WIRELESS EMBEDDED HEALTH MONITORING SYSTEMS

Project Plan
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0 LIST OF ABBREVIATIONS

DOT: Department of Transportation
EM: Electromagnetic
I2C: Inter-Integrated Circuit
IC: Integrated Circuit
LCD: Liquid-Crystal Display
PCB: Printed Circuit Board
RF: Radio Frequency
RTC: Real-Time Clock
SPI: Serial Peripheral Interface
USB: Universal Serial Bus

1 PROBLEM STATEMENT

Structural health monitoring systems allow structures to be evaluated for safety without requiring the presence of an inspector, saving time, money, and possibly lives as structural degradation can be detected much sooner than manual inspection. In this project, the group will create a wireless network of sensors. Each sensor will be embedded into highway concrete to collect long-term data and store that data in a roadside base station. The data will be composed of humidity and temperature with options to add more sensors in the future.

2 DELIVERABLES

2.1 FIRST SEMESTER

- System diagram
- Research and Planning
  - Part Selection
  - Cost estimation
  - Mesh network and power supply
  - Documentation
- Design
  - Construction of Circuits
  - Individual circuit and software testing
  - Free-space testing
  - Circuit organization
  - Base station design
- Prototype Iteration
  - Two nodes talking to each other
  - Wireless charging

2.2 SECOND SEMESTER

- Make adjustments to network
- Test sensor survivability through mixing process of concrete
- Software testing and tuning in free-space of full network
- Test full network in concrete
- Scalability
- Final Product
  - Working network with expected deliverables
  - All documentation
  - Explore using cell towers for possible communication

3 SYSTEM REQUIREMENTS

The system created for this project will meet the following criteria.

1. Sensor can communicate between multiple nodes.
2. The enclosure is water/shock resistant and can handle pressures induced by the solidification of concrete and overhead traffic.
3. Handles temperature ranges from -20̊ F to 140̊ F.
4. The battery life of each unit will last a minimum of one year.
5. Each charging of the battery will take a maximum of 12 hours.
6. Must be able to transmit and receive data between nodes through concrete.
7. Must encompass full automation of data aggregation, transmission, & receiving.
8. Must be able to detect and reroute around non-functional nodes.
9. Must record logs of all data in the base station.
10. Log files must include date, time, nodes used, and information about the samples.

3.1 DESIGN ASSESMENT

The finished prototype will be comprised of a base station and six nodes; however, the network control software will easily be up-scaled to accommodate a larger network of up to one-hundred nodes. The routing algorithm that controls the network will maximize battery life of the nodes by ensuring that traffic distributes evenly through the network. The software will also be able to route around dead nodes so the network stays active if a device becomes damaged or the battery dies. Choosing a patch antenna reduces the size of the node and gives better efficiency than a dipole antenna; however, it is directional and requires proper alignment with the charging system to charge the device.

3.2 ASSESMENT OF PROPOSED SOLUTION

Strengths: Due to the small size of the nodes, the design makes it easier to add into concrete mixture prior to pouring. This helps reduce the time and money needed in order to place individual nodes. The microcontrollers that are used consume less power than the original design with Arduinos, and are less expensive. Therefore, the new nodes can last longer with smaller batteries. Since the current design is wireless, there is no danger of having exposed wires disconnected during concrete curing process.

Weaknesses: Wireless charging is not as efficient as wired charging due to attenuation of signals in concrete. The current design implements a mesh network, which can affect the node that is closest to the base station on the side of the road. What this means is that this specific node will have to consume more power during receiving and transmitting of data, which could cause our overall system to fail because that node depletes its battery quicker. Attenuation of our transmission data is another weakness. The concrete can cause loss of data making each node send out repeated transmissions that can also drain the battery quicker.

