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WILD ANIMAL MONITORING USING SENSOR NETWORKS

[1]Mrs. Sharmila K., [2]Ms. Sivasankari A.

[*1]M.Phil Research Scholar, Department of Computer Science DKM College for Women (Autonomous), Vellore, TamilNadu, India.

[*2] Assisant Professor, Department of Computer Science DKM College for Women (Autonomous), Vellore, TamilNadu, India.

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Abstract:

Monitoring wild animals, especially those that are becoming endangered (for example, lynxes and wolves) is important for biology researchers. Solutions for the monitoring already exist; however, they all have drawbacks, such as limited range or lifetime, sensing modality, reporting delays, unreliability of operation. In this work we describe our experiences in designing an improved animal monitoring sensor system and low-level software for sensor node control and communication. The target animals for this particular research are wild lynxes or canines; however it can be extended to other animal species.The LynxNet system is based on tracking collars, built around TMote Mini sensor nodes, sensors, GPS and 433MHz radio, and stationary base stations, placed at the locations that are frequented by the animals. We present preliminary field results of our radio communication range tests.

Keywords — **Monitoring wild animals, low-level software, LynxNet system, sensors, GPS and 433MHz radio.**

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I. INTRODUCTION

Monitoring the wild animal behaviour and whereabouts is a challenge because the animals avoid human beings. The commercially available solutions provide monitoring devices that have limited sensing capabilities, communications requiring cellular coverage or have long data report delays. We propose LynxNet system with extended sensing modality and multi hop delay tolerant communication approach. Our collaborators - biology scientists aim to track Eurasian lynx (Lynx lynx) migration in Latvian forests. Our challenge is to achieve long-term operation with a single set of batteries in the forest environment with no energy harvesting. Our contribution includes design of simple yet persistent animal monitoring architecture for resource-constrained mobile sensor systems, development of efficient PHY and MAC layer radio communication protocols and analysis of radio communication range in field tests.

A number of animal monitoring sensor systems have been developed in the past few years. The most common to our hardware is ZebraNet animal tracking collar. However, not enough solar energy is available for harvesting, and lynx is smaller animal than a zebra requiring a more compact and lightweight solution. Commercial products for GPS-based tracking are available, such as Tellus collars. In comparison, LynxNet employs a wide modality of sensors in addition to GPS location, which also provide data about the surrounding environment and help to detect patterns of activities of the animal.

II. GENERAL COMPONENTS

2.1 Serial and UART

The Universal Asynchronous Receiver/Transmitter (UART) controller is the key component of the serial communications subsystem of a computer. The UART takes bytes of data and transmits the individual bits in a sequential fashion. At the destination, a second UART re-assembles the bits into complete bytes.
Serial transmission is commonly used with modems and for non-networked communication between computers, terminals and other devices.

There are two primary forms of serial transmission: Synchronous and Asynchronous. Depending on the modes that are supported by the hardware, the name of the communication sub-system will usually include A if it supports Asynchronous communications, and a S if it supports Synchronous communications. Both forms are described below.
Some common acronyms are:

- UART Universal Asynchronous Receiver/Transmitter
- USART Universal Synchronous-Asynchronous Receiver/Transmitter

2.2 MAX232

The MAX232 is an integrated circuit that converts signals from an RS-232 serial port to signals suitable for use in TTL compatible digital logic circuits. The MAX232 is a dual driver/receiver and typically converts the RX, TX, CTS and RTS signals.

The drivers provide RS-232 voltage level outputs (approx. ± 7.5 V) from a single + 5 V supply via on-chip charge pumps and external capacitors. This makes it useful for implementing RS-232 in devices that otherwise do not need any voltages outside the 0 V to + 5 V range, as power supply design does not need to be made more complicated just for driving the RS-232 in this case.

The receivers reduce RS-232 inputs (which may be as high as ± 25 V), to standard 5 V TTL levels. These receivers have a typical threshold of 1.3 V, and a typical hysteresis of 0.5 V.

