Design Considerations for Robust EtherNet/IP Networks
## Is This Important?

### Application Requirements

- **What is real-time?**
  - Application dependent ….. only you can define what this means for your application.

### Function

<table>
<thead>
<tr>
<th>Function</th>
<th>Information Integration, Slower Process Automation</th>
<th>Time-critical Discrete Automation</th>
<th>Motion Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Communication Technology</strong></td>
<td>.Net, DCOM, TCP/IP</td>
<td>Industrial Protocols - CIP</td>
<td>Hardware and Software solutions, e.g. CIP Motion, PTP</td>
</tr>
<tr>
<td><strong>Period</strong></td>
<td>10 ms to 1000 ms</td>
<td>1 ms to 100 ms</td>
<td>100 µs to 10 ms</td>
</tr>
<tr>
<td><strong>Industries</strong></td>
<td>Oil &amp; gas, chemicals, energy, water</td>
<td>Auto, food &amp; beverage, semiconductor, metals, pharmaceutical</td>
<td>Subset of discrete automation</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>Pumps, compressors, mixers, instrumentation</td>
<td>Material handling, filling, labeling, palletizing, packaging</td>
<td>Printing presses, wire drawing, web making, pick &amp; place</td>
</tr>
</tbody>
</table>

Source: ARC Advisory Group

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Is This Important?

Industrial & Information Convergence

THE CONNECTED ENTERPRISE

 Scalable, robust, secure and future-ready infrastructure:

- **Application**
- **Software**
- **Network**

Internet of Things, Internet of Everything

INFORMATION

IT

OPERATIONS

OT
Industrial Network Design Methodology

Eclipse reference models and reference architectures

Avoiding Network Sprawl!!

Enabling OEM Services to be connected – industrial and non-industrial

Convergence-Ready Solutions

Because Network Infrastructure Matters

Enabling OEM Services to be connected – industrial and non-industrial

Convergence-Ready Solutions

Because Network Infrastructure Matters
Working Design Considerations

Reference Architectures

In addition, design considerations and guidance to help reduce network latency and jitter, increase the availability, integrity and confidentiality of data, and to help design an architecture that supports scalable, robust, secure and future-ready EtherNet/IP network infrastructures.

Single Industrial Network Technology

- Robust Physical Layer
- Segmentation / Structure (modular & scalable building blocks)
- Prioritization - Quality of Service (QoS)
- Redundant Path Topologies with Resiliency Protocols
- Time Synchronization – PTP, CIP Sync, Integrated
- Multicast Management
- Convergence-ready Solutions
- Security – Holistic Defense-in-Depth
- Scalable Secure Remote Access
- Wireless – 802.11
Working Design Considerations
Reference Architectures

In addition, design considerations and guidance to help reduce network Latency and Jitter, increase the Availability, Integrity and Confidentiality of data, and to help design an Infrastructure by a Scalable, Robust, Secure and Future-Ready EtherNet/IP network infrastructure.

Single Industrial Network Technology

- EtherNet/IP
- Robust Physical Layer
- Segmentation / Structure (modular & scalable building blocks)
- Prioritization - Quality of Service (QoS)
- Redundant Path Topologies with Resiliency Protocols
- Time Synchronization – PTP, CIP Sync, Integrated
- Motion on the EtherNet/IP network
- Multicast Management
- Convergence-ready Solutions
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### EtherNet/IP Industrial Network Technology

