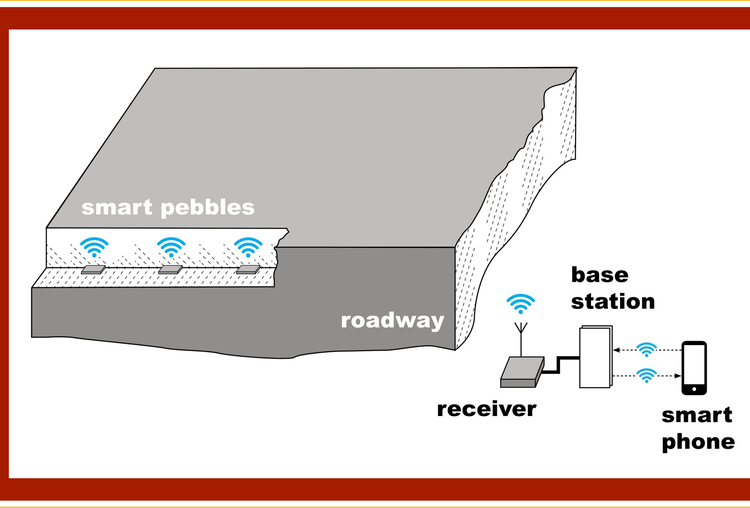
May 1622: Wireless Embedded Roadway Health Monitoring Network



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Problem Statement

Measuring the health of roads can be expensive, time-consuming, and ineffective due to the current method of manually taking readings from the outside. If the road's health is not measured frequently and accurately, the potential for accidents caused by crumbling roads increases.

Solution: The way the WERHM Network aims to solve this problem is: create small "smart pebbles," tiny wireless embedded nodes which measure temperature and humidity on a duty cycle. Nodes will be poured with the concrete, buried in the road. They will send their readings wirelessly to a base station (BS) above ground on the side of the road, and receive their new duty cycle from the BS, if it changes. Finally, the user can retrieve all data and configuring the duty cycle for the smart pebbles by interacting with the BS.

Requirements

Functional requirements:

Communication: Use wireless RF system to transmit to nodes through reinforced concrete at low power

Microcontroller: Operate on RTC interrupt to take sensor readings and transmit data through RF system

Sensor: Take measurements at lowest power possible

Power: Battery must last at least one year

Base Station: Communicate to nodes for initial setup, duty cycle; communicate with smartphone for data extraction

Android App: Determine duty cycle for nodes, receive data from base stations

Non-Functional requirements:

Microcontroller: Try to be self-recoverable; long lifetime; extensible;

Battery: Must be small enough to fit in ~1" enclosure and large enough to fill power requirement;

Base Station: Large storage capacity; Bluetooth capability;

Android Application: No crashes or bugs;

Enclosure: Rounded shape; resistant to harsh concrete environment.

Past Efforts

- **Wired Communication:** Delicate - connections destroyed during pouring and curing process of concrete
- **Wireless Communication using Zigbee operating at 2.4GHz:** Frequency too high to penetrate concrete
- Phase 1:
  - Charging circuitry prohibitively large and expensive
  - Enclosure too large to feasibly be poured with concrete (2.7"x2.7"x1.25")

System Design

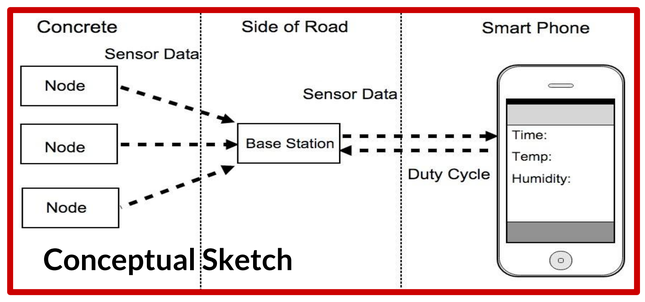
Our system is split into three sections: embedded circuit, base station, and smartphone application.

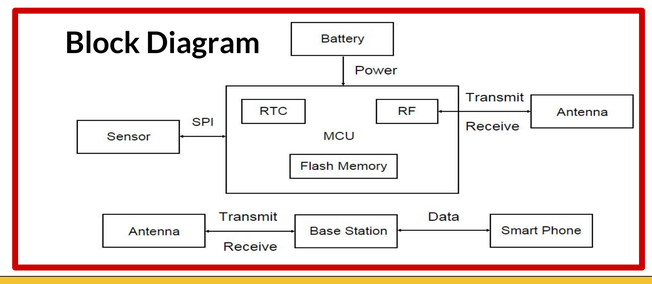
Hardware

- Powered by TI CC1310 Microcontroller, consisting of:
  - Low-power radio frequency (RF) transceiver
  - 128KB programmable flash memory
  - Real-time clock (RTC) for accurate timekeeping
  - Low active current
- Sensirion SHT71 temperature and humidity sensor
- Yageo FR4 433MHz chip antenna
- Overall PCB size: 1" x 1"

Software

- Embedded code is optimized for low power consumption
- Android applications for communication between smartphone and base station



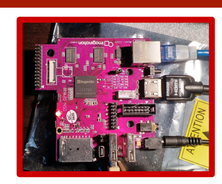


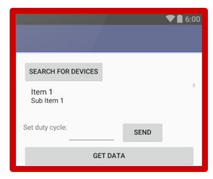
Users and Operating Environment

This application is not limited solely to roads; these smart pebble networks can be used in any concrete structure such as hospitals and large office buildings. The intended users are anyone interested in having a more accurate picture of the health of their concrete structures.

