Using Wireless Sensor Network for Habitat Monitoring: Requirements & Challenges

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Abstract: ***Wireless Sensor Network is widely used by ecologists to study surroundings of organisms.. Wireless sensor network provides accurate results and minimize human interference in habitat. Human interference can seriously affect species, plants and its behavior pattern. We discussed how sensor network can benefit society by providing Information about habitat with low power sensor nodes. For making error free system to monitor the area of interest in-depth study of the system requirements and hurdles is needed.***

Keywords: Data logging, Packets, Network patch, Transit Network., RFID technology.

1. Introduction

We are growing towards making smart world by introducing automation in various fields of life that vary from day to day needs to complex applications. Due to dynamic applications of Wireless Sensor Network (WSN), it becomes useful catalyst to shift society from manual work to automation. WSN is a group of sensors that have ability to sense the environment, to communicate with neighbor nodes or sensors and to perform basic computation on data signals. In real-world environments, research societies started applying WSN to different applications. In sensor network research applications, Habitat monitoring is field with extensive budding benefits.

2. Habitat Monitoring

2.1 What is Habitat Monitoring?

Habitat is surrounding of plant, animal or any other organism. In Habitat monitoring, data is gathered from habitat for number of applications e.g. studying species behavior, collecting information about breeding season of birds or animals, searching presence of extinct or rare species of birds or animals etc.

2.2 Why to use Sensor Network for Habitat Monitoring

As data gathering, generating behavioral patterns are major work in habitat monitoring. Manual work is error prone. Habitat monitoring in remote islands is very common in research work. It is not feasible that researcher will present all the time at area of interest to record each and every event and behavior. In spite of that, sensors are deployed in area of interest to gather the information. Species get disturbed by human presence, sometimes it can result in serious destruction like species can leave the place, behavior pattern can be changed, breeding season can be disturbed etc. Even for the plants, frequent human visit to area can introduce exotic elements that can disturb their growth. It can also affect drainage patterns.

Anderson [2] submitted report, in which it was mentioned that visit of 15 minutes to cormorant bird colony can result death of up to 20% eggs in breeding year. A. Mainwaring et al. also mentioned in [1] that researchers discovered that if Storm Petrel bird disturbed in first 2 weeks of evolution or incubation, they can destroy their burrows. When traditionally collecting data from area of interest, there is requirement of large instruments to log and compute the data to fetch information. These kinds of instruments can cause shadow effect which means alteration in behavioral pattern of species due to interruption in organism's surroundings [3]. Not only human presence but large instruments also affect the habitat.

Sensor network deployment for habitat monitoring is more economical decision for carrying research studies for long time. For example, sensors can be deployed before breeding season of organism to collect information for next few months.

3. Requirements for Habitat monitoring

3.1 Internet Connectivity

To support remote interactions Internet connectivity is required for area of interest. "Satellite Internet" is used for such place as cabling and other solutions are not feasible.

3.2 Resources

Sensors are deployed in area of interest. Positioning of sensor node, number of nodes in particular area, repetition of node for backup is to be decided by researcher that can vary according to the application. More number of nodes can increase complexity, data redundancy and less number of nodes can result in loss of useful information. For Internet connection compatible devices are needed to support Satellite Internet. Devices required for data logging, sampling and other data computation to extract the required information.

3.3 Power Supply

Sensor nodes are equipped with low power that can be rechargeable or non-rechargeable. Solar nodes are example of rechargeable sensor nodes. These solar sensor nodes are not meant for applications like undersea habitat monitoring. Enough power supply required to maintain sensor network lifetime till completion of the project. For example, In Skomer Island project [5] network was deployed for 7 months with battery powered sensors.

3.4 Database Management

Habitat monitoring is all about collecting right information at right time in right amount. Collected data signals need to be logged without interruption. Compatible devices needed to record data signal, tools required to analyze the collected signals e.g. graph generation from results. Database center can be at site near to area of interest or there is possibility after specific duration replica of data is to be sent on another site for backup or some other purpose.

3.5 Manpower

Information is to be extracted from sensed signals to compute solution of the problem. Data analyst, Scientist and expert of the field work together for this work. Engineers work to provide the technical support for devices, tools etc. Manpower also needed to deploy sensors and other devices at right time.

