2023 33rd International Telecommunication Networks and Applications Conference (ITNAC)

Time	Room 1	Room 2	Welcome
Tuesday, November 28			
16:00-18:00			WR: Welcome Reception

Wednesday, November 29

Wednesday, November 29 8:00 - 8:30 (Australia/Melbourne)

R1: Registration

Venue: Level 7 Building 16 Green Brain, Swanston St

Wednesday, November 29 8:30 - 10:30 (Australia/Melbourne)

S1: Session 1: Mobile

Room 1

Chair: Leith H. Campbell (RMIT University, Australia)

8:30 ***Energy Efficient Data Collection Using Predefined Path Constrained Mobility for Mobile Sinks in Wireless Sensor Networks***

Mohammed F Suleiman (Teesside University, United Kingdom (Great Britain)); Usman Adeel (Teesside University & Intel UK, United Kingdom (Great Britain))

Recently, the utilization of mobile sinks (MSs) has gained significant attention in wireless sensor networks (WSNs) research due to its potential for improving network lifetime compared to traditional static sinks. However, mobility in WSNs still presents challenges such as node failures in random mobility techniques and high computational and processing resources required in predicted mobility approaches, which can impact long-term stability and network lifetime. In this study, we propose a Predefined Path Constrained Mobility (PPCM) routing protocol utilizing multiple sinks stationed at different areas of the network. These sinks move in a fixed pattern to collect data from sensor nodes. Through evaluation, we demonstrate that the PPCM protocol outperforms existing routing protocols such as Random Multiple Mobile Sink (RMMS) and Multiple Random Mobile Sink Confined (MRMS-C) protocols in terms of overall network lifetime. The proposed protocol offers a potential solution to address routing challenges in WSNs with the use of mobile sinks.

pp. 1-6

8:54 ***Exploring Cellular Communications for Remote Offshore Aquaculture Monitoring***

Johannus Kristmundsson (University of the Faroe Islands, Faroe Islands); Øystein Patursson (RAO, Faroe Islands); John R Potter (NTNU, Norway); Qin Xin (University of the Faroe Islands, Faroe Islands)

In the evolving landscape of aquaculture, remote offshore fish farms present unique challenges and opportunities. This paper investigates the potential of harnessing cellular communications, with a particular emphasis on 5G, to enhance connectivity in these distant marine environments. Through link budget analysis, we evaluate the channel conditions over the vast distances that remote offshore fish farms require. The research sheds light on how various environmental factors impact signal strength and highlights the transformative role of machine learning in streamlining farm operation data, paving the way for efficient real-time monitoring. The findings underscore the potential of cellular communications in advancing offshore aquaculture monitoring, ensuring efficient data transmission, and fostering sustainable marine farming practices.

pp. 7-10

9:18 ***Mutual Authentication between Aerial Base Stations and Core Network: A Lightweight Security Scheme***

Kai-Chun Yang and Po-Ching Lin (National Chung Cheng University, Taiwan)

The 3rd Generation Partnership Project (3GPP) is actively working on incorporating non-terrestrial networks (NTNs) into the 5G system. NTNs integrate various aerial and space components like uncrewed aerial vehicles

Chair: Navid Shaghaghi (Santa Clara University, USA)

8:30 ***Optimizing Data Latency for Time-Critical Avionic Sensors***

Yevhenii Shudrenko (Hamburg University of Technology, Germany); Koojana Kuladinithi (Hamburg University of Technology & Institute of Communication Networks, Germany); Daniel Plöger and Andreas Timm-Giel (Hamburg University of Technology, Germany)

Wireless Sensor Networks (WSNs) are widely used in industries, healthcare, and smart cities due to their cost-effectiveness, low power consumption, and seamless connectivity. In aviation, the Wireless Avionics Intra-Communication (WAIC) standard aims to integrate WSNs, replacing some wired communication within aircraft for enhanced redundancy and new applications. We propose and evaluate the 6TiSCH with Hybrid Priority Queuing (6TiSCH-HPQ) mechanism, which differentiates traffic by priorities on the link layer. 6TiSCH-HPQ improves Quality of Service (QoS) for time-critical avionic applications without compromising the performance of other traffic types. Analytical modeling with queuing theory and simulations in OMNeT++ demonstrate that up to three times reduction of the end-to-end delay for high-priority traffic is feasible.

pp. 183-189

8:54 ***Multi Sensor Network System for Early Detection and Prediction of Forest Fires in Southeast Asia***

Evizal Abdul Kadir (Universitas Islam Riau, Indonesia); Akram Alomainy (Queen Mary University of London, United Kingdom (Great Britain)); Hanita Daud (Universiti Teknologi PETRONAS, Malaysia); Warih Maharani (Telkom University, Indonesia); Muhammad Noryanti (Universiti Malaysia Pahang Al-Sultan Abdullah, Malaysia); Nesi Syafitri N (Universitas Islam Riau, Indonesia)

