CIP: Not Just Another Pretty Acronym

Bringing control services to any network, from DeviceNet to Ethernet

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Although we live by the ideal that people are created equal, the same is not true for the things that people create. Just put the now-extinct Yugo side by side with any vehicle in the BMW class. One – though you'll have to guess which – undeniably is better than the other.

No matter what product category you place under the microscope, there is always quality stratification. This is particularly evident in the technology industry. A generic compact disc player, for example, is not the equal of a high-precision, high-fidelity player that would make an audiophile drool. And when the focus shifts from audio equipment to automation networks, ControlNet, DeviceNet and EtherNet/IP dominate in technological advantages and performance.

All Networks are Not Created Equal ControlNet, DeviceNet and EtherNet/IP have been designed to change with the users needs and not become obsolete. To understand the staying power of these networks, it is necessary to examine how a network is created. The seven-layer open-system interconnect (OSI) model represents the components of a standard network architecture (Figure 1). But while all open networks have all seven tiers, the technology component at each level gives users different options and capabilities. The one thing that sets ControlNet, DeviceNet and EtherNet/IP apart is the fact that they share the control and information protocol (CIP) as their application layer (layer 7).

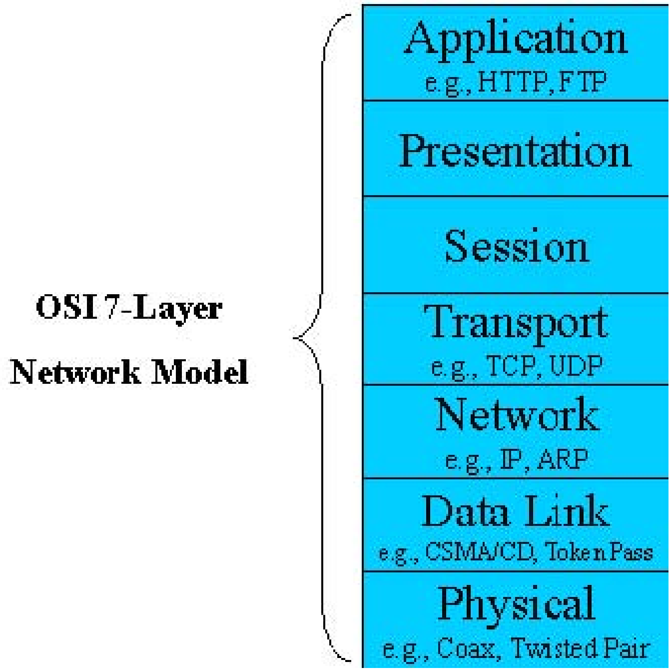


Figure 1

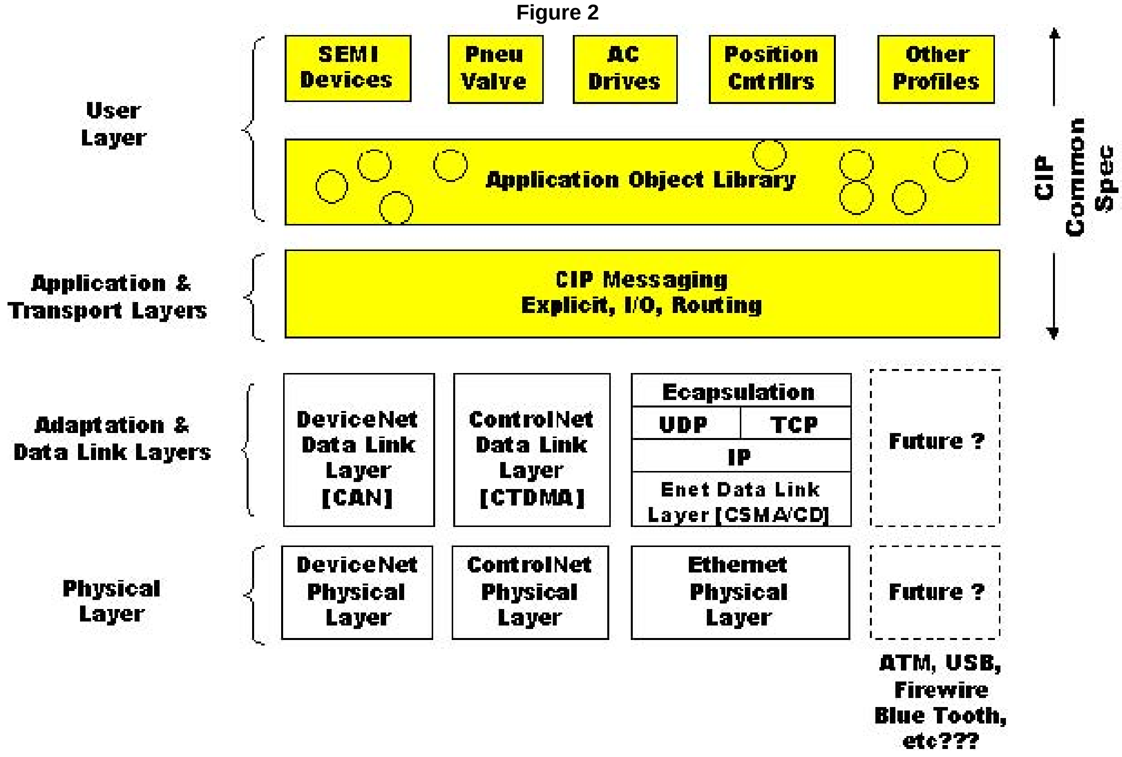
OSI Model. This seven-layer model – including examples from the Ethernet realm – represents the basic networking architecture.

In terms of industrial communications, CIP is a major differentiator. It is an object-based approach to designing network-compatible control devices that encompasses the data-addressing method and the message-exchange rules for every data packet sent over a network. Along with of sea of supportive customers and vendors, CIP has received worldwide acceptance from both the International Electrotechnical Commission and European Committee for Electrotechnical Standardization. This makes it the luxury sedan of application layers – putting the networks that use it at the head of the class.

