Remote Monitoring and Actuation Based on LonWorks® Technology

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Abstract

The LonWorks® technology is an open specification for distributed control networks. This technology allows the interconnection of intelligent sensors and actuators in a way that they are able to exchange data. In this work, we have developed a set of software tools aiming to connect a LonWorks network to the Internet, making it remotely accessible. As an application example, we used a LonWorks based commercial sensor, which can measure humidity, temperature, and some other variables. This kind of monitoring is, obviously, very important to general agricultural applications. The monitoring of these variables through the Internet brings more possibilities of application.

Key words: LonWorks, Control Networks, Remote Monitoring, Remote Operation

1 Introduction

The LonWorks technology is an open standard for distributed control networks. Created in the beginning of the 1990's decade by Echelon Corporation, USA (http://www.echelon.com), it was initially a proprietary technology, which became open by the end of 1990's. The LonWorks technology is used in large-scale in building automation area, but its applications are not restricted to this subject.

Focusing on the interconnection of LonWorks networks to the Internet, we have developed a set of software tools. An example of application is also presented in this work. We used a LonWorks commercial device named "The Nose", from PureChoice, USA (http://www.purechoice.com). It is a 5-in-1 sensor: temperature, humidity, carbon dioxide, carbon monoxide, and odours and gases (VOCs – Volatile Organic Compounds). The softwares that we have developed allow the user to view the instant values of those five variables through the Internet. It is also possible to retrieve the history of the values and plot them on a curve. An example of agricultural application is to remotely monitoring a greenhouse.

The LonWorks technology was chosen because of the large availability of products and tools. According to Echelon (1999), it has thousands of developers and millions of devices worldwide installed.

2 LonWorks Technology

Traditionally, control applications are built in a centralized manner. Sensors and actuators are physically connected to a centralized controller with processing capabilities. Sensors capture the values of some variables of interest, convert them to standardized signals (e.g. 4 - 20mA electric current) and send them to the controller. The controller runs an application that calculates the output signals, based on a specific algorithm operating with the input values. These output signals are sent to actuators, which will modify the state of the plant. Fig. 1 shows this centralized architecture.

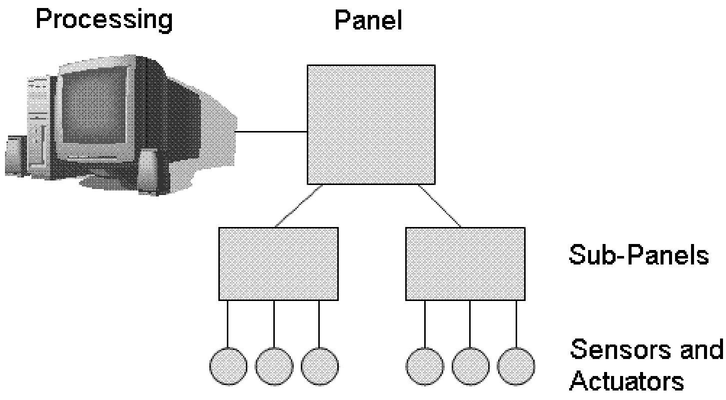

Fig. 1 Traditional control systems

Developers have created a new generation of control architectures, seeking more flexibility and productivity (Mahalik and Lee, 2002). These technologies have been created to address requirements of the automation world that, in general, could not be achieved by old control technologies or by computer data networks.

Fieldbus is a generic term used to describe communication protocols of control systems and field instrumentation. Despite some protocols and technologies that have been standardized for control applications, the industry has not yet agreed about a unique fieldbus standard, as TCP/IP is for data networks. LonWorks is a specific implementation of the fieldbus concept and is considered a promising way to implement control systems (Kim et al., 2000).

A LonWorks network can easily be compared to a computer data network (Echelon, 1999). A local area network (LAN) has the objective of interconnecting computers, enabling them to exchange data. To accomplish this, it is necessary for every machine to use a common set of communication protocols such as TCP/IP. A LonWorks network, similarly, allows the interconnection of control devices, offering a protocol stack optimized for this kind of application, where packet delays are usually not acceptable. This protocol stack is named LonWorks Protocol, also known as LonTalk®. It implements layers 1 to 7 of the OSI model.