#### Layer Reference Model

<table>
<thead>
<tr>
<th>Layer Name</th>
<th>Layer No.</th>
<th>Function</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Layer 7</td>
<td>Network Services to User App</td>
<td>CIP</td>
</tr>
<tr>
<td>Presentation</td>
<td>Layer 6</td>
<td>Encryption/Other processing</td>
<td>IEC 61158</td>
</tr>
<tr>
<td>Session</td>
<td>Layer 5</td>
<td>Manage Multiple Applications</td>
<td>Open Systems</td>
</tr>
<tr>
<td>Transport</td>
<td>Layer 4</td>
<td>Reliable End-to-End Delivery Error Correction</td>
<td>IETF TCP/UDP</td>
</tr>
<tr>
<td>Network</td>
<td>Layer 3</td>
<td>Packet Delivery, Routing</td>
<td>IETF IP</td>
</tr>
<tr>
<td>Data Link</td>
<td>Layer 2</td>
<td>Framing of Data, Error Checking</td>
<td>IEEE 802.3/802.1</td>
</tr>
<tr>
<td>Physical</td>
<td>Layer 1</td>
<td>Signal type to transmit bits, pin-outs, cable type</td>
<td>TIA - 1005</td>
</tr>
</tbody>
</table>

**Physical Layer Hardening**
**Infrastructure Device Hardening**
**Common Application Layer Protocol**

5-Layer TCP/IP Model
Working Design Considerations

Reference Architectures

Design considerations and guidance to help reduce network latency and jitter, increase the availability, integrity and confidentiality of data, and to help design and build a scalable, robust, secure and future-ready EtherNet/IP network infrastructure.

EtherCAT IP

Robust Physical Layer

Segmentation / Structure (modular & scalable building blocks)

Prioritization - Quality of Service (QoS)

Redundant Path Topologies with Resiliency Protocols

Time Synchronization - PTP, CIP Sync, Integrated Clock on the EtherNet/IP network

Multicast Management

Convergence-ready Solutions

Security - Holistic Defense-in-Depth

Scalable Secure Remote Access

Wireless - 802.11
Design and implement a robust physical layer environment classification - MICE

more than cable

connectors

patch panels

wiring management

interference mitigation

Grounding, Bonding and Shielding

standard Physical Media

twisted vs. wireless

copper vs. fiber

UTP vs. STP

singlemode vs. multimode

 multimode – LC vs. SC

standard Topology Choices

switch-level & device-level
M.I.C.E. provides a method of categorizing the environmental classes for each plant Cell/Area zone.

This provides for determination of the measure of "hardening" required for the network media, connectors, pathways, devices, and enclosures.

The MICE environmental classification is a measure of product robustness:
- Specified in ISO/IEC 24702
- Part of TIA-1005 and ANSI/TIA-568-C.0 standards

Examples of rating:
- 1585 Media: $M_3 I_3 C_3 E_3$
- M12: $M_3 I_3 C_3 E_3$
- RJ-45: $M_1 I_1 C_2 E_2$
Working Design Considerations

Reference Architectures

- Design considerations and guidance to help reduce network Latency and Jitter, increase the Availability, Integrity and Confidentiality of data, and to help design an a Scalable, Robust, Secure and Future-Ready EtherNet/IP network infrastructure.

Single Industrial Network Technology

- Robust Physical Layer
- Segmentation / Structure (modular & scalable building blocks)
- Prioritization - Quality of Service (QoS)
- Redundant Path Topologies with Resiliency Protocols
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- Option on the EtherNet/IP network
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- Convergence-ready Solutions
- Security – Holistic Defense-in-Depth
- Scalable Secure Remote Access
- Wireless – 802.11
ller modular building blocks to help 1) minimize network sprawl
2) build scalable, robust and future-ready network infrastructure
smaller fault domains (e.g. Layer 2 loops)
smaller broadcast domains
smaller domains of trust (security)
pople techniques to create smaller network building blocks (Layer 2 domains)
structure and hierarchy
Logical model – geographical and functional organization of IACS devices
Campus network model - multi-tier switch model – Layer 2 and Layer 3
Logical framework
gmentation
Multiple network interface cards (NICs) – e.g. CIP bridge
Network Address Translation (NAT) appliance
Virtual Local Area Networks (VLANs)
VLANs with NAT
ntegrated Services Router
Multiple NIC Segmentation

Plant-wide / Site-wide Network

**Enterprise-wide Business Systems**

- Levels 4 & 5 – Data Center
  - Enterprise Zone

**Level 3 - Site Operations**

- Physical or Virtualized Servers
  - FactoryTalk Application Servers & Services Platform
  - Network Services – e.g. DNS, AD, DHCP, AAA
  - Remote Access Server (RAS)
  - Call Manager
  - Storage Array

