ETHERNET/IP STANDARD

Purchasing and Application

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Industrial Ethernet

Common Industrial Protocol (CIP)

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Raleigh NC

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Scope:

This standard is written for one of the most developed, fastest growing industrial ethernet protocol, known as Ethernet/IP, and applies to all industrial and manufacturing sectors. Scope includes hardware and appliances (henceforth referred to as devices), best practice considerations for design & implementation, and:

i. Is not exclusive for the utilization at a specific type of industry.
ii. Is not exclusive to specific vendor of EtherNet/IP devices.

Intended Audience:

Control engineers, developers, E&I personnel, maintenance technicians, and related professionals responsible for Industrial Automation and Control Systems (IACS), network design, commissioning, troubleshooting, and maintaining its reliability.

References:

a) ANSI-TIA-EIA 568 B &C; 1005 - Telecommunications Cabling Standard
b) CISCO - Converged Plantwide Ethernet (CPwE)
c) CISCO - Industrial Ethernet: A Control Engineer's Guide
d) IEEE Std 802-2001 - Standard for Local and Metropolitan Area Networks
e) IEEE Std 1588-2008 - Standard for a Precision Clock Synchronization Protocol
f) ODVA - Common Industrial Protocol and Family of CIP Networks, PUB00123R1
g) ODVA - EtherNet/IP Media Planning and Installation, PUB00148R0
h) ODVA - Infrastructure Guide, PUB00035R0
i) ODVA - Recommended Functionality for EtherNet/IP Devices, PUB00070R8

Purpose:

The purpose of this standard is to aid in the purchase and application of EtherNet/IP devices on modern IACS network where robustness, reliability, and inoperability are warranted. It is intended for use but not limited in industrial or manufacturing environments where industrial ethernet are prevalent and such a standard would increase efficiency and reduce costs.

Objectives:	Recommendation:
1) Selection of devices for industrial ethernet network, with a common application layer that provides interoperability and interchangeability, and phasing out the need for vendor specific software for configuration and monitoring of individual devices. 2) Access and integrate all available operational and diagnostic data for immediate and future use. 3) Reducing Latency and Jitter and minimize time to commission and maintain. 4) Increase reliability, improve safety & security, and reduce the operating costs of EtherNet/IP devices.	a) Utilize device standards and guides, such as Cisco's CPwE and ODVA's publications to ensure hardware specifications are met b) Select devices that provide a multi-parameter capture on running and fault conditions for use in troubleshooting. i.e. port diagnostics & port status conditions that impaired operations c) Specify and design the network architecture to meet industrial's best practices i.e. ODVA - Infrastructure Guide & d) Deploy with a defense in depth approach, redundancy, and ANSI/TIA's MICE environmental classification

Specification Contents

Industrial Ethernet Protocol (Ethernet/IP) Overview:

CIP protocol is the common open application layer that links ControlNet, DeviceNet, CompoNet, and EtherNet/IP. CIP gives the user the ability to transport messages and services for a variety of industrial and manufacturing applications, including but not limited to control, motion, safety, synchronization, configuring parameters and diagnostics information.

Industrial Ethernet growth, specifically EtherNet/IP, is accelerated by the increasing need for industrial devices to be connected to plant systems such as Manufacturing Execution System (MES) and business systems such as Enterprise Resource Planning (ERP) to achieve business objectives. EtherNet/IP accomplishes these tasks by providing users with the ability to utilize both standard Ethernet (physical, data link, network and transport layers) and TCP/IP (CIP over TCP/IP) technologies for IACS applications resulting in consistent data aggregation and access.

Minimum Hardware Selection Criteria

The following criteria have been refined to a minimum to aid in selection. It is assumed that hardware in question is to be used as part of a greater system (PLC/SCADA/DCS based). For clarity, the following specified functionality should be provided within the EtherNet/IP devices itself.

1) Auto Sensing and Auto Configuring- 10/100BaseTX, Duplex, and MDIX, The bandwidth requirement will depend on the application;
2) DHCP - Server Option *
3) Dual Ethernet port design - support for ring/redundant topology *
4) Integrated Webserver/Web Browser Management *
5) Ethernet/IP enabled devices - Devices which support the required features of Ethernet/IP will be able to provide an efficient communication platform for the protocol. The benefit of Ethernet/IP enabled devices is that they have been pre-configured for plug-and-play operation, greatly reducing the setup time and effort.
6) Full-Duplex switching - is required as opposed to Half-duplex operation as it greatly reduces the amount of data collisions in an Ethernet network.

