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Mobile Data Acquisition and Control Using Internet Technology

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Abstract

Access to worldwide computers and their information has never been greater and this access continues to grow on a daily basis. The common thread between these computers and the sharing of this information is the Internet. The Internet is a worldwide network connecting users from education, business and industry through physical wires, fiber optic cables and microwave transmissions. Wireless connection to the Internet is taking place through the use of cellular phones and some hand held computers.

This research project proposed to investigate wireless connection to the Internet for use in data acquisition and control of everyday devices such as heating and cooling systems, home appliances and security systems. Although wireless technology is being used, this investigation will focus on the use of wireless technology using inexpensive microprocessors connected to cost sensitive commercial products. The actual system used in this research is a soft drink vending machine. The vending machine was connected wirelessly to a laptop computer for interrogation of the contents of the machine. The laptop computer was tested a various distances to verify that it could be use in the soft drink delivery truck. If successful, the driver could interrogate the machine for the contents and bring to the machine only that product which is necessary to restock the machine.

Even though wireless technology, inexpensive microprocessors and internet technology have been available for some time, the integration of these three technologies into a system that can acquire information and then send commands to modify its operation has had little investigation. This work could lead to devices much like the size of television remote controls that will allow information to be collected from home appliances and then acting on this information using a remote device connected wirelessly to the internet.

Synopsis of Literature and Background Information

The objective of this research is to integrate Internet technologies and wireless communication into a remote data access and control device in a cost constrained environment.

Currently work in the field of mobile connection to the Internet is divided into three (3) areas: wireless communications, embedded microprocessors and computer networking. A wealth of work is available in these three (3) areas. The most respected work in the wireless communication area is Pelton [1], Frank and Frisch [2]. In the embedded microprocessor area the most respected work comes from Short [3], Brey [4] and Hall [5] and in the computer networking area Tanenbaum [6], Stallings [7] and Comer [8] are the most widely published authors.

Interestingly, much in depth work has been done in each of the specific technical areas, but work crossing these technical lines has just started to appear in the last two years primarily in papers presented at technical conferences. Two papers presented at the Embedded Systems Conference in 1998 and 1999 by Snell [9] and Sontag [10] define connections for consumer devices on the internet for monitoring and control. Each paper describes a hardwire connection to devices on the Internet. My research will extend this technology to wireless connections so users will have more mobility.

I have done some preliminary work in this area. During the spring semester 1999, I worked with a senior project student connecting a low cost microcontroller device to web server to obtain up to date data from a remote temperature monitoring device. This project incorporated

a low cost microcontroller (PIC), an embedded computer system running LINUX and a small web server from ACME Labs. This was not a wireless project, however issues of connecting low cost microcontrollers to the Internet was studied.

This project also utilized student involvement through the Senior Project course, EET 428. This is the capstone design course for all seniors in the EET & CNS Department. The group of Travis Cole, Brian Morris and Roberto Martinez indicated their interest in working on a wireless project to gain more exposure to this technology. Several meetings were conducted to gauge the interest, background and ability of the group to assist in this research.

The first step in this process was to define the technology requirements while making the following assumptions:

- The technology will be developed within currently available hardware and software.
- The resulting device will remotely connect to the Internet using wireless technology.
- The embedded device will have as low a unit price as possible to support the technology.
- The technology will provide flexibility to address varied implementation scenarios.

The technology requirements for this project fall into five (5) categories:

- Embedded devices
- Development software
- Connection hardware
- Networking protocol
- User interface

Having researched the various avenues for implementing the above criteria, the Web enabled soft drink vending machine project was chosen because it met all the above requirements. I worked very closely with the students to implement the project according to the all stated criteria.

Summary of Findings

Although it was originally planned to use a home security system as the demonstration platform, the web enable vending machine was an equally good platform. All of the technology requirements necessary for the research project were in this system also.

Embedded Devices

After much research, the 80386EX microprocessor was chosen for this project. The 80386EX is a DOS (Disk Operating System) compatible device that is capable of being embedded in many different products. It comes with many peripheral devices on the chip for I/O, memory management, timing and interfacing. The cost is competitive with other devices being in the range of about \$4.00. In addition, software development could be done on a standard personal computer as the PC runs the same fundamental code as the 80386EX.