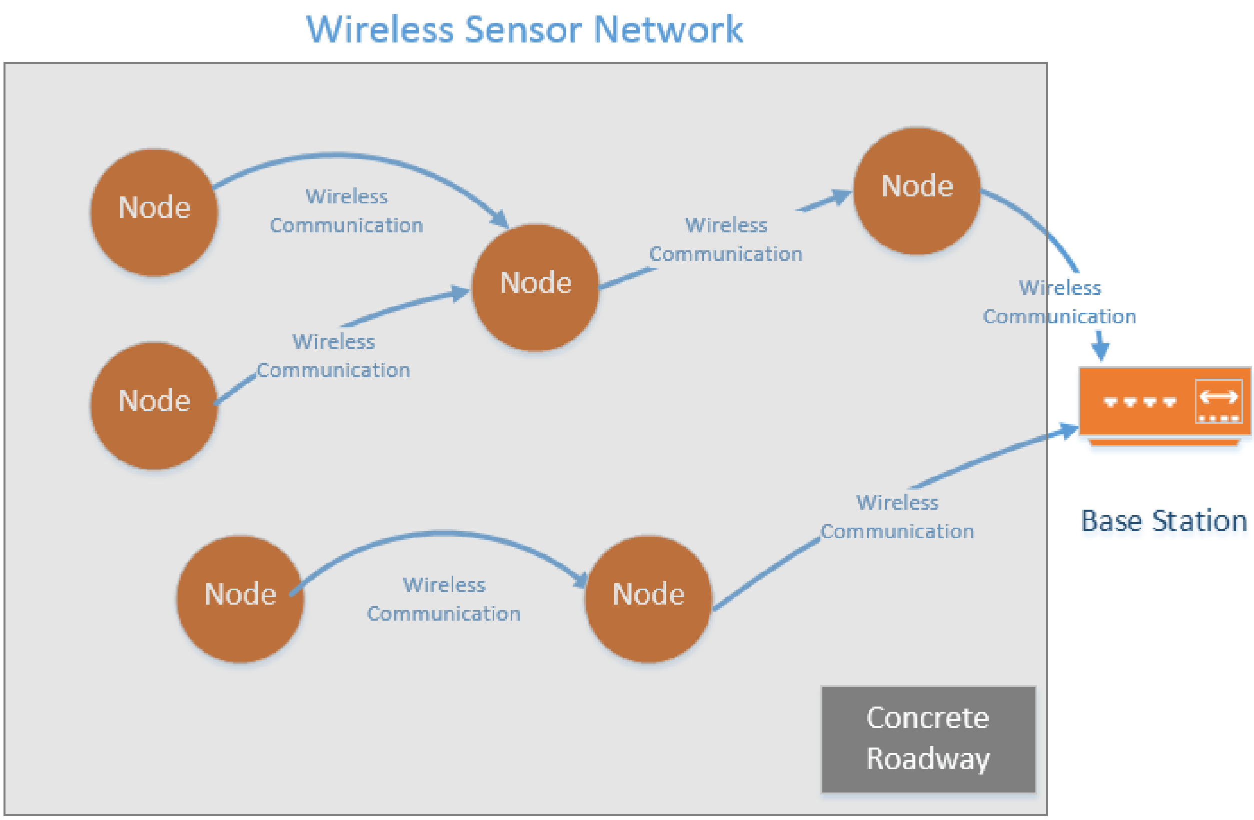
3.3 VALIDATION AND TESTING PROCEDURE

The numbers for tests correspond to the numbered requirements specified in the beginning of section 3.0

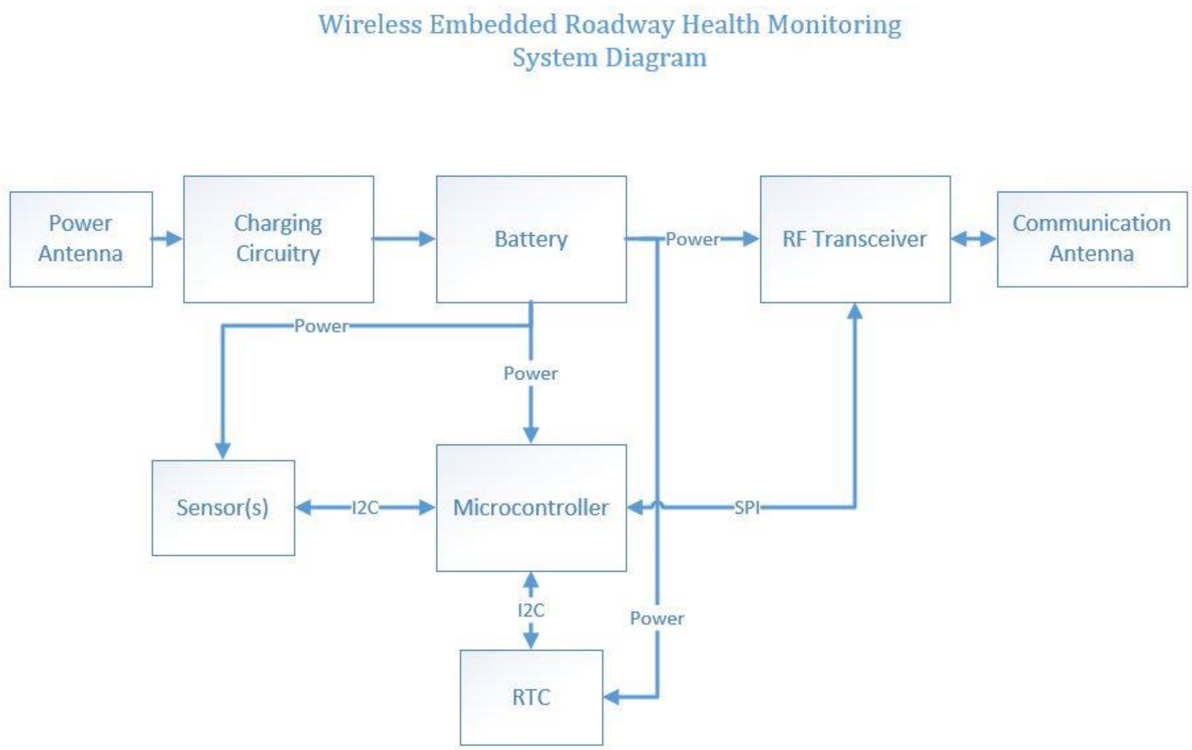
1. Between multiple sensors, one sensor will record measurements and send data to multiple nodes, one at a time to verify only the intended target receives the data.
2. Sensor container will be exposed to setting concrete to test if electronics will survive the curing process.
3. One node will be exposed to extreme temperatures and will be tested to see if node will maintain normal operation.
4. Average current draw of the node will be measured and can be used to calculate expected battery life.
5. Charge time of the system will be measured to ensure it meets the time constraint.

