Multi-Level Adaptive Remote Sensing Package for Bridge Scour Health Management

RITA Quarterly Progress Report, Q1 (August 2012 – October 2012)

Submitted by Impact Laboratory. Co-PIs Sandeep Gupta and Georgios Varsamopoulos. This report is for the following activity items:

Item No.	Task No.	Activity/Deliverable	Payable Milestone
3	2	Installation design of the data collection scheme — communication.	An analysis on the communications range, number of transceivers, battery requirements etc
4	2	Installation design of the data collection scheme — compatibility.	A design scheme on how sensor apparatuses will be able to communicate wirelessly

Research Objectives

For the first quarter the objectives encompassed research on memory storage requirements on site, energy requirement to sustain the sensor network for scour monitoring, connectivity map of the RFIDS, sensors and laptops with a feasible node placement analysis based on communication range of each component, databases and the database schema for storing sensor and RFID data and protocol for sensor pooling (data collection by the sensor using TI sensor mote). The research directly relates to the output deliverables of tasks "Installation design of the data collection scheme — communication" (also noted as "Investigate the physical requirements for communication and energy at test sites") and "Installation design of the data collection scheme — compatibility" (also noted as "Design a scheme for fitting the RFID and other sensor apparatuses with WIFI-n wireless capability").

A. Investigation of the physical requirements for communication and energy at test sites

A.1. Approach

The network consists of velocity sensors, flow depth sensor, skew sensor, temperature sensor and RFID antennas. With the available bridge architecture the range of sensor node and RFID placement and inter pier lengthwise distance is formulated for ensuring connectivity with the receiving laptop which in turn connects with the gateway. It was considered that the laptop communicates via WIFI. An assumption is made for data transfer rate considering the requirement, as specified in the project document, for calculating the expected memory storage required for sustaining the scour monitoring algorithm input data.

The database is created using PostgreSQL. PostgreSQL was chosen because it is lightweight. The EZ430-RF2500 sensor harvester is used to measure the height of flow and the signal strength. For this configuration, an Access Point (AP) connected to the PC served as the base station to which the End Devices(ED) communicated with their data. The data rate was taken to be 256 kbps (kilobits per second) and the sampling interval was taken to be ten seconds. A data-logging program on the PC logged the data from the AP and stored it in a CSV file which was then read and the data stored in the database created

A.2. Design

All the calculations are done using general notations. As shown in Figure1 the distances, and represents distance between top of the pier to the ground level, lengthwise distance between

adjacent piers and breadth wise distance between adjacent piers respectively. Two angles and are considered which velocity sensors and skew sensor respectively make with the top of the pier to which it sends its data. The flow depth sensor is assumed to be kept at the bottom and the temperature sensor at the top of the middle pier. Three data rates,, and (all in kbps) corresponding to data rates of velocity sensors, flow depth sensor, temperature sensor, skew sensor and RFID antennas are considered. The following give the calculations:

- The calculated WIFI range of the laptop can be expressed as. For the inequality it is considered that the RFID antenna is very near to the laptop and gateway is in the centroid of the bridge.
- The data which each laptop receives per second is given as kilobits.
- The duty cycle for each sensor is 6.67%.