**Level 3.5 - IDMZ**

**Industrial Zone Levels 0-3**

**Plant-wide Site-wide Operation Systems**

- **Cell/Area Zones Levels 0-2**
  - Physical or Virtualized Servers
    - FactoryTalk Application Servers & Services Platform
    - Network Services – e.g. DNS, AD, DHCP, AAA
    - Remote Access Server (RAS)
    - Call Manager
    - Storage Array

- **Cell/Area Zones**
  - Subnet 192.168.1.0/24

**Plant-wide**

- Plant LAN – VLAN17 - Layer 2 Domain
- Plant IP - Subnet 10.17.10.0/24

**Cell/Area Zone #1**
- Subnet 192.168.1.0/24

**Cell/Area Zone #2**
- Subnet 192.168.1.0/24

**Cell/Area Zone #3**
- Subnet 192.168.1.0/24

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Appliance Segmentation

Enterprise-wide / Site-wide Network

Enterprise-wide Business Systems

Plant-wide Site-wide Operation Systems

Levels 4 & 5 – Data Center
Enterprise Zone

Level 3.5 - IDMZ

Level 3 - Site Operations
Industrial Zone
Levels 0-3

Physical or Virtualized Servers
- FactoryTalk Application Servers & Services Platform
- Network Services – e.g., DNS, AD, DHCP, AAA
- Remote Access Server (RAS)
- Call Manager
- Storage Array

EtherNet/IP™

- Plant LAN – VLAN17 - Layer 2 Domain
- Plant IP - Subnet 10.17.10.0/24

Cell/Area Zones
Levels 0-2

Cell/Area Zone #1
Subnet 192.168.1.0/24

Cell/Area Zone #2
Subnet 192.168.1.0/24

Cell/Area Zone #3
Subnet 192.168.1.0/24
Integrated Services Router Segmentation

Enterprise-wide
Business Systems

Plant-wide
Site-wide
Operation Systems

Levels 4 & 5 – Data Center
Enterprise Zone

Level 3.5 - IDMZ

Level 3 - Site Operations
Industrial Zone
Levels 0-3

• Plant LAN – VLAN17 - Layer 2 Domain
• Plant IP - Subnet 10.17.10.0/24

 physical or virtualized servers
• FactoryTalk Application Servers & Services Platform
• Network Services – e.g. DNS, AD, DHCP, AAA
• Remote Access Server (RAS)
• Call Manager
• Storage Array

Cell/Area Zones
Levels 0-2

Cell/Area Zone #1
Subnet 192.168.1.0/24

Cell/Area Zone #2
Subnet 192.168.1.0/24

Cell/Area Zone #3
Subnet 192.168.1.0/24
Presentation with NAT

Enterprise-wide Network

Levels 4 & 5 – Data Center

Enterprise Zone

Level 3.5 - IDMZ

Cell/Area Zone #1

VLAN10
Subnet 192.168.1.0/24

Cell/Area Zone #2

VLAN20
Subnet 192.168.1.0/24

Cell/Area Zone #3

VLAN30

Plant-wide

Site-wide

Operation Systems

Level 3 - Site Operations

Physical or Virtualized Servers

• FactoryTalk Application Servers & Services Platform
• Network Services – e.g. DNS, AD, DHCP, AAA
• Remote Access Server (RAS)
• Call Manager
• Storage Array

Levels 0-3

Industrial Zone

Cell/Area Zones
Levels 0-2

LAN – VLAN17 - Layer 2 Domain
IP - Subnet 10.17.10.0/24

Cell/Area Zones
Levels 0-2

Cell/Area Zones
Levels 0-2

Cell/Area Zones
Levels 0-2
Segmentation Considerations

modular building blocks to help 1) minimize network sprawl
2) enable, robust and future-ready network infrastructure
3) support domains (e.g. Layer 2 loops)
4) trust domains (e.g. Layer 2 loops)
5) issues to create smaller network building blocks (Layer 2 domains)

