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SUMMARY

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1. INTRODUCTION

1.1. Report Structure

The report is organized in the following structure; first relevant background information regarding measuring the health of a bridge, WSNs, LoRa and LoRawan, and the internet of things will be presented. Following this, the aims and objectives of this report will be outlined. Next, a review of the relevant published literature will be evaluated. The design specifications and methodology for developing protoype one and two will be provided. Results from testing both prototype implementations will be presented and a discussion regarding these results and performance will be provided. Device limitations will be analysed, suggestions for further improvements will be discussed followed by a conclusion. Proceeding the conclusion will be the references and appendices.

1.2. Project Background

1.2.1. Measuring the Health of Bridges

1.2.2. Wireless Sensor Networks

Wireless Sensor Networks (WSNs) are simple, low-cost networks that primarily consist of nodes and a base station [4]. WSN nodes usually comprise of some sensing or measuring capability acting as the physical layer, and relay this information via uplink to a base station for processing and then to a network server acting as the network layer. From here, the API from a network cloud service can be used to create GUI's and other applications for researchers and consumers which acts as the application layer.

Innovating many field of industry and research, these distributed networks of nodes have been valuable in many contexts. For example, the use of ZigBee communication technology for air pollution monitoring [5] and the use of Bluetooth for communication between end-devices measuring temperature, luminance, carbon dioxide and humidity for energy-saving establishments [6]. Although these WSNs have worked in the past, the future of this technology lies in developing systems that have high scalability and range, something that ZigBee and Bluetooth inherently lack. Cellular and satellite technology are alternate approaches that offer extremely high data rates and range, however these technologies are not practical to implement in most situations due to exceedingly high costs.

1.2.3. LoRa and LoRaWAN

Low Power Wide Area Network (LPWAN) is a communication technology that boasts similar ranges to satellite (WHAT RANGE) but with lower data rate than ZigBee. The trade-off is extremely low energy consumption and deployment / maintenance cost [1]. Figure 1.1 displays the fundamental differences between each of the mentioned communication technologies. It is clear that LP-WAN immediately has many more use cases for applications that require long range but are not as concerned with data resolution or packet density. The physical layer end devices are designed to be discrete and the low maintenance cost and energy consumption allow them to be placed and forgotten for up to ten years CITE THE 10 YEARS ——————-.

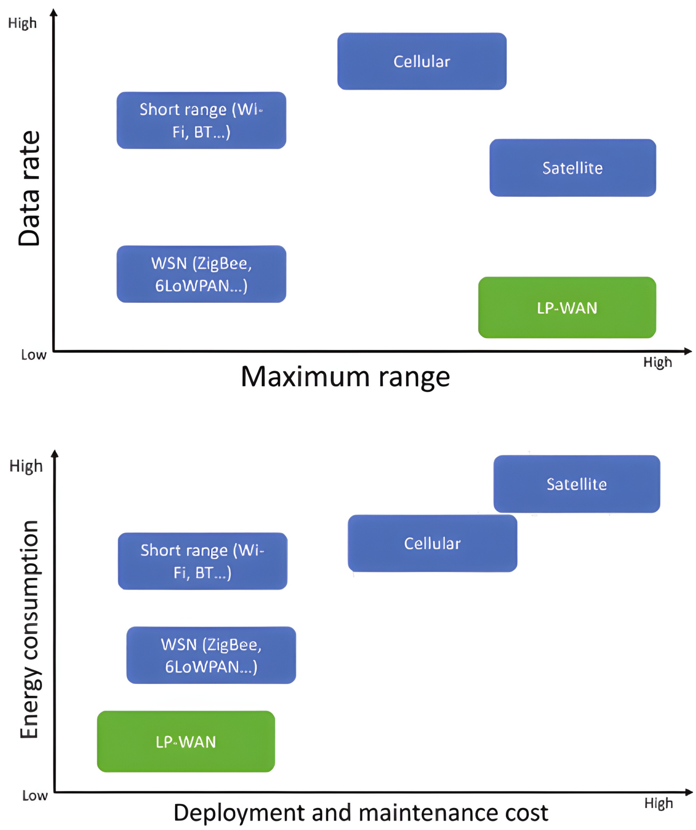

Fig. 1.1. Comparison of main IoT enabling communication technologies in terms of range, data rate, energy consumption, and costs. [1]

