School of Engineering and Built Environment
Griffith university

6002ENG - Industry Affiliates Program

Structural Health Monitoring of the Griffith Footbridge Using LoRaWAN Technology

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1 Project Background

The Griffith University Gold Coast campus' footbridge is well known in the area as it spans over the busy Gold Coast highway. Used by many students and professors each day, there is a noticeable wobble that leave some speculating about its structural integrity. Many bridges around the world are aging and deteriorating, and maintaining them is becoming an increasingly difficult task. One of the critical indications of the health of a bridge are vibrations which can indicate structural damage or excessive stress [1]. Traditional methods involve irregular, time-consuming and costly physical inspections that may fail to recognize an issue until it has become severe.

Wireless sensor networks (WSNs) using the Long Range Wide Area Network (LoRaWAN) protocol have emerged as a cost effective solution not only for bridge monitoring, but for a wide array of practical applications. The appeal of LoRaWAN is low power consumption, long-range connectivity and its low-cost infrastructure [2]. These factors make LoRaWAN an ideal candidate for facilitating an Internet of Things (IoT) system. LoRaWAN technology is versatile in the sense of its modularity especially when using modern carrier boards such as Arduino or Raspberry Pi which support a vast array of sensor modules. For example, LoRaWAN is often used in an agricultural context to monitor soil and crop health [3]. The agricultural applications of LoRaWAN showcase the technology's long distance communication capabilities which is especially useful in rural settings. Additionally, since LoRaWAN typically only sends small packets of data a few times a day, devices on the network offer low power features which can achieve autonomy for up to ten years [4].

LoRaWAN is an ideal choice to monitor the health of the Griffith footbridge as sensor nodes can be attached to sections of the bridge to detect and analyze vibrations. The nodes can transmit data wirelessly to a gateway which can be connected to cloud storage or a private database, collecting and aggregating this data for further analysis.
Implementing this system will achieve benefits such as real-time monitoring and early detection of problems which will ultimately lead to a reduced maintenance cost. In further research, machine learning algorithms can be used to detect detrimental patterns in the data [5], allowing engineers to take proactive measures in maintaining the health of the bridge. Ultimately, this project can enhance the safety and reliability of the Griffith footbridge, ensuring that it remains a vital part of the Griffith University's transportation infrastructure for many more years to come.

2 Aims and Objectives

The aim of this IAP project is to develop an IOT system capable of collecting data relevant to further research regarding the health of the Griffith footbridge. The primary data acquisition units will come in the form of three sensor nodes placed across the footbridge that collect and process vibration data in three dimensions. The aim is to packetize this data and receive payloads at a gateway via the LoRaWAN transmission protocol. Finally, the data needs to be uploaded to the TNN Cloud for data processing and analysis. Figure 1 exhibits the high level hardware diagram for the intended IoT system implementation.

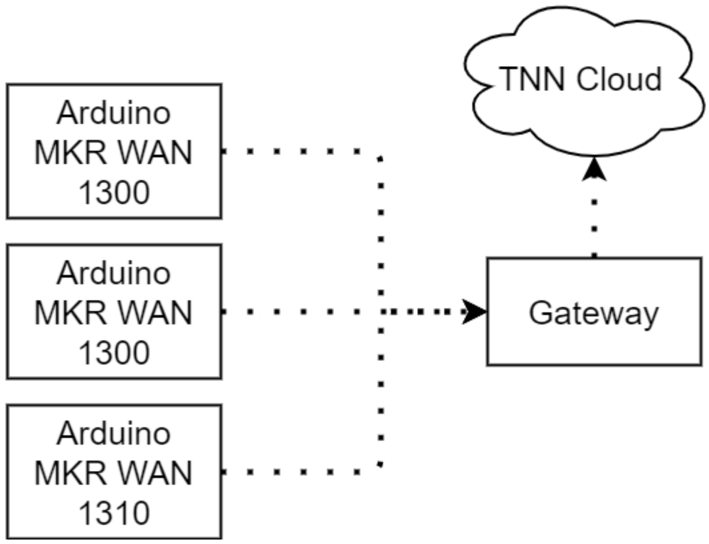

Figure 1: High Level Hardware Diagram

The aims of this project will be satisfied once the following objectives are met.

