Adding industrial toughness and reliability to Ethernet

Sponsorship Overview

Moxa Americas, Inc.

A Leader and Trusted Partner in Automation Solutions

Founded in 1987, Moxa Americas, Inc. is now one of the leading manufacturers of industrial networking, computing, and automation solutions, offering over a thousand hardware and software products. 25 years of accumulated expertise has enabled Moxa Americas, Inc. to deliver network-centric automation solutions that integrate automation and IT systems into a single network platform that simplifies management, reduces costs, and achieves greater reliability and efficiency.

Industrial Ethernet Solutions

Moxa Americas, Inc. offers a wide array of Industrial Ethernet products that feature open Ethernet infrastructure, industry-proven standards, extended temperature tolerance, environmental protection, and network redundancy to ensure network availability and reliability. Product lines include Industrial Ethernet switches, industrial wireless devices, serial cards, serial device servers, embedded device servers, and USB and fieldbus components. All products are designed to stand up to harsh environments and are ideal for deployment in mission-critical applications in fields such as maritime, oil and gas, power and utilities, rail, and factory automation.

Industrial Computing Solutions

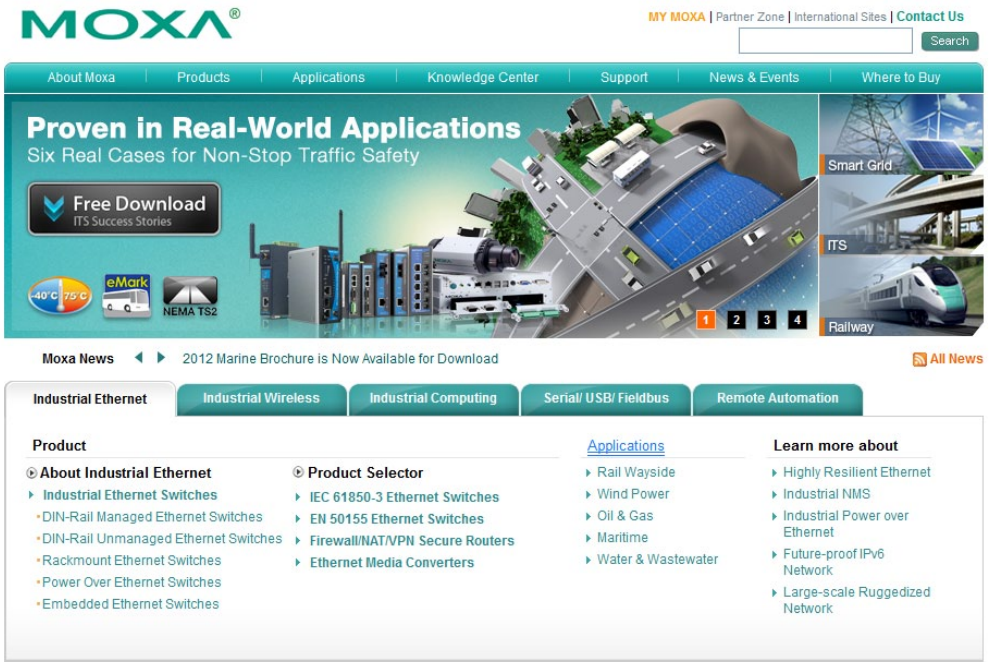
Moxa Americas, Inc.'s industrial embedded solutions are used to construct powerful front-end controllers that can execute on-site data collection and control at widely distributed remote sites through Industrial Ethernet or wireless backbones. We offer computers with rugged construction, and fanless operations, and an operating temperature range from -40 to 85°C, as well as a user-friendly environment that makes application development easy.

Moxa Americas, Inc. provides prompt and extensive customization services in In addition to a wide selection of ready-to-run products such as industrial computers, wireless computers, and wide temperature computers, prompt and extensive customization service is also available.

