Migrating Legacy Applications to the IEEE 1451 Standards

IEEE 1451.2 Can be Used as a Bridge Between Legacy Systems and Newer Networks Such as Ethernet

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1. INTRODUCTION

This paper discusses how existing products (legacy systems) can migrate into an IEEE 1451-based architecture by mapping network devices as IEEE 1451.2 channels. It reviews the advantages of doing this and describes a pilot project at the University of North Carolina at Chapel Hill (UNC) to provide web access to the university chilled water system. The project ultimately will allow the monitoring and limited control of chilled water systems in about one hundred buildings using the existing campus communications network.

2. DESCRIPTION OF THE PROJECT

The motivation for this project was a mandate from the university to make all operational data available on the campus network in order to provide the information needed to operate the university utilities (chilled water and power) in a more efficient manner. In particular, the chilled water system has installed instrumentation and control solutions that are working fine, but they did not have the network connectivity to enable relevant data to be widely distributed.

What was needed was a simple way to make this available without redesigning the whole control system that is currently in place. In other words, UNC needed a convenient means to *encapsulate* the existing solutions that were present throughout the chilled water system and expose only what was necessary to meet the university mandate.

What was done was to encapsulate a local control solution in such a way as to provide a universal connection to the campus Ethernet LAN consisting of multiple clients supporting commonly available browsers. In this way a GUI (Graphical User Interface) is provided for the local control solution without the need to design custom software for this purpose.

3. NETWORKED CONTROL

In the past, providing a networked GUI for a local control solution required, in addition to the local control hardware, custom software to allow the user to view the process as well as network drivers to interface with the particular network protocol selected. This represents a large development effort that manufacturers of measurement and control equipment had to expend to deliver a workable solution to the end user. The proliferation of network protocols has only made this situation worse.

The functionality of a network connection to a local control solution can be broken down into four levels of functionality as shown below:

Levels of functionality:

I. Remote monitoring – available now

II. SCADA – available now

III. Configuration/Function blocks – available with the IEEE 1451 standards

IV. Plug-n-Play/Self-aware – available with the IEEE 1451 standards

Remote monitoring implies simply reading a parameter form the local control loop and displaying its value on the GUI. SCADA (Supervisory Control and Data Acquisition) implies reading and writing parameters to the local control loop.

Configuration, however, can be more complex. It can range from setting parameters, which control the operation of the local control solution to describing the interconnection of the various function blocks, which define the control algorithm. Typically the configuration most likely to be changed after initial deployment are such things as the auto/manual state and tuning parameters which determine the operation of a PID algorithm. Therefor it is possible to provide a high degree of functionality with a networked GUI by simply providing the means to read and write parameters to the local control solution.

These parameters such as set point, auto/manual status, and tuning coefficients are stored locally in the electronic memory of the local control station and can be changed at the local interface to the controller or remotely at the networked GUI. Since read/writes are made to the same memory either locally or remotely via the network a consistent view of the local control solution is available regardless of location. Also, the local control station will continue to function correctly independent of the network connection.

Level IV functionality requires as a minimum that the device or solution that is connected to the network have memory that is physically connected to it. This insures that information can be conveyed to the network about the device in a standard format that can be used by the network applications. The IEEE 1451.2 TEDS meets these needs which are essential for level IV functionality. The IEEE P1451.1 standard, which is currently out for balloting, provides the network model that will meet the needs of an open interface for network applications.

The initial basic functional boundaries and interfaces defined in the IEEE 1451 series of standards are illustrated in figure 1 (taken from the IEEE 1451.2 standard).

The architecture comprises a network, a Network Capable Application Processor (NCAP), and a Smart Transducer Interface Module (STIM). Note that the transducers themselves are considered part of the STIM. In fact, in order to provide the critical self-identification features, the transducer must be inseparable from the STIM electronics during normal use. For the basic system definition shown, the intended field break is the Transducer-Independent Interface (TII) between the STIM and NCAP.

The IEEE 1451.2 standard also provides a means for manufacturers to encapsulate their proprietary control solutions. This interface standard is intended to provide connectivity of sensors and actuators to a network or digital system but can be extended to connect to a proprietary network used by a manufacturer to implement a proprietary control solution.