7) IGMP Snooping - Multicast messages are used to send point-to-multi-point messages in an Ethernet/IP network, multicast messages cannot be forwarded efficiently in a switched network unless routers, layer 3 devices or managed devices with IGMP Snooping support are used. A managed switch with IGMP Snooping will inspect Multicast packets and only forward them to the appropriate ports, if IGMP Snooping is not used then the Multicast packet with be forwarded to all ports, thereby reducing the efficiency on the network.
8) Port Mirroring - This feature will allow the traffic from any port to be duplicated on a spare port for network troubleshooting and diagnostics, increasing industrial network maintainability.
9) RSTP - 802.1D-2004 Rapid Spanning Tree to configure a simply connected active network topology from the arbitrarily connected bridges of a bridged network.
10) SNMP v1, v2, v3 for switch management - Simple Network Management Protocol or SNMP is used to for remote management, configuration and diagnostics of network infrastructure products.
11) 802.1p QoS and Port QoS - prioritizes internet traffic for applications
12) Port/Link Aggregation - ability to group two network ports to increase the bandwidth between two machines (switch or any work station).
13) 802.1Q tag VLAN and Port VLAN - A Virtual Local Area Network or a VLAN is a switched network which is separated into segments by the use of logical groups rather than the more conventional physical geographical groups. Devices that support VLAN allow the user to define a logical addressing scheme that will identify where data can be sent and reduces unnecessary network traffic and delay time.

Recommended Hardware Selection Criteria

The following criteria have been refined to a minimum to aid in selection. It is assumed that hardware in question is to be used as part of a greater system (PLC/SCADA/DCS based). For clarity, the following specified functionality should be provided within the EtherNet/IP devices itself.

1) IGMP Auto Configuration and Query **
2) IGMP Query - In a network where multicast traffic is being controlled by devices with IGMP Snooping, there must be at least one switch which can generate a periodic IGMP Query to all devices, this is to determine which devices are members of which multicast groups. RFC's specifies that the router with the lowest IP address on the network is responsible for generating the IGMP query packet. ***
3) Link Layer Discovery Protocol - 802.1AB-2005 LLDP
4) Modular mounting - Industrial DIN-Rail Enclosure or Panel mount
5) Options for industrially rated devices incorporating IP67-rated connectors (RJ45 or M12) with module and network status LEDs with device labeling for ease of use.
6) Port Security - MAC Address Based Filtering
7) Redundant Power Inputs - (10-30 VDC)
8) Store-and-forward Technology - verifies the integrity of the message before forwarding it
9) Wide operating temperature - (-40°C to 85°C) Operating Temperature
10) Commissioning. Pre-defined device data mapping, as well as sample configuration packages suitable for reuse. This includes tags aliasing and device register pre-mapping.

A device interface, accessible through a standard web browser, will be provided to ease commissioning and create reusable templates.

11) Field servicing. May include, but is not limited to reconfiguration, re-addressing communications, or replacing the entire device itself. Such servicing must be attainable through personnel mentioned in the *Intended Audience* section, enabled through the embedded Interface Access:
    a) RJ45 Port via default IP Address
    b) EIA-232 interface accessed via a 9-pin female connector. This is commonly used to access the Command Line Interface (CLI)

Recommended Transmission Media Selection Criteria

Industrial Ethernet offers a wide range of transmission media such as copper and fiber. The following are criteria to consider.

1) Ensure cabling are specified to withstand high voltage, noise, harsh, and potentially hazardous environments factors:
    a) Shielded cables are recommended for especially high noise environments
    b) Cat 5e Cord Sets rated for 600V (*see appendix)
    c) Oil Resistance
    d) Moisture resistance, UV, and weathering resistance
    e) Weld splatter resistance in addition to having good flame and fire retardant properties
    f) Flexibility and low temperature brittle point
    g) M12 connection systems - IP67 compliant
2) Determine the correct cable/fiber for the data transmission rates you need
    a) POE Requires minimum of CAT 5e cable
    b) Cat 5e (2 pair) - Up to 100Mb/s @ 100 MHz
    c) Cat 5e (4 pair) - Up to 1Gb/s @ 100 MHz
    d) Cat 6e (4 pair) - Up to 10Gb/s @ 500 MHz
    e) Cat 7 (4 pair) - Up to 10Gb/s @ 600 MHz
    f) Fiber Multimode - OM1-OM4 step-index or graded-index: Up to 10Gb/s - 33m-2km
    g) Fiber Singlemode - OS1/OS2: Up to 100Gb/s - 40km (*see appendix)
3) Industrial ethernet networks should utilize 22-24AWG stranded or solid cable types, which provide significant transmission performance advantage over traditional 26 AWG cables.
4) Industry standard limits channel length to 100M (copper cable) =
    a) 90M horizontal (solid)
    b) 10M patch (stranded)
    c) Direct connect - Solid conductor cables have full CAT 5e performance to 100M
5) Avoid service loops or stretching the cable - specify cordset lengths as closely as possible
6) Cabling must be certified for the design and performance specifications

Interface & Access

Devices configurations should be fully supported through multiple methods as previously mentioned. Also, In addition to being fully ODVA/CIP compliant, the device should have:

1) Embedded web pages to assist with configuration and monitoring with a standard web browser.

