Chapter 8

Communication Protocol

PROTOCOL DEFINED

Protocol is the name given to the hardware and software rules and procedures for making sure that any transmission errors are detected. It can also be described as a set of conventions between communicating processors governing the format and content of messages to be exchanged. Protocols can be proprietary, open or standard.

Proprietary

A protocol developed by a company for the exclusive use of that company's customers. Most current building control, fire alarm, and security protocols are proprietary.

Open

An open protocol is one which is in the public domain, and users are provided information and documentation necessary for its implementation. As an example, Xerox made Ethernet and open protocol, as did International Business Machines with its GPAX D protocol. However, it is possible to end up with too many "open protocols" and a loss of control over them.

Standard

An open protocol adopted and endorsed by a voluntary standards organization, or government agency. Such a standard protocol may include certification. IEEE based its 802.4 Standard on the Ethernet protocol. It may take too long for vendors to agree on a single standard, therefore, more than one standard will be needed.

Protocol discussion issues might include:

- What are the major benefits of having open or standard protocols for end users, consulting engineers, system managers and vendors?

- What should be the scope of such an open protocol? Should it be limited to HVAC systems? Or, should it include other systems such as lighting and security? Or, should the protocol be limited to new systems only?

- How best can standards on protocols be developed and maintained?

Almost all commercially available EMSs use a proprietary communication protocol, therefore it is not possible to mix products made by different manufacturers to form an integrated EMS. A building owner may have a DDC-EMS made by vendor "V"; a chiller with microprocessor by vendor "W"; air handling units with integrated sensors and controls by vendor "X"; room sensors controlling terminal units by vendor "Y" and a microprocessor-based fire alarm system by vendor "Z". All five building system components will probably function satisfactorily alone, as stand-alone systems, however they will not have the capability to communicate electronically with each other.

GUIDELINES

Microprocessor-based components are available from many manufacturers including EMSs and unitary control products. However, since each separate vendor has their own ideas of how to configure their equipment into a communications architecture, the result has been an equal number of different communications protocols.

Early on, manufacturers had very little concern for this potential problem. However as pressure from the building owners community increased to focus-on and solve this problem, some manufacturers are beginning to standardize. Certain aspects of their products, such as the

4-20 mA input signal, can be used by all EMS manufacturers.

In January 1987, ASHRAE formed a committee to deliberate the creation of a communications protocol that might become an industry standard. The scope of the committee is to "provide a comprehensive set of messages for conveying binary, analog, and alphanumeric data between devices." Each basic message type will also require the capacity of supplying ancillary information such as reliability, priority, real-time and other related data. This scope will also provide for the format of each data element.

Several protocol guidelines currently developed include the Open System Interconnection (OSI) by the International Standards Organization (ISO); the Public Host Protocol (PHP) and the Public Unitary Protocol (PUP) both by American Auto-Matrix. Two companies have developed and implemented protocols. Manufacturing Automation Protocol (MAP) and Technical and Office Protocol (TOP) both by General Motors; and IBM's Facilities Automation Communication Network (FACN) Protocol running a program called General Purpose Automation Executive-Distributive (GPAX-D). These protocols all attempt to allow interaction between multi-vendor systems.

A formal hierarchical identification of all data communications network functions has been established by the International Standards Organization (ISO) and referred to as the ISO Model for Open Systems Interconnection (OSI). This model, shown in Figure 8-1, identifies seven distinct levels of functional requirements pertaining to data communications network.

Realization of the ideal LAN would require all levels of functions included in the OSI standard; however, not all levels of the OSI standard need to be implemented to provide effective communications in an LAN. If only the lower levels of the standard exist, a LAN can usefully support the multiple applications. In essence, the transmission media and lower level interfaces are common so that data can be exchanged within virtual subnetworks: However, a device in one subnetwork cannot communicate intelligently with a device in another subnetwork because each application is using unique higher level implementations. This LAN would allow messages to be exchanged between these dissimilar terminals, but the message would not be understood. Nevertheless, the backbone LAN permits flexible location and relocation of the various attached equipment.