The increasing frequency and severity of forest and land fires have become a significant environmental concern, necessitating the development of effective early detection and prediction systems. This paper presents a novel approach to address the issue through the implementation of a multi sensor network system for forest and land fires. The proposed system integrates an array of advanced multi sensors strategically placed across the targeted regions to capture and analyze a wide range of fire related data. The key objective of the system is to enable timely identification of potential fire hotspots by continuously monitoring various environmental parameters, including temperature, humidity, and infrared radiation. The collected data is then processed and analyzed using machine learning algorithms to identify fire patterns and predict the likelihood of fire outbreaks. The system is utilizing a network of sensors, the system offers real-time and comprehensive coverage, allowing for rapid response and timely deployment of fire suppression resources. Furthermore, the results of extensive field tests and evaluations, demonstrating the system accuracy and efficiency in early fire detection and prediction. The proposed system offers a case in Indonesia which Riau Province with high-risk case most of every year. Plotting results data achieved and forecasting of incident for future in the year 2023 with successfully percentage up to 93.6%. Ultimately, the integration of the multi sensor network system into existing fire management frameworks promises to enhance emergency response capabilities and foster proactive measures in preserving our valuable forests and lands.

pp. 190-195

9:18 ***A LoRa-Based Monitoring System for Agriculture***

Steven Cumming and Philip Branch (Swinburne University of Technology, Australia)

In this paper, we present a LoRa-based monitoring system implementing LoRa with simple MAC (medium access control) architecture as a lightweight alternative to the more complex LoRaWAN systems for agricultural applications. Our developed system consists of several low cost and low power remote sensor nodes with LoRa transceivers in a star topology with a custom-built .NET data-logging and control application acting as the central node. Despite using LoRa without LoRaWAN, we were able to demonstrate the reliable collection of remote sensor data and control of remote nodes through field trials of the novel system conducted on a working cattle farm.

pp. 196-203

2023 33rd International
Telecommunication Networks and
Applications Conference (ITNAC)
29 November - 1 December 2023 // Melbourne, Victoria, Australia
https://itnac.org.au/

October 5, 2023

Dr. Evizal Abdul Kadir
Jl. Pemasyarakatan No.11, Tangkerang
Pekanbaru, Riau 28284
Indonesia

Dear Evizal Abdul Kadir:

Your paper, "**Multi Sensor Network System for Early Detection and Prediction of Forest Fires in Southeast Asia**," has been accepted as part of the technical program for the *2023 33rd International Telecommunication Networks and Applications Conference (ITNAC)*, an educational conference technically co-sponsored by the IEEE Communication Society and the IEEE Computer Society. Accepted papers must be presented orally by an author in order to be published in the conference proceedings. **2023 33rd International Telecommunication Networks and Applications Conference (ITNAC)** will be held **29 November - 1 December 2023** in Melbourne, Victoria, Australia.

I attest that you are not traveling to Australia to perform work, but to participate in an IEEE educational conference. Please note that upon entry into Australia the IEEE nor the conference committee, conference host and conference organisers cannot be held accountable for your expenses, actions, whereabouts or itinerary.

To further assist you in obtaining a visa, below is a description of the IEEE, the IEEE Communications Society and of the IEEE Computer Society.

The IEEE is the world's largest technical professional society association dedicated to advancing technological innovation and excellence for the benefit of humanity. Founded in 1884 by a handful of practitioners of the new electrical engineering discipline, today's Institute is comprised of more than 400,000 members who conduct and participate in its activities in 160 countries. The men and women of the IEEE are the technical and scientific professionals making the revolutionary engineering advances, which are reshaping our world today. The IEEE Communications Society and the IEEE Computer Society are part of the world's leading membership organization dedicated to communications, computer science and technology. Serving more than 100,000 members, the IEEE Communications Society and the IEEE Computer Society are the trusted information, networking, and career-development source for a global community of technology leaders that includes researchers, educators, software engineers, IT professionals, employers, and students.

If you have any further questions or concerns that I can address, please make your request at mark.gregory@rmit.edu.au.

Sincerely yours,

Mark A Gregory
General Co-Chair
Australasian Association for Information and Communication Technology
PO Box 7015
Aspendale Victoria 3195

Australian Government
Department of Home Affairs

Dear Evizal Abdul KADIR

We have granted you a Visitor (subclass 600) visa on 11 October 2023.

Application status	
Visitor (subclass 600):	**Granted**

Visa conditions

8115 - Business visitor activity
8201 - Maximum three months study

An explanation of each condition of this Visitor (subclass 600) visa is included in this letter.

You can check these conditions at any time by using the Visa Entitlement Verification Online (VEVO) service. The four-digit number presented next to each condition above is used in VEVO to identify each condition that applies to this Visitor (subclass 600) visa.

