Reference Manual

Allen-Bradley

Embedded Switch Technology Reference Architectures

Allen-Bradley • Rockwell Software

Rockwell Automation

Important User Information

Solid-state equipment has operational characteristics differing from those of electromechanical equipment. Safety Guidelines for the Application, Installation and Maintenance of Solid State Controls (publication SGI-1.1 available from your local Rockwell Automation® sales office or online at http://www.rockwellautomation.com/literature/) describes some important differences between solid-state equipment and hard-wired electromechanical devices. Because of this difference, and also because of the wide variety of uses for solid-state equipment, all persons responsible for applying this equipment must satisfy themselves that each intended application of this equipment is acceptable.

In no event will Rockwell Automation, Inc. be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment.

The examples and diagrams in this manual are included solely for illustrative purposes. Because of the many variables and requirements associated with any particular installation, Rockwell Automation, Inc. cannot assume responsibility or liability for actual use based on the examples and diagrams.

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Throughout this manual, when necessary, we use notes to make you aware of safety considerations.

WARNING: Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.

ATTENTION: Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you identify a hazard, avoid a hazard, and recognize the consequence.

SHOCK HAZARD: Labels may be on or inside the equipment, for example, a drive or motor, to alert people that dangerous voltage may be present.

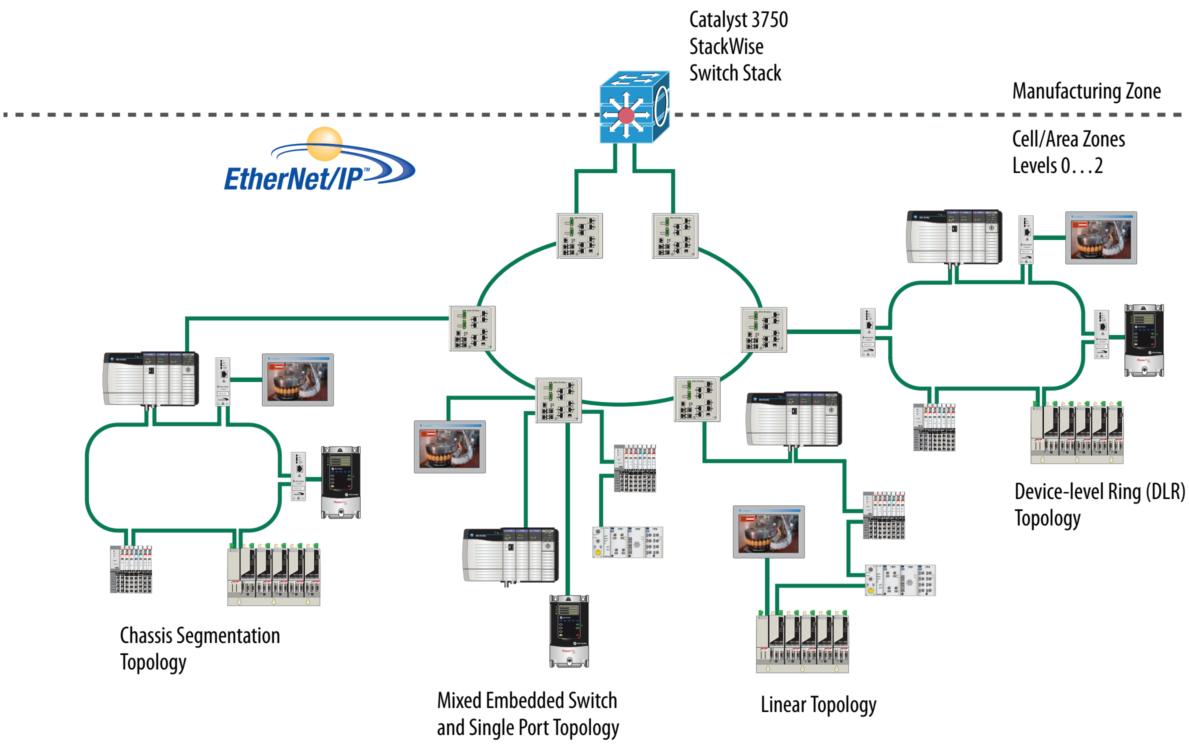
BURN HAZARD: Labels may be on or inside the equipment, for example, a drive or motor, to alert people that surfaces may reach dangerous temperatures.

IMPORTANT Identifies information that is critical for successful application and understanding of the product.

Notes:

This document provides design recommendations for connecting device-level topologies to larger, switch networks comprised of Layer 2 access switches. It also covers the implementation of embedded switch technology within the Converged Plantwide Ethernet (CPwE) Cell/Area zone. The Cell/Area zone is where the device-level topologies connect Industrial Automation and Control System (IACS) end-devices into the Cell/Area zone.

Figure 1 - Example Network



Careful planning is required to achieve the optimal design, deployment, and performance (such as latency and jitter) from both the Cell/Area IACS network and the IACS device perspective.

This document extends the following design recommendations in the Cisco and Rockwell Automation Converged Plantwide Ethernet Design and Implementation Guide, publication ENET-TD001.

See in ENET-TD001	For This Information
Chapter 1, Converged Plantwide Ethernet Overview	• Industrial characteristics • Availability • IACS communication protocols
Chapter 3, CPwE Solution Design-Cell/Area Zone	• Topology options and media considerations • Availability and network resiliency
Chapter 5, Implementing and Configuring the Cell/Area Zone	• Network resiliency (Table 5-3) • Availability and network resiliency • Implementing the EtherNet/IP network modules
Chapter 8, CIP Motion	• EtherNet/IP embedded switch technology • CIP motion reference architectures • DLR topology
Chapter 9, CIP Sync Sequence of Events	• Architecture 2 – device-level linear topology (using embedded switch technology) • Architecture 3 – device-level ring topology (using embedded switch technology)
Chapter 10, DHCP Persistence in the Cell/Area Zone	• DHCP persistence topology considerations

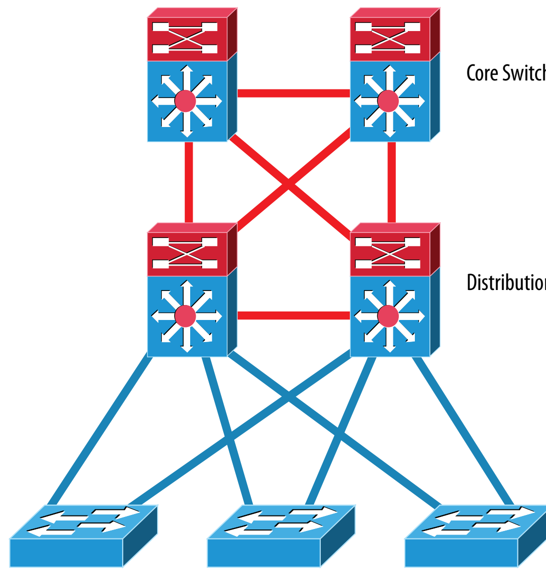
This document focuses on EtherNet/IP networks recommended by the CPwE guide and tested with Allen-Bradley devices, controllers, and applications.

Switch Topology

The CPwE logical framework follows the Campus Network Model. This model uses a multi-tier, switch topology to provide the following:

- Hierarchical segmentation
- Scalability
- Resiliency
- Traffic management
- Security

Figure 2 - Example Campus Network Model



Within this model, there are the following switch layers.

- Core switches (Layer 3) are the backbone of the network and they aggregate distribution switches.
- Distribution switches (Layer 3) aggregate access switches and provide Layer 3 services, such as routing.
- Access switches (Layer 2) aggregate IACS end-devices and device-level topologies.

Prior to the embedded switch technology, the traditional EtherNet/IP network topologies were switch-centric, using Layer 2 access switches: linear, star, ring, and redundant star. Industrial Ethernet switches (IES) in various topologies connected IACS end-devices and enabled communication between them. For the purpose of this publication, the IES switches are Allen-Bradley Stratix 8000 and Stratix 5700 switches. With embedded switch technology, IACS end-devices can be directly connected to each other without the need for additional IES switches. Embedded switch technology adds the choices of device-level topologies: linear and ring.

We recommend connecting device-level topologies to the CPwE Cell/Area zone IACS network via Layer 2 access switches. We do not recommend connecting device-level topologies directly to Layer 3 distribution switches.

Table 1 - Switch Topologies

Topology	Advantages	Disadvantages
Redundant star	• Resiliency from multiple connection failures • Faster convergence to connection loss • Consistent number of hops (typically two in a flat design) provides predictable and consistent performance and real-time characteristics • Fewer bottlenecks in the design reduces chances of segment over-subscription	• Additional wiring (and relevant costs) required to connect Layer 2 access switches directly to a Layer 3 distribution switch • Additional configuration complexity (for example, Spanning Tree with multiple blocks)
Ring	• Resiliency from loss of one network connection • Less cabling complexity in certain plant floor layouts • Multiple paths reduces potential for oversubscription and bottlenecks	• Additional configuration complexity (for example, Spanning Tree with a single block) • Longer convergence times • Variable number of hops makes designing predictable performance more complex
Linear/star	• Easy to design, configure, and implement • Least amount of cabling (and associated cost)	• Loss of network service in case of connection failure (no resiliency) • Creates bottlenecks on the links closest to Layer 3 device, and varying number of hops make it more difficult to produce reliable performance.

Device-level Topology

The embedded switch technology offers alternative network topologies for interconnecting EtherNet/IP devices by embedding switches into the end devices themselves.

Allen-Bradley devices with embedded switch technology have these features in common:

- Each device supports the management of network traffic to ensure timely delivery of critical data, that is, QoS and IGMP protocols are supported.
- Each product is designed and conformance tested according to the ODVA specification for EtherNet/IP.
- Each device supports an IEEE 1588 transparent clock for CIP motion and CIP Sync applications.
- Each device has a single network interface card (NIC) that is directly connected to a port on the embedded switch. The remaining two ports on the embedded switch are connected to ports 1 and 2 on the module, which connect the module to the device-level topology. Because these ports are connected to a single NIC, they cannot be used to connect to multiple Ethernet networks.

The embedded switch technology supports control, I/O, and HMI devices connected together in either a linear or ring topology. Use the embedded switch technology in the following situations:

- Simplify cabling by daisy-chaining devices along the length of the system.
- Support high-resiliency because in most applications a DLR will converge in 1…3ms or less.
- Support for applications, such as CIP motion and CIP safety applications.
- Allow for a network fault without tripping the safety system.
- Conserve switch ports on the access switch because device-level topologies let multiple devices be connected to the same switch port.

