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Advanced Technology for Smart Environment and Energy

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Environmental Science and Engineering

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Chapter 1
Energy Optimization Analysis on Internet of Things

Wasswa Shafik and Ali Tufail

Abstract Energy enhancement and renewable energy integration are crucial facilitators of renewable energy conversion and climate shift alleviations. The technological advancements supported by the current fifth generation (5G), like Internet of Things (IoT), Internet of Flying Things, and Internet of Drones have shown different merits within the energy market, including energy generation, storage, and delivery, as well as increased demand. It is predicted that the IoTs are to be utilized to enhance energy usage, increase sustainable energy use, and reduce the environmental effects of energy application. This study examines the latest studies on the IoT application in smart grids and overall energy networks. The study further details IoT's supporting technologies, like cloud storage and multiple data analysis tools. Moreover, a detailed identified problems for IoT deployment in the energy sector, like security and privacy and solutions, for instance, blockchain. The study offers energy regulators, managers, and analysts on the position of IoT in energy system optimization.

Keywords Internet of Things · Energy optimization · Smart energy system

1.1 Introduction

1.1.1 Concept

The future of smart networks. The wireless communications with 5G technology support regard massive connectivity as an important element of providing secure communication link and enormous IoT device quality of service and make many efforts to meet the requirements of large emerging services (Cui et al. 2020). Within the IoT, "Things" (refer to all devices that connect to the internet for resource sharing

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purposes) and the connections are associated through radio frequency distinguishing proof hardware, sensors, and situated hardware taking a certain agreement to trade and communicate data, so that the acknowledgment, area, and supervision of the protest will be ended up more brilliantly.

Its most prominent include communication and discourse between things that can moreover interact and communicate with the environment (Zhang et al. 2019a). In the current 5G and beyond networks, smart devices in billions have hinted the technology market space. Such devices noticed in this technology era include autonomous drones (fully operational without human interaction), autonomous vehicles, e-healthcare, smart home devices, smartphones with advanced properties, and wearable devices which are rising tremendously. The connectivity of these "devices" to the internet results in IoT network development (Zhang et al. 2019b). We are therefore investigating the potential for implementing such an architecture through blockchain and software-defined networks (SDN) (Yazdinejad et al. 2020).

The SDN is a modern net architecture that eliminates from data plane to control planes using mainly the switch and controller components. These components have major duties to do as in regard to the SDNs, the switch is supposed to deal with packet forwarding as well as protocol management, the controller implements the rules, maintenance, and programmability of individual network switches (Yazdinejad et al. 2018a, 2018b, 2019).

To boost network performance, IoT and SDN capabilities can work together. Additionally, the SDN controller can govern and manage changes in the network configuration caused by the dynamic design of IoT devices (Obeis et al. 2022). The lack of a centralized controller in the IoT network is one of the main issues, which may be resolved by employing the SDN controller to give IoT devices access to a centralized controller (Ojo et al. 2016).

1.1.2 Motivation

In 2022, the worldwide energy need has increased to 4.3 percent over 2021 due to increased indoor activity caused by the Coronavirus disease 2019 pandemic world lockdown, the largest rise ever since 2010 (Energy and CO_2 Status Report 2019). Consequently, the energy related to carbon dioxide (CO_2) emissions touched a track record level in 2018. In comparison to preindustrial temperatures, the earth is warming by 1.5 °C, which will most likely happen in century.

In case these trends endure, the global warming is likely to exceed 2 °C targets, posing a serious threat to the earth and human life (Summary for Policymakers 2022). Although fortunately, or unfortunately, the Covid-19 and the resulting economic catastrophe affected practically each facet of energy production, distribution, and its consumption across the world. The Covid 19 pandemic fashioned the energy companies and emissions patterns as early as 2020 when the pandemic was declared, the main components of clean energy transformation were largely unaffected (Energy and CO_2 Status Report 2019; Summary for Policymakers 2022; Home 2019; Al-Azez et al. 2019).

The energy supply chain is divided into three sections: (a) energy supply, (b) energy conversion procedure, (c) energy demand, and the industrial sector (Bhattacharyya 2020). These three elements, along with their related components. The roles of the IoT in all segments of the supply chain of energy are discussed in this study. The studies demonstrated how the IoT can help with energy efficiency and enhance the usage of renewable energy sources.

The supply chain of energy mainly has three categories (Consume, Transform, Supply). Within the supply category, several processes are done, energy extraction and treatment, followed by the primary energy supply that may include import or export stock exchange. The next step is transformation. To transform energy conversion technologies are used using T& D (transmission and distribution) systems (Bhattacharyya 2020). For T& D systems, go to consume category, this category has three steps, i.e., final energy, and appliance and useful energy. Some minimal energy loss can be lost at end use appliance, during conversions, and T&D system operation.

Real-time data is sensed and relayed by sensors and communication technologies in the IoT, enabling quick computation and effective decision-making (Tamilselvan and Thangaraj 2020). Furthermore, the IoT will assist the energy industry in transitioning from a consolidated to a smart, scattered, and interconnected energy infrastructure (Internet 2016). Because a critical prerequisite for installing local dispersed renewable energy sources, for instance, wind and solar energy (Motlagh et al. 2018), transforming a lot of small-scale energy consumers into prosumers while it is still advantageous for the grid to do so by pooling their production and maximizing their demand. To streamline, integrate, and keep an eye on operations, IoT systems employ sensors and communication technologies. Numerous people and devices' energy usage patterns can be monitored and managed over time with the aid of large data gathering and substantive data analysis (Ibarra-Esquer et al. 2017) and (Thibaud et al. 2018).

1.1.3 Methodology

The literature has extensively explored and analyzed the IoT application within various industries and sectors (Wang et al. 2020; Xing et al. 2019). Furthermore, technological assessments of the difficulties and opportunities associated with the implementation of IoT tech-tecs, for instance, sensors (Daas et al. 2019) or 5G networks (Risteska Stojkoska and Trivodaliev 2017). Most survey studies in the energy sector have concentrated on one small section, like buildings where IoT technology is used, exceptionally minimal in the energy sector(s). In the same context, a brief overview of the IoT architecture and its supporting technologies to establish a foundation for examining their position in the sector.

To have this study completed, an efficient search was done to gather and analyze the most recent body of research on the application of IoT in the energy sector. During the systematic search, we first searched for two main terms "Internet of Things (IoT)" and "energy", which are nonproprietary, within the titles and abstracts. Publication keywords accumulated in the IEEE, Google Scholar databases, Scopus and Hindawi with limiting our search to "management", "engineering" and "economics.

Decisively, we then group the related literatures in subgroups of energy optimization in the IoT and energy generation, T&D systems, and the demand side. Then, we distributed the related studies into subgroups of energy optimization in the IoT, T&D systems, and demand-side as well. Instead of focusing on specific illustrations and their limitations, we converge on IoT applications that are generally applicable to most energy systems. For instance, we don't go into detail about the type, number, and usage of home appliances, building typology, building materials, or occupant energy consumption patterns while discussing the function of IoT in smart buildings.

1.2 Internet of Things

The IoT is a novel technology that makes use of the Internet with the purpose of enabling communication between tangible objects, or "Things." Appliances and manufacturing machinery are a few examples of physical devices (Hui et al. 2020; Petroșanu et al. 2019; Luo et al. 2019; Khatua et al. 2020; Gu et al. 2019; Haseeb et al. 2019; Zouinkhi et al. 2020; Motlagh et al. 2019; Ramamurthy and Jain 2017; Jia et al. 2019; Karunarathne et al. 2018; Li et al. 2018). These Things deliver effective data sharing and allow the public to receive services through employing appropriate sensors and communication network systems. For example, reducing energy costs accomplishes logically controlling building energy consumption (Internet of Things 2022). IoT may be applied not only in energy but also in transportation, construction, manufacturing (Group 2022).