Long Range (LoRa) and Long Range Wide Area Network (LoRaWAN) technology is a form of LP-WAN communication technology developed by DEVELOPED BY WHO ———— AND CITE. The configuration of WSNs have typically been based on the deployment of Wireless Personal Area Network (WPAN) or Low Power Wide Area Network (LPWAN) standards, where nodes are setup in a mesh layout using one of the aforementioned short-range communication protocols such as ZigBee and Bluetooth [4]. The main implication with these protocols is that the mesh implementation inherently bottlenecks scalability due to exponentially increasing network requirements and power consumption [1]. LoRaWAN is a solution to implementing an LPWAN system with minimal complexity and scalability due to its star of stars configuration ——- WHAT IS STAR OF STARS AND WHY IS IT BETTER AND CITE. LoRa by definition is a chirp spread spectrum (CSS) modulation technique developed by Cycleo offering a Medium Access Control (MAC) layer protocol and operates on the 'licence-free region-dependent industrial, scientific, and medical (ISM) frequncy bands' [1]. In Australia the operational ISM band for LoRa is between 915 and 928 MHz. LoRaWAN is the ideal technology for agritulcutral and regional purposes due to its long range, low power long lifetime and scalability.

1.3. Internet of Things

The Internet of Things (IoT) is an 'interconnected network of things' [7], where 'things' in this context is defined as an end-device with WSN type capability. The IoT architecture comprises of six-layers, the coding layer, perception layer, network layer, middle-ware layer, application layer and business layer [7]. Thus to create this IoT architecture for research purposes the first five layers need to be implemented. LoRa end-devices act as the physical layer encompassing the coding and perception layer. The coding layer involves associating unique ID specifiers to each end device [7] and the perception layer is involved with on-board sensing and data acquisition. The network layer is a relay of this perceptual information to a gateway, and the middle-ware layer is the IoT cloud platform that facilitates these connections and receives information from the network layer. The application layer involves pulling the API or information from the network layer and developing apps or graphical user interfaces (GUIs) to display the data. The Things Network (TNN) is an open-source LoRaWAN network server used to construct IoT cloud applications with end-to-end encryption and secure communication [8]. TNN exists on the middle-ware layer and can be used to deploy an IoT architecture using LoRa end-devices in the coding and perception layer, and utilize the LoRaWAN communication protocol in the network layer. TNN offers a console and API to develop applications that serve as the architecture's application layer. Figure 1.2 displays an example of an IoT architecture using WSN nodes, a LoRaWAN gateway, cloud storage and user devices.

1.4. Aims and Objectives

The aim of this project is to develop and deploy a prototype IoT architecture with the purpose of collecting data relevant to the health of the Griffith footbridge. This involves implementing the first five layers of the architecture which consist of the coding layer, perception layer, network layer, middle-ware layer and application layer. This deployment will be achieved through the testing and implementation of two prototypes.

The first prototype is designed for testing the software and the first three layers of the IoT architecture. Two Arduino MKRWAN 1300 devices will be used, one acting as the

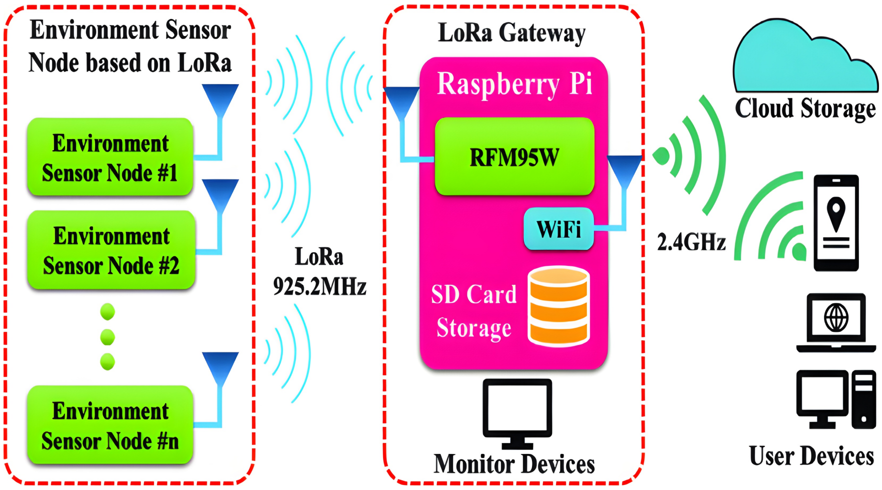

Fig. 1.2. The LoRa network architecture for agriculture area. [2]

