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A SMART SURVEILLANCE ESTABLISHMENT IN AGRICULTURE

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Abstract

As every individual knows, agriculture's history dates back several thousand years. Agricultural is a great deal of important segment of the country's economy, and it contributes significantly to the nation's economic and social progress. Agriculture is a type of science that involves producing vegetation and livestock. A significant proportion of the population in economies that are developing is involved in agriculture, in either a direct or indirect way. This study gives the adoption of LORA in the agricultural field and the view of state of the art solutions for the smart agriculture to look at the potential of the technology in different infield applications. Emerging technology for networks, including as WSN and IoT, weren't previously straightforward to design and implement in agriculture. The increase in the rate was not increased by employing outmoded, traditional methods and technologies. Furthermore, rapid population growth cannot match human needs and desires. A number of efforts have been made to increase agricultural productivity. Yet, adverse atmospheric conditions along with frequent infestations of pests cause agriculture damage. In such a case, the incorporation of modern technology such as improved sensors and the Internet of Things (IoT) could increase crop yields while minimizing economic loss. Imagine the scenarios namely irrigation system, plantation, and crop monitoring, tree monitoring and livestock monitoring which shows the heterogeneous requirements in terms of network bandwidth density sensors complexity and energy demand, as well as the late decision making. This study guides the formers in developing countries to improve their farming profit with less man power. Lora-based solution works on these above mentioned scenarios to look into the scalability interoperability network architecture and energy efficiency and provide the possible future research directions.

Keywords: Internet of Things, Wireless Sensor Network, Real Time Monitoring, Efficiency in Farming.

1. INTRODUCTION

The agricultural sector will be facing a significant challenge in the future due to various reasons like overpopulation across the world, resources in demand, changing weather conditions, and a decrease in the number of arable lands [1] and by the year 2050, the world population will reach 9.8 billion which is 25% increase over the current world population [2], [3].

To overcome these problems, we need to come up with more feasible and practical solutions to shift from the olden farming concept to smart agriculture [4], with the incorporation of information and communications technologies(ICTs) which helps the farmers to manage and optimize their work more efficiently [1].

In introducing the Internet of Things (IoT), all the problems faced in agricultural production can be improved from soil management to minimizing consumption of water, plant protection and animal health [5],[6].

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Smart devices can be installed in fields so that they can collect information and it controls the various production stages of the different processes. Therefore, growth of these technologies and wireless sensors for agriculture, edges the easy usage and operation, as well as their low cost for production, allows monitoring parameters like humidity, temperature, soil acidity, wind speed and direction, chemical concentrations, crop growth, and solar exposure to be measured in different areas as well as damages made my drought, hail or flooding. They can also be installed in regions of difficult access, such as mountainous areas, deserts and slopes, and also other potential places where agriculture can be developed [1], [5], [7].

Wireless sensor networks (WSNs) have been widely promoted in agriculture, as a means to enhance on-farm yield and profitability through the provision of real-time or on-demand sensed data. WSNs are used to transmit data wirelessly from various nodes to a relay node or a gateway [5]. In agriculture, the majority of WSN applications involve observing soil moisture and weather, with the gathered data usually employed to aid in making irrigation decisions [8].

Lack of adoption is often due to damage risks to in-field sensors and WSN nodes by machinery, weather, animals, and pests. The best solution is to create a wireless underground sensor network (WUSN) by burying all components below the cultivation depth. This operates wirelessly by sending data through both the soil and air between two buried sensor nodes as underground-to-underground ground communication (UG2UG)

1.1 Smart Agriculture in Developed Versus Developing Countries

Agriculture plays a crucial role in both developed and developing countries, but there are significant differences in how it is practiced and the challenges faced. In developed countries, agriculture is often characterized by advanced technology and mechanization, allowing for increased productivity and efficiency.

On the other hand, developing countries often face limitations in terms of resources, infrastructure, and access to modern agricultural technologies. As a result, they may rely more on traditional farming methods and face challenges such as low agricultural productivity and food insecurity. Additionally, in developed countries, agriculture is more focused on commercial production and export-oriented farming, while in developing countries it is often subsistence-based, with a greater emphasis on meeting local food needs [1].

From ancient plant domestication to modern biotechnology and the ongoing digital revolution, agriculture has continuously aimed to enhance productivity and sustainability. Smart agriculture, integrating digital technologies like AI, IoT, LoRa and big data analytics, pledges optimized resource management, improved decision-making, and resilience against climate change for sustainable farming practices [1], [7], [4].

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Fig 1: Method of spraying pesticides

A scene in a developed country (Fig. 1): under a blue sky with white clouds, several drones are seen flying over a lush green field, spraying the crops below them. The bottom photo, contrastingly, depicts a scene in a developing country where a person is seen manually spraying crops in the field. In above picture drone alone doing the work of 4-5 persons. Drone finishes the same work within 1-2hrs that a person takes around 8-9hrs.

Some of the most efficient and convenient tools in Smart Farming include:

Machine learning: Self-learning technologies provide the capability to anticipate shifts in climate patterns, variations in soil and water attributes, carbon levels, the spread of diseases and pests, and a range of other factors [4].

Smart farming sensors: Highly sensitive sensors empower farmers to monitor even the subtlest alterations in the environment and fields in real time [3].

Drones and satellites with cameras: With their help, growers can create regularly updated maps and monitor the territory remotely without the need to go to the field.

Big data: The absence of these tools makes it challenging to envision accurate forecasts, plan activities effectively, and create more streamlined business models [9]. Smart farming and big data are essential for making both immediate and long-term decisions, enabling you to take proactive steps and implement more efficient strategies in the present while also planning for the future [7].