The third part of the IoT network is communications protocols that allow separate devices to connect and share data together with controllers. The IoT platform(s) permit users to decide on the networking technology type might be the best depending on the demands. Examples of those systems include ZigBee (Haseeb et al. 2020), Bluetooth and the wi-fi. Examples of common own cellular networks in this perspective include Long-Term Evolution-4G, 5G, and 5G and beyond standards (Francia 2017).

1.3 Internet of Things in the Energy Sector

Now, the energy markets are heavily reliant on fuels (fossil-based), which account for almost 80% of global energy. Extreme manufacturing and burning fossil fuels, including air pollution and climate change have, for example, negative cultural, health, and economic implications (Admin 2018). Energy efficiency or the use of less energy for the same reason are the two main choices for minimizing adverse fossil fuel use, as well as green energy sources. The first topic covered in this part is the use of IoT during the energy producing process. Then we go on to smart cities, which serves as a collective noun for IoT-based components, including smart grids, smart homes, smart factories, and intelligent transportation (Grubler et al. 2018). We will go over each of the above-mentioned components individually.

1.3.1 IoT and Energy Generation

Since the 1990s, industrial process automation, data acquisition as well as supervisory control systems in the energy sector (Tan et al. 2017; Ramamurthy and Jain 2017). The initial stages of IoT contribute to the energy sector by reducing the possibility of output failure or blackout by tracking and regulating equipment and processes. The key problems of old power plants are reliability, performance, environmental effects, and maintenance. The age of power plant equipment, as well as poor maintenance issues, can result in significant energy losses and unreliability. Assets are frequently over 516.353 months, enormously significant, and complicated in replacement.

Nations are pressuring RESs to use less fossil fuel and concentrate on domestic energy sources. The energy system is faced with contemporary issues known as the "intermittency challenge" because of the use of weather-dependent or intermittent renewable energy (VRE) sources including wind and solar energy (SIGFOX.COM. 2022). In an energy system with a sizable percentage of VRE, matching energy generation with demand can be challenging due to supply and demand volatility, which causes mismatches over a range of time scales. IoT solutions reduce the difficulties of adopting VRE, allowing for more flexibility in regulating generation and demand, leading to larger renewable energy integration shares and lower GHG emissions (the sum of emissions of various gases: carbon dioxide, methane, nitrous oxide, and smaller trace gases such as hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF6)) (Al-Ali 2016; Karnouskos 2010; Lagerspetz et al. 2019). Additionally, by utilizing IoT, machine-learning algorithms that aid in selecting the ideal mix can be used to achieve more efficient energy utilization.

1.3.2 Smart Cities

This is a technology support city normal operation (smart urbanization), combined with overpopulation, has resulted in a slew of global issues, including pollution (Ejaz et al. 2017), power availability, and other ecological interests. The smart IoT application is supported by recent advancements in digital technologies backed by advanced high-tech features (Mohanty et al. 2016). In this era, it is possible to link smart factories, smart households, power plants, and farms to collect data on their energy usage throughout the day. Energy allocated to other portions, like factories, that routinely reduced to stabilize the entire system at the lowest cost and risk of congestion or blackout if it is found that a segment, like residential regions, consumes the most energy in the afternoon.

1.3.3 Smart Grids

Smart grids are electric grids that consist of several operations and energy quantities. These grids that take advantage of the most reliable and reliable information and communications technology to optimize and monitor energy production, transmission and distribution grids, and end-user consumption. A smart grid generates a multiple directional information flow through linking several smart meters, which can be used for device optimization and energy distribution efficiency (Hossain et al. 2016) and (Bhardwaj 2015). Applications of smart grids can be illustrated in specific subgroups of the energy system, for example, energy storage, home, among others.

1.3.4 Smart Buildings

Cities' energy use can be categorized into three categories: Residential (home); commercial (services), including restaurants, offices, and schools; all the examples of domestic energy use of the housing sector are lighting, appliances, cooking, hothouse, water, ventilation, heating, cooling, and air-conditioning system (HVAC). The HVAC energy consumption constitutes half of the overall energy usage in most households (Avci et al. 2012; Vakiloroaya et al. 2014; Jagtap et al. 2022; Lee et al. 2017; Reinfurt et al. 2017). The control of the HVAC system is also important for reducing energy consumption.

1.3.5 Smart Industry Energy Use

In the industry, IoT can be employed to create an entirely associated and scalable system that reduces energy consumption while maximizing output. Conventional factories use lots of resources to manufacture and monitor the final product's quality. Furthermore, every phase must be monitored, which necessitates the involvement of human resources (Janssen et al. 2019). Utilizing a scalable and agile framework in smart industries, on the other hand, helps to detect faults at the same time rather than waiting until the end of the energy production.

1.3.6 Intelligent Transportation

One of the greatest contributors to air pollution and energy waste in big cities is the overuse of personal vehicles in place of public transportation. Instead of a practical transportation system where each component runs independently, using IoT technology, often known as "smart transportation," offers a global management framework. Real-time data processing is also necessary for effective traffic management. It is possible to connect every element of the transportation system and the process its data at once (Su et al. 2022). Applications for smart transportation include online map-based smart parking and traffic control.

1.4 Identified Challenges of Applying Internet of Things

Apart from the numerous advantages of Internet of Things in terms of energy savings, implementing IoT in the energy segment also poses several problems that must be tackled. This segment discusses the obstacles to implement IoT-based energy systems as well as existing solutions.

1.4.1 Energy Consumption

IoT platforms are putting a lot of work into saving electricity in energy networks. To allow IoT communication in energy systems, many IoT Things transmit data. Operating the IoT system and transmitting the enormous volumes of data created by IoT devices both require a large amount of energy (Kaur and Sood 2017). IoT device energy consumption continues to be a significant issue. The power consumption of IoT devices has been reduced, although, using a variety of techniques. As an illustration, you could put the sensors in sleep mode and only use them when necessary. Other challenges include IoT integration with subsystems (Shaikh et al. 2017), user privacy (Anastasi et al. 2009; Energies 2022), security issues (Boroojeni et al. 2017), IoT standards acceptance (Wong et al. 2016; Porambage et al. 2016), and architecture design challenges (Chow 2017).

1.5 Future Trends

There are a lot of benefits in the previous sections to the application of existing IoT systems to provide energy-efficient solutions for the energy sector. However, new solutions and trends to boost IoT efficiency and resolve the challenges associated with it are necessary to deploy IoT in the energy domain. In this segment, we present two approaches to the challenges of blockchain technology and green IoT (G-IoT).

1.5.1 Blockchain and IoT

Most today's IoT systems depend on centralized cloud systems (Jayaraman et al. 2017). In various IoT applications, thousands of IoT units and devices must be connected, which is challenging to synchronize. Because IoT is centralized and server-client in design, when one server is compromised, all linked objects are also readily affected, raising system security and user privacy issues. Fortuitously, blockchain approach is suggested as a solution (Poyner and Sherratt 2018).