Development Software

The second step was to merge the development software with test routines on a web server. Here there were several options, but the most promising option appeared to be a product called emMicro, emClient and emGateway from EmWare, Inc. This web server can fit into a memory footprint as small as 30 bytes of RAM and 1K bytes of ROM [10]. This software is available for multiple microcontrollers and the company offers training to implement this technology on multiple platforms. After much investigating and attending training on EmWare's product, it was determined that a standard C environment would be the best because of its wide availability and standardization. EmWare's products are proprietary in nature and are not as widely accepted throughout the industry.

Connection Hardware

Because of the Internet network connection required, the system needed to communicate using wireless TCP/IP devices. There are a number of these devices on the market but devices that fit PCMCIA Type III slots are most appropriate for this project. Because of the mobility requirement, connections to laptop and hand held computers are essential. The biggest question here is the range of operation at a data rate suitable for this application. A compromise between the range and data rate was investigated. Of the numerous choices in wireless hardware, the IEEE 803.11b devices were chosen for this project. The speed, cost, availability and standard connection makes this the best solution.

Networking Protocol

With TCP/IP as the protocol on the Internet, the hardware interface to TCP/IP was investigated for the most cost effective implementation. Modem, wireless RS232, and multidrop connections were investigated. The outcome of the connection hardware investigation showed that direct TCP/IP connection was the fastest, most widely used and cost effective protocol connection for this work.

User Interface

This is where the investigation of the embedded devices, development software, connection hardware and networking protocol came together. Based on the results, an 80386EX was connected to a vending machine mockup. Wirelessly, using the portable development computer and a web browser, the user interrogated the condition of the vending machine. The final expected outcome is the development system communicating with the embedded controller through a web browser wirelessly. This indeed happened with the system.

In bringing these technologies together, TCP/IP drivers were loaded and interfaced with the application program running on the 80386EX. There were two sides to this interface; the interface at the microcontroller (vending machine) side and the interface to the monitoring side (laptop). Once the drivers are in place, the application software was interfaced through to a web browser. This was done using dynamic HTML (Hypertext Markup Language) scripting. This work has broken new ground in the ability to observe action at a device in real time through a web browser.

Implications, Conclusions and Potential Applications

The work could have significance to the general academic community and to Ferris. First, working with wireless Internet connections could have wide application in the classrooms at Ferris. The devices used to connect the laptop and the embedded system could connect laptop

computers with servers in a classroom environment. The advantage would be no wires running from the laptops to the server. Each laptop would be equipped with a wireless network card and all the student would need to do is start their computer within 600 feet of a wireless receiver connected to the campus network and a network session would be initiated. The cost of the network interface for the laptops is about \$100.00 and a receiver to connect up to 24 laptops is about \$300.00.

The vending machine prototype constructed has generated some interest with vending machine companies. The prototype constructed cost in the range of \$1400.00. This automated one vending machine. In larger numbers this cost could be brought down by about one-half. In conversations with vending companies, the cost needs to come down into the \$300.00 range for this technology to be profitable for vending companies. The time frame is about two years for this to happen. The cost of hardware and software may slowly come down to this point to make this technology cost effective.

The other issue for vending machine companies is the distance of communication with the IEEE 803.11b connection. From the research, the practical limit between transmitter and receiver is 600 feet. In building with much steel in it, the distance can go down to 300 feet. This distance is not practical for most deliver trucks equipped with a laptop and wireless transmitter. A more practical distance is about 1400 feet. This distance may be on the horizon with higher-powered transmitters being introduced. However, the cost of these units is about double the existing transmitters.

It appears this technology for use in a commercial product is about two years down the road. However, the technology has been proven to work. Now the cost of devices and their transmitting range must improve. It really is just a matter of time before these devices are available at the range and cost necessary to make this technology profitable for vending companies.

Another very positive aspect of this research is the student involvement. At the beginning of this project, I planned to accomplish all the work independently. However, when the opportunity to engage students in this work presented itself, I reluctantly brought them into the project. My hesitation was unfounded. The students worked extremely hard and had excellent problem solving skills. The students solved problems that occurred with the software very efficiently. This project has shown me that with the proper selection of students, undergraduate research can benefit both the institution and the student.

Future Research Enabled by the Findings

Future research coming from this project would fall into two categories: developing classroom applications for the wireless technology and producing cost effective solutions for wireless Internet control. The whole wireless field is moving at a dramatic rate. The next major step could be palm devices becoming more and more web enhanced.

Public Forum for Presentation

A paper is currently being written titled "Mobile Acquisition and Control using Internet Technology". An abstract is being submitted to The American Society for Engineering Education for their national conference next June.

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