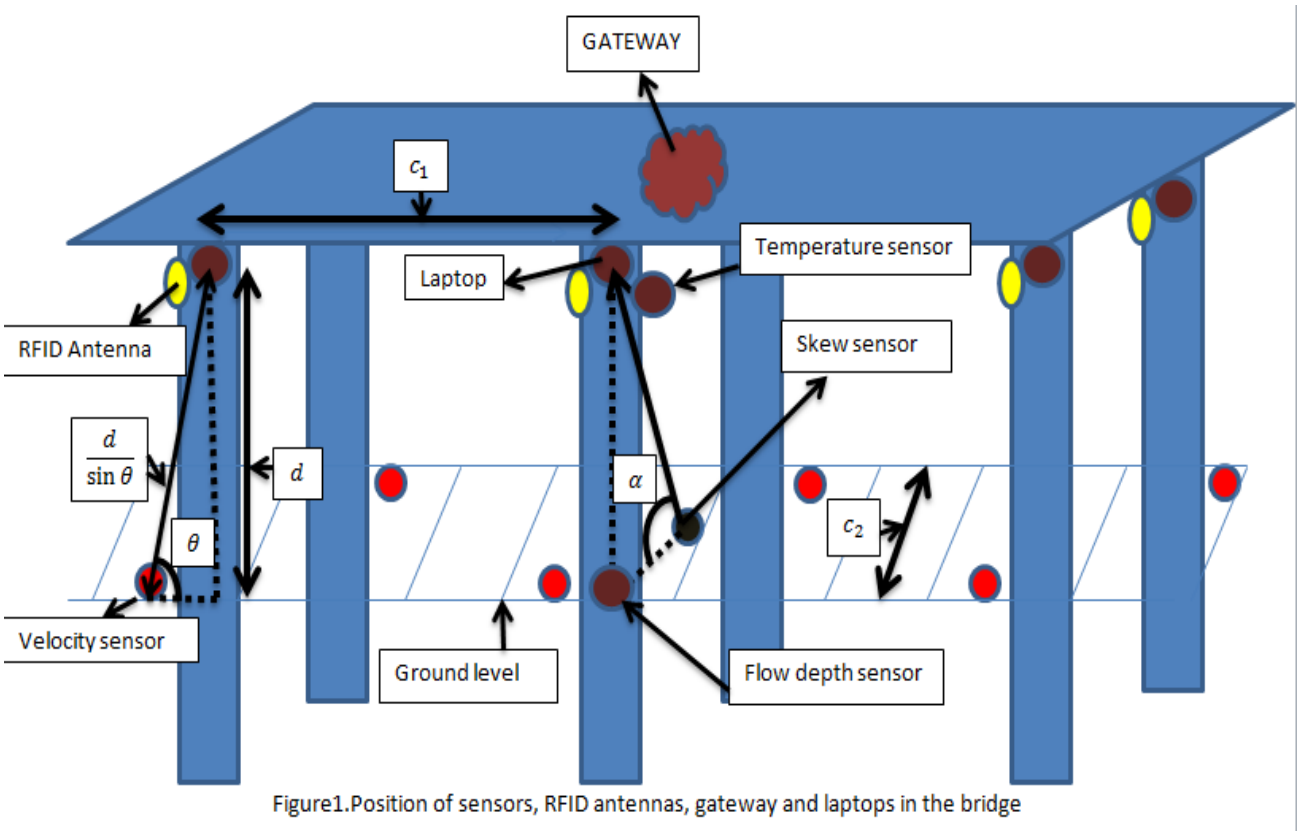

Figure1.Position of sensors, RFID antennas, gateway and laptops in the bridge

Figure1. Position of sensors, RFID antennas, gateway and laptops at the bridge. c_1 is the distance between consecutive piers along the bridge's length. d is the rise of the piers over the ground. θ is the depression angle from the piers.

The raw and total disk requirement to collect data from velocity sensors, flow depth, skew sensor, temperature and RFID with data rates corresponding to, and respectively is given in Table1. For velocity, temperature, skew and flow depth sensors it was considered one packet was send every 5 minutes and for RFID 1 packet per every 1 minute. The raw data was calculated for a time frame of 1 hour, 1 day. 1 week and 1 month (considering 30 days in a month) with the total database memory calculated for 1 day. Table2 gives a sample disk size requirement information for the generalized data of table1 with,, and taken as 256 kbps.

