THE INTERNET-ENABLED FURNACE

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ABSTRACT

From Coffee makers to refrigerators academics and manufacturers alike have attempted to jump onto the Internet connectivity bandwagon. Each making compelling arguments that such connectivity is inevitable and will be of significant benefit to the consumer and presumably to the service provider. We at the Network-Centric Applied Research Team (N-CART) labs have begun to examine the Internet as an ubiquitous means for provisioning services to devices typically not identified with connectivity. We have started with the lowly home heating plant.

It only takes a cold snap and a heating failure for one to appreciate the most important appliance in a cold climate--the furnace. We at the N-CART labs have developed a prototype system implementation and service model for the coupling of sensing with intelligent systems and wireless communications. We allow a common home furnace to communicate with its owner via email over the Internet or to broadcast requests for service via wireless pager. Our system is based on industry-standard hardware components cleverly coupled with custom software modules.

KEYWORDS

Internet Appliance, Furnace, telecommunications, monitoring.

INTRODUCTION

In 1991 at Cambridge University in the United Kingdom, Quentin Stafford-Fraser can be credited with placing the first common household appliance on the Internet--a coffee maker [1]. His group took digital pictures of the coffeepot and placed them on the Internet, letting others know when the coffee was ready. More recently, various manufacturers have attempted to gain a market foothold by introducing "network-aware" home appliances--Ceiva's Internet Picture frame [2] and ThetaCom's Internet alarm clock [3] being representative devices. Sun Microsystems and Whirlpool Corporations have announced that they will collaborate on the development of a home network architecture for Whirlpools appliances [4] using Sun's Jini [5] technology. Clearly, there is interest is exploiting the connectivity of the Internet for non-traditional computing devices on the supply side [6]. It has been predicted that 77% of U.S. homes will be connected to the Internet by 2005 [7]. Of those connected 45% will access the Internet through more than one means [8]. Clearly, there will be considerable demand for new and innovative services, as the Internet becomes an ubiquitous communication media [9].

It has been our goal within the N-CART lab to focus on a much more pragmatic problem for many home consumers--the monitoring and maintenance of their home systems. We have created a project designed to employ sensing, computation and communication to monitor and alert a homeowner or a service bureau of the status of a home heating plant. This communication takes place either at the request of the homeowner through email correspondence with the furnace or by the furnace itself initiating contact with a service provider, if intervention is required.

We believe this technology will be of interest to homeowners, landlords and other accommodation providers who wish improved fuel economy, better heating efficiency and enhanced safety. In addition, the technology will provide a foundation for studying the needs and desires of consumers for similar devices and services.

MOTIVATION: COST AND SAFETY

We have selected the home heating system for examination for several pragmatic reasons. The average existing home heating system is only about 60% efficient when well maintained. Unfortunately, many systems aren't adequately maintained and their real efficiency may be much less than 50% [10].

Within a single family residential dwelling the heating system is often the biggest single consumer of energy in the home, accounting for up to two-thirds of a household's winter energy bill. Clearly the efficiency of the heating plant should be of concern to its owner.

Heating and AC	60%
Water Heating	17%
Cooking and Refrigeration	11%
Lighting	5%
Clothes Dryer	3%
Other	4%

Table 1 Home Energy Usage (Source: Pacific Gas and Electric Company)

In addition to cost savings, the home furnace is a potential source of carbon monoxide and other dangers. In 1998 the U.S. Consumer Product Safety Commission (CPSC) [11] announced its vent pipe replacement program with the aim of reducing the risk of Carbon Monoxide (CO) poisoning within the home. CO poisoning associated with using fuel-burning appliances kills more than 200 people each year and sends about 10,000 to hospital emergency rooms for treatment.

CONCEPTUAL SYSTEM DESIGN

The conceptual architecture for our system is shown in the diagram below. The home furnace is equipped with several computing and control devices. Power for the monitoring device is provided by the furnace itself through the home electrical system and backed up with a battery in a similar manner to many electronic home thermostat systems.

