CEAT AgTech LoRaWAN Project

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Except where otherwise indicated, this thesis is my own original work.

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Abstract

Networks are needed by farmers in regional Australia to improve monitoring capabilities and insights. The current LTE implementations are costly and often do not provide coverage where needed, making them out of reach for many farming operations. Models are required to properly understand the costs involved in providing a bespoke network. In this work a comparison is presented between the relative accuracy of relevant models in the AU915 LoRa band. Data was collected from a site survey analysis of parts of the Canberra region and this was used to feed the models with accurate and up to date input data for the Mikrotik LoRaWAN gateways located on Mt Ainslie, Black Mountain and Mt McDonald. Finally the simulation results were analysed against the received power at the Mikrotik Lora9 gateway, and the errors between models and measurements were statistically analysed. It has been found that models in general tend to overestimate received field-strength values.
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Chapter 1

Introduction

In this paper an analysis is conducted on the efficacy of the Irregular Terrain Model (ITM) in predicting real world coverage of LoRa networks. The first part of the study discusses the motivations. Then visual coverage maps were produced with the CloudRF platform to provide an estimate of the coverage area to test. A survey is conducted to record real world data to be compared against model data from the CloudRF API. The experimental methodology explains the architecture of the system in terms of hardware and software and then the results are discussed in terms of a statistical analysis. Finally future improvements to the system are proposed.
To understand the accuracy of the estimated coverage using the ITM and ITWOM models a preliminary coverage map will be constructed for each model to be compared with a real world survey. The data points from the survey will then be compared against the model for accuracy.

### 2.1 Preliminary Models

To begin modelling the set of parameters shown in Table 4.1 were determined based on the equipment that was assembled for the testing. These parameters were then fed into CloudRF for producing visual coverage maps 3.1(a), 3.1(b) to aid in determining where to go when conducting the survey to understand the limits of the coverage.

### 2.2 Survey

Estimating the coverage with the model provided an approximation of where the limits of the coverage are. A tower was placed at the coordinates specified in the model and a LoRa node constructed to communicate with the tower. The roles of the Transmitter and Receiver are reversed with respect to the model, however for the purposes of this exercise the model should be reciprocal apart from some occurrences of destructive interference due to multipath. The LoRa node transmits the GPS coordinates every six seconds to the gateway, which records the coordinates and measures the signal strength before sending it to a time series database stored on a remote server. This remote server hosted a web interface to visually represent the data in real time, so that it could be known if the LoRa packets are still being received by the gateway.

This data was then put into a heatmap on a scale which closely resembles the coverage maps to allow for a visual analysis of any obvious issues with the propagation models.
Figure 2.1: Preliminary Propagation models

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Figure 2.2: Preliminary Propagation models

(a) Line of Sight model
Figure 2.3: Heatmap showing the RSSI (dBm) at the gateway.
2.3 Summary

Same as the last chapter, summary what you discussed in this chapter and be the bridge to next chapter.
Chapter 3

Experimental Methodology

3.1 Software platform

3.1.1 Survey System

The software platform is as a whole is a network which follows the client-server model. The client consisted of a LoRaWAN node running a program utilising the the LoraMAC-in-C library. This program periodically sends packet data containing GPS coordinates over the Dragino LoRa shield.

The server consisted of a Mikrotik Lora9 Gateway, sending packet data over the Semtech UDP protocol to a Chirpstack network server. This server facilitates the "over the air" join functionality in this network required for LoRa nodes to authenticate with backend servers, thus creating an encrypted session between the node and the backend server. The server is configured with the APPEUI, DEVEUI and APPKEY values which are compared against the keys on the client.

Once the client is authenticated, packet data received by the network server is sent to the application server for marshalling into an API, which in this case was configured to push each set of coordinates and the relative RSSI and SNR data into a time-series Influxdb database.

As an extension of this platform a Grafana web interface was configured to access data from the database in real-time for visual representation of data whilst the signal mapping occurred.

3.1.2 Modelling

For producing models a Python script provided by CloudRF was modified to calculate the theoretical signal strength received at the Gateway. This script sends the parameters specified in 4.1 to the CloudRF server over the API, and saves the resultant RSSI value and its respective latitude and longitude value into a csv file.

