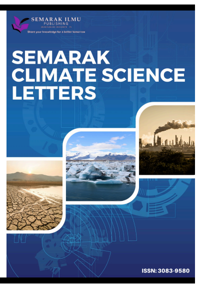
SEMARAK ILMU
PUBLISHING
202103268166(003316878-P)

Semarak Climate Science Letters

Journal homepage:
https://semarakilmu.my/index.php/scsl/index
ISSN: 3083-9580



A Recent Systematic Review on Prevention for Illegal Logging with IoT: Sensor Design, Application, and Management

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ARTICLE INFO

Article history:
Received 15 January 2025
Received in revised form 2 February 2025
Accepted 25 February 2025
Available online 15 March 2025

Keywords:
IoT; incursion; sensors; illegal logging; illegal deforestation

ABSTRACT

This study aims to critically review the literature of the assessment of the use of the Internet of Things (IoT) and blockchain technology in wireless sensor networks (WSNs) in detecting and monitoring illegal logging activities. The research methodology used in this study was based on the systematic review process, which assisted the researchers in identifying materials relevant to IoT, blockchain technology, and wireless sensor networks (WSNs), as well as summarizing and synthesizing the important elements contained therein. The researchers searched three major online scientific databases, Scopus, IEEE Explorer, and Mendeley, for relevant articles published between 2020 and 2023. The search generated 79 articles when precise search keywords and filters were used. They were then screened again using various inclusion and exclusion criteria such as article titles, languages, and important text, were carefully scrutinized to confirm that the inclusion criteria were satisfied and that the articles were appropriate for the current study’s research objectives yielding 25 publications deemed relevant to the study's objectives. Thematic analysis of the articles helped identify three major themes in sensor design, application and management. Overall, this study contributes to raising various issues about illicit logging and encroachment, seeking for a comprehensive solution that involves technological developments, legislative improvements, and an understanding of their combined effect.

1. Introduction

For several decades’ years, illegal logging and incursion pose serious threats to forests and natural habitats around the world. These activities not only cause significant damage to the environment, but also contribute to climate change, disrupt ecosystems, and affect biodiversity [1-5]. In addition,

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https://doi.org/10.37934/scsl.2.1.114b

such unhealthy activities often involve criminal networks that have led to social conflicts, human rights abuses, and corruption [6-14].

Monitoring and detecting these activities as early as possible can help prevent illegal logging and encroachment. Hence, the use of appropriate tools, such as IoT sensors and detection systems, can help prevent or minimize such activities. In particular, IoT sensors are deemed extremely useful and important, given that they can provide real-time data on environmental variables, such as temperature, humidity, and light, as well as detect movement, sound, and other indicators of human activity [15]. More importantly, by combining data from multiple sensors and using machine learning algorithms, it is possible to detect and classify illegal logging and incursion with high accuracy.

This comprehensive review was presented the current practices in the prevention of illegal logging and incursion with sensor classification and detection. The challenges and opportunities for using IoT sensors and detection systems for environmental monitoring are discussed and provide a detailed analysis of the most promising techniques and methodologies. The key factors that contribute to the success of IoT-based solutions for preventing illegal logging and incursion are highlighted, including sensor design, data management, security, and privacy. Finally, the potential impact of IoT-based solutions on environmental conservation is discussed and sustainable development and outline the future research directions in this field.

Unquestionably, a systematic review of recent literature of illegal logging and incursion can help reveal factors that may be used to mitigate this dire situation, such as technology and policy, which will have huge impact on illegal deforestation. This research aims to conduct a systematic analysis of the current practices in preventing illegal logging and encroachment, with a particular emphasis on the use of IoT sensors and detecting systems for environmental monitoring. However, the existing technique has flaws: it is inefficient, inaccurate, and has poor sensors ability, especially in complicated situations. Despite recent sensors improvements, there is no completely successful attempt in the area of IoT Sensor Design and Development Scope (Development of IoT sensors for various applications), IoT Data Management and Security Scope (Management and security of data generated by IoT devices), and IoT Applications for Environmental Monitoring Scope (Use of IoT devices for environmental monitoring and analysis). This research also aims to examine the problems and potentials of the deployment IoT sensors to identify and categorize unlawful logging activities and intrusive operations. The research also intends to identify the most promising strategies and procedures in this sector and highlight the main variables that lead to the success of IoT-based preventative solutions. Furthermore, the research emphasizes combining technology, policy, and evaluation technique in combating illegal logging and intrusion. This research attempts to shed some insights into the efficacy of IoT-based solutions and their impacts on environmental conservation and sustainable development by studying the technological and policy strategies utilized in combatting illegal deforestation. Overall, this research seeks to understand how IoT sensors and detection systems can prevent illegal logging and incursion, identify challenges and opportunities in this area, and provide recommendations for future research and implementation strategies.