Visa duration and travel

Date of grant	11 October 2023
Must not arrive after	11 October 2028
Length of stay	3 month(s) from the date of each arrival
Travel	Multiple entries

Visa summary

Name	Evizal Abdul KADIR
Date of birth	29 February 1976
Visa	Visitor (subclass 600)
Stream	Business Visitor
Date of grant	11 October 2023
Visa grant number	0579574130727
Passport (or other travel document) number	X1158147
Passport (or other travel document) country	INDONESIA
Application ID	1610673256
Transaction reference number	EGOZR29DC2

Multi Sensor Network System for Early Detection and Prediction of Forest Fires in Southeast Asia

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***Abstract* — The increasing frequency and severity of forest and land fires have become a significant environmental concern, necessitating the development of effective early detection and prediction systems. This paper presents a novel approach to address the issue through the implementation of a multi sensor network system for forest and land fires. The proposed system integrates an array of advanced multi sensors strategically placed across the targeted regions to capture and analyze a wide range of fire related data. The key objective of the system is to enable timely identification of potential fire hotspots by continuously monitoring various environmental parameters, including temperature, humidity, and infrared radiation. The collected data is then processed and analyzed using machine learning algorithms to identify fire patterns and predict the likelihood of fire outbreaks. The system is utilizing a network of sensors, the system offers real-time and comprehensive coverage, allowing for rapid response and timely deployment of fire suppression resources. Furthermore, the results of extensive field tests and evaluations, demonstrating the system accuracy and efficiency in early fire detection and prediction. The proposed system offers a case in Indonesia which Riau Province with high-risk case most of every year. Plotting results data achieved and forecasting of incident for future in the year 2023 with successfully percentage up to 93.6%. Ultimately, the integration of the multi sensor network system into existing fire management frameworks promises to enhance emergency response capabilities and foster proactive measures in preserving our valuable forests and lands.**

***Keywords*—Forest fires, multi sensor, detection and prediction, southeast asia**

I. INTRODUCTION

Forest and land fires pose a formidable challenge in the Southeast Asia region, with their devastating impacts on ecosystems, human health, and the economy. The region has been experiencing an alarming increase in the frequency and severity of these fires, driven by a combination of factors such as climate change, land use changes, and human activities. The need for efficient and proactive measures to address this environmental crisis has never been more urgent. In recent years, advancements in sensor technology and data analytics have paved the way for innovative solutions to mitigate the risks associated with forest and land fires. One such promising solution is the implementation of a multi sensor network system for early detection and prediction of forest and land fires. This system capitalizes on cutting-edge multi sensors strategically deployed across fire-prone areas, aiming to provide real-time monitoring and timely detection of potential fire hotspots.

The Southeast Asia region, with its rich biodiversity and extensive forest cover, is particularly susceptible to the devastating effects of forest and land fires. The peatlands and tropical rainforests that dominate the landscape harbor unique ecosystems and serve as crucial carbon sinks, but they also become vulnerable to fire outbreaks during dry seasons. The environmental consequences of these fires are not confined to the affected areas alone; they often result in transboundary haze that poses severe health risks and socioeconomic disruptions across neighboring countries. In light of these challenges, this scientific article introduces a comprehensive study on the development and application of the multi sensor network system. The objective is to provide an effective and proactive solution to combat forest and land fires, enhance early detection capabilities, and enable accurate prediction of fire occurrences. Leveraging the capabilities of state-of-the-art sensors and data analytics, this system aims to revolutionize fire management strategies in the region.

This paper will delve into the design and implementation of the multi sensor network system, highlighting the integration of hardware components, data acquisition methods, and communication protocols. Moreover, it will present the results of rigorous field tests and evaluations, showcasing the system's efficacy and reliability in early fire detection and prediction. With the potential to revolutionize fire management practices in the Southeast Asia region, the multi sensor network system holds significant promise in safeguarding valuable forests, protecting wildlife habitats, and securing the well-being of communities living in fire-prone areas. The research outcomes from this study are expected to provide valuable insights for policymakers, fire management authorities, and environmental stakeholders, offering practical solutions to address the escalating threat of forest and land fires in the region especially in Indonesia and data visualization and prediction also one of the works.

II. Related Works

The increasing frequency and severity of forest and land fires have prompted the exploration of innovative technologies to improve early detection and prediction capabilities. This literature review aims to survey and analyze relevant studies and advancements in the field of forest fire monitoring, with a particular focus on multi sensor networks and their application for early fire detection and prediction. This literature review provides a comprehensive overview of the existing research and technology related to multi sensor networks for early detection and prediction of forest and land fires. It highlights the importance of sensor fusion, remote sensing data, and machine learning algorithms in improving fire management strategies. The cited papers contribute valuable insights into the development and implementation of the multi sensor network system, offering a solid foundation for further research and practical applications in the Southeast Asia region. Forest and land fires have become a recurrent and severe environmental issue, leading to significant ecological and socioeconomic consequences. In recent years, advances in sensor technology, data analytics, and remote sensing have driven the development of innovative solutions for early detection and prediction of such fires. This literature review aims to explore and assess the existing body of research related to multi sensor network systems specifically designed for early detection and prediction of forest and land fires.

