Emerging Technological Methods for Effective Farming by Cloud Computing

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Abstract*—The cutting-edge technological methods that are revolutionizing the agriculture industry by leveraging cloud computing and the Internet of Things (IoT). With precision agriculture at its forefront, IoT devices and sensors collect extensive data from the field, including soil moisture levels, temperature, humidity, and crop health. This data is seamlessly uploaded to the cloud, where it is analyzed and processed in real-time to provide farmers with valuable insights. Smart irrigation systems powered by IoT and cloud computing enable precise and optimized water delivery to crops, conserving water resources and boosting crop yields. Additionally, drones equipped with cameras and sensors fly over fields, capturing high-resolution images and collecting data on crop growth patterns and health. These data-rich images are then transmitted to the cloud for further analysis, empowering farmers to detect early signs of diseases and nutrient deficiencies. Furthermore, IoT devices, such as smart collars and tags, monitor livestock health and behavior, transmitting crucial data to the cloud for analysis. This enables farmers to make informed decisions to enhance animal welfare and optimize livestock management practices. Automation and robotics are integrated into farming operations through cloud-connected machinery that can perform tasks with precision and efficiency. These devices continually learn from data collected from their operations, contributing to adaptive and intelligent farming practices. AI-powered image recognition systems, integrated with IoT devices, aid in early detection of crop diseases and pests, minimizing crop losses and ensuring sustainable farming practices. Cloud computing also fosters supply chain optimization in agriculture by seamlessly connecting stakeholders, facilitating data exchange, and enhancing collaboration. This leads to reduced food waste and improved profitability throughout the supply chain. Predictive analytics, enabled by the amalgamation of cloud computing and IoT, empower farmers to make data-driven decisions by forecasting weather patterns, market demands, and crop growth rates. These insights enable proactive planning and enhanced operational efficiency. Farm management software, hosted on the cloud, provides farmers with easy access to real-time data, streamlining operations, and enabling efficient decision-making. The combination of cloud computing and IoT has brought about a transformative paradigm shift in agriculture. By harnessing real-time data, actionable insights, and automation, farmers can achieve effective and sustainable farming practices, paving the way for a technologically advanced and environmentally conscious future in agriculture. As these technologies continue to evolve and intertwine, further advancements are expected to shape the landscape of modern farming.

***Index Terms*— Smart farming, Internet of Things (IoT), Cloud Computing, Sensors, Edge computing, Data privacy and security.**

I. INTRODUCTION

In recent years, the agriculture industry has witnessed a remarkable transformation driven by the convergence of two powerful technologies: cloud computing and the Internet of Things (IoT). This dynamic combination has opened new frontiers in farming practices, allowing for more effective and sustainable agricultural methods. Cloud computing, with its capacity to store and process vast amounts of data, seamlessly integrates with IoT devices equipped with sensors and actuators, creating a network of interconnected smart systems that revolutionize the way farmers manage their operations. Traditionally, agriculture has been reliant on traditional methods and guesswork, with limited access to real-time data and insights. However, with the advent of cloud computing and IoT, a new era of precision agriculture has emerged. IoT devices deployed in the field collect a wide array of data, such as soil conditions, weather patterns, crop health, and livestock behavior. This data is then transmitted to cloud-based platforms, where it undergoes sophisticated analysis and is transformed into actionable information for farmers. The transformative potential of this technological integration lies in its ability to optimize resource utilization, enhance decision-making processes, and foster sustainable farming practices. Precision agriculture enables farmers to make data-driven decisions, leading to more efficient use of water, fertilizers, and pesticides, ultimately increasing crop

yields while minimizing environmental impacts. Livestock monitoring systems offer real-time insights into animal health and behavior, improving animal welfare and management. Moreover, cloud computing and IoT contribute to automation and robotics in agriculture, with intelligent machines capable of performing intricate tasks with precision and consistency. This automation reduces the burden on farmers, improves productivity, and streamlines various agricultural processes. we will explore the emerging technological methods that leverage cloud computing and IoT to enhance farming practices. We will delve into the key applications of this integration, including precision agriculture, smart irrigation, drone-based crop monitoring, livestock management, and supply chain optimization. Additionally, we will investigate how predictive analytics and farm management software, enabled by the cloud, empower farmer to make proactive decision and optimize their operations. As we examine the intersection of cloud computing and IoT in agriculture, we recognize the potential to create a more sustainable and efficient farming ecosystem. With continuous advancement in technology, the future of farming holds the promise of meeting global food demands while promoting environmental conservation and economic prosperity for farmers