This extension, which we are calling a “Network Interface Module” (NIM), can provide an interface to a local control network. This will typically consist of interconnected single loop controllers with their associated process transmitters and final control elements, typically valves or other such actuators. The configuration used for the UNC project is illustrated in figure 2, where we are using Modbus to connect to a Moore Process Automation Solutions Model 354 Process Automation Controller (PAC).

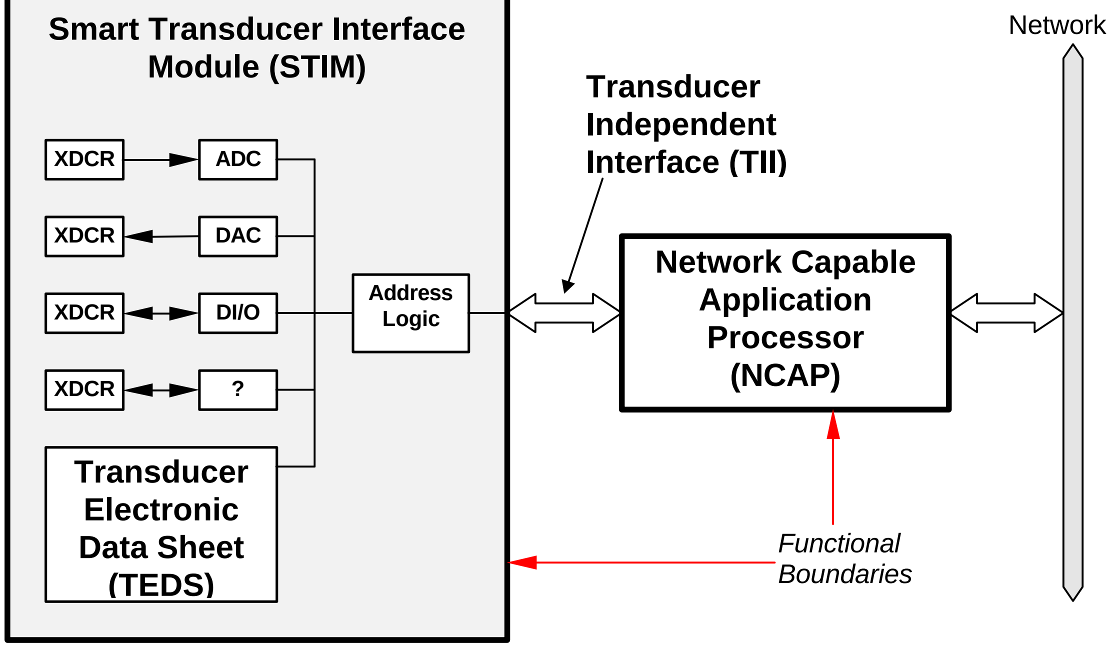

Figure 1. Initial IEEE P1451 System Block Diagram.