Table1. Generalized disk size requirement for sensors and RFID

Sensor Type /RFID	Number of Sensor(s)	Time interval between packet (in min)	Packet Size (in Kb)	One Hour Raw Memory Usage (in Kb)	One Day Raw Memory Usage (in Kb)	One Week Raw Memory Usage (in Kb)	One Month Raw Memory Usage (in Kb)	Total Database Memory usage per day (in Gb)
Velocity Sensor	6	5	b_v	72 b_v	1728 b_v	12096 b_v	51840 b_v	2.56 b_v
RFID	6	1	b_{R_ant}	360 b_{R_ant}	8640 b_{R_ant}	60480 b_{R_ant}	259200 b_{R_ant}	12.82 b_{R_ant}
Temperature Sensor	1	5	b_t	12 b_t	288 b_t	2016 b_t	8640 b_t	0.427 b_t
Flow depth sensor	1	5	b_{fd}	12 b_{fd}	288 b_{fd}	2016 b_{fd}	8640 b_{fd}	0.427 b_{fd}
Skew sensor	1	5	b_s	12 b_s	288 b_s	2016 b_s	8640 b_s	0.427 b_s

Table2. Disk size requirement with data rate value for all sensors and RFID 256 Kbps

Sensor Type /RFID	Number of Sensor(s)	Time interval between packet (in min)	Packet Size (in Kb)	One Hour Raw Memory Usage (in Mb)	One Day Raw Memory Usage (in Mb)	One Week Raw Memory Usage (in Gb)	One Month Raw Memory Usage (in Gb)	Total Database Memory usage per day (in Gb)
Velocity Sensor	6	5	256	18	432	2.95	12.66	653.36
RFID	6	1	256	90	2160	14.77	63.28	3280.61
Temperature Sensor	1	5	256	3	72	0.49	2.11	109.35
Flow depth sensor	1	5	256	3	72	0.49	2.11	109.35
Skew sensor	1	5	256	3	72	0.49	2.11	109.35

In calculating the total database memory for a particular data base it was found that for storing 4 kb of data 6221 Kb of data was required for the entire database and this result was used for interpolating the data consumed for the database in one day from the used raw memory.

All the sensors directly communicate with the cloud and RFID communicates in one hop with its respective receiver laptop with laptops directly sending data through the gateway. The connectivity map of the network for data gathering is shown in Figure2.