1. Verify that the components selected for the IoT system are compatible and capable of transmitting and receiving data.
2. Integrate an accelerometer into the system and write software that discretizes analog input data using the Fast Fourier Transform.
3. Transmit the digital data from three different sensor nodes to the gateway. The gateway must be able to receive packets, identify the respective sensor node and upload the vibration payloads to the TNN cloud.
4. Implement a solar system to constantly power the sensor nodes.
5. Design and implement a PCB carrier board for the sensor nodes.

6. Design and implement a 3D-printed enclosure to house the components of the sensor nodes. Figure 2 exhibits the detailed, high level, hardware system diagram and figure 3 contains the high level, software diagram for the transmitter and receiver systems.

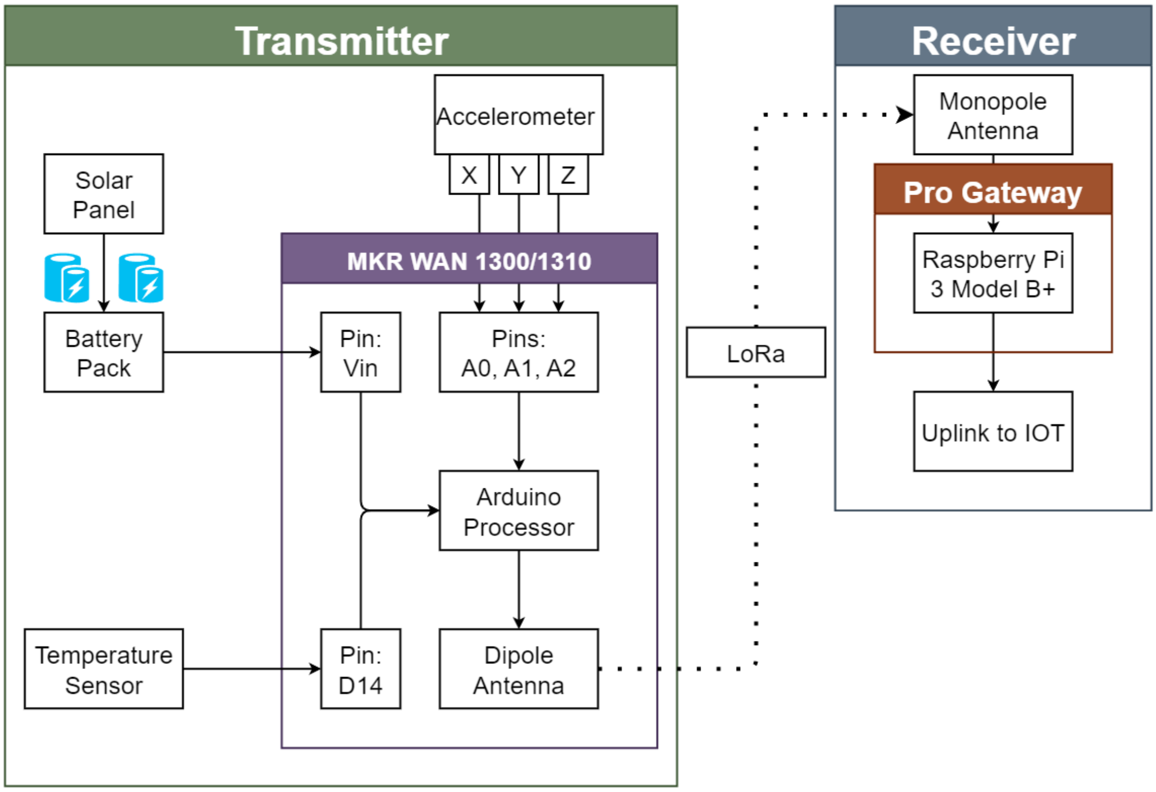

Figure 2: Detailed High Level Hardware Diagram

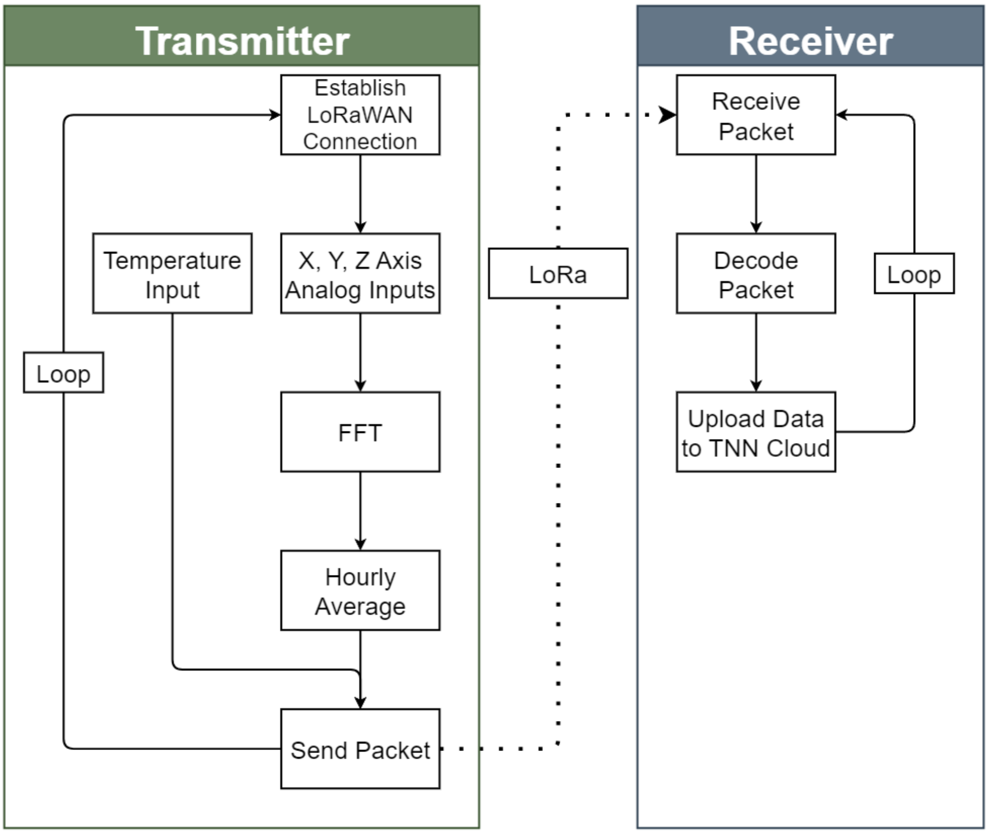

Figure 3: High Level Software Diagram

3 Expected Project Outcomes

The expected outcomes of this project exist in the form of deliverables that are required to achieve the project aims. The first outcome of this project is a functioning prototype of the IoT system. In this version, the sensor nodes will be implemented on breadboards and powered externally using a power supply. This outcome is satisfied once objectives one, two and three have been achieved. These objectives are achieved once the following system requirements have been verified.

1. The gateway shall receive packets from a sensor node 600m away.
2. The system shall communicate on the 925MHz frequency.
3. The system software shall include a sufficient sampling rate and windowing technique for the Fourier Transform such that the analog data is successfully discretized.

The second outcome is version one of the system. Version one includes implementation on a PCB carrier board, solar power and a 3D-printed enclosure. This outcome is satisfied once objectives four, five and six have been achieved. System version one is achieved when the following system requirements have been verified.