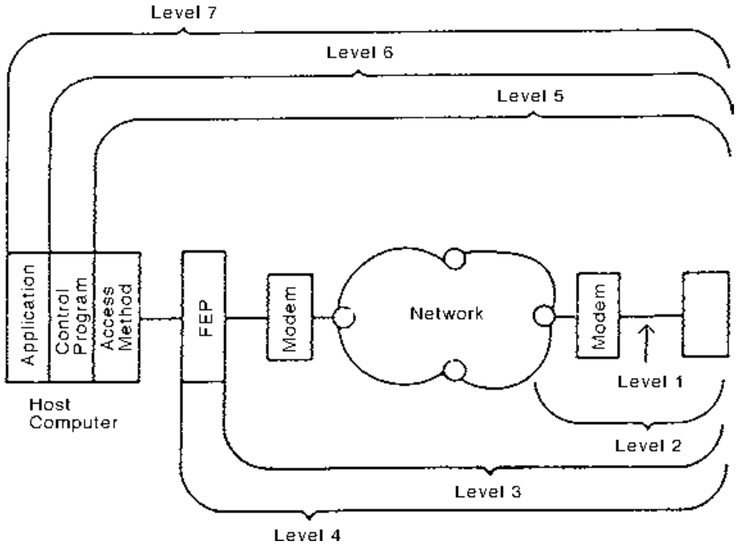


Figure 8-1. Open Systems Interconnection (OSI) Model

International standards are being developed which are defined by various levels. X.25 has been approved through level 3.

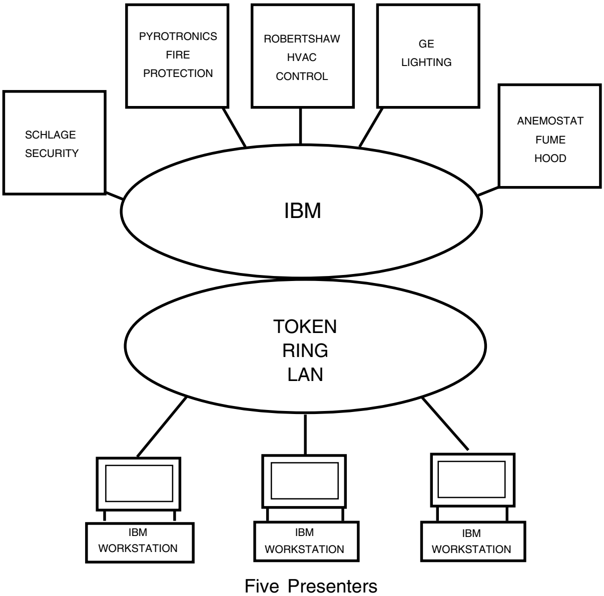
Level 1 — Physical (X.21)
Level 2 — Data Link
Level 3 — Network
Level 4 — Transport
Level 5 — Session
Level 6 — Presentation
Level 7 — Application

DEVELOPING STANDARD TECHNIQUES

While standards associations don't dwell on this fact, an overwhelming number of standards that apply in the computer industry trace their origin to the work of individuals (or individual firms) in the industry rather than standards associations. Standards as basic as the OSI seven-layer communications standard were developed by individuals working in the industry and became official standards only after they had already been adopted as defacto standards.

As demonstrated in Chapter 6, certain manufacturers are utilizing communication schemes developed in the data communication world. Another example of this is shown in Figure 8-2 where five separate manufacturers, each involved with a different building product are integrated into one "unique system." This may appear to be an open protocol however it is actually a proprietary protocol shared only by these five manufacturers.

ASHRAE's Standards Committee has been hard at work deliberating the creation of a communication protocol that might, some day, become a standard throughout the EMS industry. Refer to four articles at the end of this Chapter 8:



- Uses computer technology to integrate formerly separate functions of complementary products into one unique system
- Uses a common, easy to learn, mouse-driven graphical interface built around IBM's Presentation Manager software.
- Displays multi-window, real-time applications for different systems at the same time.
- Supports multiple users through PS/2* workstations over the token-ring network.