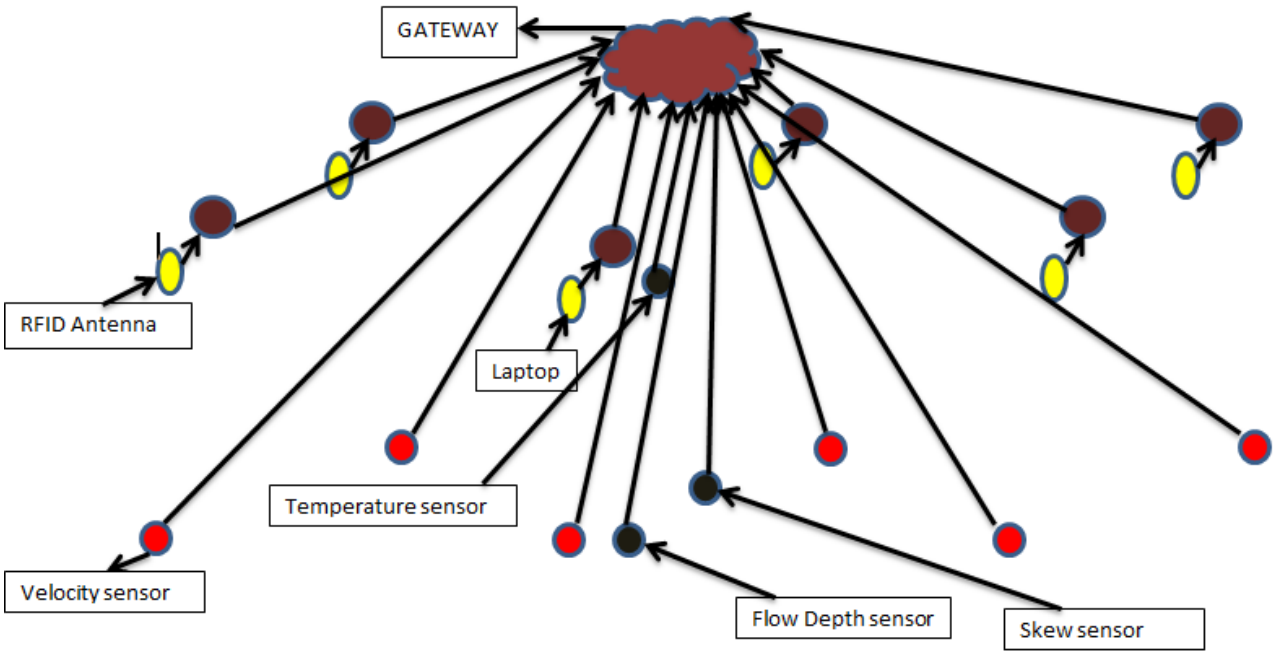

Figure2. The connectivity map of the network. All the sensors will communicate to the closest RFID-operating laptop. Then the laptops will communicate with the gateway.

The database schema for storing the data is shown in Figure3.

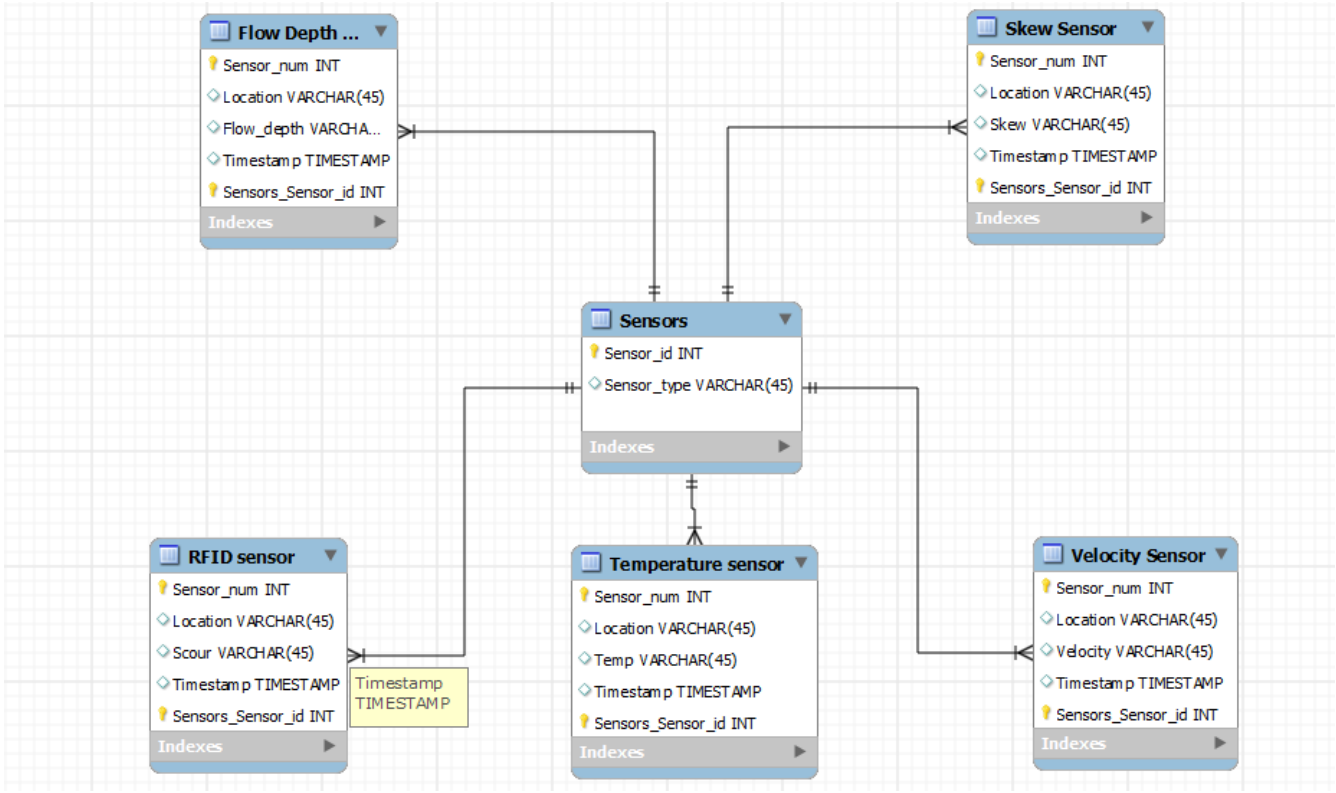

Figure3. The initial database schema. The schema is designed in a backward compatibility way so that additional sensors can be added without altering the existing schema.