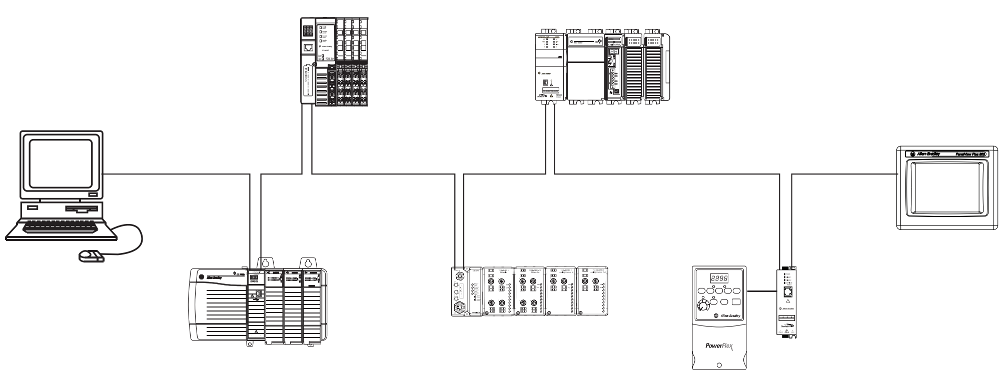
Table 2 - Device-level Topologies

Topology	Advantages	Disadvantages
Linear	• Easy to design, configure, and implement • Least amount of cabling (and associated cost)	• Loss of network service in case of connection failure (no resiliency) • Creates bottlenecks on the links closest to Layer 2 device, and varying number of hops make it more difficult to produce reliable performance.
DLR	• Resiliency from loss of one network connection • Convergence time in the 1-3ms range.	• Additional configuration required • Not natively supported on Stratix switches • Additional cabling required • Creates bottlenecks on the links closest to Layer 2 device, and varying number of hops make it more difficult to produce reliable performance.

Linear Network

A linear network is a collection of devices that are daisy-chained together. The EtherNet/IP embedded switch technology lets this topology be implemented at the device level. No additional switches are required.

Figure 3 - Example Linear Network



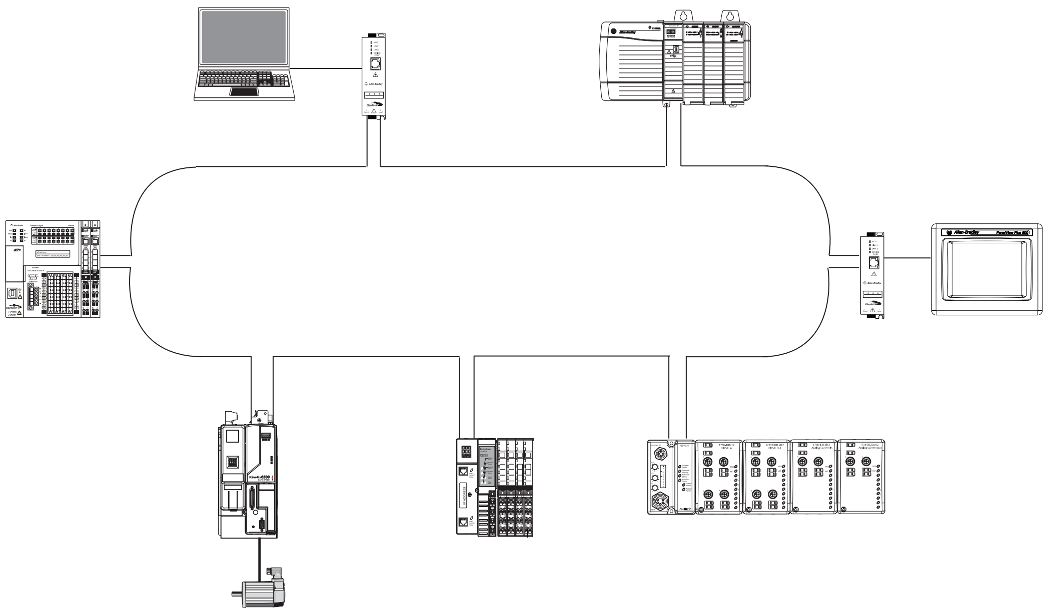
These are the primary advantages of a linear network:

- The network simplifies installation and reduces wiring and installation costs.
- The network requires no special software configuration.
- Embedded switch products offer improved CIP Sync application performance on linear networks.

Device-level Ring (DLR) Network

A DLR network is a single-fault tolerant ring network intended for the interconnection of automation devices. This topology is also implemented at the device level. No additional switches are required.

Figure 4 - Example DLR Network



During normal network operation, an active ring supervisor uses beacon, and other DLR protocol frames, to monitor the health of the network. Back-up supervisor nodes and ring nodes monitor the beacon frames to track ring transitions between Normal (all links are working) and Faulted (the ring is broken in at least one place) states. If the back-up supervisor does not hear the supervisor for a period of time, it assumes the supervisor failed and takes over the supervisor role.

The advantages of the DLR network include the following:

- Resilience to a single point of failure on the network
- Ring recovery time is less than 3 ms for a 50 node network
- Simple installation

Additional Resources

These documents contain additional information concerning related products from Rockwell Automation.

Resource	Description
Ethernet Design Considerations Reference Manual, publication ENET-RM002	Design considerations for EtherNet/IP infrastructure and protocol choices.
EtherNet/IP Embedded Switch Technology Application Guide, publication ENET-AP005	Design recommendations for linear and device-level ring topologies.
Converged Plantwide Ethernet (CPwE) Design and Implementation Guide, publication ENET-TD001	Details on EtherNet/IP topologies and supported protocols.
Integrated Architecture and CIP Sync Configuration Application Solution, publication IA-AT003	Design and implementation details for CIP Sync technology.
Industrial Automation Wiring and Grounding Guidelines, publication 1770-4.1	Provides general guidelines for installing a Rockwell Automation industrial system.
Product Certifications website, http://www.ab.com	Provides declarations of conformity, certificates, and other certification details.

You can view or download publications at http:/www.rockwellautomation.com/literature/. To order paper copies of technical documentation, contact your local Allen-Bradley distributor or Rockwell Automation sales representative.

Notes:

Design Recommendations

Use the following architectures to connect a device-level topology to the switch topology:

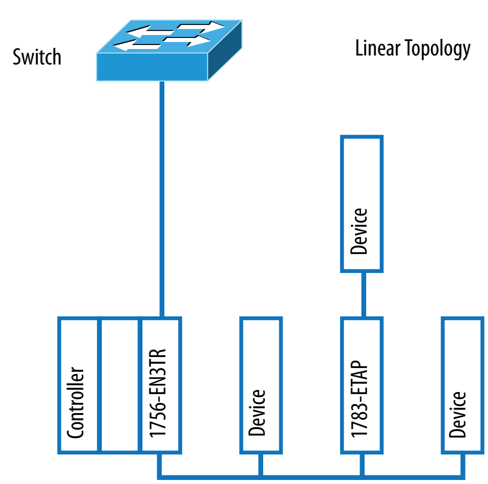
- Embedded switch
- Mixed embedded switch and single-port
- Physical chassis segmentation

Embedded Switch Topology

In this topology, the control, I/O, and HMI devices are all connected to a common ring or linear topology. Both linear and DLR topologies can be connected to a switch topology.

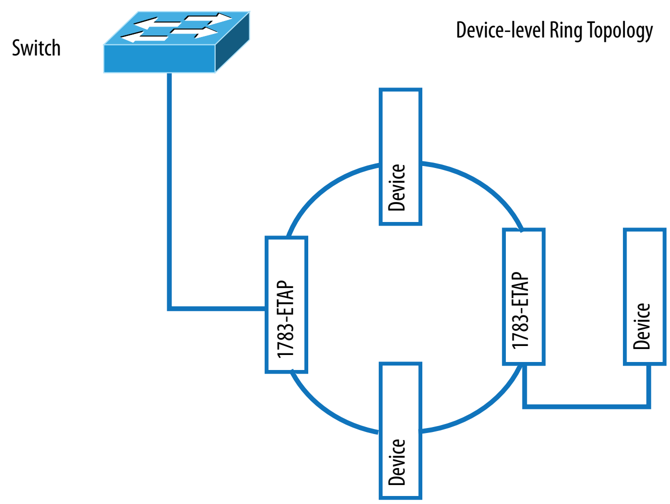
A linear topology can be directly connected to an IES interface configured with the Multiport Automation Device Smartport role.

Figure 5 - Linear Topology



Device-level ring technology is a simple, single fault technology and is not recommended as a backbone for an IES topology. The IES switches do not have native support for the DLR beacon protocol. Therefore, we do not recommend inserting an IES switch directly into a DLR ring. Instead, use a 1783-ETAP to connect the DLR topology to the IES port configured with the Multiport Automation Device Smartport role.

Figure 6 - DLR Topology

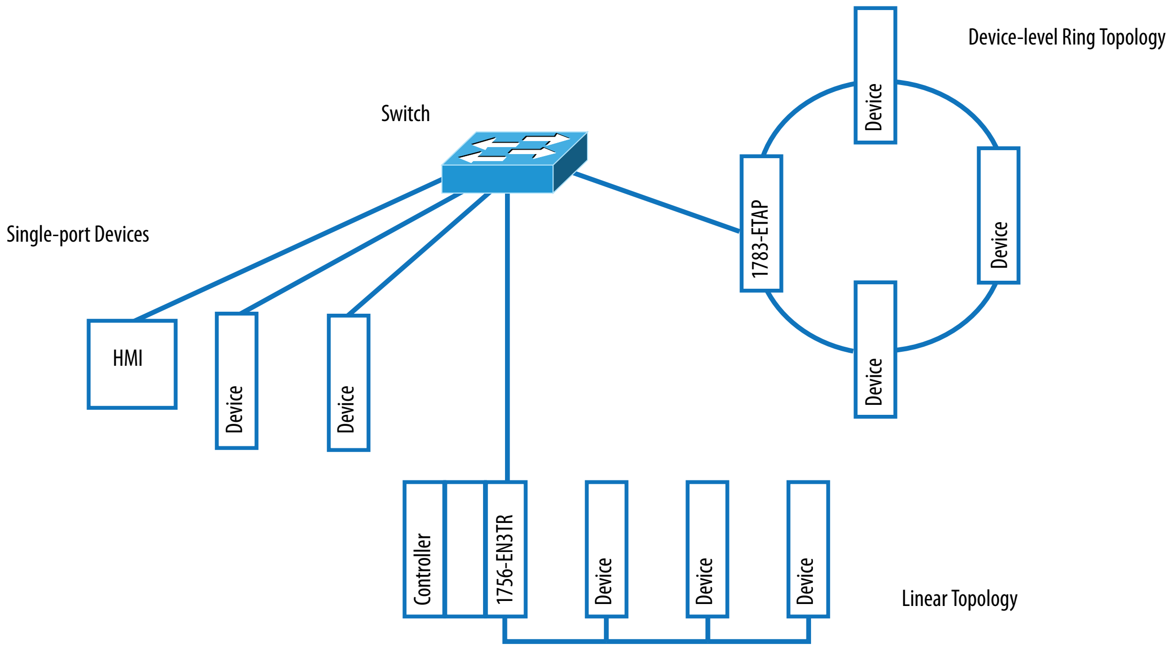


Whether a DLR or linear device-level topology, all the end-devices that are tightly-coupled to a controller must be a part of the same embedded switch topology. Those devices either have an embedded switch or use an 1783-ETAP to connect to the topology.

