

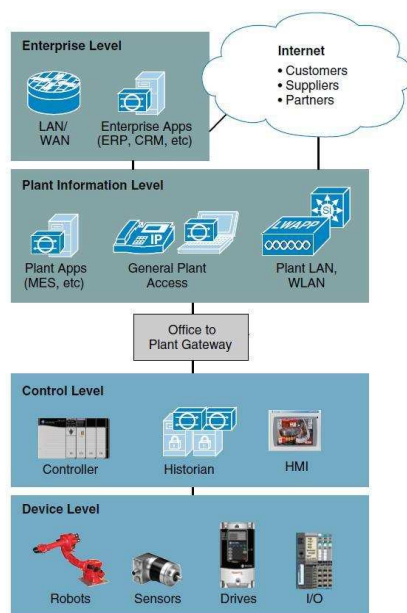
Planning for Converged Plantwide Ethernet

Keywords

Ethernet, Industrial Ethernet, Converged Plantwide Ethernet (CPwE)

Ethernet's Conquest of the Plant Network

The worldwide trend in manufacturing from specialized networks to industrial Ethernet continues unabated. Studies document the growing market share of Ethernet, which is penetrating down to the very edges of manufacturing networks – what ARC calls the device level. Manufacturing networks are distinct in that their lowest levels (see figure) are occupied by Industrial Automation and Control Systems (IACS).



Manufacturing Networks have IACS at Their Lower Levels

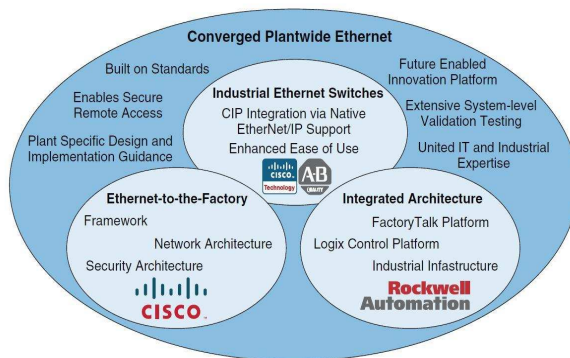
Traditionally IACS edge devices, such as sensors and actuators, have employed specialized device networks, often proprietary and deeply entrenched with the OEMs and systems integrators who develop these production systems. But the attraction of Ethernet for these applications has proved overwhelming. ARC's most recent study of this market, *Ethernet-based Device Networks Worldwide Outlook*, forecast Ethernet device-level growth of 27.5%/year during the period 2008-2012, and summarized the climate for Ethernet this way:

"The results of our latest update show a marked shift in market perception toward use of industrial Ethernet at the device level. While some of the traditional shortcomings still prevail, particularly the cost of the interface relative to alternatives, the desirability of a single, common, network technology that both simplifies network administration and enables vertical integration is readily apparent."

The Need for Converged Plantwide Ethernet (CPwE)

While the migration of the plant to Ethernet continues, simply specifying and employing Ethernet networking wherever possible is not sufficient to capture the potential cost savings, maintainability, enhanced flexibility, higher performance and efficiency. Quite to the contrary (as we will see in

several cases below) a higher level of planning, executive sponsorship and cross-functional collaboration is needed to assure that the potential benefits are indeed captured. In other words, there has to be a corporate cultural convergence along with the technology convergence to obtain all the benefits.



The Cisco-Rockwell Automation CPwE Architecture Encompasses Automation and Enterprise

The collaborative alignment and planning must extend through all silos of the manufacturing enterprise – operations, engineering, IT, staff, and management. Furthermore it should extend beyond the enterprise to critical suppliers and partners. The objective of such collaboration is the ongoing development of a control and information infrastructure that will grow by design into one that supports the operational life of today’s and tomorrow’s manufacturing process.

In their description of “Converged Plantwide Ethernet”, Cisco Systems and Rockwell Automation posit seven characteristic features of CPwE and its infrastructure:

Industrial – First is the obvious need for equipment that operates reliably in an industrial environment, requiring compliance with standards such as IEC529 or NEMA. Equally important is the fact that the layout of the production system and its automation equipment will have a major impact on the Ethernet topology employed. Depending on these systems, a linear, star, ring or hybrid network topology may be optimal, but any design choice involves tradeoffs which need to be understood.