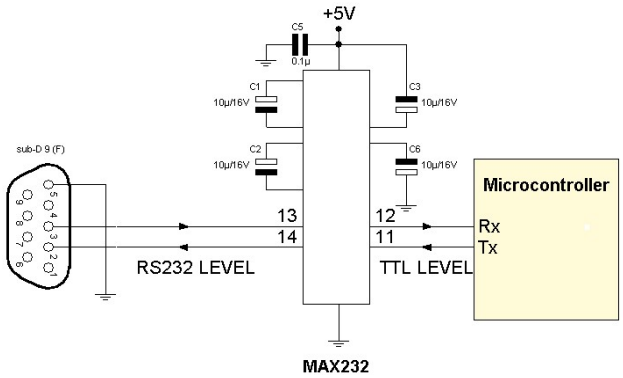

Figure 2.1 Max 232 Connecting Diagram

2.3 Relay

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits, repeating the signal coming in from one circuit and re-transmitting it to another. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

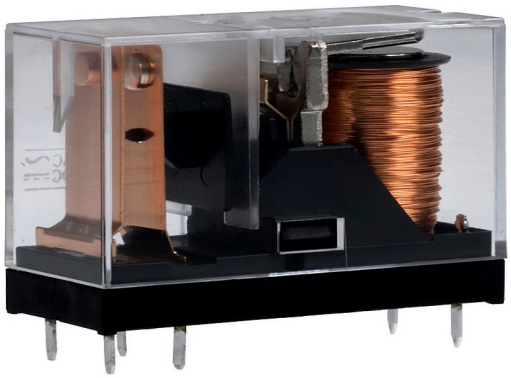

Figure 2.2: Relay Connection Diagram

2.4 Pole & Throw

Since relays are switches, the terminology applied to switches is also applied to relays. A relay will switch one or more poles, each of whose contacts can be thrown by energizing the coil in one of three ways:

- Normally-open (NO) contacts connect the circuit when the relay is activated; the circuit is disconnected when the relay is inactive. It is also called a Form A contact or "make" contact.
- Normally-closed (NC) contacts disconnect the circuit when the relay is activated; the circuit is connected when the relay is inactive. It is also called a Form B contact or "break" contact.
- Change-over, or double-throw, contacts control two circuits: one normally-open contact and one normally-closed contact with a common terminal. It is also called a Form C contact or "transfer" contact.

2.5 Relay Driver

A ULN2803 is an Integrated Circuit (IC) chip with a High Voltage/High Current Darlington Transistor Array. It allows you to interface TTL signals with higher voltage/current loads. In English, the chip takes low level signals (TLL, CMOS, PMOS, NMOS - which operate at low voltages and low currents) and acts as a relay of sorts itself, switching on or off a higher level signal on the opposite side.

2.6 ULN2803

The eight NPN Darlington connected transistors in this family of arrays are ideally suited for interfacing between low logic level digital circuitry (such as TTL, CMOS or PMOS/NMOS) and the higher current/voltage requirements of lamps, relays, printer hammers or other similar loads for a broad range of computer, industrial, and consumer applications. All devices feature open–collector outputs and freewheeling clamp diodes for transient suppression. The ULN2803 is designed to be compatible with standard TTL families while the ULN2804 is optimized for 6 to 15 volt high level CMOS or PMOS.

III. INTEL 8051 MICRCONTROLLER

3.1 Microcontroller:

A decade back the process and control operations were totally implemented by the Microprocessors only. But now a day the situation is totally changed and it is occupied by the new devices called Microcontroller. The development is so drastic that we can't find any electronic gadget without the use of a microcontroller. This microcontroller changed the embedded system design so simple and advanced that the embedded market has become one of the most sought after for not only entrepreneurs but for design engineers also.

3.2 Microprocessors & Microcontrollers:

3.2.1 Microprocessor:

A CPU built into a single VLSI chip is called a microprocessor. It is a general-purpose device and additional external circuitry is added to make it a microcomputer. The microprocessor contains arithmetic and logic unit (ALU), Instruction decoder and control unit, Instruction register, Program counter (PC), clock circuit (internal or external), reset circuit (internal or external) and registers. But the microprocessor has no on chip I/O Ports, Timers, Memory etc.