Mixed Embedded Switch and Single-port Technology

In this topology, the control, I/O and HMI devices are all connected to the same IES switch. The devices can be directly connected to the IES switch or via a device-level topology. This reduces the number of ports needed on the IES switch. It also lets you daisy-chain devices along the length of a machine (such as I/O and drives that support a conveyer belt).

Figure 7 - Mix Embedded Switch and Single-port Technology

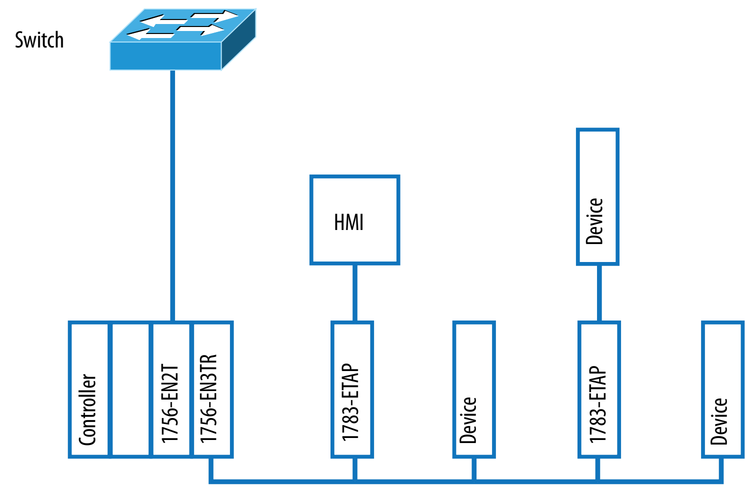


This topology is the most flexible. It lets you combine both single-port devices and devices with embedded switch technology. This topology also lets you connect multiple, device-level topologies to the same IES switch.

Physical Chassis Segmentation

Physical chassis segmentation uses a Common Industrial Protocol (CIP) bridge to connect the control, I/O, and HMI devices. In the CIP bridge, one EtherNet/IP communication device connects to the IES switch and a second EtherNet/IP communication devices connects to the device-level topology.

Figure 8 - Chassis Segmentation



This topology has the advantage that it naturally segments the control, I/O, and HMI traffics from the rest of the network. You can also achieve the same effect with subnet and VLAN design. The disadvantage of this topology is that it may require direct connection to the device-level topology for maintenance operations of non-CIP devices, such as diagnostics and configuration.

This topology can also provide a false sense of security in that it does not filter CIP traffic between the IES switch topology and the device-level topology. It acts as an application-layer bridge and forwards CIP traffic from the switch topology to the device-level topology.

Guidelines for Connecting Device-level and Switch Topologies

Use embedded switch technology to connect device-level topologies to the switch topology. We do not recommend using device-level topologies as the backbone of the network.

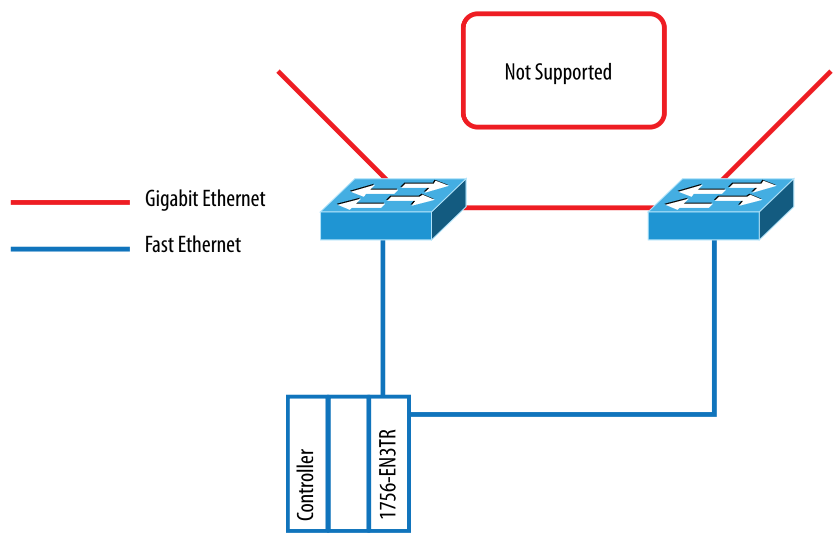
We recommend using the Express Setup utility and the Multiport Automation Device Smartport Role macro to configure the IES switch.

Table 3 - Considerations for Connecting Device-level and Switch Topologies

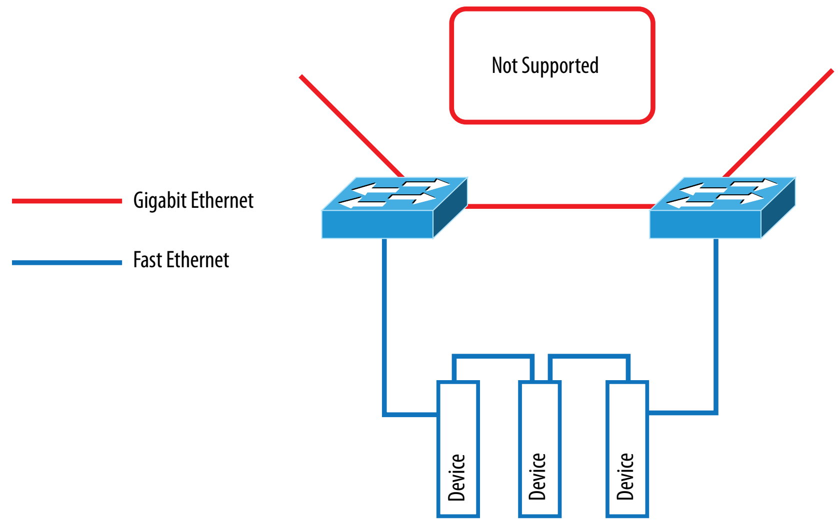
Consideration	Details
Size	While there isn't a formal limit to the number of devices in a device-level topology, Rockwell Automation tested a maximum of 50 devices. This allows for a ring fault recovery time of less than 3ms. It is important to note that the ring fault recovery time assumes the length of the links is 100m or less.
Supervisor	The DLR ring supervisor maintains a loop-free topology by blocking port 2 of the embedded-switch device. If the supervisor detects a fault in the network it unblocks port two until the fault is corrected. It is important to remember to enable a ring supervisor before closing the DLR ring. If the ring closed before the supervisor is enabled, a bridge loop results, which generates a broadcast storm. It is possible under rare circumstances (or misconfiguration) that the supervisor will fail but traffic will continue to flow. This creates an unblocked, bridge loop in the DLR ring. To avoid this, configure a secondary supervisor in the ring. In the event that the primary supervisor fails, the secondary supervisor detects the fault and block its port two in about 4 ms. Rockwell Automation does not recommends enabling a ring supervisor on a linear topology. By default, the ring supervisor sends a beacon frame every 400 µs out both ports. This beacon adds up to 2,500 pps of traffic that is only needed in a ring topology.
DHCP persistence	Because DHCP persistence supports a single IP address, do not use DHCP persistence with EtherNet/IP modules that have embedded switch technology. If you try to use DHCP persistence with these modules, only one of the modules is assigned an IP address. The remaining modules are not assigned IP addresses. For more information about DHCP persistence, see Chapter 10 of Converged Plantwide Ethernet (CPwE) Design and Implementation Guide, publication ENET-TD001.

Topology Guidelines

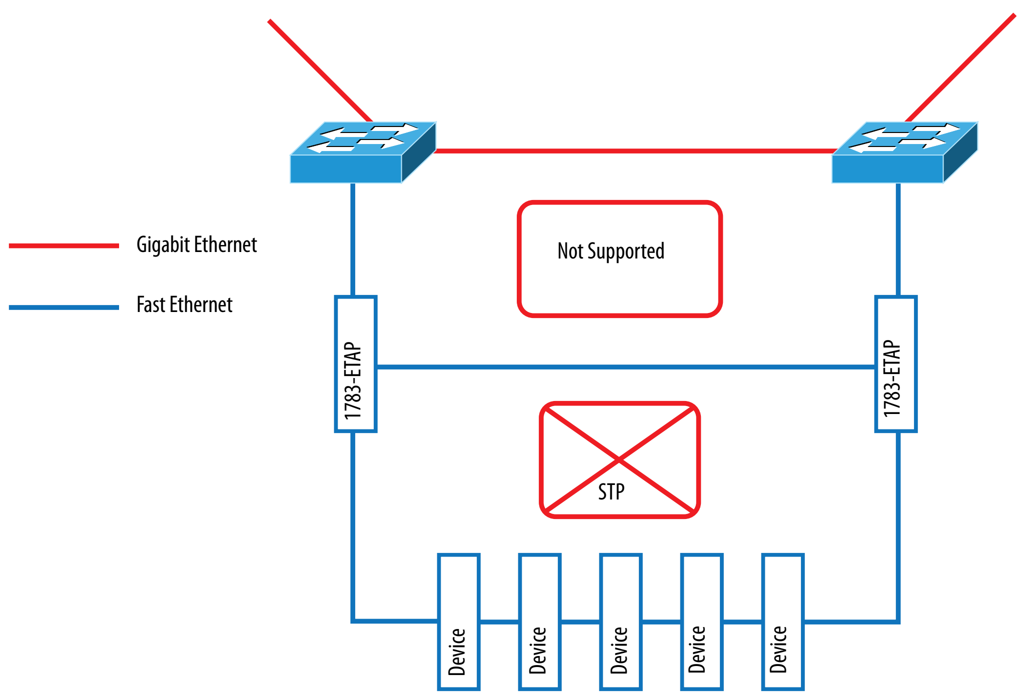
- Connecting both ports of an embedded switch device to multiple IES switches is not supported.



- Connecting both ends of a device-level linear topology to multiple IES switches is not supported.



