FOREST FIRE MONITORING SYSTEM

SHIHABUDDIN KABASHI KHATIR KABASHI

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To my beloved parents, thank you.

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ABSTRACT

The world's environmental concerns have never been larger or more complicated than they are now. Natural catastrophes have grown drastically in frequency and scale over the last few decades, threatening global regions covered by forests and urban woods. Forest fires on a large scale are one of the most dangerous natural disasters influencing climate change and human lives all over the planet. As a result, well-planned and closely coordinated effective preventive, early warning, and response techniques are required to limit their effects on people and the environment. This study describes a smart forest fire monitoring system that may be used in early fire warning systems and offers real-time temperature, humidity, flame, smoke, and location coordination monitoring. The system comprises of a single node and a gateway, and LoRa technology is the communication protocol implied in the system. The node has four sensors that measure temperature, relative humidity, gas levels in the environment, flame and location in order to evaluate the level of fire hazard and the likelihood of forest fires in a specific area. The sensor's data is uploaded to the database and Cayenne cloud for notification. Using LoRa have an impact of longer transmission range between the sensor node and the gateway as well as it has low energy consumption compared to other communication protocols. Moreover, the system proved its durability under extreme weather conditions.

ABSTRAK

Kebimbangan alam sekitar dunia tidak pernah menjadi lebih besar atau lebih rumit daripada sekarang. Bencana alam telah berkembang secara drastik dalam kekerapan dan skala sejak beberapa dekad yang lalu, mengancam kawasan global yang diliputi oleh hutan dan hutan bandar. Kebakaran hutan secara besaran adalah salah satu bencana alam yang paling berbahaya yang mempengaruhi perubahan iklim dan kehidupan manusia di seluruh dunia ini. Akibatnya, teknik pencegahan, amaran awal dan tindak balas yang berkesan yang dirancang dengan baik dan diselaraskan rapi diperlukan untuk mengehadkan kesannya terhadap manusia dan alam sekitar. Kajian ini menerangkan sistem pemantauan kebakaran hutan pintar yang boleh digunakan dalam sistem amaran kebakaran awal dan menawarkan pemantauan suhu masa nyata, kelembapan, nyalaan, asap dan penyelarasan lokasi. Sistem ini terdiri daripada koleksi nod dan get laluan, dan teknologi LoRa ialah protokol komunikasi yang tersirat dalam sistem. Setiap nod mempunyai tiga penderia yang mengukur suhu, kelembapan relatif, paras gas dalam persekitaran dan lokasi untuk menilai tahap bahaya kebakaran dan kemungkinan kebakaran hutan di kawasan tertentu. Data sensor dimuat naik ke pangkalan data dan awan Cayenne untuk pemberitahuan. Menggunakan LoRa mempunyai kesan julat penghantaran yang lebih panjang antara nod sensor dan get laluan serta ia mempunyai penggunaan tenaga yang rendah berbanding protokol komunikasi lain. Selain itu, sistem itu membuktikan ketahanannya dalam keadaan cuaca yang melampau.

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IoT	–	Wave attenuation
LPWAN	–	Low Power Wide Area Networks
NB-IoT	–	Narrowband IoT
ADR	–	Adaptive data rate
NOC	–	Network Operating Centre
DFC	–	Double Frequency Counter
CSS	–	Chirp Spread Spectrum
FSPL	–	free space path loss
RSSI	–	Received Signal Strength Indicator
PRR	–	Packet reception rate
SNR	–	Signal Noise Ratio
SF	–	Spreading factor
ToA	–	Time on air
BW	–	Bandwidth
PER	–	Packet Error Rate

CHAPTER 1

INTRODUCTION

1.1 Background of the study

The Internet of Things (IoT) seeks to allow diverse devices to communicate and cooperate to support smart services in different environments transparently to the user. In the next few years, billions of IoT devices will be installed globally, allowing smart systems for various applications [1]. Such applications include smart farming, smart cities, health care, transportation, manufacturing, and many others [1].