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Internet of Things (IoT) it offers the chance to integrate all tools and solutions into a unified system. Every device and software within this system can share data and execute specific actions based on identified patterns [10].

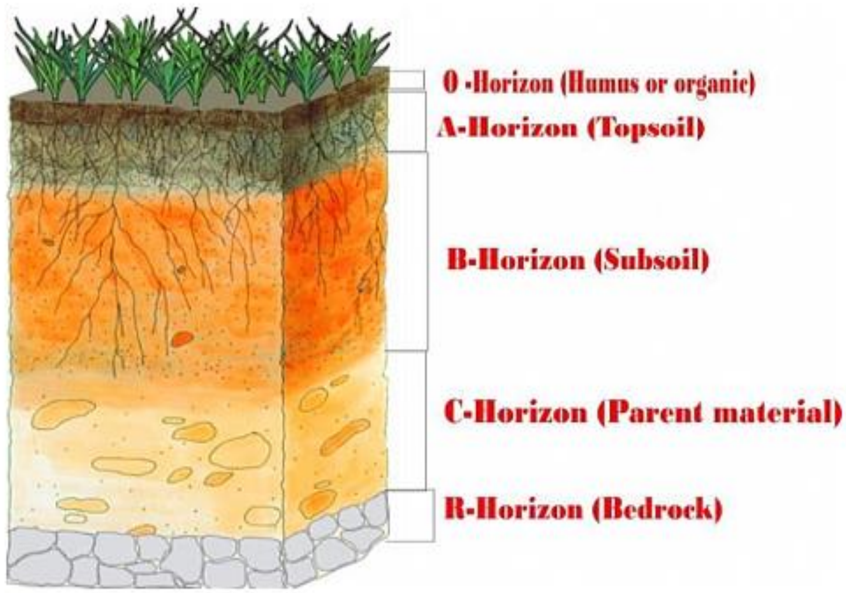

Fig 2: Soil Layers Profile

Until now, growers lacked an effective means of evaluating soil conditions beyond visual crop inspection. Soil Layers also known as horizon. The layers further classified into 0 denoted as humus is decomposed, dark-colored, carbon-rich content and biomass from microbes are combined with minerals that are fine-grained in order to produce composite formations is denoted as topsoil is made up of particles of minerals and organic material and often spreads to a depth between 5-10 inches, B denoted as subsoil refers to the thin layer of soil beneath the topsoil on the ground's surface. Like topsoil, it is made up of a fluctuating combination of tiny particles that include clay, sand, and silt, but with a significantly lower proportion of biological matter and humus, as well as a small number of smaller pebbles. The subsoil is referred to as B Horizon, C denoted as the solid materials that make up soil are in their initial state, known as the parent material. It can consist of solidified rocks, and it can also include debris that has not consolidated, such as river soil, lake or underwater sediments, icy tills, loess, ash from volcanoes, and organic material (for example, accumulations in swamps or bogs). Parent materials affect the creation of soil by influencing mineralogical content, texture, and division (layering). Dark-colored ferromagnesian (metals like iron and magnesium-containing) rocks, R denoted as bedrock refers to the hard, solid stone underlying surface layers like dirt and pebbles. Bedrock also rests beneath sand as well as additional layers on the ocean bed. Bedrock is a cohesive rock, which means it is strong and tightly compacted. Bedrock can stretch several kilometers below the earth's surface, near the bottom of the crust. However, the emergence of IoT has revolutionized agricultural landscapes, enabling fields to articulate their fundamental needs for flourishing. Soil monitoring sensors now

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offer immediate readings of soil temperature, volumetric water content, air temperature, and crucial nutrient levels like nitrogen, phosphate, and potassium (NPK). These sensors transmit this data directly from the field to the Internet, providing real-time insights. With customizable data delivery intervals, manual readings are no longer necessary. As a result, precise forecasts for optimal planting and fertilization schedules become feasible, leading to reduced water consumption and alleviating plant stress caused by excessive or inadequate watering [4].

In developed countries, the integration of Industry 4.0 technologies like IoT, AI, robotics, and big data into agriculture is a relatively recent but promising development that holds significant potential to transform the sector by enhancing efficiency and sustainability. Smart agricultural technologies enable farm monitoring and automation, swiftly detecting issues such as water stress, material wastage, crop diseases, pests, nutrient deficiencies, and animal welfare concerns. These technologies enable real-time data collection and analysis, allowing farmers to make decisions promptly [7]. For instance, IoT devices and sensors monitor soil moisture levels, temperature, humidity, and other vital parameters, providing farmers with precise insights into crop health and growth conditions. AI algorithms process this data, offering predictive analytics and actionable recommendations. As a result, farmers can optimize irrigation schedules, tailor fertilization plans, and apply pesticides only where needed, reducing input costs and environmental impact.

However, implementing smart agriculture in developed countries faces challenges:

1. **Communication Reliability Barriers:** Establishing robust and secure network architectures for large-scale IoT implementations remains a challenge. Technologies like LoRa/LoRaWAN are considered to ensure reliable information communication, especially in rural areas.
2. **Power Optimization:** Power supply in smart agricultural devices is a significant challenge. Research focuses on energy harvesting systems and optimizing power consumption in sensors and distributed computing (Edge computing) to ensure efficient energy storage and supply [1]
3. **Data/Device Heterogeneity:** Diverse agricultural data sources from various sensors using different network protocols and platforms pose compatibility challenges. Simplifying these technologies for inexperienced farmers is crucial.
4. **Physical Integration:** Deploying monitoring devices across vast and diverse farm areas, covering soil, plants, trees, and animals, presents logistical hurdles.
5. **Data Maintenance:** Interpreting and managing extensive sensor data, and employing big data analysis to understand and predict agricultural ecosystems, proves to be challenging.
6. **Generic Platform:** Developing user-friendly software platforms adaptable to diverse monitoring needs—from specific crops to livestock—poses a barrier to widespread adoption.

