LoRa Wan implementation for project Echo

Current Implementation

Previously implemented Project Echo uses Raspberry Pi 4 as Master nodes and uses Arduino Uno, Arduino Nano, Raspberry Pi Zero as sub nodes that connects to the master nodes. Uses microphones to transmit audio data and temperature/humidity sensors to transmit environmental data to the nodes via using MQTT as communication method.

LoRa Wan investigation

Due to dense vegetation LoRa settings must be optimized within a range in some important factors such as Bandwidth, Transmission (TX) Power, Spreading Factor (SF), Coding Rate, Adaptive Data Rate (ADR), Uplink frequency. Can stick with 125 KHz bandwidth which is the norm in AU915 configured with LoRa SF12 to SF7 (Spreading Factor) from LoRa Wan regional parameter and DR0 to DR5 data rates which specifically has 125 KHz bandwidth but incur very slow data rates. Wider bandwidths will support higher data rates, but receiver sensitivity and range will be reduced. Most LoRa Modules output a max of 20 to 22 dBm (decibel-milliwatts) of TX power, which if it has a higher power, it increases range and link reliability through trees. Using ADR, we can dial down the power within 14 to 20 dBm for nodes to get strong consistent signal while saving the battery, which a node may start at high SF (SF12) and network commands it down to lower SF (SF8) during occasional scenarios such as hilly forest terrain.

LoRa Wan enables an error correction with a coding rate of 4/5 (for every 4 data bits, 1 redundancy bit is sent) by default which provides a good trade-off between error correction and airtime. LoRa Wan is designed for low-duty-cycle use, but AU915 has no fixed duty-cycle limit, so for our nodes within this scenario it might be good if we had 5 to 15 minutes or an hour interval per automatic reading and event-driven uplinks to send immediate update when an event occurs, such as animal sounds. Immediate transmission needs to be send using a lower data rate which means higher SF but if ADR already optimized the node, it would use the current data rate which is fine as well. To avoid collisions between multiple events, we should implement a short random 1 to 3 seconds delay before uplink.

There are two terms called Dwell time and pseudo random frequency hopping, when the Australian rules and regulations apply for project use case. Dwell time is simple the maximum time a device is allowed to continuously transmit on a single frequency channel and according to regulations the legal dwell time limit is 400 milliseconds per channel. Pseudo-Random Frequency Hopping (PRFH) is a legal requirement to switch frequencies randomly across a set of channels when sending messages from Lora WAN devices and at least needs to hop across 20 frequencies for AU915 Lora WAN devices.

[1] , [2] , [3] , [4]

Australian Regulations that need to be followed when network establishment

- LoRa transmissions must occur within 915 MHz to 928 MHz.
- Devices must hop across at least 20 channels to be allowed upto 30 dBm EIRP, and if transmitting on a fixed frequency, we're limited to use only 3 mW (5 dBm EIRP).
- LoRa Wan devices must use pseudo-random frequency hopping across at leats 20 channels or else it violates ACMA rules unless, under 3 mW limit.
- Dwell Time per channel must not exceed 400 ms which is why SF11 amd SF12 disabled by default.
- Spreading Factor, SF7 to SF10 is allowed but SF11 and SF12 could be enabled by shortened messages to fit below 400 ms dwell time.

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Optimal Configurations

- Regional Plan: **AU915** in LoRaWAN stack or device firmware.
- Uplink frequencies: could be 8 channels (916.8 MHz, 917.0, 917.2, 917.4, 917.6, 917.8, 918.0, 918.2 MHz)

- Downlink frequency: 923.3 MHz by default
- Spreading Factor: SF7 to SF10 by default.
- Adaptive Data Rate: enable to let network dynamically choose the best SF and only enable SF11 and SF12 if shorts messages are configured to stay under 400 ms.
- Bandwidth: uplink 125 kHz
- Transmit Power: 20-25 dBm TX power
- Payload Length: below 51 bytes at SF10 to comply with 400 ms dwell time.
- Duty Cycle: below or equals to 30 seconds airtime per device per day is recommended for LoRaWAN.

Comparison between using MQTT vs LoRaWAN for project

Factor	MQTT	LoRaWAN
Protocol	TCP/IP over Wi-Fi or Cellular (4G/5G)	Long-range and low power wireless
Network Range	Over Wi-Fi a very low area, with cellular large area is covered.	Mid-range with serious conditions like dense forest
Power Consumption	High due to network is always on.	Low (depending on Spreading Factor)
Coverage	Needs cellular signal or hotspot from a device connected to cellular network.	Designed for remote areas like dense forest.

Payload Size	Large	Small
Cost	Expensive	Cheap
Signal Reliability	Depends on the signal coverage	More consistent signal in different conditions
Real-time/Periodic	Suitable for Real-time monitoring	Suitable for periodic metrics and event wise triggers

Comparative Table of Spreading Factors

Spreading Factor (SF)	Approx Data Rate (kbps)	Range in Forest	Airtime for 51 bytes	Battery Usage
SF7	~5.47	~1-2 km	~90 ms	Low
SF8	~3.13	~2-3 km	~160 ms	Low
SF9	~1.76	~3-5 km	~290 ms	Medium
SF10	~0.98	~5-7 km	~530 ms	High
SF11	~0.44	~7-9 km	~990 ms	Very high
SF12	~0.29	~10+ km	~1.6 s	Very high

Recommended Uplink Time

- Legal Dewll time limit: 400 ms per transmission on 1 channel
- LoRaWAN airtime per device per day: ≤ 30 seconds total
- Uploads per hour (average) : 2 to 6 times per hour (every 10-30 min)
- Immediate sent: On audio detection (threshold breach)
- Delay: 1 to 3 seconds random delay to avoid collisions

[6]

References

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