Remote Automation Solutions

Moxa Americas, Inc. has an extensive selection of intelligent and reliable RTU and Remote I/O products, including modular RTU controllers, cellular RTU controllers, Ethernet RTU controllers, modular remote I/Os, and compact remote I/Os. With innovative features such as Click&Go™, a built-in control logic that simplifies programming, and Active OPC Server™ for seamless communication with SCADA systems, Moxa Americas, Inc.'s RTU and remote I/O products are the ideal choice for your data acquisition, remote monitoring and alarm applications.

www.moxa.com



Industrial Ethernet Switches: Trends, Applications

Control Engineering International:

In February 2012, Control Engineering China did the "2012 CEC Industrial Ethernet Switch Application Trend Analysis" by sending control engineers a questionnaire about industrial Ethernet switches. Respondents totaled 375 from 20 industries, and 64% are end users of industrial Ethernet switches, 26% are system integrators or agents, and 10% others.

According to the survey, 63% of the companies in which the respondents work plan to purchase industrial Ethernet switches within a year. The high expense of implementing and lack of understanding of Ethernet and switch technology are two main reasons why industrial Ethernet switches haven't been more widely used in the industrial field, respondents said.

What's hindering use of the industrial Ethernet switches?

- 49% High cost of application
- 49% Lack of understanding of Ethernet and switch technology
- 36% Existing equipment's competence
- 36% Uncertainty of the Ethernet technology and its utility effect
- 4% Other

Source: *Control Engineering China* online survey on industrial Ethernet, March 2012

When considering buying a new Industrial Ethernet switch, 76% expressed concern about its stability, the most important consideration, by far, when purchasing. The second biggest concern is low maintenance cost at 56%.

Types of industrial Ethernet switches selected differ among industries. Users prefer purchasing modular Ethernet switches, managed Ethernet switches, and rack-mounted Ethernet switches. For demanding applications, the modular Ethernet switch was most widely selected, at 60%. Managed Ethernet switches accounted for 56% of responses, double that of unmanaged Ethernet switches.

The survey involved more than 30 industrial Ethernet switch brands. The leading five are manufactured in foreign-funded (non-China-based) enterprises. The two most popular brands were attractive to nearly half of respondents.

Various managed and modular Ethernet switches are named in the linked article below, "Modular, managed industrial Ethernet switches."

-*Control Engineering China* March 2012 article edited by Mark T. Hoske, content manager CFE Media, *Control Engineering, Plant Engineering, and Consulting-Specifying Engineer*, mhoske@cfemedia.com.

Who Puts the "Industrial" in Ethernet?

Mark T. Hoske, *Control Engineering*

Industrial Ethernet hardware can take plant-floor punishment without pampering in enclosures, allowing shorter cable runs with simpler distributed (rather than centralized) designs, and higher reliability than commercial-level Ethernet switches, routers, hubs, gateways, and connectors. Industrial ratings (such as NEMA 4x or IP67 and beyond) applied to Ethernet hardware mean that equipment can handle temperature extremes (as much as -40 to 85 °C), and even liquid and dust, and maintain reliable performance for years instead of months.

If commercial Ethernet devices are reliably enclosed and cooled, that might be enough to preserve reliability. Beyond that, higher costs for industrial design will cut down on mean time between failures, possibly preventing a process interruption or data loss. It all depends on the application. Cisco Systems Inc., for instance, while well-known in various network application spaces, is among companies that realize that industrial environments pose rugged challenges. Cisco forged agreements with Honeywell and Rockwell Automation, who have greater understanding of customer needs in process and discrete manufacturing operations.

Industrial wrapping

Enclosures can work wonders, admits Tom Edwards, senior technical advisor, Opto 22. Edwards contends that installation is mainly "what makes Ethernet hardware suitable for industrial environments…. Most of the off-the-shelf equipment is perfectly suitable for industrial installation if it can be protected from the normal bumps and scrapes ... in these types of settings. Most of the extra cost of 'industrial' equipment is the packaging added to keep it from being damaged and to make it fit in a 19-in. rack."

