An Approach to Design Habitat Monitoring System using Sensor Networks

Ramanjyot Kaur, Meenakshi Sharma

Abstract- **The emerging networking technologies have revolutionized the ways individuals and organizations exchange information and coordinate their activities. Another revolution in wireless technologies shall be witnessed; this will involve observation and control of the physical world. The availability of micro-sensors and low-power wireless communications will enable the deployment of densely distributed sensor/actuator networks for a wide range of biological, earth and environmental monitoring applications in marine, soil and atmospheric contexts. This paper provides an in-depth study of applying wireless sensor networks to real-world habitat monitoring. It also discusses a set of system design requirements that cover the hardware design of the nodes, the design of the sensor network, the capabilities for remote data access and management. Further this paper discusses the system architecture and factors to be considered to design a Habitat Monitoring System.**

Keywords- **Wireless Sensor Networks, Base Stations, Patch Gateways, Sensor Nodes.**

I. INTRODUCTION

Smart environments represent the next evolutionary development step in building, utilities, industrial, home, shipboard, and transportation systems automation. Like any sentient organism, the smart environment relies first and foremost on sensory data from the real world. Sensory data comes from multiple sensors of different modalities in distributed locations. The smart environment needs information about its surroundings as well as about its internal workings [9].

Researchers use the semiconductor manufacturing techniques to build exceptionally small mechanical structures that sense fields and forces in the physical world. These inexpensive, low-power communication devices can be deployed into a physical space, providing dense sensing close to physical phenomena. These individual devices are wireless sensors.

Manuscript received May 26, 2011.

Ramanjyot Kaur is Lecturer in the Department of Computer Science and Engineering in SBBSIET, Jalandhar, India.
(e-mail:er.ramanjyot@gmail.com).
Meenakshi Sharma is Lecturer in the Department of Computer Science and Engineering in SBBSIET, Jalandhar, India.
(e-mail:meenakshis84@gmail.com).

The concept of wireless sensor networks is based on a simple equation [6]:

Sensing + CPU + Radio = Thousands of potential applications

The field of wireless sensor networks combines sensing, computation, and communication into a single small device. The power of wireless sensor networks lies in the ability to deploy large numbers of sensor nodes that assemble and configure themselves. The use of sensors ranges from real-time tracking to monitor the environmental conditions, the ubiquitous computing environments and to monitor the health of structures or equipments. The most straightforward application of wireless sensor network technology is to monitor remote environments for data trends. Such an application that uses wireless sensor networks is the Habitat Monitoring.

II. HABITAT MONITORING

Habitat monitoring delivers ecologists data on localized environmental conditions at the scale of individual organisms to help settle large-scale land-use issues affecting animals, plants and people [11]. Habitat monitoring represents a class of sensor network applications with enormous potential benefits.

The environment is instrumented with numerous networked miniature sensors which enable long-term data collection. A sensor's intimate connection with its immediate physical environment allows each sensor to provide localized measurements and detailed information. The integration of local processing and storage allows sensor nodes to perform complex filtering and triggering functions. The ability to communicate not only allows sensor data and control information to be communicated across the network of nodes, but nodes to cooperate in performing more complex tasks such as statistical sampling, data aggregation, system health and status monitoring [4, 5].

Wireless sensor networks are an important technology for large-scale monitoring, providing sensor measurements at high temporal and spatial resolution [2]. The simplest application is sample and send where measurements are relayed to a base station, but WSNs can also perform in-network processing operations such as aggregation, event detection, or actuation.

A. System Architectures

The system architecture for habitat monitoring is a tiered architecture. Using a multi-tiered network is advantageous as each layer involves monitoring several areas of interest. The architecture needs to address the possibility of disconnection at every level. The architecture of a habitat monitoring system is as shown in figure 1.

The lowest level consists of the **sensor nodes** that perform general purpose computing and networking to application-specific sensing. These are small, battery powered devices placed in areas of interest. A sensor node is built around a low-power microcontroller running at a few MIPS with a few kilobytes of RAM. The sensing elements take the form of a probe connected to a general-purpose signal acquisition board or are integrated into the packaging with microcontroller and wireless transmitter.