Figure 8-2. Robertshaw's Facility Integrator

1. *Energy User News*, 2 pages, January 1987

2. *Energy User News*, 2 pages, July 1988

3. *ASHRAE Journal*, 8 pages, January 1989

In 1991, ASHRAE Standards Project Committee SPC 135P (the "P" is for "proposed") came up with a name chosen for this standard protocol: "BACnet—A Data Communications Protocol for Building Automation and Control Networks. "BACnet could have a positive impact in running a BAS efficiently such as:

- It will provide "gateways to let new systems into the fold." So, rather than presenting a handicap to owners of existing systems, BACnet will increase the potential of their systems.

- It will help relieve the burden on users with respect to having to deal with different programming languages.

- It will provide for common operator interfaces by allowing "the sharing of information between panels of different manufacturers."

- It will aid owners of DDC systems by allowing the sharing, on screen, of information from the panels of different manufacturers.

- It will help establish a truly competitive bidding process in the EMS market. In other words, you, as a present owner of one manufacturer's system will not be "stuck" with that manufacturer at upgrade time.

One approach to BACnet compliance is the use of gateway technology, which according to some, is economical and provides minimal risk to vendors and users. A gateway is a computer that connects two different communications networks together. The gateway will perform the protocol conversions necessary to go from one network to the other. A bridge, by contrast, is a device that connects two networks of the some type together.

Some BAS companies have used the term Integrator to describe their connectivity to qualified third-party controllers.

In general, a EMS vendor's Integrator panel contains the necessary protocol conversions to connect to chillers, boilers, refrigeration units, electric switchgear, AC drives, fume hoods, and control equipment from other manufacturers. See Figure 8-3.

The cost of these panels can range from $5,000 to $8,000 each and so the benefits obtained (monitoring as well as control) must be carefully examined.