To make an Ethernet device industrial, says Greg Paukert, product manager, Tyco Electronics, using impact resistant plastics and rubber materials "seals against many chemicals including water to give the product a 10- to 20-year performance life." Connectors that use a positive locking coupling system ensure the interconnection is "fully-engaged and properly mated," Paukert adds.

When people think of industrial grade, they think of hardware that can operate under the harshest conditions, says Chris Harris, communications product manager, AutomationDirect. Various standards apply to making Ethernet industrial.

"Industrial hardware is expected to operate properly even when subjected to extreme temperatures, power surges (IEEE-472), extreme vibration (IEC 68-2-6), and when in hazardous locations [UL 1604, CSA C22.2/213 (Class 1, Div. 2)]," Harris says.

Design differences, says Eddie Lee, director of marketing, Moxa Americas, Inc., mean that "specifications of industrial Ethernet switches usually are two to three times stronger than the ratings found in comparable office grade equipment." The Class 1, Div. 2 rating for industrial Ethernet switches allows operation in hazardous locations where combustible gases or particles may be present, Lee says, such as in oil and gas, semiconductor, pulp and paper, and other markets.

How often a switch is exposed also makes a difference, says, Richard Hutton, automation product manager, Schneider Electric North America. "If a switch or cable is being accessed frequently, a more rugged connection point or device is required."

Signal interference

Skip Hansen, I/O systems product manager, Beckhoff Automation, explains that a "noisy environment may be one with welders, variable frequency drives (VFDs) and induction heaters. The switches used should have the ability to be mounted in a control cabinet or stand alone. In the case of stand-alone, switches certified to the IP67 protection class should be considered."

Other contributors to industrial electrical noise include solenoids, motors, and motion controls, says Larry Komarek, Phoenix Contact automation product manager, Americas Business Unit. "Industrial Ethernet devices designed to the IEC 61000-4 series of specifications have two to three times higher electrical noise immunity than commercial devices, which are typically designed to the EN 55024 and 50082-1 specifications," Komarek says. Paukert from Tyco says expects more use of "shielded, plated plastic receptacles for >20dB down shield effectiveness."

Hardened cabling

Whether network devices are distributed and exposed, or centralized and enclosed, "commercial off-the-shelf (COTS) Ethernet cabling and connectivity are not tough enough to withstand these stressors and continue to deliver the signal transmission performance required for automation and control networks," says Frank Koditek, Belden industrial market manager. Within a plant, Koditek warns, networking components, as well as their cables, may be exposed to temperature extremes, sunlight, solvents, oils, moisture, and chemicals.

They're also subject to mechanical stresses on cables from excessive pulling, and the risk of abrasion, crushing or cut-through resulting from plant floor activities. Category 6 or 5e Ethernet cables avoid "classic network failure scenarios, from incremental damage and performance degradation, to intermittent operation, to catastrophic failure," Koditek says.

Connectors, network failures

Connectors matter, as well. Ed Nabrotzky, general manager, industrial communication, Woodhead Industries, says, "Almost 70% of network failures happen because of a mechanical failure involving the cabling and connectors. Things can be jarred loose, worn out, improperly installed after a shut down, or even severed after being driven over by a forklift. Commercial grade cables and plastic connectors simply aren't made to withstand the abuse present on the factory floor." Special materials and design techniques create rugged products that can survive industrial conditions, Nabrotzky says.

Some off-the-shelf RJ45 connectors perform adequately when tested against the recognized shock and vibration specifications; others do not, says Brian Oulton, marketing manager, Logix/NetLinx Business, Rockwell Automation. "Many industrial Ethernet standards also recognize IP65 and IP67 environmentally sealed connectors (for example, M12) that are effective in many industrial applications," Oulton says.

Tougher protocols inside

In addition to hardened devices, cables, and connectors, plant-floor applications also can require industrial protocols running over Ethernet physical layer.

