Internet of Machines

DESIGN DOCUMENT

Team Number 15

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1 Introduction

1.1 Project statement

The ambition of our project is to collect data from sensors related to the operation of a machine and send that data from a Raspberry Pi to a central server over an internet connection. This system will help users monitor the operational status of their machines over time.

1.2 Purpose

To be able to compile operation data from various types of machinery to a centralized, accessible format, owners and operators of these tools will be able to better manage their use and maintenance, increasing the lifespan and productivity of their overall operation. This could include small farms with a few pieces of equipment all the way up to a factory with several hundred machines. Our ultimate goal is to create a system that will help both get the most out of their equipment.

1.3 Goals

Our goals are as follows:

- Create a product that meets the specifications of our sponsor.
- Understand data collection using Raspberry Pi.
- Successfully transmit data using a LoRA connection.
- Understand data management on a Linux server.

2 Deliverables

By May of 2017 (The end of the spring 2017 semester), we plan to have completed and be able to deliver the following:

1. A prototype of our communications system able to transmit sensor data from a drone to a ground station through LoRA connection, including a central server and web front-end for use of storing and displaying the data in a reasonable format, respectively.
2. Full documentation of our project and a full recommendation report regarding implementation of our system in a commercial setting.

The working prototype will be delivered with accompanying hardware and software. Documentation and recommendations will also be delivered to our sponsor, Vermeer, for detailed explanations.

3 Design

3.1 SYSTEM SPECIFICATIONS

The system can be separated physically with transmitter hardwares loaded on a drone and repeater system on the ground. For the transmitter part, sensors and LoRA module SX1272 will be equipped on a Raspberry Pi board. For the repeater part, same LoRA model will be equipped on another Raspberry Pi board. This board will also connect to the internet.

3.1.1 Non-functional

- The client system must have reasonable portability, such that it could be used to measure data from a variety of different devices, while not impeding regular operation of said devices.
- The client must be expandable, such that it can support an arbitrary number of sensors/retrieve an arbitrary amount of sensor data
- The client system must be able to send relevant data to the server in a timely and stable rate.
- The server and client must be configurable to associate the client with the server.

3.1.2 Functional

- The system on the client machine must be able to retrieve relevant data from a set of sensors, including sensors both internal and external relative to the raspberry pi. This includes:
    - Uptime (how long the system has been running since the previous power on).
    - Lifetime (how long since the system was initialized).
    - Temperature and humidity
    - Other unique, system-specific data based on the machine that is being monitored.
- The client system must be able to connect to the server system over a LoRa connection at a range of several miles (1-5 miles).
- The server system must be able to serve a multitude of clients simultaneously.
- The server must be able to distinguish clients, and compile data from each independent client in a format which can be compiled and exported into a Microsoft Excel spreadsheet format (EG .xls, .csv).

3.2 PROPOSED DESIGN/METHOD

We will choose the model of Raspberry Pi based on adaptability and modularity, particularly with LoRA model SX1272. Due to these hardware choices, we are planning on implementing our software with the language Python. This hardware will be used for both the client module (the unit responsible for collecting and transmitting sensor data) and the server module (the unit responsible for congregating data from a number of clients into a usable and organized format).

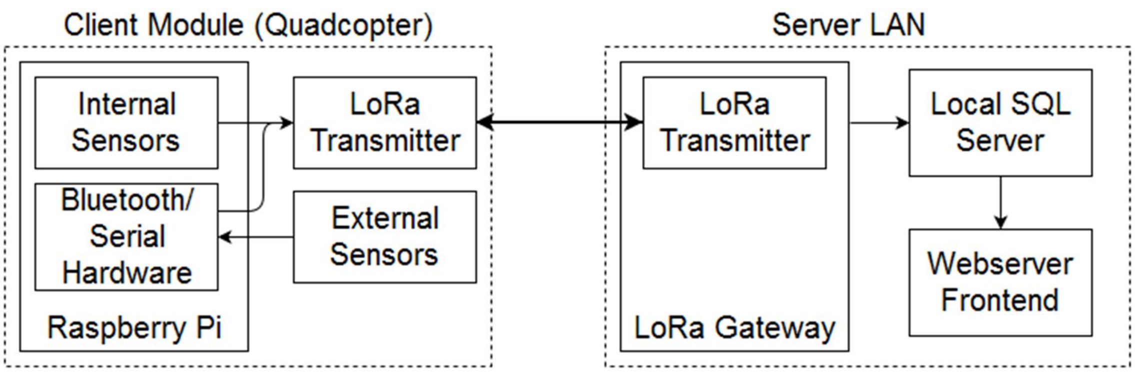
The functions required of the client system are:

