GE
Intelligent Platforms

Network Redundancy with PROFINET and MRP

Survive a network failure without duplicating the network

control logic

Introduction

Ensuring high levels of system uptime is essential for many control systems, as this drives productivity and profitability. The risk of downtime is a significant concern since it negatively impacts operational resources and the bottom line. According to the ARC Advisory Group, plant downtime costs average about $12,500 per hour–of course, these costs will be less for some control systems and much more for others.

Ethernet-based I/O networks provide many compelling advantages over the alternatives. However, like a traditional fieldbus, they also provide many opportunities for failures in the numerous network interface modules, ports, and cables that run throughout the installation. To guarantee a high level of system uptime, some technique must be used to ensure that I/O communication is not disrupted when one of these components fails.

There are several Ethernet technologies that are intended to ensure that a failure in an Ethernet network won't disrupt communications over that network. However, what constitutes a "disruption" varies from one domain to another.

For example, the Rapid Spanning Tree Protocol (RSTP) is sometimes used to provide network redundancy for IT networks. That protocol is often an acceptable redundancy solution on those networks since the applications and Ethernet protocols used can tolerate the RSTP recovery time, which can be several seconds long. In contrast, the requirements for network redundancy on a control system's I/O network are much more demanding, so a different approach is desirable.

The most obvious approach to provide network redundancy that satisfies the demands of a control system's I/O network would be to duplicate the entire network infrastructure–cables, conduits, switches, network interfaces and so forth, as illustrated in Figure 1. The obvious approach, however, is not always the best approach. Duplicating the network adds significant costs, including equipment purchase, installation, maintenance and repair.

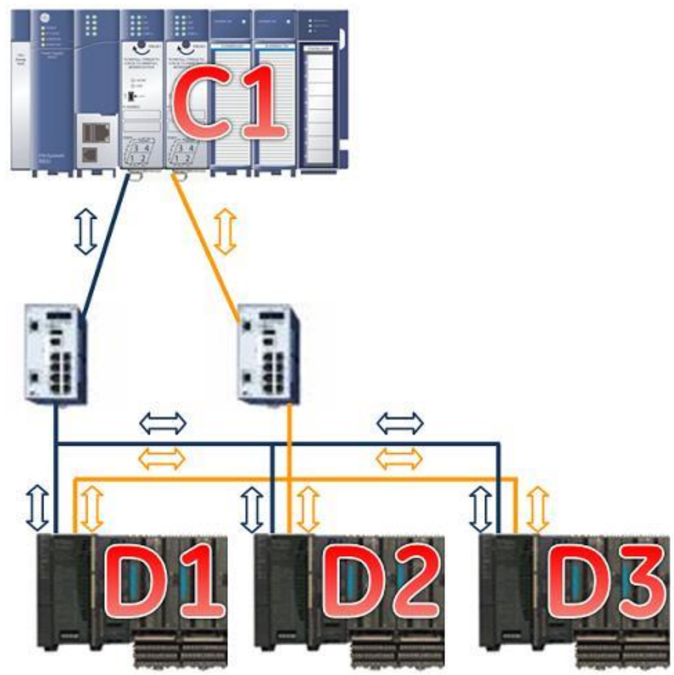

Figure 1: Traditional Network Redundancy

This white paper presents GE Intelligent Platforms' solution for ensuring that a network failure won't disrupt a control system's I/O network. It describes how the PROFINET Media Redundancy Protocol (MRP) works and the performance to expect from GE's MRP implementation. Finally, it describes how the built-in network diagnostics provided by GE's PROFINET solution can be used to unambiguously identify and visualize failures, facilitating quicker and easier repairs.

Media Redundancy using MRP

Let's say you wanted to take a vacation to the beach. You wouldn't plan two parallel paths in the event of an accident blocking your way. Instead, you would allow your GPS to monitor the path and, in the event of an accident, reroute you around the blockage along the most efficient alternate route.

Traditional network redundancy schemes required two duplicate parallel networks to achieve a reliable backup connection to each node on the network. MRP provides each node on the network with a backup physical connection to every other node on the network, but in a much more cost-effective way: a ring topology. As Figure 2 depicts, adding one additional cable between the first and last nodes on the network provides two physical communications paths between each node on the network with minimal additional infrastructure.