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LoRa technology has extremely transformed agriculture in developed nations by allowing smart farming practices through its long-range, cost-effective communication capabilities [11] With LoRa-enabled sensors, farmers remotely monitor vital parameters like soil moisture, temperature, and crop health, facilitating instructed decisions on irrigation, fertilization, and pest control [7] Weather stations equipped with LoRa sensors provide real-time data for accurate forecasting [9], and risk management, all while consuming minimal power, long-range covering, reducing maintenance costs, and ensuring continuous data collection without frequent battery replacements [5], [12]

Furthermore, advanced analytics and machine learning transform data from LoRa sensors into actionable insights and predictive representatives. These analyses empower farmers to make knowledgeable decisions, optimize crop management techniques, and improve resource utilization. LoRa seamlessly blends with existing agricultural systems, simplifying adoption without significant infrastructure changes. Continuous innovation in IoT and wireless communication technologies further drives the development of more efficient and reliable LoRa-based solutions for farming needs [7].

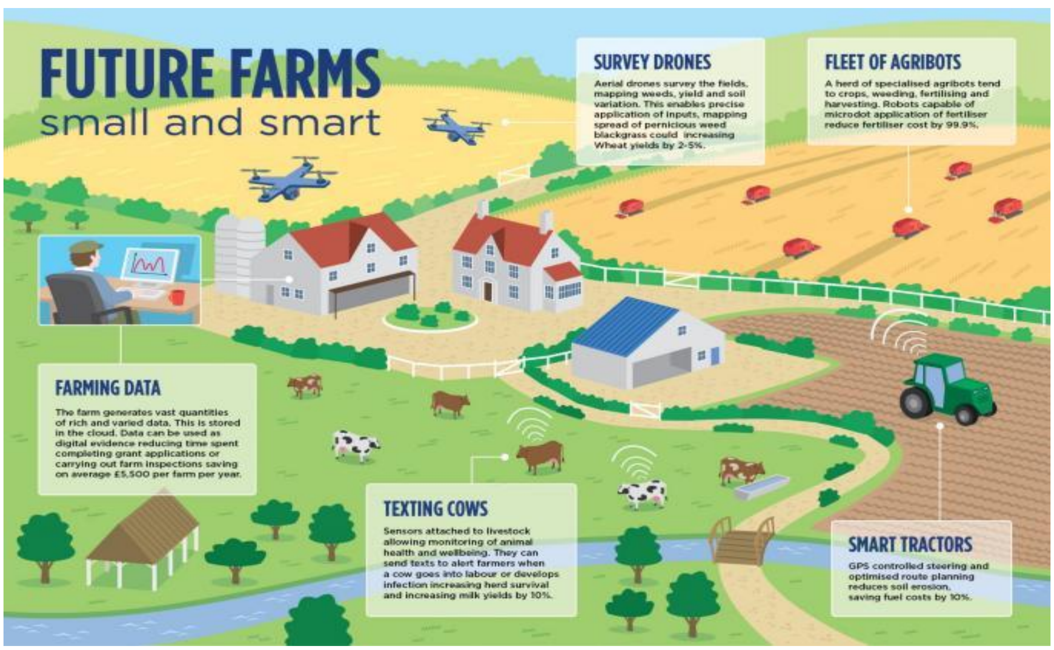

Fig 3: Future Smart innovative agriculture methods

An illustrative depiction of a high-tech future farm (Fig. 3). It features four key sectors: survey drones, smart tractors, 'texting' cows, and farming data. The drones and a fleet of agribots appear to be involved in the surveying and tending to the fields. Meanwhile, cows equipped with sensors for health monitoring are scattered across the field. The tractors, portrayed as being guided through GPS controlled steering and optimized route planning, are working on the farm.

A farmer is also present in the scene, presumably operating technology involved in running these smart systems. Various sections of the image provide explanations on how

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this data-driven farming operates, detailing contexts like rich data being stored in the cloud, the potential to increase wheat yields and milk yields, reduction in time spent completing grant applications or carrying out farm inspections, and savings in fuel costs. The general backdrop is of an idyllic rural farm, complete with a farmhouse, a barn, a silo, and green fields under clear blue skies.

In developing countries, LoRa's affordability, low power consumption, and long-range capabilities are particularly advantageous for smart agriculture applications [13]. Its ability to operate in remote areas with limited connectivity makes it a suitable choice for enhancing agricultural practices in regions where resources and infrastructure may be limited.

The deployment of LoRa technology in the context of key benchmark scenarios such as watering systems, cultivation, and monitoring of crops, tree surveillance, and animal monitoring in poor nations can considerably increase numerous elements of smart agriculture [4], [13].

1.2 Irrigation Techniques:

The significance of monitoring soil water status in agriculture is to acquire substantial water savings and improve productivity while lowering energy costs associated with water pump management. It emphasizes the importance of analyzing the soil-plant-atmosphere sequence for effective water management. Various sensor technologies, including costly ones like lysimeters or micro-meteorological sensors, and more affordable options like time domain reflectometry (TDR) or gravimetric methods, are mentioned for measuring parameters like evapotranspiration (ET) and soil moisture.

