Faculty of Computer Science
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Thesis Proposal for MCS Degree Program

Software Architecture for Environmental Sensor Webs

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June 4, 2003

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1. Introduction

Sensor webs provide a convenient way to quickly deploy web-enabled environmental, industrial and military sensors. As the technology of integrated, low-powered, Complementary Metal Oxide Semiconductor (CMOS) communication devices and sensors becomes mature, the variety of networked sensors has increased rapidly. Sensors can be used in the field to monitor the environment or used inside industrial or medical buildings and sites to monitor air quality, water quality, or unauthorized access, (see Table 1). A well-defined overall sensor web software architecture remains as a fruitful area in the development of sensor web systems.

The research program proposed here will investigate how a general-purpose architecture for sensor webs can be constructed. The architecture must support quick deployment of multiple sensor platforms in a diversity of areas and can be accessible from web browsers. A test of the prototype web architecture will be tested in an environmental monitoring application.

This research is part of the Geomatics for Informed Decisions (GEOIDE) project MNG#BER [8].

Table 1. Partial list of types of environmental sensors available for field use.

Attribute measured	Manufacturer	Device name	Units of measurement	Range
Acceleration	Analog Devices Inc	ADXL202	g	-2 to +2
Electrical Conductivity	ESIS PTY Ltd	EC4	µS/cm	0 to 20,000
Dissolved Oxygen	Sensorex Corp.	CS511-L	mg/l	0 to 20
Humidity	Blue Earth Research	MiniCap2	RH(Relative Humidity)	10% to 90%
PH	ESIS PTY Ltd	PH3	pH	0 to 14
Precipitation	Eigenbrodt Corp.	ANS 410 Automatic Rain Gauge	mm/min	≤ 20
Temperature	Analog Devices Inc	AD7418AR	°C	-55 to +125
Water Flow Rate	SonTek Corp.	YSI Argonaut ADV	m/s	0.001 to 6
Water Level	ESIS PTY Ltd	WL5	m	0 to 50
Wind Speed	E.S.I Environmental Sensors Inc.	Wind Speed Sensor 2740	m/s	0.4 to 76

2. Background Information

Sensor webs, which are also called networked sensors or distributed sensing, are a set of low-powered integrated sensor platforms and a monitoring station using wired or wireless communications to exchange the data.

A sensor platform is an integrated computing, communication, sensing, and power platform [9]. For example, the *Mica* wireless sensor platform built by a UC Berkeley team for habitat monitoring is one of them. Mica's Atmel Atmega 8-bit microcontroller runs at 4 MHz and delivers 4 MIPS, with 128K bytes in flash program memory and a 4-Kbyte SRAM. It has an internal 8-channel 10-bit DAC, 48 I/O lines, and an external universal asynchronous transceiver. *Mica* uses a 916MHz ISM (Industrial, Scientific and Medical) Band transceiver; with a data transfer rate of 40 Kbps and radio frequency (RF)

power is 0.75 mW. During an active mode the current draw is at 12 mA when the transceiver transmits the data and 1.8 mA when receiving the data. It only consumes less than 1 μA in sleep mode [5]. Since the platform is used in environmental applications, light and temperature sensors for example can be built into it for monitoring purposes [9]. *Mica* runs on two AA-batteries with a power supply of 3 volts. A company called Crossbow Technology Inc. is now producing *Mica2* [6](with radio range up to 1,000 feet) and complimentary interface boards.

Another well-known sensor platform developed by Motorola is called the *neuRFon* platform. *NeuRFon* employs today's advanced sensor web technology. Each *neuRFon* device consists of a transducer (sensor or actuator) and a communication circuit. Devices communicate with their neighbouring devices to transmit, refine and make decisions according to the data gathered [15].

The rich design of sensor platforms has promoted a number of sensor web projects. These include (a) BBN Technologies' Smart Sensor Web [2], (b) Habitat Monitoring by UC Berkeley which uses the Mica platform [12], (c) UCLA's WINS (Wireless Integrated Network Sensors) [1], (d) MIT's power aware microsensor network [4], and (e) neuRFon network by Motorola making use of the neuRFon device [10].

The wireless sensor network for habitat monitoring was developed on Great Duck Island, Maine by a group of researchers from UC Berkeley in collaboration with the Intel Research Lab and College of the Atlantic in Bar Harbour Maine. The project utilizes the *Mica* sensor platform with built-in sensors for temperature, barometric pressure, and humidity.

A tiered system architecture was introduced into the sensor network with three major components: *sensor nodes, gateway,* and *base station* (see Figure1). The lowest level component is the sensor node which carries out the basic computations and networking based on the information collected or sensed. The sensor nodes form a multi-hop network by forwarding each other's message, which extends the connectivity options as well as meets the power requirements of the small devices. All the data are then transmitted through the network to the gateway. The gateway is responsible for transmitting the collected data using wireless communication to the remote base station that provides WAN (wide area network) connectivity and data logging [12].