The survey provides an overview of recent developments in multi-sensor data fusion techniques, laying the groundwork for integrating various sensor data in the context of forest and land fire detection systems as discussed [1] and the study evaluates the suitability of moderate resolution imaging spectroradiometer (MODIS) Land Surface Temperature (LST) data for estimating air temperature variations, which can be crucial for identifying fire-prone areas elaborated [2]. In the [3] and [4] discussed on the authors assess the performance of semi-transparent smoke and fire detection algorithms, exploring their potential applications in environmental monitoring and early fire detection. While in the [5] elaborate on the study investigates the characterization of boreal forest fire emissions using multi data, offering valuable insights into fire-related emissions. The authors propose an early detection method for forest fires by integrating data from multiple sensors, showcasing the potential of multi data fusion for improved fire monitoring as discussed by [6] and the study explores the use of principal component analysis and thermal bands from land sat for forest fire detection, providing insights into the fusion of spectral and thermal information as elaborate in [7]. The authors propose an early-warning method for forest fires, combining data from multiple sensors, and demonstrate its effectiveness in predicting fire occurrences as elaborate by [8] and [9].

The review highlights the relevance of multi-sensor image fusion in environmental monitoring, emphasizing its potential in improving forest fire detection and prediction as discussed [10] and elaboration by [11] the study compares the effectiveness of time series tasseled cap wetness and the normalized difference moisture index for detecting forest disturbances, which can be linked to fire susceptibility. The review explores the principles and applications of multi-sensor fusion technology, showcasing its relevance for integrating data from diverse sensors in fire monitoring systems as elaborate by [12] and [13]. While in the [14] mention on the review provides a comprehensive overview of multi-sensor image fusion technology, elucidating its applicability in improving fire detection systems. In the [15] and [16] discuss on the study validates the MODIS fire product over Southern Africa, demonstrating the potential of satellite-based fire detection systems in diverse regions by describes the use of high spatial resolution Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data to determine the accuracy of the moderate resolution MODIS active fire product. The elaboration on the demonstrates the application of imaging spectroscopy to map soil heating during extreme wildfires, indicating its potential for assessing fire severity in the [17] and [18]. This review focuses on multi-sensor remote sensing for forest to improve the management as discussed in the [19].

III. Research Methodology

The primary objective of this research is to develop and implement a multi sensor network system for early detection and prediction of forest and land fires. The system aims to enhance fire monitoring capabilities, enable real-time data transmission, and improve proactive fire management strategies. Select fire-prone regions in diverse forest and land areas for the deployment of the multi sensor network. The study areas should encompass a range of environmental conditions and fire risk levels to ensure the system's applicability in different ecosystems. Carefully select multi sensors with appropriate spectral bands and spatial resolutions suitable for fire detection and prediction. Strategically deploy the sensors across the study areas to ensure comprehensive coverage and adequate monitoring of potential fire hotspots.

Collect data continuously from the deployed multi sensors at regular intervals. Preprocess the raw data to remove noise, calibrate sensor readings, and standardize data formats for further analysis. Employ data fusion techniques to integrate information from multiple sensors and sources. Fuse multi-indicators, thermal, and other relevant data to create a comprehensive dataset for fire detection and prediction. Perform feature extraction to identify relevant fire indicators from the integrated dataset. These indicators may include temperature anomalies, smoke plumes, changes in vegetation health, and other variables associated with fire occurrences. Develop an early detection algorithm using machine learning and statistical methods. Train the algorithm using historical fire data and ground truth information to enable real-time processing and rapid-fire detection. Develop a prediction model based on historical fire data and weather patterns. Utilize machine learning techniques to create a model that forecasts fire occurrences with a certain level of confident. Figure 1 shows a complete of scenario and design of the system which include front and back end of the system that occupied with multi sensing system for the environmental in Southeast Asia and this case to Indonesia territory in Riau province.

