Hirschmann Networking Interoperability in a Rockwell Automation Environment

White Paper

Hirschmann Interoperability
White Paper

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Introduction

EtherNet/IP ("IP" meaning "Industrial Protocol") was developed by Rockwell Automation to work in conjunction with TCP (UDP)/IP. EtherNet/IP is a network suitable for use in industrial environment and time-critical applications. It utilizes standard Ethernet and TCP/IP technologies and an open Application Layer protocol called Control and Information Protocol (CIP). CIP is also used in DeviceNet and ControlNet networks. The open Application Layer protocol makes interoperability and interchangeability of industrial automation and control devices on EtherNet/IP a reality for automation and control applications.

EtherNet/IP supports both time-critical (implicit) and non time-critical (explicit) message transfer services. Exchange of time-critical messages is based on the producer/consumer model where a transmitting device produces data on the network and many receiving devices can consume this data simultaneously.

Consequently, EtherNet/IP support several communication functions:

- Time-critical message exchange (for I/O control)
- Human Machine Interface
- Device configuration and programming
- Device and network prognostics and diagnostics
- Compatibility with SNMP and devices with embedded TCP/IP and Web-browser services

The Rockwell Automation Encompass program is a product-referencing initiative to verify equipment that complements Rockwell Automation's control solutions. Hirschmann is member of the Encompass program as a global partner supporting Ethernet on the factory floor.

This section is divided into two parts:
The first part covers interoperability considerations noted by Rockwell Automation and Hirschmann's responses.
The second part describes interoperability testing conducted by Hirschmann at a General Motors site using Rockwell Automation, Hirschmann and Cisco equipment.

1. Vendor interoperability considerations

1.1 Switches vs. Hubs

Rockwell Automation recommends the use of switches in the control network, rather than hubs, because they increase system performance for several reasons:

- Switches direct traffic, so unicast packets are only seen by two interested ports
- Setting ports to full-duplex mode eliminates collisions, which reduces worst-case response time and makes it possible to calculate network and system response times

The ideal is one device per switch port. While it's possible to connect multiple devices to a hub, which in turn is connected to a switch, this topology can compromise system performance.

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In Rockwell Automation tests, a switch (100 Mb/s, full-duplex) had a maximum 15ms response. But a hub (10 Mb/s, half-duplex) exhibited a 160ms response. According to Rockwell Automation:

The switch test ran for 360,000 samples over a 5-hour period. The hub test ran for only 1.5 hours, at which time a CIP connection was lost and the test was aborted.

Each point on the curve (Figure RA-1) represents system response time for each sample; the vertical axis shows the number of occurrences for each response time. If you add all the responses for the switch curve, the total will be 360,000 samples. The number of samples that had a system response of 6ms was approximately 9500.

The bell shaped curve is practically coincidental for both the switch and the repeater. However, the hub did have a few responses up to 160ms. The reason for the long response times with a hub was that a large number of consecutive collisions occurred. For the hub, response times in the range of 16-160ms occurred infrequently but they did happen.

Conclusion: The worst-case performance for a hub is at least 10 times worse than with a switch.

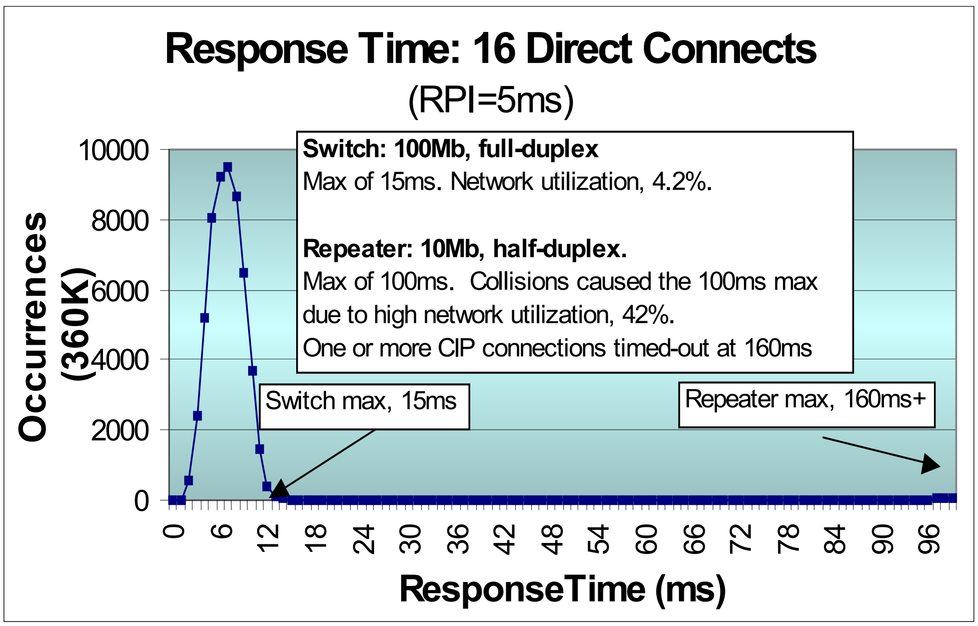

Figure RA-1: Rockwell Automation hub vs. switch response testing (Courtesy of Rockwell Automation)

Hirschmann concurs with Rockwell Automation’s recommendations regarding switch versus hub performance.