1. The system shall transmit and receive packets every hour.
2. The system shall be always on and always operational.
3. The system shall be resistant to water damage and overheating.
4. The system shall successfully aggregate data on the TNN Cloud.

4 Methodology And Project Schedule

4.1 Project Methodology

The project methodology will define the process of verifying the project objectives and outcomes. The first methodology explicitly describes the verification process for the system prototype and how the corresponding objectives and requirements will be satisfied. The first objective will be satisfied through integration testing of the selected components. A test application will be created containing a test sender and listener program. This will send an arbitrary packet of information between a single sensor node and the gateway. This objective is verified once the payload has successfully been uploaded to the TNN cloud. The second objective will be satisfied through integration testing by integrating an accelerometer into the system. For this objective to be achieved, the test application will include an FFT to discretize the analog input. This objective is verified once the accelerometer data has been uploaded to the TNN cloud. The third objective will be satisfied through integration testing by further editing the test application and integrating another two sensor nodes into the system. The packets transmitted by the sensor nodes must include their respective identification which will be used to identify the packets at the gateway. This objective is verified when the data on the TNN cloud specifies its respective sensor node. The first and second prototype system requirement can be satisfied through field testing by verifying that project objectives one, two and three are achievable with a distance of 600m between the furthest sensor node and the gateway. Requirement three can be verified through experimental testing by creating a test application to send known analog inputs. The requirement is met when the digital data received by the gateway is the expected value after FFT.

The second methodology explicitly describes the verification process for version one of the system and how the corresponding objectives and requirements will be satisfied. The fourth objective will be satisfied through theoretical and field testing. The theoretical testing will be achieved by completing power calculations for the sensor node and the field testing will be achieved by verifying that the sensor nodes can be sufficiently powered. This objective is verified once version one system requirement one is satisfied and there is an uninterrupted hourly transmission of packets. The fifth objective will be satisfied through integration testing by implementing the system on a PCB carrier board instead of a breadboard. For this objective to be achieved, all previous objectives must be re-verified. The sixth objective will be satisfied through environmental testing of the 3D-printed enclosure. The primary environmental testing will be to verify the integrity of the enclosure under heavy rain conditions. Once version one of the system has been integrated into the enclosure, temperature sensors will be included to measure the temperature of the embedded electronics. The software will be updated to include the average system temperature in each packet. This objective, and system version one requirements two and three are satisfied once project objectives one to four are validated in the environmental testing. Requirement four can be verified through field testing by observing the data uploaded to the TNN cloud over a specified period of time. If the data is uploaded and stored in the cloud as expected, then this requirement is satisfied.

4.2 Tasks and Schedule

Figure 4 presents the projected timeline for the completion of this project.