6. Nodes will be placed in concrete chambers and tested to verify data can be transmitted between them.
7. Nodes will be tested to ensure data is automatically collected and transmitted on a timely basis.
8. A network will be created in free space, then a node(s) will be intentionally deactivated to see if the network can re-route around the lost nodes.
9. One sensor will be configured to send data to the base station, which will be extracted to see if any data is lost or corrupted.
10. Verify that transmitted data contains all specified information.

4 CONCEPT SKETCH/MOCKUP



4.1 HARDWARE BLOCK DIAGRAM



4.2 MEASUREMENT EQUIPMENT

Data transmitted between each node and data received will be monitored accurately. Additionally, measurements of signal intensity through concrete must be analyzed. Power consumption measurements will inform user whether charging needs to be conducted.

4.3 SOFTWARE & CONTROLS

All programing code is written in C, developed in Texas Instrument's Code Composer Studio.

4.4 HARDWARE

The circuit will be printed onto a PCB and the components will be surface mounted to decrease size and increase efficiency. The enclosure for the PCB will not allow water or concrete to seep inside also the enclosure will not crack due to the pressures of the road or chemical processes.

4.5 CONTROL & AUTOMATION

System will autonomously collect data every 30 minutes and transmit once every 24 hours. The system will charge wirelessly once every half a year.

5 INTERFACE DESCRIPTION

For this project, the base station is the only user interface. This could include features such as a way to change sampling rate of the nodes in the network and a USB port for data extraction. This interface could include several buttons that allow a user to interact with the system. Currently a Raspberry Pi will function as the base station. A LCD screen and keypad will be used as a way to interact with the system.

6 WORK BREAKDOWN STRUCTURE

Every member of the group project is expected to remain up-to-date with all facets of the project. In order to ensure that the project plan is carried out successfully, each group member has been designated to a particular r ole as to preserve the group's stability and maximize work efficiency. The group member roles are designated as:

Positions

Mitch Balke

– Team Leader

Brandon Wachtel and Tyler Fish

– Team Communications

Brandon Maier and Johnnie Weaver

– Webmasters

Trieu Nguyen and Chris Sheafe

– Key Concept Holders.