2) Dual port ethernet switch functionality to facilitate ring or linear topologies (versus independent cables for each device, ex. star). This option is necessary in high density installations, such as motor control centers.
3) Led indicators should be provided on device to aid in troubleshooting.
4) Up-to-date EDS (electronic data sheet) files should be easily sourced via vendor website, without login access requirements.
5) Fully developed add on instructions (AOI), sample program, and/or faceplate should be available for common control platforms, such as Rockwell's Logix and FactoryTalk View Studio platform.

CIP Components & Compatibilities

EtherNet/IP devices must go through Conformance & Performance Testing. In addition to being fully ODVA/CIP compliant, the device should have or be:

1) Electronic Data Sheet (EDS) - An ESD for each device should be provided.
2) CIP Objects - are used to group various information about the device. There are objects types specified by the ODVA, and additional ones may be vendor specific:
    a. Identity object - provides identification of and general information about the device. The Identity Object MUST be present in all CIP products.
    b. TCP/IP Interface object - provides the mechanism to configure a device's TCP/IP network interface. i.e. device's IP Address, Network Mask, and Gateway Address
    c. Ethernet Link object - maintains link-specific counters and status information for an Ethernet 802.3 communications interface. Each device shall support exactly one instance of the Ethernet Link Object for each Ethernet 802.3 communications interface on the module. A request to access instance 1 of the Ethernet Link Object shall always refer to the instance associated with the communications interface over which the request was received.
    d. Vendor device object - vendor specific object
3) Producer-consumer services that let you simultaneously control, configure, and collect data from devices over a single network or utilize a single network.
4) Compatible with standard Internet and industrial protocols such as HTTP, FTP, SNMP, DHCP, and OPC
5) In compliance with IEEE Std 802-2001, provides users with multiple network interface speeds i.e. 10, 100 Mbps, 1 Gbps or more, and a flexible network architecture compatible with commercially available Ethernet installation options including copper, fiber, fiber ring and wireless, and topologies including star, linear and ring.
6) Support for power-up delays, motion, and functional safety implemented in devices with QuickConnect, CIP Motion, and CIP Safety respectively.*

Networking Best Practices

There are industrial best practices for mitigating latency and jitter, and to increase data Availability, Integrity, Confidentiality, and Security the *Intended Audience* should have:

1) Robust Physical Layer
    a. Capacity Planning
    b. Utilize Cat 5E or higher for noise immunity and speed
    c. Route all EtherNet/IP cable at least 5' from high noise equipment or electromagnetic interference.
    d. Ensure that the communication cable cross a power line at 90 degrees if required

    e. Use fiber over copper cable if electromagnetic disturbances are unavoidable or the distance exceed the recommended 100M for coper, as well as speed constraints.
2) IP Addressing
    a. Allocating, recycling, and documenting IP addresses and subnets in a network
    b. forecast the IP address capacity requirements and future growth in every accessible subnet on the network
    c. Hierarchical addressing
3) Segmentation
    a. Structure and Hierarchy
    b. Multi-tier Network Model
    c. Logical Framework
    d. Organization into levels and zones
    e. Topology
    f. Virtual LANs (VLANs)
4) Resiliency Protocols and Redundant Topologies
    a. Utilize a 1 Gbps fiber uplinks and redundant paths between switches for optimal network resiliency
    b. Resilient Ethernet Protocol (REP) is a Cisco proprietary protocol that provides an alternative to the Spanning Tree Protocol (STP)
    c. Rapid Spanning Tree Protocol (RSTP) is the default spanning-tree protocol for preventing loops on Ethernet networks
    d. DLR protocol is a layer 2 protocol that provides link-level, physical redundancy that provides network convergence in the 1…3 ms range.
    e. N-Tron proprietary Ring Management - N-Ring Aging Time has a default of 20 seconds and is separate from the Bridging Aging Time
    f. Network Address Translation (NAT) is designed for IP address conservation or is used to configure multiple machines to have identical network settings
    g. Parallel Redundancy Protocol provides network nodes two alternate paths for the traffic to reach its destination *
5) Time Synchronization
    a. IEEE1588 compliance - synchronization of clocks across a system of interconnected devices using CIP Sync. ****
6) Prioritization - Quality of Service (QoS)
    a. See *Minimum Hardware Selection Criteria*, Item 11
7) Multicast Management
    a. See *Minimum Hardware Selection Criteria*, Item 7
8) Security, Castle Approach - layered security approach that uses several forms of network security to protect against intrusion attacks. They work designed to work with or overlap the other technologies mitigate attack. Some of these may include but are not limited to:
    a. Isolate IACS networks from untrusted networks, Firewalls and DMZs (Demilitarized Zones)
    b. Utilize managed devices
    c. Lock down or disable all unused ports and turn off unused services.
    d. Allow real-time connectivity to external networks only if there is a defined business requirement or control function.
    e. Manage Authentication
    f. Implement Secure Remote Access
    g. Watch IP traffic on IACS boundaries suspicious communications.
    h. Monitor IP traffic within the control network for malicious content.
    i. Physical Access Control and Video Surveillance Technologies