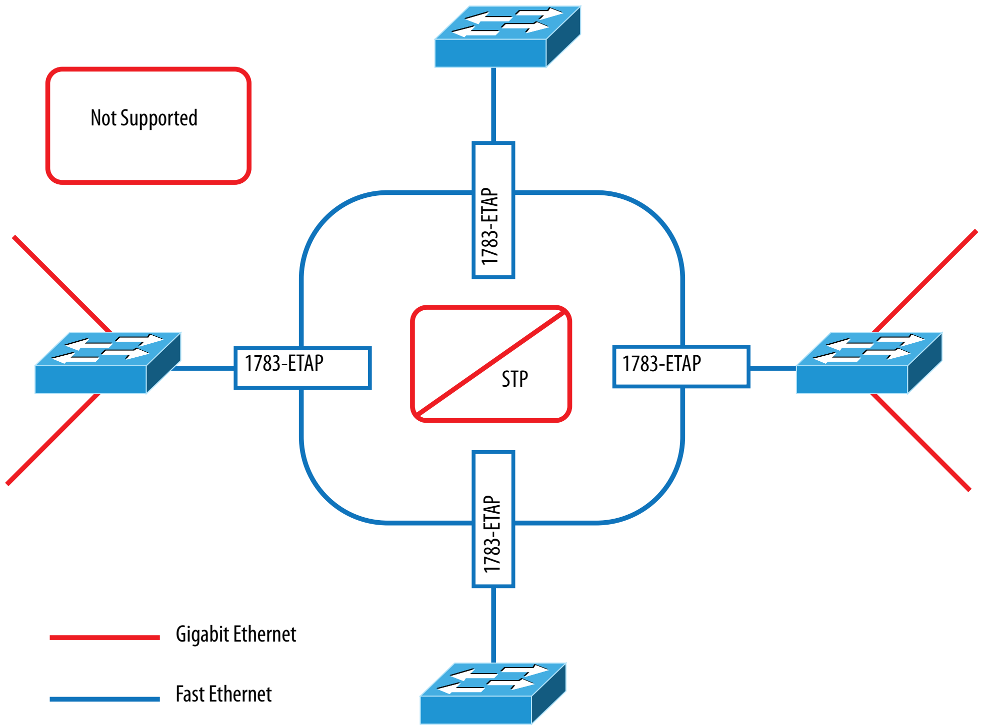
- Connecting multiple ETAP devices from the device-level ring topology to multiple IES switches in a switch topology is not supported.



- Embedded-switch technology devices do not support switch topology spanning tree protocol (STP).

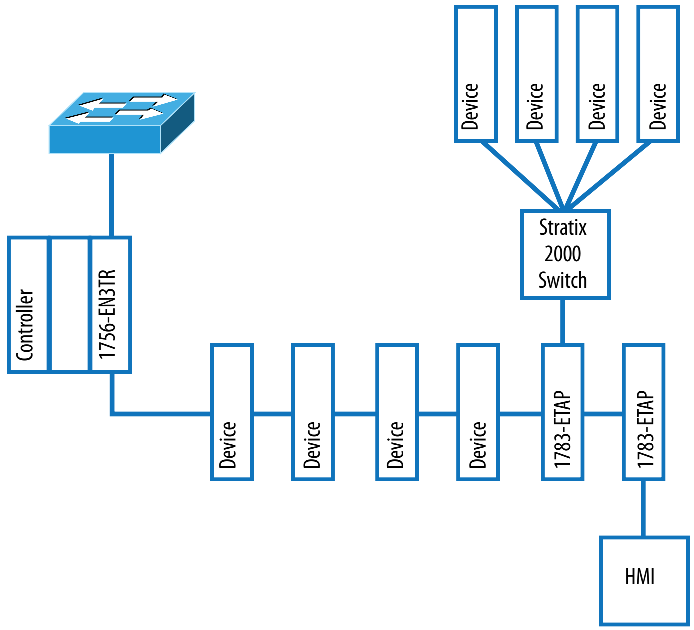
  The DLR topology is not compatible with the Spanning Tree Protocol (STP). The ring supervisor will block STP messages (BPDUs) between switches. Attempting to run STP over a DLR ring can lead to broadcast storms and other network outages.

- Connecting multiple managed switches to a common linear or DLR topology is not supported. For example, do not use a DLR topology as a backbone network for switches.



Connecting managed switches together via a device-level topology can introduce significant risk into the network. Many of the protocols used by managed switches expect that the switches are direct neighbors to each other. Inserting device-level topologies between the managed switches may lead to unexpected results.

You can connect multiple, single-port devices to either a device-level linear or DLR topology by using a combination of an ETAP device and an unmanaged switch.



In this case, the unmanaged switch does not introduce a loop into the network and does not interact with the IES switches.

Considerations for Resiliency Protocols

For more information on protocols, see Chapter 3 in Converged Plantwide Ethernet (CPwE) Design and Implementation Guide, publication ENET-TD001.

Table 4 - Protocol Guidelines

Protocol	Topology	Recommendations
REP	Ring	Use the mixed topology when connecting an embedded switch topology to a REP ring. This gives the most flexibility in connecting control, I/O, and HMI devices to the REP network.
MSTP	Ring Redundant star	Any communication from a device-level topology to a switch topology has the potential for packet loss. For example, peer-to-peer or controller-to-I/O between the device-level topology to the switch topology. This packet loss can be severe enough (80…100 ms) to cause I/O timeouts. The packet loss does not occur between devices on a device-level topology. If you must mix MSTP protocol with embedded switch topology, we recommend using either a device-level or physical chassis segmentation topology. The device-level topology limits the scope of the issue to communication through the switch and peer-to-peer devices. The chassis segmentation topology keeps the embedded switch topology completely isolated from the MSTP network.
EtherChannel	Redundant star	Use the mixed topology when connecting to a network using EtherChannel protocol. It gives the most flexibility for connecting control, I/O, and HMI devices to the EtherChannel network.
Flex Links	Redundant star	Use the mixed topology when connecting to a network using Flex Links protocol. It gives the most flexibility for connecting control, I/O, and HMI devices to the Flex Links network.

Notes:

Test Architectures and Results

The test architectures were designed to investigate the interaction between switch topologies and device-level topologies.

Topology	Configuration
Switch, redundant star topology	• Stratix 8000 switches were configured using the Express Setup utility • The embedded switch topologies were configured using the Multiport Device Smartport role • Protocols include the following: – MSTP – EtherChannel (LACP) – Flex Links
Switch ring topology	• Stratix 8000 switches were configured using the Express Setup utility • The embedded switch topologies were configured using the Multiport Device Smartport role • Protocols include the following: – MSTP – REP

The tests record the occurrences of I/O timeouts by using ControlLogix and GuardLogix controllers. Any timeouts or faults on the controllers are counted as a timeouts in the test results. The tests use a traffic generator (ixia traffic simulator) to measure network recovery performance for both unicast and multicast traffic. For more information about test procedures, see Chapter 7 of Converged Plantwide Ethernet (CPwE) Design and Implementation Guide, publication ENET-TD001.

The tests use the following control hardware.

Table 5 - Control Hardware

Location	Hardware	Firmware Revision
DLR topology	1783-ETAP devices	2.2
	2094-EN02D-M01-S1 drives	2.1
	1734-AENTR EtherNet/IP adapters	3.6
	1732E-IB16M12DR I/O modules with embedded-switch technology	1.7
	1732E-IB16M12SOEDR I/O modules with embedded-switch technology	1.7
	1756-EN2TR scanner with embedded-switch technology	5.7
	1756-EN3TR scanner with embedded-switch technology	5.7
Controllers	GuardLogix: 1756-L62S	20.11
	ControlLogix: 1756-L72, 1756-L75	20.11

The tests use the following switch hardware.

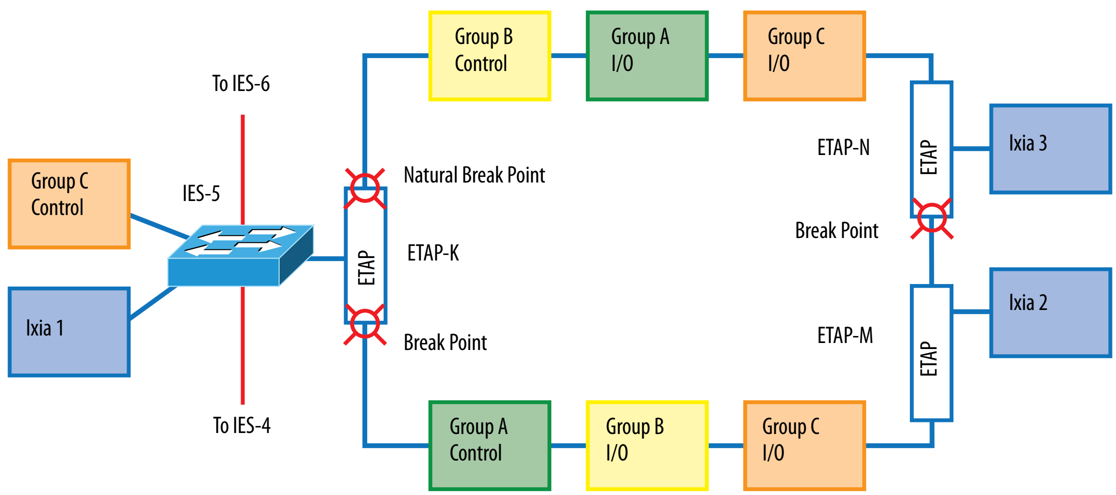
Table 6 - Switch Hardware

Location	Internetworking Operating System (IOS)	Feature Set/License
Stratix 8000	12.2(58)SE2	LAN Base K9
Cisco 3750-X	15.0(1)SE2	IP Services K9
Cisco 4500 Supervisor Engine 6-E	15.0(2)SG3	Enterprise Services K9

Device-level Ring Tests

The first set of DLR tests focuses on the device-level ring itself. The ring has two supervisors configured. ETAP_K is the primary supervisor and ETAP_N is the secondary. There are three break points in the ring:

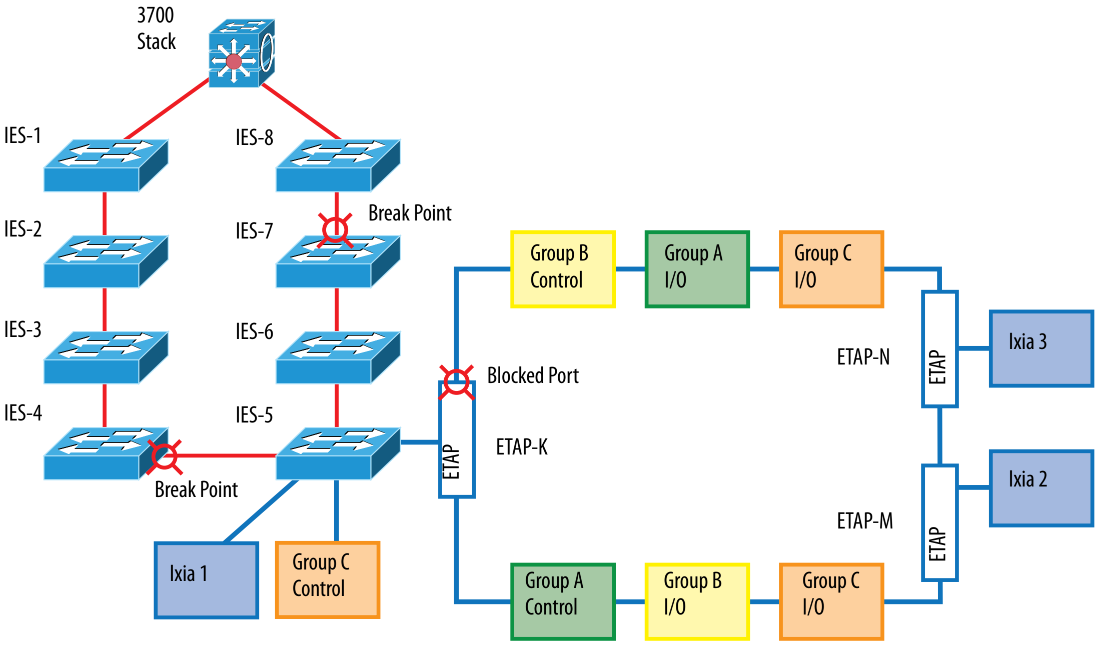
- ETAP_K Port 2 (natural blocking port for DLR topology)
- ETAP_K Port 1
- ETAP_N Port 2



The controllers and their respective I/O are split across these boundaries. For example, the controllers in the block Group A Control own the I/O and drives in the respective Group A blocks. A topology change in the DLR always forces some of the traffic to be redirected down an alternate path.

