UNIVERSITI PUTRA MALAYSIA

IMAGE TRANSMISSION OVER LORA FOR MANGROVE MONITORING

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By

AKRAM HUSSEIN A. JEBRIL

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

January 2019

DEDICATIONS

I would like to dedicate this work with love, gratitude and full respect to my priceless parents: Hussein & Fatima, my beloved wife: Aya, my lovely children: Safwan & Zumorrod and my pretty sisters & wise brothers. Also to all those who supported me by an encouraging word.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

IMAGE TRANSMISSION OVER LORA FOR MANGROVE MONITORING

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January 2019

Chairman: Associate Professor Ir. Dr. ADUWATI BINTI SALI, PhD
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LoRa as a Low Power Wide Area Network (LPWAN) is considered as one of the future wireless communication standard for IoT Internet of Things (IoT), this because it offers features such as; long range, low cost, less power consumption which make it an optimum alternative to the current wireless networks such as; ZigBee, Wi-Fi, Bluetooth-LE, IEEE 802.15.4, Sigfox and traditional cellular technologies. LoRa can replace the current technologies and communication systems used to monitor mangrove forests in Malaysia, where it covers a 2% of the total land area. It also provides a protection for the beaches and coastlines from storms, waves, floods, and soil erosion. However, LoRa has a limited bandwidth which makes it difficult to transfer data from image sensors in mangrove forests. This thesis has a significant contribution in proving the concept of using LoRa for the first time worldwide as the wireless sensor network to monitor mangrove forests; and overcome the problem of transferring images over LoRa limited bandwidth by proposing a novel image transmission scheme. This novel scheme converts images with resolution of 160x120 pixels taken for mangrove forests to hexadecimal format in form of packets then transfer these packets over LoRa physical layer. Indoor and outdoor tests were conducted before visiting the mangrove forests to find the optimum LoRa sittings of Spreading Factor (SF), Coding Rate (CR) and preamble numbers. In addition, the measurements of Packet Loss Rate, Peak Signal to Noise Ratio (PSNR) and Structural Similarity Index Measure (SSIM) for each transferred image over LoRa were conducted to evaluate the transferred images over LoRa physical layer using the novel scheme. The positive outcome of images transmission over LoRa physical layer was used for the first time up to 7km with PSNR values between 30dB and 70 dB which indicate to higher quality of the received images,also, the project does not need to additional costs such as; building complicated infrastructures or even buying repeaters. This research proves the concept of point- to-point communication by transmitting image data over the LoRa physical layer despite its limitation in

data transmission. In addition, the possibility of using LoRa as a preferred technology in terms of the long range, low cost, and lower power consumption for mangroves monitoring in Malaysian.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PENGHANTARAN IMEJ MELALUI LORA UNTUK PENGAWASAN BAKAU

Oleh

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LoRa sebagai Low Power Wide Area Network (LPWAN) atau Rangkaian Berkuasa Rendah Kawasan Luas dianggap sebagai salah satu taraf masa hadapan komunikasi tanpa wayar untuk Internet of Things (IoT), ini disebabkan oleh ciri-ciri yang ditawarkan seperti; berjarak jauh, kos yang rendah, penggunaan kuasa yang rendah menjadikan ia alternatif terbaik kepada rangkaian tanpa wayar yang sedia ada seperti; ZigBee, Wi-Fi, Bluetooth-LE, EEE 802.15.4, Sigfox dan teknologi selular tradisional. LoRa boleh menggantikan teknologi terkini dan sisten komunikas yang digunakan untuk pengawasan hutan bakau di Malaysia, yang melitupi 2% daripada jumlah kawasan tanah. Rangkaian ini juga memberi perlindungan kepada pantai dan pinggiran daripada ribut, ombak, banjir dan runtuhan tanah. Walaubagaimanapun, Lora mempunyai jalur lebar yang terhad, menyebabkan kesukaran dalam pemindahan data daripada sensor gambar dalam hutan bakau. Tesis ini memberi sumbangan yang ketara dalam membuktikan konsep penggunaan LoRa buat pertama kalinya di seluruh dunia sebagai sensor rangkaian tanpa wayar untuk pengawasan hutan bakau; dan mengatasi masalah pemindahan imej yang disebabkan jalur lebar LoRa yang terhad dengan mencadangkan skim penghantaran imej baharu. Skim baharu ini menukarkan imej dengan resolusi 160x120 pixels yang diambil daripada hutan bakau kepada format hexadecimal dalam bentuk paket dan memindahkan paket-paket inikepada lapisan fizikal LoRa. Pengujian tertutup dan terbuka telah dilakukan sebelum melawat hutan bakau untuk mencari kedudukan LoRa bersesuaian untuk Spreading Factor (SF), Coding Rate (CR) dan nombor preamble . Tambahan lagi, pengukuran Packet Loss Rate, Peak Signal to Noise Ratio (PSNR) dan Structural Similarity Index Measure (SSIM) untuk setiap pemindahan imej mengunakkan LoRa telah dilakukan untuk menguji pemindahan imej melalui lapisan fizikal LoRa mengunakkan skim baharu. Keputusan positif pemindahan imej mengunakkan lapisan fixikal LoRa telah digunakkan