Verified transactions are always held in a block that is associated with the last block in a way that proofs are never lost. Besides, any person can document and view the history of all transactions at each node. Every member of the blockchain is therefore immediately aware of any modification of the block (Jayaraman et al. 2017; Poyner and Sherratt 2018). Furthermore, thousands of IoT Things can be easily organized by way of the distributed database of blockchain. A secure distributed database (Li et al. 2017) is made possible by using Blockchain consensus algorithms established on pair-to-peer nets. Blockchain (Song et al. 2017) would then provide a decentralized, private-by-design IoT to provide security.

More specifically, blockchain allows objects to store and exchange app updates. If an upgrade is applied to the blockchains as a legitimate block, it is hard to delete or alter it. There are innocuous testing nodes that accept the precision of updated information and guarantee security against any attacks. As a result, blockchain will offer alerts, availability, and innocuousness to IoT-based networks (Meddeb 2016; Chen et al. 2014; Al-Qaseemi et al. 2016; Kshetri 2017).

In the energy market, blockchains can improve energy stability and reliability by offering a shared network for storage systems. Real and high-quality data freely are shared between devices, and citizens can access energy information directly without the third-party intervention (Alladi et al. 2019). Neighbors can quickly share electricity. As a result, without the intervention of regulators, not only will people's confidence be strengthened, but also costs associated with connecting to centralized grids will be reduced. Another value is that through tracking an area's consumption data, Blockchain allows energy delivery to regulate energy transfer to that specific area centrally. Besides, blockchain-based IoT networks assist in the diagnosis and repair of smart grid equipment (Christidis and Devetsikiotis 2016; Hawlitschek et al. 2018; Huh et al. 2017; Conoscenti et al. 2016).

1.5.2 Green Internet of Things

As these systems are soon to be used on a large scale, the energy based IoT devices is a major obstacle. A great deal of energy is required to power billions of devices linked to the Internet. Low-carbon, high-efficiency linking networks are required to solve these problems. Fortunately, G-IoT (Boudguiga, et al. 2017; Green Internet of Things for Smart World 2015; Nguyen et al. 2022; Lee et al. 2014; Nesa and Banerjee 2019; Yang et al. 2021; Zhao et al. 2022; Shafik et al. 2019a, 2019b, 2020a, 2020b, 2020c, 2020d, 2020e, 2020f, 2020g, 2021, 2022a, 2022b; Meng et al. 2020; Shafik and Matinkhah 2018, 2019, 2020a, 2020b, 2021; Jun et al. 2021; Matinkhah et al. 2019; Thilakarathne et al. 2022; Lin et al. 2021; Shafik and Mostafavi 2019; Shafik and Matinkhah 2019; Matinkhah and Shafik 2019, 2019a; Matinkhah and Shafik 2019b; Mostafavi and Shafik 2019; Popli et al. 2022; Majumdar et al. 2022; Shafik 2021) was developed in these conditions. The energy-efficient characteristics of G-IoT, including architecture, production, implementation, and disposal are important during the life cycle (Shokoor et al. 2022) and (Shafik and Mostafavi 2020), radiofrequency identification scale is concentrated to reduce the volume of content in each radiofrequency identification tag, which is difficult to recycle (Shafik et al. 2019c; Shafik and Matinkhah 2020c; Ebrahimy et al. 2019; Azrour et al. 2021a, 2021b).

1.6 Conclusions

Energy services are about to enter a new age of transformation. Large-scale applications of variable renewable energy in clustered energy networks, the need for energy efficiency, necessitates system-wide, interconnected approaches to reduce energy and environmental effects. In this respect, new technologies similar to IoT will assist the power (energy) market is moving from a centralized to a smart decentralized and streamlined framework. We examined the IoT position in the energy sector in general, and smart grids in this study. We categorize multiple IoT usage cases in every segment of the energy supply from energy generation to energy grids to end-user(s) industries or factories. Furthermore, various IoT device components, for instance, facilitating connectivity and sensor technology, and how they can be used in the energy field. We talk about cloud storage and data system analytics, like data collection and simulation resolution that can be utilized in smart applications of energy, from small devices, buildings to smart home, smart villages to big smart cities. As prospective research paths, we emphasize Blockchain and green IoT as alternatives to these problems.

References

Admin (2018) 8 types of sensors that coalesce perfectly with an IoT app—IT Firms, top IT Firms—result of in-depth research & analysis. https://www.itfirms.co/8-types-of-sensors-that-coalesce-perfectly-with-an-iot-app/. Accessed 04 Oct 2022

Al-Ali AR (2016) Internet of things role in the renewable energy resources. Energy Procedia 100:34–38. https://doi.org/10.1016/j.egypro.2016.10.144

Al-Azez ZT, Lawey AQ, El-Gorashi TEH, Elmirghani JMH (2019) Energy-efficient IoT virtualization framework with peer to peer networking and processing. IEEE Access 7:50697–50709. https://doi.org/10.1109/ACCESS.2019.2911117

Alladi T, Chamola V, Rodrigues JJPC, Kozlov SA (2019) Blockchain in smart grids: a review on different use cases. Sensors 19(22). https://doi.org/10.3390/s19224862

Al-Qaseemi SA, Almulhim HA, Almulhim MF, Chaudhry SR (2016) IoT architecture challenges and issues: aack of standardization. In: 2016 future technologies conference (FTC), pp 731–738. https://doi.org/10.1109/FTC.2016.7821686

Anastasi G, Conti M, Di Francesco M, Passarella A (2009) Energy conservation in wireless sensor networks: a survey. Ad Hoc Netw 7(3):537–568. https://doi.org/10.1016/j.adhoc.2008.06.003

Avci M, Erkoc M, Asfour SS (2012) Residential HVAC load control strategy in real-time electricity pricing environment. In: 2012 IEEE Energytech, pp 1–6. https://doi.org/10.1109/EnergyTech.2012.6304636

Azrour M, Mabrouki J, Guezzaz A, Kanwal A (2021a) Internet of things security: challenges and key issues. Secur Commun Netw 1–11. https://doi.org/10.1155/2021/5533843

Azrour M, Mabrouki J, Fattah G, Guezzaz A, Aziz F (2021b) Machine learning algorithms for efficient water quality prediction. Model Earth Syst Environ https://doi.org/10.1007/s40808-021-01266-6

Bhardwaj A (2015) Leveraging the internet of things and analytics for smart energy management. TATA Consult Serv Mumbai India

Bhattacharyya SC (2020) Energy economics: concepts, issues, markets and governance. Springer, London

Boroojeni K, Amini MH, Nejadpak A, Dragičević T, Iyengar SS, Blaabjerg F (2017) A novel cloud-based platform for implementation of oblivious power routing for clusters of microgrids. IEEE Access 5:607–619. https://doi.org/10.1109/ACCESS.2016.2646418

Boudguiga A et al (2017) Towards better availability and accountability for IoT updates using a Blockchain. In: 2017 IEEE European symposium on security and privacy workshops (EuroS PW), pp 50–58. https://doi.org/10.1109/EuroSPW.2017.50

Chen S, Xu H, Liu D, Hu B, Wang H (2014) A Vision of IoT: applications, challenges, and opportunities with China perspective. IEEE Internet Things J 1(4):349–359. https://doi.org/10.1109/JIOT.2014.2337336

Chow R (2017) The last mile for IoT privacy. IEEE Secur Priv 15(6):73–76. https://doi.org/10.1109/MSP.2017.4251118

Christidis K, Devetsikiotis M (2016) Blockchains and smart contracts for the internet of things. IEEE Access 4:2292–2303