For these applications, Wireless networks are essential to cover a wide area in a building, a farm, city, or monitoring the environment [2][3]. Usual wireless technologies employed for this goal, for instance Bluetooth, Wi-Fi and ZigBee, have a range of few meters or tens of meters [4]. Multihop communication have been applied in mesh network topologies to increase the coverage area[1][5]. Recently, to propose a practical solution for applications that require energy efficiency and a wide area coverage Low Power Wide Area Networks (LPWAN) were used [6]. Long Range Wide Area Network (LoRaWAN) and SigFox in the unlicensed bands and Long Term Evolution for M2M (LTEM) and Narrowband IoT (NB-IoT) in the licensed bands The most are the most leading technologies for LPWAN [7]. Long Range (LoRa) is one the highly employed in applications because of the capability to develop private networks operating in the unlicensed frequency bands (868 MHz in Europe and 915 MHz in USA and Brazil)[1][8]. Creating and efficient sensor node with less power consumption requires set of algorithms. For example, Adaptive data rate (ADR), Automatic Sleep mode, and other algorithms are required for efficiency. LoRa technology have the advantage of long-range communication with low data rates and energy consumption. LoRa transmission distance reaches up to 13km in free space path loss (FSPL)[2] and up to 5km in dense urban environments [1]. Therefore, Wifi and Cellular require a larger Power Consumption but also limited by the distance that can be up to ~ 5 km on Cellular communications [3]. Moreover, Multihop communication is used to expand the coverage area and improving the energy efficiency of wireless networks, extending battery life due to lower transmission power when compared to single-hop networks. The LoRa network consists of end-devices that transmit data to the gateway forming a star network topology. In this research Multihop LoRa network for forest fire monitoring is implemented, this extends the coverage area and enhances the energy efficiency of the network.

The Multihop LoRa system technology is capable of solving some of the environmental and economic challenges faced by traditional forest fire the monitoring function in three ways: 1) Cover wide forest area divided in clusters; 2) Constantly update the server with information regarding fire break out and 3) The system is complicated and need regular and stabile monitoring and notification, so the goals of this project are , first build an IoT mentoring and control system considering less human interaction, second using prediction analysis for forecasting the temperature and Atmosphere gases (N2, O_2, CO, CO2, H_2O, etc.)

IoT gateway it is key device to tying Internet of Things devices together. Device connectivity, protocol translation, data filtering and processing, security, updating, administration, and other key services are all performed by IoT gateways. Newer IoT gateways also serve as platforms for application code that analyses data and transforms a device-enabled system into an intelligent component.

IoT gateways connect edge systems such as devices, controllers, and sensors to the cloud. Protocol translation and device management were the main duties of traditional gateways. They were not intelligent, programmable devices that could perform in-depth and complex processing on IoT data. Today's "smart" IoT gateways delivered by companies such as Dell, Wind River/Intel, NEXCOM and others are full-fledged computing platforms running modern operating systems (for example, Linux or Window). These systems are sometimes also called "intelligent gateways," but the line is blurring, and the non-intelligent gateway market is likely to become largely irrelevant in coming years. New generation IoT gateways open huge opportunities to push processing closer to the edge, improving responsiveness and supporting new operating models. Consider the building systems use case above: A building management company may control millions of square feet of office and industrial space from a remote location using a distributed IoT network of sensors and controllers connected through the cloud. However, transmitting every routine packet of information generated by the sensors from dozens of facilities would quickly overwhelm the headquarters systems of the management company. They care about serious issues, out-of-bounds environmental conditions, and other factors worthy of additional attention.