II. OVERVIEW

The integration of cloud computing and the Internet of Things (IoT) has ushered in a transformative era in agriculture, known as precision agriculture or smart farming. This convergence of technologies has revolutionized farming practices by providing real-time data collection, analysis, and automation, enabling farmers to make data-driven decisions and optimize their operations. At the heart of this transformation lies precision agriculture, where IoT devices and sensors deployed in the field continuously gather data on various parameters such as soil moisture levels, temperature, humidity, and crop health. This data is seamlessly transmitted to cloud-based platforms, where it is processed, analyzed, and converted into actionable insights for farmers. One of the key applications of this integration is in smart irrigation systems. By combining IoT data on weather patterns, soil moisture, and crop water requirements, farmers can optimize water usage and ensure precise water delivery to crops, leading to more efficient resource utilization and higher crop yields. Drone-based crop monitoring is another crucial aspect of cloud computing and IoT in agriculture. Drones equipped with cameras and sensors fly over fields, capturing high-resolution images and collecting data on crop growth patterns and health. This data is sent to the cloud for analysis, enabling farmers to detect early signs of diseases, nutrient deficiencies, or other issues affecting crop productivity. Moreover, cloud computing and IoT have transformed livestock management through the use of smart collars or tags attached to animals. These IoT devices monitor livestock health and behavior, transmitting crucial data to the cloud for analysis. This empowers farmers to make informed decisions to enhance animal welfare and optimize livestock management practices.

Automation and robotics play a vital role in the future of agriculture through cloud-connected machinery capable of performing various tasks with precision and efficiency. These devices continuously learn from data collected from their operations, contributing to adaptive and intelligent farming practices. Beyond field-level applications, the integration of cloud computing and IoT has facilitated supply chain optimization in agriculture. By connecting stakeholders and enabling seamless data exchange, cloud-based platforms enhance collaboration and efficiency throughout the agricultural supply chain, reducing food waste and improving profitability. Predictive analytics, made possible by cloud computing and IoT, empowers farmers with valuable insights by forecasting weather patterns, market demands, and crop growth rates. Armed with this information, farmers can proactively plan and optimize their operations for better outcomes. Farm management software hosted on the cloud provides farmers with easy access to real-time data, streamlining operations, and enabling efficient decision-making. the combination of cloud computing and IoT has redefined agriculture, enabling precision farming, smart irrigation, drone-based crop monitoring, livestock management, automation, supply chain optimization, predictive analytics, and streamlined farm management. With continuous technological advancements, these methods have the potential to create a more sustainable, efficient, and productive farming ecosystem, addressing the global

food demand while promoting environmental conservation and economic growth for farmers.

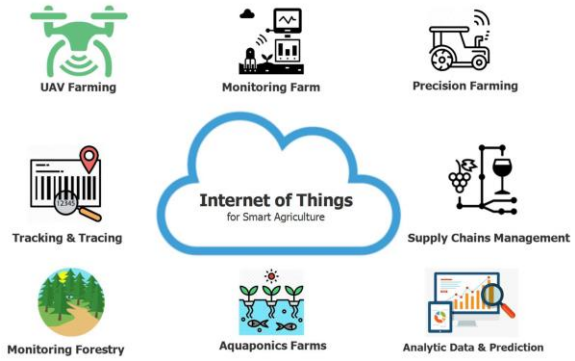

Figure1: Smart Farming cloud computing

Farmers in a rural region have adopted a precision agriculture approach to optimize their crop yields and reduce losses. They have deployed a network of IoT sensors throughout their fields, collecting data on soil moisture levels, temperature, humidity, and other environmental factors. These sensors are connected to a cloud-based platform that continuously receives and stores the data. In addition to the IoT sensors, the farmers use drones equipped with high-resolution cameras to monitor their crops from above. The drones fly over the fields regularly, capturing detailed images of the crops and transmitting them to the cloud. The cloud-based platform then uses image recognition algorithms to analyze the images and detect any signs of diseases or pest infestations.

Let's say the platform detects irregular patterns on the leaves of some plants, indicating a potential disease outbreak. Upon receiving the alert from the cloud-based system, the farmers can quickly respond to the issue. They can access the data and images through their smartphones or computers, enabling them to identify the specific area affected and the severity of the problem. With this real-time information, the farmers can take immediate action, such as targeted pesticide application or isolation of the affected area, to prevent the disease from spreading further. Additionally, the cloud-based platform can provide recommendations based on historical data and disease patterns, assisting the farmers in choosing the most effective treatment options. By leveraging cloud computing and IoT for crop monitoring and disease detection, these farmers can significantly improve their crop management practices. Early detection of diseases and pests allows for timely interventions, minimizing crop losses and reducing the need for excessive pesticide use. This not only increases the overall crop yield and quality but also contributes to more sustainable and environmentally friendly farming practices. The combination of cloud computing and IoT in precision agriculture has empowered farmers with real-time data, advanced analytics, and actionable insights, enhancing their ability to manage crops effectively and ensure a successful harvest. As technology continues to advance, such examples will become more prevalent and contribute to the ongoing transformation of the agriculture industry.