A LonWorks network may be seen as a group of devices working in a peer-to-peer communication scheme. It is possible to implement monitoring (sensors) and actuation (actuators) to control a plant. Each device connected in a LonWorks network is named “node”. LonWorks nodes are not “dumb” devices without intelligence capabilities. They have their own microprocessor, which implements both: the application software and the LonTalk protocol. Each node processes received data and makes a decision, which can result in sending new packets to the network or some actuation over the physical world. LonWorks networks have a flat, non hierarchical, architecture, as can be seen in Fig. 2.

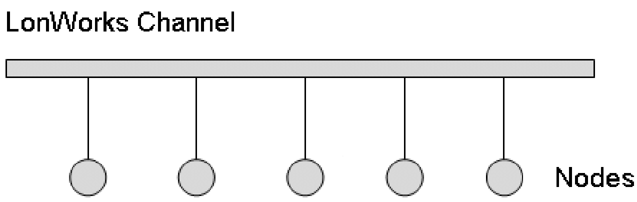

Fig. 2 LonWorks network

In a simplified way, distributed control happens in the following manner: a LonWorks sensor gets a specific information from the physical world (e.g.: carbon dioxide concentration) and sends it to an actuator through the LonWorks network in a standard protocol. The actuator processes this information and takes another decision, which may interfere in a physical process. Considering the fact that LonWorks sensors have processing capabilities, they may be composed by a set of “raw” transducers. The software that runs on the sensor’s microprocessor uses this raw data to compute a new value that is sent to the network. There is no need of an external processing element to make this calculation.

It becomes clear that a central controller (traditional approach) (Echelon, 1999) is not needed anymore in the LonWorks scheme. In this distributed control approach, each node is able to communicate with each other one, process data, and take decisions by themselves. More details about LonWorks technology can be found in Echelon (1999).

2.1 Network variables

A LonWorks node can be logically seen as a “black box” with inputs and outputs. These inputs and outputs are named network variables. Each network variable has a type that defines the data format associated to it. A LonWorks sensor, for example, will likely have only output network variables. The sensor gets one or more measurements of physical world variables and makes them available to the LonWorks network in a standardized way through output network variables. In other words, a network variable is a data item associated with a type, which can be an output or an input of a LonWorks node.

A simple LonWorks-based temperature sensor could be seen, for example, as a block with an unique output network variable: the temperature. Another node, let us say, a LonWorks-based display, could be considered a block with just an input variable: the value to be displayed. Logical connections between output and input variables are called bindings. When an output variable has its value changed (e.g., when the temperature changes), the connected input network variables of the other nodes (or even of the same node) are automatically updated. This update is accomplished through LonTalk messages that are exchanged between the nodes over the LonWorks network.

The LonMark® association incorporates many LonWorks manufacturers and has the objective of standardizing network variable types, among other things. These standardized types are called Standard Network Variable Types (SNVTs). Devices implemented under LonMark guidelines are considered to be interoperable, that is, they are able to exchange information in a known and standardized format. So, a malfunctioning node can be replaced by an equivalent node, even if it is manufactured by another company that is also LonMark certified. The major benefit is that the user will not depend on only one manufacturer anymore. Maybe this is the greatest advantage of using open systems.

3 LonWorks and the Internet

The emergence of the Internet in the last decade has changed the way people get in touch with other people. According to Raji (2002), the most common applications of the Internet, electronic mail and the World Wide Web, have become indispensable tools for many business and families. The power of the Internet could be extended to connect everyday devices (lamps, switches, TVs, air-conditioners, etc), and not just computers. It could be implemented by assigning an IP address to each device and embedding a small web server into them. However, the Internet’s technology was not designed to connect small, embedded devices. This idea has practical limits concerning cost, size, installation requirements and others. Control networks are able to link intelligent devices together, considering these requirements, providing a low-cost, reliable and flexible networking platform optimized for needs of control (Raji, 2002).

The Internet is successful in connecting geographically distant computer networks. It seems natural to try to use its existing infrastructure to connect local control networks. While control networks address specific requirements, the Internet could be used to interconnect them with other control networks and with data networks. Although real-time control over the Internet is a problem not yet solved (Overstreet and Tzes, 1999), information (data and control) could flow through wide areas, allowing several new applications. The application described in this paper is an example.