The second set of device-level tests focuses on the switch ring topology. In these tests, the ring is connected to additional switches. There are three break points in this topology:

- Between IES-4 and IES-5
- Between IES-7 and IES-8
- ETAP_K Port 2 (natural blocking port for DLR topology)

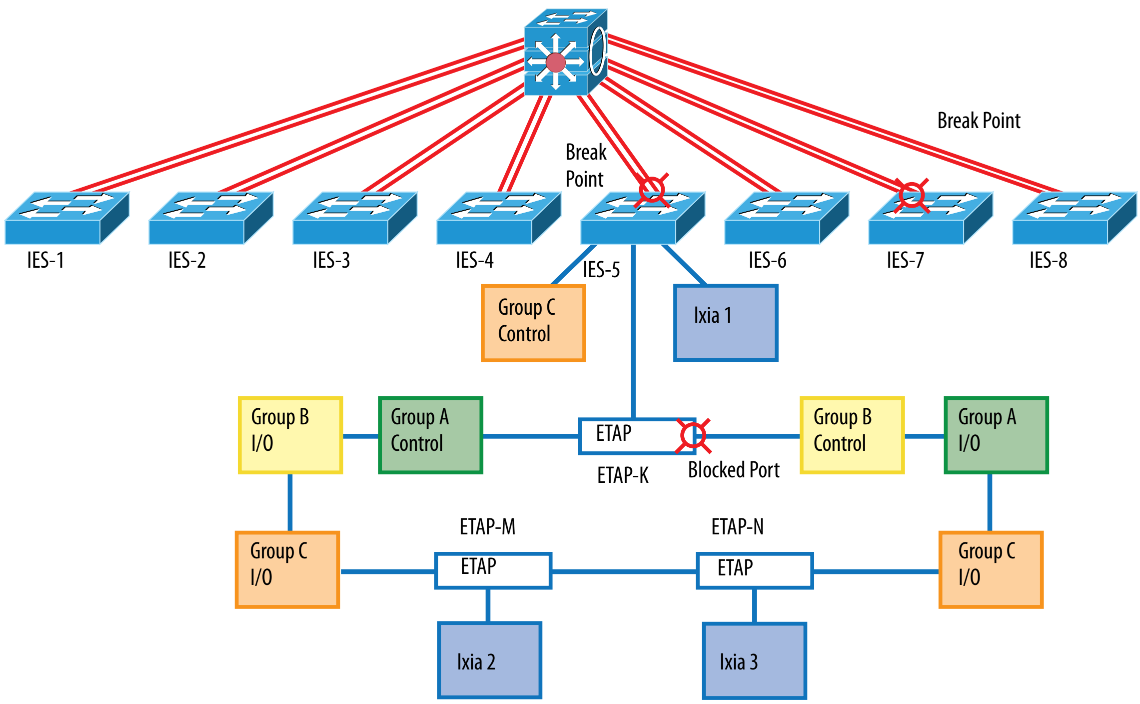


In the switch topology, the controllers in Group C Control own the I/O in the Group C sections of the device-level topology.

Redundant Star Tests

In the redundant star tests, the DLR topology is connected to switches in a redundant star topology. There are two break points in the redundant star topology:

- Between IES-5 and the 3750
- Between IES-7 and the 3750
- ETAP_K Port 2 (natural blocking port for DLR topology)



Test Permutations

The following tests were performed.

Test	Description
Switch ring	This test measures timeouts in the DLR topology due to 10 software shutdowns and 10 physical disconnections in the switch ring. The test examines the following conditions: • Does a topology change impact traffic on the device-level topology? • Does a topology change impact traffic flowing between the switch topology and the device-level topology? This test assesses DLR outages when the main switch ring experiences a disruption. This test verifies that a disruption to the switch ring has no impact on the DLR topology. The ring break alternates between IES-4 and IES-7. The ETAP_K is connected to a switch port with the ab-multiport-device macro applied.
Switch redundant star	This test measures timeouts in the DLR topology due to 10 software shutdowns and 10 physical disconnections in the redundant star topology. This test assesses DLR outages when the redundant switch topology experiences a disruption. This test verifies that a disruption to the switch ring has no impact on the DLR topology. The ETAP_K is connected to a switch port with the ab-multiport-device macro applied.
DLR break supervisor port 1	This test measures timeouts in the DLR topology due to port 1 of the supervisor experiencing 10 software shutdowns and 10 physical disconnections. This test verifies connectivity from outside the DLR topology to inside at a topology change. All traffic traveling into and out of the ring is switched from port 1 on ETAP_K to port 2.
DLR break mid-point	This test measures timeouts in the DLR topology due to port 2 of the ETAP in the DLR topology experiencing 10 software shutdowns and 10 physical disconnections. This test introduces a timeout in the DLR topology that disrupts traffic in the DLR topology. During normal operation all local ring traffic is flowing through this port. Upon failure, ETAP_K unblocks port 2 and all local ring traffic flows through ETAP_K.
DLR disable supervisor	This test measures timeouts in the DLR topology when the supervisor is disabled. This test verifies the detection of a failed supervisor. The backup supervisor must detect that the supervisor is no longer present and block port 2. A loop will exist in the network for as long as 4 ms during this test.

Switch Ring Timeout

One set of tests uses a switch ring with MSTP; the second set uses a switch ring with REP. The tests record the following timeouts:

- Between the switch topology and the device-level topology
- On the device-level topology.

With both protocols, the blocked/broken port alternated between IES-4 and IES-7.

- MSTP naturally blocks between IES-4 or IES-5. A block on either of these ports is acceptable. A failure introduced at IES-7 forces a topology change.

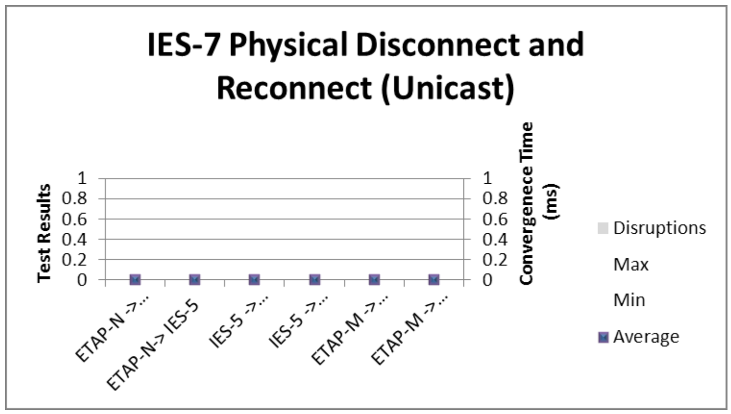
  A physical failure consists of unplugging the fiber cable from the port. A software failure consists of shutting down the interface.
- REP does not have a naturally blocked port. The test initially forces IES-4 to be the alternate. From there the test alternately fails IES-7 and IES-4.

  A physical failure consists of unplugging the fiber cable from the port. A software failure consists of shutting down the interface.

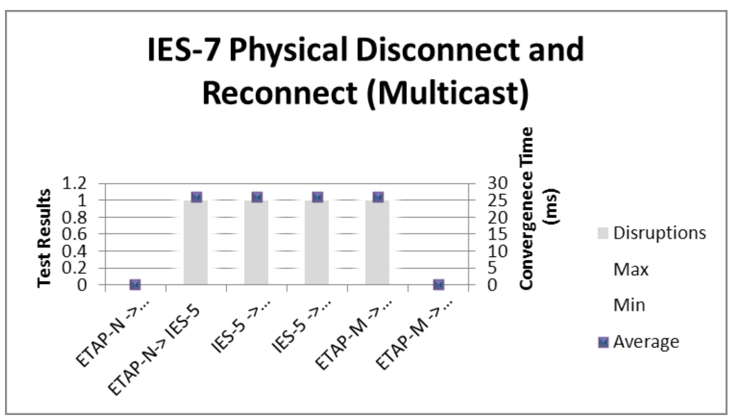
Summary:
- With MSTP, there were unicast, multicast, and safety I/O timeouts between the switch topology and the DLR topology.
- With REP, there were no I/O timeouts between the switch topology and the DLR topology.
- There was no impact to traffic on the DLR topology.

Switch Ring MSTP: Physical Disconnects

Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	0	0	0	0
ETAP-N-> IES-5	0	0	0	0
IES-5 -> ETAP-N	0	0	0	0
IES-5 -> ETAP-M	0	0	0	0
ETAP-M -> IES-5	0	0	0	0
ETAP-M -> ETAP-N	0	0	0	0

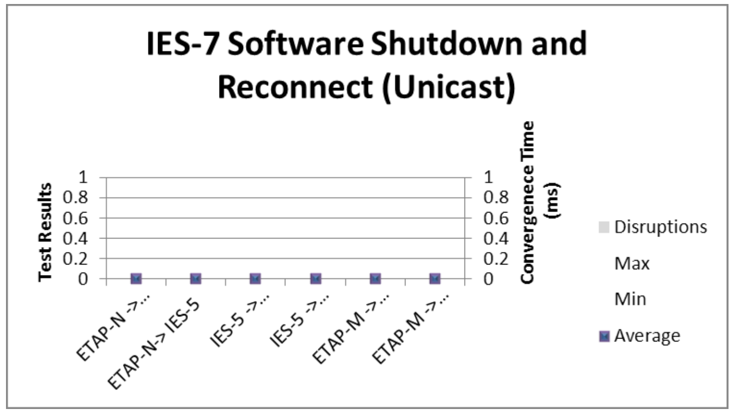


Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	0	0	0	0
ETAP-N-> IES-5	1	25.85	25.85	25.85
IES-5 -> ETAP-N	1	26.05	26.05	26.05
IES-5 -> ETAP-M	1	26.05	26.05	26.05
ETAP-M -> IES-5	1	25.8	25.8	25.8
ETAP-M -> ETAP-N	0	0	0	0