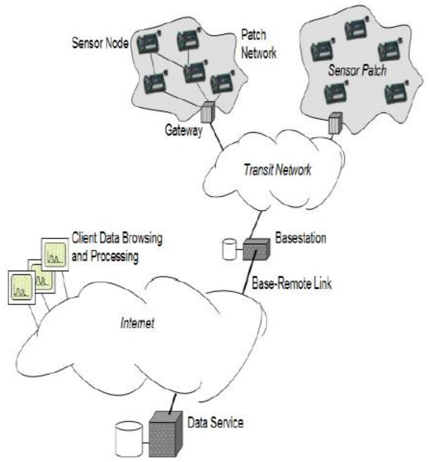

Figure 1: Architectural design for Habitat Monitoring

Individual sensor nodes communicate and coordinate with one another in the same geographic region. This coordination makes up the **sensor patch**. The sensor patches are typically small in size (tens of meters in diameter). Sensor nodes are deployed in dense sensor patches that are widely separated. Each patch encompasses a particular geographic region of interest.

The sensor nodes transmit their data through the sensor patch to the sensor network **gateway.** By relying on the gateway, sensor nodes may extend their lifetime through extremely low duty cycles. The gateway is responsible for transmitting sensor data from the sensor patch through a local transit network to the remote base station that provides WAN connectivity and data logging.

The **base station** connects to database to provide data to remote end-users. The base station includes WAN connectivity and persistent data storage for the collection of sensor patches. Many habitats of interest are quite distance apart so the WAN connection will be wireless. The base station will typically take a form of a WAN connection, interfaces to the sensor network gateways, a persistent storage component and a general-purpose computer. The set of components needs to be reliable, enclosed in environmentally protected housing, and provided with adequate power.

III. DESIGN REQUIREMENTS of HABITAT MONITORING SYSTEM

The architecture of the habitat monitoring system describes the components of the network. The design requirements of sensor node include hardware and software design. The sensors are enclosed in protective packaging and transmit their readings to a gateway node. Two implementations are analysed for the gateway and transit network by examining power consumption and robustness.

A. Sensor Network Node

The Motes are used as the sensor nodes. The latest member of the mote family is called Mica [7]. Mica uses a single channel, 916MHz radio from RF Monolithic to provide a bi-directional communication at 40kbps, an Atmel Atmega 103 microcontroller running at 4MHz, and considerable amount of non-volatile storage (512 KB). A pair of conventional AA batteries and a DC boost converter provide a stable voltage source, though other renewable energy sources can be easily used. Small size (approximately 2.0 x 1.5 x 0.5 inches) and wireless communication capabilities allow us to deploy the motes in remote locations without interfering with the existing habitat. Figure 2 shows a wireless sensor network node.

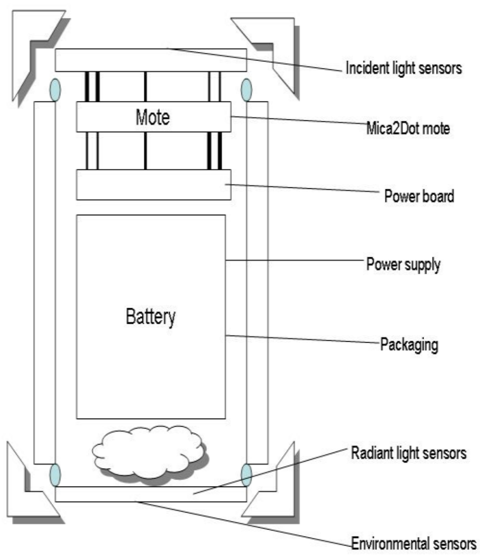

Figure 2: Wireless Sensor Network Node

Mica Design combines an Atmega103 processor with a RFM TR1000 radio, external storage and communication acceleration. The form factor (1.25´ 2.25 inch) is a similar size as a pair of AA batteries, although, we have compressed a variant of the design to about the size of a 2.5-centimeter coin .5 cm thick.