A common application layer, such as CIP, is the key to advanced communication and integration between networks. CIP builds in a standard set of services for control, configuration and data collection, and provides benefits such as: media independence; fully defined device profiles; control services; multiple data exchange options; seamless, multi-hop routing; unscheduled and scheduled communication; and producer/consumer services.

Media Independence CIP was designed to be wire independent, meaning it can work with any data-link and physical layer. While most application-layer protocols are thoroughly intertwined with the entire stack, CIP is more like a separate specification, making it easy to adapt it to various lower layers (Figure 2).

Figure 2



Media Independence. CIP can merge with virtually any physical or data-link layer. To date, this has included DeviceNet, ControlNet and standard Ethernet (to form EtherNet/IP).

Why is this important? Each physical media has different environmental and application capabilities. If an end user needs an intrinsically safe network, for example, it will impact the type of media or data-link layer used. As a result, the manufacturer usually ends up with an application layer that meets their lower-layer requirements. Because there are several environments in a single plant, multiple networks are usually needed. So unless you migrate to network media like DeviceNet, ControlNet and EtherNet/IP, there will be numerous application-layer protocols operating at the same space. This leads to drastic differences in how devices are configured, data is exchanged, etc. And it also affects and the training and maintenance costs for users, and product development costs for device makers.

Plus, as commercial technology evolves, CIP can migrate to networks that emerge as viable plant-floor options (e.g. Firewire/1394). This allows users and device makers to adopt and integrate new technologies without scrapping their previous investments.

Seamless, Multi-Hop Routing CIP was designed with routability in mind. It provides a common routing method so that you can easily network information from EtherNet/IP to ControlNet to DeviceNet, or any combination thereof. While it is possible to use a gateway to connect networks with dissimilar application layers, gateways are more expensive, typically require significant configuration/programming and generally reduce the data available to the upper levels. Since CIP routing was designed to work in conjunction with Internet Protocol (IP) routing, you can browse from anywhere on the Internet through a CIP router. As a result, you can see down to the smallest sensor on DeviceNet and view its diagnostics or change its configuration (assuming appropriate security access, of course).

