Online Monitoring Inside a Building Based on Energy Efficient Wireless Sensor Network

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Abstract -- **The online monitoring of industrial processes, weather forecasting, Glacier monitoring, Volcano monitoring, battlefield scenario or any other remote and difficult to reach areas has always been a challenge for the researchers. The web enablement of wireless sensor networks (WSNs) can be proved as the boon for the remote sensing & monitoring applications. In this paper, we propose an application level system design methodology for measurement of different physical quantities like temperature, light, humidity, acceleration and pressure inside an institute building (distance=100m) using Crossbow MICAz Wireless Sensor Nodes operating at 2.4 GHz frequency. The adapted system design methodology used in this paper, can be applied directly to any kind of practical WSN scenario with respective constraints & applications.**

Keywords: Wireless Sensor Networks (WSNs), MICAz motes, Online monitoring, Energy Efficiency.

I. INTRODUCTION

THE wireless sensor networks can be deployed for online monitoring of Voltage, Humidity, Temperature, Pressure, Light, and Acceleration inside a building as shown in Fig.1. The Crossbow MICAz motes are equipped with temperature, light, humidity, acceleration and pressure measurement sensors operating at 2.4 GHz frequency. These sensor nodes are supplied by a 3 volts battery supply (two 1.5 volts, 500mAh, pencil size cells, AA ratings).

The physical quantities under observation are given as:

A. *Light:* Light is an electromagnetic radiation which is visible to human eye. The light incident over a surface is measured by luminance.
Common Units: Lux (Lumen/m2), Candela (Lumen/Solid Angle)

B. *Voltage:* The electric potential difference between two points is called electric potential difference.
Common Units: Volts (V), Joule/Coulomb.

C. *Temperature:* It is a measure of Heat radiations.
Common Units: Fahrenheit (F), Degree Celsius (^{o}C), Kelvin (K)

D. Relative Humidity: The humidity is measured by three ways as Absolute, Relative and specific humidity. Relative humidity is the measure of amount of water vapor contents in the free air. The relative humidity is mostly used for whether fore -casting and most of the practical applications.
Common Units: The relative humidity is usually expressed by %.

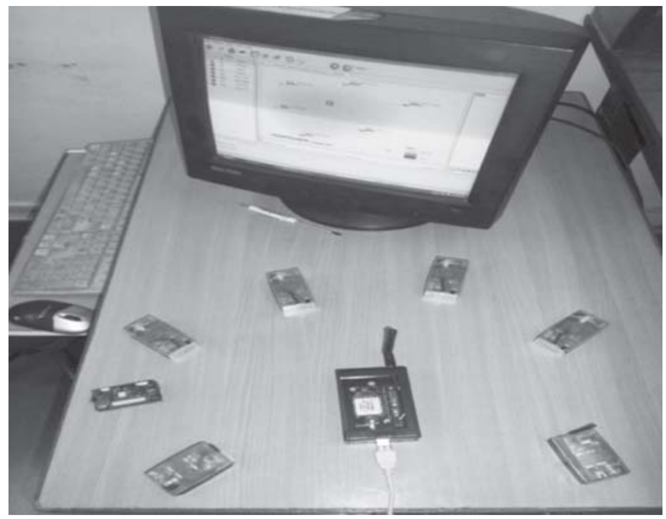

Figure 1. Crossbow Wireless Sensor Nodes (popularly known as MICAz motes) with Gateway and Local Monitoring Server deployed on a Table inside the lab.

E. *Acceleration:* The rate of change of velocity with respect to time of an object is called acceleration. Common Unit: meter/sec2.

F. *Pressure:* It is defined as the force per unit area in a particular direction.. Common Units: Pascal (P) =N/m2 , 1 Bar=10-5 P, or mille bar (mbar).