Choice of protocols "depends on the nature of the automation equipment in a particular location," says Brian Tutor, product manager for Lantronix, "however the most commonly utilized protocols in industrial environments are Modbus TCP, EtherNet/IP, and Profinet. (Control Engineering provided research on Industrial Ethernet protocol usage in the December 2006 issue.) "Typical rugged characteristics of Ethernet protocols include: wide temperature (-40 to 70 °C), high shock and vibration tested, electric isolation and FM Class 1, Div. 2 approval for hazardous locations," Tutor says.

Rockwell's Oulton suggests that industrial Ethernet protocols and connected products should contain appropriate error checking and diagnostics to take action if communications is in-error or interrupted. "For example, many protocols contain checksums and appropriate acknowledgement to ensure timely and reliable data delivery, and many I/O products are designed to move to a user-selected value if communications stops," Oulton says.

Switched Ethernet cuts collisions

Today's switched Ethernet has moved past prior issues with communications reliability and performance, according to Paul Wacker, product marketing manager, Moxa Americas, Inc. "Network contention issues (called collisions) have virtually been eliminated with the use of Ethernet switches, which intelligently forward messages from one device to another, ensuring deterministic performance," Wacker says. "Magnetic coupling and differential signaling utilized by 10/100 Base-TX Ethernet reduces communications disturbances caused by differences in ground potential between devices and external EMI/RFI sources. For additional levels of protection, fiber optic cable should be used."

Schneider Electric's Hutton likes industrial Ethernet hardware designs that incorporate added security or redundancy measures to keep a system up and running, such as the use of rapid spanning tree functionality, individual IP address filtering and the use of fiber optic dual cabling.

Installation, maintenance

Because industrial Ethernet is rapidly becoming the primary real-time network within and between automation control systems, Phoenix Contact's Komarek says, network infrastructure products often are supported by the plant floor personnel who support the control systems. "Software configuration interfaces, wiring and mounting arrangements must be similar to the PLC/PC-based control systems they are supporting," Komarek says. "In IT-based systems, software configurations are made in DOS-like text screens. Industrial options such as memory modules, diagnostic displays, etc., allow installation by plant personnel without access to laptops. IT devices rely on a central supervisory console to diagnose system status."

Self-serve design is an advantage, adds Hutton, when "industrial Ethernet systems are being designed for minimal upkeep with simple tools and interface methods like Web browser views for data and configuration. Plant maintenance personnel can maintain and monitor the system themselves, rather than waiting for an IT professional for assistance."

Mounting expediency is another reason to go industrial, says Moxa Americas, Inc.'s Lee. Industrial Ethernet switches are often housed in rugged metal enclosures using DIN-rail or panel mounting options, he says, while most commercial switches cannot mount conveni-

ently inside control panels without the inefficiencies of building a shelf and strapping the unit in place. Also, Lee adds, industrial grade equipment often has an alarm contact, which could help avoid or minimize downtime.

Capital versus lifecycle costs

Sometimes people select commercial products because of lower capital costs. Lifecycle costs can make an industrial design worth the investment when environmental factors cause more frequent replacement of commercial products.

Companies with capital cost constraints no longer have to choose lower-cost commercial products that are less rugged, suggests Larry Winchester, business development manager, Ethernet Direct. "Many companies are using commercial switches or unmanaged industrial switches due the high price of industrial managed switches. Ethernet Direct has lowered the cost of Industrial Ethernet products up to 40% compared to other industrial brands without sacrificing quality, reliability, and performance," Winchester says, by automating comparison, selection, quotation, and ordering. Online support and extensive industrial Ethernet reference libraries provide a high level of support, he adds.

Additional products, contacts, and resources follow at bottom.