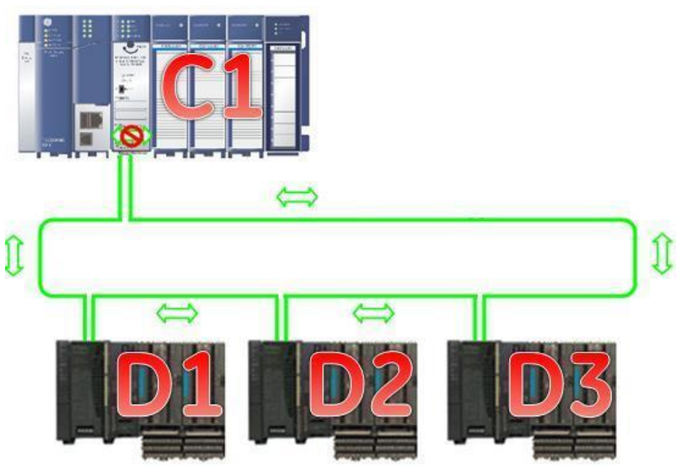

Figure 2: Network Redundancy through a Ring Topology

MRP defines two types of ring participants: one node is the Media Redundancy Manager (MRM), depicted as C1 in Figure 2; and all other nodes are Media Redundancy Clients (MRC), shown as D1, D2, and D3 in Figure 2. Like a GPS, the MRM monitors the PROFINET ring. If it discovers a break in the network, the MRM notifies the other MRC ring participants of a network failure and quickly identifies the most effective alternate route.

Ethernet networks require loop-free topologies to operate correctly. MRP avoids network loops through its novel method for monitoring the health of the ring network. As depicted in Figure 3, as long as the MRM can successfully send MRP Test Packets from one of its ring ports and receive them on its other ring port, the MRM views the ring as healthy and forwards no data between its ring ports.

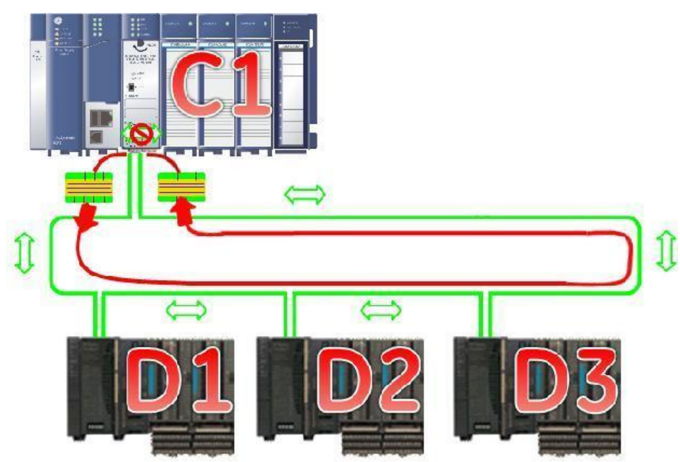

Figure 3: MRP Test Packets

What happens, however, if a failure occurs in the network? If, as shown in Figure 4, a cable or network port fails, the MRM (C1) determines there is a break in the network. The MRM then begins forwarding data between its two network ports and notifies the other MRC ring participants that this new data path is available for immediate use.

Network Redundancy with PROFINET and MRP

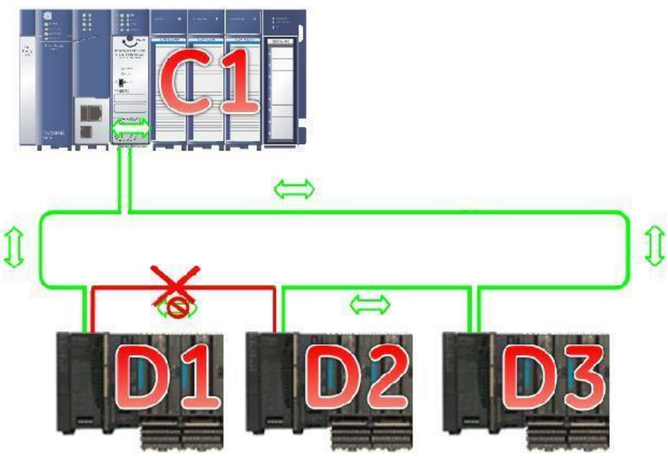

Figure 4: Network Cable or Port Failure Detected

In the same way, if a node on the network fails, the MRM (C1) determines there is a break in the network. The MRM then begins forwarding data between its two network ports and notifies the other MRC ring participants that this new data path is available for immediate use. Figure 5 depicts this scenario.