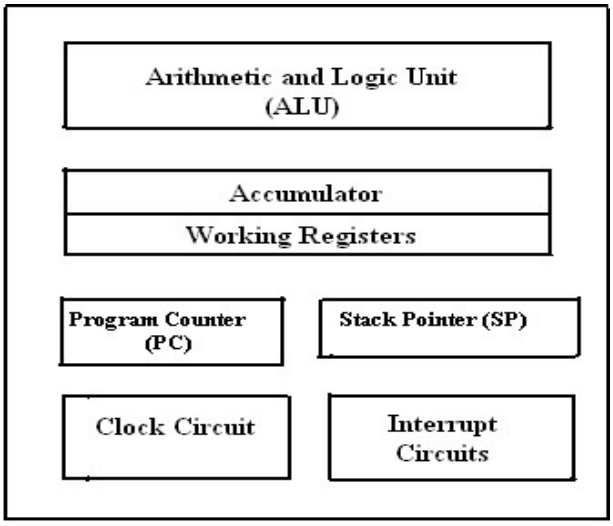

Figure 3.1 Block diagram of a Microprocessor

3.3 Evolution of Microcontrollers:

The first microcontroller TMS1000 was introduced by Texas Instruments in the year 1974. In the year 1976, Motorola designed a Microprocessor chip called 6801 which replaced its earlier chip 6800 with certain add-on chips to make a computer. This paved the way for the new revolution in the history of chip design and gave birth to a new entity called "Microcontroller". Later the Intel company produced its first Microcontroller 8048 with a CPU and 1K bytes of EPROM, 64 Bytes of RAM an 8-Bit Timer and 27 I/O pins in 1976. Then followed the most popular controller 8051 in the year 1980 with 4K bytes of ROM, 128 Bytes of RAM, a serial port, two 16-bit Timers, and 32 I/O pins. The 8051 family has many additions and improvements over the years and remains a most acclaimed tool for today's circuit designers. INTEL introduced a 16 bit microcontroller 8096 in the year 1982. Later INTEL introduced 80c196 series of 16-bit Microcontrollers for mainly industrial applications.

3.4 Microcontroller Development Tools:

To develop an assembly language program we need certain program development tools. An assembly language program consists of Mnemonics which are nothing but short abbreviated English instructions given to the controller. The various development tools required for Microcontroller programming are explained below.

1. Editor: An Editor is a program which allows us to create a file containing the assembly language statements for the program. Examples of some editors are PC write Word star. As we type the program the editor stores the ACSII codes for the letters and numbers in successive RAM locations. If any typing mistake is done editor will alert us to correct it. If we leave out a program statement an editor will let you move everything down and insert a line. After typing the entire program we have to save the program. This we call it as source file. The next step is to process the source file with an assembler.

3.5 INTEL 8051 Microcontroller:

The 8051 microcontroller is a very popular 8-bit microcontroller introduced by Intel in the year 1981 and it has become almost the academic standard now a days. The 8051 is based on an 8-bit CISC core with Harvard architecture. Its 8-bit architecture is optimized for control applications with extensive Boolean processing. It is available as a 40-pin DIP chip and works at +5 Volts DC. The salient features of 8051 controller are given below.

SALIENT FEATURES: The salient features of 8051 Microcontroller are

i. 4 KB on chip program memory (ROM or EPROM)).
ii. 128 bytes on chip data memory(RAM).
iii. 8-bit data bus
iv. 16-bit address bus
v. 32 general purpose registers each of 8 bits

IV. TECHNOLOGY USED

4.1 GPS -Global Position System

Global Positioning System (GPS) is a satellite-based radio-positioning and time transfer system designed, financed, deployed, and operated by the U.S. Department of Defense. GPS has also demonstrated a significant benefit to the civilian community who are applying GPS to a rapidly expanding number of applications. What attracts us to GPS is:

- The relatively high positioning accuracies, from tens of meters down to the millimeter level.
- The capability of determining velocity and time, to an accuracy commensurate with position.
- The signals are available to users anywhere on the globe: in the air, on the ground, or at sea.
- It is a positioning system with no user charges that simply requires the use of relatively low cost hardware.
- It is an all-weather system, available 24 hours a day.
- The position information is in three dimensions, that is, vertical as well as horizontal information is provided.