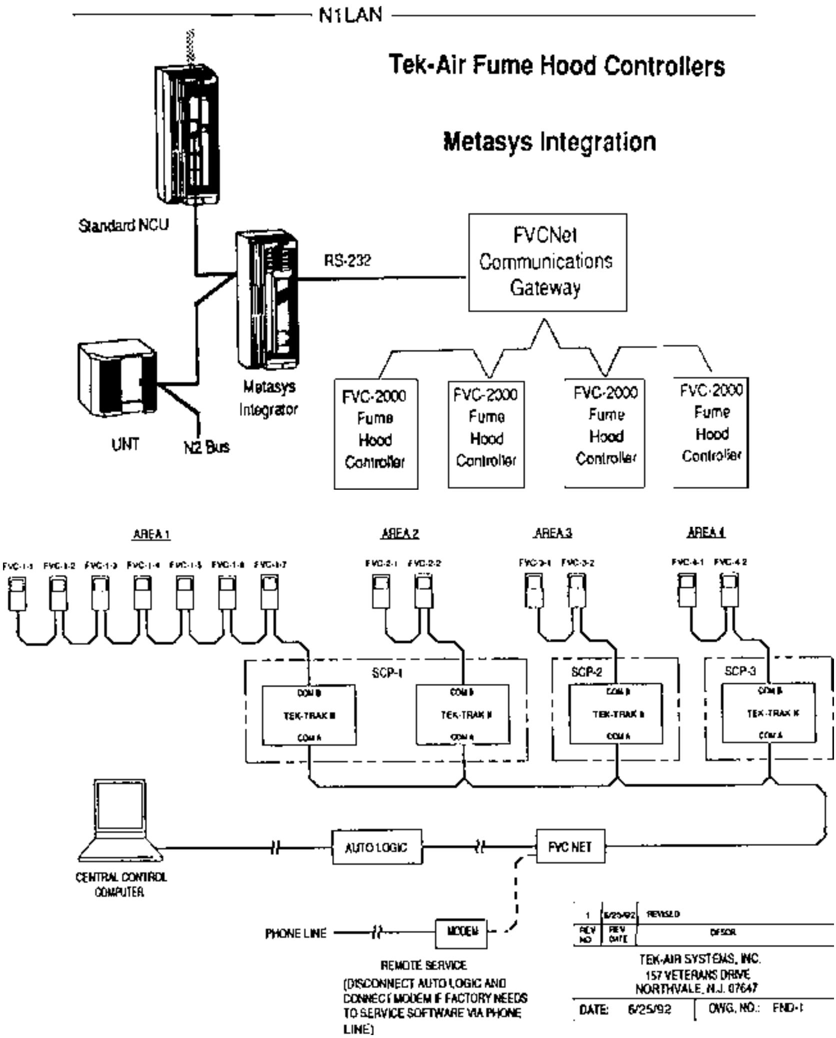


Figure 8-3. Gateway/Integration

From *Energy User News*—January 26, 1987

ASHRAE Forms Group to Seek Standard EMS Protocol

By Vito Racanelli

NEW YORK—The Standards Committee of The American Society of Heating, Refrigerating and Air Conditioning Engineers (Ashrae) approved the formation of a special project committee aimed at defining a standard communications protocol for energy management systems, Energy User News Has learned.

The group's decision, reached on the opening day of its Winter Meeting here, was announced at an EUN panel discussion last Monday by H. Michael Newman, vice chairman of the Technical Committee on Control Theory and Application (TC 1.4), which requested the formation of the special project committee.

Newman, manager of facilities engineering at Cornell University, Ithaca, N.Y., and EUN's institutional energy manager of 1986, has been nominated for the position of chairman of the new committee.

A standard protocol, if incorporated by manufacturers into their EMS systems, would allow users who are configuring multiple EMS installations to link equipment from different vendors, and would facilitate shared monitoring and control between different vendors' EMS.

This, in turn, will allow users greater freedom in specifying equipment, and offer more options in a competitive bid situation, according to Newman. Users would not be locked into buying one vendor's equipment, he added.

The time frame in which an Ashrae standards committee can arrive at a standard EMS protocol is uncertain, hinging on wide vendor cooperation, Newman, said. "The time it will take to define a standard depends on how soon and how intensely the various vendors get involved. If they decide to play ball, it could take six months to a year. If their cooperation is less than complete, it could take forever," he continued.

He added, however, that the vendors seem to support the idea of a standard protocol, and that he was "fairly optimistic" about the timely establishment of a standard.

At EUN's panel discussion on EMS standardization last Monday, Newman said that a standard could probably be developed in one to three years. Other panelists from such EMS vendors as Honeywell Inc., Minneapolis; Johnson Controls Inc., Milwaukee; MCC Powers, Northbrook, Ill.; Novar Controls Corp., Barberton, Ohio; and The Trane Co., LaCrosse, Wisc., said that their respective companies would support Ashrae's efforts to define a standard communications protocol. A transcript of the panel discussion will appear in the March edition of Energy User News Magazine.

EUN reported last year that EMS manufacturers such as Honeywell, Johnson and MCC Powers were generally skeptical of current software approaches to linking disparate EMS systems to a single host computer, citing what they considered a limit to the amount of control functions that could be shared by systems linked to a host by software (see Feb. 24, 1986 EUN, page 1, and March 3, 1986 EUN, page 9). Terry Weaver, vice president of the Electronic Systems and Services Division of Johnson Controls, said at that time that forming a standardization committee within the industry would be the most positive step toward a standardization of EMS protocols.

The committee's purpose is specifically to define the content and format of messages communicated between computer equipment used for the digital monitoring and control of building HVAC systems.

Newman's nomination as chairman of the new committee is subject to approval by the Ashrae Standards Committee, which will convene in three months.

No one has been named to the new committee, according to Newman. However, he added that the committee will be made up of 5 to 13 members from EMS manufacturers, the National Board of Standards, the National Research Council of Canada, Ottowa, and users.

The committee will then prepare the technical content of the standard and make it available for public review.

Users interested in participating in the committee should contact H. Michael Newman, Ashrae Standard Project Committee, 135 P, 1791 Tullie Circle, NE, Atlanta, GA 30029.

