



Recommended Functionality for EtherNet/IP Devices

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1 Introduction

1.1 Scope of Document

The purpose of this document is to recommend functionality related to the EtherNet/IP protocol implementation in EtherNet/IP devices. The recommendations are a result of work generated by the ongoing series of EtherNet/IP Implementors Workshops. The recommendations are being made to help ensure interoperability between devices and provide a minimum level of capability required for user applications.

1.2 Interpreting the Recommendations

The recommendations cannot be interpreted as “requirements” from the perspective of the EtherNet/IP specification. However from the perspective of the Implementors Workshop, it is useful to be able to state whether or not a device adheres to the Functionality Recommendations (and future workshop recommendations) for the type of device. Therefore, this document uses language similar to the EtherNet/IP specification to make clear what is required (specified with the use of "**shall**") and what is optional (specified with the use of "recommended") in order for a device to adhere to the recommendations.

It should be understood that a device may be compliant to the EtherNet/IP specification yet not meet the minimum recommendations described in this document for the type of device. Such a device is a valid EtherNet/IP device; however, the vendor will not be able to state that the device meets the workshop recommendations.

1.3 Future Revisions of the Recommendations

This document represents “V2.0” of the Functionality Recommendations. Further revisions of the document are anticipated as work progresses in the Implementors Workshop and other ODVA SIGs. Work is currently in progress in the following areas:

- EtherNet/IP specification clarifications.

1.4 Organization of the Document

This document is primarily organized by EtherNet/IP device classification, and includes the following sections:

Common Device	This section includes EtherNet/IP functionality recommendations that are common across multiple types of devices. The sections for the specific types of devices will add recommendations to those described in this section.
Explicit Message Server Device	This section explains the functionality that is recommended for explicit message server devices over and above the Common Device section.
Explicit Message Client Device	This section explains the functionality that is recommended for explicit message client devices.
Adapter Device	This section explains the functionality that is recommended for Adapter class devices over and above that in the Common Device section.
Scanner Device	This section explains the functionality that is recommended for Scanner class devices over and above that in the Common Device and Adapter Device sections.

2 Common Device Recommendations

This section includes EtherNet/IP functionality recommendations that are common across multiple types of devices. The succeeding sections for the specific types of devices may add recommendations to those described in this section.

2.1 CIP

1. The device **shall**, at a minimum, provide support for:
 - a) 3 concurrent Encapsulation sessions.
 - b) 6 concurrent Transport Class 3 Explicit Messaging connections.
 - c) More than 1 Transport Class 3 connection per Encapsulation session.

Rationale: A server should be able to handle requests from 3 client nodes, 2 continuous and 1 transitory (e.g. controller, HMI, and commissioning tool). Some clients may require more than 1 CIP Class 3 connection on a given Encapsulation session.

2. The device **shall** support both unconnected and connected messaging concurrently in an Encapsulation session.

2.2 TCP/IP Suite

1. The device **shall** support the TCP/IP features required by the EtherNet/IP specification in Volume 2, Section 9-3.
2. The device **shall** follow the recommendations put forth in the ODVA document Recommended IP Addressing Methods for EtherNet/IP Devices, Version 1.0, June 10, 2003 (PUB00028). In summary, this document specifies the following features in regards to IP addressing:
 - a) The device **shall** by default issue BOOTP or DHCP requests at initial power up “out-of-box” (from the vendor).
 - b) The device **shall** facilitate enabling and disabling BOOTP or DHCP via the TCP/IP Object (Class 0xF5).
 - c) The device **shall** allow its IP address (and other IP parameters) to be set using the TCP/IP Object. This requirement does not prohibit the device from other means of setting these parameters.
 - d) The device **shall** allow the user to make a valid IP address persistently stored in non-volatile memory, via attributes and services of the TCP/IP Object.
3. The device **shall** support, at a minimum, 3 concurrent TCP connections for CIP. If other protocols (HTTP, FTP, etc.) are supported, the number of concurrent TCP connections supported should account for these protocols in addition to the connections reserved for CIP.
4. The device **shall** provide support for UDP requests. The List Identity command is typically transmitted as a UDP broadcast by network tools.
5. The device **shall** cease sending BootP/DHCP requests once an IP address has been obtained from the BootP/DHCP server and has been successfully applied. It is understood that a DHCP-configured device will attempt to renew its IP address at some point, but this requirement is for the initial requests.

6. The device **shall not** issue BootP/DHCP requests when configured to use a static IP address as indicated by the Startup Configuration bits being set to zero in the Configuration Control Attribute of the TCP/IP Object.