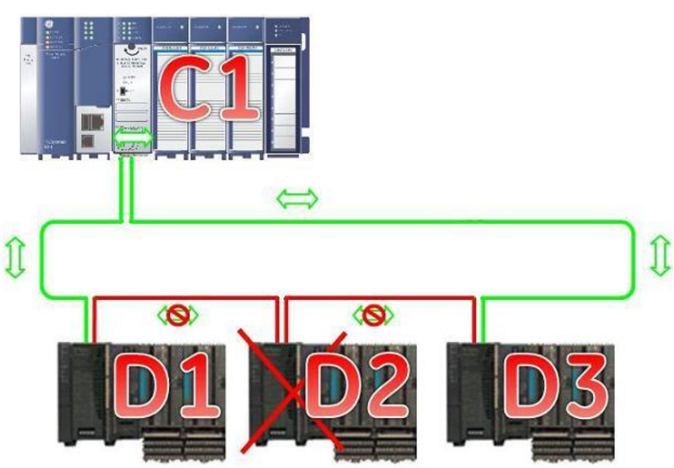

Figure 5: Network Node Failure Detected

The PROFINET controller is not required to be the MRM in the MRP ring. In

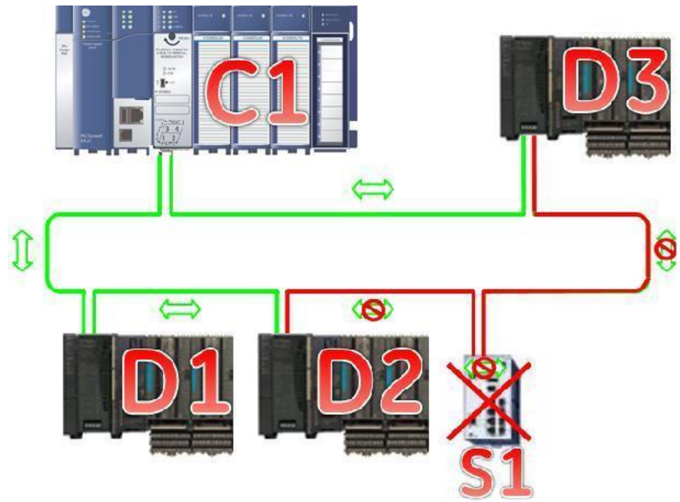

Figure 6, an MRP-enabled switch, S1, acts as the MRM and the PROFINET controller, C1, acts as just another MRC. What happens, however, if the MRM node fails? As depicted in

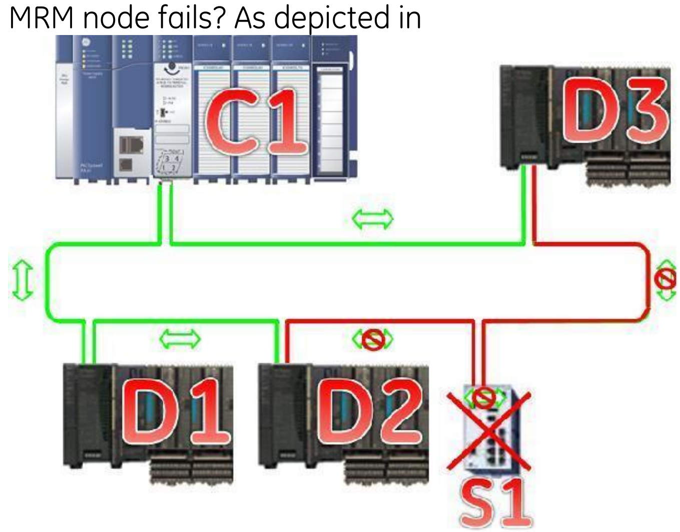

Figure 6, no change in topology is required if the MRM (S1) fails. Since the MRM avoided loops in the network by not forwarding data between its ring ports, the structure of the network remains unchanged and MRC units C1, D1, D2, and D3 do not need to update their network topologies.