2. Literature Review

The forest ecosystem is critical for supplying natural resources and habitat for a variety of flora and fauna. For decades, it has been under constant threat from illegal logging carried out by unscrupulous individuals. Clearly, this illicit practice has a negative impact on the forest ecology, resulting in a variety of adverse events such as the denuding of water catchment areas that gives rise to massive flash floods [16]. Taking cognizant of such threats, there have recently been initiatives to enhance public awareness of the necessity of forest protection. For example, the creation of games aimed at engaging and teaching people about the importance of forest conservation is one of the strategies being explored by practitioners. Such novel games serve as interactive instruments for communicating the message of environmental preservation and the need to combat illegal logging to the common people [17].

Therefore, it is imperative that efforts should be dedicated to investigate the use of sophisticated sensors in an Internet of Things (IoT) environment to detect and prevent such threats by protecting forest resources from illegal activities. In this regard, the deployment of intelligent forest alert monitoring systems is deemed appropriate as they can improve automated decision-making processes to take preventative actions based on several parameters, generate alerts, and implement measures to reduce the risks associated with high temperatures, humidity, smoke, and illegal tree smuggling. Ideally, each sensor used in these systems should follow a distinct algorithm created for the IoT application. A good case in point is a study carried out by the authors that employed such a system in an actual dense forest in Malaysia, the aim of which was to the examine the effectiveness of the system in monitoring and forecasting untoward events, such as forest fire. To help realize this effort, a proactive approach to forest management was entailed by integrating modern sensors and IoT technologies to help forecast or predict impending dangers and threats to the selected forest. It must be emphasized that early and targeted preventative actions must be timely executed to prevent or reduce the damage caused by wildfires and other illegal forest-related activities. The findings of the study can shed a greater insight into the understanding of practicality of such a system in mitigating potential problems of rampant unauthorized logging activities, which will have a huge impact on forest conservation and preservation [18].

A Video Surveillance Unit (VSU) prototype was developed that ran on two embedded Machine Learning (ML) algorithms to identify and warn potential forest fires. Essentially, the VSU prototype uses low-power hardware and ML models to analyze audio samples and visuals to identify fires in real-time. While the individual performance of the two ML models was equivalent, their combined use, using a recommended technique, dramatically helped increase its accuracy, precision, recall, and F-score, whose percentage scores were 90%, 85%, and 87%, respectively. For this system to work remotely, the Long-Range Wide Area Network (LoRaWAN) protocol was deployed to enable the distant communication of monitoring of forest fire. This approach effectively helped deliver event-driven data to the right personnel, helping them to provide fast mitigative responses. Effectively, the VSU prototype helped provide an efficient early forest fire detection and response solution by merging ML algorithms, low-power devices, and a dependable communication protocol.

To date, innovative sensing technologies based on the Internet of Things (IoT) play a critical role in the intelligent agricultural business. These systems, however, are prone to malfunctions, failures, and malicious assaults. To make matters worse, such sensors often work in demanding and hostile conditions, which might result in early sensor failures or abnormality and inaccurate outlier data. As such, these problems may have severe implications on the intelligent network's performance and dependability. As a result, precisely identifying IoT sensor behaviors in various situations is critical, especially in differentiating between suitable, defective, hacked, or attacked sensor activities. Against such a backdrop, this paper proposes an effective technique based on spatial correlation theory to overcome such problems. In this study, the evaluation of the sensor behaviors was performed with the use of Moran's I index tool, which was implemented using Classification and Regression Trees (CART), Random Forest (RF), and Support Vector Machine (SVM) models. Also, the use of edge computing technologies helped facilitate real-time anomaly detection. A real dataset of Forest Fire occurrences was used to assess the effectiveness of the proposed technique, which was carried out in comparison to other techniques used reported in three recent publications. Remarkably, the former technique outperformed its main three rivals, signifying that it has the potential to significantly assist the precision farming industry by allowing informed decision-making, secure operation of the IoT field network, better production, and enhanced operational efficiency. Such a finding is in line with the assertion that the overall performance and efficacy of IoT-based innovative agricultural systems are dependent on their ability to recognize the sensor behaviors [7].