From *Energy User News*—July 11, 1988

Ashrae Protocol Group Adopts Message Syntax

By Richard Mullin

OTTAWA, ONTARIO—Ashrae's standards committee studying the development of a communications protocol for building controls systems agreed at its meeting last month to adopt a message syntax that will be used in its final protocol, according to Michael Newman, chairman of the committee.

The committee held its third full meeting during Ashrae's summer convention here. Newman and others in attendance said the event was characterized by a greater spirit of cooperativeness among the various controls firms than has been evident at previous meetings. "We're out of the political issues and into the technical issues," Newman said.

The Abstract Sylitax Notation (ASN.1) adopted by the committee is an International Organization of Standards (ISO) syntax notating the components of messages that will be conveyed by the protocol. It essentially establishes a language. The committee's Primitive Data work group will, using ASN.1, begin work on encoding data for the protocol, which will establish the type of data to be transmitted, according to Lawrence Gelburd, director of firmware engineering for American Auto-Matrix, Export, Pa., and head of the committee's object type and properties group.

Newman, who is the manager of facilities engineering, computer section, at Cornell University, Ithaca, N.Y., said the group is currently studying various national and international communications standards, such as the Manufacturing Automation Protocol (MAP), a seven-layer local area network under development by General Motors and other users and system vendors for factory automation.

Newman said the Ashrae committee's protocol will likely emulate Mini MAP, which includes the physical, data link and application layers of the full MAP system—the seven layers of which are still not fully defined.

"Every industry has gone through this," said Newman. "There are standards for office automation, electronic fund transfer, automated tellers, all of which use an ISO-OSI (open systems interface) layered architecture. We are trying to make sure we don't fly in the face of the other standards."

Commenting on a shift in the committee's emphasis, Gelburd said, "The whole tone is more like 'let's get a first draft together,' not 'should we get a draft together.' Everybody has their shirt sleeves up and is cooperating. Everyone sees the handwriting on the wall."

Joe Prokop, supervisor, advanced technologies for Johnson Controls Inc., Milwaukee, agreed. "It's no longer a question of whether there should be a protocol or if Johnson should comply. It's a given. A year ago we wondered if the thing would fly or if it was worth the time."

While agreeing that the committee members are cooperating more, Gideon Shavit, chief engineer with Honeywell Inc.'s Commercial Buildings Group, Minneapolis, raised a long-running issue of contention in an interview with EUN last week—the issue of where the protocol should reside. While many on the committee are pursuing a controller-to-controller approach, Shavit said a system-to-system method in which each manufacturer's components operate as autonomous "islands" may be more cost-effective for users.

A controller-to-controller method may create a situation in which system failures are difficult to identify, whereas a system link would corral problems within one vendor's patch of equipment, he said.

Extra cost with the controller-to-controller method would arise from the need to purchase extra monitoring equipment or even establish a third-party service entity for mixed vendor systems, said Shavit.

Newman, however, said that Shavit may be concentrating on an application that is too specific. The committee, he said, is not focusing on where a protocol should reside, but simply on a method of exchanging information between any type of system link.

Prokop and Newman said the committee has not compiled statistics on the overall number of users who feel they would benefit from a protocol—a major issue of contention at the time that the protocol issue emerged (See Feb. 24, 1986 EUN, page 1).

From *ASHRAE Journal*—January 1989

Standardizing EMCS Communication Protocols

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

By Steven T. Bushby and H. Michael Newmam
Member ASHRAE *Member ASHRAE*

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 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 multivendor 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 multivendor 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