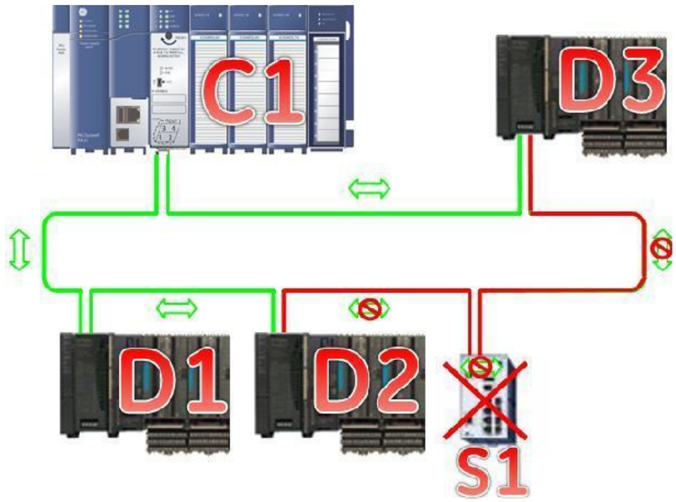

Figure 6: MRM Node Failure Detected

How PROFINET IO works with MRP

PROFINET IO is a robust communications protocol that makes allowances for intermittent network interruptions without losing communications between an IO controller and its IO devices. Within a single PROFINET connection (PROFINET Application Relationship), the protocol describes three types of communications data: record data; acyclic real-time data; and cyclic real-time data. Record data is used to establish new connections, parameterize IO devices, and convey other configuration data. Acyclic real-time data is used for alarm reporting. Finally, cyclic real-time data is used to convey module input and output data on a regular, determined, interval.

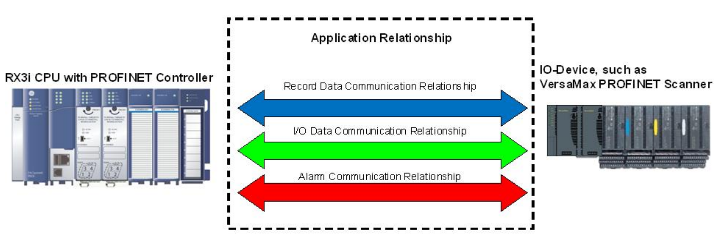

Figure 7: PROFINET Communications Types

Since the cyclic real-time data exchange between an IO controller and IO device occurs at a regular, pre-determined time interval, this data exchange is also used as a watchdog for the overall IO controller-to-IO device application relationship. Simply put, if an IO controller or IO device misses three consecutive cyclic real-time data exchanges from its counterpart, that partner is considered lost and the IO device or IO controller will default input and/or output data as configured. The IO controller then will periodically try to reestablish a connection to the IO device, and if successful, cyclic real-time data exchange will also resume. Acyclic data types have their own retry mechanisms to ensure data integrity, but do not directly factor into the connection status of an IO controller or IO device.

In the event that a network interruption causes a cyclic real-time data packet from an IO controller to be lost, the IO device will simply hold its outputs constant until the next cyclic real-time data packet arrives. The converse is true if a cyclic real-time data packet from IO device to the IO controller is lost. As long as network connectivity is restored by MRP in less than:

3x cyclic I/O update rate

then PROFINET communications will continue seamlessly, even if the network topology changes between the nodes!

Faster than a speeding bullet

The MRP standard guarantees ring network recoveries will take place in 200 ms or less. The GE Intelligent Platforms implementation can guarantee recovery times as much as two orders of magnitude faster, depending upon the network media type. Network recovery can complete in less than:

- 3 ms for 100 Mb copper networks. This means no loss of device during recoveries, even when communicating with a PROFINET IO update rate as low as 1 ms.
- 10 ms for 100 Mb fiber networks.* This means no loss of device during recoveries when communicating with PROFINET IO update rates as low as 4 ms.
- 30 ms for 1 Gb networks.* This means no loss of device during recoveries when communicating with a PROFINET IO update rate as low as 16 ms.