LoRa node (layer one and two) and the other acting as a pseudo LoRaWAN gateway (layer three). The first MKRWAN 1300 is equipped with an ADXL335 3-axis accelerometer and is placed on a metal beam. The beam is vibrated along the z-axis and the device samples the acceleration. The device finds the maximum frequency peak and maximum acceleration and transmits the data via a LoRa packet. The second device receives the LoRa packet and logs the data via a serial connection. A python program is used to establish serial connection with the devices and log the output to a text file. Another python program is then used to plot the serial output data using matplot library pyplot. The high level system diagram in figure 1.3 presents the desired implementation of this prototype.

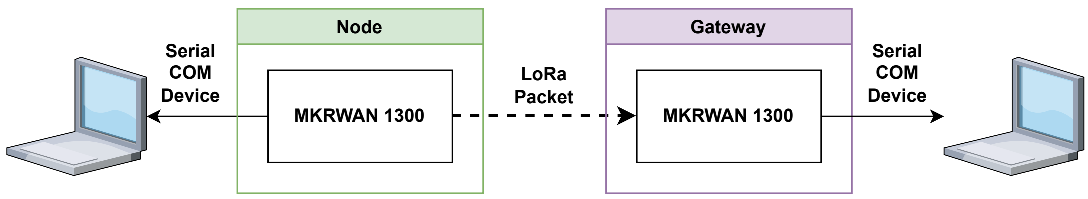

Fig. 1.3. Prototype 1 High Level System Diagram

The aims of prototype 1 will be satisfied once the following objectives are met.

1. Verify that the two MKRWAN devices are capable of communicating over the LoRaWAN protocol
2. Integrate an accelerometer onto the node and write software that samples and discretizes the raw acceleration values
3. Write software to compute the FFT of these discrete values and find the peak frequency
4. Write software to log and plot the raw acceleration from the node

5. Send and receive the maximum acceleration and peak frequency from the node to the gateway

6. Write software to log and plot the maximum acceleration and peak frequency from the gateway

7. Test the maximum range of LoRa packets between the node and gateway

The second prototype is designed for testing the software, PCB, enclosure and first five layers of the IoT architecture. The two MKRWAN 1300 devices are now both nodes and are implemented onto a custom designed PCB. This PCB is enclosed in a custom 3D printed enclosure and sits behind the guard rail of the Griffith foot bridge. The two nodes sample the maximum frequency and maximum acceleration of the bridge and transmit this data via LoRa packets to a Wisgate Edge Lite 2 LoRaWAN gateway. This gateway uploads the data via WIFI or Ethernet to the TNN cloud which acts as the middle-ware layer. — APPLICATION LAYER WHAT IS THE IMPLEMENTATION — Figure 1.4 displays the high level system diagram for the second prototype.