In principle, a flood occurs when an overwhelming amount of water or sludge accumulates on previously dry terrain. Water runoff from numerous sources, such as canals, generally causes floods, resulting in water exceeding its normal capacity. Over recent years, urban floods have become a seriously issue, which has been driven by heavy rainfall, deforestation, urbanization, insufficient water and sewerage management, and a lack of environmental awareness in hydrological planning. Admittedly, one of the difficulties in handling floods is gathering and transferring reliable flood information from impacted regions to the control center. To reduce property losses during floods, it is critical to convey gathered data from impacted regions to the monitoring center as soon as possible without depending on fully established wireless data transmission technologies from the Internet of Things (IoT). In this respect, the Internet of Everything (IoE) idea goes beyond the Internet of Things, adding complexity to information transmission owing to the dynamic nature of wireless nodes in their surroundings. Nevertheless, this increases the possibility of data inflation of flood-predictable region between the data source and the control room. Various approaches for monitoring flood-prone regions have been used in the past. One of the primary issues, however, is guaranteeing fast and reliable data exchange between source and destination nodes without delays or data loss. Furthermore, while receiving data in a wireless ad-hoc environment employing IoT-based sensors, the contemporaneous quality of video footage must be considered. Moreover, distinguishing flood incidents from other calamities increases the complexity of the data acquired. Taking these considerations into account, the proposed study has three main goals: constructing a mobile ad-hoc flooding environment, developing an urban flood high-definition video surveillance system employing IoT-based sensors, and performing simulation tests. The study aimed to overcome the issues related to flood monitoring, data transfer, and video quality in wireless ad-hoc situations, which are critical factors in flood monitoring systems [19].

As acknowledged, massive loss of forests has caused severe implications, resulting in natural catastrophes such as floods, landslides, droughts, and climate change. As highlighted, Illegal and excessive logging activities are a main cause of deforestation, which are generally remain unreported until the forests have become totally stripped off of their trees. Further exacerbating this problem is due to inadequate or poor forest monitoring, which has led to the high pace of forest degradation. In this paper, the authors aim to examine the use of remote sensing technology, especially the Google Earth Engine (GEE) platform, in conjunction with artificial intelligence and machine learning methods, to monitor and categorize forest conditions and identify instances of illegal logging activities. Using remote sensing technologies and machine learning algorithms, it is now feasible to properly monitor forest conditions and identify areas in danger of illicit logging activities. One of the main reasons for using this platform is that, even in cloud cover, Sentinel 1 and 2 satellite photography broadly covers wooded regions. In particular, the GEE platform's random forest classification algorithm was used to analyze forest condition data from 2021, covering an area of 2,843,938.87 hectares. According to the research results, 38.46% of the existing forest areas comprised non-forest estates, while 61.54% were areas covered with dense forests. Furthermore, the research detected 1,971 and 1,680 forest change events during sensitive times, respectively, representing a total incident area of 7,599.28 hectares. Such findings may help relevant stakeholders to take preventative measures to avoid deforestation, safeguard natural resources, and promote sustainable forest management [20].

The articles selected and reviewed in this paper highlight the need for forest preservation, the difficulties involved, and the ways in which technology may be used to improve forest monitoring and management. In the first article, the authors argue that accurate environmental sound categorization (ESC) in forests is impossible without a large dataset like FSC22. This dataset is essential for enhancing environmental monitoring and avoiding illicit operations in forests using Deep Learning algorithms, since it consists of several acoustic classes representing forest noises [21]. The devastating effects of forest degradation in several areas in the Amazon are highlighted in the second article. As highlighted, deforestation has cause massive degradation of the environment, which in turn has led to high carbon emissions. In view of such revelations, there is a compelling need to invest in more efforts to mitigate or control deforestation, which has a chain reaction affecting the biodiversity and the socio-economic wellbeing of those living in such areas on forest residents [22]. In the final article, the authors discuss the timber industry in Ecuador, which has been a source of new jobs, manufactured commodities, and economic growth. However, deforestation, illogical logging, and inadequate afforestation initiatives have made this industry unsuitable in the long term [23]. To fulfil market needs, improve competitiveness, and encourage sustainable practices, a discussion of the present level of technology used in timber harvesting and wood processing in Ecuador is also highlighted.

Collectively, the articles discussed above offer a compelling argument for the value of forest preservation and the effectiveness of modern tools and concerted community effort in ensuring long-term forest sustainability. This discussion paves the way for further in-depth study of these topics in the future, which will help with more well-informed decision-making and strategic planning for forest conservation. By highlighting the importance of technology and collaborative efforts in developing sustainable practices, these articles help shed light on crucial concerns in forest conservation. Naturally, effective decision-making and strategic planning in forest conservation are needed to help mitigate deforestation more effectively.

3. Materials and Methods

In choosing the appropriate articles for this study, the systematic review process consisting of three main phases was conducted, which are discussed in the following sub-sections.

3.1 Identification

The first step of the systematic review process is keyword recognition. This was performed to identify relevant keywords contained in relevant thesauruses, dictionaries, encyclopaedia, and previous studies. Accordingly, the selected keywords were used as the search strings on several leading online scientific databases, such as Scopus, IEEE Explorer, and Mendeley (see Table 1). Through this step, 1,358 papers were successfully retrieved from the three databases.