1.2 Problem statement

Wildfires have devastating effects on local and global ecosystems, as well as major infrastructure damage, injuries, and human deaths; as a result, fire detection and precise monitoring of disturbance type, magnitude, and impact across huge areas are becoming increasingly vital. Forest fires were formerly mostly spotted by human observation from fire lookout towers, using only crude technologies like the Osborne fire Finder; however, this method is inefficient since it is prone to human mistake. Other systems are mainly costly, they don’t cover wide range of area and there is no real time monitoring and notification. Another point, low data rate, Long range, low energy consumption, and cost efficiency are all criteria for smart forest fire monitoring systems. Short-range radio technologies, such as ZigBee and Bluetooth, are not ideal for applications requiring long-range communication. Cellular networks (3G, 4G, and 5G) can give more coverage, but also demand a disproportionate amount of device power. As a result, the need for forest fire monitoring applications has prompted the development of a new wireless communication technology.

1.3 Objectives

This research work embarks on the following objectives:

a) To design a smart fire monitoring system using LoRa communication module, where the end-node sensor send their information e.g., flame, temperature, humidity, and Atmosphere gases to the Network Operating Centre (NOC).

b) To develop NOC and web-based system where all data from End-Node can be stored simultaneously on LAMP server and monitored remotely, and the use of Cayenne cloud for notification purposes.

c) To conduct experiments to determine the functionalities and operation of the proposed smart fire monitoring system.

1.4 Scopes of study

The scopes of the research are:

a) After making the monitoring system, the end node unit should be able to send the sensor's data to the gateway unit using LoRa. One sensor Node is used to cover a range of approximately 5 trees and is located at university Malaysia Pahang (UMP) Gambang. The work does not include Multihop but its applicable. The system uses LAMP server to store the monitoring readings in the database and upload to Cayenne cloud for notification.

1.8 Outline of the report

In this project report, the smart forest fire monitoring system is implemented, it consist of five chapters and it's structured as follows. Chapter1 presents the introduction which includes the background study, problem statement, objectives of the project, and the scope of the project. Chapter 2 presents the related works which we use in this project. Chapter 3 elaborates on the methodology used to develop the algorithm and the scheme followed to meet our objectives. Chapter 4 discusses the findings and observations after preforming testing and measurements activities. In chapter 5 we summarize the outcomes and a highlight the main contributions. The V-diagram is used to provide a big picture in order to clarify on how to reach our goal in solving the problem stated in section 1.2

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

A forest fire is an out-of-control fire that occurs naturally. Forest fires are in nature destructive and spread so quickly that it takes a long time for firefighting troops to get control of the situation. Forest fires disrupt nature's equilibrium and damage biodiversity by diminishing a diverse kind of species. Traditional fire protection approaches aren't working, therefore it's now more important than ever to promote public awareness about forest fires, especially among those who live near forest regions. For instance, forest fire dangers in Turkey's Çanakkale Province skyrocket during the summer months. According to reports, around 35% of forest fires were started on purpose, 3% were caused by thunderbolts and other natural causes, and 48% were caused by unexplained sources [1]. Another example is the fire that broke out in Algeria, namely in Tizi Ouzou's north-eastern district. According to preliminary data, this year's flames wreaked more havoc on Algeria's woods than all of the previous fires combined from 2008 to 2020.

This chapter look in depth into the related works in LoRa communication and provided an insight into this technology as well as Multihop LoRa communication protocol. The second part of this chapter discussed existing forest fire monitoring system via IoT and LoRa.

2.2 Related Works

2.2.1 LoRa Communication

C. P. Mundkur et al [11] used LoRa simulator to compare goals, performance, and advantage of LoRa over SigFox. The results showed that LoRaWAN target key necessities of web of things, for example, mobility, and localization services. Moreover, the Link budgets are about the same for SigFox and LoRaWAN. Lastly, SigFox and LoRaWAN provide secure bi-directional communication.