3.2 Hardware platform

The hardware platform starting from the LoRaWAN node.
### Experimental Methodology

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ITM</th>
<th>LOS</th>
<th>ITWOM</th>
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<td>Frequency (MHz)</td>
<td>917.5</td>
<td>917.5</td>
<td>917.5</td>
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<tr>
<td>RF Power (dBm)</td>
<td>20</td>
<td>20</td>
<td>20</td>
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<td>Bandwidth (MHz)</td>
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<td>Latitude, Longitude</td>
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<td>-35.2697, 149.1588</td>
<td>-35.2697, 149.1588</td>
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<td>Transmitter Height (m)**</td>
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<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Azimuth (degrees)</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Downtilt (degrees)</td>
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<td>1</td>
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<td>11.15</td>
<td>11.15</td>
</tr>
<tr>
<td>Rx Antenna Gain (dBi)</td>
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<td>5.15</td>
<td>5.15</td>
</tr>
<tr>
<td>Feeder Line Loss (dB)**</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Receiver Height (m)**</td>
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<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Propagation model</td>
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<td>Line of Sight</td>
<td>ITWOM 3.0</td>
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<td>Average</td>
<td>Average</td>
</tr>
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<td>ON</td>
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<td>Radio climate</td>
<td>Continental Temperate</td>
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<td>N/A</td>
</tr>
<tr>
<td>Land Cover</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>My clutter</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Table 3.1: Parameters used as the preliminary model inputs.

![LoraWAN Node hardware block diagram](attachment:figure3.1.png)

Figure 3.1: LoraWAN Node hardware block diagram
Chapter 4

Results

The tests at the tail ends of the estimated coverage map is promising for the functionality of the system, though the model is not very accurate.

To perform a formal analysis on the data it first had to be cleaned. The data collected contained a lot of noise, such as timing which exceeded our packet transmit interval. Timings which exceed 6s between them are likely to be a retransmission of old data as the LoRa node was configured to attempt to retry the transmission up to 3 times. A Python script was created to remove any data points which are >8s or 250m apart which substantially improved the average error from 8 dB to -0.5 dB.

4.1 Statistical Analysis

Comparing the real world data against the ITM shows in 5.1(a) that the error is somewhat normally distributed with a sample standard deviation of 13.52 dB. The average deviation from the model is -0.35 dB. This suggests that the source of error might be a somewhat even split in the chance of it causing an overestimation or underestimation.

(a) ITM error histogram resembles a normal distribution.

Figure 4.1: Error histogram resembles a normal distribution
4.2 Discussion

4.2.1 Issues with the survey data

With 95% of the data fitting between +/- 27 dB it suggests that there are some problems with the data and or the model. Some notable issues on the node side are that the GPS data will often be >15 meters away from the road in places where the car was driven on the road. It is also unknown how long it takes for the data from the GPS to get to the LoRaWAN gateway. At the speeds travelled on the roads approaching 27 metres per second in some parts, this means that if the data takes 3 seconds to get to the gateway it will not be accurate by the time the gateway receives the packet. If retries are added to the mix it is even worse, as packets are sent at 6 second intervals.

Another variable in the system is that it’s not understood exactly what the effective sensitivity of the LoRaWAN gateway is. The specification states that the sensitivity should be -123 dBm at a spreading factor of 7 which under noisy environments this is not always going to translate into reality. With several packets at the same location when the node was stationary having RSSI values vary by as much as 19 dB it is suggesting that there could be a noise source involved.

4.2.2 Issues with the model

When producing the model it was found that the only data available on CloudRF was 30m satellite radar data. This means that objects smaller than 30m are not shown. This is a source of uncertainty in the model, and it is not well understood how much this contributes to the sample standard deviation found in [5.1(a)]. It is also not known for the antennas used where the main radiation lobe comes from and how the models interpret this information. It was assumed that the top of the antenna will radiate in the model which is not necessarily the case for a phased collinear antenna such as the 11dBi Laird antenna used.

4.2.3 summary

Overall the resultant data points show that coverage is achievable at the tail ends of the ITM. The uncertainty in the measurements with respect to the model is large enough to suggest that more work needs to be done to understand how well the model relates to real world results.
Conclusion

In this paper it was found that the ITM model had a lot of uncertainty compared with real world results. Then visual coverage maps were produced with the CloudRF platform which predicted the tail ends of the coverage. A survey was conducted to record real world data to be compared against model data from the CloudRF API. The experimental methodology explained the architecture of the system in terms of hardware and software and then the results were found to show that the model was accurate to approximately 13.5dB for 68% of the samples. From this it can be said that the hardware and software require improvements to eliminate probable sources of uncertainty.

5.1 Improvements

To eliminate probable sources of uncertainty in the hardware I would start by using a GPS unit which is accurate in the centimetre range as many data points were found to be off the roads the car was driven on for the testing. It would also be helpful to use a drone such that many data points can be taken from locations systematically after acknowledgements have been received.

In the software system retransmissions should be disabled to prevent old data from being used, and timestamps should be sent with the LoRa packet payload in order to allow for the elimination of old data from the dataset.

The Dragino LoRa shield did not provide accurate SNR and RSSI values on the node receiver end, so these should be improved with better hardware.