Table 1
Search strings and filters in different databases for literature review on the use of IoT sensors in logging and deforestation (2020-2023)

Scopus	TITLE-ABS-KEY (sensor* AND (logging OR deforestation) AND iot) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j")) Date of accessed: May 2023
IEEE Explore	sensor* AND (logging OR deforestation) AND iot Filters Applied: Journals 2020 - 2023 Date of accessed: May 2023
Mendeley	sensor* AND (logging OR deforestation) AND iot Date of access: May 2023

3.2 Screening

Usually, duplicated papers would be excluded in the first phase of the screening process. In this phase, followed by the removal of 9 articles in the second phase of the process, which was based on several inclusion-and-exclusion criteria developed by researchers. For example, the first criterion was that all articles must be research articles, because they serve as the primary source of practical information. This means that publication materials in the form of systematic review, meta-analysis, meta-synthesis, book series, books, chapters, and conference proceedings were omitted from the study. Furthermore, the review exclusively focused on papers written in English and published between 2020 and 2023, resulting in 1272 articles being selected for further analysis.

3.3 Eligibility

In the third phase, known as eligibility phase, a total of 77 articles were shortlisted. Subsequently, the titles and key contents of the articles were thoroughly reviewed at this stage to ensure selected articles would meet the inclusion requirements and fit into the present study with the current research aims. As such, 52 articles were removed because they were not related to pure science and lacked empirical evidence. Finally, 25 articles were made available for the ensuing review process (see Table 2).

Table 2
The selection criterion table

Criterion	**Inclusion**	**Exclusion**
Language	English	Non-English
Timeline	2020 – 2023	< 2020
Literature type	Journal (Article)	Conference, book, review
Publication Stage	Final	In Press

3.4 Data Abstraction and Analysis

In this study, an integrative analysis was employed as one of the assessment strategies to examine and synthesize numerous research designs (quantitative, qualitative, and mixed methods). Essentially, the main aim of the analysis was to identify relevant topics and subtopics. The data collecting stage was the initial step in the theme development. Figure 1 shows the flow of reviewing analysis that led to the identification and selection of 25 articles deemed appropriate for the study.

The authors assessed their impacts by identifying and establishing relevant groups in the second stage. The detection and classification had a huge impact on determining the most relevant articles to choose from using appropriate themes, notions, or ideas. The principal author worked closely with other co-authors to create such themes, depending on the evidence needed in the context of this research. Throughout the data analysis process, a log was kept to record all the analyses, views, riddles, or other thoughts to facilitate smooth data interpretation. Finally, the authors contrasted the results with previous results to detect any inconsistencies in the theme design process. It is worth mentioning that if there were any discrepancies among the concepts, the authors would discuss together to resolve such an issue. Eventually, the developed themes were finely adjusted to ensure consistency. The experts (a public health specialist and a medical science specialist) recruited in this study helped perform the analysis to establish the domain validity, making the importance and suitability of sub-themes clearer. Based on the experts' comments and professional judgments, the authors made the necessary amendments.