Fully Defined Device Profiles A CIP device profile fully defines a device as viewed from the network. Device profiles model a device as a specific collection of objects and any interaction(s) among the objects. For each device type the profile identifies the required objects, and which attributes and services of those objects are mandatory. This ensures devices are interoperable and provides a mechanism for interchangeability among devices of the same type, even though they may be from different vendors. Others "advertise" such profiles, but from a practical standpoint these networks often provide little more than simple identity (i.e. they tell you if a device is a drive or motor starter and provide a list of device parameters with no common defined behavior). In other words, they have no real object model.

By using profiles defined by CIP, the functionality of a particular device is broken down into logical elements (i.e. their objects). A motor starter, for example, consists of an identity object, an overload object and a discrete output object. The same overload object is also used in the soft start and AC drive profiles. That means the configuration options, run-time data and diagnostics associated with the overload protection function of a motor starter, soft start and drive have the same base elements. This delivers the portability, reuseability and consistency that product developers and user's crave.

In addition, developers can easily port a DeviceNet device onto EtherNet/IP because the application objects – defining how the device works, what it does and what it can communicate – are the same. Regardless of which CIP network the device is connected to. Because each device type has the same required objects, devices from different vendors have the same behavior when viewed from the network. In addition to outlining the required device parameters, these profiles allow for vendor-specific, value-added additions. However, CIP specs require the default (i.e. unconfigured) behavior for such options to allow the device to act the same as the defined, open profile. This preserves multi-vendor interoperability and interchangeability.

Control Services CIP is a connection-based protocol that logically joins objects (i.e. end points) together across a network. Data exchange on connections can be uni-directional, bi-directional or multicast. When an I/O connection is established, the devices agree on the data to be exchanged, the time-out between them and the exchange trigger mechanism.

With I/O control messaging, immediate and precise notification of errors is essential to protect employees and expensive equipment, and to troubleshoot quickly. CIP allows all sides of the connection to maintain a configurable timer based on the expected packet rates so they can quickly determine when communication is lost. If a time-out occurs, fault action is taken and the device(s) go to a predetermined state (based on a user configuration).

CIP also provides run-idle indication. Run-idle indication sends connections into an "idle" state when the user puts a controller, for example, into program mode. This is important because when one of the end points of a connection is idle, the others are made aware that the data it is producing (or consuming) may not be actively updated (or applied). Devices can then locally execute their pre-configured idle action.

Multiple Data Exchange Options I/O triggers, like polling, cyclic or change-of-state, are the different methods of exchanging data on I/O connections. Depending on the application, one of these methods will make the most sense. While CIP gives the flexibility to choose between the triggers, most control protocols usually only provide one method. CIP allows you to select trigger and expected packet rate on a per-connection basis (Table 1).

Polling: Controller asks each device for messages

Cyclic: Endpoints send their messages at pre-determined intervals

Change of State (CoS): Endpoints send their messages when a change occurs

Table 1

	DeviceNet	**ControlNet**	**EtherNet/IP**
Message Types			
I/O Control (implicit)	✓	✓	✓
Messaging (explicit)	✓	✓	✓
Both at the same time	✓	✓	✓
Node Relationships			
Master/Slave	✓	✓	✓
Multi-Master	✓	✓	✓
Peer-to-Peer	✓	✓	✓
I/O Exchange			
Polled	✓	✓	✓
Cyclic	✓	✓	✓
COS (Change of State)	✓	✓	✓
Delivery Mechanisms			
One: One (Point-to-Point)	✓	✓	✓
One: Many (Multicast)	✓	✓	✓
One: All (Broadcast)	✓	✓	✓
Routable Protocol	✓	✓	✓

Complete Control. CIP provides a complete set of services required for control for ControlNet, DeviceNet and EtherNet/IP – including multiple I/O exchange options.