Fault Diagnostics

Onboard diagnostics such as device health & status must be readily assessable to alert and fault if device components including power supply, microprocessor, memory, analog-to digital converters, or other related functions fail.

1) Alarm Output - Configurable Alarm Contact
2) ESD and Surge Protection - on all Built-in Ports
3) Fault Status LED - Configurable
4) Port Diagnostics provides individual port status
    a) Link Status
    b) Speed and Duplex setting
    c) Admin Enabled
    d) Port Role
    e) Trend Analysis
        i) Bandwidth utilization
        ii) Broadcast transmit and receive in frames per second
        iii) Multicast transmit and receive in frames per second
        iv) Unicast transmit and receive in frames per second
        i) Port Errors
5) Fault Event Log

* Where applicable

** Plug-and-play to handle most Ethernet control networks, especially for EtherNet/IP multicast traffic

*** Where IGMP Auto Configuration and Query is not available

**** Where IEEE-1588 Precision Time Sync protocol is warranted (i.e. Motion Applications)

Appendix

Transmission Media & Hardware Ordering Options

Copper & Hardware

Part Number	Description
ISFCH5C02A**-XG	Panduit - 2 pair CAT5E 600V
ISFCH5C04A**-XG	Panduit - 4 pair CAT5E 600V
ISPS688FA	Panduit - Category 6/5e RJ45 Field terminable plug
ISPS5E44MFA	Panduit - M12 D-Code Field Terminable Plug
CDPP8RG	Panduit - Modular Patch Panel 8-port
CADIN1IW***	Panduit - DIN Rail Adapter 1-port
7957A - DataTuff® Cat 5e	Belden - 4 pair CAT5E 600V

Fiber & Hardware

Part Number	Description
FRME2U	Panduit 2RU Fiber Optic Rack Mount Panel supporting up to 6 FAP Adapter Panels
FAP6WAQDLC2	Panduit OM3/OM4 FAP loaded with 6 LC Duplex Multimode Fiber Optic Adapters
FAP12WAQDLC2	Panduit OM3/OM4 FAP loaded with 12 LC Duplex Multimode Fiber Optic Adapters
FAPB	Panduit Blank Adapter Panel
FLCSMCXAQY	Panduit OM3/OM4 LC Opticam II Terminations
FX2ERLNLNSNM001	Panduit OM3 LC/LC Duplex Patch Cord 1 meter

FOPRX06Y	Panduit Opti-Core Inter-locking Armored Cable fiber 6 Fiber OM3
FOPRX12Y	Panduit Opti-Core Inter-locking Armored Cable fiber 12 Fiber OM3
FOPRX24Y	Panduit Opti-Core Inter-locking Armored Cable fiber 24 Fiber OM3
FRME1U	Panduit 1RU Fiber Optic Rack Mount Panel supporting up to 3 FAP Adapter Panels
ZDF242430	Panduit Industrial Distribution Frame - Supports two rack mount switches. Includes NEMA4 enclosure 12RU, Pre-Installed: (1) Square hole front and rear rack angles, (1) FRME1U fiber enclosure, (2) CPPL48WBLY 48-port patch panel, (1) RGRB19CN grounding bar, (3) equipment ground whips, (1)10" DIN Rail, (2) fiber spools, (1) back panel, (2) ESD ports, 30" length of duct, cage nuts, labeling for cable routing, strain relief bars Included Accessories: (1) ESD wrist strap, (1) HLS-15R0 hook and loop, (1) RGCBNJ660P22 #6 AWG grounding cable, mounting hardware, conduit schedule and ingress template, installation guide