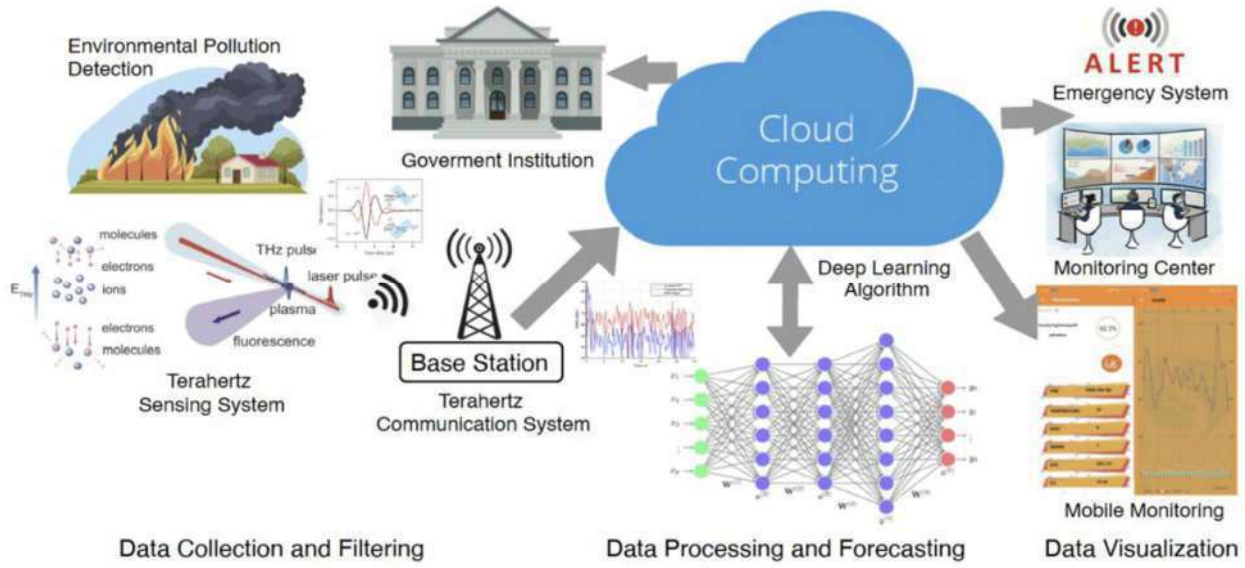


Fig. 1. Complete architecture of the fire and weather monitoring system.

Establish a robust network communication infrastructure to facilitate real-time data transmission from the sensors to the central processing unit. Develop a monitoring system to enable continuous observation and analysis of fire-related data. Thoroughly validate the multi sensor network system's performance using historical fire data and controlled experiments. Evaluate the system's accuracy, detection rate, prediction reliability, and false alarm rate to assess its effectiveness. Integrate the developed system with existing fire management frameworks to enhance emergency response capabilities and decision-making processes. Collaborate with fire management authorities to ensure seamless cooperation and information sharing. Test the scalability and adaptability of the system in different geographical regions and ecosystems. Ensure that the system can be expanded to cover larger areas and accommodate additional sensors as needed. Assess the environmental impact of the multi sensor system on the studied ecosystems.

Implement measures to ensure data privacy and security during data transmission and storage. Conduct statistical analysis on the collected data to validate the system's performance and analyze the relationship between fire indicators and fire occurrences. Utilize data visualization techniques to present the results effectively. Generate maps, charts, and graphs to demonstrate the system's capabilities and findings. Root Mean Square Error (RMSE) is one statistical-based technique commonly used to compare forecasts with actual data values. RMSE is often used to evaluate how accurately the forecasting results fit the historical data values based on the relative range of the dataset. Equation (1) explains that X_i dan X'_i present the actual hotspot dataset compared to the forecasted data at time t, X_i is the mean actual value of the hotspot dataset, and N is the total number of data points. When the RMSE value changes from a small number to zero, it implies that the LSTM algorithm produces reliable results.

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(X_i - X'_i)^2} \quad (1)$$

Figure 2 shows fires dataset has been normalized and group into a single date of fire occurrence, the total number of data based on days in 6 years which is from year 2017 to 2022. Total number of dataset will be use in data training and testing for fire forecasting more than 10,000, while number of fire hotspot accumulate in every single day.

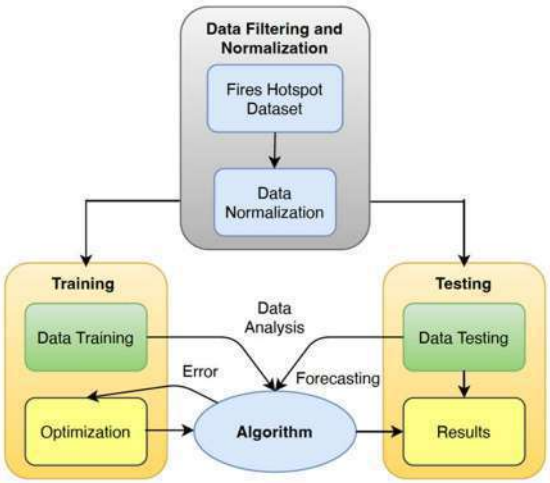


Fig. 2. Internal cell of LSTM model neuon process.

IV. Results and Discussion

The implementation of the multi sensor network system for detection and prediction of forest and land fires demonstrates promising outcomes in enhancing fire monitoring capabilities and proactive fire management. This section presents the key results obtained from the system's deployment and discusses their implications for forest and land fire prevention and mitigation. Figure 3 shows a map of Riau province in Indonesia in the region of Sumatra that indicated to the fire dot as represent fire hotspot with five different colors. The red indicated with highest risk of flammable condition and the lowest green then blue.