Figure 2 shows the basic block diagram for online monitoring of a building using six wireless sensor nodes deployed in each room. The objective of this paper is to measure online these physical quantities with smallest battery power consumption of the devices (sensor nodes). Here, we control the data rate (refreshing time), transmission distance and node deployment topology to minimize the battery power consumption. The paper is organized as follows: section II describes online monitoring,

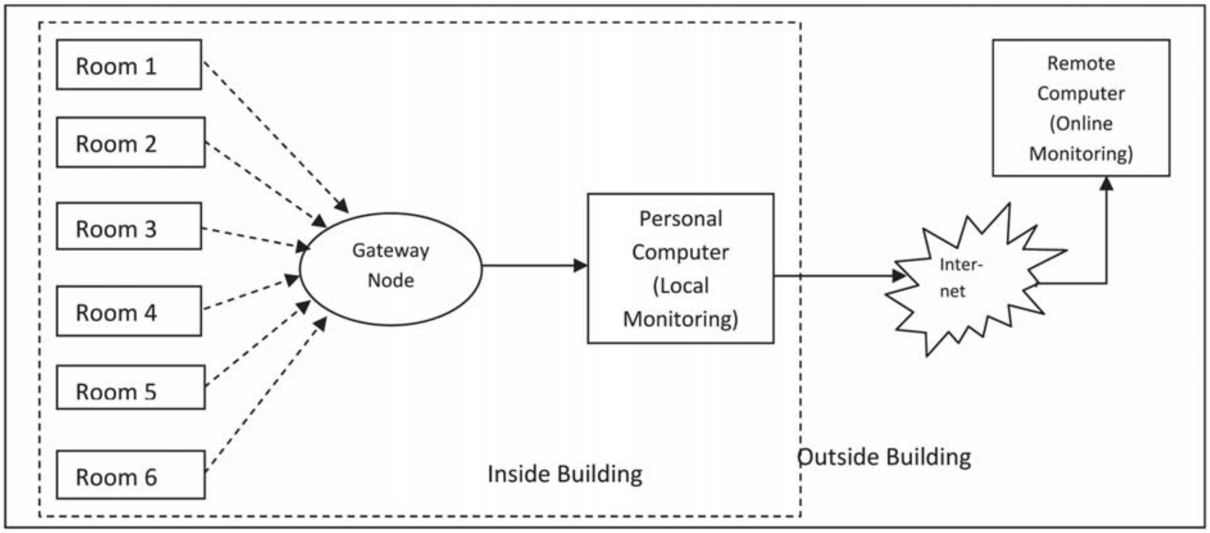

Figure 2. Block diagram for online monitoring of a building using six wireless sensor node deployed in each room.

section III gives energy efficiency of WSN, in section IV online monitoring setup details have been discussed, section V gives results, and finally, section VI gives conclusion.

II. RELATED WORK

Tao Zheng et al. [1] have shown an intelligent WSN deployment scheme for environmental and Air conditioning control inside a building. Qifen Dong et al. [2] have shown the framework for designing of Building monitoring system using WSNs. Tang Yu Liang [3] have used WSN for online monitoring of structural health parameters of a building.

III. ONLINE MONITORING SYSTEM CONFIGURATON

The server computer can be programmed to send the measured results (local data) in the tabular format, periodically via e-mail (online data) to other user who is sitting at a remote location worldwide. Also, the all the modern operating systems (Window 7, Linux, Apple Mac OS) have inbuilt feature of remote desktop sharing which enables the online monitoring of measured data. First we create a wireless sensor network scenario in the lab and deploy six sensors nodes.

Then we set wireless sensor network parameters and acquire the live data. Then we can do the analysis as follows:

A. Keeping the data rate (refreshing time in seconds) constant and changing the internodes distance (in meters).

B. Keeping the internodes distance constant and changing the refreshing time.

C. Keeping the sensor node ON time for long time periods and checking the residual battery voltage after each hour.

For example, we can take reading at a data rate of 1second at an internodes distance of 10 meter only. Then, we can take reading by keeping the data rate constant (i.e. 1s) and increasing the distance (d) by a step size of 10 m up to 100m, and then we observe that the battery consumption decreases sharply. Similarly, we can keep distance (d) as constant (say 10 m) and increase the refreshing time (i.e. data rate) of sensor nodes then the battery consumption increases sharply. The Table 1 shows various sensors and data acquisition boards practically used for designing as well as implementation of WSN nodes. Also, the sensor nodes energy depends on the ON time of the nodes. If we keep the sensor nodes in ON mode for long time periods continuously then sensor node battery energy decreases as shown by Table 4.