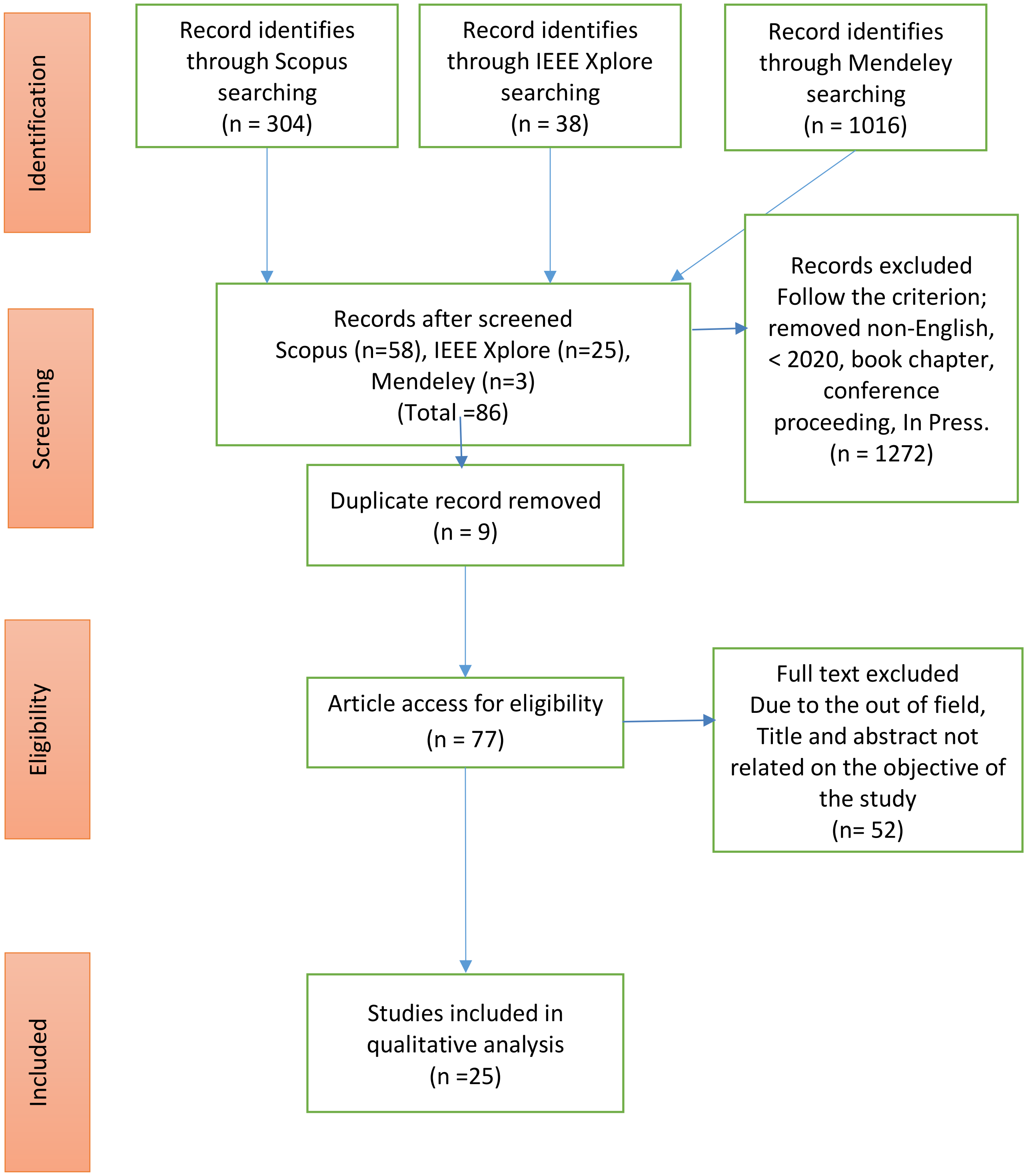

Fig. 1. Flow diagram of the proposed searching study [24]

4. Discussion of Themes

Several themes emerged from the narrative review, namely IoT Sensor Design and Development Scope (Development of IoT sensors for various applications), IoT Data Management and Security Scope (Management and security of data generated by IoT devices), and IoT Applications for Environmental Monitoring Scope (Use of IoT devices for environmental monitoring and analysis), which are discussed in the following sub-sections.

4.1 IoT Sensor Design and Development Scope – Development of IoT Sensors for Various Applications

Figure 2 shows the development of Internet of Things (IoT) sensors for various applications requires accurate identification of IoT sensor activities in appropriate, flawed, and compromised settings. A significant part of this study was dedicated to developing and testing a novel approach to distinguish sensor behavior in different scenarios using spatial correlation theory. The validation of this approach was conducted using Moran's I index tool. Machine learning algorithms, including Classification and Regression Trees (CART), Random Forest (RF), and Support Vector Machine (SVM), were used to test this approach. Real-time anomaly detection was facilitated by the use of edge computing technology [18,26].The novel approach was tested against a real dataset related to forest fires, which was compared with those of three recent works, yielding promising results in terms of the accuracy of real-time detection of IoT sensor behavior. From the practical perspective, such a detection accuracy will have implications on the development of applications in the precision farming industry, aiding in secure IoT field network management, productivity increase, and improved operational efficiency [26].The IoT platform discussed in this paper supports a wide range of applications and is highly versatile. Given such versatility, it is suitable for signal acquisition from resistive nano sensors, such as silicon nanowires, carbon nanotubes, graphenes, and other 2D materials. Moreover, with its low power consumption, the platform can fit seamlessly with various IoT sensing applications [27].