LoRa can enable remote monitoring of soil moisture levels and weather conditions in agricultural fields, allowing farmers to optimize irrigation schedules [3]. It facilitates the deployment of low-cost sensors across vast farmlands, transmitting data reliably over long distances to a central hub, enabling precise water management. Several LoRa-based irrigation systems employing development boards like Arduino, ESP32, etc., are emphasized, some integrating energy harvesting for extended procedure [1], These systems use various sensor data and AI to create smart irrigation models for precise water distribution [3]. Instances include machine learning-based models using LoRa technology to predict soil moisture or employing Penman-Monteith-based irrigation models for optimal strategies based on crop growth stages and ET estimation.

Most LoRa-based systems for irrigation include climate, humidity, and moisture levels in the soil sensors, with machine learning employed for a small number of applications [3]. Furthermore, while evapotranspiration-based methodologies are relatively rare due to costs, combining inexpensive sensors and AI can potentially reduce expenses, making such measurements more accessible. Optimizing LoRaWAN communications by adjusting duty cycles based on system activity could further reduce water and energy usage [4], [14].

Therefore, the importance of sensor technology, AI integration, and communication protocols in developing efficient and cost-effective irrigation systems for agriculture helps in minimizing water usage while maximizing crop output.

1.3 Plantation and Crop Monitoring:

Sensor-based monitoring systems play a crucial role in agricultural settings, particularly in plantations and crop fields [15, 16]. These systems enable precise adjustments in pesticide and fertilizer applications, thus maintaining and improving productivity. Utilizing a multitude of sensors, including ultrasonic, optical, and weather stations, provides data on factors like nutrient levels, weather impacts, and crop conditions.

One significant aspect is optimizing productivity. Sensors facilitate production optimization by modifying pesticide and fertilizer application rates based on spatial and temporal variations in crop necessities. This strategy not only enhances yields but also reduces resource usage, making agricultural practices more sustainable.

Using LoRa-based sensors, farmers can monitor crucial parameters such as temperature, humidity, and soil conditions in real time across large plantations. This technology allows for the early detection of potential issues like diseases, pest infestations, or adverse weather conditions, enabling timely intervention to protect crops as it is efficient in transmitting data from sensor nodes to gateways and servers for analysis. LoRa's long-range and low-power capabilities make it suitable for wide-scale deployment in agricultural fields, enabling real-time monitoring and control [5]. However, challenges exist in deploying monitoring systems over wide areas and wireless channels [16, 17].Optimizing the limited payload size in LoRa packets for transferring a wide range of parameters remains an obstacle, particularly for devices located in open locations that are exposed to outside influences such as humans, animals, or agricultural equipment. These substances may mistakenly displace the sensor from where it originally was or harm it [1].

1.4 Tree Monitoring

Trees serve an important function in society, helping to avoid soil erosion, purifying the air, and producing wood or fruit. Continuous monitoring of tree conditions and microclimate characteristics is critical in urban/rural green spaces and forests. This monitoring focuses on determining growth rates, danger of failure, and the trees' functional responses to their surroundings [16]. Accurate readings require long-range transmission, dense sensor installation (one sensors each tree), and biological parameter assessment at specific tree locations.

Computing water transfer (sap flow) in the trunk is critical, and is frequently accomplished using Granier's heat balance approach. This method analyzes temperature differences between probes in the stem to gauge transpiration activity, assisting in accurate sap flow proportions. Technologies like TreeTalker (TT) monitor sap flow, wood temperature, humidity, light transmission through the canopy, trunk growth, accelerations, air temperature, and humidity. Another method, electrical impedance spectroscopy (EIS), characterizes tree health conditions. EIS determines physiological states like hydration

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levels and disease presence in trees. Integrating EIS into sensor nodes enables health analysis and data transmission via protocols like LoRaWAN [1]. LoRa-enabled sensors can track environmental factors affecting tree growth, such as soil moisture, sunlight exposure, and temperature, aiding in efficient orchard management. With LoRa's long-range capabilities, even remote or dispersed tree clusters can be effectively monitored and managed, contributing to improved yield and tree health.

However, scrutinizing tree systems face challenges due to foliage obstructing wireless transmission [7]. Node densification and employing drones with gateways become vital in nonhomogeneous vegetation environments, addressing communication issues and ensuring effective data collection [1].

1.5 Livestock Monitoring:

The progress of smart livestock practices focuses on enriching diverse aspects of animal husbandry, encompassing productivity, reproduction, feeding, and waste management [5]. These advancements directly impact farmers' income and elevate milk and meat production. Achieving these objectives necessitates continuous monitoring of animals' overall health conditions by tracking biological signals associated with disease symptoms [16]. Wearable sensor technologies offer a promising avenue for remotely controlling individual animals, streamlining urgent interventions, and addressing labor-intensive concerns more efficiently. However, in large systems for livestock farming, a lack of network accessibility and limited contact with animals make it difficult to efficiently use such technology. LoRaWAN technology emerges as a suitable solution for these applications due to its ability to meet these requirements. LoRaWAN-based tracking devices attached to livestock can provide real-time location monitoring and behavioral data, ensuring better herd management and preventing loss or theft. Vital parameters like temperature, activity levels, and feeding patterns can be remotely monitored using LoRa technology, allowing farmers to ensure the well-being of their livestock [5].

Furthermore, LoRa's scalability allows for the integration of multiple sensors and devices, facilitating comprehensive monitoring and management across large agricultural landscapes [5]. Collaborative efforts between organizations, and technology providers can help overcome initial setup costs and promote the adoption of LoRa technology, ultimately delegating farmers in developing countries to enhance productivity, conserve resources, and improve livelihoods in the agricultural sector.