TABLE 1 - SENSORS AND DATA ACQUISITION BOARDS

Sensor/Data Acquisition Board	Motes Supported	Features
MTS-420 CA Sensor Board	IRIS, MICAz, MICA 2	Light, Temperature, Relative Humidity, 2-axis Accelerometer, barometric Pressure & GPS module
MDA-320 CA Data Acquisition Board	IRIS, MICAz, MICA 2	General purpose module for data interface of all type of sensors

IV. OPTIMIZING WIRELESS SENSOR NODE`S BATTERY LIFE TIME

For a sensor network with total non-rechargeable initial energy E_0, the expected network life E [Tl], measured as the average amount of time (in months) until the network is considered non-functional is given as [4]:

$$E\left(T_l\right) = \frac{E_0 - E(E_w)}{P_c + \lambda E\left(E_r\right)} \qquad \text{..... (1)}$$

Where, Pc is the constant continuous power consumption of all sensors in the network, E [E_w] is the expected wasted energy (i.e. the total unused energy in the network when it is dies), λ is the expected sensor reporting rate (packets arrival rate) defined as the number of data collections per unit time, E[Er] is the expected reporting energy consumed by all sensors in a randomly chosen data collection.We observe that the battery voltage consumption of the sensor node increases, if the data rate (refreshing time) is increased or internodes distance is increased. On the other hand, the battery voltage consumption of sensor node decreases, if the data rate is reduced or internodes distance is decreased.

V. ONLINE MONITORING HARDWARE SETUP

In our hardware approach, we take a Crossbow Wireless Sensor Network kit with six sensor nodes and one gateway node with two Personal computers (Local server & remote client). The crossbow WSN kit consists of a Gateway node (MIB 520 USB Gateway) and six wireless sensor nodes (MTS 310 MICAz Motes) and a software application “Mote View” installed on the personal computer system. Each sensor node has a unique identification (id) number and name in the network.

The Table 2 shows various sensor identification numbers as provided by WSN server administrator.

TABLE 2: SENSOR NODES IDS

Node id	Node Name
00	Gateway
01	Room 1
09	Room 2
7069	Room 3
7088	Room 4
7092	Room 5
7123	Room 6

The Table 3 shows Wireless Sensor Network (WSN) Parameters taken into account while performing the research experiment.

TABLE 3: NETWORK PARAMETERS

Parameter	Value
WSN Operating Mode	Acquire Live Data
Data Acquisition Type	Local Server
Gateway Interface Board	MIB 520 Gateway
Serial Port	COM1
Baud Rate	57,600
Database	Postgre SQL
Sensor Board	MTS 310 MICAz mote
Application Name	XMT 5310

Figure 3. WSN nodes deployed inside the building.

Figure 3 shows WSN nodes deployed inside a room which later distributed into six different rooms of the building. Figure 4 shows server computer screenshot (Mote view) for visualizing the topology of deployed sensors within the building. Figure 5 shows screenshot of Mote view 2.0 visualizing all sensor node ids with sensor network topology with live data.

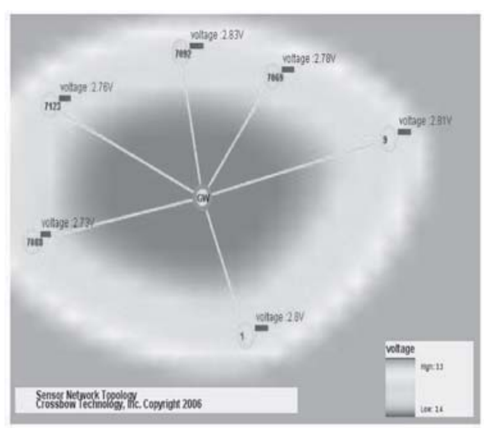

Figure 4. Server Computer screenshot (Mote view) for visualizing the topology of deployed sensors within the building.