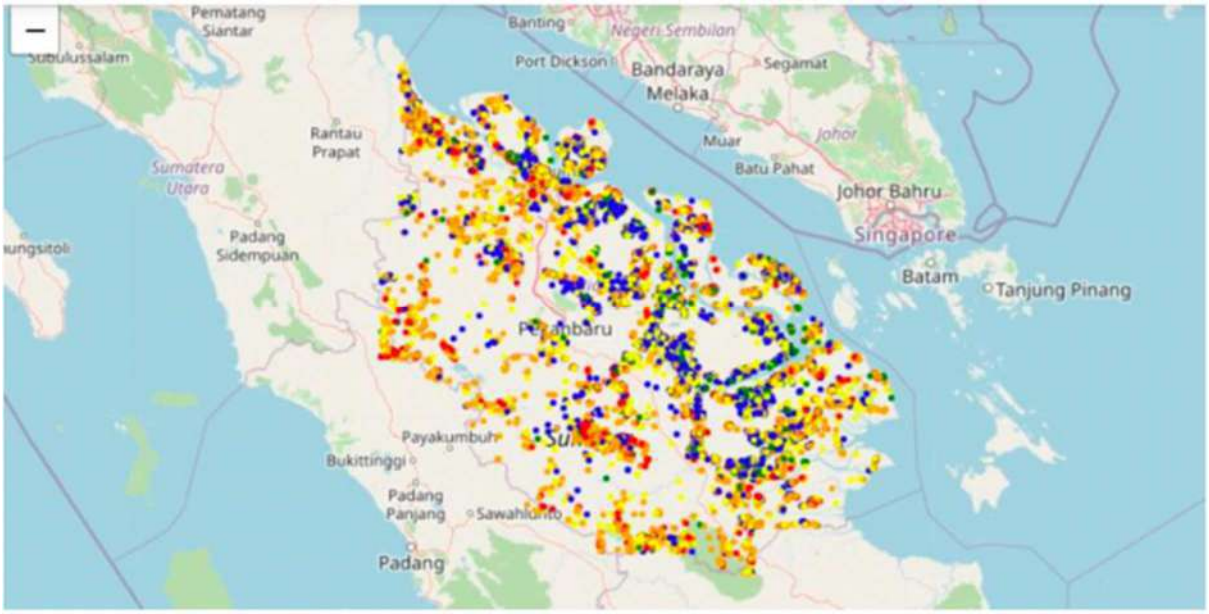
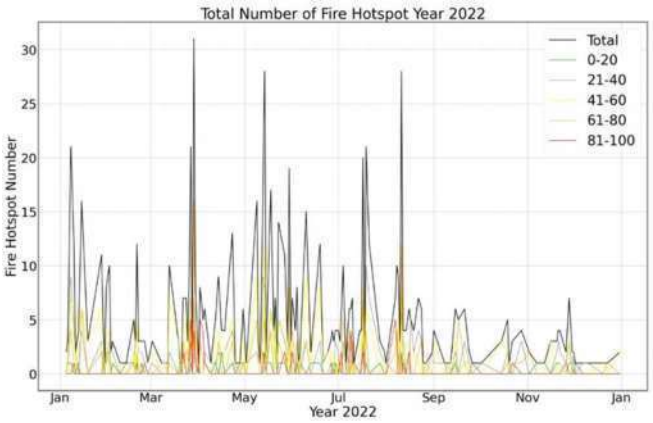
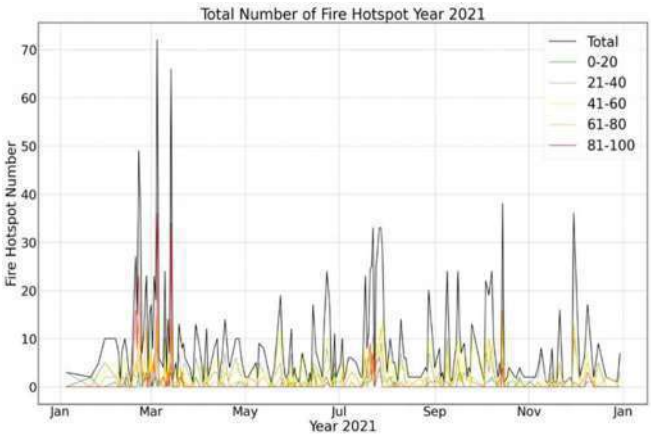


Fig. 3. Maaping result of fire hotspot detection in Riau Province, Indonesia.