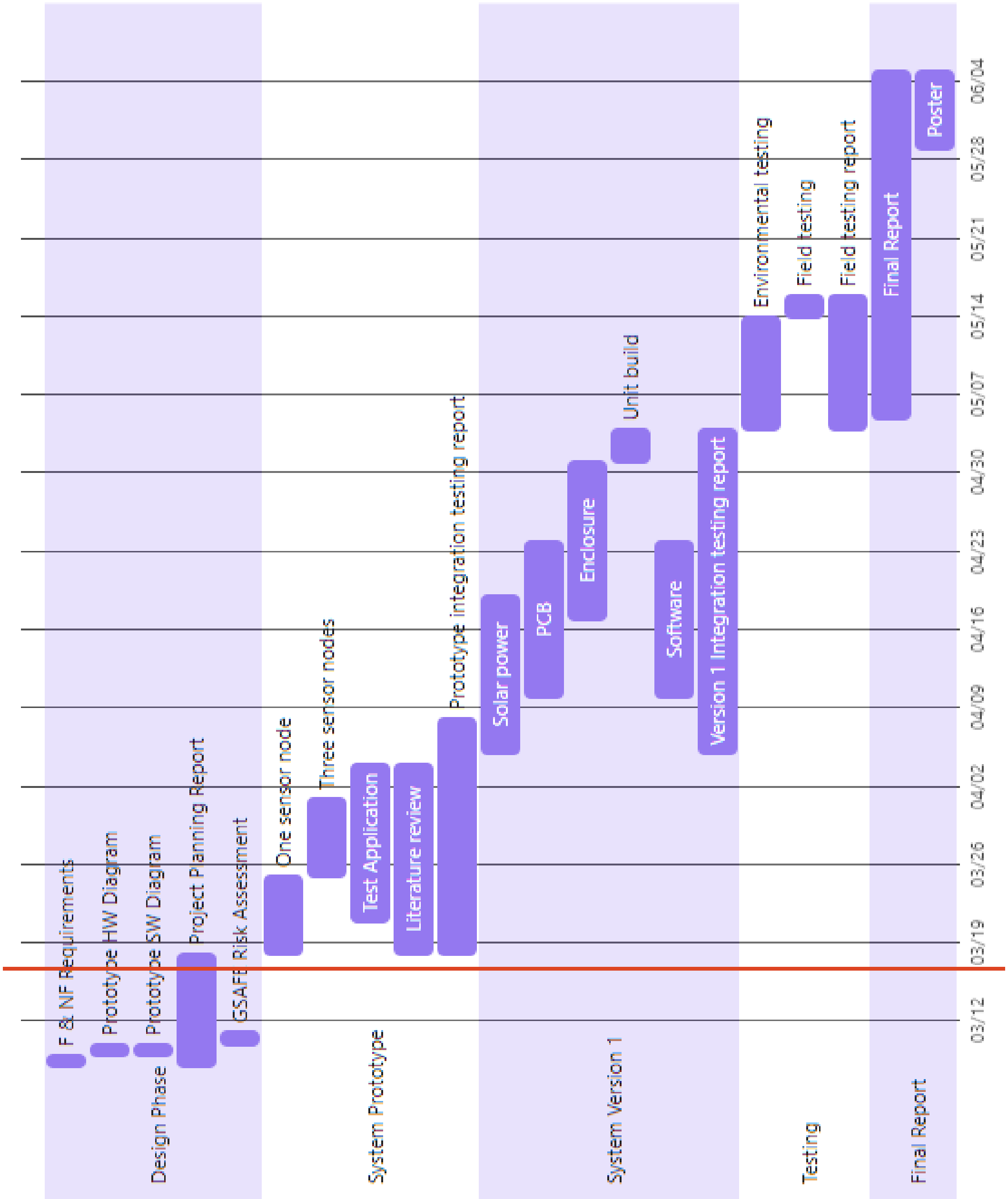

Figure 4: Project Timeline Gantt Chart

4.3 Resources

The hardware for the prototype phase of the project has been supplied by the university. This includes 2 x MKR WAN 1300, 1 x MKR WAN 1310, 1 x Arduino Pro Gateway, 3 x accelerometer, 3 x dipole antennas.

Additional costs will be required when system version 1 is reached which include temperature sensors, ABS printing filament, PCB, solar panel and battery. A rough estimate of the costs for each sensor node is shown in table 1.

Item	**Estimated Cost**	**Supplier**	**Lead Time**
Temperature Sensor	$7.00	Jaycar	1 Day
PCB	$20.00	TBC	1 Week
ABS Filament	$25.00	Jaycar	1 Day
Solar Panel with Battery	$10.00	Core Electronics	1 Week
Total	$62		2 Weeks, 2 Days

Table 1: Estimated Costs Per Sensor Node

The equipment in the Griffith electrical and mechanical labs will be utilized to build and test system version 1. Equipment includes power supply, soldering station, oscilloscope, multi-meter and an experimental vibrating beam setup. A personal 3D-printer will be used to manufacture the enclosures. Software will be written in the Arduino IDE, and the Arduino TNN cloud website will be used to access data from the gateway. 3D modeling for the enclosures will be completed in Onshape and CAD design for the PCB will be completed in Altium Designer.