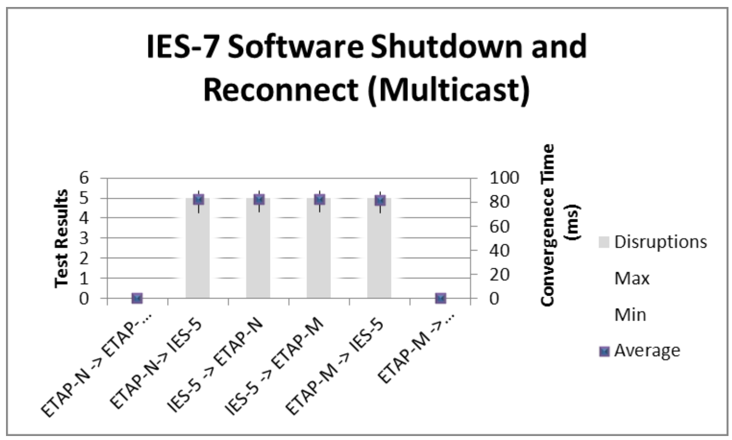


Switch Ring MSTP: Software Shutdown

Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	0	0	0	0
ETAP-N-> IES-5	0	0	0	0
IES-5 -> ETAP-N	0	0	0	0
IES-5 -> ETAP-M	0	0	0	0
ETAP-M -> IES-5	0	0	0	0
ETAP-M -> ETAP-N	0	0	0	0



Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	0	0	0	0
ETAP-N-> IES-5	5	89.05	71.4	81.95
IES-5 -> ETAP-N	5	89.75	71.7	82.5
IES-5 -> ETAP-M	5	89.75	71.7	82.5
ETAP-M -> IES-5	5	88.8	70.9	81.65
ETAP-M -> ETAP-N	0	0	0	0



Switch Redundant Star Timeout

There is one set of tests for each of these protocols: MSTP, Flex Links, and EtherChannel. The tests record the following timeouts:

- Between the switch topology and the device-level topology
- On the device-level topology.

The block/broken port depends on the topology.

- The MSTP test evaluates the impact of topology changes on traffic between devices on IES-5 and devices on the DLR topology. In the MSTP topology, one of the gigabit Ethernet ports was the root port and the other was the alternate.

  The test alternates failing and then restoring the root port on IES-5. This failure introduces a topology change on IES-5 and may impact traffic between IES-5 and the DLR topology. The same set of tests were executed against the root port on IES-7. A topology change on IES-7 should not impact traffic between IES-5 and the DLR topology.
- The Flex Links test evaluates the impact of topology change on traffic between the devices on IES-5 and the devices on DLR topology. In the Flex Links topology, gi1/1 was the active port and gi1/2 was the backup.

  The test alternates failing and restoring the active port on IES-5. The same set of tests were executed against the active port on IES-7
- The EtherChannel (LACP) test evaluates the impact of a topology change on traffic between the devices on IES-5 and the DLR topology. In the EtherChannel topology, gi1/1 was Link A and gi1/2 was Link B.

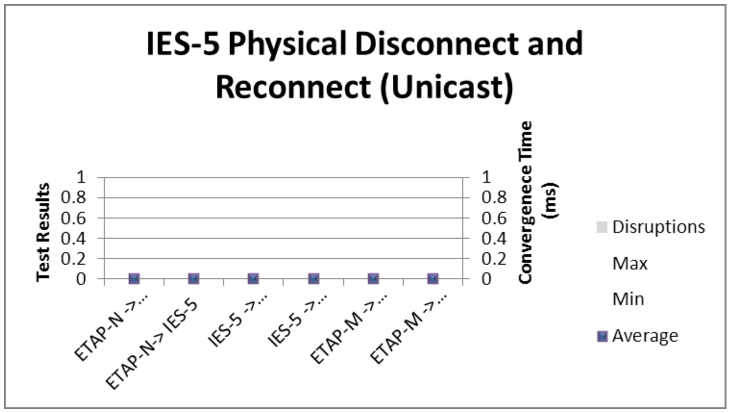
  The test alternates failing and restoring Link A on IES-5. The same set of tests were executed against Link B on IES5, Link A on IES-7, and Link B on IES-7.

Summary:

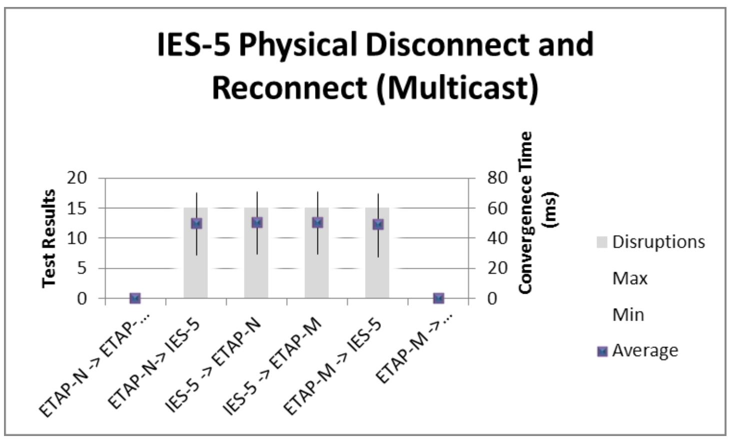
- With MSTP, there were unicast, multicast, and safety I/O timeouts between the switch and DLR topologies when there was an uplink failure on IES-5.
- With MSTP, there were no I/O failures between the switch and DLR topologies when there was an uplink failure on IES-7.
- With Flex Links, there were no I/O failures between the switch and DLR topologies.
- With EtherChannel, there were no I/O failures between the switch and DLR topologies.
- There was no impact to traffic on the DLR topology.

Switch Redundant Start MSTP: Physical Disconnects

Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	0	0	0	0
ETAP-N-> IES-5	0	0	0	0
IES-5 -> ETAP-N	0	0	0	0
IES-5 -> ETAP-M	0	0	0	0
ETAP-M -> IES-5	0	0	0	0
ETAP-M -> ETAP-N	0	0	0	0

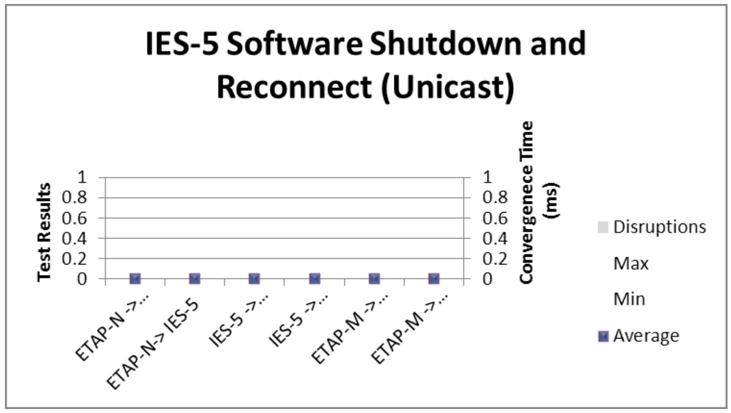


Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	0	0	0	0
ETAP-N-> IES-5	15	69.9	28.65	49.7
IES-5 -> ETAP-N	15	70.6	29.25	50.45
IES-5 -> ETAP-M	15	70.6	29.25	50.45
ETAP-M -> IES-5	15	69.4	27.8	48.95
ETAP-M -> ETAP-N	0	0	0	0

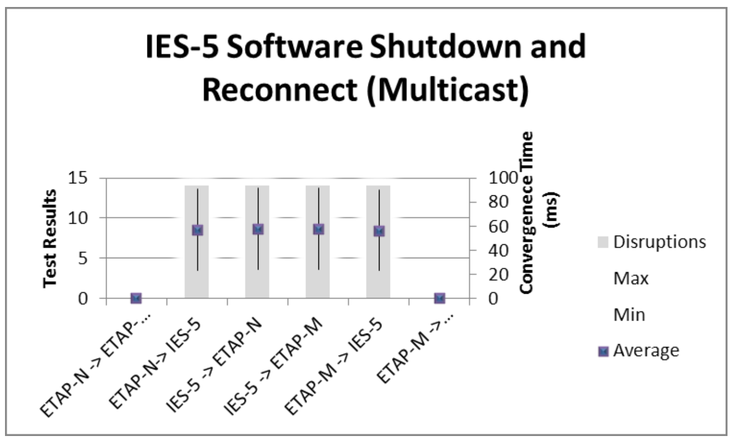


Switch Redundant Start MSTP: Software Shutdowns

Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	0	0	0	0
ETAP-N-> IES-5	0	0	0	0
IES-5 -> ETAP-N	0	0	0	0
IES-5 -> ETAP-M	0	0	0	0
ETAP-M -> IES-5	0	0	0	0
ETAP-M -> ETAP-N	0	0	0	0



Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	0	0	0	0
ETAP-N-> IES-5	14	90.9	23.25	56.4
IES-5 -> ETAP-N	14	91.85	23.7	57.15
IES-5 -> ETAP-M	14	91.85	23.7	57.15
ETAP-M -> IES-5	14	90.2	23.1	55.95
ETAP-M -> ETAP-N	0	0	0	0



DLR Break Supervisor Port 1

A DLR topology naturally blocks port 2 of the supervisor. In the test topology, failing port 1 of the supervisor forces all traffic into and out of the ring to failover to port 2.

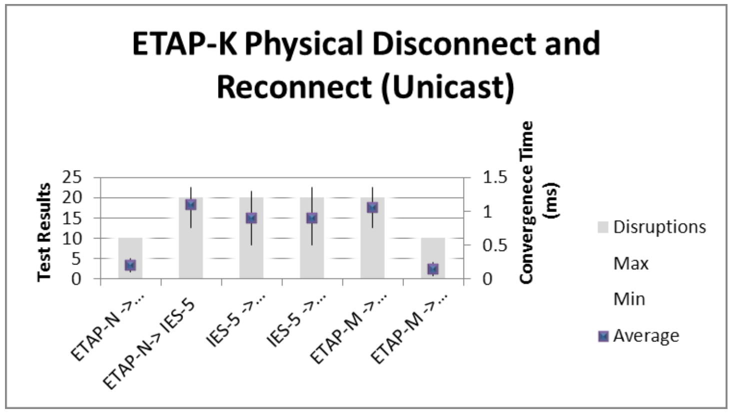
- A physical failure consists of disconnecting the cable from ETAP_K port 1.
- A software failure consists of disabling port 1 via RSLinx Classic software.

Summary:

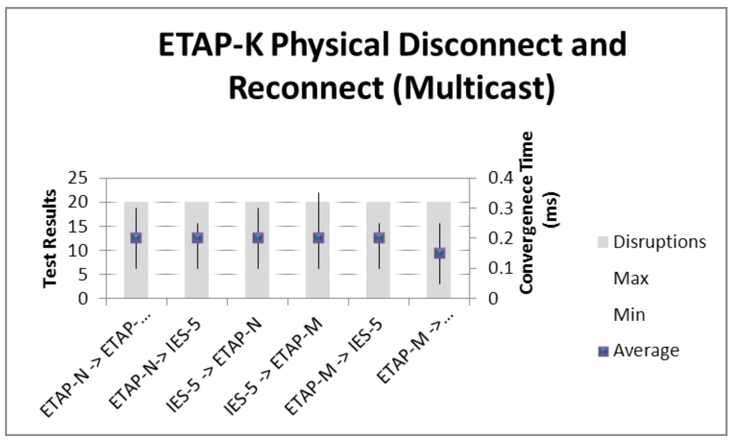
- There were zero I/O connection timeouts.