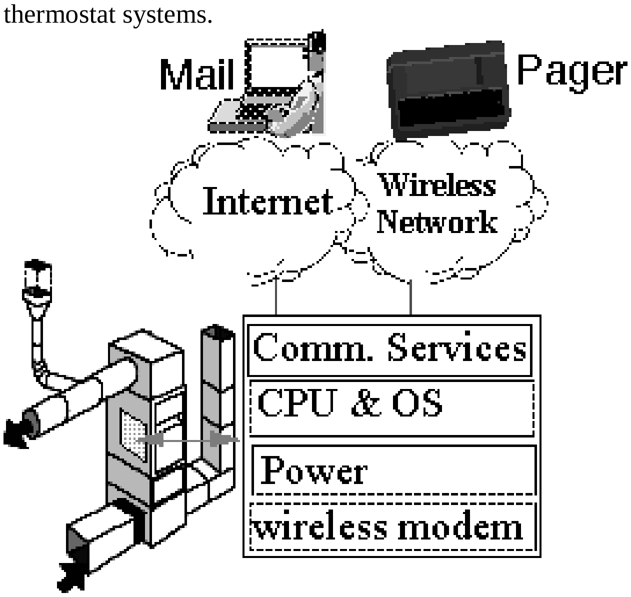

Figure 2 Internet Furnace Conceptual Architecture

Monitoring of furnace operation is accomplished through a series of sensors distributed throughout the critical components of the furnace such as the motor and belt, gas jets and flame plenum. The sensors are monitored by a microprocessor mounted on the furnace. Communication is provided via a wireless modem that serves the twin purpose of facilitating communication with the homeowner through email and with service providers via pages.

EXPERIMENTAL APPARATUS

Within our lab we have developed a prototype system to mimic the functionality of both the furnace itself and the monitoring device. This setup is shown in the diagram below.

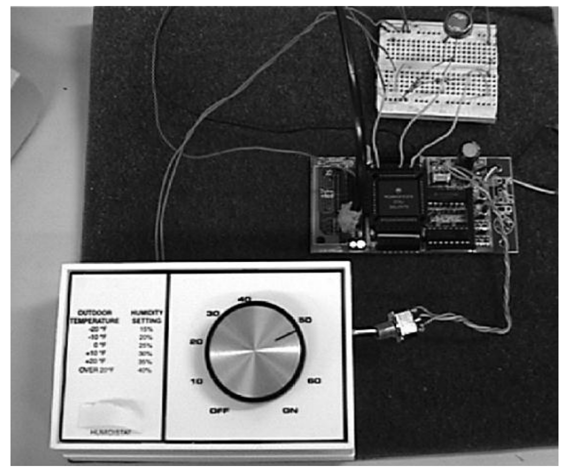

Figure 3 Experimental Setup (Linux server not shown)

We have employed various simple sensors such as a thermistor (heat), Cadmium sulphide photoresistors (light) and a hygristor-based humidistat (humidity) to provide inputs to the analog ports of the MC68HC11-based monitoring system. Monitoring of the micro-controller is provided through a serially connected PC running the Linux operating system. The PC is responsible for data collection, interpretation and the provision of communication services with the outside world. For the purposes of the experiment only wire-line communication was examined.

APPLIANCE LOG AS A BASIS FOR INTELLIGENT COMMUNICATION

Our monitoring system creates an entry in a service log file stored on the PC each time it encounters an event based on change in temperature, humidity or luminescence. In addition, communication events are also logged. Excerpts from such a log are shown below.

Thu Mar 1 15:55:27 EST 2001
INFO: Furnace Started.
Thu Mar 1 15:55:28 EST 2001
STATUS: Furnace report. email sent to root.
Thu Mar 1 19:43:42 EST 2001
CRITICAL: Furnace encountered a critical fault. email sent to root.
Thu Mar 1 19:43:42 EST 2001

CRITICAL: Furnace encountered a critical fault. email sent to root.
…

The appliance log forms the basis for all reports mailed to the homeowner and can be examined by service technicians maintaining the furnace via a locally connected display device.

Email messages are formatted on the system PC and transmitted on a pre-scheduled basis to the homeowner. This functionality allows the homeowner to take preventive action if a drop in furnace efficiency is detected or a fault is found.

Automatic paging is attempted when the system detects a major fault. The pager messages are directed at specific pager numbers and contain numerically encoded log details about the furnace requesting service such as sensor anomalies and severity codes. This is intended to provide enough information for the service provider to determine the severity of the problem and allow limited remote diagnosis to take place.

RESULTS AND OBSERVATIONS

Various trials have been conducted using our experimental apparatus employing the sensors as discussed. We have observed that by employing the two-tiered architecture involving a micro-controller coupled with a more capable PC server we can provide a wide variety of sensor monitoring services in association with a very flexible information interface tool.

FUTURE WORK

Clearly the next step is to build a working prototype attached to a suitable home furnace running under expected operational conditions. In addition, we have planned to expand our interface options to include web-based support either through a traditional PC-based web browser or by a Wireless Access Protocol (WAP) gateway for PDAs and Mobile phones. This new interface will allow us to support certain personalization options on the furnace that cannot be easily implemented in our current email interface.

At present, support for intelligent reporting is extremely limited. The system provides only limited access to historical data stored in the sensor logs and no analysis tools. We will be working to improve the system's historical reporting and analysis tool set providing limited support for visualization tools.

Our current implementation is quite bulky requiring both a micro-controller and off-board PC, we plan to port the system to a single board computer in the near future. This will enable us to provide support for a wider variety of sensing functions.

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