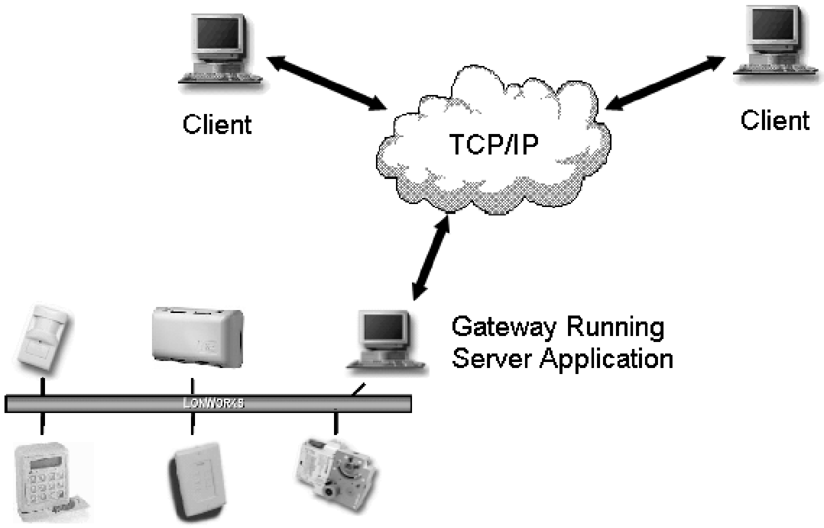

Fig. 3 System architecture

4 Application Overview

We have developed a set of softwares for Windows platform that allows a remote user to access a LonWorks network through the Internet (or any other TCP/IP network).

Fig. 3 shows the system architecture. A PC works as a gateway, and therefore must be connected to both sides: LonWorks (LonTalk protocol) and Internet (TCP/IP). Many hardware interfaces designed to connect a PC to a LonWorks network are commercially available from different manufacturers. It works like an Ethernet interface. We used a PCLTA-20, a LonWorks interface PCI card available from Echelon. On the Internet side, a special protocol developed as part of this work is used over TCP. A client application may be executed in any computer connected to the Internet. It will communicate with a server application running on the gateway through the protocol that we have developed, and then it becomes possible to access LonWorks networks from anywhere in the world.

As an application example, we used a commercial LonWorks node, "The Nose", created by PureChoice. There are two versions of this sensor: one with three sensors (temperature, humidity and carbon dioxide), and another one with five sensors (temperature, humidity, carbon dioxide, carbon monoxide and odors and gases). The latest version was chosen for this application.

We used MySQL (http://www.mysql.com) database server software to store the data collected from "The Nose" along the time. With this solution, the user can retrieve the history of the Nose's five variables through a chosen period of time, and plot it on the screen through a friendly interface in the client application. This is only possible because the protocol used to make the communication between the client and server applications (Fig. 3) allows the history data to be retrieved.

The gateway software has the responsibility of storing the values read from "The Nose". The database server runs in the same machine (gateway) and is also used to store other information, such as users, passwords, access permissions and address information of devices connected to the LonWorks network. Fig. 4 illustrates this solution.

We must emphasize that the developed softwares are not restricted to monitoring "The Nose" only. It is possible to access a lot of devices connected to the LonWorks network. Moreover, the softwares offer the possibility to remotely access actuators. Thus, a remote user can change, through the Internet, a set-point of a LonWorks node. A set-point is also an example of an input network variable.

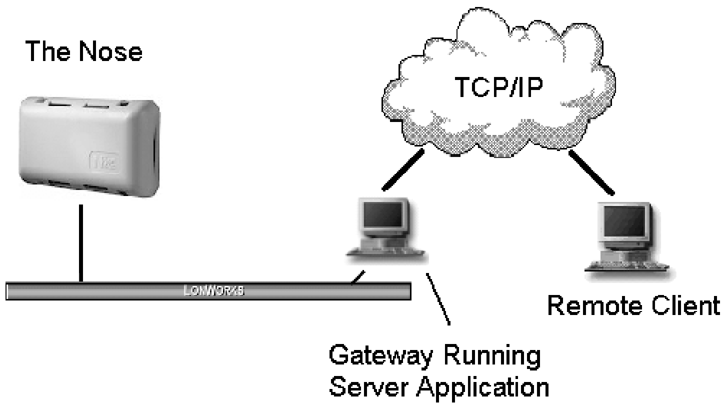

Fig. 4 Solution architecture

5 Software Description

The set of softwares is composed by three applications: the server, the client and the administrator.