1. 2 Autonegotiation

Rockwell Automation recommends the use 802.3u autonegotiation and/or manual port speed and duplex setting.
Hirschmann managed switches support both 802.3u autonegotiation and manual port speed and duplex settings.

On segments supporting time-critical I/O messaging, all network components should operate in full-duplex mode. Exceptions: when Rockwell Automation legacy products are connected to Fast

Ethernet switches, switch ports must be forced to 10-Mb/s, half-duplex mode. These legacy products include:

- PLC5
- Sidecar
- SLC5/05

All Logix family hardware—such as ControlLogix—is capable of 10/100-Mb/s and half-/full-duplex operation, and therefore should be linked to 100-Mb/s and full-duplex ports.

Manual configuration is now possible for 1756-ENBT, 1788-ENBT, and 1794-AENT modules with auto-negotiation being the default.

Hirschmann switches support autonegotiation and can be manually configured to match legacy connections.
Be sure to connect only ports which are set on both sides to autonegotiation or if manual configuration to same duplex mode. If only one side is set to autonegotiation, set the other side to half- duplex (never use full- duplex in this case)

1. 3 Wire-speed switches

Rockwell Automation recommends the use of non-blocking, wire-speed switches.
Hirschmann RS2 and MICE switches are non-blocking, wire-speed switches.

Switch performance must be able to handle the load generated by the number of attached devices. Rockwell Automation gives an example for a 10 port switch, with each port connected to a 1756-ENBT module. Each can produce a maximum rate of 5000 packets per second. Note that with multicast “implicit” communication (UDP/IP), a packet IS produced every Requested Packet Interval (RPI) and consumed every RPI. Therefore, each port is handling bi-directional traffic: for every 2500 packets/second sent, 2500 packets/second are received.

Modules	Maximum packet rate (packets per second)	Producing Controller: Produce Tag frame size (bytes)	Consuming Controller: CIP frame size (bytes)	Total bytes	Total bits (Mb/s)
Module A					
Switch Port 1	5000	66		330,000	
Switch Port 2	5000		566	2,830,000	
Module B					
Switch Port 3	5000	66		330,000	
Switch Port 4	5000		566	2,830,000	
Module C					
Switch Port 5	5000	66		330,000	
Switch Port 6	5000		566	2,830,000	
Module D					
Switch Port 7	5000	66		330,000	
Switch Port 8	5000		566	2,830,000	
Module E					
Switch Port 9	5000	66		330,000	
Switch Port 10	2500		566	2,830,000	
TOTALS				15,800,000	126.4

Figure RA-2: Switch/controller configuration

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Note: Currently manufactured Rockwell Automation Logix products with EtherNet/IP interfaces are not able to produce or consume 2500 pps of the 566 bytes. The packet rate will be smaller in this case.

Therefore in this application using a 10-port switch, the fabric must be able to handle at least 126.4 Mb/s. Because switches can typically handle wire speed on all ports (2 GB/s for a 10 port switch), this application poses no problem.

But merely adding another switch can create congestion on the uplink (Figure RA-3). Rockwell Automation gives the example of a 10-port switch (1) connected to another switch (2), so controller A on switch 1 can send multicast to controller B on switch 2.

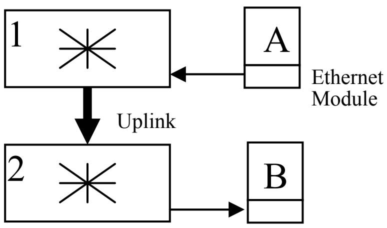

Figure RA-3: Uplink load

If VLAN configuration is not used, all the multicast traffic from switch 1 will pass through the uplink at the following rate:

10 ports [2500 pps x 562 bytes/packet x 8 bits/packet] = 112.4 Mb/s

Even if the uplink port is configured for full 100-Mb/s full-duplex operation, it won't be able to handle the traffic. Gigabit switches with uplink ports that can be configured for higher throughput are required.

For unicast "explicit" messaging (TCP/IP), Rockwell recommends reserving 10% of the bandwidth within each EtherNet/IP module (Figure RA-3).