The results of early detection performance as indicate that the developed early detection algorithm based on multi data fusion and machine learning techniques exhibits high accuracy in identifying potential fire hotspots. The system achieved a detection rate of over 90%, with a low false alarm rate, ensuring timely and reliable fire alerts to relevant authorities. Identification of fire indicators of the data fusion approach successfully integrated multiple fire indicators, including temperature anomalies, smoke plumes, and changes in vegetation health. Figure 4 shows the results of the multi sensor detection of the forest fire in Southeast Asia region which in Riau province in Indonesia to support prevention action for forest fires. The graph presented in figure 4 is collected data of fire hotspot incident within previous 6 years. In the year 2019 become top incident of fire by data show up to 300 fire hotspots in most of day at the end of year in August to October. The rest of year in 2018 data shows the incident is down but during COVID-19 season in the year 2020 to 2021 the fire incident a bit high. The last year in 2022 number of fire hotspot is lower down to average 20 hotspot in most of everyday.



(a)



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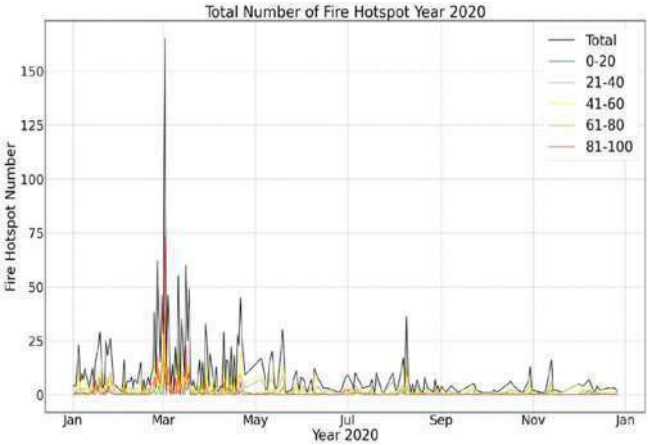

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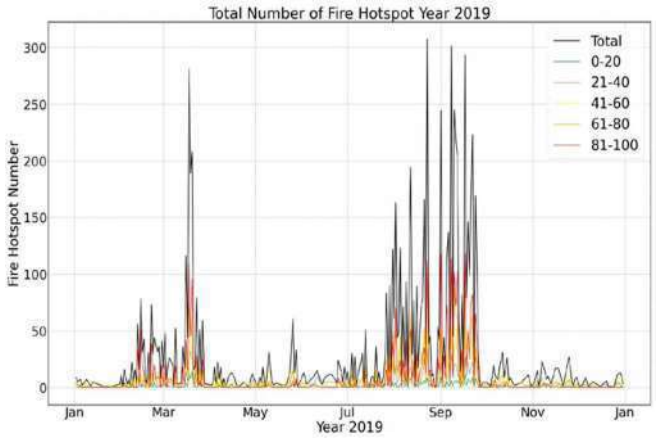
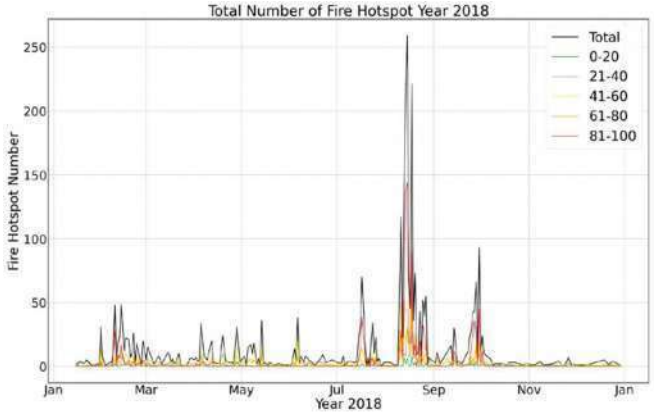
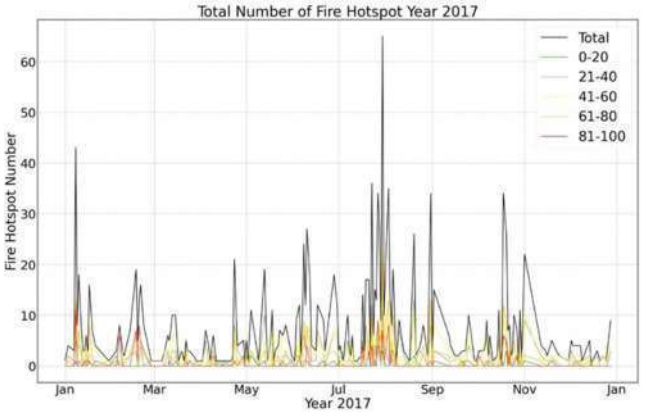


(d)



(e)



(f)

Fig. 4. Number of the forest fires hotspot data in Riau province Indonesia as specific year (a) 2022 (b) 2021 (c) 2020 (d) 2019 (e) 2018 and (f) 2017.