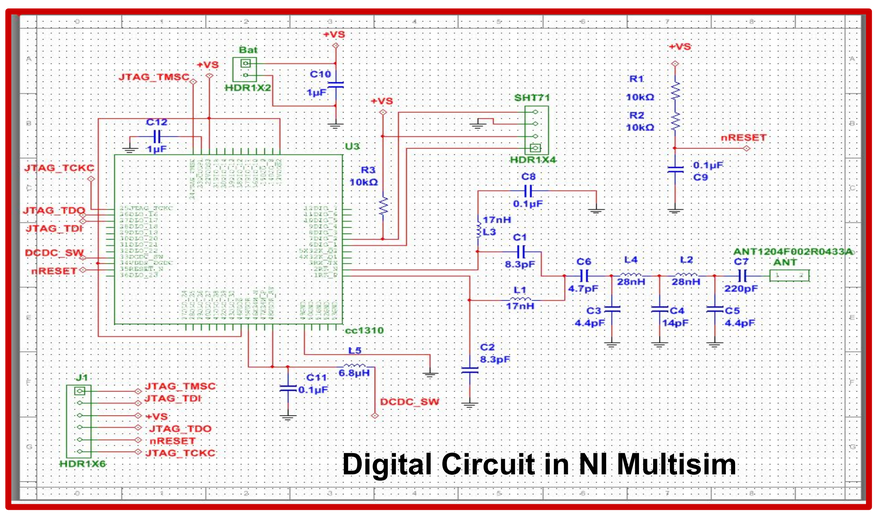
Base Station & Android Apps

- Base Station is the system's access point
  - Collect readings from network
  - Send duty cycle to nodes
  - Creator CI20 Microcomputer
- Smartphone is mobile station
  - Retrieve all readings from base station
  - Send duty cycle to base station

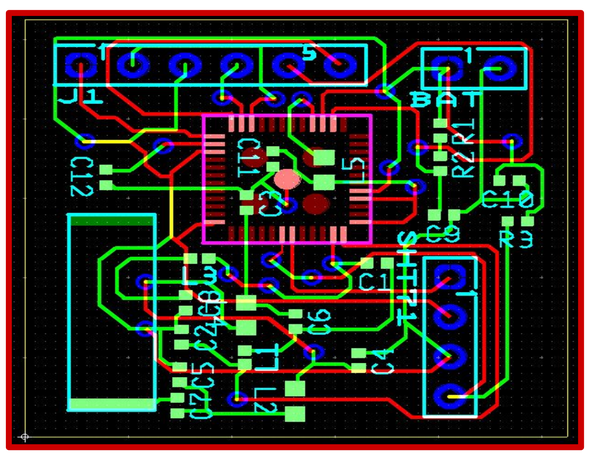




Digital Circuit and PCB Layout



Digital Circuit in NI Multisim



PCB Layout in NI Ultiboard

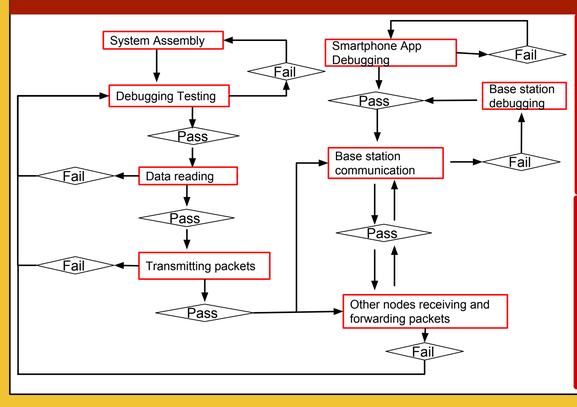
Enclosure

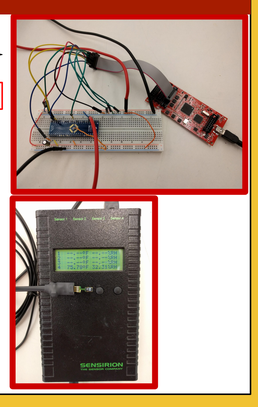
- 3D printed enclosure is roughly 1"x1.5"x0.8"
- Can withstand the heat, pressure, and acidity of curing concrete
  - Also allowing the sensor to accurately take measurements
- Material used: ABS plastic
- Protects circuit board from corrosion

Technologies Used

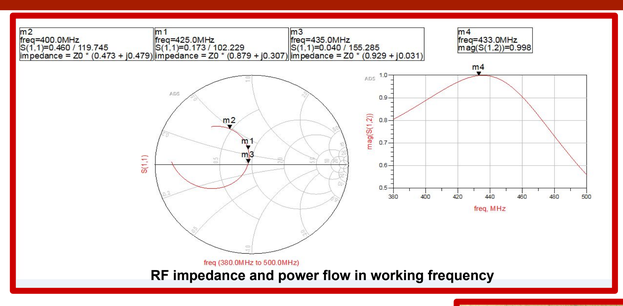
- Microcontroller
  - Code Composer Studio v6
  - C programming language
- Base Station and smartphone
  - Android Studio
- Enclosure
  - Solidworks
- RF Testing
  - ADS
- Circuit Design
  - Multisim and Ultiboard

Testing Strategies



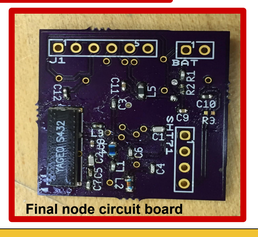


Result



RF impedance and power flow in working frequency

- Package size decreased by 7.6x, much smaller than Phase 1
- Between base station and smartphone, data retrieval is wireless and duty cycle can be easily changed



Final node circuit board