4.2 GPS Work

A GPS receiver calculates its position by carefully timing the signals sent by the constellation of GPS

satellites high above the Earth. Each satellite continually transmits messages containing the time the message was sent, a precise orbit for the satellite sending the message (the ephemeris), and the general system health and rough orbits of all GPS satellites (the almanac). These signals travel at the speed of light through outer space, and slightly slower through the atmosphere. The receiver uses the arrival time of each message to measure the distance to each satellite thereby establishing that the GPS receiver is approximately on the surfaces of spheres centered at each satellite.

Space Segment

The Space Segment of the system consists of the GPS satellites. These space vehicles (SVs) send radio signals from space. The nominal GPS Operational Constellation consists of 24 satellites that orbit the earth in 12 hours. There are often more than 24 operational satellites as new ones are launched to replace older satellites. The satellite orbits repeat almost the same ground track (as the earth turns beneath them) once each day.

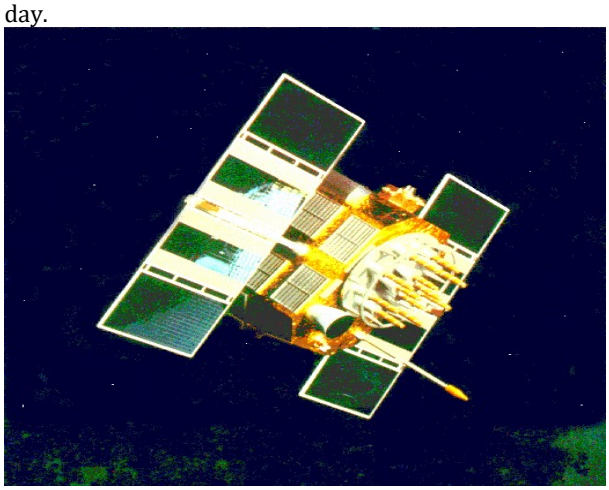

Figure 4.1: Satellites

User Segment

The GPS User Segment consists of the GPS receivers and the user community. GPS receivers convert SV signals into position, velocity, and time estimates. Four satellites are required to compute the four dimensions of X, Y, Z (position) and Time. GPS receivers are used for navigation, positioning, time dissemination, and other research. Navigation in three dimensions is the primary function of GPS. Navigation receivers are made for aircraft, ships, ground vehicles, and for hand carrying by individuals.

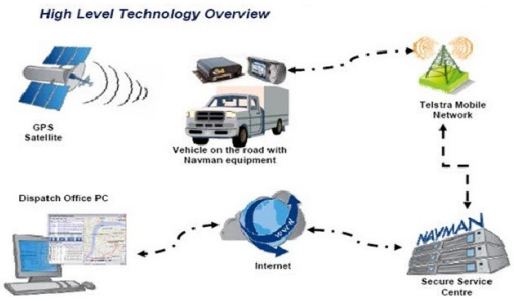

Figure 4.2: Technology Overview

V. GSM- GLOBAL SYSTEM FOR MOBILE COMMUNICATION

5.1 GSM

GSM (Global System for Mobile communications) is the most popular standard for mobile phones in the world. Its promoter, the GSM Association, estimates that 80% of the global mobile market uses the standard. GSM is used by over 3billion people across more than 212 countries and territories. Its ubiquity makes international roaming very common between mobile phone operators, enabling subscribers to use their phones in many parts of the world. GSM differs from its predecessors in that both signaling and speech channels are digital, and thus is considered a second generation (2G) mobile phone system

5.2 GSM Security:

GSM was designed with a moderate level of security. Communications between the subscriber and the base station can beencrypted.GSM uses several cryptographic algorithms for security. TheA5/1andA5/2 stream ciphers are used for ensuring over-the-air voice privacy.

5.3 Voice Codec's:

GSM has used a variety of voice codec's to squeeze 3.1 kHz audio into between 5.6 and 13 Kbit/s. Originally, two codec's, named after the types of data channel they were allocated, were used, called Half Rate (5.6 Kbit/s) and Full Rate(13 Kbit/s). These used a system based upon linear predictive coding (LPC). In addition to being efficient with bitrates, these codec's also made it easier to identify more important parts of the audio, allowing the air interface layer to prioritize and better protect these parts of the signal.