The GE Intelligent Platforms solution is 100 percent compliant to the MRP standard and will work seamlessly with other products that implement the MRP standard. How, then, can the GE Intelligent Platforms PROFINET with MRP implementation provide these substantial performance improvements over the published MRP standard?

- Fast detection of network link failures–in as little as 3 μs on the VersaMax PNS.
- The GE Intelligent Platforms implementation supports MRP Link Change messages (Figure 8), an optional part of the MRP standard. An MRC experiencing a network link failure sends these messages to the MRM immediately, allowing the network to be healed without needing to wait for multiple test-packet timeouts to detect the failure.

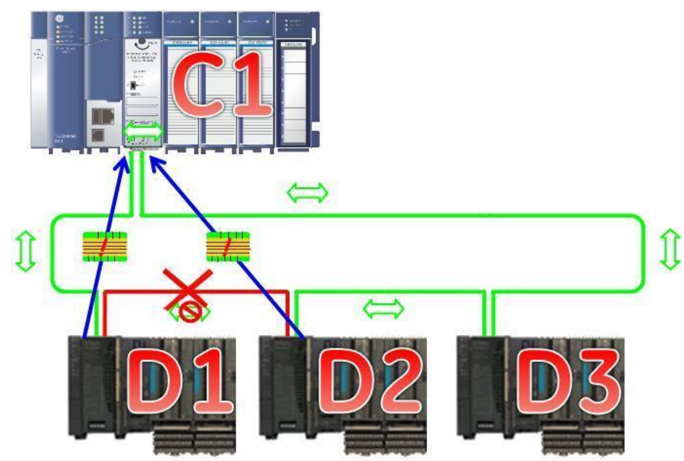

Figure 8: MRP Link Change Messages Speed Recovery

- An optimized switch reconfiguration algorithm for GE Intelligent Platforms products with MRM capability. This means faster switch reconfiguration at the ring manager for faster overall network recovery times.
- Fast topology reconfiguration on all GE Intelligent Platforms MRC nodes.

Network Diagnostics

Even though the GE Intelligent Platforms PROFINET with MRP solution provides fast detection and uninterrupted recovery from network failures, determining what needs repair quickly is crucial to maintaining critical control applications. GE Intelligent Platforms' PROFINET IO controllers and IO devices provide built-in diagnostic data that indicates link failures as well as overall node health. These indications can be used to:

* The next release is targeted to reduce this recovery time to less than 3 ms. This means no loss of device during recoveries, even with a 1 ms PROFINET IO update rate.

- Identify the failure of a network cable.
- Identify the failure of a network port.
- Identify the failure of a network node.

These indications are available automatically in the customer's process data. This allows the data to be used by:

- User Program Logic to react to any given failure, taking appropriate actions depending upon the severity of the network failure.
- HMI or other visualization technologies to clearly and concisely indicate to operators or maintenance personnel the location and nature of the network failure.
- Historian or other telemetry software for trending or other data analysis activities.

For customers who require it, GE Intelligent Platforms' PROFINET IO controllers and IO devices also provide Simple Network Management Protocol (SNMP) and Link-Layer Discovery Protocol (LLDP) data, which can be used by standard IT-style tools to monitor the network. The simplicity and power of visualizing the built-in diagnostic data through the standard HMI interface, however, provides the advantages of a simple interface for operators and maintenance engineers and fewer development tools to procure and maintain.

Conclusion

Network redundancy can be used to ensure that a network failure doesn't disrupt a control system's I/O network. Although duplicating the network is an obvious way to achieve network redundancy, it carries with it significant additional costs. PROFINET with MRP provides network redundancy with minimal impact to total cost of ownership.

Not all implementations of MRP are equally capable. A simplistic implementation of MRP can only guarantee that the network is healed within 200 ms, which isn't fast enough for many control applications. However, GE Intelligent Platforms' more sophisticated implementation of MRP is fast enough to meet the demanding requirements for network redundancy on a high-speed I/O network, supporting cyclic I/O update rates as fast as 1 ms.

After surviving a network failure, it is vital to quickly determine what needs repair in order to properly maintain the control application. GE Intelligent Platforms' PROFINET solution provides built-in network diagnostic data that integrates easily with the control system solution, including HMIs and User Program Logic. These built-in network diagnostics can be used to unambiguously identify and visualize failures, facilitating quicker and easier repairs.