THE CIP ADVANTAGE:
PROVEN AND FUTURE-PROOF, CIP PROVIDES A UNIFIED ARCHITECTURE FOR DELIVERING STANDARDS-BASED OPEN NETWORKING TECHNOLOGIES THROUGHOUT THE ENTERPRISE

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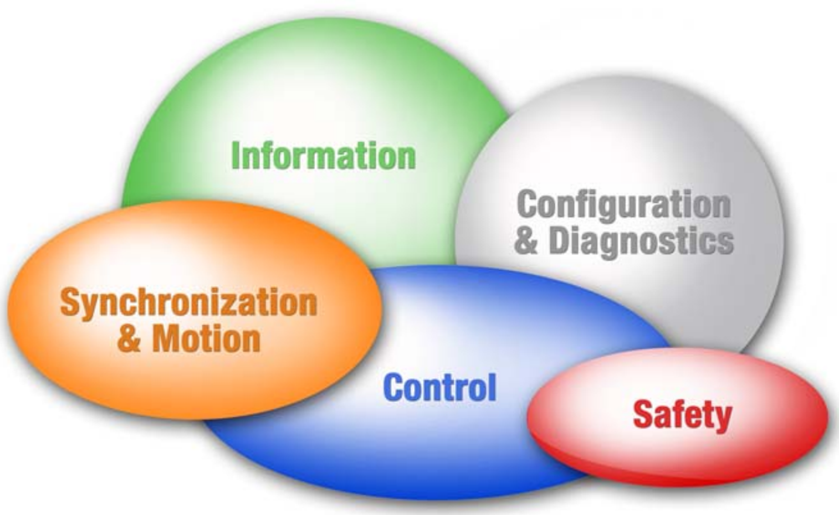
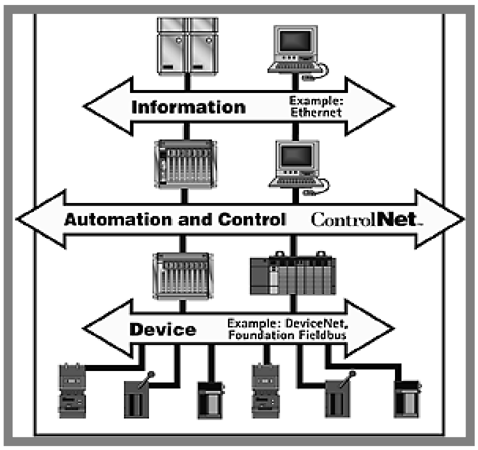
Summary

As a single, media-independent platform that is shared by a variety of networking technologies, the Common Industrial Protocol (CIP™) provides the interoperability and interchangeability that is essential to open networks and open systems. CIP Networks allow manufacturers worldwide to integrate their manufacturing networks—including control, safety and synchronization—with enterprise-level Ethernet networks and the Internet. A proven and future-proof network architecture, CIP allows users to benefit from the many advantages of open networks today, while protecting their existing automation investments when upgrading in the future.

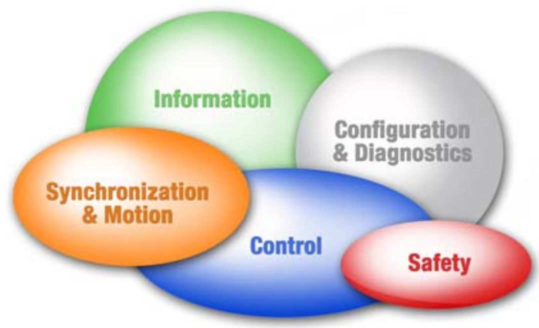


The CIP Value Proposition

Traditionally, networks used in manufacturing enterprises have been optimized for performance in specific applications: most commonly for device, control, information and safety. While well suited to the functionality for which they were designed, these networks were not developed with a single, coherent enterprise architecture in mind. Since efficiency, reliability and, ultimately, profitability are generally dependent on having more than one of these capabilities, manufacturers have been forced to implement several different networks, none of which communicates innately with the other. As a result, most manufacturing enterprise network environments are characterized by numerous specialized—and generally incompatible—networks existing in one space.