5.1 The server

The server is the application that runs on the gateway machine (Fig. 3). It is able to communicate with the LonWorks network and the IP network. Echelon has some commercial tools, like LNS DDE, which allows high-level access to network variables from the LonWorks network. However, we have built the server application based on the Echelon's OpenLDV driver interface.

OpenLDV is a software layer that provides an interface for sending and receiving low-level LonTalk messages through Echelon's family of LonWorks network interfaces. It is licensed for royalty-free use exclusively with this Echelon's family of products.

A MySQL database server provides the relational database used by the server application. The database server runs on the same machine and stores information about the nodes' address (in this case, "The Nose"), configuration data (e.g., sampling period) and network variables' log (e.g., temperature and humidity).

The server application listens to a preconfigured TCP port, allowing clients to connect to it through the TCP/IP network. When a client connects, user authentication must be done. A user name and password is sent to the server, which compares them to the users and passwords present in the database provided by MySQL. If the authentication process is successful, the client application becomes able to send commands to the server. These commands are processed and the results are sent back to the client. In our application, for example, the client can ask the server about the instant value of the temperature read by "The Nose". When the client receives the answer, it is displayed on a user-friendly interface.

The communication between the client and the server occurs over a specific application protocol developed as part of this work. This is a text protocol (not binary) that defines several commands. A command may require one or more parameters and is sent from the client to the server, having the purpose of getting some answer (e.g., the value of a variable) or modify some configuration or state.

The server runs a thread responsible for reading the values of the variables measured by "The Nose". This thread also saves them into the database. The sampling period configuration is in the same database and can be changed by the administrator application, which is explained below. The server software is able to accept commands asking for the history of values of any variable in a specific time interval.

Permission control is also available: each user is associated with a group of users. Each group of users is linked with a set of permissions. Permissions establish which users are able to access each input or output network variable of the LonWorks network.

5.2 The client

The client application provides a graphical, user-friendly interface, enabling the user to access LonWorks network variables from a remote PC through an IP network. When the client is initiated, it asks for an IP address, a TCP port number, a user name and a password. The client tries to connect to the server using the IP address and the TCP port number. If the connection is established, the user name and password are sent. If they are correct, LonWorks network data becomes remotely available and can be obtained through the commands defined by the protocol developed in this work. Input network variables and configuration parameters can also be changed.

In this application, we have only five output network variables from “The Nose”: temperature, humidity, carbon dioxide, carbon monoxide, and odours and gases. We have developed an interface where the user can retrieve logged values of those variables and plot them onto graphics. Fig. 5a and Fig. 5b show two screenshots. Fig. 5c shows the real-time monitoring.

5.3 The administrator

The administrator application works as a TCP client, like the client application described above does. The difference between the client and the administrator is that the latter has the objective of configuring some parameters of the server, while the first is basically used to interact with network variables of the LonWorks network.

The user interface of the administrator application is oriented to parameter input. The user types the configuration parameters (e.g., the address of “The Nose” on the LonWorks network) and the application is responsible for sending the corresponding configuration commands to the server.

6 Discussion

Although there are several products available in the market allowing the interconnection of LonWorks networks and IP networks (e.g., Echelon’s i.LON 100) , we developed a simple and flexible solution that can be applied in future projects of the Agricultural Automation Laboratory, Polytechnic School, University of São Paulo.

The hardware access routines were written in C++ language, while the GUIs (Graphical User Interfaces) and the TCP/IP communication part were developed with Borland® Delphi™. Because of the benefits of object orientation, which was fully applied in the source code, it is relatively easy to understand, modify, maintain, and improve the solution. The developed objects could be considered a simple framework to create new specific applications and GUIs over the proposed architecture.

This system was developed to monitor a greenhouse remotely, keeping the history of the Nose’s variables available through the Internet. It was tested with two Noses on the same network, but it can be used with more Noses and other LonWorks nodes. The variables’ sampling period should be adjusted according to the number of variables to be polled over the network, aiming the avoidance of traffic overflow problems.

Others LonWorks based sensors and devices can be added to improve the same system, for example, a luminosity sensor.

