricultural intelligence is the focus which draws lessons from that experience. Novel approaches and research concepts are put forth for sensor network design in order to tackle the unique problems faced by developing nations. It consisted a multi-sink architecture with corresponding back- link/storage aware complementary routing, a zone-based joint topology control and power scheduling method and a parameter-energy-environment aware task scheduling approach.[43]

Norio (2011) et al. designed open source, authorized partners are free to use their own technology to create additional sensor devices and link them to the e-kakashi platform. Accredited partners have secure access to and storage of data via API on the e-kakashi platform. Demonstrated how the internet of things and the e-kakashi information cloud related to agricultural data and its use cases.[103]

Zheng (2012) et al. specialized sensor nodes are designed and an information gathering system for the agricultural environment is introduced. It has used to manage multitasking. The operating system undergoes optimization based on demand to improve system performance. To create a user-friendly, touchable graphical user interface is ported. The suggested system combines low power consumption embedded technology, wireless communication, system-on-a-chip, micro - electro-mechanism system and low power consumption embedded technology to accomplish data gathering, processing and transmission tasks.[39]

Polpitiya (2012) et al. described how to create an affordable wireless sensor network that can monitor an agricultural area from one place and be flexible enough to accommodate different kinds of farming. It also looks at whether it would be possible to build and market reasonably priced agricultural electronics. In addition to being easy to use and dependable, the environmental monitoring system must be reasonably priced for the typical farmer and flexible enough to accommodate the various needs of various farming practises.[50]

Manlio (2014) et al. addressed the UAVs radio propagation model when they function as mobile nodes in a wireless sensor network on the ground. UAVs have received a lot of interest from the scientific community as well as the market. The result is more precise radio propagation models are required in order to assess the viability and efficacy of using UAVs in a variety of scenarios. The primary contribution is employing an unmanned aerial vehicle to operate and communicate with a ground wireless sensor network, that may be too many variables to account for in the traditional two-ray route loss model.[99]

Julius (2014) et al. described a novel IEEE 802.11 based method for soft real-time networks. The concept is to forecast the real-time service quality for moving agricultural vehicles by using available sensory data, such as the transmitter's signal strength and the relative positions of the vehicles. The technique is implemented in a prototype way on board two agricultural vehicles. [132]

Sanku (2015) et al. proposed a wireless sensor network based hardware prototype for agricultural field intruder detection. It has been named Agricultural Intrusion Detection (AID). It has assisted in setting off alarms in the farmer's home and simultaneously sends a text message to the farmer's mobile device when an intruder enters the field. It has built and constructed wireless sensor boards with Advanced Virtual RISC (AVR) microcontrollers across an outside environment to execute the proposed scheme and assessed the performance.[11]

Rabin (2017) et al. presented a clustering algorithm based on a Low Energy Adaptive Clustering Hierarchy (LEACH) protocol, that has minimized energy dissipation from sensors during data transmission which helps in agriculture monitoring with low cost. The LEACH protocol has been adjusted to extend the sensor network's lifespan. This updated version of the LEACH algorithm lowers energy consumption in WSN at each stage. In contrast to existing protocols, the modified LEACH protocol balances the energy in the network and reduces energy consumption by 10%.[27]

Zhenzhen (2018) et al. presented and implemented a research on agricultural machinery operation system based on Beidou navigation system in order to address the issues of high material input costs in traditional agriculture, heavy people reliance and low agricultural production efficiency. To precisely position locomotives performance and provide real-time monitoring of locomotive performance, the system combined BeiDou satellite positioning technology, wireless communication technology and geographic information technology.[142]

Yuki (2019) et al. presented a low power wide area wireless internet of things system for agriculture. A sensor network, remote control devices, and a smartphone application make up the internet of things system. Farmers have technology at a reduced cost by sharing the LPWA communication infrastructure, which covers every field on a large farm. Farmers can also support one another by using the smartphone application, which gives them the ability to share farm information while maintaining control over their privacy.[136]

Jennifer (2019) et al. researched blueberries from the point of harvest to the point of distribution. The agricultural technique has wider effects such as lowering food loss and waste and enhancing availability, forecasting, response time and other aspects. For the first significant portion of the F2F trip, a WSN architecture, implementation and real-world experimental findings are described. A balance of technical proficiency and use case expert knowledge of operations, infrastructure, trends, constraints and user experience on the floor is needed for this application-driven design.[146]