Traditionally, manufacturing networks were optimized for performance in specific applications but were not developed within a single, coherent enterprise network architecture.



Now, as manufacturers require seamless connectivity throughout the enterprise, hierarchically-based network architectures are being replaced with application-based architectures. As a result, seamless, multi-hop routable networking is starting to displace copper and wire on the plant floor.

Today, however, corporate expectations for the manufacturing automation network landscape have changed dramatically, thanks to the rapid and ubiquitous adoption of Internet technology. Companies of all sizes, all over the world, are trying to find the best ways to connect the entire enterprise. No longer is control of the manufacturing processes enough: the new manufacturing mandate is to enable users throughout the company to access manufacturing data from any location, at any time, and to integrate this data seamlessly with business information systems.

During recent years, a rapidly increasing number of users worldwide have looked to "open" systems as a way to connect their disparate enterprise processes. However, the great promises of open systems have often gone unfulfilled. The devices, programs and processes used at the various layers of the seven-layer Open System Interconnect (OSI) model have different options, capabilities and standards (or lack of). Integrating these networks requires extra resources and programming. Even then, gaps between the systems often cannot be fully and seamlessly bridged. Consequently, users compromise their investments and rarely achieve all of the productivity and quality benefits promised by open network technology.

Common application layers are the key to advanced communication and true network integration. The Common Industrial Protocol (CIP™), managed by ODVA, allows complete integration of control with information, multiple CIP Networks and Internet technologies. Built on a single, media-independent platform that provides seamless communication from the plant floor through the enterprise with a scalable and coherent architecture, CIP allows companies to integrate I/O control, device configuration and data collection across multiple networks. This ultimately helps minimize engineering and installation time and costs while maximizing ROI.

CIP provides users with many networking advantages, including:

- Comprehensive suite of messages and services for manufacturing automation provides functionality needed for control, configuration, information, safety, synchronization and motion.
- Producer-consumer architecture allows efficient use of network bandwidth.
- Seamless bridging and routing allows topology options for network architectures without having to program or configure intermediate devices.
- Device profiles provide common application interface.
- Conformance practice helps to ensure interoperable, multi-vendor systems.
- Specification management and enhancement process promotes stable, open and expanding network technologies.

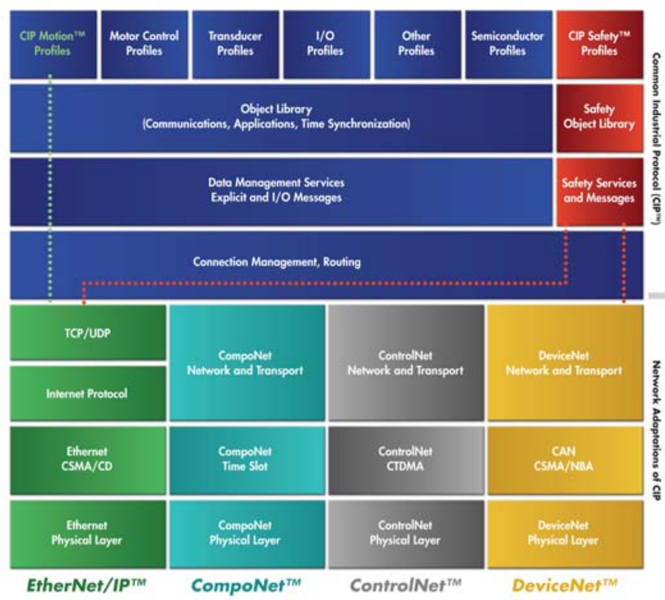
These advantages are covered in greater detail in “The CIP Advantage” section of this paper.

The Family of CIP Networks

The CIP Networks DeviceNet™, ControlNet™, CompoNet™ and EtherNet/IP™—open networks that are supported by technology providers around the world—share the Common Industrial Protocol at their upper layers while remaining media-independent at the lower layers. As a result, users can specify the best physical implementation of a CIP Network for their application while alleviating the need for costly and complex gateways to connect networks with dissimilar upper-layer protocols.