A. Sensors and Devices

The foundation of the IoT ecosystem in smart farming is the deployment of a wide range of sensors and devices throughout the farm. These sensors can include soil moisture sensors, temperature sensors, humidity sensors, weather stations, GPS trackers, livestock wearables (e.g., smart collars or ear tags), and drones equipped with cameras and sensors. These devices collect data on environmental conditions, crop health, and livestock behavior.

B. Connectivity

To transmit data from the sensors and devices to the cloud, a reliable and scalable connectivity infrastructure is essential. This can include various communication technologies such as Wi-Fi, Bluetooth, Zigbee, Lora WAN, or cellular networks like 4G/5G, depending on the farm's size, location, and data requirements.

C. Edge Computing

In many smart farming scenarios, it's beneficial to process certain data locally at the edge of the network. Edge computing allows for real-time data analysis and decision-making without relying solely on cloud processing. This is especially useful when low latency is crucial for time-sensitive actions, such as automated machinery or livestock monitoring.

D. Gateway Devices

Gateways act as intermediaries between the sensors/devices and the cloud. They aggregate data from multiple sensors and devices and transmit it to the cloud for further processing and storage. Gateways also play a role in data filtering and security.

E. Cloud Computing

The cloud serves as the central platform for data storage, processing, and analysis. It offers the computational power and scalability required to handle vast amounts of data generated by the IoT devices. Cloud services also include databases, machine learning algorithms, and data analytics tools for extracting valuable insights from the data.

F. Data Storage

Cloud-based databases store the collected sensor data securely. This allows for historical data analysis, trend identification, and long-term monitoring of the farm's performance.

G. Data Analytics and AI

Cloud-based data analytics and artificial intelligence (AI) algorithms process the raw data from the sensors and generate actionable insights for farmers. AI-powered algorithms can detect crop diseases, optimize irrigation schedules, predict weather patterns, and provide recommendations for improved farm management.

H. Visualization and User Interface

User-friendly dashboards and applications provide farmers with easy access to real-time data, analysis reports, and alerts. These interfaces allow farmers to monitor their farms remotely, make informed decisions, and take appropriate actions when necessary.

I. Integration with Farming Equipment

To achieve true automation and optimized farming practices, the IoT ecosystem must integrate with farming equipment, such as smart irrigation systems, autonomous machinery, and precision livestock management tools. Integration ensures that these devices act on the insights generated by the cloud-based analytics.

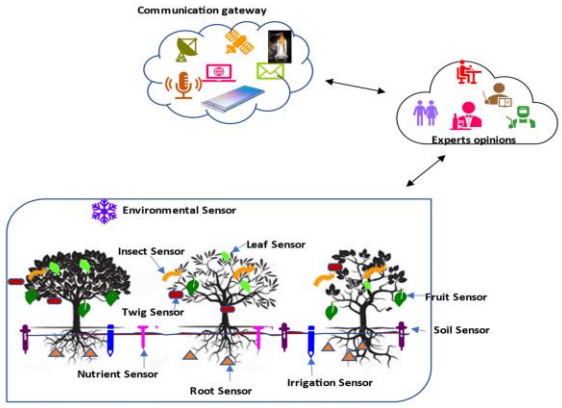

Figure2: Agriculture Smart farming Internet of Things.

III. FUTURE OUTCOME

The future outcome of continued advancements in the IoT ecosystem architecture for smart farming with cloud computing holds immense promise for the agriculture industry. As technology evolves and new innovations emerge, we can anticipate the following future outcomes.

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I. Hyper-Precision Agriculture

Future developments in sensor technology and data analytics will enable even more precise and granular insights into crop health, soil conditions, and weather patterns. Hyper-precision agriculture will allow farmers to tailor treatments and interventions to individual plants or even specific areas within a field, maximizing resource efficiency and crop yields.

II. AI-Driven Autonomous Systems

The integration of artificial intelligence (AI) with IoT and cloud computing will lead to highly autonomous farming systems. AI-powered drones, robots, and machinery will be capable of performing complex tasks such as precision planting, selective harvesting, and targeted pest control with minimal human intervention.