Project Focus

Brandon Wachtel, Johnnie Weaver, and Trieu Nguyen

– Power Supply and Charging Station

Mitch Balke and Brandon Maier

– Embedded Programing and Network setup

Tyler Fish and Chris Sheafe

-Communication Aspect and Wireless Charging System

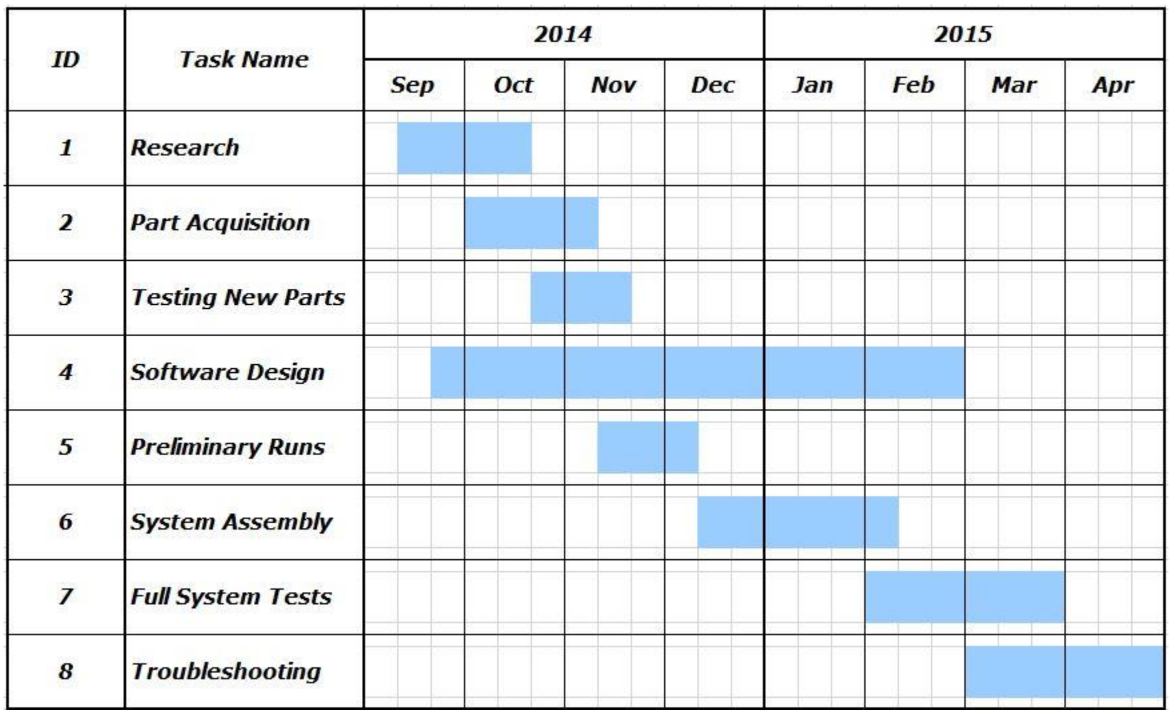
7 POTENTIAL MARKET

Major concrete companies who focus on recording specific data inside the concrete can use this project. The DOT will be a huge user for this product since the data can help predict when they need to resurface a road or completely re-build it. Overall, the data that is received will help produce a better concrete product for longer lasting roadways and concrete structures. Clients also receive a better return on their investment. If the DOT knows when the road is about to expire, they do not have to replace it early hence, acquiring a better value from the roadway. The application of wireless sensing also extends to bridges, skyscrapers, and tunnels. The same concept of better value can be applied to these concrete structures but more importantly, they can be used to avoid catastrophes from derelict bridges and other structures.

8 RESOURCE REQUIREMENTS

Resource	How will we get it?	Estimated cost (per node)
Humid/Temp Sensor	Provided by client	N/A
IC's	Provided by TI Samples/Electronic Distributors	$12.00
Antennas	Electronics distributors	$5.00
Node Enclosure	Enclosure distributor	$6.00
Battery	Electronics distributors	$8.00
Passive Components	Electronics distributors	$3.00

9 PROJECT SCHEDULE



10 RISKS

10.1RISKS TO THE PROJECT TIMELINE

Our biggest obstacle and risk is how long it will take to communicate between two microcontrollers. If wireless communication is delayed, development of the network routing algorithm will be delayed until the wireless communication can be implemented. In addition, the enclosure could be a risk if it is not strong enough to resist the pressure of the concrete or the chemical reactions that take place during the curing process.

10.2PHYSICAL DANGERS

The main physical risks regarding this project is the possibility to be burned from soldering, possibly being shocked, and injuries with cutting tools. Some non-visible risks could be from the effects of EM and RF power transfer.

11 CONCLUSION

Future applications of this project will help to maintain concrete integrity and decrease the need for manual inspections of civil structures. Implementation of this network will help to make wireless sensor networks for monitoring structures more feasible to implement in production. Further refinement to the concrete mixture can be improved upon data collection during curing process. Economically, the use of wireless sensor networks is beneficial to owners of such structures in the sense that they can wait longer before having to replace a roadway.