buat pertama kali mencakupi 7km dengan nilai PSNR diantara 30dB dan 70 dB yang menyatakan kualiti tinggi imej yang diterima, tambahan pula, projek ini tidak memerlukan kos tambahan seperti; membina infrastruktur yang rumit atau membeli pengulang (repeaters). Kajian ini membuktikan konsep komunikasi 'point-to-point' dengan memindahkan imej mengunakkan lapisan fizikal LoRa walaupun terdapat limitasi dalam transmisi data. Dengan itu, kemungkinan pengunaan LoRa sebagai teknologi pilihan bertambah oleh kerana pembolehan teknologi berjarak jauh, kos yang rendah, penggunaan kuasa yang rendah untuk pemantauan bakau di Malaysia.

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I certify that a Thesis Examination Committee has met on 1, Feb, 2019 to conduct the final examination of AKRAM HUSSEIN A. JEBRI on his thesis entitled "IMAGE TRANSMISSION OVER LORA FOR MANGROVE MONITORING in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

BW	Bandwidth
CF	Carrier Frequency
CSS	Chirp Spread Spectrum
CR	Coding Rate
CRC	Error Correction Code
dBm	Decibel Mill watts
DBPSK	Differential Binary Phase-Shift Keying
FEC	Forward Error Correction
FSK	Frequency Shift Keying
GFSK	Gaussian Frequency Shift Keying
IoT	Internet of Things
KB	Kilo Bit
LoRa	Long Range
LPWAN	Low Power Wide Area Network
MSE	Mean Squared Error
NB	Narrow Band
PoC	Proof-Of-Concept
PSNR	Peak Signal to Noise Ratio
SF	Spreading Factor
SSIM	Structural Similarity Index Measure
TP	Transmission Power
UART	Universal Asynchronous Receiver/Transmitter
WSN	Wireless Sensor Network
TTL	Through The Lens
JPEG	Joint Photographic Experts Group
SD	Storage Device

CHAPTER 1

INTRODUCTION

1.1 Background

Long Range radio (LoRa), is a type of communication system family called (LPWAN) which stands for Low Power Wide Area Network that provides a good enough coverage area with less power consumption, the secret behind this type of technology is that it falls in between short-range multi-hop technologies and proper broadband cellular systems. LPWAN technologies are characterized by long-range links (in the orders of kilometers) and have star network topologies, with the peripheral nodes connected directly to a concentrator that, as for short range multi-hop WSNs, acts as a gateway towards the IP-world.

LoRa wireless communication system falls under Internet of Things (IoT) category, in which less of everything concept is provided for the end devices connected to LoRa system, such as less memory, less power, less bandwidth and less energy. In this research, for the first time ever, LoRa proposed to use as an WSN monitoring network for Mangrove trees in Malaysia.