Conoscenti M, Vetrò A, Martin JCD (2016) Blockchain for the Internet of Things: a systematic literature review. In: 2016 IEEE/ACS 13th international conference of computer systems and applications (AICCSA), pp 1–6. https://doi.org/10.1109/AICCSA.2016.7945805

Cui G, Li X, Xu L, Wang W (2020) Latency and energy optimization for MEC enhanced SAT-IoT networks. IEEE Access 8:55915–55926. https://doi.org/10.1109/ACCESS.2020.2982356

Daas MJ, Jubran M, Hussein M (2019) Energy Management Framework for 5G Ultra-Dense Networks Using Graph Theory. IEEE Access 7:175313–175323. https://doi.org/10.1109/ACCESS.2019.2957378

Di Francia G (2017) The development of sensor applications in the sectors of energy and environment in Italy 1976–2015. Sensors 17(4), Article no. 4. https://doi.org/10.3390/s17040793

Ebrahimy MM, Shafik W, Matinkhah SM (2019) A networked 5G unmanned aerial vehicle communication pricing and challenges. In: International conference on networking, communication and computing technology

Ejaz W, Naeem M, Shahid A, Anpalagan A, Jo M (2017) Efficient energy management for the internet of things in smart cities. IEEE Commun Mag 55(1):84–91. https://doi.org/10.1109/MCOM.2017.1600218CM

Energies | Free Full-Text | Internet of Things for modern energy systems: state-of-the-art, challenges, and open issues. https://www.mdpi.com/1996-1073/11/5/1252. Accessed 19 Mar 2022

Global Energy & CO_2 Status Report 2019—Analysis. IEA. https://www.iea.org/reports/global-energy-co2-status-report-2019. Accessed 15 Mar 2021

Group TM Smart sensor technology for the IoT. https://www.techbriefs.com/component/content/article/tb/pub/features/articles/33212. Accessed 12 Apr 2022

Grubler A et al (2018) A low energy demand scenario for meeting the 1.5 °C target and sustainable development goals without negative emission technologies. Nat Energy 3(6). https://doi.org/10.1038/s41560-018-0172-6

Gu S, Li J, Wang Y, Wang N, Zhang Q (2019) DR-MDS: an energy-efficient coding scheme in D2D distributed storage network for the internet of things. IEEE Access 7:24179–24191. https://doi.org/10.1109/ACCESS.2019.2900537

Haseeb K, Almogren A, Islam N, Ud Din I, Jan Z (2019) An energy-efficient and secure routing protocol for intrusion avoidance in IoT-based WSN. Energies 12(21). https://doi.org/10.3390/en12214174

Haseeb K, Almustafa KM, Jan Z, Saba T, Tariq U (2020) Secure and energy-aware heuristic routing protocol for wireless sensor network. IEEE Access 8:163962–163974. https://doi.org/10.1109/ACCESS.2020.3022285

Hawlitschek F, Notheisen B, Teubner T (2018) The limits of trust-free systems: a literature review on blockchain technology and trust in the sharing economy. Electron Commer Res Appl 29:50–63. https://doi.org/10.1016/j.elerap.2018.03.005

Home (2019) SDG Summit. https://sustainabledevelopment.un.org/sdgsummit. Accessed 07 Mar 2022

Hossain MS, Madlool NA, Rahim NA., Selvaraj J, Pandey AK, Khan AF (2016) Role of smart grid in renewable energy: an overview. Renew Sustain Energy Rev 60:1168–1184.https://doi.org/10.1016/j.rser.2015.09.098

Huh S, Cho S, Kim S (2017) Managing IoT devices using blockchain platform. In: 2017 19th international conference on advanced communication technology (ICACT), pp 464–467. https://doi.org/10.23919/ICACT.2017.7890132

Hui H, Ding Y, Shi Q, Li F, Song Y, Yan J (2020) 5G network-based Internet of Things for demand response in smart grid: a survey on application potential. Appl Energy 257:113972. https://doi.org/10.1016/j.apenergy.2019.113972

Ibarra-Esquer JE, González-Navarro FF, Flores-Rios BL, Burtseva L, Astorga-Vargas MA (2017) Tracking the evolution of the internet of things concept across different application domains. Sensors 17(6). https://doi.org/10.3390/s17061379

Internet of Things. https://www.ibm.com/cloud/internet-of-things. Accessed 24 July 2022

Jagtap S, Rahimifard S, Duong LN (2022) Real-time data collection to improve energy efficiency: a case study of food manufacturer. J Food Process Preserv 46(8)

Janssen M, Luthra S, Mangla S, Rana NP, Dwivedi YK (2019) Challenges for adopting and implementing IoT in smart cities: an integrated MICMAC-ISM approach. Internet Res 29(6):1589–1616. https://doi.org/10.1108/INTR-06-2018-0252

Jayaraman PP, Yang X, Yavari A, Georgakopoulos D, Yi X (2017) Privacy-preserving Internet of Things: from privacy techniques to a blueprint architecture and efficient implementation. Future Gener Comput Syst 76:540–549. https://doi.org/10.1016/j.future.2017.03.001

Jia M, Komeily A, Wang Y, Srinivasan RS (2019) Adopting Internet of Things for the development of smart buildings: a review of enabling technologies and applications. Autom Constr 101:111–126. https://doi.org/10.1016/j.autcon.2019.01.023

Jun Y, Craig A, Shafik W, Sharif L (2021) Artificial intelligence application in cybersecurity and cyberdefense. Wirel Commun Mob Comput. https://doi.org/10.1155/2021/3329581

Karnouskos S (2010) The cooperative internet of things enabled smart grid, pp 07–10

Karunarathne GGKWMSIR, Kulawansa KADT, Firdhous MFM (2018) Wireless communication technologies in the Internet of Things: a critical evaluation. In: 2018 international conference on intelligent and innovative computing applications (ICONIC), pp 1–5. https://doi.org/10.1109/ICONIC.2018.8601226

Kaur N, Sood SK (2017) An energy-efficient architecture for the internet of things (IoT). IEEE Syst J 11(2):796–805. https://doi.org/10.1109/JSYST.2015.2469676

Khatua PK, Ramachandaramurthy VK, Kasinathan P, Yong JY, Pasupuleti J, Rajagopalan A (2020) Application and assessment of internet of things toward the sustainability of energy systems: challenges and issues. Sustain Cities Soc 53:101957. https://doi.org/10.1016/j.scs.2019.101957

Kshetri N (2017) Can blockchain strengthen the internet of things? IT Prof 19(4):68–72

Lagerspetz E et al (2019) MegaSense: feasibility of low-cost sensors for pollution hot-spot detection. In: 2019 IEEE 17th international conference on industrial informatics (INDIN), pp 1083–1090. https://doi.org/10.1109/INDIN41052.2019.8971963

Lee C, Kim D, Kim J (2014) An energy-efficient active RFID protocol to avoid overhearing problem. IEEE Sens J 14(1):15–24. https://doi.org/10.1109/JSEN.2013.2279391

Lee CKM, Zhang SZ, Ng KKH (2017) Development of an industrial Internet of things suite for smart factory towards re-industrialization. Adv Manuf 5(4):335–343. https://doi.org/10.1007/s40436-017-0197-2

Li Z, Shahidehpour M, Aminifar F (2017) Cybersecurity in distributed power systems. Proc IEEE 105(7):1367–1388. https://doi.org/10.1109/JPROC.2017.2687865