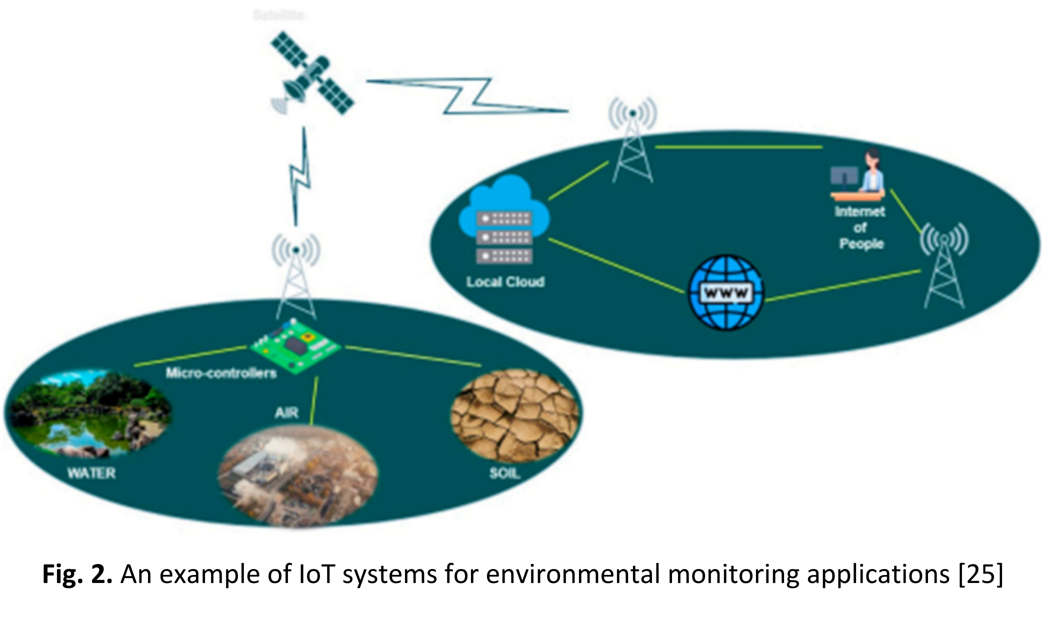

Fig. 2. An example of IoT systems for environmental monitoring applications [25]

In a case study on oil pipeline monitoring, we propose a hybrid architecture based on 2.4 GHz-based Zigbee and LoRa communication. We designed and implemented customized end-devices and a LoRa-based gateway for sensing critical parameters. Evaluation parameters for both Zigbee and LoRa were thoroughly studied through simulations and real-time experiments, with data logged into the Cayenne cloud [28]. We also focused on detecting wildfires in advance and protecting forest resources from unlawful activities through advanced sensor integration. Therefore, an innovative forest alert monitoring system was proposed, which is capable of performing automated protective actions based on several parameters, such as temperature, humidity, and smoke. This system was tested and verified in a natural forest setting. We discuss regarding our experiences in developing and deploying environmental sensors, drawing on six years of work with open-source hardware and software based on the Arduino platform. A water table depth probe, air and water quality sensors, multi-parameter weather stations, a time-sequencing lake sediment trap, and a sonic anemometer for tracking sand transport were the six case studies that were presented. We proved that, with careful, sensor-specific calibration and field testing, manual design and fabrication could result in research-grade scientific instruments for a fraction of the cost of standard methods [29].

4.2 IoT Data Management and Security Scope – Management and Security of Data Generated by IoT Devices

In this theme, the IoT WSN platform was presented, and the Riverbed Modeler Simulation Program was used to examine the network efficacy across various Wireless Sensor topologies, namely Star, Tree, and Mesh topology. This platform can support numerous scenarios, each with multiple sensors represented by ZigBee endpoints. As demonstrated, these sensors gathered information of the smart home and transmitted it to the controller, represented by the ZigBee coordinator. After user authentication via a specific application with three routing topologies, this controller then transmitted the data to the server for user monitoring via any gateway (Wi-Fi). It was discovered that the IoT WSN tree topology was preferable when the objective was to increase throughput, albeit at the expense of data loss with an acceptable delay. As the number of sensors increased, the Star topology was observed to be capable of enhancing network performance in terms of data loss and throughput, whereas the Mesh topology resulted in the least data loss despite low throughput. These results confirm that the selection of a suitable routing topology is essential for minimizing the performance degradation of IoT WSNs caused by interference between Wi-Fi and ZigBee networks that operate on the same frequency band (2.4 GHz) [27].

Focusing on the implications of retrofit solutions, the study also addresses a scenario in which a company with legacy devices attempted to leverage the benefits of blockchain technology. As a proposed underlying infrastructure, the BISS:4.0 platform was designed to integrate blockchain technologies into existing enterprise environments. A security analysis of IoT and blockchain revealed potential attacks and countermeasures applicable to such a case [30,31].

As a result, while using such a platform, the vulnerabilities of centralized systems need to be addressed carefully because a potential attacker with access might possibly reveal, alter, or delete crucial data and exploit event handling features. Using a decentralized ledger, blockchain technology provides integrity, immutability, and non-repudiation for any Internet of Things deployment. In this respect, a custom smart contract can help facilitate the use of decentralized and immutable event management capabilities. In this study, the researchers propose an innovative IoT architecture incorporating an Ethereum-based private (Quorum) blockchain that executes a unique ad-hoc smart contract, as well as a message queue telemetry transport (MQTT)-based communication mechanism between sensor and actuator nodes. Such a scheme has been validated in the context of forest fire risk detection [32].The study also highlights the limitations of cloud services in the Internet of Things, including the creation of data silos, reliance on third-party operators, and susceptibility to single points of failure. To address these issues, a blockchain-based IoT sensor data logging and monitoring system was developed, with a focus on modularity, data economy, and accessibility. Although the prototype's data availability and integrity considerably improved, massive operational costs were unavoidable because of the fees associated with smart contract computation. Thus, this calls for strong collaboration between relevant practitioners and stakeholders, which will have a huge impact on the implementation of solutions [33].