4. System Architecture

System for habitat monitoring is organized in multi-level architecture to provide support at each level. Figure 1 shows the devices involved at each level of architecture.

4.1 Sensor Network Patch

Sensor network patch consists of sensor nodes that sense the surroundings for temperature, light, air or any other event depending on application. Multiple patches are installed in area of interest to minimize the complexity of the system. As the sensor nodes are low power devices, number of sensors, deployment strategy, number of nodes in sleep mode at particular time etc. is to be determined by researchers for successful completion of project. To maintain network lifetime of nodes, behavior of nodes can be organized for change of state like active, idle, sleep. Further data can be aggregated to reduce the amount of signals to be sent. Data aggregation also reduces data redundancy.

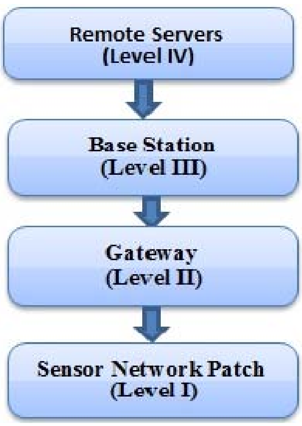

Figure 1: Hierarchy of Devices

4.2 Gateway

Gateway works as intermediate between sensor network patch and base station. Gateway is provided to each network patch of the system. Hardware specification of gateway is much higher than the sensor node such as processing power and storage due to this it can be used for computation of data signals. In figure 2, it is shown that through transit network gateway can communicate with base station.

4.3 Base Station

Base station is data center near to area of interest. Data packets are received from gateways. End user fetches data from base station. Base station is connected to Internet; type of connectivity depends on location of area of interest. In most of the Internet connectivity is provided by Satellite communication channel. Replicas of data can be sent to remote server and bas station can also receive required data from remote servers.

4.4 Remote Servers

Remote Servers can be located at any region or multiple regions. Backup of data is maintained at these servers by collecting data replicas of base station. In case of data loss for some technical or another reason at base station retrieval is possible from remote server.

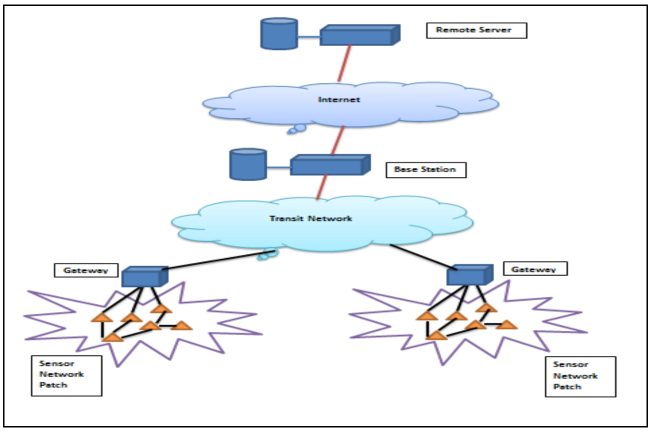

Figure 2: Multi-Tier Architecture for Habitat Monitoring

5. Challenges for Habitat Monitoring

5.1 Possibility of Interruption

At each level (sensor network patch, gateway and base station) possibility of interruption exists, it can be due to technical or environmental issues. For technical issues, the device needs to be rectified or replaced immediately for minimizing the data loss. At each level secondary memory is provided, data is cached at each level. In case of interruption previous state of the system can be obtained. Secondary storage is limited, timely backup of cached data is mandatory. Researchers need to be prepared with backup plans to handle these situations.

5.2 Network Lifetime

Maintaining the appropriate network lifetime for particular application is the major concern with the sensor network. As sensor nodes are low power devices, in most of the situations of habitat monitoring it is non-rechargeable. Improving network lifetime of sensor network is ongoing research topic. It is not feasible to replace a dead node with the new one in deployed network. Researchers proposed many routing algorithms to improve network lifetime. LEACH [4], protocol introduces the concept of data aggregation with cluster formation. SEP [6] routing protocol was devised for heterogeneous nodes. Placement of sensor nodes, routing algorithms, how to manage state of nodes (active, sleep, idle) etc. factors affect network lifetime and varies according to the project type and duration. Researcher need to determine prerequisites of projects accurately.