M. Swain et al [4] used MATLAB simulator to Implement a gateway, a custom-based sensor node, and handheld device for real-time transmission of agricultural data to a cloud server. Calibration of certain LoRa field parameters, such as link budget, spreading factor, and receiver sensitivity, to investigate and extract the correlation of these parameters on a custom-built LoRa by the simulation tool. The article addressed also agricultural challenges regarding low power use and long-range transmission for effective implementation of the IoT. These challenges are overcome by integrating a long-range (LoRa) communication modem with customized, low-power hardware for transmitting agricultural field data to a cloud server. Also, hybrid range-based localization algorithms were utilized. The results show hybrid range-based localization algorithms are more scalable and reliable for deployment in the agricultural field.

S. Spinsante et al [12] used LoRaSim to Compare different path loss models based on a field measurement campaign of LoRa Received Signal Strength Indicator (RSSI) values within school campus. With the aim to improve the accuracy and number of nodes supported, with a given a target mean DER. Hence, two modifications to the LoRa simulator were proposed: Firstly, implemented additional path loss models to let LoRaSim adapt to different environmental scenarios. Secondly, introducing a GPS-based positioning of the nodes, as an alternative of a random one, as originally available by the simulator. The results show that, 3GPP path loss models are more useful and permit the installation 0f 100 nodes in urban areas, compared to the 64 nodes offered by the default Log-Distance model. Moreover, the implementation of GPS-based location of nodes allows to simulate a more realistic network deployment that optimizes the estimation of the mean DER. Thus, regardless of the path loss model applied, a 34.6% increase of the mean DER was obtained.

B. Reynders et al [10] discussed the scalability challenges, which affected the adoption of LoRaWAN. The analysis showed that LoRaWAN is effective for IoT deployment and verified the existence of scalability challenge which is still an open issue. Moreover, scalability issue often give rise to other challenges such as network coverage, capacity, and interference.

The communication settings of LoRa, such as bandwidth, spreading factor, coding rate, and transmission frequency, impact throughput, reliability, and communication range. An analysis on different LoRa communication settings on real IoT cases (smart metering, smart parking, smart street lighting, and vehicle fleet tracking). The results shows, the settings recommended for LoRaWAN, e.g. (SN5) along with LoRa's slowest data rate setting (SN1) do not scale well regarding the number of nodes nor with the data generation rate as well as they also consume more energy. Moreover, the LoRa physical layer setting (SN3) demonstrates the best performance amongst the evaluated settings. Which shows 380% higher PDR and 0.004 times the energy consumption. Furthermore, modification of the LoRaWAN channel access mechanism showed slight improvement on PDR for the evaluated settings [11].

The coverage of blind spots in IoT, and proposed a solution to overcome the problem by implementing a multi-hop uplink solution that is LoRaWAN-compatible and can be used as an extension to already deployed gateways, in which end nodes send data messages to intermediate nodes, which relay them to gateways by selecting routes based on a simplified version of destination-sequenced distance vector routing and a carrier activity detection mechanism is also proposed, the protocol specification and detailed description of a prototype implementation, as well as experimental performance results. The results show that, a multi-hop extension to LoRaWAN is feasible, even with the 868 MHz band's duty cycle restriction. The obtained throughput values are adequate for the majority of IoT applications in which uplink packets contain mostly sensor readings. This solution extends communication range at the expense of reduced throughput and PRR. Though, some issues were left unresolved for future work such as describing the bottleneck topology for a larger number of LNs [12].

Forest fire is a disturbing and horrible accident, the author provided a hardware setup of Flame Sensor Module integrated in a LoRa / GPS HAT which can be used to avoid fires disasters. The Flame Sensor Module is a sensor component that detects fire, and the LoRa / GPS HAT is a hardware media data transmission communication using radio frequency. A prototype fire detector can be built by connecting every device on a network. As a consequence, the detection limit of the flame Sensor Module YL-38 with low heat is only 15 cm, while detection at high flames is up to 30 cm. LoRa can transfer data at a maximum distance of 1.3 km when tested with the LOS method.. While, in the LoRa Non-LOS test with various obstacle, shows LoRa can receive data at a maximum distance of 400 m. Moreover, additional information such as the intensity of the light on the fire, the temperature of the fire, the size of the affected area, and so on, can be collected in the future. The receiver's responses were also text-only and further development can automatically output locations on digital maps and send notifications [13].