ONLINE EXTRAs

Products : "Industrial Ethernet: Hubs, routers, switches, wireless"
www.controleng.com/article/CA644026.html

Industrial Networking April 2007
www.controleng.com/article/CA6433403.html

Tutorial: Wireless Ethernet transmission options, CE Online April 5, 2007
www.controleng.com/article/CA6430704.html

More power over Ethernet (PoE) February 2007
www.controleng.com/article/CA6412709.html

Industrial Ethernet Protocols December 2006
www.controleng.com/article/CA6396565.html

Industrial Networks (Product Research) July 2007
www.controleng.com/article/CA6347555.html

Serial-to-Ethernet Connectivity June 2006
www.controleng.com/article/CA6339793.html

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Is it Practical to use Ethernet for All Industrial Networking?

The variety of networking protocols that we have available grew out of a desire to have the right tool for the right job. Engineers have always wanted to match the network to the needs of the application. Here are some basic considerations:

- How much information has to be communicated?
- Does the system need to carry power to individual devices?
- Must the devices operate in a hazardous environment?
- How fast does the communication need to be?

Ethernet can work in just about any situation, but there are exceptions. To use a crude analogy, let's say you wanted to reduce the variety of cars and trucks on the road so you could simplify repairs, manufacturing, etc. If everybody drove the same vehicle, maintenance would be much easier to deal with. So you give everyone a full-size white utility van. Problem solved. If you need cargo, you're covered. Ladders? Put on a roof rack. Big family? Add seats. Some modifications are possible, but everybody has the same platform. Maybe it only gets 10 mpg, but it's standard. That's sort of the way it is with Ethernet.

Like a big van, Ethernet is good at moving large amounts of data, it can be fast, and it can carry power to devices. If your van is full of cargo or people every time you drive it, it all makes sense. But, if you commute 20+ miles to work and it's just you, it's lots of vehicle to move one person. A small car would be much more efficient for commuting.

Historically the thought of moving Ethernet to the shop floor was pooh-poohed because it was overkill: far too much expensive overhead for low-data devices. But the picture has changed. There are fewer low-data devices, and Ethernet is not as expensive. Field devices that used to be very simple have become more sophisticated and gained diagnostic capabilities. The infrastructure to process Ethernet-based data is less expensive, so the two extremes are moving closer together. If that big van can get 50 mpg and costs $10,000, maybe you won't mind driving it all the time.

The challenge will be converting users and equipment manufacturers. More field devices that used to communicate via an analog signal or a fieldbus protocol will need to be changed to Ethernet. Users can't make the change until those devices are available. Manufacturers won't make them until they see demand. It's an evolutionary process, and it could take some time for it to become a groundswell. Nonetheless, such technological changes are happening faster these days than they have historically, so don't be surprised if it becomes a reality faster than you expected.

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Extending Industrial Reliability to Control Rooms

Ray Hsu, Product Manager,
Moxa

Manufacturers are asking industrial automation networks to do more than ever before. Today, automation control systems are expected to provide greater operational visibility of manufacturing processes throughout the organization, from field sites to the control room, so as to reduce the cost of operations, maximize return, and ensure operator safety.

However, system integrators who try to deploy an integrated industrial network face one unique challenge: **their network is more vulnerable in the control room than at field sites.**

In most cases, system integrators deploy a mixed-mode networking solution, where they use commercial-grade switches in control rooms and industrial-grade switches at field sites. Because of this mix of commercial and industrial equipment, the industrial-grade performance of the entire network is compromised. How to achieve highly reliable networking performance has thus become a big headache, as seen in an actual case involving a major petrochemical company in the Middle East. The problems this company needed to confront are encountered everywhere and everyday by system integrators worldwide.

Petrochemical Company Embraces Industrial Switches in Control Rooms to Reduce Downtime and Improve Productivity

One of the world's leading petrochemical companies, located in the Middle East, used to deploy a mixed-mode solution for its industrial networks. The company used Moxa's EDS series industrial DIN-Rail switches in the field site and commercial-grade switches in the control room, where two air-conditioners were installed for redundancy to keep the temperature stable.