5.4 GSM Frequencies:

GSM networks operate in a number of different frequency ranges.

a) Most2GGSM networks operate in the 900 MHz or 1800 MHz bands.

b) The rarer 400 and 450 MHz frequency bands are assigned in some countries where these frequencies were

previously used for first-generation systems.
c) Most3GGSM networks in Europe operate in the 2100 MHz frequency band.
d) GSM-900 uses 890–915 MHz to send information from the mobile station to the base station (uplink) and 935–960 MHz for the other direction (downlink), providing 124 RF channels (channel numbers 1 to 124) spaced at 200 kHz. Duplex spacing of 45 MHz is used.

5.5 GSM Modem

This GSM Modem can accept any GSM network operator SIM card and act just like a mobile phone with its own unique phone number. Advantage of using this modem will be that you can use its RS232 port to communicate and develop embedded applications. Applications like SMS Control, data transfer, remote control and logging can be developed easily. The modem can either be connected to PC serial port directly or to any microcontroller. It can be used to send and receive SMS or make/receive voice calls. It can also be used in GPRS mode to connect to internet and do many applications for data logging and control.

5.6 Interfacing with microcontroller

Connect MCU TXD/RXD through MAX232 so your MCU can communicate with GSM Modem.

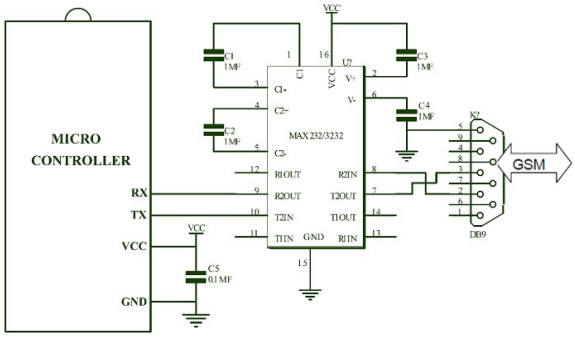

Figure 5.1: Interfacing with Microcontroller

VI. ZIG-BEE

ZIG-BEE is the set of specs built around the IEEE 802.15.4 wireless protocol. The IEEE is the Institute of Electrical and Electronics Engineers, a non-profit organization dedicated to furthering technology involving electronics and electronic devices. The 802 group is the section of the IEEE involved in network operations and technologies, including mid-sized networks and local networks. Group 15 deals specifically with wireless networking technologies, and includes the now ubiquitous 802.15.1 working group, which is also known as Bluetooth®. The standard itself is regulated by a group known as the ZIG-BEE Alliance, with over 150 members worldwide.

Due to its low power output, ZIG-BEE devices can sustain themselves on a small battery for many months, or even years, making them ideal for install-and-forget purposes, such as most small household systems. Predictions of ZIG-BEE installation for the future, most based on the explosive use of ZIG-BEE in automated household tasks in China, look to a near future when upwards of 60 ZIG-BEE devices may be found in an average American home, all communicating with one another freely and regulating common tasks seamlessly.

6.1 GHz RF MODEM

RF modem can be used for applications that need two way wireless data transmission. It features adjustable data rate and reliable transmission distance. The communication protocol is self controlled and completely transparent to user interface. The module can be embedded to your current design so that wireless communication can be set up easily.

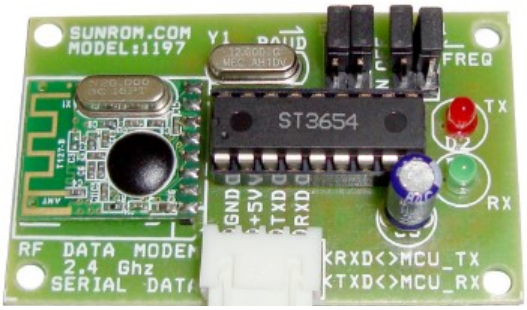

Figure 6.1: RF Modem

VII. SOFTWARE SPECIFICATION

7.1 Language Specification:
.Net Technology:

The .NET Framework is a new computing platform that simplifies application development in the highly distributed environment of the Internet.