Module	Total bandwidth (packets/second)	10% reserved for explicit messaging (packets/second)
1756-ENBT	5000	500
1756-ENET/B	900	90
1788-ENBT	5000	500
1794-AENT	9500	950

Figure RA-3: Bandwidth reservation recommended for modules

Note: Because explicit messaging throughput depends on the availability of the network and the target device, reserving bandwidth does not necessarily guarantee throughput at the required level.

1. 4. IGMP snooping

Rockwell Automation recommends the use of IGMP to support the use of multicast traffic. Hirschmann RS2 and MICE switches support IGMP v1 and v2 as well as IGMP query.

Switches that support IGMP snooping typically require a router on the system to initiate queries. But due to difficulties that routers have with multicast traffic in general and to delays that routers introduce specifically, EtherNet/IP's multicast "implicit" messages will not work with a router. Thus, Rockwell Automation recommends that "if your control system is a stand-alone network or is required to continue performing if the router is out of service, make sure the switch you are using supports IGMP snooping without a router present." Which means that the switch needs to support the IGMP querier mode.

1. 5. VLAN Implementation

Rockwell Automation recommends the use of 802.1Q VLANs.
Hirschmann managed switches all support VLANs as defined in IEE802.1Q and confirms VLAN interoperability with Logix equipment, as described below.

Besides upgrading switches, there are two ways around the problem of handling uplink load, both involving creating a subnet. The first method is to add another 1756-ENBT module to controller A in order to talk to controller B, which is now on the same physical subnet.

The second method is to create a logical subnet with a VLAN (Figure RA-4). This restricts multicast traffic only to the ports in the switch that connect interested nodes. Because a VLAN prevents multicast packets from flooding every port on a switch, module processing power is conserved and the need for additional switches can be minimized.

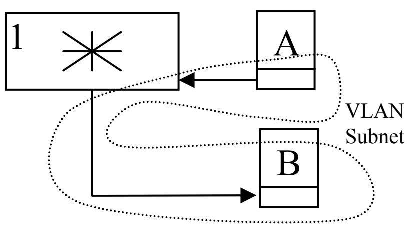

Figure RA-4: Using VLAN to balance load

1. 6 SNMP Management

Rockwell Automation recommends the use of switches that include SNMP to support NMS services.
Hirschmann managed switches support SNMP and OPC in conjunction with HiOPC.

Capabilities:	**Rockwell Automation legacy products: PLC5 Sidecar SLC5/05**	**Logix family- 1756-ENBT 1788-ENBT 1794-AENT**	**Hirschmann RS2 and MICE switches:**
Ethernet (10 mb/s)	half-duplex only	x	x
Fast Ethernet (100 mb/s)	X	x	x
Gigabit Ethernet			Q3, 2004
Autonegotiation	X	x	x
Services supported over EtherNet/IP:			
Port mirroring	X	x	x
IGMP v1	X	x	x
VLAN	X	x	x
SNMP/NMS support	X	x	x
RMON	X	x	x
Security			
Strong password	X	x	x
Port security (ACL)	x	x	x

Figure RA-5: Summary of features supported by Rockwell Automation EtherNet/IP products

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1. 7 Port mirroring

Rockwell Automation recommends the use of port mirroring as a means of connecting to a traffic analyzer. This permits system diagnosis without affecting the dataflow in the run-time system.

Hirschmann managed switches support port mirroring.

2 Field interoperability testing

2.1 Testing conditions for 802.1Q VLANs and IGMP

To validate the interoperability of Hirschmann and Rockwell Automation equipment with regard to VLAN and IGMP protocols, extensive testing was conducted in the spring of 2003 at the General Motors Network Engineering Center. Tested equipment included Rockwell Automation Logix Controllers and HMI workstations. These were connected to Hirschmann MICE 3124 and 2108 switches in the control LAN, which were connected to a Cisco Catalyst 2955 industrial switch and to an enterprise-level Catalyst 2950 switch and 3550 switch/router in the Plant/Enterprise LAN.

802.1Q VLAN testing was performed to validate that no issues were encountered and no tagging differences were found in readability and passing native VLAN (untagged VLAN) packets. Up to 35 VLANs were tested, including setups with multiple VLANs per port—a condition not implemented by a major automotive manufacturer. While VLAN testing directly concerns switch function, not PLC Ethernet module functions, it does show that VLAN segmentation can be employed to handle various levels of traffic generated by PLCs.

IGMP testing was performed in two scenarios: an IGMP test scenario with Rockwell Automation Logix equipment in the control LAN, and an IGMP/VLAN test scenario confirming the Catalyst 3550 router's support of multicast routing between VLANs without the need to reconfigure Hirschmann switches.

IGMP issues are encountered with EtherNet/IP's multicast "implicit" messaging, as noted above, and Logix interfaces only support IGMP v1. Consequently in all scenarios, IGMP v1 querying was enabled on all Hirschmann switches. While not generally advisable, this configuration solved IGMP leak issues encountered during testing, as described below.

