Standardizing EMCS communication protocols

ASHRAE SPC 135P is working to address the communication requirements of all devices used in controlling HVAC&R systems

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THE USE of distributed, microprocessor-based, energy management and control systems (EMCSs) is now a fact of life in the building control industry. Microprocessor-based components are available from many manufacturers and are being installed in ever-increasing numbers. Almost all commercially available EMCSs use proprietary techniques to exchange information among the distributed devices making up the control system. As a result, in most cases, it is not possible to mix products made by different vendors and expect them to work as an integrated system (Newman 1983). Building owners and operators are unhappy with this situation because it forces them to return to the same vendor whenever additions or changes need to be made to their EMCS. Some potential customers, including the U.S. military, have decided to delay purchasing new EMCSs until standards are in place to protect their investment.

Pressure from the building community and a request from ASHRAE Technical Committee (TC) 1.4, Control Theory and Application, resulted in action by the ASHRAE Standards Committee. On January 18, 1987, the committee voted to approve the formation of a Standards Project Committee (SPC) to deliberate the creation of a communication protocol that might become an industry standard. SPC 135P was formed and held its first meeting in June 1987. Membership consists of approximately equal numbers of vendors, users and general interest people.

What is a communication protocol?

A communication protocol is a set of rules governing the exchange of data between two computers. In the broadest sense, a protocol encompasses both hardware and software specifications including the physical medium; rules for controlling access to the medium; mechanisms for addressing and routing messages; procedures for error detection and recovery; the specific formats for the data being exchanged; and the contents of the messages.

The proposed standard being developed is intended to address the communication requirements of all devices that might be used in the control of HVAC&R systems. This includes current devices as well as consideration of the possible requirements of future control equipment. The SPC will not directly address the needs of other types of building services, such as lighting control, and fire and security, although these might be integrated with HVAC control in the future. Through careful planning, the protocol for HVAC&R control systems can be structured to permit extension by the simple addition of protocol services which are specific to the new applications while using others which are included in the standard.

Some people have suggested that SPC 135P should address the protocol requirements for unitary controllers as a first step to accelerate the development process and then address the requirements for higher level controllers. Implicit in this suggestion is the assumption that it is somehow easier to communicate with unitary controllers than other types of controllers, presumably due to their relatively simple functionality compared with "general purpose" controllers. But, this is not so. Analysis shows that the basic elements of communication between HVAC&R controllers are largely independent of the particular devices (ASHRAE 1987). All HVAC&R controllers, for example, need to exchange information about setpoints, parameters for tuning control loops, analog and binary inputs, and analog or binary outputs. There is no fundamental difference between unitary controllers and other types of controllers in this regard. The difference is mainly in the number of inputs, outputs and kinds of parameters which are involved and perhaps the frequency of information exchange. Parameters may vary from application to application but their format and the protocol for their exchange need not differ from one type of device to another.

Consequently, the consensus within the SPC is to address the communication requirements of all HVAC&R control equipment. Any services that the protocol provides which may be applicable to only certain types of controllers can be dealt with by defining classes of operation consisting of subsets of protocol services.

At the other end of the spectrum, it has been suggested that the SPC should only address communication between "front