DLR Break Supervisor Port 1: Physical Disconnects

Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	10	0.3	0.1	0.2
ETAP-N-> IES-5	20	1.35	0.75	1.1
IES-5 -> ETAP-N	20	1.3	0.5	0.9
IES-5 -> ETAP-M	20	1.35	0.5	0.9
ETAP-M -> IES-5	20	1.35	0.75	1.05
ETAP-M -> ETAP-N	10	0.25	0.05	0.15

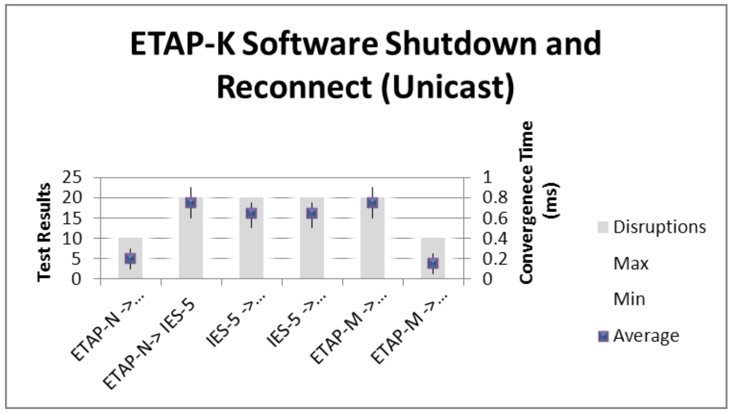


Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	20	0.3	0.1	0.2
ETAP-N-> IES-5	20	0.25	0.1	0.2
IES-5 -> ETAP-N	20	0.3	0.1	0.2
IES-5 -> ETAP-M	20	0.35	0.1	0.2
ETAP-M -> IES-5	20	0.25	0.1	0.2
ETAP-M -> ETAP-N	20	0.25	0.05	0.15

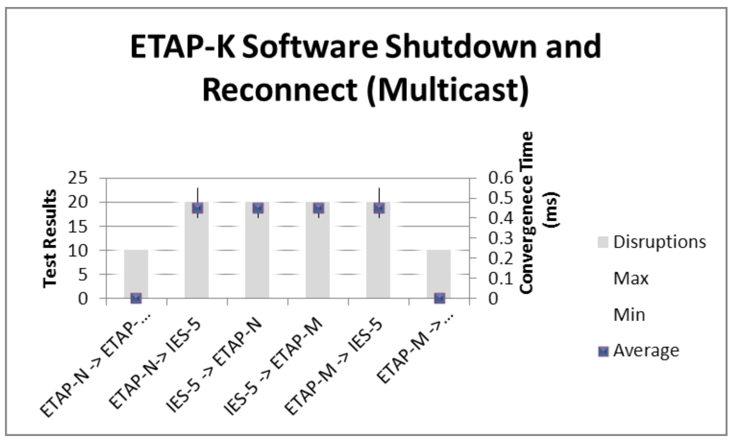


DLR Break Supervisor Port 1: Software Shutdowns

Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	10	0.3	0.1	0.2
ETAP-N-> IES-5	20	0.9	0.6	0.75
IES-5 -> ETAP-N	20	0.75	0.5	0.65
IES-5 -> ETAP-M	20	0.75	0.5	0.65
ETAP-M -> IES-5	20	0.9	0.6	0.75
ETAP-M -> ETAP-N	10	0.25	0.05	0.15



Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	10	0	0	0
ETAP-N-> IES-5	20	0.55	0.4	0.45
IES-5 -> ETAP-N	20	0.45	0.4	0.45
IES-5 -> ETAP-M	20	0.45	0.4	0.45
ETAP-M -> IES-5	20	0.55	0.4	0.45
ETAP-M -> ETAP-N	10	0	0	0



DLR Break Midpoint

This test breaks the DLR topology in the middle of the ring.

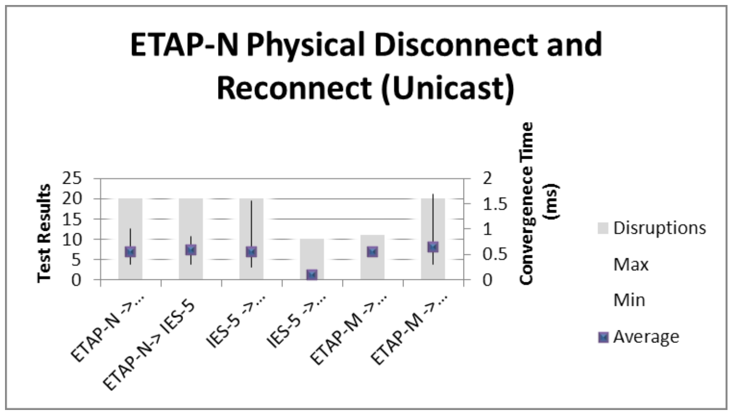
- A physical failure consists of disconnecting the cable from ETAP_N port 2.
- A software failure consists of disabling port 2 via RSLinx Classic software.

Summary:

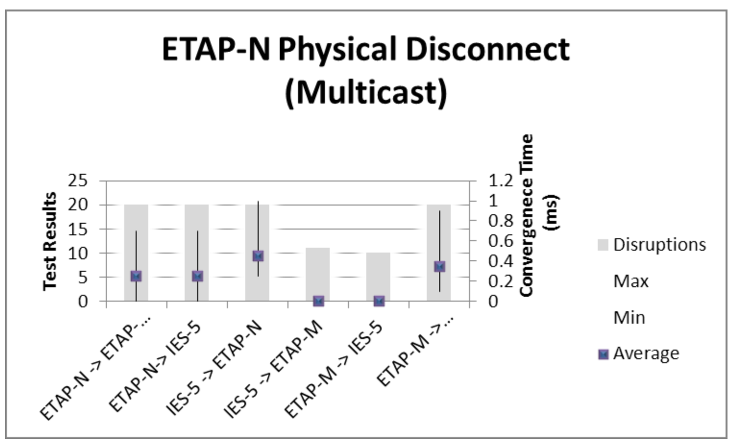
- There were zero I/O connection timeouts.
- On average, outages due to a link failure are 1…2 ms.
- A network convergence event in the DLR topology has no impact on traffic in the switch topology.

DLR Break Midpoint: Physical Disconnects

Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	20	1	0.3	0.55
ETAP-N-> IES-5	20	0.85	0.3	0.6
IES-5 -> ETAP-N	20	1.55	0.25	0.55
IES-5 -> ETAP-M	10	0.2	0.05	0.1
ETAP-M -> IES-5	11	0.65	0.5	0.55
ETAP-M -> ETAP-N	20	1.7	0.3	0.65

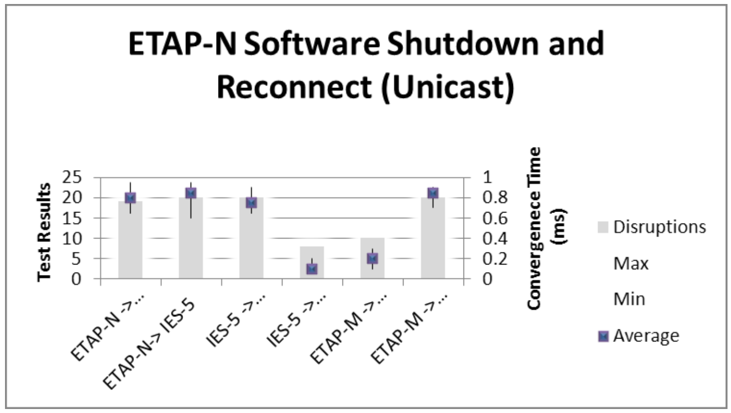


Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	20	0.7	0	0.25
ETAP-N-> IES-5	20	0.7	0	0.25
IES-5 -> ETAP-N	20	1	0.25	0.45
IES-5 -> ETAP-M	11	0	0	0
ETAP-M -> IES-5	10	0	0	0
ETAP-M -> ETAP-N	20	0.9	0.1	0.35

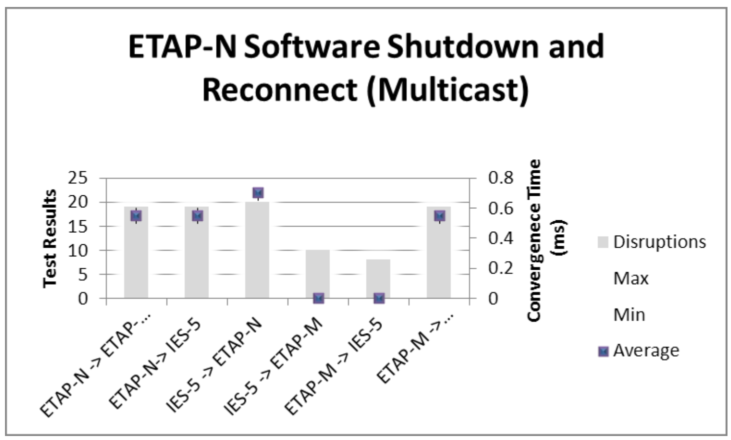


DLR Break Midpoint: Software Shutdowns

Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	19	0.95	0.65	0.8
ETAP-N-> IES-5	20	0.95	0.6	0.85
IES-5 -> ETAP-N	20	0.9	0.65	0.75
IES-5 -> ETAP-M	8	0.2	0.05	0.1
ETAP-M -> IES-5	10	0.3	0.1	0.2
ETAP-M -> ETAP-N	10	0.9	0.7	0.85



Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	19	0.6	0.5	0.55
ETAP-N-> IES-5	19	0.6	0.5	0.55
IES-5 -> ETAP-N	20	0.7	0.65	0.7
IES-5 -> ETAP-M	10	0	0	0
ETAP-M -> IES-5	8	0	0	0
ETAP-M -> ETAP-N	19	0.55	0.5	0.55



DLR Disable Supervisor

There are certain rare cases where the supervisor can fail but still maintain the ring. In these cases, a bridge loop is created and causes a network failure. This test validates that a backup supervisor can detect the loss of the ring supervisor and restore the blocked port. ETAP_N is configured to be the backup supervisor and will take over the supervisor role.