Li S, Xu LD, Zhao S (2018) 5G Internet of Things: a survey. J Ind Inf Integr 10:1–9. https://doi.org/10.1016/j.jii.2018.01.005

Lin Y, Ahmad Z, Shafik W, Khosa KS, Almaspoor Z, Alsuhabi H et al (2021) Impact of facebook and newspaper advertising on sales: a comparative study of online and print media. Comput Intell Neurosci. https://doi.org/10.1155/2021/5995008

Luo X, Zhang H, Zhang Z, Yu Y, Li K (2019) A new framework of intelligent public transportation system based on the internet of things. IEEE Access 7:55290–55304. https://doi.org/10.1109/ACCESS.2019.2913288

Majumdar P, Mitra S, Bhattacharya D (2022) Green IoT for smart agricultural monitoring: prediction intelligence with machine learning algorithms, analysis of prototype, and review of emerging technologies. In: Handbook of intelligent computing and optimization for sustainable development, pp 637–53

Matinkhah SM, Shafik W (2019a) Smart grid empowered by 5G technology. In: 2019a smart grid conference (SGC), Tehran, Iran, pp 1–6. https://doi.org/10.1109/SGC49328.2019.9056590

Matinkhah SM, Shafik W (2019b) A study on financial pricing and applications models on 5g. In: 4th international conference in financial mathematics, Yazd, Iran, pp 54–60

Matinkhah SM, Shafik W (2019c) Broadcast communication analysis for 5g media radio access networks. In: 16th conference on broadcast and exhibition, Tehran, Iran.

Matinkhah SM, Shafik W, Ghasemzadeh M (2019) Emerging artificial intelligence application: reinforcement learning issues on current internet of things. In: 2019 16th international conference in information knowledge and technology, Tehran, Iran. https://civilica.com/doc/982297/

Meddeb A (2016) Internet of things standards: who stands out from the crowd? IEEE Commun Mag 54(7):40–47. https://doi.org/10.1109/MCOM.2016.7514162

Meng H, Shafik W, Matinkhah SM, Ahmad Z (2020) A 5g beam selection machine learning algorithm for unmanned aerial vehicle applications. Wirel Commun Mob Comput. https://doi.org/10.1155/2020/1428968

Mohanty SP, Choppali U, Kougianos E (2016) Everything you wanted to know about smart cities: the Internet of things is the backbone. IEEE Consum Electron Mag 5(3):60–70. https://doi.org/10.1109/MCE.2016.2556879

Mostafavi S, Shafik W (2019) Fog computing architectures, privacy and security solutions. J Commun Technol, Electron Comput Sci 24:1–14. https://doi.org/10.22385/jctecs.v24i0.292
Motlagh NH, Khajavi SH, Jaribion A, Holmstrom J (2018) An IoT-based automation system for older homes: a use case for the lighting system. In: 2018 IEEE 11th conference on service-oriented computing and applications (SOCA), pp 1–6. https://doi.org/10.1109/SOCA.2018.8645771
Motlagh NH, Bagaa M, Taleb T (2019) Energy and delay aware task assignment mechanism for UAV-based IoT platform. IEEE Internet Things J 6(4):6523–6536. https://doi.org/10.1109/JIOT.2019.2907873
Nesa N, Banerjee I (2019) SensorRank: an energy-efficient sensor activation algorithm for sensor data fusion in wireless networks. IEEE Internet Things J 6(2):2532–2539. https://doi.org/10.1109/JIOT.2018.2871469
Nguyen D, Dow C, Hwang S (2022) An efficient traffic congestion monitoring system on internet of vehicles. Wirel Commun Mob Comput. https://www.hindawi.com/journals/wcmc/2018/9136813/. Accessed 12 Sept 2022.
Obeis NT, Lehmoud AA, Mutar AF (2022) Content delivery network for secure of software defined networking by using IPv4, OpenFlow, and ALTO. Period Eng Nat Sci (PEN) 10(2):231–240. https://doi.org/10.4108/eetiot.v8i29.1108
Ojo M, Adami D, Giordano S (2016) An SDN-IoT architecture with NFV implementation. In: IEEE globecom workshops (GC Wkshps), pp 1–6. https://doi.org/10.1109/GLOCOMW.2016.7848825
Petroșanu DM, Căruțașu G, Căruțașu NL, Pîrjan A (2019) A review of the recent developments in integrating machine learning models with sensor devices in the smart buildings sector to attain enhanced sensing, energy efficiency, and optimal building management. Energies 12(24). https://doi.org/10.3390/en12244745
Popli S, Jha RK, Jain S (2022) Green IoT: a short survey on technical evolution & techniques. Wirel Pers Commun 123(1):525–53
Porambage P, Ylianttila M, Schmitt C, Kumar P, Gurtov A, Vasilakos AV (2016) The quest for privacy in the internet of things. IEEE Cloud Comput 3(2):36–45. https://doi.org/10.1109/MCC.2016.28
Poyner IK, Sherratt RS (2018) Privacy and security of consumer IoT devices for the pervasive monitoring of vulnerable people.https://doi.org/10.1049/cp.2018.0043
Ramamurthy A, Jain P (2017a) The internet of things in the power sector opportunities in Asia and the pacific. https://think-asia.org/handle/11540/7821. Accessed 09 Apr 2022
Ramamurthy A, Jain P (2017b) The internet of things in the power sector: opportunities in Asia and the pacific, vol 48. Asian Development Bank
Reinfurt L, Falkenthal M, Breitenbücher U, Leymann F (2017) Applying IoT patterns to smart factory systems. Adv Summer Sch Serv Oriented Comput Summer SOC
Risteska Stojkoska BL, Trivodaliev KV (2017) A review of Internet of Things for the smart home: challenges and solutions. J Clean Prod 140:1454–1464. https://doi.org/10.1016/j.jclepro.2016.10.006
Shafik W, Matinkhah SM (2020a) A portable fuzzy sink scheme for wireless sensor network life expectancy enhancement. IEEE Iran Jt Congr Fuzzy Intell Syst. https://doi.org/10.1109/CFIS49607.2020.9238684
Shafik W, Matinkhah SM (2021) Unmanned aerial vehicles analysis to social networks performance. CSI J Comput Sci Eng 18(2):24–31
Shafik W, Mostafavi S (2020) Knowledge engineering on internet of things through reinforcement learning. Int J Comput Appl (IJCA) 177(44):1–7
Shafik W, Matinkhah SM, Ghasemzadeh M (2019b) Fog-mobile edge performance evaluation and analysis on internet of things. J Adv Res Mob Comput 1(3):1–17. https://doi.org/10.5281/zenodo.3591228
Shafik W, Matinkhah SM, Ghasemzadeh M (2020g) Theoretical understanding of deep learning in uav biomedical engineering technologies analysis. SN Computer Science 1(6):1–13. https://doi.org/10.1007/s42979-020-00323-8