However, when both air-conditioners malfunctioned, the indoor temperature would rise to over 50°C—beyond the tolerance levels of the commercial-grade equipment—and cause the switches to shut down, creating problems for plant-wide system monitoring and management. Moreover, the switches' built-in cooling fans and the high noise interference at the location lead to a great deal of maintenance workload. As a result, the company not only suffered financial losses, but also lost credibility with their customers.

In the past, the company addressed these ongoing problems by constantly replacing their switches. After consulting Moxa, they deployed Moxa's fanless industrial rackmount switches in the control room, which can comfortably operate in a -40 to 75°C temperature range. The original mixed-mode solution turned into a fully-industrial Ethernet solution. This single change has successfully saved the company a great deal of maintenance and troubleshooting hassles.

Three Major Reasons Why Mixed-mode Networks are Insufficient

The mixed-mode approach used to be an efficient network solution. The rugged industrial-grade switches at field sites deliver high reliability with advanced network redundancy technology in the event of a single device or link failure. Meanwhile, the commercial-grade switches in the control room require lower unit costs.

However, with the growth of large-scale networks, the networking structure has become more complex, with stricter requirements for reliability, scalability, and efficiency. In the following section, we will explore how the mixed-mode approach now falls short on three levels.

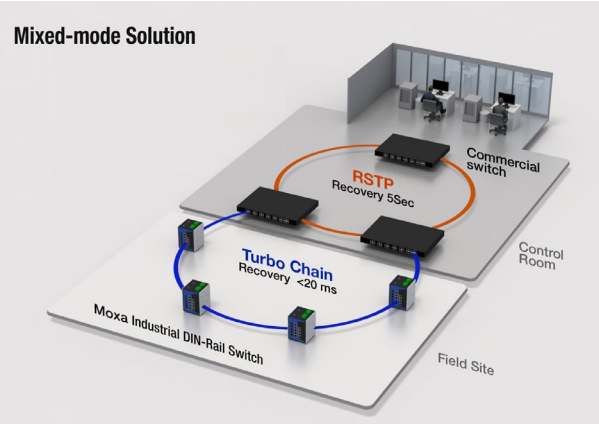
1) Product factors: commercial-grade switches fail to meet the requirements of mission-critical applications

At present, the number of large-scale industrial networking applications—such as oil and gas, ITS, railway, and mining—is growing. Accordingly, the network structure has transformed from a typical two-layer structure into a three-layer structure, which includes the field-level, control-level, and information-level. In this structure, control rooms are usually located next to the field sites, and experience environmental conditions that include EMI, power surges, other electronic noise, and extreme hazards. These harsh environmental conditions are too much for commercial-grade switches to handle, and can greatly affect the reliability and performance of commercial-grade switches.

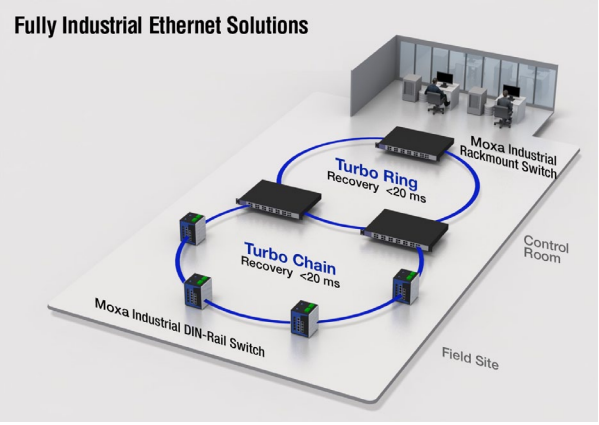
2) System factors: commercial switches cripple the performance of industrial switches

The less robust commercial devices in the control room are a weak link in the overall industrial network, and can actually drag down the performance of the industrial-grade half of the network. For example, industrial switches typically support advanced redundancy topologies, such as ring topology, which can deliver network self-recovery in under 20 ms. However, the commercial- grade switches of the sort typically deployed in control rooms use less advanced redundancy technology, such as RSTP, which can, at best, deliver network self-recovery in about 5 to 10 seconds. When these two systems are combined, the

commercial-grade component of the network becomes a bottleneck in system recovery, adversely affecting the recovery time of the entire system.