2.3 Ethernet and Physical

For those devices which contain multiple Ethernet interfaces, the following recommendations apply to each of the device's externally exposed EtherNet/IP interfaces.

1. The device **shall** support Full and Half Duplex. It is recommended that Full Duplex be used for the best network performance and determinism.
2. The device **shall** support 10/100Mbps.
3. The device **shall** provide auto negotiation of duplex and data rate with a configurable manual override. Auto Negotiation plus Manual Override provides support for the widest possible range of network infrastructure devices, e.g. switches. The device **shall** store the link settings (e.g. Auto-Negotiate, Fixed Speed & Duplex) in non-volatile memory such that they are persistent through a cycle of power to the device.
4. The device **shall** follow the recommendations put forth in the ODVA document Recommended IP Addressing Methods for EtherNet/IP Devices, Version 1.0, June 10, 2003 (PUB00028). In summary, this document specifies the following features in regards to Ethernet and Physical Layer:
 - a) For 100Base-T devices, the device **shall** allow the user to select auto-negotiation or manual setting of duplex mode and port speed, per the Ethernet Link Object
 - b) The Ethernet MAC address **shall** be visible on the device (e.g., on a label). Note that the address may be hidden after the device is installed.
5. It is recommended that the device physical layer conform to the EtherNet/IP Industrial Conformance Level. Note that this recommendation does not apply to PC-based or transitory devices. This includes:
 - a) EtherNet/IP industrial physical layer. (Volume 2, Section 8.6)
 - b) EtherNet/IP specific LED, or equivalent, indicators (Module Status, Network Status). (Volume 2, Section 9.4)
6. It is recommended that the device have LED, or equivalent, indication for Ethernet Link Status, Transmit and Receive. It is recommended that LED behavior on all future development follow the behavior described below.
 - a) Devices with a single indicator:

Indicator	Single Color LED		Bi-Color LED	
	State	Description	State	Description
Link Status	Off On Flashing	No link Link Port activity	Off Solid Green Solid Amber Flashing Green Flashing Amber Solid Red	No link Link Port disabled Port activity Collision Major NIC Fault e.g. POST error

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b) Devices with a two Indicators:

Indicator	Single Color LED		Bi-Color LED	
	State	Description	State	Description
Link Status	Off On	No link Link	Off Solid Green Solid Amber Solid Red	No link Link Port disabled Major NIC Fault e.g. POST error
Activity	Off Flashing	No activity Port activity	Off Flashing Green Flashing Amber	No activity Port activity Collision

c) Devices with a three Indicators:

Indicator	Single Color LED		Bi-Color LED	
	State	Description	State	Description
Link Status	Off On	No link Link	Off Solid Green Solid Amber Solid Red	No link Link Port disabled Major NIC Fault e.g. POST error
Transmit	Off Flashing	No activity Port activity	Off Flashing Green Flashing Amber	No activity Port activity Collision
Receive	Off Flashing	No activity Port activity	Off Flashing Green	No activity Port activity

2.4 EDS File

1. The EDS file for the device **shall** include the [Capacity] section. This is used to declare the I/O Connection capacity supported by the device. Definitions per section 7-3.6.11 of Volume 1, Edition 2.1.

2.5 Performance

The performance values in this section will be based on benchmark procedures to be created by the Performance Working Group. When these are created, this section will be updated. The values listed below are recommendations based on an absence of significant background traffic.

List Identity Response/UDP	< 250ms
List Services Response/TCP (assuming existing TCP connection)	< 250ms
Unconnected explicit response - No TCP connection established (Specific internal object/attribute would be tested)	< 500ms
Unconnected explicit response - TCP connection established (Specific internal object/attribute would be tested)	< 100ms
Connected explicit response (Specific internal object/attribute would be tested)	< 100ms
Two back-to-back explicit message requests without dropping either	≥ 1ms

Status Note: The Performance Working Group is working on Version 1 of their document, which focus on Transport Class 1 Cyclic connections. Future versions will focus on the explicit data that is mentioned above.

2.6 Duplicate IP Address Detection

The device **shall** support duplicate IP address detection by implementing the algorithm described in the ODVA document *IPv4 Address Conflict Detection for EtherNet/IP Devices v1.5*, June 6, 2006.

3 Explicit Messaging Server Device Recommendations

This section explains the functionality that is recommended for explicit message server devices over and above the Common Device section.

3.1 Example Devices

- Text Display device
- Data Acquisition Input devices
- Data Logger

3.2 CIP

No addition to Common Device Recommendations.

3.3 TCP/IP Suite

No addition to Common Device Recommendations.

3.4 Ethernet and Physical

No addition to Common Device Recommendations.