2. KEEP AN EYE ON YOUR FARM'S ENVIRONMENT

IoT technology provides convenient and cost-effective solutions for monitoring weather conditions given in Fig.4, detecting floods, and maintaining water quality, offering accurate data for well-informed decisions regarding fields and crops [2].It provides remote access to real-time data on specific elements such as river and canal water levels, rainfall, temperature fluctuations, wind behavior, pressure in the air, and dryness at where you are precisely. This accessibility empowers the optimization of labour, water usage, and crop health through intelligent precision agriculture solutions [12]. Implementing a network of LoRaWAN sensors and gateways across fields allows for the immediate measurement

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of environmental indicators, proactively identifying potential issues before they escalate into critical situations [3].

Fig 4: Standardization Automatic Weather Station

3. SMART PLANT CARE TECHNIQUES

The agricultural sector stands as a foundational pillar in our society's economic activities, serving not only as a primary source of food but also as a contributor to foreign exchange. Among the significant agricultural subsets, horticulture, encompassing vegetables, fruits, ornamental plants, and biopharmaceutical plants, holds a strategic role. According to the Survey of Survei Pertanian Antar Sensus (SUTAS), the count of agricultural business households (RTUP) engaged in horticulture amounts to 10,104,683 households, ranking as the fourth-largest subset following food crops, livestock, and plantation households. However, despite this substantial household count, the contribution of horticulture to the 2019 Quarter I Gross Domestic Product (GDP) is merely 1.36 percent, equivalent to 126,060.6 billion. This disparity suggests that the potential of horticulture remains underutilized, prompting the need to measure production for strategic commodities within this sector. While horticultural crops are widely cultivated in Indonesia, the yield remains suboptimal due to insufficient knowledge in cultivation techniques, environmental factors, and pest and disease management [5]. There exists a misconception among some individuals that farming does not require specific high skills or updated knowledge in agriculture contributing to the gap in updated agricultural practices among farmers. Plant disease detection has become a compelling area of focus for artificial intelligence engineers in agriculture. Various models have been developed to assess their ability to accurately detect diseases and offer early warnings to farmers. A study comparing six traditional machine learning algorithms for classifying healthy and diseased papaya leaves.

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4. LORA IN AGRICULTURE

LoRaWAN (Long Range Wide Area Network) technology plays a major role in monitoring different concepts of agriculture, include farm assets, crop conditions, and livestock. This technology seamlessly integrates with the broader Internet of Things (IoT) or Smart Farming paradigm [2], [11], Through the utilization of IoT-generated data, agricultural producers and businesses can make well-informed decisions. The accessibility of this data on cellphones or computer monitors empowers farmers and ranchers with timely and comprehensive information, enhancing their ability to make informed decisions in managing agricultural operations [7]. The general architecture of LoRa is given below in Fig.5.

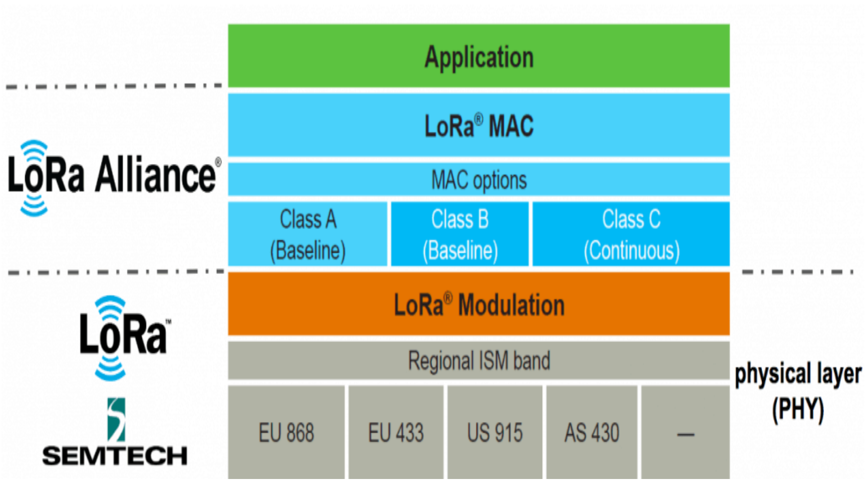

Fig 5: Architecture Model of LoRa

The component is supplied with power by an STM32L072CZ microcontroller and an SX1276 transceiver which is given below in the Fig.6. The transceiver utilizes the LoRa far-reaching modem, which offers ultra-long-range spread-spectrum transmission and exceptional radio immunity while minimizing current usage.

Fig 6: LoRa B-L072Z-LRWAN1 STM32

LoRa have the characteristics features of low power battery which extends 10 to 20 years of lifetime. It has the range in between 1 to 10 km and the establishment of infrastructure

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investment cost will be very low. It is more secure (through AES128 encryption). Another one of the main feature is GPS tracking lifelong. The materials needed to establish connection in LoRaWAN given in Table1.

Table 1: List of materials needed for connection

Sl. No	Materials	Description
1	STM32	LoRa board installed with STM32.
2	STM32 cube package	Package installation carried out to create the connection in between software and hardware kit.
3	Software Deployment	Software run on python platform as open source.
4	Gateway Settings	Connection established through gateway link.

Using the Things Network to Manage LORAWAN Systems

The Things Networking (TTN) functions as a network server that collects data from gateways and makes it available over the internet. It is a non-profit, freely available social network committed to supporting users in handling LoRaWAN information obtained via devices with sensors and making it accessible via the web for viewing. To link nodes and gateways that support LoRaWAN to The Things Network, various procedures must be followed. Each LoRaWAN gateway and sensor device has an individual address known as a EUI (Extended Unique Identifier), which is globally distinctive. Registering the EUI of each device under a TTN application is a crucial step in this configuration process. This registration allows the devices to communicate effectively within the TTN network and also shown in Fig.7.