Rockwell Automation Rule: Logix devices communicate using a "producer/consumer" model. PLCs that are consumers issue IGMP membership reports, but producers do not. This can cause leaking of multicast traffic, because the producers do not register their status with the switch they are attached to.

Hirschmann recommends enabling the query function on switches to allow the producers to register on the switch even without a membership report.
Note: Logix devices that produce multicast traffic only support IGMP v1 at this time.

2.2 VLAN-enabled Hirschmann switches and Logix Controllers

Configuration for all Hirschmann switches:
VLAN enabled
VLANs configured-1 VLAN 1 (default)
Multicast- IGMP enabled
Query enabled
IGMP v1
Code version- 3.1

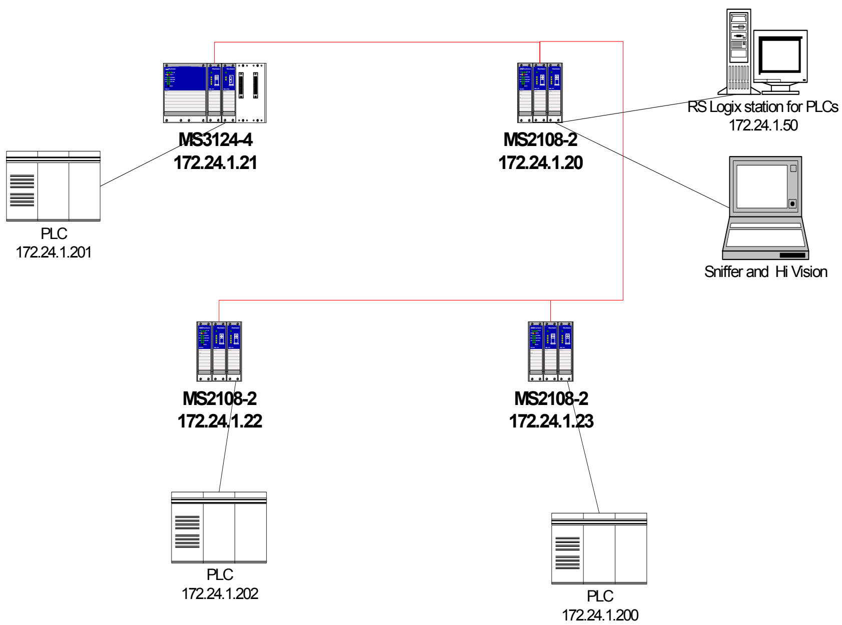

Figure RA-6: VLAN-enabled Hirschmann switches and Logix Controllers

Test objective:
Verify IGMP functionality for both IGMP snooping and query support on control LAN.

Observations:
In a Rockwell Automation environment, Hirschmann recommends enabling query functionality while using IGMP snooping. While this does work, several side effects were observed:

1. All switches respond to IGMP membership reports. (It is normally recommended that only one device in the VLAN be the querier.)
2. Because of the multiple queriers, traffic not intended for other switches was nevertheless sent up all the switch uplinks. This is due to the function of multicasting that any multicast traffic be transmitted to any and all querying devices on that VLAN.
3. In environments where there is a querying router as well as querying switches, traffic is sent up the uplink to the router through the backbone network. Because the intervening switches between the Hirschmann switches and the router are aware of multiple active queriers on the network, some additional traffic is generated that would not occur if a single querier was present on the LAN.

Conclusion:
Hirschmann switches interoperate in a Rockwell Automation environment with IGMP v1 query enabled.

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Multicast packets leaks did not occur during testing when all the switches were configured with querying enabled. When querying was turned off on any or all Hirschmann switches, leaking occurred after 5 minutes, which is the time out period for the IGMP table on the switch. Also, IGMP Forward ALL was turned off on all ports.

Additional traffic created by the multiple queriers is not an issue. The switches respond to the membership queries with general responses, not specific queries. This implies that the querier responds with only one packet sent to the entire network on multicast group 224.0.1.40. A specific report would create a multicast response from the querier to each and every multicast group on the network. This would increase utilization on the inter-switch links.