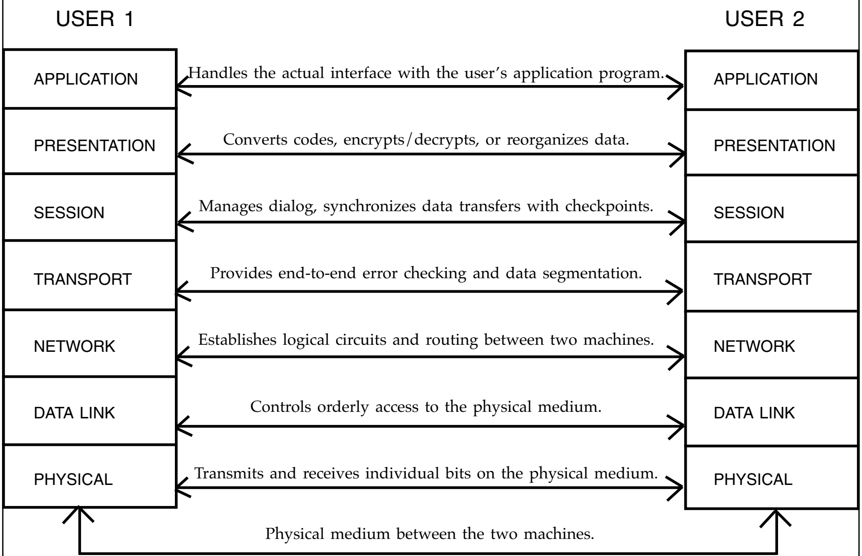


Figure 1—In the OSI model, each computer has equivalent data communication software with layered or hierarchical functionality. Each layer communicates logically with the corresponding layer in. the other machine. A "user" is an application program with the need to communicate with another machine.

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 model in a standard. This is called a "collapsed architecture" and has been used for some real-time 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.

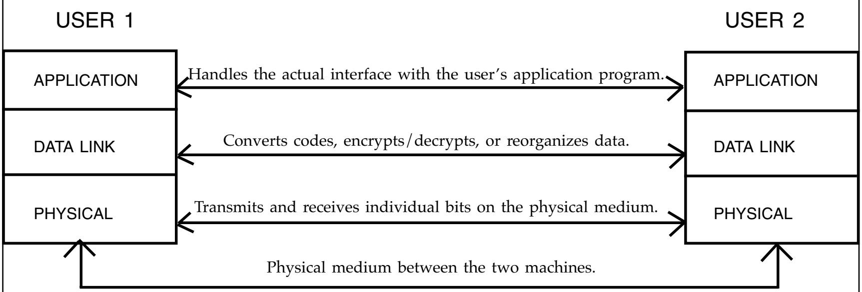


Figure 2—In a "collapsed" architecture, one or more layers of the seven-layer model are omitted. Any missing functionality, if it is required, must be built into the user programs. This three-layer model is the basis for the "Enhanced Performance Architecture" subset of the Manufacturing Automation Protocol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

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.

References

ASHRAE 1987. "Minutes of SPC 135P Application Services Working Group. December 10, 1987," SPC 135P AS-OO3.

Bushby, ST 1988 "Application L&M Communication Protocols for Building Energy Management and Control Systems." *ASHRAE Transactions*, Vol. 94, Pt. 2, Paper No. 3174.

ISO, 1984, *ISO Standard 7498,* "Information Processing Systems—Open Systems Interconnection—Basic Reference Model." International Organization for Standardization. Available from ANSI, 1400 Broadway, New York, New York 10018.

ISO. 1987. *ISO DIS 9506.* "Manufacturing Message Specification—Part 1: Service Definition," International Organization for Standardization. Available from ANSI, 1400 Broadway, New York, New York 10018.

Newman, H.M., 1988. "Data Communications in Energy Management and Control Systems: Issues Affecting Standardization." *ASHRAE Transactions*, Vol. 89, Pt. 1, Paper DC-83-5 No. 3.

About the authors

Steven T. Bushby is an engineer in the mechanical systems and controls group, building environment division, Center for Building Technology, National Institute of Standards and Technology, Gaithersburg, Maryland. He received a bachelor's degree in chemical engineering from Northwestern University and a master's degree in chemical engineering from Colorado State University.

H. Michael Newman is manager of the facilities engineering computer section. Cornell University, Ithaca, New York, which oversees the university's extensive multi-vendor EMCS. He received his bachelor's and master's degrees in engineering physics from Cornell and did postgraduate work in astrophysics in the NASA Center for Radiophysics and Space Research.