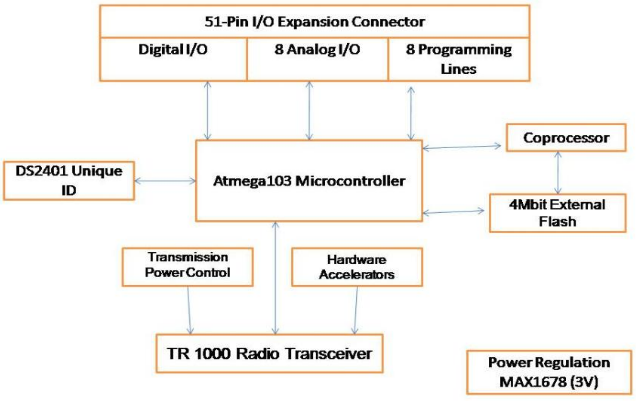

Figure 3: Block diagram of Mica architecture.

Mica architecture, as shown in Figure 3 consists of five major modules:

- Processing
- Radio frequency (RF) communication
- Power management
- I/O expansion
- Secondary storage

The main microcontroller is Atmel ATMEGA103L or ATMEGA128 running at 4 MHz and delivering about four million instructions per second (MIPS) [1]. This 8-bit microcontroller has: 128-Kbyte flash program memory, 4-Kbyte static RAM, internal 8-channel 10-bit analog-to-digital converter, three hardware timers, 48 general-purpose I/O lines, one external universal asynchronous receiver transmitter (UART), and one serial peripheral interface (SPI) port. To provide each node with a unique identification, a Maxim DS2401 silicon serial number—a low-cost ROM device with a minimal electronic interface and no power requirements [3].

B. Sensor Board

Sensor Board is designed to provide the data of the monitoring. For habitat monitoring the MicaWeather Board are used. The MicaWeather Board integrates the required sensors into a single small package. The board operates at low duty-cycles and low sampling rates so that power may be conserved. The MicaWeather Board Revision 1.0 includes temperature, photoresistor (light), barometric pressure, humidity and passive infrared (occupancy) sensors. The sensor is sensitive to 0.1 mbar of pressure and has an absolute pressure range from 300 to 1100 mbar.

C. Patch Gateways

The gateway nodes directly affect the implementation of the underlying network. These can be implemented by two designs in parallel:

- An 802.11b single hop network with an embedded Linux system
- A single hop mote-to-mote network.

With the patch gateways the sensors can stretch up to thousands of meters. To act as the sensor patch gateway CerfCube [8] can be used. CerfCube is a small, StrongArm-based embedded system. Functionality of CerfCubes is easy as they run on an embedded version of the Linux operating system. The patch gateway consumes about 2.5W power. For power requirements, a rechargeable battery with capacity between 50 and 100Watt-hours is attached to it.

D. Base-station installation

To provide remote access to the habitat monitoring network, the collection of sensor network patches is connected to the Internet. The base station connects the network to the wide-area network. This can be implemented through two-way satellite connection. The satellite system is connected to a laptop which coordinates the sensor patches and provides a relational database services.

E. Database Management System

The base station can use Postgres SQL database. The database stores timestamped readings from the sensors, health status of individual sensors, connectivity and routing information and the metadata which stores sensor locations. This information is specified by the database schema which is used to record both raw and calibrated sensor.

F. User Interfaces

User interfaces are implemented on top of the sensor network database. These systems provide a standard for analyzing geographical data. The user interfaces in habitat monitoring systems can be implemented through Matlab. There can also be a number of web based interfaces that include a java applet. With the user interfaces the users can interact with the sensors and take notes and tag sensors with location, time and batteries.

IV. Factors Affecting Design of Habitat Monitoring System

There are many factors which have to be considered while designing a sensor network for Habitat Monitoring. The most relevant are presented below:

A. Power management

This is essential for long-term operation, especially when it is needed to monitoring remote and hostile environments. Harvesting schemes, cross-layer protocols and new power storage devices are presented as possible solutions to increase the sensors lifetime.

B. Scalability

A wireless sensor network can accommodate thousands nodes. Current real WSN for environment proposes the use of tens to hundreds nodes. So it is necessary to prove that the available theoretical solutions are suited to large real WSN.