Fig 7: TTN connection Message

Viewing the Data on My Devices Cayenne

Certainly! Utilizing My Devices Cayenne, a free and open-source website, serves as a viable approach to render data viewable on the internet. This platform functions as a server, offering visual dashboards specifically designed for sensor data obtained through LoRaWAN technology. Cayenne is a server that generates visual dashboards from

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sensor data collected using LoRaWAN technology. The Cayenne web dashboard enables users to visualize sensor data and set rules to send email or text message notifications when the data reaches a certain threshold. The LoRa cloud system architecture given in Fig.7.

Fig 8: LORA Cloud system

Gateway Selection

The gateway selection criteria were based on the distance that existed between stations and the Free Field Zone (FFZ) perimeter. In the scenario of Group 1, which consists of locations 21–25, these are the distances and altitudes of each station. These lengths range from 3.85 km to 8.20 km, with only stations 23 and 24 exceeding an individual figure of over 5 km. Notably, these distances are inside the permitted range of LoRa signaling [15]. The gateway connection needed NUCLEO-L073RZ and SX1272 low power radio frequency expansion board and also it connected with antenna through that it will send all the details about weather condition as well as live monitoring updates to the personal computer (PC). The USB (Universal Serial Bus) and Ethernet cable act as an intermediator in-between LoRa and modem. To collect all the data, MyDevices Cayenne an open source free platform utilized. In Fig.9 the strength of internet latency sends to PC.

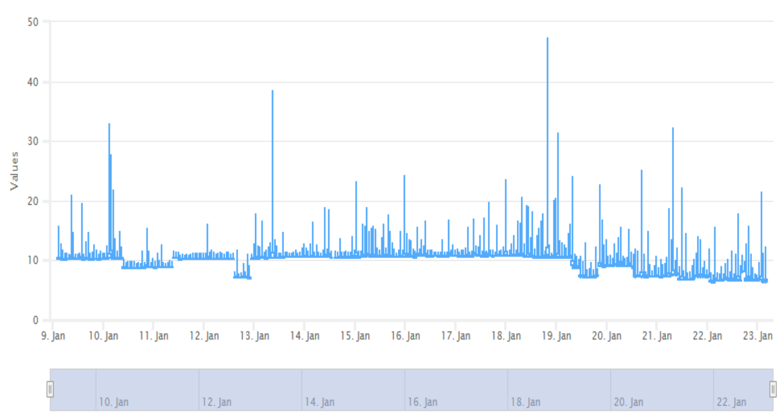

Fig 9: Internet Latency created by LoRa

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Once the connection established PC receive the signal from antenna and also it gets the establishment connection with software [18]. The root path will be linked with software package successfully through this the connection begins Fig.10.