Hierarchy
Design Considerations

Architectures

In consideration and guidance to help reduce network **Latency** and **Jitter**, to **Availability**, **Integrity** and **Confidentiality** of data, and to help design and design a **Robust**, **Secure** and **Future-Ready** EtherNet/IP network infrastructure:

- **EtherNet/IP** Technology
- **Layer 2 Structure** (modular & scalable building blocks)
- **Quality of Service (QoS)**
- **Topologies with Resiliency Protocols**
- **Networkization – PTP, CIP Sync, Integrated EtherNet/IP network management**
- **Ready Solutions**
- **Dynamic Defense-in-Depth**
- **Remote Access 2.11**
Path Topologies with Resiliency Protocols

**Switch-level Topologies**

- **Ring Resilient Ethernet Protocol (REP)**
- **Star/Bus Linear**

**Device-level Topologies**

- Switch-level and Device-level Topologies
Path Topologies with Resiliency Protocols

- Create a switching (bridging) loop
- Configuration, a loop will lead to a broadcast storm, flooding the network, which will consume available
- Break down a Layer 2 switched (bridged) network
- Ethernet frames do not have a time-to-live (TTL)
- Can loop forever
Path Topologies with Resiliency Protocols: Avoidance

The resiliency protocol maintains redundant paths while avoiding switching (bridging) loop.
Path Topologies with Resiliency Protocols:

Resiliency (healing, recovery, etc.) must occur before the Industrial Automation and (IACS) application is impacted.
Path Topologies with Resiliency Protocols:

Forwarding

Link Failure

Perturbation must occur quickly enough to avoid a Logix Controller connection timeout:

- Instruction - Explicit, CIP Class 3
  - Out - 30 second default
- Out/Consumer - Implicit, CIP Class 1
  - Out - 4 x RPI, with a minimum of 100 ms
- CIP, CIP Class 1
  - Out - 4 x RPI by default
Path Topologies with Resiliency Protocols:

- Don’t forget about potential loops on the switch itself
## Path Topologies with Resiliency Protocols

### Industrial versus COTS - Panel & DIN Rail Mounting vs. Table & Rack (e.g. 1RU)

<table>
<thead>
<tr>
<th>Managed Switches</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Loop prevention</td>
<td>More expensive</td>
</tr>
<tr>
<td></td>
<td>Security services</td>
<td>Requires some level of support and configuration to start up</td>
</tr>
<tr>
<td></td>
<td>Diagnostic information</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Segmentation services (VLANs)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prioritization services (QoS)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Network resiliency</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Multicast management services</td>
<td></td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Managed Switches</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inexpensive</td>
<td>No loop prevention</td>
</tr>
<tr>
<td></td>
<td>Simple to set up</td>
<td>No security services</td>
</tr>
<tr>
<td></td>
<td>Limit management capabilities</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Managed Switch Technology</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cable simplification with reduced cost</td>
<td>Limited management capabilities</td>
</tr>
<tr>
<td></td>
<td>Ring loop prevention &amp; Network resiliency</td>
<td>May require minimal configuration</td>
</tr>
<tr>
<td></td>
<td>Prioritization services (QoS)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Time Sync Services (IEEE 1588 PTP Transparent Clock)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diagnostic information</td>
<td></td>
</tr>
<tr>
<td>Resiliency Protocol</td>
<td>Mixed Vendor</td>
<td>Ring</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------</td>
<td>------</td>
</tr>
<tr>
<td>(802.1D)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>P (802.1w)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>P (802.1s)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>T+</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Channel (P 802.3ad)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Links</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>ODVA</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Path Topologies with Resiliency Protocols

Ring Topology with Device Level Ring Protocol

- Blocks traffic on one port
- Frames on both ports to detect break in the ring
- Restored, supervisor hears beacon on both ports, and transitions to normal ring mode, one port
Path Topologies with Resiliency Protocols