Emmanuel (2020) et al. offered a novel multi-objective optimisation framework for the clustering based on agricultural internet of things that aimed to maximize coverage stability and power consumption. Energy management, connection and application related issues arise during the planning, design and operation stages of CA-Iot networks, and these issues frequently lead to conflicting MOO problems. The relationships between these goals and how they affect the lifetime of the network and its operational effectiveness are yet unclear.[129]

Khujamatov (2020) et al. examined how IoT and WSN are now being used in agriculture as well as their prospective benefits in the future. Global experience has demonstrated that wireless sensors are used in the quality of work for remote monitoring, control, monitoring and sales of agricultural goods utilizing Iot, sensors and communication methods. Opened a new line inquiry by the widespread adoption of digital technology and wireless sensor networks (WSN) in all fields.[21]
Natalia (2020) et al. designed a network interconnection unit to address the interoperability between electronic control units on agricultural machinery. The NIU has used the ISO 11783 protocol implementation to link two heterogeneous physical networks-one based on the IEEE 802.15.4 standard and the other on the CAN 2.0 B standard in order to expand the latter protocol for wireless applications.[144]
Sun Jie (2020) et al. designed a system for controlling the agricultural environment using wireless sensors. Parameter acquisition and transmission can be realized with the STM32F103C8T6 series 32-bit microcontroller as the primary control chip, sensor acquisition, NRF24L01 radio frequency and GPRS wireless data transfer. The system is powered by solar energy. More advanced computer software has real-time device control and data storing and display capabilities. The experimental findings has demonstrated the excellent precision with which the system has measured the data.[38]
Lei Liu (2021) et al. developed to enable wireless sensor network networking and TOSSIM is used to simulate the network, a distance-based routing method is used. It addresses the issue of packet loss in wireless network data transmission by examining the TinyOS operating system’s mechanism and message structure. Developed a MAC protocol based on network synchronization to guarantee dependable data transfer. The experimental results have demonstrated that the two nodes has transmitted data normally when the communication distance is 230m and the bit error rate is very low when the communication distance is less than 310m and the bit error is greatly reduced when the distance exceeds 360m and the when the distance exceeds 400m.[25]
Giovanni (2022) et al. suggested a paradigm for assessing the network security of agricultural vehicles using four primary criteria, GPS security, remote control via radio-links, wireless gateways and CANbus security and network segmentation. Described the associated techniques and procedures and showed the testbed are built to evaluate the suggested procedures.[105]
Samriti (2022) et al. offered the analysis and discussed in addition to the responses to the survey questions. Research and findings demonstrated that the basic network infrastructure for agricultural areas is reasonably priced, however the addition of certain features to the sensing devices significantly raises the cost. Furthermore, poor internet connectivity in rural areas and farms limits the information sharing between farmers and agricultural experts.[150]
Bancha (2023) et al. determined the vegetation effect for wireless sensor networks using an adaptive neuro-fuzzy inference system, the experiment’s measurement data set, which includes the height of the rice planted at 105cm and the antenna height of 55cm, was utilizedto determine the vegetation effect for wireless sensor networks. The 2400 MHz and 930MHz frequencies were employed at varying ranges, ranging from 5m to 55m. When compared to the Weissberger model, the ANFIS model produced more accurateresults.[125]

CONCLUSION

The role of modern technologies significantly influences the success of businesses and the development of various fields. In particular, wireless networks possess the capability to provide solutions to complex problems. They have reshaped numerous industries, with the agricultural sector, in particular, benefiting from their sustainability and innovations. Food production is a paramount focus for every nation, as the level of food security directly impacts a country's economic standing in the global market. The transformative power of wireless networks has a positive impact on agricultural productivity. Farmers are increasingly motivated and aware of the utility of smart agricultural devices in their farming practices. These technologies assist farmers in reducing labor, costs, and the time required for disease identification and prevention. This research sheds light on the advantages and challenges addressed by wireless networks in the agricultural sector.

Future Enhancement :

While this paper provides a clear explanation of the solutions to numerous agricultural farming challenges, further research is required to explore the full potential of wireless networks in disaster management. This paper aims to raise awareness about disaster management among academics.

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