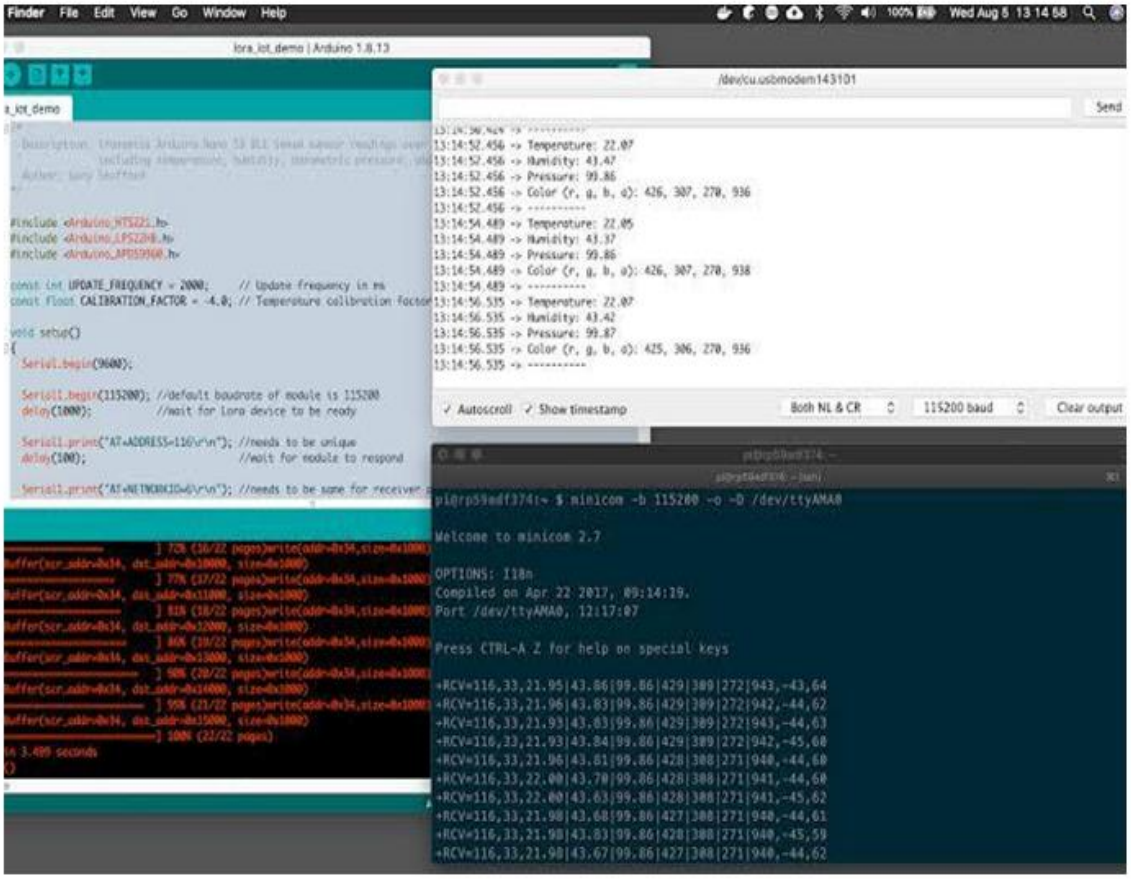

Fig 10: Screen shot after the connection established

To analyze the real time internet access speed, the comparative study report for 2 countries India vs Tokyo were given in the below Fig. 10a & b. From the data collection report speed factor is highly comes in developed country compared to developing country. Mobile broadband has a strong favorable impact on human development, particularly in poor nations, according to regression analysis [19]. The results remain resilient after using several robustness tests, such as sample modifications, outlier tests, and modifying model specifications. This outcome is fair given the leapfrogging hypothesis and the fact that mobile phones only replace fixed lines in emerging countries. Another argument could be the diminishing rewards of technology. Although industrialized countries have achieved saturation, emerging countries have recently seen significant development in mobile broadband [19]. This simultaneously explains why mobile broadband, rather than mobile cellular subscriptions, has a statistically significant positive impact. In future it will be drastically get improve in rural areas as well as urban area of developing country with advancement of technology.

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avg	min	max	mdev	timestamp
6.712ms	6.133ms	12.377ms	1.173ms	2024-01-23 09:10:03
6.592ms	6.160ms	11.281ms	0.949ms	2024-01-23 08:09:46
7.326ms	6.263ms	21.498ms	3.018ms	2024-01-23 07:10:27
6.888ms	6.425ms	9.641ms	0.823ms	2024-01-23 06:10:02
6.620ms	6.371ms	7.681ms	0.320ms	2024-01-23 05:09:39
6.624ms	6.404ms	7.870ms	0.345ms	2024-01-23 04:10:15
6.826ms	6.374ms	8.805ms	0.689ms	2024-01-23 03:09:51
6.834ms	6.369ms	11.118ms	0.995ms	2024-01-23 02:10:15
7.329ms	6.384ms	15.779ms	2.173ms	2024-01-23 01:09:50
6.884ms	6.442ms	12.802ms	1.166ms	2024-01-23 00:09:50
8.173ms	7.901ms	9.969ms	0.373ms	2024-01-22 23:09:49
8.217ms	7.858ms	10.869ms	0.585ms	2024-01-22 22:09:39
6.617ms	6.404ms	9.275ms	0.502ms	2024-01-22 21:09:51
7.289ms	6.422ms	17.927ms	2.382ms	2024-01-22 20:09:40
6.847ms	6.359ms	11.097ms	0.939ms	2024-01-22 19:09:39
6.690ms	6.504ms	7.829ms	0.264ms	2024-01-22 18:09:37
6.977ms	6.460ms	11.683ms	1.003ms	2024-01-22 17:09:38
6.730ms	6.541ms	8.073ms	0.346ms	2024-01-22 16:09:37
7.018ms	6.469ms	10.262ms	0.933ms	2024-01-22 15:09:37

(a)

avg	min	max	mdev	timestamp
215.116ms	215.046ms	215.152ms	0.027ms	2024-01-23 09:48:47
259.797ms	214.852ms	366.770ms	68.249ms	2024-01-23 08:48:39
215.138ms	214.849ms	215.872ms	0.156ms	2024-01-23 07:48:25
215.094ms	214.863ms	215.222ms	0.084ms	2024-01-23 06:48:41
215.068ms	214.775ms	215.232ms	0.092ms	2024-01-23 05:48:37
215.106ms	214.973ms	215.171ms	0.044ms	2024-01-23 04:48:42
215.091ms	214.998ms	215.160ms	0.045ms	2024-01-23 03:48:39
215.087ms	214.814ms	215.148ms	0.063ms	2024-01-23 02:48:39
215.086ms	214.772ms	215.196ms	0.081ms	2024-01-23 01:48:26
215.041ms	214.778ms	215.138ms	0.090ms	2024-01-23 00:48:38
215.097ms	214.807ms	215.783ms	0.149ms	2024-01-22 23:48:31
215.132ms	214.807ms	215.797ms	0.182ms	2024-01-22 22:51:02
215.092ms	214.946ms	215.251ms	0.067ms	2024-01-22 21:48:43
215.121ms	214.833ms	215.922ms	0.179ms	2024-01-22 20:48:42
215.098ms	214.817ms	215.673ms	0.135ms	2024-01-22 19:48:25
214.980ms	214.780ms	215.151ms	0.109ms	2024-01-22 18:48:24
215.047ms	214.831ms	215.252ms	0.093ms	2024-01-22 17:48:27
215.099ms	214.987ms	215.172ms	0.045ms	2024-01-22 16:48:32

(b)

Fig 10a&b: Internet speed factor in India vs Tokyo

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To determine the optimal station concerning small distance, an average value calculation was executed for the distances between each station and the others within the cluster. This assessment aimed to identify the station that, on average, exhibited the closest proximity to the remaining stations in the cluster.

Lora Applications and Usage

LoRaWAN (Long Range Wide Area Network) technology is critical for monitoring various aspects of agriculture, including farm assets, crop conditions, and livestock. This technology seamlessly integrates with the broader Internet of Things (IoT) or Smart Farming paradigm [16], [10]. Through the utilization of IoT generated data, agricultural producers and businesses can make well-informed decisions [2]. LoRaWAN enables the installation of miniature devices with sensors in farms, allowing for real-time monitoring of critical parameters including downpours, moisture in the soil, and temp [8]. Moreover, producers can use LoRaWAN to monitor the water level in remote livestock containers around fields. The accessibility of this data on cellphones or computer monitors empowers farmers and ranchers with timely and comprehensive information, enhancing their ability to make informed decisions in managing agricultural operations.