Standard enabling suppliers to develop products
and linear topologies, fiber and copper

time managed to ensure timely delivery of Quality of Service, IEEE-1588 Precision Time
Management)

Fault tolerant network

3 ms convergence for simple device networks
Path Topologies with Resiliency Protocols

A chain of switch ports connected to each other and the same REP segment ID. A ring switch-level topology can be built with REP and a single fault tolerant network for IACS applications that can tolerate up to a 100 ms presence recovery time (on fiber interfaces). A switch-level resiliency protocol with Industrial Automation and IT applications, included with Cisco switch stack, Stratix 5700, 8300.
Internet Protocol
Ethernet Protocol

Considerations

For IACS applications that can tolerate up to a 100 ms network convergence recovery time, Cisco and Rockwell recommend either a redundant star switch topology with the Flex Links resiliency protocol, or a ring topology utilizing the ODVA DLR resiliency protocol.

For fast RPIs and SFPs for all inter-switch links – ring and redundant star switch-level topologies. For IACS applications that can tolerate up to a 100 ms network convergence recovery (recovery from a failure) than RPVST+ or MSTP for a switch ring.
Path Topologies with Resiliency Protocols

Redundant Path Topology and Resiliency Protocol is application dependent

Device-level topologies

- Star Topology

Vendor environment - Legacy Migration

- Version of EtherNet/IP IACS devices

Hierarchal architecture - Layer 2 vs. Layer 3

Network Convergence time, Packet loss, Latency & Jitter
Design Considerations

Architectures

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EtherNet/IP network

cation

cation

ready Solutions

acid Defense-in-Depth

re Remote Access

2.11
e-Ready Network Solutions

Partner Solution(s)
- e.g. Machine

Partner Solution(s)
- e.g. Process Skid

Plant-wide / Site-wide Industrial Automation Systems

Plant-wide Industrial Automation Systems

Design and deployment considerations that a trusted partner (e.g. OEM, SI, contractor) has to take into account to achieve seamless integration of their solution (machine, skid) into their customers' plant-wide/site-wide network infrastructure.
Industrial network technology that fully utilizes standard Ethernet and IP networking technology as the multi-network infrastructure.

Infrastructure devices – asset utilization

Sustainability

Firm, subnet, default gateway (routability)

Inventions – static/dynamic, hardware/software configurable, NAT/DNS services

, switch-level and device-level topologies

a prioritization

Prevention, redundant path topologies with resiliency protocols

ion Services

ision Time Protocol (PTP w/E2E); CIP Sync applications – first fault, SOE, CIP Motion

gment with end user: business practices, corporate/local standards, industrial security policies, current status of network infrastructure

security, access control lists, application security (FactoryTalk Security), remote access

trial automation and control system (IACS) security standards such as ISA/IEC-62443 (formerly ISA 99) and NIST 800-82
Resilient Ethernet Protocol (REP) in a Plantwide Ethernet Architecture

802.11 Wireless LAN Technology within a Plantwide Ethernet Architecture

Design Considerations for Securing Industrial Automation and Control System Networks

Recommendations for Plant-wide EtherNet/IP Deployments

Manufacturing Computer and Controller Assets

Ensure Remote Access to plant-floor Applications and Data...
CCNA for Industrial Applications - Training and Certification
- Training - TBD
- Exam - TBD

- Industrial IP Advantage
  - E-learning modules
  - CPwE Design Considerations and Best Practices
Industrial Networks with Cisco Networking Training Class

Rockwell Automation now offers an exclusive opportunity to become a certified Cisco Networking Specialist.

Install, maintain and troubleshoot industrial networks

Drawings to recognize industrial topologies and materials

Work availability, reliability and cyber security

In order to pass the Industrial Networking Specialist Exam (600-601)? Take the Managing with Cisco Networking Technologies (IMINS) being held April 27-May 1st in Burr Ridge. Mention you were at the Process Summit and receive a 10% discount on the Course!

Visit the Rockwell Automation booth for more information.
Considerations for Robust EtherNet/IP Networks