III. Predictive and Prescriptive Analytics
The future IoT ecosystem will harness the power of big data and advanced analytics to predict trends and proactively provide prescriptive actions. Farmers will receive proactive alerts on potential challenges, such as weather anomalies or disease outbreaks, along with recommendations for mitigating actions.

IV. Edge and Fog Computing
As the need for real-time processing grows, edge and fog computing will become more prevalent in the IoT ecosystem. These technologies enable data processing closer to the data source, reducing latency and ensuring timely responses for critical agricultural operations.

V. Seamless Integration with Supply Chains
The IoT ecosystem will seamlessly integrate with agricultural supply chains, facilitating end-to-end traceability and transparency. From farm to fork, stakeholders will have access to real-time data, ensuring food safety, quality, and efficiency throughout the supply chain.

VI. Climate-Smart Agriculture
Climate change adaptation and mitigation will be at the forefront of future agricultural practices. The IoT ecosystem will play a crucial role in climate-smart agriculture, helping farmers adapt to changing weather patterns, optimize water usage, and reduce greenhouse gas emissions.

VII. Personalized Farming Solutions
The IoT ecosystem will offer personalized solutions tailored to individual farms and crops. Machine learning algorithms will continuously learn from historical data and specific farm conditions, providing customized recommendations and insights for optimal farm management.

VIII. Global Connectivity and Collaboration
Advancements in communication technologies and cloud infrastructure will enable seamless global connectivity among farmers, researchers, and agricultural experts. This interconnectedness will foster knowledge-sharing, collaborative problem-solving, and access to best practices worldwide.

IX. Environmental Sustainability and Biodiversity
The IoT ecosystem's increased focus on sustainability will lead to more environmentally friendly agricultural practices. Farmers will be better equipped to implement biodiversity-enhancing measures, such as precision habitat management and sustainable crop rotations.

X. Data Privacy and Security
As the IoT ecosystem becomes more pervasive in agriculture, ensuring data privacy and security will be critical. Future developments will prioritize robust encryption, secure data transmission, and adherence to data privacy regulations to safeguard farmers' sensitive information.

IV. OUTCOME

The outcome of implementing an IoT ecosystem architecture for smart farming with cloud computing is a more efficient, productive, and sustainable agricultural sector. The integration of real-time data, advanced analytics, and automation empowers farmers to adapt to evolving challenges and opportunities, ultimately leading to a more resilient and technologically advanced agricultural ecosystem. the IoT ecosystem architecture for smart farming with cloud computing is a highly efficient, sustainable, and technologically advanced agricultural sector. The integration of AI, predictive analytics, and autonomous systems will drive agricultural productivity to new heights, ensuring food security while safeguarding the environment. Farmers will benefit from real-time insights, personalized solutions, and enhanced collaboration, positioning the agriculture industry for a prosperous and resilient future.

CONCLUSION

The integration of cloud computing and the Internet of Things (IoT) in smart farming has ushered in a new era of precision agriculture, revolutionizing traditional farming practices. This powerful combination has enabled farmers to leverage real-time data, advanced analytics, and automation to make data-driven decisions, optimize resource utilization, and enhance agricultural productivity. The IoT ecosystem architecture for smart farming has brought about significant benefits and positive outcomes for the agriculture industry. Improved crop yields, resource efficiency, and early disease detection have become the norm, leading to increased profitability and sustainability for farmers. Livestock management has

been optimized, ensuring healthier animals and more efficient farming practices. As technology continues to evolve, the future holds even more promise for smart farming with cloud computing and IoT. Hyper-precision agriculture, AI-driven autonomous systems, and predictive analytics will become commonplace, empowering farmers with ever more granular insights and efficient automation. Farming will transition to a climate-smart approach, adapting to changing environmental conditions while reducing the ecological footprint. The seamless integration of the IoT ecosystem with supply chains will enhance traceability, food safety, and transparency, ensuring consumers receive high-quality produce. Global connectivity and collaboration will foster knowledge-sharing and best practices across borders, contributing to a more sustainable and interconnected agricultural community. However, as the IoT ecosystem expands, ensuring data privacy and security will remain paramount. Robust measures must be in place to safeguard sensitive information and maintain trust among farmers and stakeholders. In the face of population growth, climate change, and resource limitations, the IoT ecosystem architecture for smart farming presents a pathway towards a more sustainable, efficient, and resilient agricultural sector. By embracing technology and innovation, farmers are poised to address global food demands, promote environmental conservation, and drive economic prosperity for rural communities. As we look to the future, the continued evolution of smart farming with cloud computing and IoT promises a brighter and more productive future for agriculture.