Usage of Lora

A) Smart City:

1. Smart Lighting: Efficient control and monitoring of streetlights, reducing energy consumption [1].
2. Air Quality and Pollution Monitoring: Sensors can collect real-time data on air quality, helping in pollution management [8], [20].
3. Smart Parking and Vehicle Management: Monitoring parking spaces and managing traffic flow.
4. Facilities and Infrastructure Management: Remote monitoring and management of public infrastructure [5].
5. Fire Detection and Management: Early detection of fires through sensors for prompt response [8].
6. Waste Management: Monitoring waste bins for optimization of collection routes and schedules.

B) Industrial Applications:

1. Radiation and Leak Detection: Early detection of leaks and radiation in industrial settings for safety.
2. Smart Sensor Technology: Deployment of sensors for monitoring various parameters in industrial processes [8].
3. Item Location and Tracking: Efficient tracking of assets, inventory, and goods in industrial environments.
4. Shipping and Transportation: Real-time tracking and monitoring of shipments and vehicles.

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5. Item Location and Tracking: Efficient tracking of assets, inventory, and goods in industrial environments.
6. Shipping and Transportation: Real-time tracking and monitoring of shipments and vehicles.

5. ISSUES IN IMPLEMENTATION

Implementing LoRa technology delivers a transformative solution for diverse industries seeking efficient and long-range communication for Internet of Things (IoT) devices [2], [10]. However, amid its promising advantages, several challenges dominate over its seamless integration and overall adoption. While LoRa offers several advantages such as long-range communication, low power consumption, and scalability, there are also some challenges and issues associated with its implementation:

1. **Interference and Environmental Factors:** Radio frequency interference from other wireless devices operating in the same frequency band can affect LoRa communication. Additionally, environmental factors like terrain, buildings, and physical obstacles can affect signal strength and transmission reliability [17], [21]. These factors can lead to packet loss, increased latency, and reduced overall performance of LoRa networks. Enforcing proper signal shielding techniques and strategically placing LoRa gateways can help mitigate these interferences and environmental challenges for more consistent communication.
2. **Limited Bandwidth:** LoRa operates in unlicensed frequency bands, leading to limited bandwidth availability. As more devices use the same frequency spectrum, network congestion might occur, affecting data transmission speed and reliability. As the number of devices utilizing the unlicensed frequency bands increases, contention for available bandwidth can intensify, potentially causing delays and reduced throughput for LoRa devices. Implementing efficient protocols and managing network traffic intelligently can help alleviate the impact of limited band-width, optimizing data transmission within LoRa networks [21], [22].
3. **Network Scalability:** While LoRa networks supports an infinite number of devices, scaling up a network can pose challenges in managing and coordinating a high volume of devices efficiently. Network architecture, handling simultaneous communications, and optimizing data transmission become critical. Integrating robust network management tools and employing hierarchical architectures can aid in scaling up LoRa networks effectively [15]. Allowing for better management of the increasing number of devices. Implementing strategies such as adaptive data rate control and efficient routing protocols assists in optimizing communication and handling simultaneous transmissions within the expanded network infrastructure.
4. **Security Concerns:** Security is a crucial aspect of IoT deployments. LoRaWAN, the networking protocol built on top of LoRa, has safety features, but there have been concerns about potential vulnerabilities in implementations. Ensuring end-to-end encryption, device authentication, and secure data transfer is essential to prevent data breaches or unauthorized access. Addressing security concerns in LoRaWAN

implementations requires continuous vigilance, regular updates, and adherence to best practices to fortify the network against potential vulnerabilities or exploits. Employing robust encryption methods, regular security audits, and timely patches or updates can significantly enhance the overall security posture of LoRaWAN deployments, safeguarding sensitive data and devices from potential threats[18] [23].

5. **Network Planning and Optimization:** Designing an efficient LoRa network requires careful planning of gateway placement, and viewing factors like coverage area, signal propagation [17] and interference. Optimizing the network to achieve desired coverage while minimizing power consumption and maximizing data transmission efficiency is complex. Effective network planning in LoRa involves extended site surveys, simulations, and analysis to strategically position gateways for optimal coverage and signal strength.

6. CONCLUSION

The integration of LoRaWAN technology within agriculture represents a significant leap towards improving productivity, sustainability, and efficiency in farming practices. As concerned, its ability to enable real-time monitoring of crucial agricultural parameters like soil moisture, temperature, and rainfall, along with tracking farm assets and livestock, empowers farmers and ranchers with valuable data for informed decision-making.

The outcome of the establishment connection with overall performance 94% achievement succeeded without normal natural disturbance. However, despite its promising benefits, the implementation of LoRa technology in agriculture encounters various challenges. Issues such as initial setup costs, the need for technical expertise for deployment, and ensuring seamless connectivity in remote areas pose significant hurdles.

Moreover, addressing concerns related to data security and privacy remains a crucial aspect that requires careful consideration. In conclusion, while LoRa technology holds immense potential to revolutionize agriculture by providing essential data and insights, there is a need for concerted efforts.

Collaboration among stakeholders, investment in infrastructure, and education for farmers on the benefits and use of this technology are pivotal for successful integration. Overcoming these challenges will pave the way for a more resilient, efficient, and sustainable agricultural sector globally, bridging the gap between developed and developing countries in adopting smart agricultural practices. As advancements continue, the continued refinement and integration of LoRa technology will play a main role in modifying the future of agriculture towards greater productivity, sustainability, and stability.

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