2.3 Hirschmann switches, Logix Controllers and enterprise switches in a cascade structure

Configuration for all Hirschmann switches:
VLAN enabled
VLANs configured-1 VLAN 1 (default)
Multicast- IGMP enabled
Query enabled
IGMP v1
Code version- 3.1

Configuration for Cisco switches:
IGMP snooping enabled
Router: IGMP v1, query enabled, query interval: 60 seconds
(Hirschmann switches are set to the same number for their query interval)

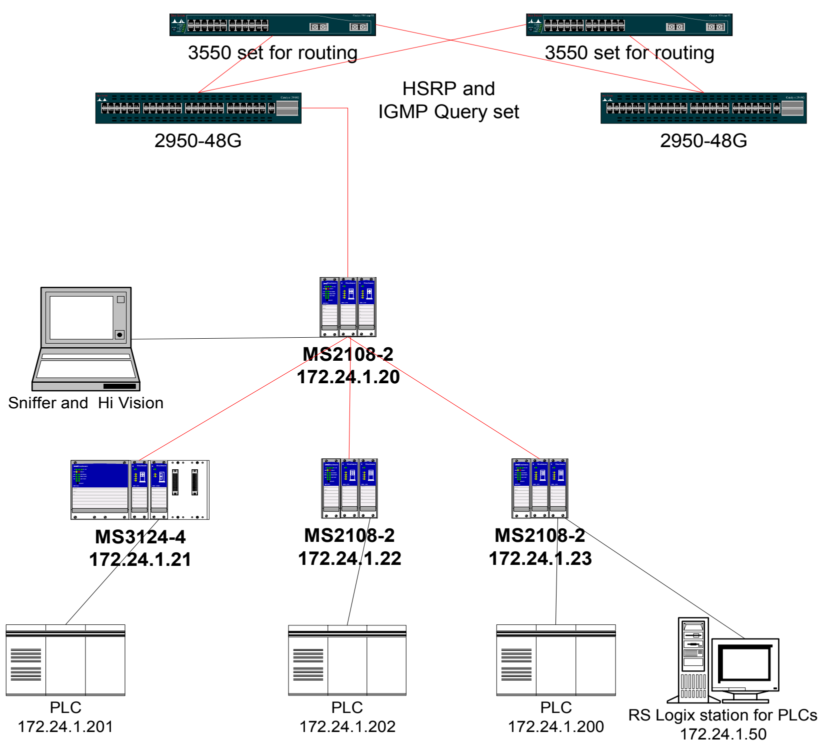

Figure RA-7: VLAN-enabled Hirschmann switches and Logix PLCs in a cascade structure

Test objective:
Verify IGMP functionality for both IGMP snooping and query support at control and plant/enterprise levels.

Observations:
IGMP traffic going up the uplink out of switch 172.24.1.20 into the Cisco environment is a normal occurrence and is restricted to the VLAN for the Controllers and no others. When the querier on the router was disabled, the traffic going up the uplink out of .20 stopped as there was no querier in that direction.

Conclusion:
Hirschmann switches interoperate without the need for reconfiguration in a Rockwell Automation and Cisco environment with VLAN and IGMP v1 query enabled. This IGMP switch setting, however, necessitates some changes to the network configuration of a Rockwell Automation Logix/Cisco Catalyst network, as described below.

2.4 Hirschmann switches, Logix Controllers and enterprise switches in a parallel structure

Configuration for all Hirschmann switches:
VLAN enabled
VLANs configured-1 VLAN 1 (default)
Multicast- IGMP enabled
Query enabled
IGMP v1
Code version- 3.1

Configuration for Cisco switches:
IGMP snooping enabled
Router: IGMP v1, query enabled, query interval: 60 seconds
(Hirschmann switches are set to the same number for their query interval)

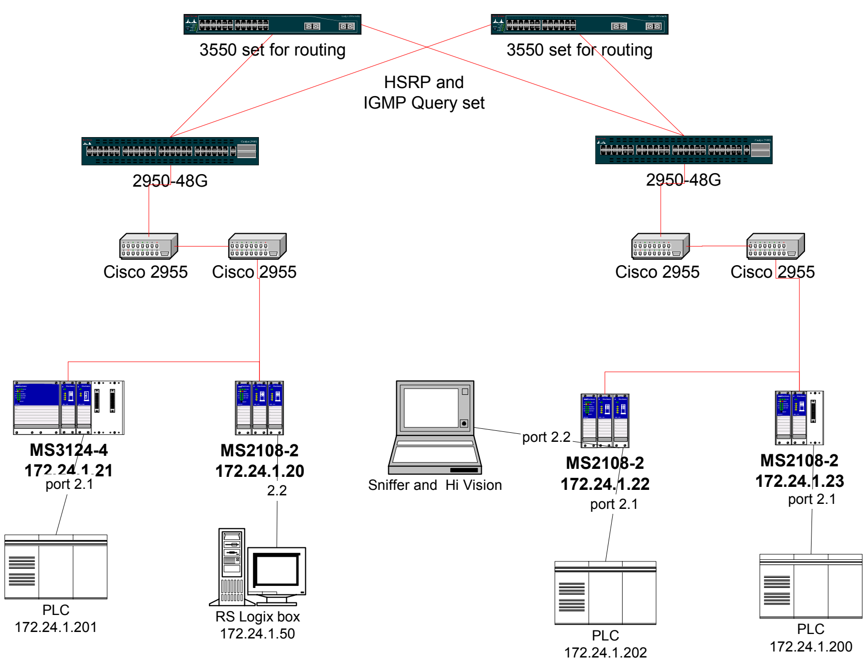

Figure RA-8: VLAN-enabled Hirschmann switches and Logix PLCs in a parallel structure

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Test objective:
Verify IGMP functionality for both IGMP snooping and query support at control and plant/enterprise levels.