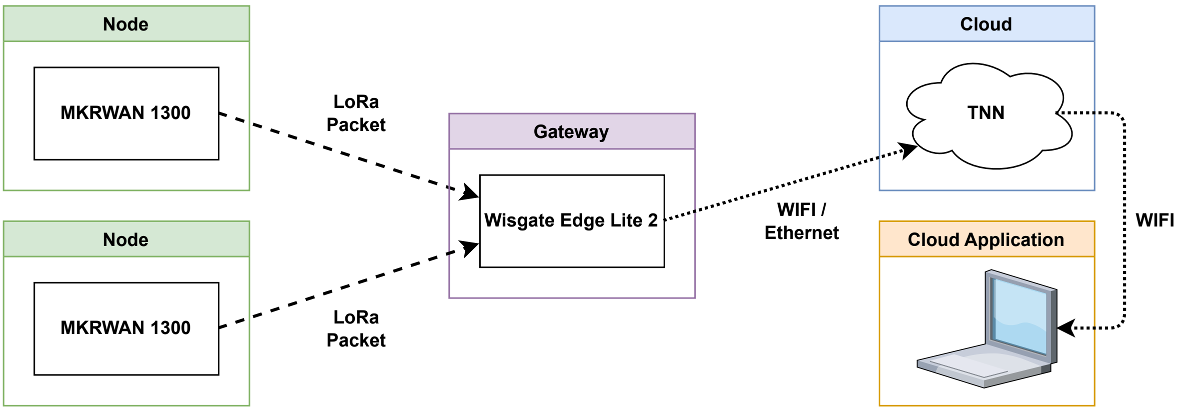

Fig. 1.4. Prototype 2 High Level System Diagram

— ADD TO PROTO 2 OBJECTIVES ONCE I COMPLETE TESTING — The aims of prototype 2 will be satisfied once the following objectives are met.

1. Design, fabricate and test a custom PCB to replace the breadboard from prototype 1

2. Design and fabricate an enclosure to be placed behind the rail of the Griffith foot-bridge

3. Configure both MKRWAN devices as nodes and establish a LoRaWAN connection to the gateway with a network connection to the cloud

4. Create a cloud application to log LoRa packets from the nodes

5. Verify software and range capabilities through system integration testing on the bridge

2. REVIEW OF PUBLISHED LITERATURE

2.1. Review of the Published Literature

This literature review analyses the works already conducted in the field of WSNs and LoRaWAN communication protocol in terms of signal strength, IoT architecture and security. The relation of this report in regards to the existing literature will be discussed.

Gehani et al. in 2021 [3] implements a LoRaWAN IoT architecture for measuring Agro-Informatics regarding the detection and classification of pathogens affecting the roots of plants. The signal strength of the LoRa packet was measured in terms of received signal strength indication (RSSI) and signal-to-noise ratio (SNR) in various depths between 0 cm to 60 cm. The experimental setup consisted of a simple transmission and receiving Adafruit Feather M0 microcontrollers using an RFM95W based LoRa radio transceiver operating on the US915 MHz frequency. A rechargeable 3.7 lithium polymer 500 mAh battery was used for the power supply and a ceramic antenna was used for the buried microcontroller. The transmitting node was initially placed inside a bucket containing dry soil, and the receiving node placed 3 m away logged the RSSI and SNR for ten LoRa packets. A diagram of the experimental setup is shown in figure 2.1.

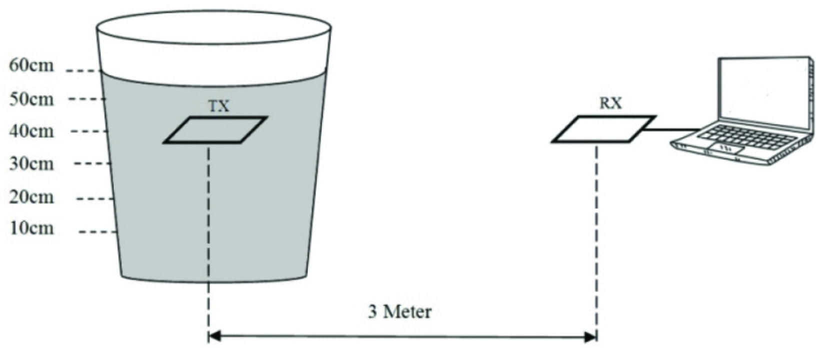

Fig. 2.1. Experimental Setup for LoRa Node in Soil [3]

The results conclude that the LoRa transmitter was capable of transmitting packets when buried within 60 cm with the recommendation that depth does not exceed 50 cm. The depth of the transmitter node proved to be inversely proportional to the RSSI value which did not drop below the minimum signal power required for demodulation. The results of the depth transmission in this study are helpful in deducing appropriate enclosure thickness for the purposes of this report.

Fox et al. in 2019 [9] presents the design architecture for a LoRaWAN based IoT system for services a local region in Ireland. The IoT architecture in this study consisted of an Arduino Pro Mini as an end-device powered by two double A batteries. A Multi-connect Conduit IP67 was chosen as the gateway, using a 3dBi dipole antenna. The IBM cloud platform was deployed using an MQTT broker as the backend.

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