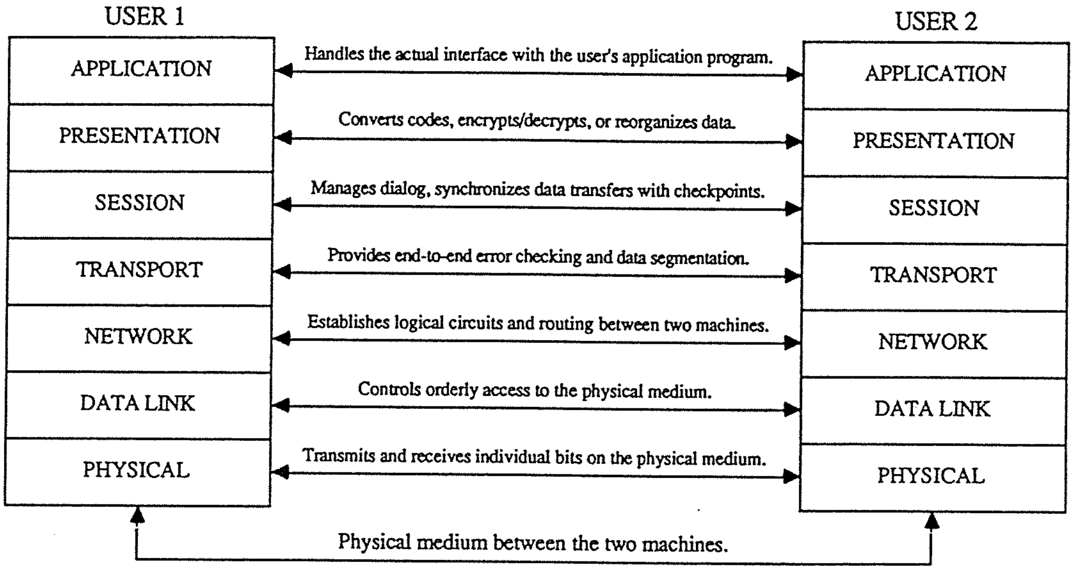

Figure 1—In the OSI model, each computer has equivalent data communication software with layered or hierarchical functionality. Each layer communicates logically with the corresponding layer in the other machine. A "user" is an application program with the need to communicate with another machine.

ends" of control systems allowing proprietary communication protocols to be used at lower levels. Controllers made by different vendors still would not be able to communicate directly. This approach fails to simplify the problem for the same reasons mentioned previously. In addition, such a standard would provide the user with less flexibility in configuring a multi-vendor system than a standard that addresses communication at all levels. For these reasons an approach limited to a "host-to-host" protocol also has been rejected (ASHRAE 1987).

The OSI reference model

There is an overwhelming international trend toward writing computer communication protocol standards based on an architecture called the Open Systems Interconnection (OSI)—Basic Reference Model (ISO 1984). This international standard is essentially a blueprint for developing multi-vendor computer communication protocol standards. In the OSI model, the complex problem of computer-to-computer communication has been broken down into seven smaller, more manageable sub-problems, each of which concerns itself with a specific communication function. In the jargon of the OSI model, each of these sub-problems forms a "layer" in the protocol architecture.

The seven layers are arranged in a hierarchical fashion as shown in *Figure 1*. A given layer provides services to the layers above and relies on services provided to it by the layers below. A key to understanding layered architectures is to think of each layer as a black box with carefully defined interfaces on the top and bottom. The user's application program connects to the OSI application layer and communicates with a second, remote user application program. This communication appears to take place between the two applications as if they were connected directly through their application layer interfaces. No knowledge or understanding of the other layers is required. In a similar manner, each layer of the protocol relies on lower layers to provide communication services and establishes a virtual peer-to-peer communication with its companion layer on the other system. The only real connection takes place at the physical layer.

This approach to communication protocol standards has been adopted by many organizations. Two well known protocols of this type are the Manufacturing Automation Protocol (MAP) and the Technical and Office Protocols (TOP). The U.S. government has adopted the OSI model in its approach to Federal Information Processing Standards (FIPS) and has released an OSI procurement policy called the Government Open Systems Interconnection Profile (GOSIP). Other national governments have begun to develop their own GOSIP programs. Many local area network products are built on the lower layers of the OSI model, and many computer companies are modifying their networks to become OSI compatible or to build bridges to permit connection to OSI networks.

This movement to embrace OSI is a good reason to look at the OSI architecture but, by itself, is not reason to adopt it for EMCS standards. Why is there so much interest in OSI? What are the benefits? What are the costs?

Adoption of the OSI architecture for an EMCS protocol standard provides several potential advantages including:

- Lower hardware cost due to economies of scale. The lower layers will be implemented in silicon. Large quantities of chips for this purpose will be manufactured for the computer industry, and the HVAC&R industry can use the same chips.
- Layered architectures permit updating the standard in a modular fashion. Only the layer being updated needs to be changed. This is important for a rapidly changing technology like computer control systems. This also can reduce the cost of updating implementations to comply with changes in the standard.
- Integrating other types of building services becomes easier because only application layer services need to be added.
- Unique circumstances of a particular job—throughput requirements, distances involved, and the presence of sources of electromagnetic interference—can be accommodated because the physical and data link layers may be changed without affecting the higher layers.