Observations:
IGMP traffic going up the uplink out of .20 and .23 switch uplinks into the Cisco environment is a normal occurrence and is restricted to the VLAN for the Controllers and no others. When the querier on the router was disabled, the traffic going up the uplink out of switches .20 and .23 stopped, as there was no querier in that direction.

Conclusion:
Hirschmann switches interoperate without the need for reconfiguration in a Rockwell Automation and Cisco environment with VLAN and IGMP v1query enabled. This IGMP switch setting, however, necessitates some changes to the network configuration of a Rockwell Automation Logix/Cisco Catalyst network, as described below.

3. Handling IGMP "leaks"

Situation:

Multicast EtherNet/IP traffic is produced and consumed by Rockwell Automation Logix Controllers in ways that require IGMP v1 on all Hirschmann switches to be configured as queriers. Normally, one IGMP v2 multicast router is the only station that queries the network to see if there are stations interested in receiving multicast messages (Figure RA-9). In other words, the querier is the only source of multicasts.

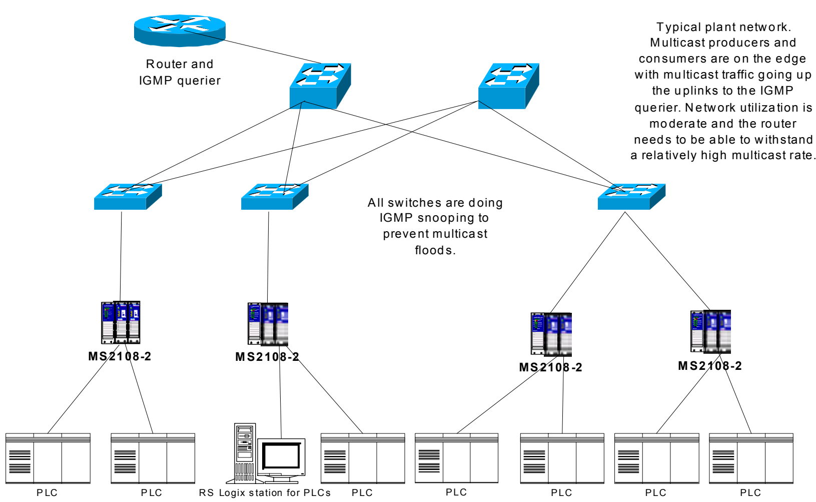

Figure RA-9: Plant structure with multicast producers and consumers with router for IGMP queries

But with IGMP v2 in a Rockwell Automation environment, switch 4 will allow multicast packets generated by PLC to flood all ports, because the switch hasn't learned through its own query process that port 8 is linked to a node that is NOT interested in receiving the packet (Figures RA-10, RA-11, RA-12).