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REFERENCES

[1] Quy, V.K.; Nam, V.H.; Linh, D.M.; Ngoc, L.A.; Gwanggil, J. Wireless Communication Technologies for IoT in 5G: Vision, Applications, and Challenges. Wirel. Commun. Mob. Comput. 2022, 2022, 3229294. [CrossRef]

[2] Sinche, S.; Raposo, D.; Armando, N.; Rodrigues, A.; Boavida, F.; Pereira, V.; Silva, J.S. A Survey of IoT Management Protocols and Frameworks. IEEE Commun. Surv. Tutor. 2020, 22, 1168–1190. [CrossRef]

[3] Elijah, O.; Rahman, T.A.; Orikumhi, I.; Leow, C.Y.; Hindia, M.N. An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits and Challenges. IEEE Internet Things J. 2018, 5, 3758–3773. [CrossRef]

[4] Wang, X., Yang, W., Wheaton, A., Cooley, N., & Moran, B. (2010). Efficient registration of optical and IR images for automatic plant water stress assessment. Computers and Electronics in Agriculture, 74(2), 230–237. https://doi.org/10.1016/j.compag.2010.08.004.

[5] Li, W.; Logenthiran, T.; Phan, V.; Woo, W.L. A Novel Smart Energy Theft System (SETS) for IoT-based Smart Home. IEEE Internet Things J. 2019, 6, 5531–5539. [CrossRef]

[6] Shin, D.; Yun, K.; Kim, J.; Astillo, P.V.; Kim, J.-N.; You, I. A Security Protocol for Route Optimization in DMM-Based Smart Home IoT Networks. IEEE Access 2019, 7, 142531–142550. [CrossRef]

[7] An, J.G.; Le Gall, F.; Kim, J.; Yun, J.; Hwang, J.; Bauer, M.; Zhao, M.; Song, J.S. Toward Global IoT-Enabled Smart Cities Interworking Using Adaptive Semantic Adapter. IEEE Internet Things J. 2019, 6, 5753–5765. [CrossRef]

[8] Cirillo, F.; Gomez, D.; Diez, L.; Maestro, I.E.; Gilbert, T.B.J.; Akhavan, R. Smart City IoT Services Creation through Large-Scale Collaboration. IEEE Internet Things J. 2020, 7, 5267–5275. [CrossRef]

[9] Ammad, M.; Shah, M.A.; Islam, S.U.; Maple, C.; Alaulamie, A.A.; Rodrigues, J.J.P.C.; Mussadiq, S.; Tariq, U. A Novel Fog-Based Multi-Level Energy-Efficient Framework for IoT-Enabled Smart Environments. IEEE Access 2020, 8, 150010–150026. [CrossRef]

[10] Metallidou, C.K.; Psannis, K.E.; Egyptiadou, E.A. Energy Efficiency in Smart Buildings: IoT Approaches. IEEE Access 2020, 8, 63679–63699. [CrossRef]

[11] Quy, V.K.; Nam, V.H.; Linh, D.M.; Ban, N.T.; Han, N.D. Communication Solutions for Vehicle Ad-hoc Network in Smart Cities Environment: A Comprehensive Survey. Wirel. Pers. Commun. 2022, 122, 2791–2815. [CrossRef]

[12] Kiani, F.; Seyyedabbasi, A.; Nematzadeh, S.; Candan, F.; Çevik, T.; Anka, F.A.; Randazzo, G.; Lanza, S.; Muzirafuti, A. Adaptive Metaheuristic-Based Methods for Autonomous Robot Path Planning: Sustainable Ag-ricultural Applications. Appl. Sci. 2022, 12, 943. [CrossRef]

[13] Patle, K.S.; Saini, R.; Kumar, A.; Palaparthy, V.S. Field Evaluation of Smart Sensor System for Plant Disease Prediction Using LSTM Network. IEEE Sens. J. 2022, 22, 3715–3725. [CrossRef]

[14] Vangala, A.; Das, A.K.; Kumar, N.; Alazab, M. Smart Secure Sensing for IoT-Based Agriculture: Blockchain Perspective. IEEE Sens. J. 2020, 21, 17591–17607. [CrossRef]

[15] Citoni, B.; Fioranelli, F.; Imran, M.A.; Abbasi, Q.H. Internet of Things and LoRaWAN-Enabled Future Smart Farming. IEEE Internet Things Mag. 2019, 2, 14–19. [CrossRef]

[16] Kumar, R.; Mishra, R.; Gupta, H.P.; Dutta, T. Smart Sensing for Agriculture: Applications, Advancements, and Challenges. IEEE Consum. Electron. Mag. 2021, 10, 51–56. [CrossRef]