With media independence come choice: the ability to choose the CIP Network best suited for your application.

- ***EtherNet/IP***
  Ethernet IEEE-802.3 technology provides a specification of the physical media, defines a simple frame format for moving packets of data between devices and supplies a set of rules determining how network devices respond when two devices attempt to use a data channel



The OSI model is an ISO standard for network communications that is hierarchical in nature. Networks that follow this model—such as DeviceNet, ControlNet, CompoNet and EtherNet/IP—define all necessary functions, from the physical implementation up to the protocol and methodology, to communicate control and information data within and across networks.

simultaneously. This is known as CSMA/CD (Carrier Sense Multiple Access/Collision Detection).

However, by itself, the Ethernet specification lacks the communication protocol features needed to implement fully functional networks (i.e., an addressing scheme and mechanisms to establish a connection with a device and exchange data). TCP/IP provides these features, and, though it will run on alternate physical media, it has become inextricably linked with Ethernet due to desire of organizations to connect their own intranets and with the World Wide Web over the Internet.

EtherNet/IP is a CIP adaptation of TCP/IP that fully utilizes the IEEE-802.3 Ethernet physical layer while supporting both TCP and UDP at the transport layer. Thus, EtherNet/IP—CIP plus Internet and Ethernet standards—provides a pure Ethernet solution for control networks and enables Internet and enterprise connectivity anywhere, anytime.

CIP, running on EtherNet/IP, can coexist with any other protocol running on top of the standard TCP/UDP Transport Layer, and it can co-exist with other CIP Networks.

- ***DeviceNet***
  DeviceNet is a digital, multi-drop network that connects and serves as a communication network between industrial controllers and I/O devices. Each device or controller is a node on the network. A producer/consumer network that supports multiple communication hierarchies and message prioritization, DeviceNet is essentially CIP running on the cost-effective CAN bus.

  At the physical layer, DeviceNet uses a trunkline/dropline topology that provides separate twisted pair busses for signal and power distribution. DeviceNet supports both isolated and non-isolated physical layer design of devices. An opto-isolated design option allows externally powered devices (e.g., AC drives starters and solenoid valves) to share the same bus cable.

  DeviceNet also has the unique feature of offering optional power on the network. This allows devices with limited power requirements to be powered directly from the network, reducing connection points and physical size.

- ***ControlNet***
  ControlNet is a real-time, control-layer network that provides deterministic, high-speed (5 Mbits/sec) transport of time-critical I/O and messaging data—including upload/download of programming and configuration data and peer-to-peer messaging—on a single physical media link. ControlNet uses a Concurrent Time Domain, Multiple Access (CTDMA) algorithm to ensure the precise time for message delivery. This protocol is based on a fixed, repetitive time cycle called a Network Update Time (NUT).

  ControlNet utilizes multiple media types, including coaxial and fiber cable, including RG-6 quad shield cable, which is inexpensive and used widely in the cable TV industry. In addition, ControlNet provides duplicate node ID detection and optional media redundancy that transparently allows higher system availability.

- ***CompoNet***
  CompoNet, the newest of the family of CIP Networks, meets the requirements of applications using large numbers of simple sensors and actuators by providing high speed communications with configuration tools and combining this with efficient construction, simple set-up and high availability – all on a single network. CompoNet offers an advanced physical layer that minimizes signal degradation and transmission delays, while providing the user with a flexible network architecture offering a range of data rates — 4, 3 and 1.5 Mbps and 93.75 kbps — and overall network lengths up to 1500 meters with repeaters.

  CompoNet offers quick and easy installation using cost-effective flat network cable with pressure-clamping IDC connectors (IP20) or round cable (no network power) that allow for flexible cabling topologies including daisy-chain and trunk-line. An optional flat cable-connector system is rated for IP54. For further flexibility, in addition to extending the transmission distance, repeaters can be used where the cable media needs to be changed (from round to flat, or vice-versa) in different parts of the system due to environmental needs.

  In its data link layer, CompoNet utilizes Time Division Multiple Access ("TDMA"). This media access control approach is designed to avoid collisions and provide a deterministic network with the ability to update large numbers of nodes at state-of the-art update rates.