3.5 EDS File

No addition to Common Device Recommendations.

3.6 Performance

No addition to Common Device Recommendations.

4 Explicit Messaging Client Device Recommendations

This section explains the functionality that is recommended for explicit message client devices.

4.1 *Example Devices*

- Simple HMI
- Data Logger
- Diagnostic Tool

4.2 *CIP*

1. The device **shall** meet the minimum requirements defined in the CIP and EtherNet/IP specifications for a messaging client, which includes certain explicit server functionality such as Identity object support.
2. The device **shall** support the initiation of both connected and unconnected explicit messaging.

4.3 *TCP/IP Suite*

The device **shall** meet the minimum requirements defined in the CIP and EtherNet/IP specifications for a messaging client.

4.4 *Ethernet and Physical*

No addition to Common Device Recommendations.

4.5 *EDS File*

The device **shall** meet the minimum requirements defined in the CIP and EtherNet/IP specifications for a messaging client.

4.6 *Performance*

No addition to Common Device Recommendations.

5 Adapter Device Recommendations

This section explains the functionality that is recommended for Adapter class devices over and above that in the Common Device section.

There are several references in this section to "rack-based" devices. For the purpose of this document, a rack-based device is one that conforms to the Modular description in the CIP specification (section 7-3.7, Volume 1, Edition 2.1).

5.1 Example Devices

- Block I/O
- Weigh Scale
- AC Variable Frequency Drive

5.2 CIP

1. The device **shall** support all recommendations described in the Common Device Recommendations.
2. The device **shall** accept, at a minimum, 2 Transport Class 1 I/O connections. (Rationale: 1 Exclusive Owner or Input Only connection for a controller and 1 Input Only or Listen Only connection for a monitoring device)
3. The following recommendations pertain to Transport Class 1 connections supported by the device.
 - a) The device **shall** support bi-directional connections, i.e. accept a Fwd_Open with non-null O->T and T->O connection types. The device may also support uni-directional connections (with a null connection type in either O->T or T->O).
 - b) The device **shall** support Cyclic trigger type.
 - c) It is recommended that the device support Change of State trigger type with Production Inhibit Timer (PIT) for discrete I/O devices. COS trigger type is optional for non-discrete devices and for rack connections on rack-based devices.
 - d) The device **shall** support multicast T->O connection and unicast O->T connection. The device **shall** also support Unicast T->O connections.
 - e) The device **shall** support an Exclusive Owner connection if the device has output data.
 - f) The device **shall** support a Listen Only or Input Only connection supporting more than 1 listener if the device has input data. Note that this is necessary regardless of whether the device has output data or not.
 - g) The device **shall** provide a "heartbeat" connection path to be used for connection pairs where application data is only flowing in one direction. Note: Connections to the heartbeat connect path are configured with 0 data length and do not include a 32-bit Real-Time Header (Run/Idle Header).
 - h) The device **shall** support Electronic Keys in the Fwd_Open connection path. The device **shall** also support a Null key segment and no key segment.
 - i) The device **shall** support the 32-bit Real-Time Header (Run/Idle Header) in the O->T connection data. Note that the device may also support other connection data formats as well.

4. The device **shall** accept a Configuration path as part of the Fwd_Open request. This is not a requirement for rack-based devices.

Devices with configuration data **shall** accept Fwd_Opens with all 3 types of data segments: None, Null, or Non-Null.

If no configuration data is required by the device, the device **shall** still specify and accept a Configuration path. This unused configuration path may be the same as the “heartbeat” path associated with the I/O connection(s).

Devices not requiring configuration data **shall only** accept Fwd_Opens with Null or No data segments; Fwd_Open requests containing Non-Null data segments **shall** be rejected.

Examples of data segment types:

Non-Null	0x80 0x01 0x12 0x34
Null	0x80 0x00
None	-

5. The device **shall** support the Assembly object. Assembly object instances **shall** be used to specify connection paths for Transport Class 1 connections. Path segments in the Fwd_Open **shall** use the compressed format in the following order: Configuration instance, Consumed Data connection point, Produced Data connection point, and data segment if present. This is not a requirement for rack-based devices.
6. The device **shall** provide access to configuration parameters via Explicit Messaging. Note that it is not necessary to utilize the Parameter Object. This is not a requirement for rack-based devices.
7. The device **shall** provide access to I/O Data attribute via Explicit Messaging, e.g. Assembly object, instance attribute 3. Write requests are to be rejected if the assembly is linked to an active I/O connection. This is not a requirement for rack-based devices. The I/O data **shall not** include the 32-bit Real-Time Header (Run/Idle Header).