5 Risk Assessment

5.1 Risk Assessment Risk Matrix

	Consequences				
Likelihood	**Catastrophic (Cat)**	**Major (Maj)**	**Moderate (Mod)**	**Minor (Min)**	**Insignificant (Ins)**
Almost Certain (AC)	**Very High (VH)**	**Very High (VH)**	**High (H)**	**Medium (M)**	**Very Low (VL)**
Likely (L)	**Very High (VH)**	**High (H)**	**Medium (M)**	**Low (L)**	**Very Low (VL)**
Possible (P)	**High (H)**	**High (H)**	**Medium (M)**	**Low (L)**	**Very Low (VL)**
Unlikely (U)	**Medium (M)**	**Medium (M)**	**Low (L)**	**Very Low (VL)**	**Very Low (VL)**
Rare (R)	**Low (L)**	**Low (L)**	**Low (L)**	**Very Low (VL)**	**Very Low (VL)**

Table 2: Risk Assessment Matrix

Risk Level	**What should I do?**
Extreme	Eliminate from activities
High	Eliminate from activities
Medium	Specific monitoring or procedures required, management responsibility must be specified
Low	Manage through routine procedures. Unlikely to need specific application of resources

Table 3: Risk Level Management

5.2 Identified Risks

15802	RISK DESCRIPTION	TREND	INHERENT	CURRENT	RESIDUAL
	IAP: s5138877, Barber Jessy - Investigating the Health of a Footbridge using LoRaWAN technology		Medium	Low	Very Low

RISK OWNER	RISK IDENTIFIED ON	LAST REVIEWED ON	NEXT SCHEDULED REVIEW
Jessy Barber	14/03/2023	14/03/2023	14/03/2025

RISK ACTIVITIES	RISK FACTOR(S)	INHERENT	EXISTING CONTROL(S)	CURRENT	PROPOSED CONTROL(S)	TREATMENT OWNER	DUE DATE	RESIDUAL
Electrical equipment Will often handle sensitive electronics during the design and build process of the project. Will often use high voltage/current capable electrical equipment such as power supplies.	Risk of electrocution and short circuiting components. Risk of blowing a component and inhaling toxic fumes.	Low	Control: Ensure the workplace is clear and eye protection is worn. Control: Ensure that adequate training for electrical equipment has been attained.	Very Low				Very Low
Soldering electrical connections Soldering electrical connections between electronics with a soldering iron in an electrical engineering lab.	Soldering electronic connections. Risk of burns & inhalation of solder fumes.	Low	Control: Eye protection and gloves. Control: Extractor fans / ventilation.	Very Low				Very Low
Working on the footbridge Fastening three sensor nodes in their enclosures to the Griffith footbridge.	Sensor nodes need to be fastened to the footbridge. The footbridge is situated over busy highway traffic. There is a risk of dropping equipment onto the road below and causing an accident.	Medium	Control: The footbridge has protective railing.	Low	Design the module to be as small and lightweight as possible. Design a secure fitting so that there is no chance of the sensor nodes falling. Plan where the sensor nodes will sit along the bridge before implementation. Gain approval from supervisor for field implementation of equipment. Conduct implementation on	Jessy Barber Yong Zhu	15/04/2023 14/04/2023	Very Low
Vibrating beam experiment Conducting a vibrating beam experiment to test sensor nodes in a mechanical engineering lab.	Risk of crushing or physical injury if not securely fastened.	Low	Control: Cannot enter labs without enclosed footwear.	Very Low	Ensure the space surrounding the experiment is clear. Ensure that distance is kept whilst the experiment is running.	Jessy Barber	31/03/2023	Very Low

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Figure 5: GSAFE Risk Assessment

6 Ethics Issues Related to the Project

The IAP project is considered outside the scope of the University's research ethics arrangements as the IAP project does not involve human or animal research.

References

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