The CIP Application Coverage for Safety, Synchronization and Motion

With the safety and motion extensions to CIP, users can eliminate the need for separate, purpose-built motion and safety networks, providing lower system cost, improved system performance, seamless integration, and reduced system complexity.

- ***CIP Safety™***
  CIP Safety expands the application coverage of CIP Networks to encompass functional safety applications such as light curtains and emergency stops. An extension to CIP consisting of the objects, services and profiles needed for safety devices and applications, CIP Safety integrates seamlessly with CIP. Since the safety functionality is incorporated in each device, rather than in the network infrastructure, CIP Safety allows both standard and safety devices to operate on the same open network. This capability gives users a choice of network architectures—with or without a safety PLC—for their functional safety networks. It also allows safety devices from multiple vendors to communicate seamlessly across standard CIP Networks to other safety devices. CIP Safety is certified by TÜV Rhineland to meet IEC61508 and EN954-1 (SIL3/Cat.4).

- ***CIP Motion™***
  Motion control networks have become the interface of choice for control of today's high performance digital servo drives because of the advantages they provide when compared with traditional analog interfaces. Acceptance of Ethernet on the factory floor, combined with new advances in Ethernet technology, now position Ethernet as a solution that offers the capability of integrating motion and field device control on a common network. As a result, ODVA has introduced CIP Motion, which provides extensions to CIP that facilitate distributed motion control over CIP

Networks. These extensions, together with CIP Sync, provide a rich motion control infrastructure.

When applied to EtherNet/IP, CIP Motion offers a high performance motion control solution that has distinct technical and business advantages over other emerging motion control networks, including:

- Integration of field devices and high performance servo drives on the same network, thus eliminating the need for a separate motion control network;

- Motion support over EtherNet/IP, while still retaining IEEE 802.3 and TCP/IP compliance, by leveraging standard, unmodified, switched Ethernet with Quality of Service (QoS) prioritization and time stamped data delivery. This allows use of standard Ethernet components and infrastructure, provides support for any IEEE 802.3 compliant nodes without the use of special switches or gateways and allows support of future Ethernet and EtherNet/IP enhancements; and

- Superior drive interchangeability, extensibility, scalability and simplicity. CIP Motion's comprehensive drive device profile scales to support drives ranging from simple VFD drives to high performance servo drives. The device profile defines variable-size motion control connections for unicast controller-to-drive communication, as well as multi-cast controller-to-controller connections that are critical for line-shafting applications. CIP Motion is the first device profile that delivers on the promise of true device interchangeability. It is an intrinsically simple profile based on contemporary drive behavior and control-centric design.

Supporting motion control over EtherNet/IP, as CIP Motion does, results in lower system cost, improved system performance, and reduced system complexity.

- ***CIP Sync™***

  CIP Sync expands the application coverage of CIP Networks to encompass a variety of applications requiring synchronization of distributed controllers, including motion control applications such as electronic line shafting, camming and phase lock control. CIP Sync is an extension of CIP that includes a master real-time clock and a mechanism for sharing that time reference among multiple distributed devices. Additional objects and profiles ensure that actions occur at a specific time. CIP Sync can maintain synchronization of multiple distributed devices to nanonsecond resolution for unparalleled accuracy and repeatability. CIP Sync is scalable from small to large systems without degradation to its real-time performance.

  This approach to synchronization allows users to achieve real-time performance using standard EtherNet/IP devices and standard Ethernet infrastructure devices based on the IEEE-802.3 standard and the Internet TCP/IP Suite. Because it is fully compatible with IEEE-802.3, Ethernet and the TCP/IP Suite, users can upgrade network performance as higher speed Ethernet devices become available. CIP Sync also complies with the IEEE-1588™ "Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems."

The CIP Advantage

Since CIP is a common application layer protocol, it provides a unified, scalable architecture that is missing among other open networks. CIP Networks offer many other distinctive features and capabilities that make them the ideal choices—and the only truly open solutions—for fully integrating the manufacturing enterprise.