4.3 IoT Applications for Environmental Monitoring Scope – Use of IoT Devices for Environmental Monitoring and Analysis

The Weather Chimes project uses a low-cost, open-source hardware and software suite that allows access to real-time environmental sensor data through a Wi-Fi connection in Figure 3. The system supports scientists, educators, and paractitioners in obtaining and interacting with environmental data remotely. The study highlights the transformation of data collection processes into IoT-compatible formats, enabling new ways of accessing and understanding natural phenomena. Weather Chimes not only enables online data observation but also facilitates the transformation of data into auditory signals and soundscapes through sonification processes or creative animations. Lab and field tests have validated the system's sensor and online data logging performance.

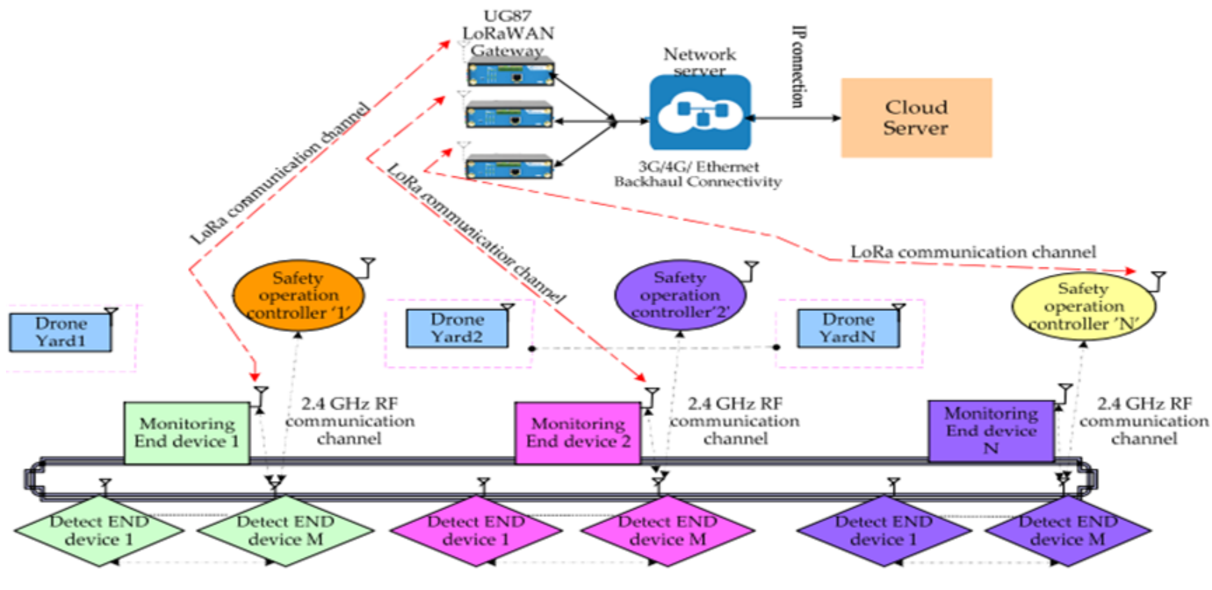

Fig. 3. S Hybrid Architecture of LoRa and Zigbee modem for pipeline parameters monitoring in oil and gas field [28]

The application of Weather Chimes in an undergraduate classroom and STEM education workshop highlighted its effectiveness in teaching environmental sensor concepts and exploring the interrelationships between different environmental factors [34]. A novel hierarchical approach for forest fire detection is presented in this study. The approach utilizes multimedia and scalar sensors in a hierarchical manner to minimize the transmission of visual data. Also, a lightweight deep learning model was developed for edge devices to improve detection accuracy and reduce traffic. The above system was evaluated through real testbed experiments, network simulations, and cross-validation, demonstrating high accuracy and energy efficiency. Revealingly, the proposed approach outperformed existing methods in terms of computational requirements and model size, making it suitable for edge computing applications [33].