[17] Chang, Y.; Lai, Y. Campus Edge Computing Network Based on IoT Street Lighting Nodes. IEEE Syst. J. 2020, 14, 164–171. [CrossRef]

[18] Sutjarittham, T.; Habibi Gharakheili, H.; Kanhere, S.S.; Sivaraman, V. Experiences with IoT and AI in a Smart Campus for Optimizing Classroom Usage. IEEE Internet Things J. 2019, 6, 7595–7607. [CrossRef]

[19] Rani, S.; Ahmed, S.H.; Shah, S.C. Smart Health: A Novel Paradigm to Control the Chickungunya Virus. IEEE Internet Things J. 2019, 6, 1306–1311. [CrossRef]

[20] Zhou, Z.; Yu, H.; Shi, H. Human Activity Recognition Based on Improved Bayesian Convolution Network to Analyze Health Care Data Using Wearable IoT Device. IEEE Access 2020, 8, 86411–86418. [CrossRef]

[21] Humayun, M.; Jhanjhi, N.; Hamid, B.; Ahmed, G. Emerging Smart Logistics and Transportation Using IoT and Blockchain. IEEE Internet Things Mag. 2020, 3, 58–62. [CrossRef]

[22] Song, Y.; Yu, F.R.; Zhou, L.; Yang, X.; He, Z. Applications of the Internet of Things (IoT) in Smart Logistics: A Comprehensive Survey. IEEE Internet Things J. 2021, 8, 4250–4274. [CrossRef]

[23] Shafique, K.; Khawaja, B.A.; Sabir, F.; Qazi, S.; Mustaqim, M. Internet of Things (IoT) for Next-Generation Smart Systems: A Review of Current Challenges, Future Trends & Prospects for Emerging 5G-IoT Scenarios. IEEE Access 2020, 8, 23022–23040. [CrossRef]

[24] Available online: https://www.un.org/development/desa/en/news/population/world-population-prospects-2019.html (accessed on 7 May 2021).

[25] Yang, X.; Shu, L.; Chen, J.; Ferrag, M.A.;Wu, J.; Nurellari, E.; Huang, K. A Survey on Smart Agriculture: Development Modes, Technologies, and Security and Privacy Challenges. IEEE/CAA J. Autom. Sin. 2021, 8, 273–302. [CrossRef]

[26] Ayaz, M.; Ammad-Uddin, M.; Sharif, Z.; Mansour, A.; Aggoune, E.-H.M. Internet-of-Things (IoT)-Based Smart Agriculture: Toward Making the Fields Talk. IEEE Access 2019, 7, 129551–129583. [CrossRef]

[27] Alfred, R.; Obit, J.H.; Chin, C.P.-Y.; Haviluddin, H.; Lim, Y. Towards Paddy Rice Smart Farming: A Review on Big Data, Machine Learning, and Rice Production Tasks. IEEE Access 2021, 9, 50358–50380. [CrossRef]

[28] Zikria, Y.B.; Ali, R.; Afzal, M.K.; Kim, S.W. Next-Generation Internet of Things (IoT): Opportunities, Challenges, and Solutions. Sensors 2021, 21, 1174. [CrossRef]

[29] Kour, V.P.; Arora, S. Recent Developments of the Internet of Things in Agriculture: A Survey. IEEE Access 2020, 8, 129924–129957. [CrossRef]

[30] Saad, A.; Benyamina, A.E.H.; Gamatié, A. Water Management in Agriculture: A Survey on Current Challenges and Technological Solutions. IEEE Access 2020, 8, 38082–38097. [CrossRef]

[31] Tyagi, S.K.S.; Mukherjee, A.; Pokhrel, S.R.; Hiran, K.K. An Intelligent and Optimal Resource Allocation Approach in Sensor Networks for Smart Agri-IoT. IEEE Sens. J. 2020, 21, 17439–17446. [CrossRef]

[32] Li, X.; Pu, T.; Li, L.; Ao, J. Enhanced Sensitivity of GaN-Based Temperature Sensor by Using the Series Schottky Barrier Diode Structure. IEEE Electron Device Lett. 2020, 41, 601–604. [CrossRef]

[33] Gopalakrishnan, S.; Waimin, J.; Raghunathan, N.; Bagchi, S.; Shakouri, A.; Rahimi, R. Battery-Less Wireless Chipless Sensor Tag for Subsoil Moisture Monitoring. IEEE Sens. J. 2021, 21, 6071–6082. [CrossRef]