- **Comprehensive suite of messages and services for manufacturing automation provides functionality needed for control, configuration, diagnostics information, safety, synchronization and motion.**
  Common network application layers are the key to advanced communication and true network integration. Built on a single, media-independent platform that provides seamless communication from the plant floor through the enterprise with a scalable and coherent architecture, CIP allows companies to integrate I/O control, device configuration and data collection across multiple networks. This ultimately helps minimize engineering and installation time and costs while maximizing ROI.

- **Producer/consumer architecture allows efficient use of network bandwidth**
  CIP is a producer/consumer-based model, rather than a traditional source/destination model. The primary benefits of producer/consumer networks are more efficient use of bandwidth and the ability to deliver messages on an exception basis, rather than only as defined when the system is configured. When a message is produced onto a network, it is identified not by its destination address, but by its connection ID. Multiple nodes may then consume the data to which the connection ID refers. As a result, if a node wants to receive data, it only needs to ask for it once in order to consume the data each time it is produced. And, if a second (third, fourth, etc.) node wants the same data, all it needs to know is the connection ID to receive the same data simultaneously with all other nodes.

  On the other hand, using the source/destination model, nodes receive only the packets that contain their destination node number. If more than one node needs the same data, it must be transmitted multiple times, which is inherently inefficient. This can also cause synchronization problems, as nodes requiring the same data obtain it at slightly different times. Both scheduled and unscheduled messages must be packaged in the same data frame and pre-defined during system configuration.

- **Seamless bridging and routing allows topology options for industrial network architectures without having to program or configure intermediate devices.**
  Seamless bridging and routing is the key to building an enterprise-wide networking architecture incrementally. Very few, if any, manufacturers design and implement every aspect of their enterprise network at one time, and even fewer never make changes or upgrades to the original networks. With the ability to construct their networks incrementally under a future-proof, unified architecture, users can select the networks that best address their requirements throughout the enterprise on an "as needed" basis—without affecting existing performance.

  The ability to originate a message on one CIP Network, such as DeviceNet, and then pass it to another CIP Network, such as EtherNet/IP, with no presentation at the application layer, sets CIP Networks apart from others, and is possible because CIP is a media-independent protocol. A set of objects included in the specification defines the mechanisms that a routing device can use to forward the contents of a message from one network port to another without acting on the contents of that message. When using routing devices that support these objects, the user's only responsibility is to describe the path that a message must follow. CIP ensures that the message is handled correctly, independent of the networks involved. Thus, the CIP protocol provides the foundation for a comprehensive network architecture that allows CIP Networks with different physical and data link layers to be connected without using gateways.

Gateways typically are required for transmitting and using the data contained within messages that are sent across dissimilar network boundaries. These gateways, and the software overhead needed to support them, introduce system complexity, force performance compromises and compromise functionality in the real-world environment of industrial automation.

A good framework for understanding the limitations of the gateway approach is the process of translating one human language to another. This process is more of an art than exact science because the meanings of words and phrases often do not directly translate. As a result, the translator must exercise his or her own judgment in choosing words and phrases to translate from one language to another. The person hearing the translation must make further subjective decisions about how to interpret the translation. Just as miscommunication is a frequent result of the human language translation process, communication gaps or misunderstandings often occur when messages based one upper-layer protocol are translated and transmitted to those based on a different upper-layer protocol. Users of CIP Networks, however, can be assured that the performance and functionality of their interconnected networks is not compromised, giving them the flexibility to combine network topology options that best address their specific application needs.

- **Device profiles provide common application interface**
  Interoperability and interchangeability are the keys to open networks and open systems. CIP includes fully defined device profiles that model a device as a specific collection of objects and interactions between objects. For each device type, the profile identifies the required objects, as well as the attributes and services of those objects. These profiles ensure that devices are interoperable, and provide a mechanism for interchangeability among devices of the same type, even though they may come from different vendors.