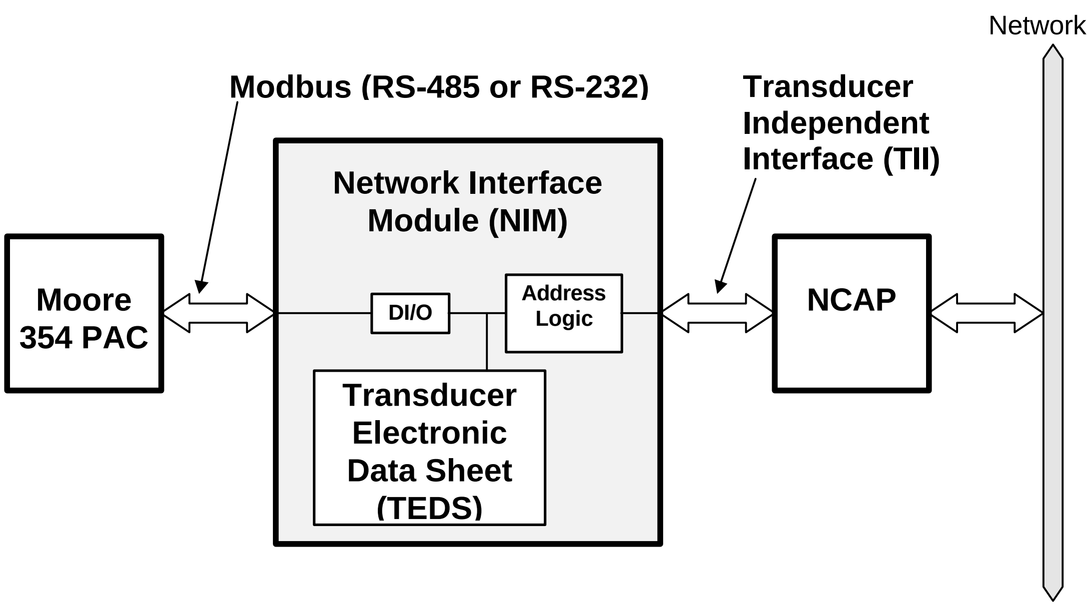

Figure 2. Modbus Legacy System Extension to IEEE 1451.2.

A NIM is not really an IEEE 1451.2 STIM because it does not contain the transducers and because the TEDS is not inseparable from the transducers. However, this distinction is transparent to the NCAP and therefore to users and other devices on the network.

Note that NIMs can be envisioned for any of the legacy networks or communication protocols.

4. NETWORK-BASED CONTROL

Control can be implemented over networks by passing sensor signals and actuator commands over a given network. However, this can introduce problems of stability and lack of robustness caused by the latency and non-determinacy of existing networks, which are outside the control of the control solution provider. Additionally the requirements of a multitude of network protocols make the task of providing a particular control solution to a broad group of end users not worth the required investment.

Control can be divided into two categories: *supervisory* which is not time-critical within the bounds of the network in use and *regulatory* (PID) which is time critical. This project relates to a means to separate these two domains into entities that can be effectively managed and developed by different vendors yet retain a plug and play capability. Specifically, network providers will have a universal method to connect to the products of control solution providers.

The needs of UNC can easily be met with a Network STIM since in this case level III and IV functionality is not needed or desired. It is not desired because the control solution must run independent of the network status and be immune from security issues. In this case the NIM communicates with the local control solution via Modbus and provides an IEEE 1451.2 connection to the NCAP. The TEDS channels are mapped to Modbus registers and limited set point control is provided as actuator channels. However, the user sets tight limits on the range of control by setting desired min and max values on the actuator channels that represent control loop set points.

5. DEMONSTRATION HARDWARE

Figure 3 illustrates the arrangement that is being used at UNC. The campus Ethernet network connects together a series of NCAP/NIM combinations that are, in turn, connected to the Moore 354 PAC controllers.

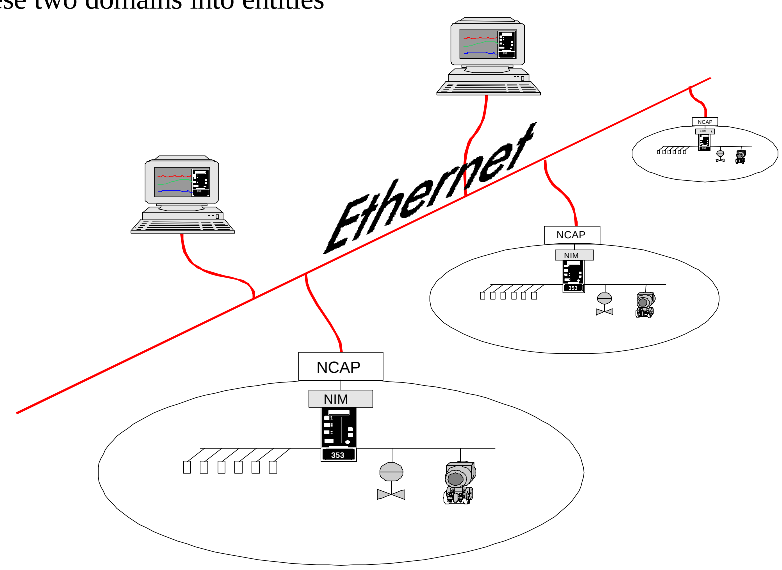

Figure 3. Bridging Islands of Automation with IEEE 1451.