In this mixed-mode network, Turbo Chain can recover in under 20 ms but is held back by the commercial switches in the control room, which use RSTP and slow down the recovery time of the broader network.



This fully-industrial Ethernet network experiences end-to-end fast recovery time thanks to industrial-grade network redundancy protocols at both the field site and control room

3) Cost factors: interoperability issues create higher costs

Think about this scenario: when there is a network issue in a network composed of switches from multiple vendors, the operator must approach more than one service contact window. What's worse, it's not always obvious in which part of the network, the control center or the field site, a network issue actually resides. As a consequence, it's not possible to immediately receive support from a single trusted source. Instead, for every issue the operator must spend time simply identifying which service contact window is responsible for a given problem.

On top of this, there are additional maintenance requirements due to the commercial-grade product performance of the switches in the control room. This is the consequence of choosing a mixed-mode network: the total cost of ownership is higher. The following table lists the pros and cons when choosing a mixed-mode network solution.

An Improved Approach: The Fully-Industrial Ethernet Network

As demonstrated in the table above, mixed-mode networks may seem to be a cost effective option, since the commercial-grade switches have lower per-unit cost. In the end, however, the mixed-mode strategy will create more costs than it saves. There is an obvious better strategy: *for **industrial** systems, deploy a **fully-industrial** Ethernet network.* This delivers consistent, industrial-grade performance across the entire network, in both control center and field site.

A fully-industrial network eliminates the inconsistent performance that afflicts mixed-mode networks. The switches in the control room no longer under-perform their counterparts in the field site, and will be able to deliver the same high MTBF and exceptional ruggedness as the industrial-grade field switches. Obtaining service is easier now as well, because the entire network can be sourced to a single vendor. All of the switches support industrial-grade network recovery so the overall network recovery time is extremely rapid, under 20 ms.

Mixed-Mode Networks		
	Pros	**Cons**
Product level	Reliable data communication in field sites	Lower tolerance for the operating environments in control rooms
System level	--	• Network availability and reliability are compromised due to downtime caused by inconsistent performance of commercial switches in control rooms • Mediocre network convergence time
Cost factor	Lower unit cost	Higher total cost of ownership, including downtime, troubleshooting, and maintenance

Maintenance costs are lowered even further when fanless wide temperature switches are deployed: without fans to clean, system operators are saved a common and time-consuming maintenance hassle. In the final analysis, the fully industrial network represents superior value by eliminating the high TCO of operating commercial switches in industrial applications.

Complete Industrial Networks		
	Pros	**Cons**
Product level	High Reliability: • Fanless cooling • Wide operating temp. (-40 to 75°C) • Industrial approvals	--
System level	• Millisecond-speed network convergence • Maximized network uptime	Need to learn how to use new devices
Cost factor	Lower total cost of ownership	Higher unit cost

Industry Leaders are 60% More Likely to Implement a Fully-Industrial Ethernet Network

According to a research conducted by the business intelligence firm Aberdeen Group1, industry-leading companies outperform their peers in the following parameters: downtime, TCO, overall equipment effectiveness, and operating margin. For example, industry-leading companies only allow 3 hours of downtime per year, while the industry average is 19.7 hours. In addition, industry-leading companies achieve 5% reduction in total cost of ownership for the industrial network, while the industry average only achieves 2% reduction.