[34] Udutalapally, V.; Mohanty, S.P.; Pallagani, V.; Khandelwal, V. sCrop: A Novel Device for Sustainable Automatic Disease Prediction, Crop Selection, and Irrigation in Internet-of-Agro-Things for Smart Agriculture. IEEE Sens. J. 2020, 21, 17525–17538. [CrossRef]

[35] Spachos, P.; Gregori, S. Integration of Wireless Sensor Networks and Smart UAVs for Precision Viticulture. IEEE Internet Comput. 2019, 23, 8–16. [CrossRef]

[36] Abdelnour, A.; Buchin, F.; Kaddour, D.; Tedjini, S. Improved Traceability Solution Based on UHF RFID for Cheese Production Sector. IEEE J. Radio Freq. Identif. 2018, 2, 68–72. [CrossRef]

[37] Friha, O.; Ferrag, M.A.; Shu, L.; Maglaras, L.; Wang, X. Internet of Things for the Future of Smart Agriculture: A Comprehensive Survey of Emerging Technologies. IEEE/CAA J. Autom. Sin. 2021, 8, 718–752. [CrossRef]

[38] Farooq, M.S.; Riaz, S.; Abid, A.; Abid, K.; Naeem, M.A. A Survey on the Role of IoT in Agriculture for the Implementation of Smart Farming. IEEE Access 2019, 7, 156237–156271. [CrossRef]

[39] Mishra, D.; Zema, N.R.; Natalizio, E. A High-End IoT Devices Framework to Foster Beyond-Connectivity Capabilities in 5G/B5G Architecture. IEEE Commun. Mag. 2021, 59, 55–61. [CrossRef]

[40] Javed, F.; Afzal, M.K.; Sharif, M.; Kim, B. Internet of Things (IoT) Operating Systems Support, Networking Technologies, Applications, and Challenges: A Comparative Review. IEEE Commun. Surv. Tutor. 2018, 20, 2062–2100. [CrossRef]

[41] Poyen, F.B.; Ghosh, A.; Kundu, P.; Hazra, S.; Sengupta, N. Prototype Model Design of Automatic Irrigation Controller. IEEE Trans. Instrum. Meas. 2021, 70, 9502217. [CrossRef]

[42] Wang, Y.; Rajib, S.M.S.M.; Collins, C.; Grieve, B. Low-Cost Turbidity Sensor for Low-Power Wireless Monitoring of Fresh-Water Courses. IEEE Sens. J. 2018, 18, 4689–4696. [CrossRef]

[43] El-Basioni, B.M.M.; El-Kader, S.M.A. Laying the Foundations for an IoT Reference Architecture for Agricultural Application Domain. IEEE Access 2020, 8, 190194–190230. [CrossRef]

[44] Alam, M.M.; Malik, H.; Khan, M.I.; Pardy, T.; Kuusik, A.; Le Moullec, Y. A Survey on the Roles of Communication Technologies in IoT-Based Personalized Healthcare Applications. IEEE Access 2018, 6, 36611–36631. [CrossRef]

[45] Chettri, L.; Bera, R. A Comprehensive Survey on Internet of Things (IoT) Toward 5GWireless Systems. IEEE Internet Things J. 2020, 7, 16–32. [CrossRef]

[46] Pal, A.; Kant, K. NFMI: Connectivity for Short-Range IoT Applications. Computer 2019, 52, 63–67. [CrossRef]

[47] Collotta, M.; Pau, G.; Talty, T.; Tonguz, O.K. Bluetooth 5: A Concrete Step Forward toward the IoT. IEEE Commun. Mag. 2018, 56, 125–131. [CrossRef]

[48] Bacco, M.; Berton, A.; Gotta, A.; Caviglione, L. IEEE 802.15.4 Air-Ground UAV Communications in Smart Farming Scenarios. IEEE Commun. Lett. 2018, 22, 1910–1913. [CrossRef]

[49] Gente, R.; Busch, S.F.; Stubling, E.-M.; Schneider, L.M.; Hirschmann, C.B.; Balzer, J.C.; Koch, M. Quality Control of Sugar Beet Seeds with THz Time-Domain Spectroscopy. IEEE Trans. Terahertz Sci. Technol. 2016, 6, 754–756. [CrossRef]

[50] Afsharinejad, A.; Davy, A.; Naftaly, M. Variability of Terahertz Transmission Measured

in Live Plant Leaves. IEEE Geosci. Remote Sens. Lett. 2017, 14, 636–638. [CrossRef]