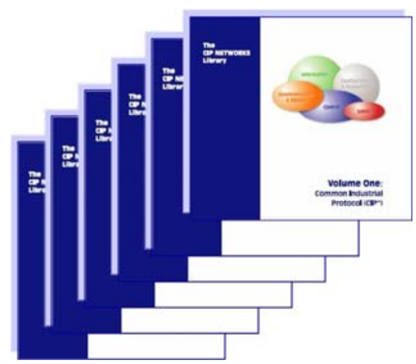
  Device profiles defined in CIP allow device functionality to be broken down into logical elements. For example, a motor starter consists of an identity, an overload and a discrete output object. The same “overload” object will be used in other device profiles, such as the AC drive. Thus, configuration, run-time data and diagnostics associated with the overload protection function will have the same base elements in all device types that use this object. Portability, reusability and consistency in the application of networks are crucial to achieving the highest return on investment for manufacturing automation systems.

- **Conformance practice helps to ensure interoperable, multi-vendor systems.**
  ODVA manages the development of the Common Industrial Protocol and the family of CIP Networks, and assists manufacturers and users of CIP Networks through tools, training and marketing activities. In addition, ODVA offers conformance testing to help ensure that products built to its specifications operate in multi-vendor systems. ODVA also is active in other standards development organizations and industry consortia to drive the growth of open communication standards.

  ODVA is committed to providing industry with vendor-independent assurance that network products implementing CIP comply with the specifications, rules and guidelines contained in The CIP Networks Library. Understanding that customer satisfaction with CIP Networks is directly linked to the ease of interoperability of these products in multi-vendor systems, this assurance is achieved through conformance testing practice and the shared commitment of ODVA members to comply with the responsibilities mandated in ODVA's Terms of Usage Agreement, the document through which ODVA licenses vendors to make and sell products that implement the Common Industrial Protocol (CIP™). These include (but are not limited to): obtaining Declarations of Conformity from ODVA, if applicable, for all CIP Network Products; following the most current edition of the specifications, rules and guidelines as published in The CIP Networks Library; and making a strong statement in the product documentation that is provided to customers that the products comply with the specifications.

- **Specification management and enhancement process promotes stable, open and expanding network technologies**
  CIP is the only completely standards-based protocol in the industry. Some other open protocols are developed using proprietary implementations of Ethernet. As a result, users cannot benefit from the cost savings and easy availability of purchasing all system components off the shelf: users are reliant on the vendor that supplies the proprietary version of Ethernet. More importantly, system interoperability and stability is jeopardized.

  The specifications for CIP Networks undergo a rigorous cycle of member review and testing to ensure that they are truly open, rather than driven by one vendor's product development agenda, and that the networks perform reliably using a variety of system components. As a result of ODVA's exacting specifications development process and strict conformance to industry standards, users are assured of a network architecture that is built on open, stable and interoperable network technologies that support multi-vendor systems.



  As a Standards Development Organization (SDO), ODVA advocates the adoption of open standards for communication networks used in industrial applications. ODVA works with other SDOs around the world to develop and promote compatible standards, without which it is impossible to achieve true openness and interoperability. The result is that CIP Networks have been accepted as international standards by the IEC and ISO.

  Secure in the knowledge that CIP Networks and their components are formally certified for performance and reliability in an open, future-proof environment, a rapidly growing community of users and vendors around the world is implementing CIP Networks. This, in turn, will lead to an ever-larger selection of CIP Network products, decreasing product prices as user and supplier acceptance continues growing, and easily obtainable parts for maintaining and upgrading systems.

Conclusion

Future manufacturing network architectures will move away from hierarchically based network architectures—the traditional "device," "control" and "information" level networks—towards an application-based architecture. To integrate control with information and Internet technology, manufacturing automation needs a network architecture designed for plant floor-to-enterprise connectivity and TCP/IP routing capability. Industrial Ethernet must exist somewhere in this architecture. Economical deployment will hinge on using COTS technology wherever possible, requiring the use of industrial Ethernet that is compatible with standard Ethernet switches and routers.

ODVA, through the Common Industrial Protocol, Ethernet, TCP/IP and the Internet, are providing users with a network architecture that meets the application requirements for control, information, safety and synchronization in manufacturing processes today. At the same time, this architecture incorporates the connectivity and commercial requirements for integration of manufacturing networks with enterprise-level Ethernet networks and the Internet in the future.

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