Aberdeen investigated what differentiates these industry-leading companies, and discovered an interesting pattern behind their outstanding performance: **industry-leading networks were 60% more likely to deploy industrial Ethernet switches instead of commercial switches in the control room,** compared with the industry average. By building fully-industrial networks, these industry-leading organizations are able to achieve lower total cost of ownership, higher uptime, and greater equipment effectiveness.

Moxa's Full Spectrum of Industrial Rackmount Switches

Moxa's IKS series and ICS series industrial rackmount Ethernet switches are designed to create reliable and scalable networks for mission-critical applications that require many connections at the control centers or field site control cabinets.

Moxa's rackmount solutions include Layer 2, and Layer 3 Ethernet switches that are capable of high Gigabit data rates yet remain flexible and easy to deploy thanks to high modularity. The Layer 3 switch models can efficiently consolidate traffic from subnets or VLANs into a core backbone. For control rooms that need even greater port density and network bandwidth, the ICS series switches feature 48 Gigabit Ethernet ports and up to 4 10-Gigabit Ethernet ports. Built for industrial applications, the switches feature industrial-strength reliability, and possess a variety of industry-recognized certifications to guarantee high network availability and environmental adaptability.

	Commercial Rackmount Switches	**Moxa Industrial Rackmount Switches**
Longevity	• 5-7 years design life • 1-2 year warranty	**• 20-25 years design life** **• 5 year warranty**
Network consistency	No, must use devices and obtain support from multiple vendors	**Yes, can normalize entire network around a single industrial vendor**
Electrical and physical resistances	• 0 to 40°C • Modest ESD, surge, EFT protection • No vibration, shock, impact protection	**• -40 to 80°C** **• High ESD, surge, EFT protection** **• Rated against vibration, shock, and impact**
Network redundancy recovery time	• Combined RSTP/Ring redundancy • Recovery time 5-10 seconds	**• Turbo Ring and Turbo Chain redundancy** **• Recovery time within 20 milliseconds**
Device cost	**Low**	Moderate
Total cost of ownership	*High*	***Low***

Visit our website to view more product information:
http://www.moxa.com/product/rackmount_ethernet_switch.htm

For detailed information:

- Complete product information available here.
- Learn more about fully-industrial Ethernet networks at our rackmount microsite.
- See how Moxa's fully-industrial Ethernet solution improved the overall network effectiveness of a leading coal mining company here.

Appendix A: Key Evaluation Factors

Evaluation Factors		Moxa Industrial Rackmount Ethernet Switches	Commercial Rackmount Ethernet Switches
A. Electrical - Surge Levels & EMI/RFI			
ESD	Enclosure port contact	+/- 6 kV	+/- 4 kV
	Enclosure port air	+/- 8 kV	+/- 4 kV
Radiated RFI Standard (RS)	Signal ports	10 V/m @ 80~1 GHz	3 V/m @ 80~1 GHz
Surge	Signal ports	2 kV DM	1.5 kV
	Power supply	2 kV DM	0.5 kV
EFT	Signal ports	1 kV	0.5 kV
	Power supply	2 kV	1 kV
B. Physical Environment			
Low air temperature operation		-40°C, 24-hour test & 48-hour cycling test	0°C
High air temperature operation		+80°C, 24 hours, 95% humidity test & 48-hour cycling test	40°C
Low air temperature for storage and transportation		-40°C, 16-hour test	-40°C
High air temperature for storage and transportation		+85°C, 20-hour test	70
Stationary vibration		5~500 Hz sine resonance	n/a
Shock		half-sine duration: 11ms peak acceleration: 15 g	n/a
Free fall		mass less than 20 kg: 0.9m	n/a
C. Longevity			
Design life		20-25 years	5-7 years in IT applications
Warranty		5 years	1-2 years
D. Performance Testing			
100% Burn-in		All models undergo a 100% burn-in test	Not usually required
Certifications		Certified test data per EN 60950-1, NEMA TS2, DNV/GL/ABS/LR/NK, EN 50121-4, FCC Part15, CISPR (EN 55022) class A	Type test data submission accepted