1. Retrieve data from sensors in a timely manner
2. Establish a consistent LoRA connection to the server module
3. Parse data to central server over established connection

The functions required of the server system are:

1. Broadcast connectable signal to client modules
2. Receive data packets from clients in a timely manner
3. Organize data based on time/client ID
4. Publish data to excel doc/web server

The following graphic is a hardware-level diagram of the proposed design:



3.3 DESIGN ANALYSIS

As we have not started to build this project yet, we can only suspect problems that we need to fix.

1. What data is useful/get accurate data
2. Connection bug/bad connection
3. Packet loss/incomplete packet/software reliability

4 Testing/Development

4.1 Hardware determination

Compared the following parameters for cellular transmission [1] versus LoRA uplink transmission[2]: transmission distance, capital cost, service cost, and potential scalability. We completed the comparison through applied research of current cellular and LoRA technologies and available cellular service providers.

4.2 Hardware testing

For future testing of the design, the following section outlines the basic functional tests, as well as the measure of success for each system included from the acquisition to storage of the experimental data. All testing will require the use of the Raspberry Pi, it's onboard Unix operating system and an embedded programming language to be decided.

Testing is scheduled to begin in the Spring of 2017, after all parts have been ordered and delivered, as well as all the required planning and documentation is completed.

Functional Block	Hardware	Test	Measure of Success
Drone Operation	TBD	Take the drone out and fly it around.	Determine the team member with the best flying skills. Drone operation can be sustained for a long period of time in order to test other systems (i.e. battery, etc.)
Sensors -> Transmitter Pi	Sensors Temp Accelerometer Raspberry Pi	Connect sensors to the Raspberry Pi and write a program to have the sensors read their data into the Unix command line.	Verify the temperature & accelerometer data is correct by controlling variables associated with each, and comparing to the data read into the command line.
Transmitter Pi -> Receiver Pi	Transmitter Pi Raspberry Pi LoRA Transmitter Receiver Pi Raspberry Pi LoRA Receiver	Send test information over LoRA. Measure receive success rate and data rate.	90% Transmission Success 10kbit/s bitrate
Receiver Pi -> Cloud Storage	Receiver Pi Raspberry Pi LoRA Receiver Ethernet interface to internet link	Send test information over ethernet and internet link. Measure receive success rate and data rate.	95% Transmission Success 1Mbps bitrate

5 Results

At the present time there has been no testing to yield results. As stated above, serious testing will commence once all parts have been ordered and received, which will more than likely be in Spring 2017.

However, during our initial design, conducted research on several factors to compare the costs and benefits of a cellular uplink versus a LoRA uplink.

Parameter	Cellular Result	LoRA Result
Transmission Distance	Limited to areas of network coverage. In populated areas: transmission distance is non-issue.	2km line-of-sight
Cost (Capital & Service)	Small initial capital investment, but high monthly service fees	Slightly higher initial capital, due to both transmitter and receiver No service fees
Scalability	Increase in units leads to linear increase in monthly service costs	One receive station can host multiple receive units. Highly scalable.

6 Conclusions

To this date we have done research and planned our best viable option for this project. Our aim, is to design and implement a method for remote operational data collection laterally scalable to a network of machines. To do this, we plan to use simple sensors connected with a Raspberry Pi, equipped with LoRA technology to transmit to a central node Raspberry Pi. This is an ideal method for this task, this method for data transmission is reliable to 2 kilometers, which far surpasses wifi, and requires no contract with carriers, as cellular data would, which makes our solution economical.

7 References

1. 3GPP, "LTE," in *3GPP - A Global Initiative*, 2008. [Online]. Available: http://www.3gpp.org/technologies/keywords-acronyms/98-lte. Accessed: Oct. 27, 2016.

2. Libelium Cominicaciones Distribuida S.L. (2016). *LoRaWAN Technology for Arduino, Waspnote and Raspberry Pi.* [Online). Available FTP: https://www.cooking-hacks.com/documentation/tutorials/lorawan-for-arduino-raspberry-pi-waspmote-868-900-915-433-mhz.