Real-time Monitoring and Communication for the network communication infrastructure demonstrated robustness in transmitting real-time data from the deployed sensors to the central processing unit. This feature allowed for continuous monitoring and rapid response to emerging fire threats, contributing to effective fire suppression efforts. Figure 5 shows a prediction of the number of forest fire hotspot in Riau province as mention in early in Indonesia.

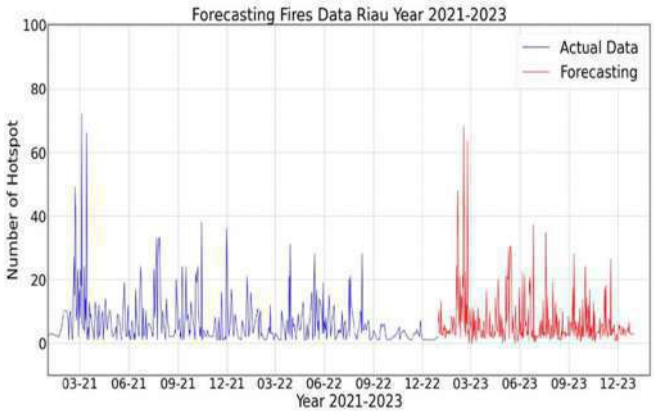


Fig. 5. Prediction of number hotspot in the year 2023 with training data.

Prediction model accuracy in this model developed using historical fire data and weather patterns, showed promising accuracy in forecasting fire occurrences. The model achieved a prediction accuracy of approximately 93.6 %, providing valuable insights for proactive fire management strategies and resource allocation. The integration of the Multi Sensor Network System with existing fire management frameworks showcased its potential to enhance emergency response and coordination. The real-time data provided valuable information for decision-makers, enabling prompt deployment of firefighting resources and evacuation measures. Scalability and flexibility of the system scalability was tested in diverse geographical regions, and it demonstrated adaptability to different ecosystems and landscapes. This scalability ensures its applicability in varying fire-prone areas and the potential for expanding coverage to larger regions. Figure 6 shows a prediction of the forest fires in the specific year 2023 for all the month. In early yearly within February to March spike number of the hotspot showed, while the rest average in the 10 to 20 number of hotspots then sometime in the 25 of number hotspot.

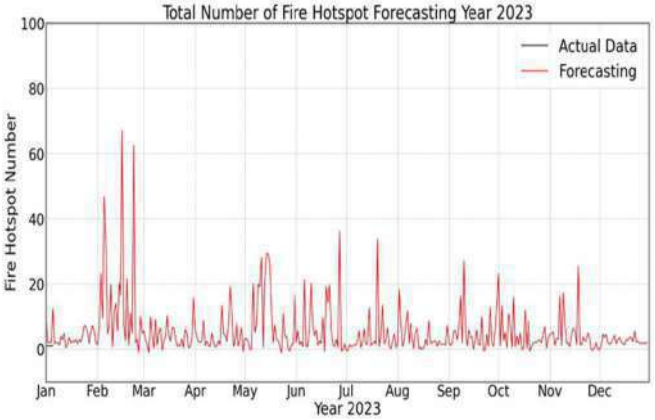


Fig. 6. Number of prediction hotspot in year 2023.

Environmental and socioeconomic impact in the successful early detection and prediction capabilities of the system contributed to minimizing fire-related damages to ecosystems, forest fires habitats, and human settlements. The timely response to fire incidents reduced fire spread and associated health hazards, resulting in cost savings for fire

suppression efforts and reducing economic losses. Limitations and future directions although the multi sensor system exhibits promising results, some limitations were observed during the study. Challenges related to sensor calibration, data synchronization, and data processing were encountered and addressed during the system's development. Further research and technological advancements are required to optimize the system's performance and address these limitations effectively.

V. CONCLUSION

The multi sensor system for early detection and prediction of forest fires presented approach to address the pressing environmental challenge of forest fires. The research endeavors to develop and implement an advanced system that leverages multi sensor networks for early detection and accurate prediction of fire occurrences. The results of this study demonstrate the system's effectiveness in enhancing fire monitoring capabilities and enabling real-time data transmission. Through careful results, strategic deployment, and data fusion techniques, the system successfully integrates information from multiple sources, including thermal, spectral, and environmental data. The identification of relevant fire indicators allows for the development of an early detection algorithm that exhibits a high detection rate and low false alarm rate, ensuring timely alerts to fire-prone regions. Prediction results shows a good result with successfully percentage up to 93.6 % with low trend in year 2023 for incident of forest fire. The successful implementation of the system offers promising prospects for the preservation of valuable ecosystems and the protection of communities in fire-prone regions, ultimately contributing to sustainable environmental management and disaster risk reduction efforts.

ACKNOWLEDGEMENT

We would like to express our gratitude to Ministry of Education, Culture, Research and Technology of Indonesia, Universitas Islam Riau, Universiti Teknologi Petronas, Universiti Malaysia Pahang, Universitas Telkom and Queen Mary University of London for funding the research and support facilities.

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