Two designs were implemented for the transit network: an 802.11b single hop with an embedded Linux system and a single hop mote to mote network. The first design employs CerfCube[3] as the sensor patch gateway with a CompactFlash 802.11b adapter. CerfCube SA-1110 SBC has a Intel StrongArm SA1110 CPU running at 192MHz with a 16MB Intel StrataFlash memory using a 16-bit data bus. It also has a power requirement at 2.5W, and is deployed with a 12dbi omni directional 2.4GHz antenna that covers a range of 1000 feet. The mote to mote network has one mote in the base station and the other in the sensor patch. Both motes are connected to 14dbi directional 916MHz Yagi antennae with a communication range of more than 1200 feet. A database is also attached

to the base station over the Internet to provide data storage. Eventually, the refined sensing data can be visualized through a web browser user interface [12].
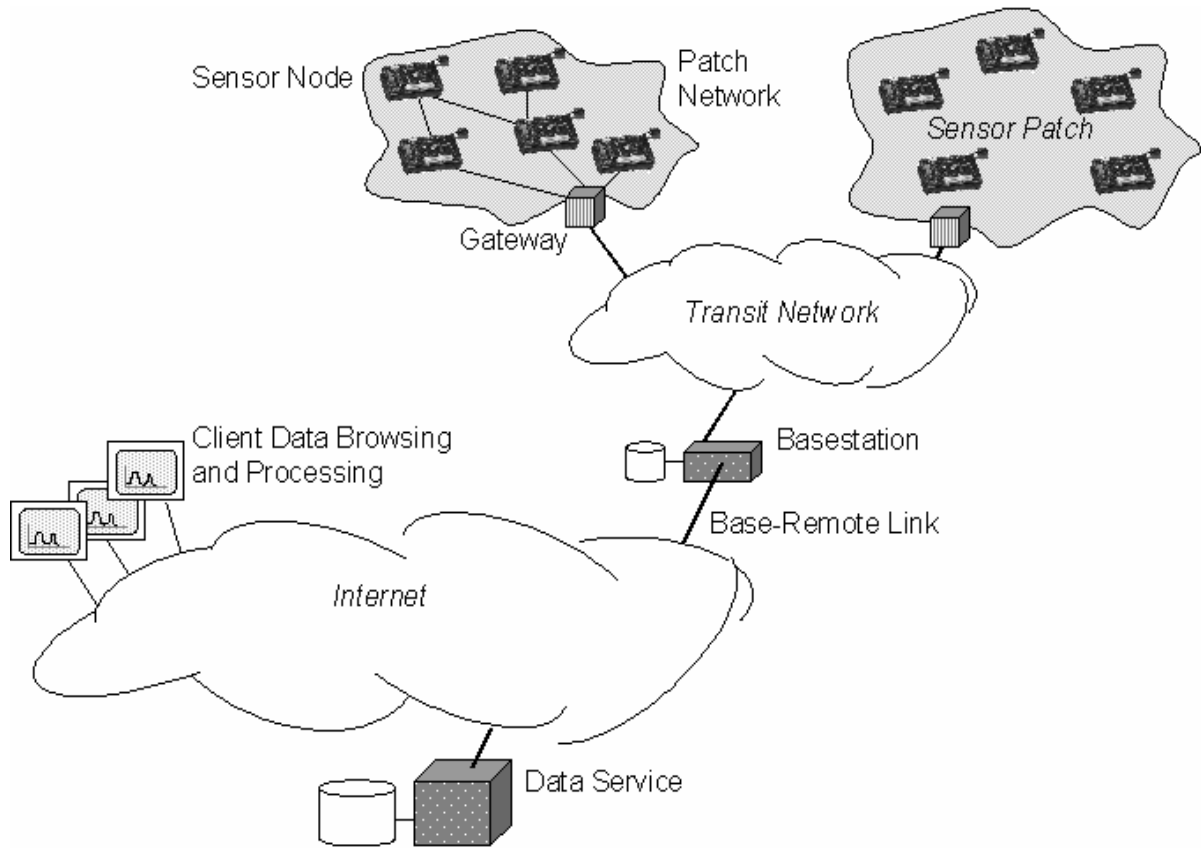

Figure 1. Example sensor web architecture for habitat monitoring (from [12]).

3. Objectives

The following questions will be addressed in this research program:

1. How can a computer language for sensor web configuration be built?

2. What are the commonly used software components of a sensor web?

3. What is the best way to write a user-friendly and lightweight web interface for sensor web configuration and monitoring?

4. How can sensor web software components be designed to make our software architecture compatible with most of the available hardware sensor platforms?

Based on these questions, our objectives for this research program become:
1) to develop a computer language for sensor web configuration,
2) to research and design the software components of a general-purpose sensor web architecture,

3) to build a user-friendly web interface for sensor web configuration and monitoring that uses the language from 1),
4) to experimentally validate our web sensor architecture using one of the available hardware sensor platforms.

Our sensor web architecture should be lightweight and user-friendly. By lightweight we mean that our architecture keeps the sensor constraints to a minimum and can be deployed using Open Source [7,14] software.

4. Methodology

Our sensor web system architecture will be based on the functionality available from the *Mica* architectures. The following are the proposed steps in our research:

1. A context-free grammar (CFG), which is used to describe the grammar of programming languages [16], will be used to define a protocol for configurating web sensor systems.