The actual transducers are connected to the PAC controllers using a combination of direct connections and Lonworks. All of this is transparent to the NCAP and to the operator or end user.

The Modbus registers and coils used to communicate with the Moore PAC 354 have been mapped to IEEE 1451.2 transducer channels. The NCAP reads a temperature sensor that is attached to the Lonworks network off the PAC 354 just as if it were a hard-wired temperature STIM.

The NCAP used for the UNC project is the Hewlett-Packard BFOOT-66501 Embedded Ethernet Controller with the optional web server interface. Moore Process Automation Solutions built the initial NIMs to prove the concept. EDC later started building its own version of the Modbus NIMs as a commercial product, and has combined the NCAP and NIM into a single device which has been designated the EDC 1400 Ethernet-to-Modbus Bridge.

The browser-based operator interface for the initial demonstration of the Ethernet-to-Modbus bridge is shown in figure 4. The central portion of this web page is a Java applet. On the right side is a simulation of the faceplate of the PAC 354 controller. In this instance, it is controlling a dummy process in the laboratory at EDC and all variables are simply scaled from 0 to 100%.

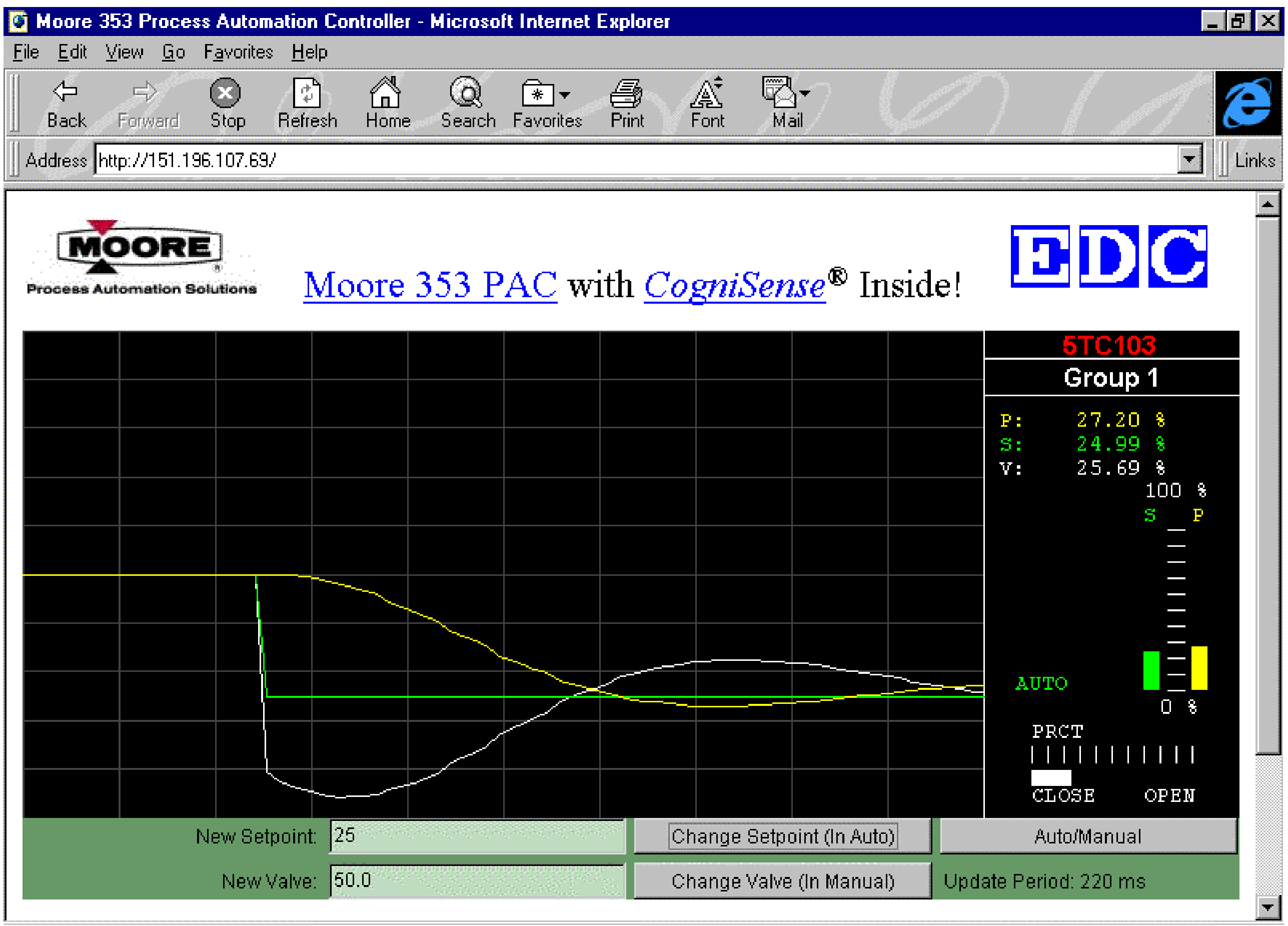

Figure 4. Ethernet-to-Modbus Bridge Demonstration.

The designations follow process control conventions. "P" is the actual value of the process, "S" is the set point or desired value, and "V" is the controller output or valve setting. In this on-line Internet demonstration, which is still running at EDC and can be accessed on their web site at www.smartsensor.com, you can remotely change the process between the automatic and manual modes, and you can change the set point (in automatic mode) or the valve setting (in manual mode) over a range that has been limited by the TEDS. Note that the HP NCAP serves this page. No other computer or server is involved.

The trend chart traces in figure 4 show the results of changing the set point from 50% to 25% in automatic mode. The set point trace drops immediately from 50 to 25, the valve (controller output) also drops immediately, while the process moves more slowly down to the new value. A slight overshoot and oscillation is encountered before the process settles down at the new value.

Figure 5 shows a browser screen for an in-service NCAP and NIM at UNC. This unit is attached to the PAC 354 controller for a small water chiller plant located on an auxiliary site a few miles from the main UNC campus. This shot was captured from a computer in the main chiller water facility and illustrates the ability to monitor remote facilities using in-place infrastructure such as Ethernet and computers with web browsers.