[51] Wang, X.; Zhang, J.; Yu, Z.; Mao, S.; Periaswamy, S.C.G.; Patton, J. On Remote Temperature Sensing Using Commercial UHFRFID Tags. IEEE Internet Things J. 2019, 6, 10715–10727. [CrossRef]

[52] Ali, S.; Glass, T.; Parr, B.; Potgieter, J.; Alam, F. Low-Cost Sensor with IoT LoRaWAN Connectivity and Machine Learning-Based Calibration for Air Pollution Monitoring. IEEE Trans. Instrum. Meas. 2021, 70, 5500511. [CrossRef]

[53] Joris, L.; Dupont, F.; Laurent, P.; Bellier, P.; Stoukatch, S.; Redouté, J. An Autonomous Sigfox Wireless Sensor Node for Environmental Monitoring. IEEE Sens. Lett. 2019, 3, 5500604. [CrossRef]

[54] Popli, S.; Jha, R.K.; Jain, S. A Survey on Energy Efficient Narrowband Internet of Things (NBIoT): Architecture, Application & Challenges. IEEE Access 2019, 7, 16739–16776. [CrossRef]

[55] Sundaram, J.P.S.; Du, W.; Zhao, Z. A Survey on LoRa Networking: Research Problems, Current Solutions, and Open Issues. IEEE Commun. Surv. Tutor. 2020, 22, 371–388. [CrossRef]

[56] Xing, C.; Li, F. Unlicensed Spectrum-Sharing Mechanism Based onWi-Fi Security Requirements Implemented Using Device to Device Communication Technology. IEEE Access 2020, 8, 135025–135036. [CrossRef]

[57] Jiang, X.; Zhang, H.; Yi, E.A.B.; Raghunathan, N.; Mousoulis, C.; Chaterji, S.; Peroulis, D.; Shakouri, A.; Bagchi, S. Hybrid Low-PowerWide-Area Mesh Network for IoT Applications. IEEE Internet Things J. 2021, 8, 901–915. [CrossRef]

[58] Gutiérrez, J., Villa-Medina, J. F., Nieto-Garibay, A., & Porta-Gandara, M. Á. (2014). Automated irrigation system based on wireless sensor network and GPRS module. IEEE Transactions on Instrumentation and Measurement, 63(1), 166–176. https://doi.org/10.1109/TIM.2013.2276487

[59] Elijah, O., Rahman, T. A., Orikumhi, I., Leow, C. Y., & Hindia, M. H. D. N. (2018). An overview of internet of things (IoT) and data analytics in agriculture: Benefits and challenges. IEEE Internet of Things Journal, 5(5), 3758–3773. https://doi.org/10.1109/jiot.2018.2844296

[60] Dahane, A., Kechar, B., Meddah. Y & Benabdellah. O. (2019). Automated irrigation management platform using a wireless sensor network. In Sixth international conference on internet of things: systems, management and security (IOTSMS), Granada, Spain, pp. 610–615. https://doi.org/10.1109/IOTSMS48152.2019.8939170

[61] O. Heen, C. Neumann, L. Montalvo, and S. Defrance. 2012. Improving the resistance to side-channel attackson cloud storage services. In Proceedings of the 2012 5th International Conference on New Technologies,Mobility, and Security (NTMS'12). 1–5.

[62] YitaoDuan. 2014. Distributed key generation for encrypted deduplication. In Proceedings of the 6th Edition of the ACM Cloud Computing Security Workshop (CCSW'14). 57–68.

[63] Duplicati. 2016. Home Page. Retrieved December 7, 2016, from http://www.duplicati.com. Cynthia Dwork. 2008. Differential privacy: A survey of results. In Theory and Applications of Modelsof Computation. Lecture Notes in Computer Science, Vol. 4978. Springer, 1–19. DOI:http://dx.doi.org/ 10.1007/978-3-540-79228-4_1

[64] Stefan Dziembowski. 2006. Intrusion-resilience via the bounded-storage model. In Theory of Cryptography— TCC 2006. Lecture Notes in Computer Science, Vol. 3876. Springer, 207–224. DOI:http://dx.doi.org/10.1007/11681878_11

[65] TaherElgamal. 1985. A public key cryptosystem and a signature scheme based on discrete logarithms. IEEE Transactions on Information Theory 31, 4, 469–472. DOI:http://dx.doi.org/10.1109/TIT.1985.1057074

[66] SaschaFahl, Marian Harbach, Thomas Muders, Matthew Smith, Lars Baumg¨artner, and Bernd Freisleben. 2012. Why Eve and Mallory love

Android: An analysis of Android SSL (In)Security. In Proceedings ofthe 19th ACM Conference on Computer and Communications Security (CCS'12). 50–61.