The disadvantages of adopting the OSI approach are increased overhead and complexity. The OSI model was designed to deal with the problems associated with large, complex networks communicating with other networks anywhere in the world. Much of this complexity is not needed in an EMCS. This is a serious problem but it has a simple solution. There is precedent for including only selected layers of the OSI

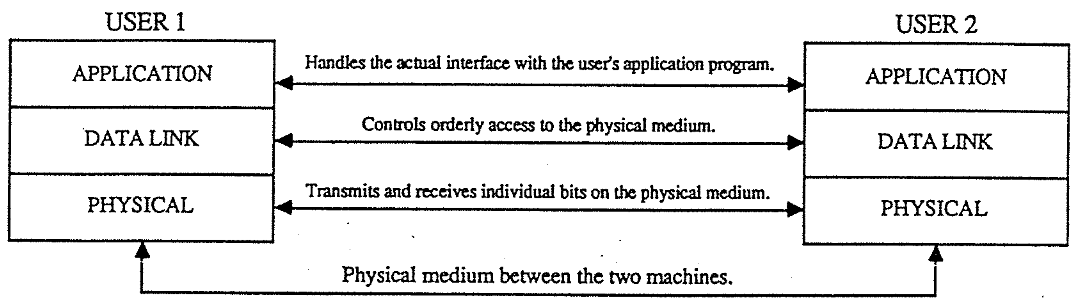

Figure 2—In a "collapsed" architecture, one or more layers of the seven-layer model are omitted. Any missing functionality, if it is required, must be built into the user programs. This three-layer model is the basis for the "Enhanced Performance Architecture" subset of the Manufacturing Automation Protocol known as Mini-MAP.

model in a standard. This is called a "collapsed architecture" and has been used for some realtime control applications in other industries. One example of a collapsed architecture is shown in *Figure 2*.

The approach of SPC 135P

SPC 135P has decided to follow the OSI model but is considering the use of a collapsed architecture. Only OSI layers that provide services useful in EMCS applications will be included in the proposed standard. Precisely which layers will be included is undecided.

The expertise of ASHRAE is in building control, not computer communication. The SPC recognizes that it would not be useful to focus on the protocol issues that pertain to the lower layers of the OSI model. It is the application layer that is the appropriate place to concentrate our efforts and that is what is being done. It is almost certain that standards developed by other bodies will be adopted for the lower layers, possibly more than one in some cases, thus offering designers the possibility of certain cost-performance tradeoffs.

Three separate working groups are currently active within the SPC: the Application Services Working Group, the Object-Types and Properties Working Group and the Data Encoding Working Group. The application layer of the OSI model is where the protocol requirements that are unique to a particular application (e.g., HVAC&R control, lighting, security, fire and smoke control) reside. Lower layers provide services that are presumed to be required for all applications. The Application Services Working Group is addressing the issue of which functions or services need to be provided by the application layer to meet the needs of an EMCS (Bushby 1988). A list of these services has been developed and the group is in the process of formalizing a description of each service, how it will work and how it might interact with other services.

The Object-Types and Properties Working Group is addressing the issue of accessing information through the use of name referencing. The idea is to eliminate the need for knowledge of hardware configuration when requesting information. A name can be used to request a desired piece of information, eliminating the need to specify a particular hardware pin location or a memory address. Requesting a chilled water setpoint temperature, for example, will not require any knowledge of how that information is stored in the controller. In fact, any controller can be represented as a set of objects, each of which maps in a standardized way to the actual hardware and software.

There is a close relationship between standardized object-types and the application services needed in the protocol. If object-types are constructed carefully, a small number of application services which provide an ability to read or change the properties of objects can provide many of the application needs of an EMCS. For example, requesting the current value of a particular property of an object would be done in the same way whether the property represented a sensor reading, a program parameter or a schedule. Reducing the number of application services required can simplify the protocol and make it easier to implement.

The Data Encoding Working Group is developing a way to represent the information content of the communication in digital form. This process involves encoding application service requests and their associated parameters and deciding data formats for representing the properties of objects. One part of this activity amounts to deciding how to represent fundamental types of data such as integers, real numbers and boolean values. As with other aspects of the protocol development, one important consideration is efficiency, i.e., compactness of representation.

A comprehensive approach to the needs of the HVAC&R industry is being taken by SPC 135P to ensure that the resulting standard will stand the test of time in this rapidly changing field. The ASHRAE standard could become the basis for communication protocols that meet the requirements of integrated services embodied in the concept of intelligent buildings. ■

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