proposed a hardware system that is able to quickly detect forest fires at long distances is suggested in this paper, which uses LoRa (long-range) technology based on LoRaWAN (Long-range Wide-Range Network) protocol that can connect low-power devices in large geographic areas as an innovative and excellent solution for low-data transmission and low-power transmission in large areas and because of its superb efficiency [14].

Accordingly, the system can be operated in extreme temperature, but if it is located in the middle of the fire, it may be affected. The flames can be seen from a distance of 100 centimetres using the flame detector. It detects and sends information about the start of a potential fire, and the choice of using LoRa technology in the proposed system is due to the ability to connect low power units distributed over large areas and because it is an innovative solution for long-distance, low-power long transmissions at high levels and because it is highly effective for the transmission of long-distance data and low transmission power.

The author[15] presented a cost-effective, efficient hardware approach to manage environmental variations in agriculture using real time data, which is easy to set up and maintain, network implementation costs are reduced by using open-source hardware and the use of long-range (LoRa) radio transceiver improves transmission and power consumption. In a nutshell, the provision of farmers with useful data allows wireless sensor networks to improve agricultural sustainability. Using software and hardware designs open-source in combination with LoRa transceivers, cost-effective solutions for sensing applications in agriculture allowing long distances drives and a wide coverage from a single gateway, by using LoRa transceiver and an efficient Chan-Talk management process to reduce energy use with a new collision handling protocol for data transmission.

the author investigated the use of Multihop LoRa topologies to enable energy efficient connectivity in smart cities applications [2]. The results showed that to obtain a 90% packet reception rate (PRR), a two-hop network provides 50% energy savings compared to a single-hop network while a 35% coverage at a particular SF.

2.2.2 Multihop in LoRa

A typical LoRa network has a star-of-stars topology, in which end devices use LoRa PHY to connect with one or more gateways. End devices can connect with a single or more gateways through LoRa PHY. The entrances, or base stations, as some call them. The gateways, also known as base stations, are connected to a shared network server using the standard IP protocol. As illustrated in Figure 2.1, the network server is linked to an application server [2].

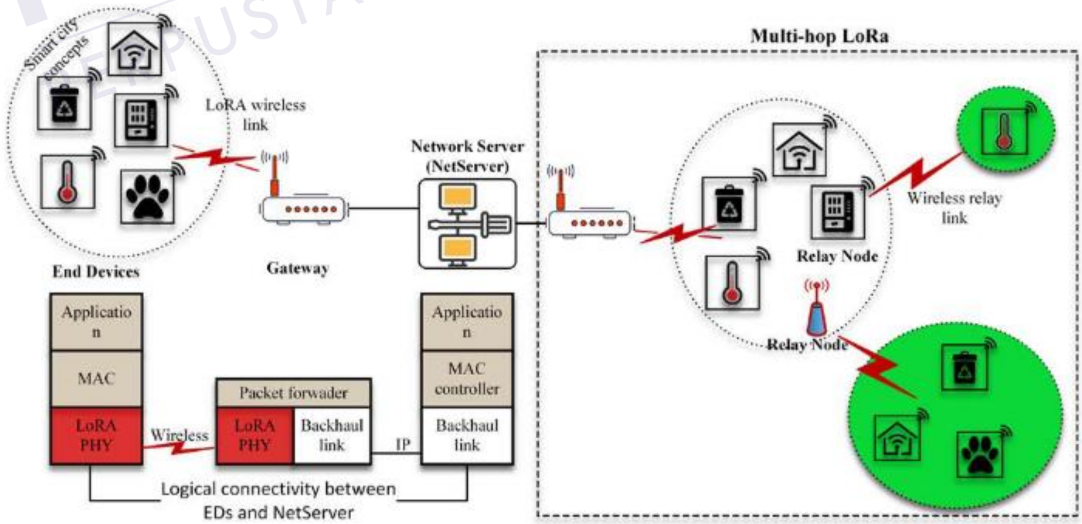

Figure 2.1: LoRaWAN architecture and its extension for multi-hop communication [2].