5.3 Manageability

As sensor nodes are grouped in different network patches. In network there can be large number of nodes, collecting data logs from all the nodes is necessary. Database management system should be capable of differentiating data logs from different gateways. Availability of technical team to support the system for maintaining the continuity in the process is must. These issues are to be handled wisely to protect system from information loss. Input to Data sampling, graphs and other analyzing techniques should be accurate and non-redundant. As area of interest cannot be visited on daily basis provision for management from remote site is to be provided by using standard protocols.

5.4 Choice of Resources

For deploying system for habitat monitoring, different type of devices, mechanisms are available. Before choosing standards for the project, application area needs to be studied carefully. Following are some examples for criteria to choose a device for the project.

- Type of sensor node according to hardware specification
- Type sensor node according to sensing ability (temperature, light etc.)
- Type of gateway according to hardware specification
- Tools for data analysis
- Communication protocol, it can be same or multiple for each patch of network
- Percentage of data aggregation, etc.

5.5 Mapping with User Queries

System for habitat monitoring is to be built for collecting information. Data is gathered in form of values of some event or readings like temperature. For each application it is necessary to map the data values to user queries. End-user is not concerned with the raw data. For example, user wants to know which month is breeding season for Cranes. Sensors have the data in yes or no for particular time period. Database Administrator has to ensure that these reading are mapped with user queries by understanding the end-user's need.

5.6 Accuracy of the Results

Result of the habitat monitoring project can be key points for further research and other strategies. System has to ensure that retrieved information is correct. Accuracy of the result leads to further growth of the project. In initial phase of project, readings are checked for correctness by comparing with manual values.

5.7 System Testing

In sensor network, mechanisms are tested on simulators for analyzing the working, checking for other parameters like energy consumption by nodes, data sampling rate etc. But in real life environment there are many hidden issues with deployment of network and working. In that case, system testing is a brain storming task.

6. Previous Projects for Habitat Monitoring

6.1 Great Duck Island

In 2002 [1], researcher deployed sensor network on Great Duck Island, Maine, United States for observing the behavior of small seabird storm petrel. These birds come to land only in breeding season. UCB Mica mote deployed in area of interest contains barometer, temperature, photo resistor and humidity sensor. Inside 1 burrow 32 motes are deployed. Sensor network patch forwards the data signals to CerfCube gateway. Further signals are transmitted to base station. Remote server collects replicate files after 15 minutes, with Postgress database. Research was carried out to answer the following questions:

1. What changes occur in burrow's environment in duration April to October that is breeding season of the bird?
2. What is the optimal climate requirement for breeding season in burrow's surrounding?
3. What are the changes in environment by large number of petrels?

6.2 Skomer Island

Skomer Island [5] is in south western Wales, home of Manx Shearwater seabird. In this project, ecosystem of the island is monitored by observing Manx Shearwater bird. In 2007, sensor network was deployed for monitoring bird's activity. Temperature and humidity reading were collected inside and outside of the bird's burrow. In 2008 and 2009, errors were fixed to increase reliability of the system. Around 20 sensor nodes were deployed in burrow that can sense temperature, humidity, movement and weight to monitor following parameters:

- Identification of individual bird by using RFID tag.
- Identification of bird's presence in burrow.
- Weight of tagged birds to inspect food measured at the time of entering and leaving the burrow.

- Collecting reading for temperature and humidity of burrows and its surroundings.

6.3 Sonoma Redwood Tree Monitoring

This project was carried out in 2005 on Sonoma County, California for monitoring surroundings of redwood tree. In [7], a case study is represented in which readings are measured for 44 days of the surroundings of redwood tree. Deployed sensor nodes in the project can sense humidity, temperature and solar radiations. Readings were sent to base station after every 5 minutes.

7. Conclusions

Technology can be healthy when it works for service of society. Wireless sensor network can be solution to many complex problems. By monitoring habitat, ecologists can find tremendous hidden aspects of environment that can be beneficial for the growth of society. Wireless sensor network made the monitoring process more accurate and feasible. To build an optimal habitat monitoring system, its requirements need to be identified properly before devising the system.

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