Mangrove is mainly considered as a tropical forest, which grows in swamps, estuaries and coastal areas that they are located between latitudes 32 degrees N and 38 degrees S. These forests are remarkably widespread along different sites especially in the tropical districts such as; Malaysia. The value of these forests is highly touched through the complete coastal ecosystem it has provided as it is considered as one of the most world's productive ecosystem [7]. So far, mangrove forest is the most dominant coastal vegetation community in tropical Asia, with the center of distribution is in Malay-Indonesian region [8]. In addition to that, 2% of total Malaysian land area is covered by mangroves forest with number of 645,852, and it ranks the third place after Indonesia and Australia [9].

Those forests are distributed among different areas in Malaysia, while Sabah covers 57% of its total existence, then Sarawak covers 26% and at last, Peninsular covers 17% [9]. Furthermore, mangroves contribute to the highest rate of degradation among the other habitats, which is about 1% of the existing area per one year [10]. The socioeconomic value and ecosystem services of mangroves is considered one of the most important natural products that are priceless and underestimated.

Those ecosystems need to be monitored and observed for any natural conversion or disappearing in order to prevent any extra population or disorder habit caused by humans to preserve those natural factors which contribute to the hu-

man survival. For this matter, different technologies and communication systems had been used in order to monitor this kind of forests, most of them are characterized by a short range and low power attributes, while the area it covers is insufficient to provide a significant an reliable data in less time with less power consumption.

1.2 Problem Statement

LoRa technology is unlicensed frequency, in Malaysia the frequency band is from 919 to 923 MHz which can be utilized as a wireless sensor network for monitoring Mangrove forests in Malaysia, which constitute an important ecosystem in order to preserve the nature that contributes to the human life to the most extent possible. A set of benefits that this ecosystem provided made it a major source for different sustainable resources such as food production, provision of building materials and medicines. The need to employ monitoring tools and communication systems is essential, that play a major part in protecting these ecosystem elements from several dangerous and risky factors. Nowadays, mangroves trees in Malaysia are monitored using Wireless Sensor Network, installed by Ericson Company. This network system includes Soil Moisture Sensor, Smoke Sensor, Sea level measurement Sensor, Temperature Sensor, and Monitoring Cameras and so on.

LoRa as an LPWAN technology for IoT applications and end devices has many distinct features and attributes over a normal Wireless Sensor Network. Those features include longer area coverage for 15 Kilometer in Rural areas [11]. Moreover, it consumes less power than any other communication systems so the battery life installed in sensors will last longer than any other battery for any other communication system [12], furthermore; it is considered the best solution for data transmissions between IoT end devices [13]. However, using LoRa as the main infrastructure for the communication system has difficulties since it is able only to send 50 kbps per second and can transmit data only in 36 second each one hour of transmission time [14, 15]. This limitation makes the operation of data transmission not sufficient to send an image data at once, even if we use image compression techniques..

The main idea of this project revolve around using LoRa technology for image capturing process, then convert its format data to hexadecimal format and gather them into packets, can be easily transferred through limited LoRa bandwidth network, then reform them into the original format and compare them with the original images to know to what extent LoRa can be used for monitoring mangrove forests. Before conducting the test on mangrove forests indoor and outdoor tests will conducted to find the optimum settings and configuration for the LoRa transmitter and receiver.

This work will lead to comprehensive success and solution to cover the widest

area of lands and consume the least power for long battery life age. For any case, utilizing LoRa for image transmission will be a great step to move forward to the next generation for IoT devices and technology.

1.3 Research Questions

Many questions come once we think to apply this approach of using Lore over image transmissions, these questions can be listed as follows:

1. What are the advantages and disadvantages of using LoRa over ordinary wireless multimedia Sensor Network for image transmission?
2. What is the outcome of utilizing LoRa technology? Will the outcome match the expected results?

1.4 Objectives

The main goals of this dissertation are essentially the criteria that decide which degree the project is a success and match certain requirements. The set of objectives that determine the value of this work are:

1. TTo investigate and design an image transmission over LoRa with the constraints of data transmission.
2. To design and implement Proof-Of-Concept (PoC) of image transmission over LoRa for indoor, outdoor and environment monitoring (i.e. mangrove areas).
3. To evaluate the performance of image transmission over LoRa in terms of Peak Signal to Noise Ratio (PSNR) and Structural Similarity (SSIM) index.

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LIST OF PUBLICATIONS

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