Shafik W (2021) A fast machine learning for beam selection in 5G unmanned aerial vehicle communications, MSc. dissertation, computer engineering department, Yazd University
Shafik W, Matinkhah SM (2018) How to use Erlang B to determine the blocking probability of packet loss in a wireless communication. In: 13th symposium on advances in science & technology, Mashhad, Tehran
Shafik W, Matinkhah SM (2019) Admitting new requests in fog networks according to erlang b distribution. In: 27th Iranian conference on electrical engineering, Yazd, Iran. https://doi.org/10.1109/IranianCEE.2019.8786518
Shafik W, Matinkhah SM (2020b) Dimensional fast machine learning algorithm for mobile unmanned aerial vehicle base stations. Int J Adv Appl Sci 28–38. https://doi.org/10.11591/ijaas.v10.i1
Shafik W, Matinkhah SM (2020c) A study of reinforcement learning on internet of things. In: International conference on science, engineering & technology, Singapura, Singapore
Shafik W, Matinkhah SM (2019) Privacy issues in social web of things. In: 5th international conference on web research, Tehran, Islamic Republic of Iran, pp 208–214. https://doi.org/10.1109/ICWR.2019.8765254
Shafik W, Mostafavi SA (2019) Knowledge engineering on internet of things through reinforcement learning. Int J Comput Appl 975. https://doi.org/10.5120/ijca2020919952
Shafik W, Matinkhah SM, Ghasemzadeh M (2019a) A fast machine learning for 5g beam selection for unmanned aerial vehicle applications. J Inf Syst Telecommun 7(28):262–278. https://doi.org/10.7508/jist.2019.04.003
Shafik W, Matinkhah SM, Ghasemzadeh M (2019c) Emerging artificial intelligence application reinforcement learning issues on current internet of things. In: 10th conference on information and knowledge technology (IKT), Tehran, Iran
Shafik W, Matinkhah SM, Afolabi SS, Sanda MN (2020a) A 3-dimensional fast machine learning algorithm for mobile unmanned aerial vehicle base stations. Int J Adv Appl Sci https://doi.org/10.11591/ijaas.v10.i1.pp28-38
Shafik W, Matinkhah SM, Ghasemzadeh M (2020b) A mobile fuzzy sink scheme for wireless sensor network period improvement. In: 8th Iranian joint congress on fuzzy and intelligent systems, Mashhad, Iran, pp 211–216. https://doi.org/10.1109/CFIS49607.2020.9238684
Shafik W, Matinkhah SM, Asadi M, Ahmadi Z, Hadiyan Z (2020c) A study on internet of things performance evaluation. J Commun Technol, Electron Comput Sci 1–19. https://doi.org/10.22385/jctecs.v28i0.303
Shafik W, Matinkhah SM, Ghasemzadeh M (2020d) Internet of things-based energy management, challenges, and solutions in smart cities. J Commun Technol, Electron Comput Sci 27:1–11. https://doi.org/10.22385/jctecs.v27i0.302
Shafik W, Matinkhah SM, Sanda MN (2020e) Network resource management drives machine learning: a survey and future research direction. J Commun Technol, Electron Comput Sci 1–15. https://doi.org/10.22385/jctecs.v30i0.312
Shafik W, Matinkhah SM, Etemadinejad P, Sanda MN (2020f) Reinforcement learning rebirth, techniques, challenges, and resolutions. Int J Inform Vis 4(3):127–135. https://doi.org/10.30630/joiv.4.3.376
Shafik W, Matinkhah SM, Sanda MN, Shokoor F (2021) Internet of things-based energy efficiency optimization model in fog smart cities. Int J Inform Vis 5(2):105–112. https://doi.org/10.4108/eetiot.v8i29.1108
Shafik W, Matinkhah SM, Shokoor F, Sharif L (2022a) A reawakening of machine learning application in unmanned aerial vehicle: future research motivation. EAI Endorsed Trans Internet Things 8(29). https://doi.org/10.4108/eetiot.v8i29.987
Shafik W, Matinkhah SM, Shokoor F (2022b) Recommendation system comparative analysis: internet of things aided networks. EAI Endorsed Trans IoT 8(29). https://doi.org/10.4108/eetiot.v8i29.1108
Shaikh FK, Zeadally S, Exposito E (2017) Enabling technologies for green internet of things. IEEE Syst J 11(2):983–994. https://doi.org/10.1109/JSYST.2015.2415194

Shokoor F, Shafik W, Matinkhah SM (2022) Overview of 5G & beyond security. EAI Endorsed Trans Internet Things 8(30)

SIGFOX.COM. https://www.sigfox.com/en. Accessed 12 Apr 2022

Song T, Li R, Mei B, Yu J, Xing X, Cheng X (2017) A privacy-preserving communication protocol for IoT applications in smart homes. IEEE Internet Things J 4(6):1844–1852. https://doi.org/10.1109/JIOT.2017.2707489

Su Z, Feng W, Tang J, Chen. Z, Fu Y, Zhao N, Wong KK (2022) Energy efficiency optimization for D2D communications underlaying UAV-assisted industrial iot networks with SWIPT. IEEE Internet Things J

Summary for Policymakers—Global Warming of 1.5 °C. https://www.ipcc.ch/sr15/chapter/spm/. Accessed 06 June 2022

Tamilselvan K, Thangaraj P (2020) Pods—a novel intelligent energy-efficient and dynamic frequency scalings for multi-core embedded architectures in an IoT environment. Micro process Microsyst 72. https://doi.org/10.1016/j.micpro.2019.102907

Tan YS, Ng YY, Low JS (2017) Internet-of-things enabled real-time monitoring of energy efficiency on manufacturing shop floors. Procedia CIRP 61:376–381. https://doi.org/10.1016/j.procir.2016.11.242

Thibaud M, Chi H, Zhou W, Piramuthu S (2018) Internet of Things (IoT) in high-risk Environment, Health and Safety (EHS) industries: a comprehensive review. Decis Support Syst 108:79–95. https://doi.org/10.1016/j.dss.2018.02.005

Thilakarathne NN, Kagita MK, Priyashan WD (2022) Green internet of things: the next generation energy efficient internet of things. Appl Inf Process Syst 391–402. Springer, Singapore. https://doi.org/10.1007/978-981-16-2008-9_38

Vakiloroaya V, Samali B, Fakhar A, Pishghadam K (2014) A review of different strategies for HVAC energy saving. Energy Convers Manag 77:738–754. https://doi.org/10.1016/j.enconman.2013.10.023

Wang J, Jiang C, Zhang K, Hou X, Ren Y, Qian Y (2020) Distributed Q-learning aided heterogeneous network association for energy-efficient IIoT. IEEE Trans Ind Inform 16(4):2756–2764. https://doi.org/10.1109/TII.2019.2954334

Wong TY, Shum C, Lau WH, Chung SH, Tsang KF, Tse CF (2016) Modeling and co-simulation of IEC61850-based microgrid protection. In: 2016 IEEE international conference on smart grid communications (SmartGridComm), pp 582–587. https://doi.org/10.1109/SmartGridComm.2016.7778824

Xing G et al (2019) Energy consumption in relay underwater acoustic sensor networks for NDN. IEEE Access 7:42694–42702. https://doi.org/10.1109/ACCESS.2019.2907693

Yang Z, Jianjun L, Faqiri H, Shafik W, Talal Abdulrahman A et al (2021) Green internet of things and big data application in smart cities development. Complexity. https://doi.org/10.1155/2021/4922697

Yazdinejad A, Parizi RM, Dehghantanha A, Zhang Q, Choo KKR (2020) An energy-efficient SDN controller architecture for IoT networks with blockchain-based security. IEEE Trans Serv Comput 13(4):625–638. https://doi.org/10.1109/TSC.2020.2966970

Yazdinejad A, Bohlooli A, Jamshidi K (2018a) Efficient design and hardware implementation of the OpenFlow v1.3 Switch on the Virtex-6 FPGA ML605. J Supercomput 74(3):1299–1320. https://doi.org/10.1007/s11227-017-2175-7