5.3 TCP/IP Suite

No addition to Common Device Recommendations.

5.4 Ethernet and Physical

No addition to Common Device Recommendations.

5.5 EDS File

1. The device **shall** support all recommendations described in the Common Device Recommendations.
2. The format of the I/O connection data **shall** be detailed in the EDS [Assem] section.
3. The EDS file **shall** include the [Connection Manager] section. This will allow easy configuration of connections from scanners supporting the Connection Configuration object.

5.6 Performance

1. The device **shall** support all recommendations described in the Common Device Recommendations.
2. The device **shall** conform to the following I/O performance measures under no background traffic:

Minimum Supported Connection RPI	$\leq 100\text{ms}$
Mean measured packet interval (MPI) with respect to reported API	$< \pm 10\%$
Average jitter of the measured mean MPI	$< \pm 10\%$
Maximum jitter of the measured mean MPI	$< \pm 50\%$

3. The device **shall** conform to the following I/O performance measures under a steady-state amount of background traffic:

Mean MPI with respect to reported API	$< \pm 10\%$
Average jitter of the measured mean MPI	$< \pm 25\%$
Maximum jitter of the measured mean MPI	$< \pm 100\%$

4. The device **shall** conform to the following I/O performance measures under a burst of background traffic during a steady-state amount of background traffic:

Return to within this percentage of the mean MPI with respect to reported API within the test period	$< \pm 10\%$
Maximum jitter of the measured mean MPI	$< 400\%$

6 Scanner Device Recommendations

This section explains the functionality that is recommended for Scanner class devices over and above that in the Common Device section. The Scanner device recommendations are for any device that originates Transport Class 1 connections.

6.1 Example Devices

- Programmable Controller
- Soft Controllers
- Robot

6.2 CIP

1. The device **shall** support all recommendations described in the Common Device Recommendations.
2. The device **shall** support, at a minimum, origination of 8 Transport Class 1 I/O connections. Although the actual number of connections supported is application specific, support for 64 or more is recommended.
3. The following recommendations pertain to originated Transport Class 1 I/O connections.
 - a) It is recommended that the device support the Change of State trigger type with Production Inhibit Timer (PIT).
 - b) The device **shall** support the Cyclic trigger type.
 - c) The device **shall** support the Listen Only and Input Only connection types.
 - d) The device **shall** support the Exclusive Owner connection type.
 - e) The device **shall** support multicast T->O and unicast O->T. The device shall also support unicast T->O.
 - f) The device **shall** support the 32-bit Real-Time Header (Run/Idle Header) in the O->T connection data. O->T connections to the Heartbeat connection path with 0 data length **shall not** include the Real-Time Header. Support for connections without the Real-Time Header (according to specifications in [Connection Manager] section of the adapter's EDS file) is recommended.
4. The device **shall** be able to deliver a device Configuration Assembly (of ≤ 400 bytes) as part of Fwd_Open.
5. The device **shall** provide access to I/O data collected as a result of its “scan list” via Explicit Messaging, e.g. Assembly object instance attribute 3. The I/O data **shall not** include the 32-bit Real-Time Headers (Run/Idle Header).
6. It is recommended that the Connection Configuration object be supported. This will provide a standard means of configuring the scanner.

7. It is recommended that the device accept (be a target of), at a minimum, 2 Transport Class 1 I/O connections. If this functionality is supported, the connections **shall** support the Transport Class 1 connection features defined for the Adapter class device (section 4.2, items 2-5).
8. It is recommended that the device support the Extended Symbolic path segment in the Fwd_Open as an originator and a target. This would provide interoperable peer-to-peer communication with current EtherNet/IP scanners.

6.3 TCP/IP Suite

1. The device **shall** support all recommendations described in the Common Device and Adapter Device Recommendations.
2. The device **shall** support IGMP V2 with the following behavior:
 - a) Upon receiving a Fwd_Open response to a multicast connection request, an IGMP Membership Report **shall** be issued to join the multicast group.
 - b) Upon closing the multicast connection, an IGMP Leave Group **shall** be issued.

6.4 Ethernet and Physical

No addition to Common Device and Adapter Device Recommendations.

6.5 EDS File

1. The device **shall** support all recommendations described in the Common Device Recommendations.
2. If the device accepts Transport Class 1 connections from other devices, the EDS file **shall** include the [Connection Manager] section. This will allow easy configuration of connections from scanners supporting the Connection Configuration object.

6.6 Performance

1. The device **shall** support all recommendations described in the Common Device Recommendations.
2. If the device supports Adapter functionality, then the device **shall** support all the recommendations described in the Adapter Device Recommendations.