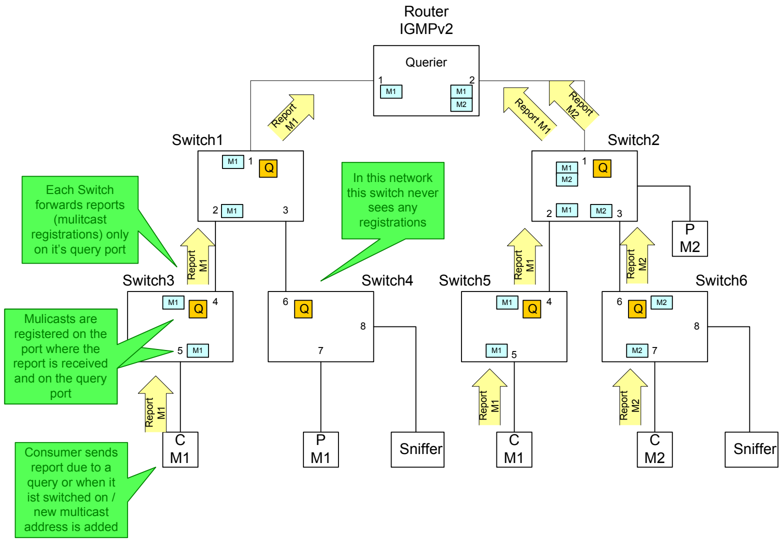

Figure RA-10: Problem—IGMP v2 query propagated by switch 4

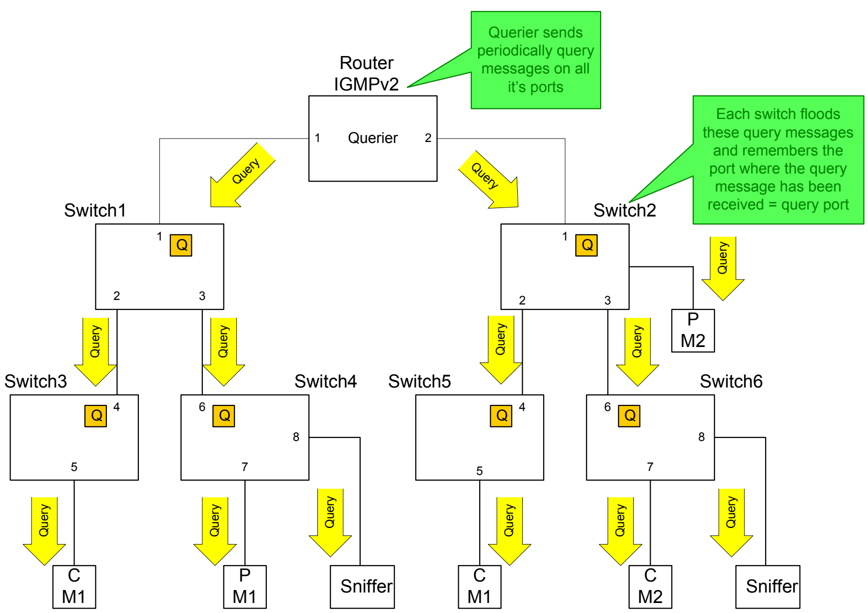

Figure RA-11: Problem—IGMP v2 report from P M1 not sent, so report not registered by switch 4

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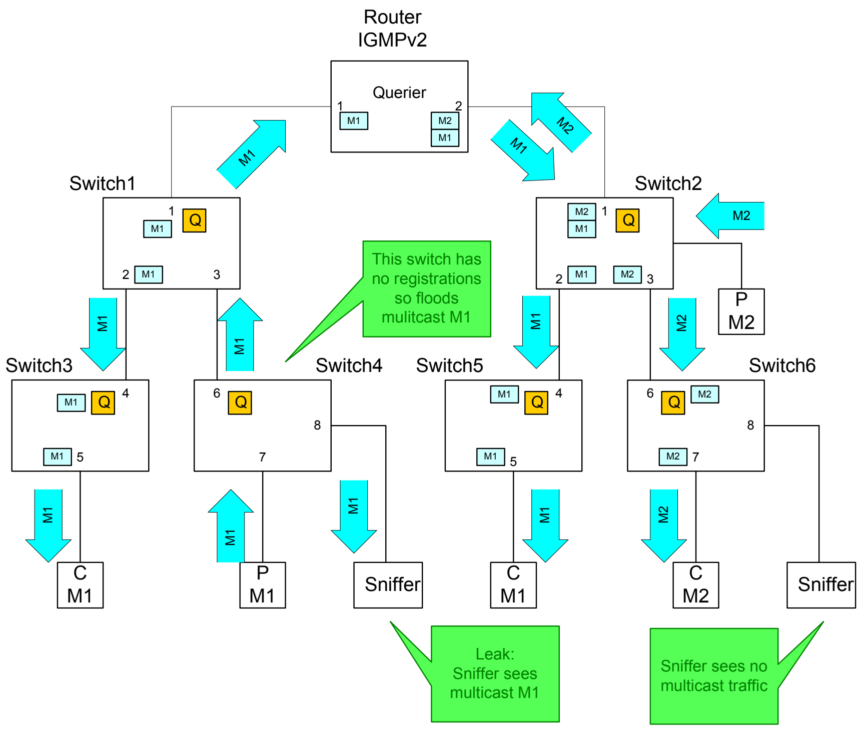

Figure RA-12: Problem—PLC M1 multicast is flooded to all switches

Solution:

Logix Controllers using EtherNet/IP can all generate multicast traffic using implicit messaging. Thus, the network must use IGMP v1, which support multiple queriers on the network, to allow all devices that produce or consume multicast traffic to register with the querier. With querying enabled, switch 4 issues a query and receives a report to build its own multicast group table (Figures RA-13, RA-14). Now switch 4 will direct multicast packets generated by the PLC only to port 6 (Figure RA-15). The switch will also send the multicast traffic to other switches that are query-enabled to direct the packets only to interested nodes (in the case of multicast 1, these nodes are controller C-A, C-B, and C-C).