Yazdinejad A, Bohlooli A, Jamshidi K (2018b) P4 to SDNet: automatic generation of an efficient protocol-independent packet parser on reconfigurable hardware. In: 2018b 8th international conference on computer and knowledge engineering (ICCKE), pp 159–164. https://doi.org/10.1109/ICCKE.2018.8566590

Yazdinejad A, Bohlooli A, Jamshidi K (2019) Performance improvement and hardware implementation of open flow switch using FPGA. In: 2019 5th conference on knowledge-based engineering and innovation (KBEI), pp 515–520. https://doi.org/10.1109/KBEI.2019.8734914

Zhang X, Zhang X, Han L (2019a) An energy-efficient internet of things network using restart artificial bee colony and wireless power transfer. IEEE Access 7:12686–12695. https://doi.org/10.1109/ACCESS.2019.2892798

Zhang G, Shen F, Liu Z, Yang Y, Wang K, Zhou M (2019b) FEMTO: fair and energy-minimized task offloading for fog-enabled IoT networks. IEEE Internet Things J 6(3):4388–4400. https://doi.org/10.1109/JIOT.2018.2887229

Zhao L, Zhu D, Shafik W, Matinkhah SM, Ahmad Z et al (2022) Artificial intelligence analysis in cyber domain: a review. Int J Distrib Sens Netw 18(4). https://doi.org/10.1177/15501329221084882

Zhou K, Yang S, Shao Z (2016) Energy internet: the business perspective. Appl Energy 178:212–222. https://doi.org/10.1016/j.apenergy.2016.06.052

Zhu CM, Leung VC, Shu L, Nga EC (2015) Green internet of things for smart world. IEEE Access 3:2151–2162.https://doi.org/10.1109/ACCESS.2015.2497312

Zouinkhi A, Ayadi H, Val T, Boussaid B, Abdelkrim MN (2020) Auto-management of energy in IoT networks. Int J Commun Syst 33(1). https://doi.org/10.1002/dac.4168

Chapter 2
UAV-Enabled WSN and Communication Framework for Data Security, Acquisition and Monitoring on Large Farms: A Panacea for Real-Time Precision Agriculture

Oladayo O. Olakanmi, Mbadiwe S. Benyeogor, Kosisochukwu P. Nnoli, and Kehinde O. Odeyemi

Abstract Precision agriculture necessitates the use of sensors and wireless communications technologies for data security, gathering, and analysis. However, most farms are located outside telecommunications infrastructure coverage, thereby creating challenges to their usage for precision farming. Also, the vulnerability of sensitive agricultural data to unauthorized access can undermine food security, prompting the need for a cybersecurity framework to safeguard data communications between farm-wide wireless sensor networks (FWSNs) and cloud server/ground base stations. To collect data from FWSN and relay them to the cloud server/ground base station, we adopted an unmanned aerial vehicle (UAV) to carry a special data acquisition gadget that we developed. As an intermediary airborne system, this acts as a mobile base or repeater station that relays data between farm sensor nodes and the cloud server/ground base station. We also proposed a security scheme to secure the UAV-routed data transmission between the FWSN and the cloud server/ground base station. Results show that our system reduces data traffic, improves response time, and ensures the security of the FWSN.

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2.1 Introduction

Precision farming involves the collection, transmission, processing, and archiving of farm-borne data and information for efficient farm management and decision making (Abd El-kader and Mohammad El-Basioni 2013). This is based on the effective integration of smart sensors and communication technologies, such as wireless sensor networks (WSNs). The WSNs make it possible to monitor and specifically target each farm activity at a low cost, regardless of the farm's geographical area and location. However, an obstacle to precision agriculture is the limitation of readily available WSN technology, as most farms are located in regions with little or no telecommunication network coverage. Although the adoption of fixed base stations (i.e. repeaters) may solve these problems, however, this would increase the overhead cost of the project. In general, WSNs produce large amounts of sensitive data at regular intervals, which are not only susceptible to cyber attacks but also require high-bandwidth channels.

To solve these problems, we adopted the latest variant of the unmanned aerial vehicle (UAV) model in Benyeogor et al. (2022), coupled with radio or Internet capability and a secure data aggregation scheme for effective data acquisition. The UAV acts as an airborne mobile base station with integrated cyberphysical and telemetric capabilities that extends its data communication coverage at a minimal cost (Yaqot et al. 2021; Bacco et al. 2018; Radoglou-Grammatikis et al. 2020). Each farm-wide WSN (FWSN) comprises several sensor nodes that, in turn, consist of a radio-enabled microcontroller that aggregates data from heterogeneous sensors. These low-level sensors could be used to measure farm variables such as soil fertility, moisture, pH, temperature, humidity, egg counts, animal health status and/or location. The proposed system could enable farm managers to monitor and respond to different situations on the farm in real-time via a remote server or base station with analytical front-end applications for interpreting sensors' data and proffering appropriate decisions to actors (i.e., actuation mechanisms) such as an irrigation system or other farm mechanization for effective precision farming.

2.2 Related Work

The UAV is not only capable of providing ideal remote monitoring platforms, but is also capable of solving compatibility and reliability problems in precision farming. It provides small ground sampling distances, coverage on demand, and fast turnaround of information to farmers (Jr. and Daughtry 2018). This was demonstrated in Haque et al. (2014), where an autonomous low-weight, and low-cost UAV was developed using an Android-based flight controller. This system also uses the Google Maps application for localization, trajectory planning, and navigation.

To improve UAV performance, Daniel et al. (2015) proposed two approaches for mathematical modeling of UAV dynamics and kinematics. Their dynamics model was based on Lagrangian mechanics and Denavit-Hartenberg formulas, while their kinematic mathematical model was derived from classical mechanics equations. They applied their model for the control of one axis motion of a UAV. In Yang and Wang (2013), Runfeng and Xi introduced a novel solution for the incline detection of UAVs, which involved coupling a special robot vision camera with an inclinometer to analyze and formulate intelligent behavior for UAVs. Their system-aided a prototype UAV that is controlled by an on-board microprocessor to achieve and maintain level attitude for sustained periods of time (a crucial feat for the deployment of UAVs as airborne mobile base stations). Most of these UAVs have low battery life, poor power-material balance or are too expensive for economic use, and are therefore not suitable for use as mobile base stations for widely separated FWSNs as required for large-scale precision farming. In a closely related work, Caruso et al. investigated how near a UAV must fly over the sensors of an on-the-ground WSN to properly collect data (Caruso et al. 2021). According to them, this might be used as a criterion for selecting the suitable UAV, installing sensors at the appropriate spacing on the field, and resolving trade-offs between field size and UAV autonomy and flight path. Also, Zeng et al. explored various applications of UAVs as aerial base stations (i.e., signal amplifiers or repeaters) in future wireless communications systems, citing the cost-effectiveness of the approach (Zeng et al. 2016). Similar to this, Singh and Sharma devised a UAV-based platform for collecting and managing agricultural crop information in real-time. Singh et al. (2022). According to them, their system is 96.3% efficient and has high potential in agricultural applications such as crop health monitoring, spraying fertilizers, and pesticides. This method was experimentally explored by Lottes et al. in (2022), where they employed a machine learning-based approach for analyzing the spatial distribution of crops and weeds on farms using aerial photographs captured by a UAV.