7 Conclusion

Due to the large availability of LonWorks-based products, many different solutions can be implemented according to the problem’s requirements. Consumers are more independent of specific manufacturers because LonWorks is an open technology. Moreover, the LonMark Association establishes rules and guidelines to provide interoperability between different products, which is one of the key reasons for the success of the technology.

The application proposed in this paper was applied to assist the research of cultures inside greenhouses, verifying their evolution according to some environment conditions. However, the focus was to show the remote monitoring solution, which can be applied in several situations.

Remote monitoring and operation are important tools for research in general. Data can be collected from the field in an automated way, without the necessity of a human operator do the measurements. Errors are reduced and efficiency is improved. Since data is automatically collected, its processing can be automatized too. Human interference is also remotely possible through the presence of actuators connected to the LonWorks network.

Applications of remote monitoring and operation of LonWorks-based systems in agriculture and environment are being successfully implemented. In China, Shangai water authorities are using it in flood gates to allow quick response to rising waters, preventing flooding in the Taihu River Valley. More details can be found on the Internet at http://www.echelon.com/about/press/shanghaiwater.htm.

The availability of a simple and flexible tool that allows the construction of specific applications for remote monitoring and operation with LonWorks technology will improve the quality and give more possibilities to research projects and activities of the Agricultural Automation Laboratory, Polytechnic School, University of São Paulo.

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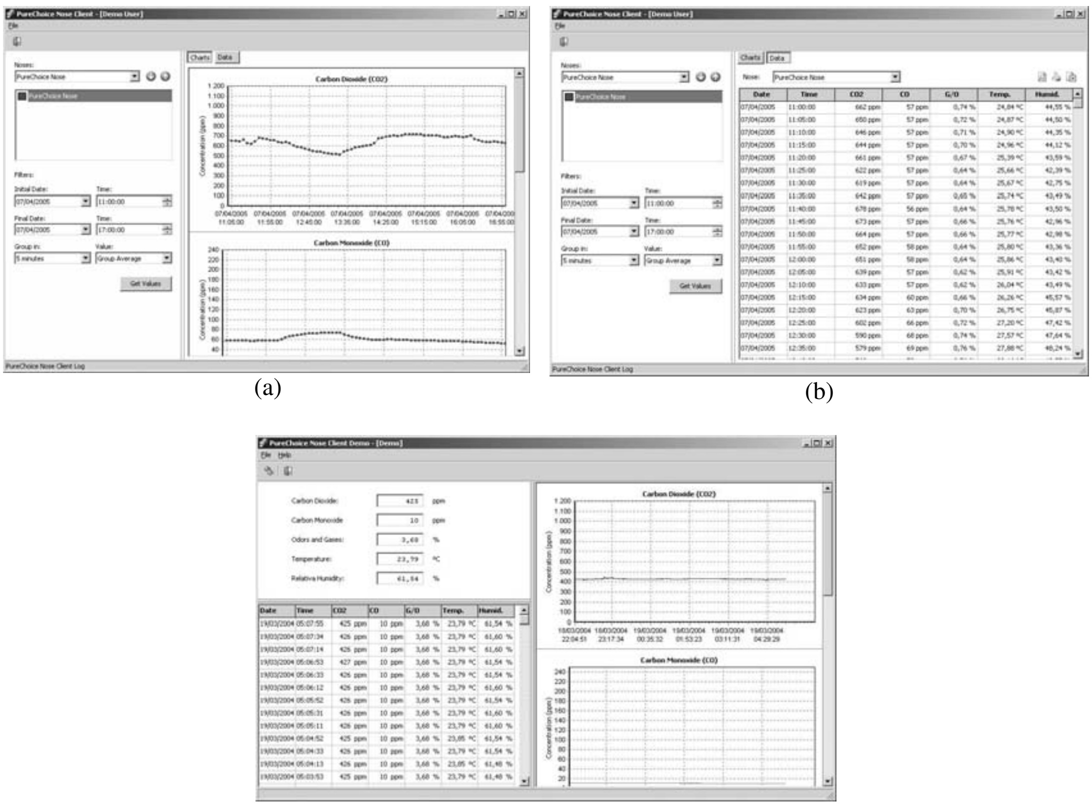

(a) (b)

(c)

Fig. 5 Screenshots of the client application

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