Objectives of. Net framework:

- To provide a consistent object-oriented programming environment whether object codes is stored and executed locally on Internet-distributed, or executed remotely.
- To provide a code-execution environment to minimizes software deployment and guarantees safe execution of code.
- Eliminates the performance problems.
- There are different types of application, such as Windows-based applications and Web-based applications.
- To make communication on distributed environment to ensure that code be accessed by the .NET Framework can integrate with any other code.

7.2 components of .net framework:
7.2.1 The common language runtime (CLR):

The common language runtime is the foundation

of the .NET Framework. It manages code at execution time, providing important services such as memory management, thread management, and remoting and also ensures more security and robustness. The concept of code management is a fundamental principle of the runtime. Code that targets the runtime is known as managed code, while code that does not target the runtime is known as unmanaged code.

7.3 The .net frame work class library:

It is a comprehensive, object-oriented collection of reusable types used to develop applications ranging from traditional command-line or graphical user interface (GUI) applications to applications based on the latest innovations provided by ASP.NET, such as Web Forms and XML Web services.

7.4 features of the common language runtime:

The common language runtime manages memory; thread execution, code execution, code safety verification, compilation, and other system services these are all run on CLR.

- Security.
- Robustness.
- Productivity.
- Performance.

7.5 Data access with ado.net:

As you develop applications using ADO.NET, you will have different requirements for working with data. You might never need to directly edit an XML file containing data - but it is very useful to understand the data architecture in ADO.NET.

ADO.NET offers several advantages over previous versions of ADO:

- Interoperability
- Maintainability
- Programmability
- Performance Scalability

7.6 MS-SQL SERVER 2005:

7.6.1 FEATURES OF SQL-SERVER 2005

The OLAP Services feature available in SQL Server version 7.0 is now called SQL Server 2005 Analysis Services. The term OLAP Services has been replaced with the term Analysis Services. Analysis Services also includes a new data mining component. The Repository component available in SQL Server version 7.0 is now called Microsoft SQL Server 2005 Meta Data Services. References to the component now use the term Meta Data Services. The term repository is used only in reference to the repository engine within Meta Data Services SQL-SERVER database consist of six type of objects,

They are,

- TABLE
- QUERY
- FORM
- REPORT
- MACRO

7.7 Module:

Modules are units of code written in access basic language. We can write and use module to automate and customize the database in very sophisticated ways. It is a personal computer based RDBMS. This provides most of the features available in the high-end RDBMS products like Oracle, Sybase, and Ingress etc. VB keeps access as its native database. Developer can create a database for development & further can create. The tables are required to store data. During the initial Development phase data can be stored in the access database & during the implementation phase depending on the volume data can use a higher – end database.

7.8 Circuit Diagram

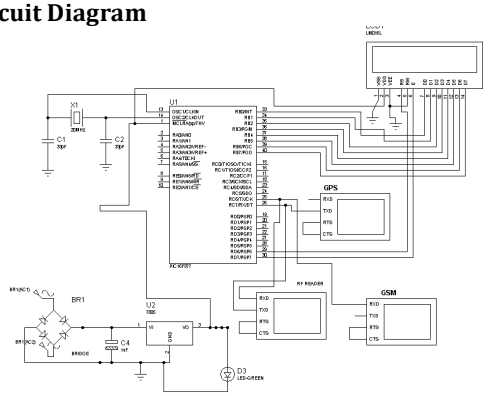

Figure 7.1: Connection diagram of GPS and GSM

VI CONCLUSION

In this paper, we have presented our experiences designing LynxNet – an animal monitoring system in the wild. We have created a hardware prototype of a highly mobile, energy-efficient monitoring system that gathers accurate GPS position and multimodal sensor data and disseminates it through the system of delay tolerant network nodes to the consumer. Our field tests show that radio communication range of 200-250m is achievable and should be considered in further system design. mobile OS etc.

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BIOGRAPHIES

1.Ms. Sharmila K., M.phil Research Scholar, Department of computer Science DKM College for Women (Autonomous), Vellore, TamilNadu, India

2. Mrs. Sivasankari A., Asst. Prof Department of Computer Science DKM College for Women (Autonomous), Vellore, TamilNadu, India