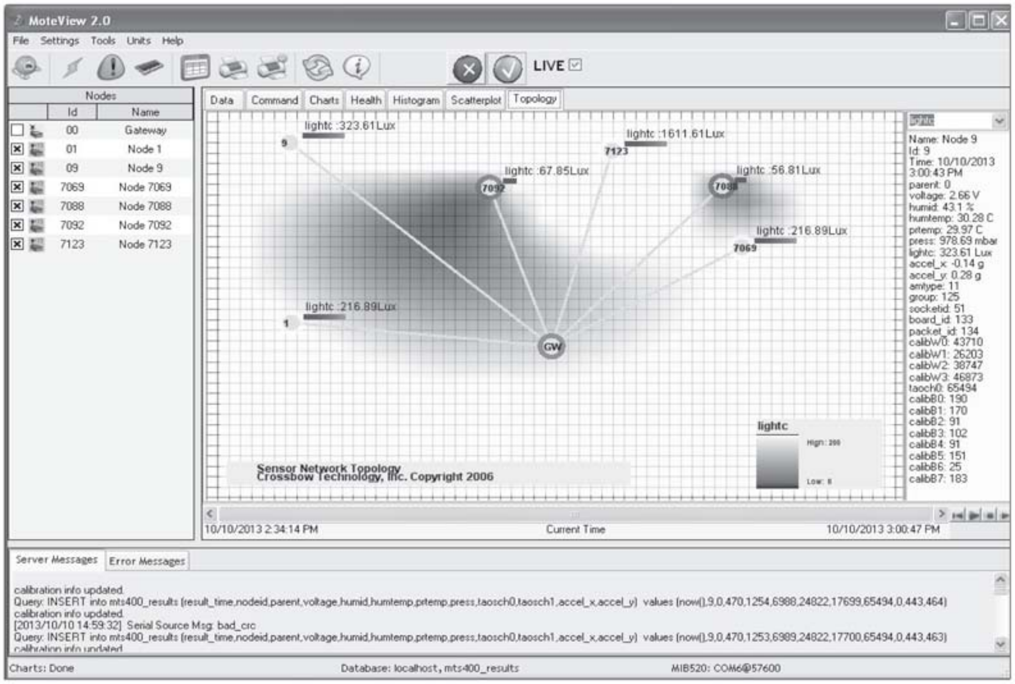

Figure 5. Screenshot of Mote view 2.0 visualizing all sensor node ids with sensor network topology with live data.

TABLE 4: ONLINE MONITORED DATA WITH SENSOR NODE IDS AND VALUES OF VOLTAGE, HUMIDITY, TEMP., PRESSURE, LIGHT AND ACCELERATION ON REMOTE COMPUTER

Time	Node Id	voltage [V]	humid [%]	humtemp [C]	prtemp [C]	press [mbar]	lightc [lux]	accel_x [g]	accel_y [g]
10-10-2013 14:02	1	2.7107	43.8	30.05	29.742	978.78	224.25	0.02	0
10-10-2013 14:02	9	2.776	44.6	30.24	29.715	977.08	224.25	0	0.02
10-10-2013 14:02	7092	2.6091	43.5	29.83	29.775	978.7	224.25	-0.04	-0.04
10-10-2013 14:02	7088	2.6589	45.3	29.38	29.331	977.21	216.89	-0.38	-0.36
10-10-2013 14:02	7123	2.6533	44.4	30	29.619	977.77	224.25	0	-0.02
10-10-2013 14:02	7069	2.676	44.1	30.12	29.76	978.82	216.89	-0.18	0.24
		Sum=16.084							
Time	Node Id	voltage [V]	humid [%]	humtemp [C]	prtemp [C]	press [mbar]	lightc [lux]	accel_x [g]	accel_y [g]
10-10-2013 15:05	1	2.6703	43.6	30.1	29.723	977	216.89	-0.02	0.02
10-10-2013 15:05	9	2.6703	42.4	30.19	29.843	978.76	323.61	-0.12	0.28
10-10-2013 15:05	7069	2.6533	42.7	30.12	29.811	976.78	250.01	-0.38	-0.34
10-10-2013 15:05	7088	2.5929	44.3	28.49	28.617	978.9	216.89	-0.04	-0.04
10-10-2013 15:05	7092	2.699	44	29.09	28.996	978.81	323.61	0.06	0
10-10-2013 15:05	7123	2.6477	43.2	29.93	29.73	977.65	224.25	-0.04	-0.02
		Sum=15.930							
Time	Node Id	voltage [V]	humid [%]	humtemp [C]	prtemp [C]	press [mbar]	lightc [lux]	accel_x [g]	accel_y [g]
10-10-2013 16:04	1	2.6646	44	30.18	29.812	977.03	216.89	-0.02	0.04
10-10-2013 16:04	9	2.6646	42.8	30.3	29.978	978.61	323.61	-0.14	0.28
10-10-2013 16:04	7092	2.6932	54.1	32.24	31.807	977.57	64.17	-0.02	0
10-10-2013 16:04	7088	2.5506	54	31.79	31.633	977.84	53.13	-0.06	-0.06
10-10-2013 16:04	7123	2.6477	52.8	33.03	32.61	976.04	1611.6	-0.08	-0.02
10-10-2013 16:04	7069	2.6477	43.4	30.02	29.857	976.4	216.89	-0.34	-0.34
		Sum=15.868							