The study highlights the challenges in transferring flood data from affected areas to control centres, emphasizing the need for immediate data transmission. Currently, existing techniques for monitoring flood regions face difficulties in sharing data without delays or losses. This problem becomes more challenging when trying to distinguish flood events from common incidences in wireless ad hoc environments employing IoT-based sensors. In view of this problem, a study was conducted with the aims of designing a mobile ad-hoc flooding environment, constructing an urban flood high-definition video surveillance system with IoT-based sensors, and performing simulation experiments. Performance analysis carried out revealed promising results, notably a significant reduction in path failure, packet loss rate, end-to-end delay, and transmission time compared to the that of the secondary path [32]. A monitoring system utilizing IoT technology was also developed to monitor indoor air quality. The system integrates sensors for temperature, humidity, and air quality, which send signals to the Node MCU ESP8266 module for processing. The Wi-Fi module in the module transmits the sensor data to the IoT Thing Speak platform for logging and graphical representation. The system has the potential to raise awareness of the importance of quality clean air, according to an evaluation of its performance [25,35].

The implementation of IoT technology in smart lampposts has also been explored, enabling various applications to run on a single system. The lampposts were mainly embedded with multiple sensors, communication protocols, and energy distribution infrastructure. The proposed architecture integrated LoRa for long-range communication and Wi-Fi for the interconnection with an IoT server. A real-time performance evaluation demonstrated that the sensing, communication, and monitoring of environmental parameters and images improved significantly [36]. Lately, the combination of AWS cloud technology and mobile connectivity presents a new approach to IoT connectivity services. The MQTT communication protocol is used for device interaction and data exchange. The solution allows for rapid prototyping and improved connectivity within the IoT system [29,36,37].

In addition, an intelligent autonomous lighting and air ventilation system was designed and implemented, featuring energy-aware self-sufficient lighting and monitoring of temperature, humidity, CO2 concentration, and smoke. The system helped enable HTTP protocol-based monitoring over smartphones or PCs, and real-time data logging into a cloud server for remote access. The analysis of its performance showed the use of the proposed system helped reduce energy consumption and economic costs significantly [35].

5. Conclusion

The findings of this review offer a useful guide for designing and developing IoT sensors for effective environmental monitoring at both local and global level. As reviewed, the evaluation of IoT and blockchain technologies within wireless sensor networks (WSNs) highlights the importance of data management and security associated with IoT devices. The performance of the Star, Tree, and Mesh WSN topologies could be negatively impacted by interference from Wi-Fi and ZigBee networks, according to an analysis of their effectiveness using the IoT WSN platform and the Riverbed Modeller Simulation Program. The Tree topology had the highest throughput, which was followed by the Star topology and Mesh topology, suggesting that choosing the right routing design is essential. Also, the examination of the integration of blockchain technology with older systems using the BISS:4.0 platform revealed crucial security features, such as decentralisation, integrity, immutability, and non-repudiation. In particular, a customised smart contract and private blockchain based on Ethereum could be deployed to administer ad hoc events and monitor forest fire risks. The study also identified several shortcomings of cloud services using IoT, such as the creation of data silos, reliance on third parties, and susceptibility to single points of failure. As such, a blockchain-based recording and monitoring solution for IoT sensor data was proposed to combat these issues by emphasizing on modularity, data economy, and accessibility, which would lead to improved availability and integrity of data. Clearly, there are multiple IoT applications, ranging from an open-source system for real-time environmental sensor data collection and innovative data interactions to an advanced autonomous illumination and air ventilation system. Other applications include hierarchical forest fire detection using lightweight deep learning models, a mobile ad-hoc flooding environment, an urban flood video surveillance system, and an IoT system for monitoring interior air quality. It might be argued that these numerous applications serve to enhance the effectiveness, accuracy, and accessibility of Internet of Things technology across a range of sectors, including infrastructure development, disaster detection, environmental monitoring, and autonomous systems.

6. Future Studies

The findings of this study can provide a guideline for designers and developers to develop effective and efficient IoT sensors for environmental monitoring. As demonstrated, data management and security in wireless sensor networks (WSNs) are the key criteria of evaluation for the Internet of Things (IoT) and blockchain technologies. The comparison of Star, Tree, and Mesh WSN topologies revealed that the interference between Wi-Fi and ZigBee networks may degrade network performance, entailing careful considerations of routing design. Also, blockchain technology can be incorporated into legacy systems utilising the BISS:4.0 platform to maximize the benefits of decentralisation and immutability. Likewise, ad hoc event management and forest fire risk monitoring can be enhanced with customized Ethereum-based blockchain. As such, a blockchain-based approach for capturing and monitoring IoT sensor data can be employed to overcome problems associated with cloud services in IoT, such as data silos and reliance on third parties, which leads to higher data availability and integrity. Clearly, there are definitely areas for improvement in the development of sensors, blockchain integration, network topology, data management, and security, which may necessitate additional research in this area.

7. Funding Statement

This study was carried out with the financial assistance provided by the Malaysian Ministry of Higher Education through the Prototype Research Grant Scheme. The project's identification number is 10233, and the reference code is PRGS/2/2015/WAB08/UPSI/02/1

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