The schema consists of a table called sensors which contain information regarding the sensor type and the sensor id. The sensor id maps it to the particular sensor table.

id 0: RFID sensor
id 1: Temperature sensor
id 2: Velocity sensor
id3: Flow depth sensor
id4: Skew sensor

Each sensor table consists of the number of the sensor(local to the sensor type), the data type and timestamp. There is a one to many mapping from the sensors table to the different sensors. The location row refers to which pier of the bridge it is in and is referred by the co-ordinates.

An initial prototype of the data sensing and collection procedure was performed with EZ430-RF2500 sensor. Figure 4 shows the data received from the AP which is saved using logging software which monitors the particular COM port while Figure 5 shows the data as it is inserted in the database.

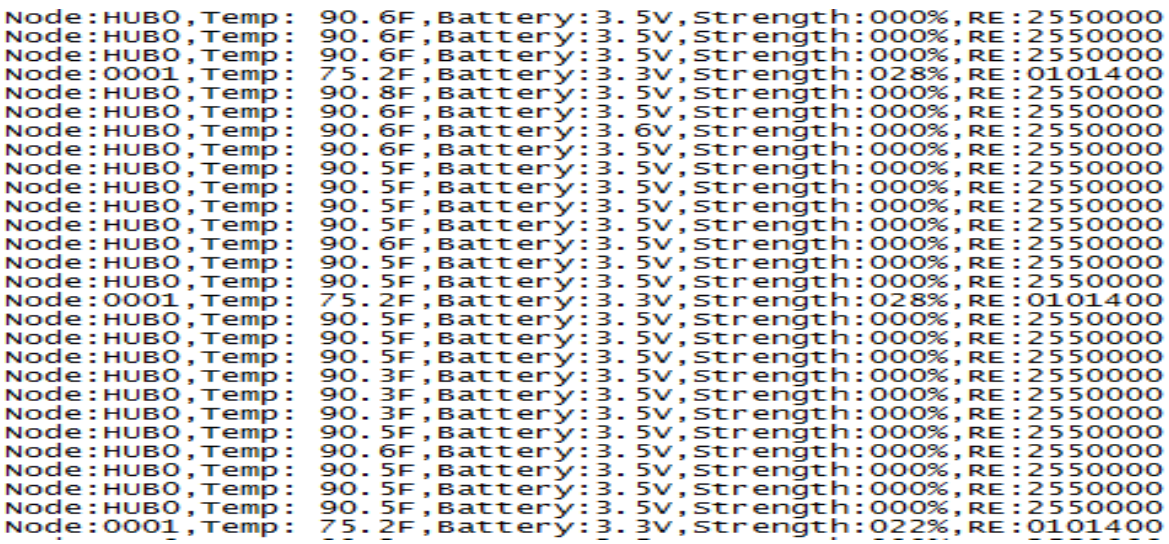

Figure4. Sample log output from data collection

```
postgres=# COPY sensor_data from 'C:\Users\Public\data1.txt' DELIMITERS ',' CSV;

COPY 6
postgres=# select * from sensor_data
postgres-# SELECT * FROM sensor_data
postgres-# \d sensor_monitor
Did not find any relation named "sensor_monitor".
postgres-# \d sensor_data
 Table "public.sensor_data"
  Column  | Type | Modifiers
----------+------+-----------
 node     | text |
 temp     | text |
 battery  | text |
 strength | text |
 re       | text |


postgres-# select * from sensor_data;
ERROR:  syntax error at or near "SELECT"
LINE 2: SELECT * FROM sensor_data
        ^
postgres=# SELECT * FROM sensor_data;
   node    |    temp     |   battery    |   strength    |      re
-----------+-------------+--------------+---------------+--------------
 Node:HUB0 | Temp: 79.8F | Battery:3.5V | Strength:000% | RE:2550000
 Node:HUB0 | Temp: 80.0F | Battery:3.5V | Strength:000% | RE:2550000
 Node:HUB0 | Temp: 80.2F | Battery:3.5V | Strength:000% | RE:2550000
 Node:HUB0 | Temp: 80.2F | Battery:3.5V | Strength:000% | RE:2550000
 Node:HUB0 | Temp: 80.2F | Battery:3.5V | Strength:000% | RE:2550000
 Node:HUB0 | Temp: 80.2F | Battery:3.5V | Strength:000% | RE:2550000
(6 rows)
```