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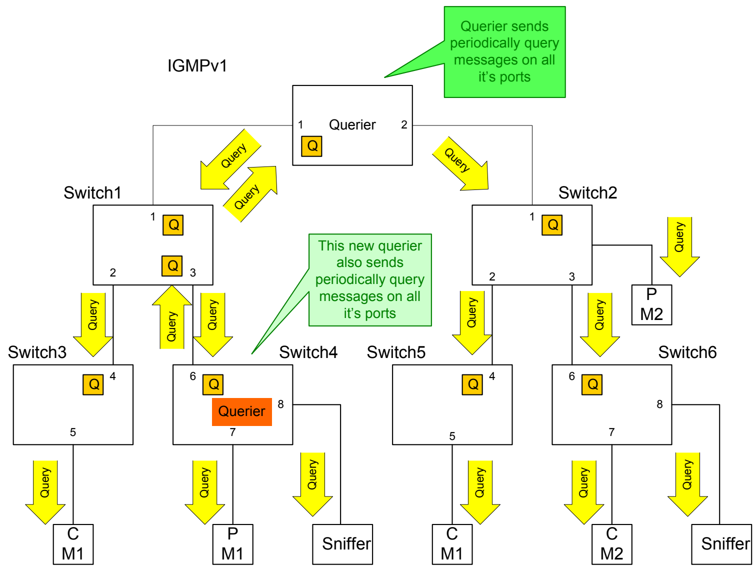

Figure RA-13: Solution—IGMP v1 query enabled on switch 4

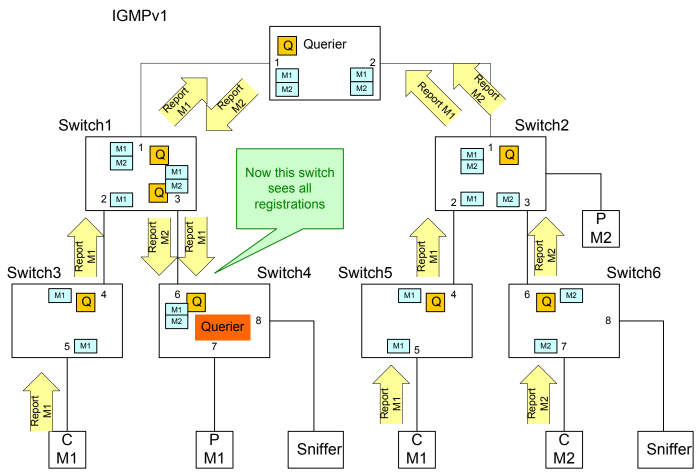

Figure RA-14: Solution—IGMP v1 reports registered on switch 4

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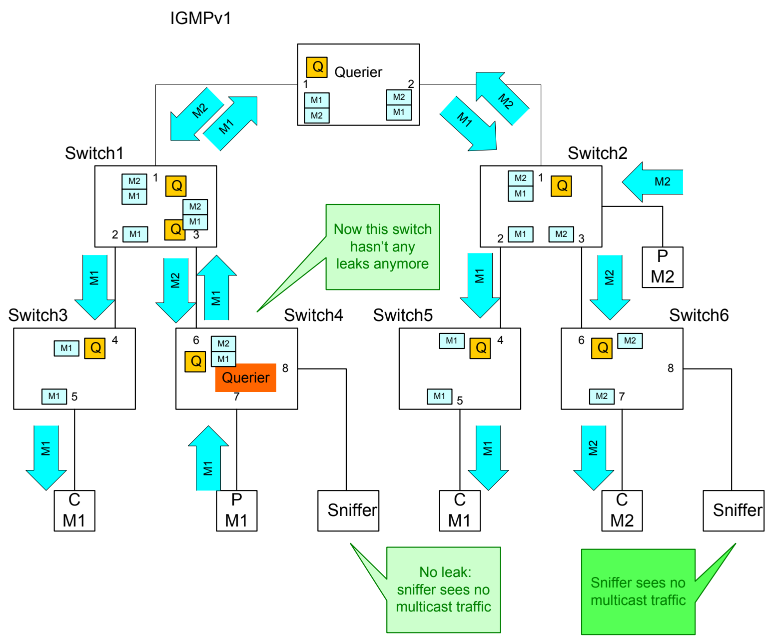

Figure RA-15: Solution—PLC M1 multicast is directed only to interested nodes (C-A, C-B, and C-C)

Considerations include:

1. Since all queries are flooded on each switch, a bit more query and report traffic will exist on the network, depending on the number of queriers.

2. Extra query and report traffic will only be an issue on very large networks, because of the low repetition rate of queries (once per 125s).

3. More multicast producers create more backbone traffic, but backbones are normally designed to handle necessary traffic, allowing all multicasts to be registered and flooded.

Note: Rockwell Automation and the ODVA Workgroup are looking into extending the specification in a way that all stations producing multicasts also should register for their multicasts. This would be the best solution to solve the leak problem.

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