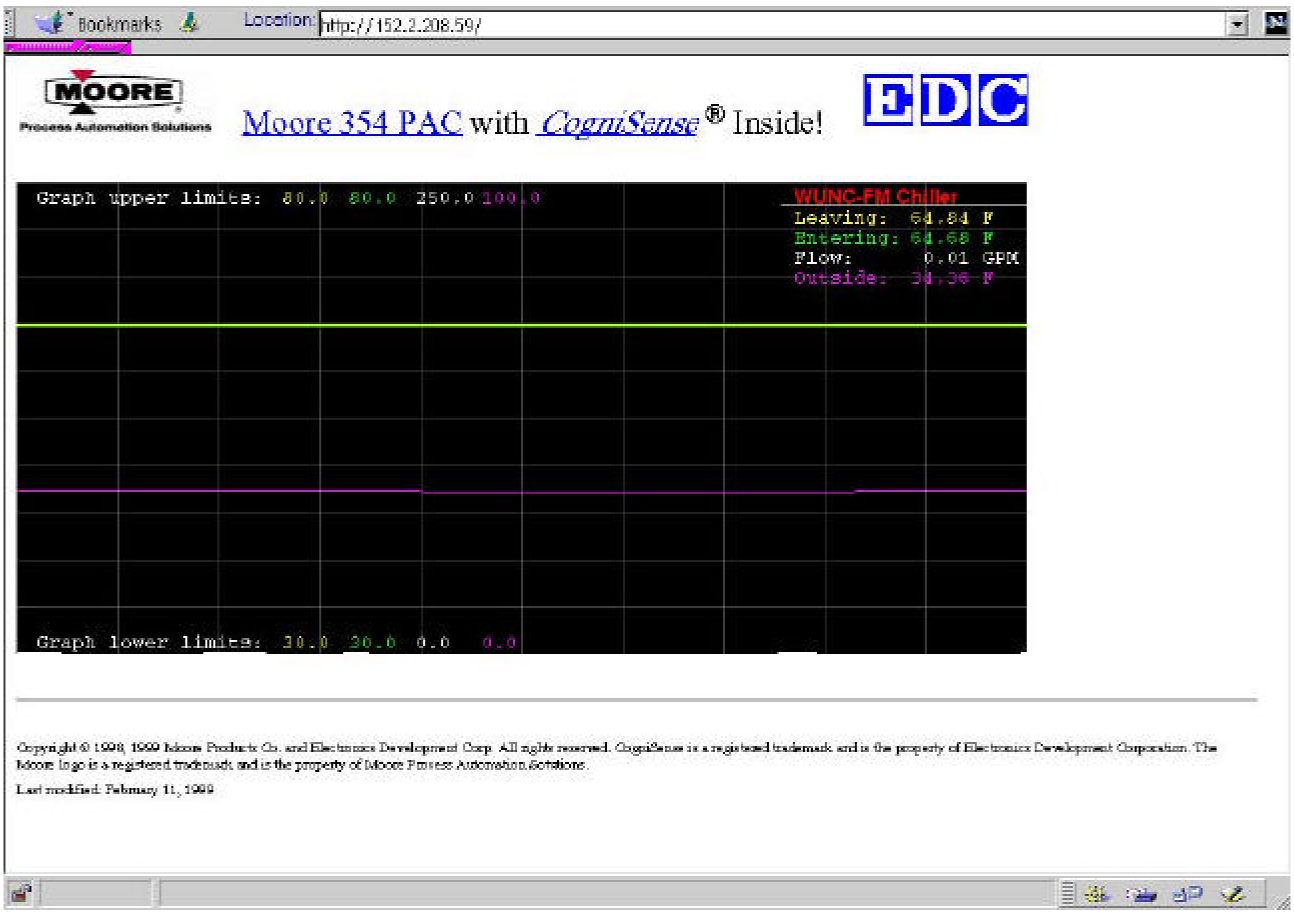

Figure 5. Monitoring Chiller Water Plant at UNC.

Note that the faceplate and control buttons were eliminated from this in-service unit. This is to prevent inadvertent (or deliberate) disruption of the operation of the water chiller. By eliminating the actuator channels from the Modbus to IEEE 1451.2 channel mapping, the NCAP no longer has the ability to change the process in any way.

Note also that, since the operator display is generated by a Java applet, it is a simple matter to change the appearance of the data and to add or remove control functions. This is another example of the power and flexibility afforded by the use of open standards.

At the time this screen shot was captured, the chilled water pump was not running (flow essentially zero), the inlet and outlet temperatures were both approximately 65º F, and the outside temperature was 34º F. The low outside temperature explains why there was not much demand for chilled water that particular day.

Another interesting feature of figure 5 is that the data is presented in the conventional units for the process under control (F and GPM). The underlying data is in strict SI units as required by IEEE 1451.2, but the Java applet converts those to the units most meaningful to the operators.

6. FUTURE PLANS

At the time of this writing, we have installed one prototype Ethernet-to-Modbus adapter on a chilled water plant. We anticipate that by the time this paper is published we will have installed additional adapters on the chilled water control bridges in several buildings scattered around the Chapel Hill campus. These additional units may include a limited ability for remote control of the chilled water bridges.

7. SUMMARY

In summary, why should one take a perfectly good control solution that is well understood by the operators, break it, and reassemble it with one of the multitude of fieldbus protocols that may not be as well understood and may be more difficult to maintain? Of course, put this way, no one would!

However, in the case at UNC there was a need to bridge their islands of automation so that additional value can be obtained in the supervisory category of control, e.g. improved efficiencies on a campus-wide basis without jeopardizing the existing regulatory control system already in place.

The legacy network system extension to IEEE 1451.2 described in this paper has proven able to meet that need in a way that provides flexibility and scalability in a truly open interface.

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