Figure5. Data storage using PostgreSQL

2. Future Plans

For the next quarter the group plan propose to research deeply on the environmental effects on wireless communication with special consideration of unique environmental effects for the test sites proposed along with the enhancement of Task 2 (data gathering scheme).

Table 1. Planned work for the Second Quarter (November 2012 – January 2013)

Item No.	Task No.	Activity/Deliverable	Payable Milestone
21	2	Implement the basic functionality of the designed data collection scheme	evaluation of the efficiency of the tested data collection
22	2	Install wifi-n sensors to sensor apparatuses	Successful integration of the sensor data reporting
32	5.b	(Outreach) (Shared) Establish a project website hosted by the AIMS Center at ASU	Update the project website
33	5.b	(Outreach) (Shared) Write technical reports (e.g., quarterly reports, RITA Special Reports and Fact Sheets), conference articles, and/or peer-reviewed journal papers (manuscripts).	Quarterly reports, RITA Special Reports and Fact Sheets, at least one conference articles or per-reviewed journal paper (manuscript)
34	5.b	(Outreach) (Shared) Interact with Advisory Board and targeted focus groups of experts and potential users.	Insightful comments needed for improving and implementing MARSS.

3. Problems Encountered

The sensors types used in the analysis were selected according to available data. Also several assumptions had to be made because actual bridge sites in Arizona have not been selected yet, and data on the selected bridge sites in Iowa were not available on time. This study will be enhanced when data will start being produced by the sensors.

4. Funds Expended and Program Schedule

Table 1: Planned, Actual, and Cumulative Labor Hours

Item No.	Task No.	Labor Hours (Gupta)				Labor Hours (Varsamopoulos)				Labor Hours (Graduate Students)				
		Charged		Matched		Charged		Matched		Charged		Matched		
		Plan.	Act.	Plan.	Act.	Plan.	Act.	Plan.	Act.	Plan.	Act.	Plan.	Act.	Cumul.
3	2	0	0	-	21	49	49	0	0	26.5	26.5	0	0	102
4	1	0	0	-	21	49	49	0	0	26.5	26.5	0	0	102
13	5.b	0	0	-	3	11	11	0	0	0	0	0	0	11
15	5.b	0	0	-	4	11	11	0	0	0	0	0	0	11

Table 3: Planned, Actual, and Cumulative Expenditures

Item No.	Task No.	Labor Costs (wages + fringe + indirect + tuition)				Supplies (+ indirect)		Travel (+ indirect)		Equipment		
		Charged		Matched		Charged		Charged		Charged		
		Plan.	Act.	Plan.	Act.	Plan.	Act.	Plan.	Act.	Plan.	Act.	Cum.
3	2	$6,817	$6,817	$4,159	$3,839	0	0	0	0	0	0	$6,817
4	1	$6,817	$6,817	$6,817	$3,839	0	0	0	0	0	0	$6,817
13	5.b	$1,000	$998	$586	$537	0	0	0	0	0	0	$1,000
15	5.b	$1,272	$1,272	$800	$742	0	0	0	0	0	0	$1,272
Total		$15,906	$15,904	$12,362	$8,957	$0	$0	$0	$0	$0	$0	$15,906

5. Labor Hours

Table 4: Labor hours expended for all staff categories

Item No.	Task No.	Labor Hours (faculty)		Labor Hours (Graduate Students)	
		Charged	Matched	Charged	Matched
3	2	49	21	53	0
4	1	49	21	53	0
13	5.b	11	3	0	0
15	5.b	11	4	0	0