2. Based on the configuration grammar, we will construct a software architecture of sensor web systems and implement it using Java.

3. Upon the completion of the prototype architecture, we plan to perform a test on the architecture in the field using sensors. Figure 2 shows the proposed validation site. The following list describes aspects of this experimental validation:

    a) The *Mica2* platform [6] will be used as our experimental platforms with built-in sensors to monitor the water level, water temperature, dissolved oxygen, and water flow rate. A set of such sensors will be placed in or along the Saint John River and Nashwaak River to perform the monitoring.

    b) The StrongArm-based Linux embedded system—CerfCube [3], will act as the patch gateway to collect the messages from the sensors and forward to the base station by wireless communication.

    c) We will set up a base station at UNB, which basically comprises a PC and some data storage (e.g. MySQL database), to communicate with the sensors in the field and collect the sensing data to evaluate the architecture.

    d) A user interface for monitoring the real-time environmental data will be implemented using a Java applet. Thus the data can be visualized in a browser with Java plug-in installed over the Internet.

4. Communication between the gateway and base station can be provided in a number of ways. These include [11]: a) 1xRTT (single carrier Radio Transmission Technology) provided by Aliant Telecom, b) General Packet Radio Service (GPRS) from Rogers, c) Cellular Digital Packet Data (CDPD), by Aliant telecom, d) 802.11b wireless community net access provided by Brunnet with access point already set up on the top of Gillin Hall, e) Proprietary community access client provided by Motorola canopy and Brunnet, f) Satellite communication systems [13]. Based on the cost and

efficiency of the services, d) wireless community net access appears to be the most efficient access for the planned gateway.
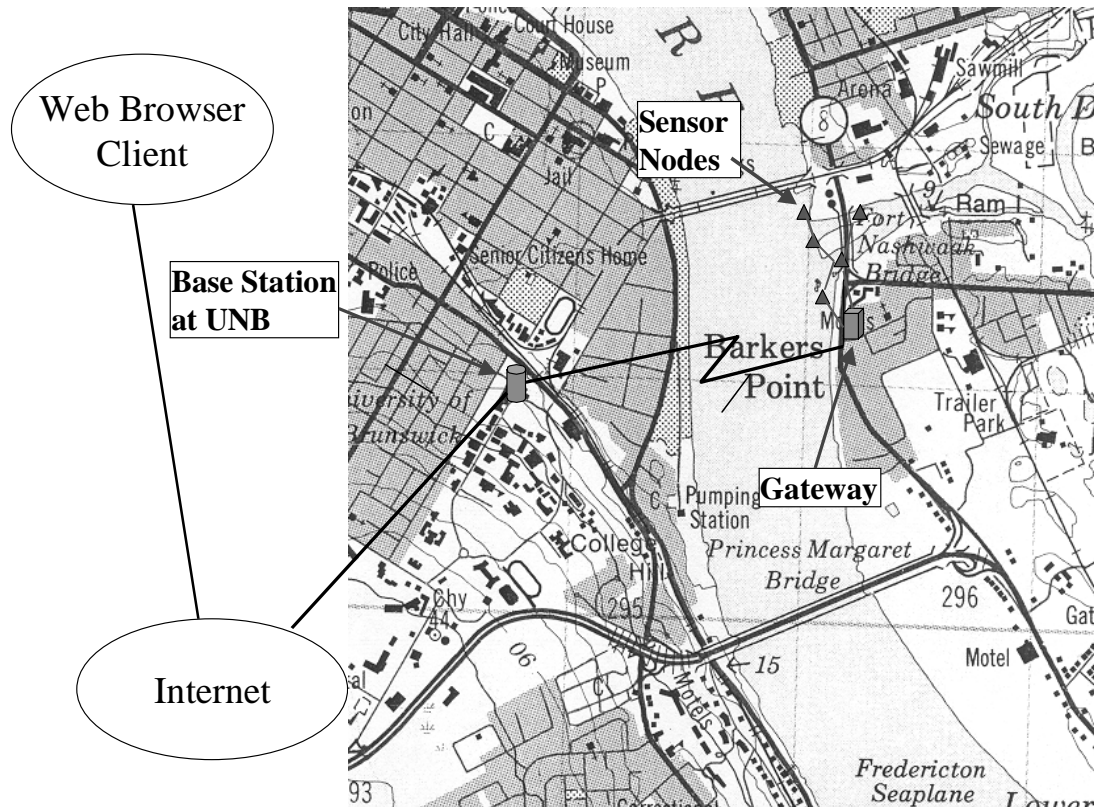

Figure 2. Proposed experimental validation site.

5. Schedule

Task	Start Date	End Date
Proposal presentation		June, 2003
Sensor web configuration language design	May, 2003	September, 2003
Sensor web software architecture design and implementation	June, 2003	July, 2003
Experiments, validation and field testing	July, 2003	October, 2003

| Thesis preparation | January, 2004 | March, 2004 |
| Thesis oral presentation | April, 2004 | |

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