Secondly, FWSNs could produce large amounts of sensitive data, which are not only susceptible to cyber-attacks but also require high bandwidth channels. Many security and aggregation approaches have been proposed for different networks (Geneiatakis et al. 2017; Ren et al. 2017; Tanaka et al. 2016; Zhou et al. 2019; Sivaraman et al. 2015; Olakanmi 2017; Azrour et al. 2021; Guezzaz et al. 2022). However, these aggregation schemes would be too complex for resource-constrained FWSN gateways. Meanwhile, Bayerlein et al. in (2021) proposed a multi-UAV Path Planning scheme for wireless data harvesting with deep reinforcement learning that can be adapted to various parametric changes of a data harvesting mission, such as the number of deployed UAVs, number, geospatial factors, maximum flight time, etc., without the need to perform expensive recomputations or relearn control policies. In relation to this, several approaches were already proposed to improve the observability of precision farming by enhancing data communication in FWSN systems (Olakanmi and Adama 2020; Gong et al. 2015; Saikia et al. 2017; Kim et al. 2017;

Lu et al. 2008; Kim et al. 2008; Gupta et al. 2016; Mabrouki et al. 2021). However, these favor the adoption of multipath as the best approach to developing WSN protocols for reliable data communication in FWSNs. Inline with this, Olakanmi and Adama (2020) proposed a secure multipath routing protocol based on sectorization and best-neighboring node selection models. According to them, this could satisfy the performance requirements of FWSNs in precision agriculture. Overall, multipath solutions are capable of increasing the reliability of FWSN system even though they could incur high computational and communication costs. Therefore, they are stark choices for precision farming. In essence, this suggests a dual approach involving the improvement of both the design and model of the UAV and FWSN systems, respectively, for effective data harvesting and precision farming. To solve the latter, we adopted and improved on the UAV model of Benyeogor et al. in (2022), which has demonstrates high aerodynamic efficiency, and sufficient payload carrying capacity/flight time. Hence, based on these literature, especially the works of Caruso et al. (2021); Zeng et al. (2016); Singh et al. (2022); Olakanmi (2017), the present paper focuses on employing the UAV model in Benyeogor et al. (2022) for efficient and cost effective aerial data communication in the FWSN.

2.3 Data Aggregation Scheme for FWSN Gateway

Our FWSN is clusterized into different clusters, the core of which is the gateway that consists of a microcontroller and a transceiver. The wireless transceiver serves as an access point through which data enter or exit a cluster. Each gateway aggregates the readings of its sensors and sends them to the UAV once they reach the range ($\approx$100 m) during data collection. The UAV is embedded with a wireless transceiver to collect data from a specific FWSN, which comprises several sensor nodes, as shown in Fig. 2.1. The UAV semi-autonomously flies to the vicinity of the base station that houses the Farm manager server (FMS) to relay the harvested data, by means of radio telemetry. Meanwhile, the same data are uploaded to the cloud server, using a WiFi connection, once the UAV is within the coverage of the mobile network.

Each multisensor node (or simply sensor node) can comprise sensors such as a temperature sensor to measure the temperature of a farmland soil, as shown in Fig. 2.2. The soil temperature would be a good indicator to inform a farmer on how much irrigation his farmland would require. A soil moisture sensor is also included to estimate the percentage of moisture contained in a farmland soil. This enables a farmer to determine when the soil is saturated with water and when to stop irrigation. A leaf moisture sensor can also be used to estimate the average volume of moisture on the surface of a leaf, which, together with soil temperature and moisture sensors, is a pointer to the level and timing of the required irrigation. The air temperature and relative humidity sensors are sensors that could help a farmer correctly estimate the weather and atmospheric conditions of the farm. This information would further help the farmer in determining what type of crops to plant per time and when to plant such crops. Obtaining environmental farmland data from a single geographical

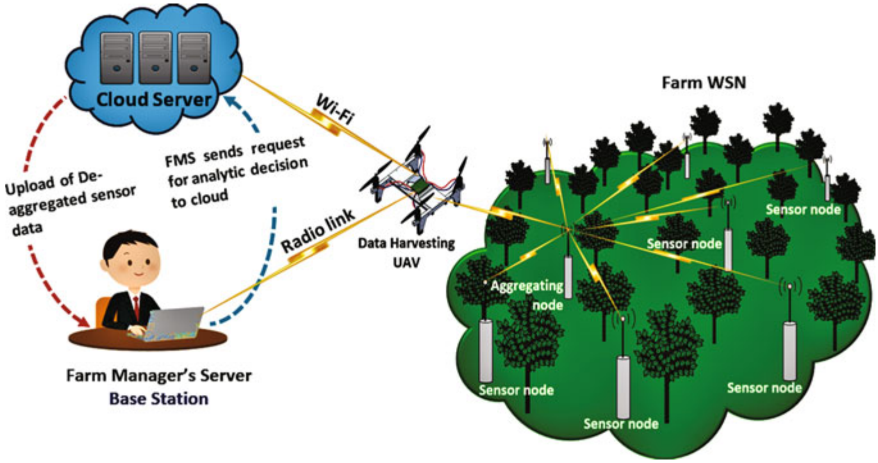

Fig. 2.1 Model of the farm wireless sensor network system

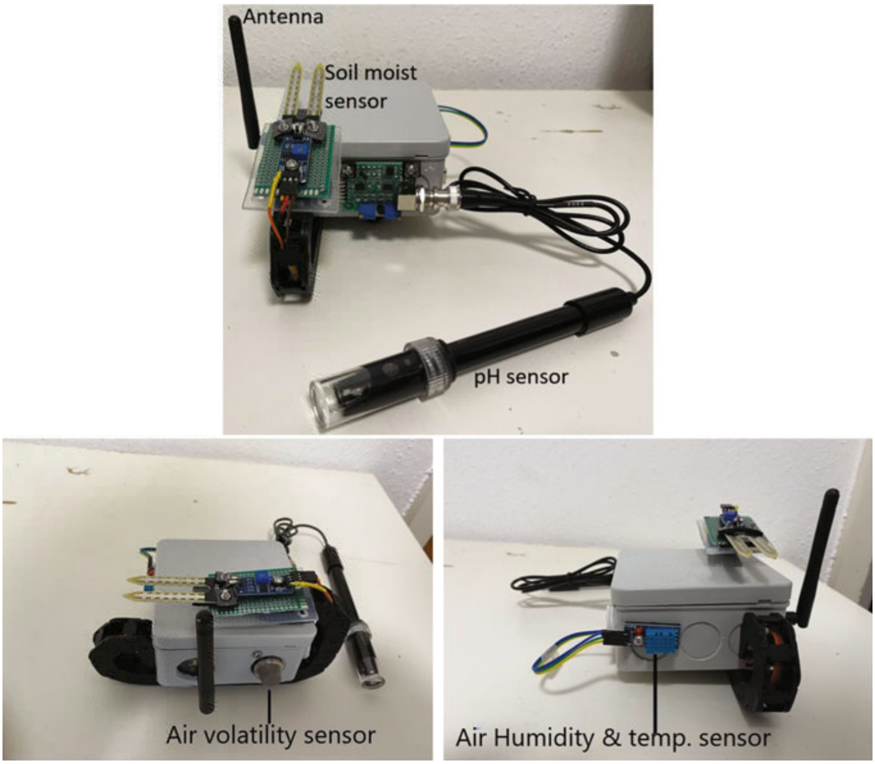

Fig. 2.2 Different views of the developed multisensor node consisting of soil pH sensor, soil moisture sensor, air volatility sensor and air humidity or temperature sensor