C. Remote management

Systems installed on isolated locations cannot be visited regularly, so a remote access standard protocol is necessary to operate, to manage, to reprogramming and to configure the WSN, regardless of manufacturer.

D. Usability

The WSNs are to be deployed by users who buy them off the shelf. The WSN need to become easier to install, maintain and understand. It is necessary to propose new plug and play mechanisms and to develop more software modules with more user-friendly interface.

E. Standardization

The IEEE 802.15.4[10] represents a millstone in standardization efforts. Although, the compatibility between off-the-shelf modules is very low. It is important to specify standard interfaces to allow interoperability between different modules vendors in order to reduce the costs and to increase the available options.

F. Size

Reducing the size is essential for many applications. Battery size and radio power requirements play an important role in size reduction. The production of platforms compatible with the smart dust can be determinant in WSN environmental monitoring.

G. Price

Available sensor platforms on the market are expensive which precludes its use widely. Produce cheaper and disposable sensor platforms it is also a challenge.

V. IMPLEMENTATION ISSUES

Wildlife researchers and biological scientists study living organisms and their relationship with their habitat. They study animals and wildlife—their origin, behavior, diseases, and life processes. There is a study of the relationships among organisms and their environments, examining the effects of population size, pollutants, rainfall, temperature, and altitude. This paper proposes an approach which can be used to monitor the activities of birds in the Hari-ke-Pattan, National Wetland & Wildlife Sanctuary in Punjab. This place witnesses the influx of nearly 350 species of exotic migratory birds from as far as Siberia during the freezing winters. By implementing a Habitat Monitoring System at Hari-ke-Pattan track of each bird's activity can be kept. This can include the day and night activities of birds. Results gathered from these can be used to determine during which part of the day the birds are most active. To implement such a system sensors need to be attached on the bodies of the birds.

VI. CONCLUSIONS

Habitat monitoring represents an important class of sensor network applications. The habitat monitoring architecture meets the requirements of the life scientists and streamed sensor readings from various locations. Because end users are only interested in the sensor data, the sensor network system must deliver the data of interest. The low-level energy constraints of the sensor nodes combined with the data delivery requirements leave a clearly defined energy budget for all other services. Tight energy bounds and the need for predictable operation guide the development of application architecture and services.

REFERENCES

[1] Atmel Corporation, Atmega103 (L) Datasheet (2001) Atmel Corporation: http://www.atmel.com/atmel/acrobat/doc0945.pdf.

[2] Corke P., Wark T., Jurdak R., Hu W., Valencia P., and Moore D. (2010) "Environmental Wireless Sensor Networks", Proceedings of IEEE, Vol. 98, pp. 1903-1917.

[3] Dallas Semiconductor, DS2401 Silicon Serial Number: http://pdfserv.maximic.com/arpdf/DS2401.pdf.

[4] Estrin D., Girod L., Pottie G., and Srivastava M. (2001) "Instrumenting the world with Wireless Sensor Networks", International Conference on Acoustics, Speech, and Signal Processing.

[5] Estrin D., Govindan R., Heidemann J.S., and Kumar S. (1999) "Next century challenges: Scalable coordination in sensor networks", Mobile Computing and Networking, pp. 263–270.

[6] Hill J.L. (2003) "System Architecture for Wireless Sensor Networks", University of California, Berkeley, Spring.

[7] Hill J. and Culler D. (2002) "Mica: a wireless platform for deeply embedded networks", IEEE Micro, Vol. 22 No. 6,pp.12–24.

[8] Intrinsyc Corporation. Cerfcube embedded StrongARM system. http://www.intrinsyc.com/products/cerfcube/.

[9]Lewis F. L. (2004) "Wireless Sensor Networks", Smart Environments: Technologies, Protocols, and Applications.

[10] Oliveira L.M.L, Rodrigues J.J.P.C (2011) "Wireless Sensor Networks: a Survey on Environmental Monitoring", Journal of Communications Vol. 6, No. 2, pp. 143-151.

[11] Szewczyk R., Osterweil E., Polastre J., Hamilton M., Mainwaring A. and Estrin D. (2004) "Habitat Monitoring with sensor networks", Vol. 47, No. 6 Communications of the ACM.