VI. RESULTS

Table 4 shows the results obtained by the server computer system. In this Table, date and time of the measured data, Node id numbers, measured voltage (volts), relative humidity (%), humid-temp (^{o}C) pressure, light and acceleration are shown.

There are three sets of readings shown at a time interval of one hour each. The total residual battery voltage during first observation is 16.084 volts. After one hour it remains 15.930 volts and in next one hour it reduces to 15.868 volts. Thus we observe that, the network sensor node voltage consumption is a function of ON time also, apart from data rate and internodes distance as we have discussed in the earlier section III. Thus, sensor node energy consumption can be minimized by keeping the sensor node in to the ON mode for small time periods, choosing minimum internode distance (d) & large sampling nitoring of a building application.

Humidity (%), humid-temp (^oC), temp. (^oC), Pressure ctions) inside a building using energy efficient wireless sensor networks (WSN). The network sensor node voltage consumption is a function of its ON time. The network life time equation as given in eq.1 is valid here, as shown in result Table 4. Also, we observed that, the battery voltage consumption of the sensor node increases, if the data rate (refreshing time) Sampling intervals for remote monitoring of a building application scenario.

TABLE 5 - MICAz SENSOR NODE RESIDUAL VOLTAGE

Time (Hours)	Sensor Voltage (V)
1 Hour	16.084
2 Hour	15.93
3 Hour	15.868

Table 5 shows MICAz Sensor node residual battery voltage w.r.t time. Figure 6 shows graphical representation of the data as provided in Table 5.

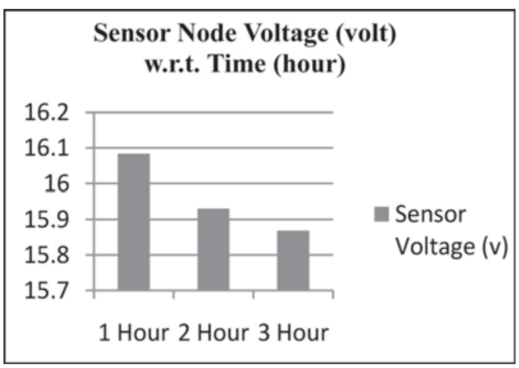

Figure 6. MICAz sensor node residual battery voltage.

VII. CONCLUSION

We provided an innovative idea for online monitoring of the different physical quantities (like voltage (volts), relative Humidity (%), humid-temp (degree Celcius), temp. (degree Celcius), Pressure (millibar), Light (lux), acceleration of the nodes in x-direction & y-directions) inside a building using energy efficient wireless sensor networks (WSN). The network sensor node voltage consumption is a function of its ON time. The network life time equation as given in eq.1 is valid here, as shown in result Table 4. Also, we observed that, the battery voltage consumption of the sensor node increases, if the data rate (refreshing time) is increased or internodes distance is increased. On the other hand, the battery voltage consumption of sensor node decreases, if the data rate is reduced or internodes distance is decreased. This online monitoring approach using WSN can be applied to any type of general practical WSN scenario applications like industrial process monitoring, remote healthcare monitoring etc. with respective design constraints & limitations.

VIII. ACKNOWLEDEMENT

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