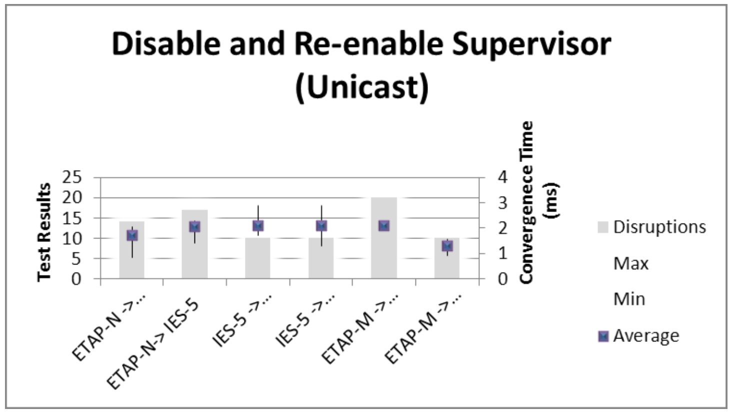
A failure consists of disabling the ring supervisor on ETAP_K via RSLinx Classic software.

Summary:

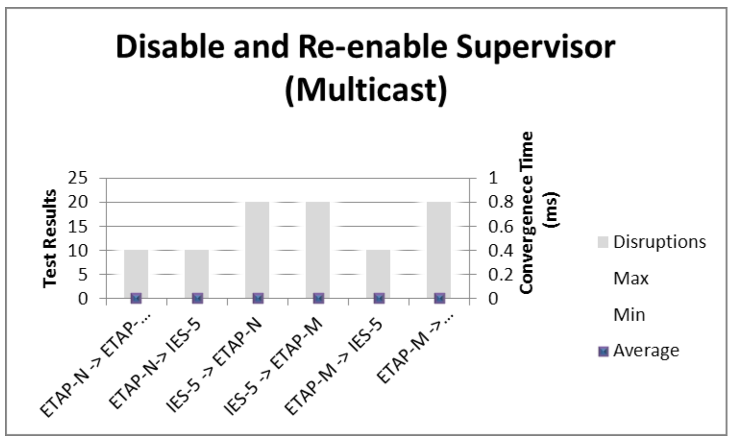
- There were zero I/O connection timeouts.

DLR Disable Supervisor

Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	14	2.05	0.85	1.7
ETAP-N-> IES-5	17	2.3	1.4	2.05
IES-5 -> ETAP-N	10	2.9	1.7	2.1
IES-5 -> ETAP-M	10	2.9	1.3	2.1
ETAP-M -> IES-5	20	2.2	1.95	2.1
ETAP-M -> ETAP-N	10	1.55	0.9	1.3



Connection	Disruptions	Max (ms)	Min (ms)	Ave (ms)
ETAP-N -> ETAP-M	10	0	0	0
ETAP-N-> IES-5	10	0	0	0
IES-5 -> ETAP-N	20	0	0	0
IES-5 -> ETAP-M	20	0	0	0
ETAP-M -> IES-5	10	0	0	0
ETAP-M -> ETAP-N	20	0	0	0



Test Configuration

Multiport Automation Device Smartport Role

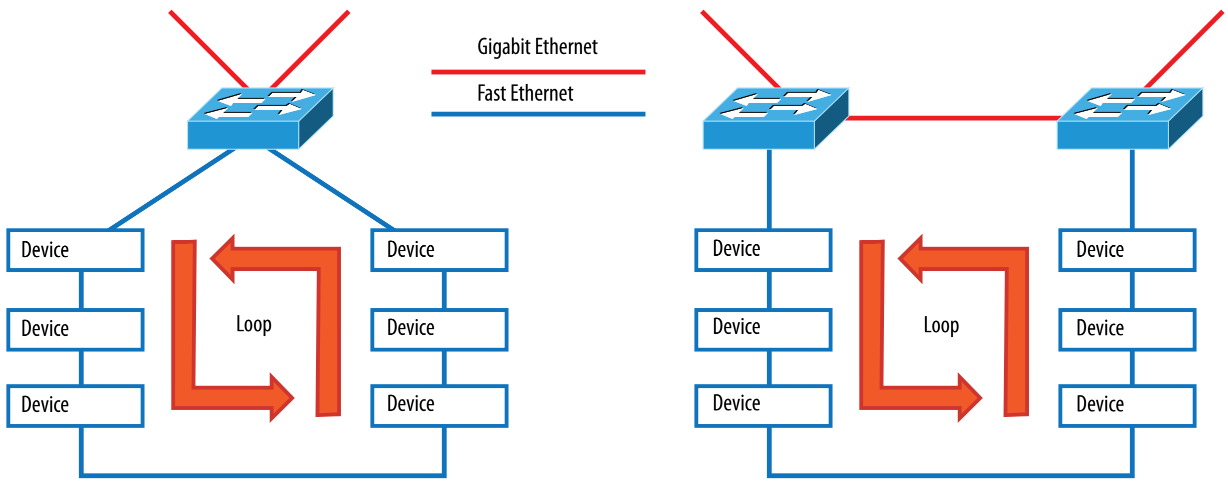
The Stratix 5700, 8000, and 8300 switches use Smartport roles to simplify the configuration of the switch. A new role, which was added in IOS version 12.2(58)SE2, supports linear and ring embedded switch topologies. Linear topologies can be connected directly to the switch. However, a ring topology must be connected to the switch via a 1783-ETAP, 1783-ETAP1F, or 1783-ETAP2F device.

```
Macro name : ab-multiport-device
Macro type : default interface
# macro keywords $access_vlan
#macro description ab-multiport-device
switchport host
switchport access vlan $access_vlan
service-policy input CIP-PTP-Traffic
priority-queue out
srr-queue bandwidth share 1 19 40 40
alarm profile ab-alarm
load-interval 30
no cdp enable
no udld port aggressive
mls qos trust dscp
```

This macro is based on the ab-ethernetip macro, also known as the Automation Device Smartport role. There are two key changes in the ab-multiport-device macro.

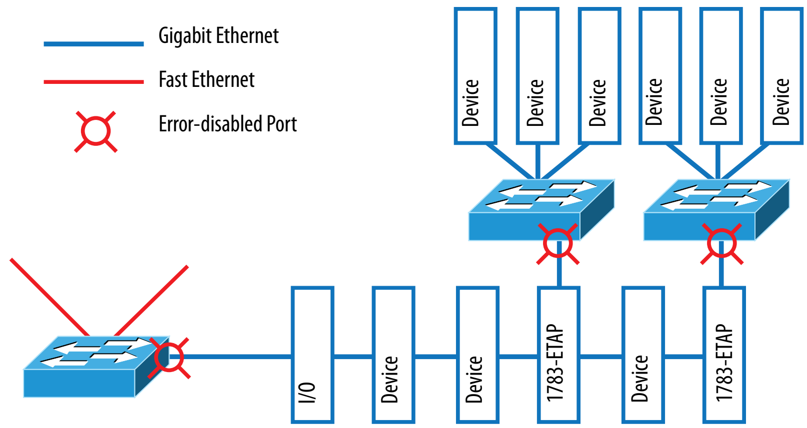
- Port-security was removed to allow multiple devices to be connected to the interface. This is essential to allow for linear or ring topologies of embedded switch devices.
- The QoS settings on the interface were changed. In addition to the existing service policy, the interface now trusts the DSCP value. The switch continues to classify and internally mark traffic based on the service policy. The switch will trust the DSCP in any packet that does not match the service policy instead of internally marking the packet at DSCP 0.

The Express Setup on the Stratix 8000 switch enables BDPU filter on all interfaces configured for spanning-tree portfast. The Multiport Automation Device Smartport role enables portfast on the interface and therefore BPDU filter. Do not connect two ports configured with the ab-multiport-device together, either directly or indirectly. If two ports configured ab-multiport-device are connected together a bridge loop will be formed. There are two potential failure modes. The best case failure is the BPDU Guard will detect the loop and err-disable one or both ports. The worst case failure is that the loop will be undetectable and will generate a broadcast storm that will take down the network.



Do not use the Multiport Automation Device Smartport role when connecting multiple switches to a common embedded switch network. Once a link is established, BPDU Filter prevents the interface from sending BDPUs. However, immediately after link-up the interface will send a few BPDUs to ensure a loop free topology. If these BPDU packets make it across the embedded switch network, BPDU Guard will force the neighboring switches to err-disable their interface that connects to the two-port topology. An interface in the err-disable state will attempt to clear the error condition every 30 seconds. This will bring the failed switch back on-line. Again, when the switch leaves the err-disable state it will send a few BPDUs to ensure a loop free topology. These BPDUs will cause any other switches connected to the embedded switch network to fail into the err-disable state. This pattern of switches alternately connecting and failing will continue indefinitely.

In addition, there may be other management protocols running between the switches that expect them to be directly adjacent. These protocols can potentially cause other interruptions.



Supervisor Configuration

Do not enable a ring supervisor on an embedded-switch linear topology. By default, the ring supervisor sends a beacon frame every 400 µs out both ports. These beacons add 2,500 pps of traffic that is only needed in a ring topology.

Do configure both a primary and secondary supervisor in an embedded-switch ring topology. The primary and secondary supervisors are determined by the Supervisor Precedence. In the case of DLR, the supervisor with the highest precedence value will become the active supervisor on the network. If both supervisors have the same precedence value, the device with the highest MAC address will become the supervisor.

The default Beacon Timeout is based on a nominal 50-device, embedded switch ring with 100 m cables between devices. There are cases where the timeout may need to be increased to prevent unnecessary ring faults.

- Networks with more than 50 embedded switch devices on the ring
- Networks where the circumference of the embedded switch ring is greater than 5 km

Notes:

Rockwell Automation Support

Rockwell Automation provides technical information on the Web to assist you in using its products. At http://www.rockwellautomation.com/support, you can find technical manuals, technical and application notes, sample code and links to software service packs, and a MySupport feature that you can customize to make the best use of these tools. You can also visit our Knowledgebase at http://www.rockwellautomation.com/knowledgebase for FAQs, technical information, support chat and forums, software updates, and to sign up for product notification updates.

For an additional level of technical phone support for installation, configuration, and troubleshooting, we offer TechConnect℠ support programs. For more information, contact your local distributor or Rockwell Automation representative, or visit http://www.rockwellautomation.com/support/.

Installation Assistance

If you experience a problem within the first 24 hours of installation, review the information that is contained in this manual. You can contact Customer Support for initial help in getting your product up and running.

United States or Canada	1.440.646.3434
Outside United States or Canada	Use the Worldwide Locator at http://www.rockwellautomation.com/support/americas/phone_en.html, or contact your local Rockwell Automation representative.

New Product Satisfaction Return

Rockwell Automation tests all of its products to ensure that they are fully operational when shipped from the manufacturing facility. However, if your product is not functioning and needs to be returned, follow these procedures.

United States	Contact your distributor. You must provide a Customer Support case number (call the phone number above to obtain one) to your distributor to complete the return process.
Outside United States	Please contact your local Rockwell Automation representative for the return procedure.

Documentation Feedback

Your comments will help us serve your documentation needs better. If you have any suggestions on how to improve this document, complete this form, publication RA-DU002, available at http://www.rockwellautomation.com/literature/.

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