If you have an application that needs data produced at the same rate, such as every 10 milliseconds, you can use cyclic. In another application where the data doesn't change very often, but you need to know right away when it does, CoS makes the most sense. With CoS, data is sent only when there is a new value or at the scheduled "heartbeat" rate - which ever happens first. The heartbeat allows the application to distinguish between "there's been no change of state" and "the connection has been lost."

Unscheduled and Scheduled Communication CIP also has the ability to work with the data-link layer (i.e. layer 2 of the OSI model) to provide the most efficient data delivery. Multiple communication methods help deliver messages efficiently, which is necessary for ultimate control of an application. The issues surrounding the transportation of data packets is best described by looking at the transportation choices people have. When you drive a car, for example, you can access the freeway at any time. However, thousands of other people may have picked the same option. The freeway could be stop-and-go or completely free of traffic. You eventually get to your destination, but you risk being extremely late. This is similar to unscheduled data transportation.

If a car is not viable, another option is the train. With this mode of travel, you arrive at the station and buy a ticket for train 12 heading from Cleveland to Chicago. The train has predetermined departure and arrival times, and a reserved track (much like scheduled communication). You will arrive on time. The train may not be as convenient or flexible as a car, but a reserved seat on the train with predetermined arrival and departure times is necessary when precision is critical.

With some automation networks, you are locked into a specific type of travel due to the application layer the network uses. This is not the case with a CIP-based network, because it offers the full spectrum of travel options for your data.

Producer/Consumer Services It is important to have a protocol at the application layer that allows you to take advantage of producer/consumer services. Producer/consumer is a term that references the method in which information is shipped on the data-link layer. Using producer/consumer, the data "producer" puts a number at the front of each packet. This is what's usually referred to as the data identifier or connection ID. The message is then sent out of the network and each device screens the ID to determine if the data is for its consumption. If so, the device becomes the "consumer." As a result, multi-cast communication happens naturally and efficiently in a producer/consumer environment. That's because the user can configure each device to listen for and consume data with specific connection IDs (while ignoring the rest of the traffic).

The alternate to the producer/consumer model is source/destination. With the source/destination model, nodes only receive packets that contain their destination (DST) node number (Figure 3). If more than one node needs the same data it must be transmitted multiple times. This is inherently inefficient. And it can cause synchronization problems as nodes needing the same data get it at slightly different times.

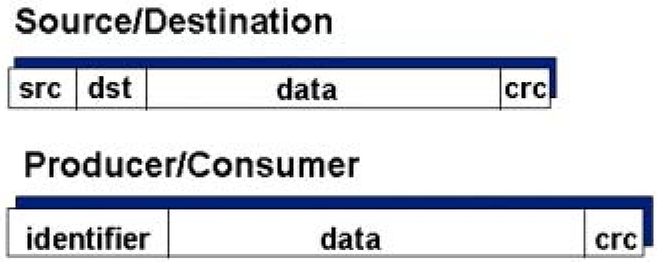


Figure 3

Producer/Consumer Communication. Instead of data identified as source to destination, it's simply identified with a unique number. As a result, multiple nodes can consume the same data at the same time from a single producer, resulting in efficient use of bandwidth.

Most industrial-networking protocols are designed for source/destination communication (master/slave is an even more limited subset). CIP, however, joins forces with producer/consumer technology at the data-link layer to offer a superior message-delivery mechanism.

When coupled with producer/consumer, CIP allows for master/slave, peer-to-peer, multicast and broadcast communications. Since it supports all of the major communication relationships useful for automation, it really is the most flexible and complete protocol. And it’s another reason CIP networks are future proofs.

Yugo or luxury sedan? In a perfect world, every network on the market would provide the same range of services and work in seamless harmony with all competitors. And cats and dogs would peacefully coexist. At the outset of the 21st century, however, neither has happened.

As a result, it’s important for customers to recognize that technologies are stratified and to invest wisely. DeviceNet, ControlNet and EtherNet/IP use CIP. And whether comparing the Yugo to a high-performance automobile or an average application layer to CIP-one undeniably is better than the other.

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Publication NETS-WP004A-EN-P — July, 2001