The end devices can transmit(receive) to(from) the gateway [2][1]. However, the emphasis is on the event-triggered uplink transmissions. The gateway functions transparently as a relay between the end devices and the network server. The network server manages the overall network. It allocates resources, for example, the spreading factor or the bandwidth for an efficient data rate and also authenticates the end devices. The application server handles data encryption and decryption and the admission of the end devices to the network. The most common approach for accessing the wireless medium is by using A simple duty cycled ALOHA protocol, regulated by the network server [2].

The first LoRa topology is discussed in [2][5][1] which introduces a relay node between an end device and the gateway. The relay node employs decode-and-forward scheme based on LoRa modulation. The second topology extends the LoRaWAN's star-of-star architecture by allowing a LoRa gateway to connect to multiple LoRa gateways over LoRa PHY. As wide-area networks in urban settings employ massive devices, it becomes difficult for a central gateway to gather/process information from all the devices simultaneously.

In a star-of-stars topology [16][1], the devices are categorized into several clusters. Clustering is considered a powerful tool to streamline the operations of the network to maximize energy efficiency and consequently prolonging network lifetime [17]. Each cluster contains multiple end devices and a gateway of its own. Each end device communicates with the gateway of the cluster. Thus, each gateway has to deal with a smaller number of devices as compared to the scenario when a single central gateway receives data from every device. Cluster gateways then transmit the data to a central gateway where it can be processed and relayed to the network server. This formation realizes a two-hop LoRa network, which is tested in this article for range extension and power efficiency for different SFs and the permitted range of transmission powers

2.3 Existing forest fire monitoring system

Animals might be utilized as biological sensors, according to the authors of article [18]. Tortoises, for example, are excellent at detecting ground fires. The trouble with this type of reptile is that they move slowly, making it tough to keep up with them..

In Individual sensors (fixed, PTZ, or 360-degree cameras) or ground sensor networks are used in terrestrial-based early detection systems [19]. To ensure proper visibility, these sensors must be strategically positioned. As a result, they are generally found in watchtowers, which are buildings with a high point of view that may be utilized not only for detection but also for verification and localization of reported fires. Optical and infrared cameras are utilized for early fire detection, and they may gather data in a range of resolutions from low to ultra-high for various fire detection scenarios [20][21]. UAV-based forest fire monitoring, detection, and fighting systems were firstly introduced in the US and Europe. The UAV is equipped with a visual camera and an onboard imaging system was used for forest fire imaging [22].

Other UAV systems employed deep learning , which combined a UAV with GPS and a saliency detection algorithm to localize and segment the fire area in aerial photos [23]. Then, for both low and high-level fire classification, a 15-layered deep convolutional neural network architecture was used. Using a ZenMuse XT2 dual vision sensor, the author [24] gathered 4K data and used an adaptive sub-region select block to find fire potential locations in 4K resolution photos. Then, for fire detection, a YOLOv3 backbone topology was employed.

W. Benzekr et al [25] created a fire detector using a Node MCU that is connected to a temperature sensor, a smoke sensor, and a signal. The temperature sensor detects warmth, while the smoke sensor detects any smoke created by food or fire. The Arduino buzzer serves as a warning signal. When a fire breaks out, it consumes nearby marchers and emits smoke. A fire alarm can also be triggered if there is a little amount of smoke from candles or oil lights used in the home. Likewise, whenever the warm force is high, the warning is activated. When the temperature drops to normal room temperature and the smoke level drops, the bell or warning is turned off.

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