Interconnectivity and interoperability – the ability to interconnect and interoperate a wide range of IACS network devices and applications through a common, standard network. In the CPwE interconnectivity, or co-existence, is achieved by employing standard Ethernet at OSI Layer 1-2, and the Internet Protocol Suite (IP, UDP, and TCP, plus associated protocols) at OSI Layers 3-4. While standard IP provides portability across local area networks (LANs), wireless LANs (WLANs), and wide area networks (WANs), it does not provide application level interoperability. For this, the CPwE specifies CIP (the Common Industrial Protocol), an application layer

protocol at OSI Layer 7. Compliance with the CIP application layer interface enables IACS device-level interoperability. This combination of CIP and the standard unmodified TCP, UDP, IP, Ethernet layers is also known commercially as EtherNet/IP (a trade mark of ODVA, Inc.).

Real-time communication, determinism, and performance – standard Ethernet meets the real-time communication and deterministic closed-loop control requirements (indeed, far more than is required for most IACS applications). The need here is for design practices that meet the application needs for real-time communication and deterministic performance. These design guidelines must be robust enough so that network equipment performs reliably within specified limits, has enough spare capacity for growth, and utilizes the appropriate mechanisms for prioritization of traffic to assure that required performance is delivered for each type of traffic under all conditions.

Availability – Here the need is to match the value of increased network availability with the value of increased manufacturing productivity. This is accomplished by choosing from among high-availability designs with various topologies, monitoring protocols, and recovery protocols. High availability is also achieved by reducing MTTR, through automated integration and parameterization of replacement devices.

Security – Without proper security design and implementation, moving the production systems to CPwE can potentially expose the IACS assets to security risks that originate on the enterprise network or even the Internet. Mitigating these risks is an unavoidable challenge (the enterprise network faces very similar risks). However the IACS applications require a tuned or customized security solution because production systems require greater availability than most enterprise applications and are less tolerant of even short service disruptions. CPwE recommends a distinct manufacturing security policy utilizing a defense-in-depth approach.

Manageability – IT, operations, and engineering may all take part in the monitoring and maintenance of the plant network. Common assets, both tools and people, can be utilized to provision and troubleshoot plant and enterprise networks. Organizational and cultural challenges can exist with the collaboration of groups that traditionally had little interaction. IACS applications will still be maintained by plant technicians and engineers,

whose work may need to be coordinated with IT professionals, making effective management both a technical and organizational challenge.

Scalability – Ethernet networks in IACS applications scale over three to four orders of magnitude from the smallest to the largest, and often are significantly larger than the traditional fieldbus networks they replace. CPwE designs need to match the requirements for size, growth, performance, capacity, and network segmentation that are specific to each IACS application.

This Cisco-Rockwell CPwE definition represents an excellent statement of the requirements of industrial Ethernet installations. However this architecture and solution set is almost never applied in one step to existing plants. Production systems and processes evolve over time with very few “rip and replace” events. To get a perspective of how industrial Ethernet reference architectures have been utilized in practice, ARC spoke with several global manufacturers, each with deep expertise in CPwE.

Global Pharmaceutical Formalizes Factory Network Design

ARC spoke with a major global pharmaceutical company concerning their factory network infrastructure practices. Pharmaceutical manufacturing consists of two major operations. The first is primary or bulk manufacturing, where the active pharmaceutical ingredients (APIs) are made and isolated. Then the secondary manufacturing operations process the APIs

A small yield increase in critical operations would result in millions of dollars of annual revenue, so these operations supported mature data historians, analytics, and Ethernet network infrastructure.

into various deliverable forms through operations like drying, tableting, filling, finishing, and packaging.

The trend in this company was for extensive network infrastructure to be deployed first in the API operations and then migrate “downstream” towards packaging. In their bulk manufacturing processes a very small change in yield could result several million dollars of additional revenue annually. Consequently API plants had already deployed extensive data collection and analytics, and these were supported by a mature Ethernet network infrastructure. From there, industrial Ethernet had migrated into the secondary manufacturing plants and processes, which had far more varied operations, systems, and machinery than the less numerous and relatively large bulk plants.

The number of systems, machines and devices networked by Ethernet exploded, yet at first the company did not apply rigorous design principles to these upgrades. As network complexity grew in a largely uncoordinated fashion, the firm encountered some serious network growth pains that adversely impacted their production. At that point, everyone in the company could perceive the value of sound infrastructure, and the company developed and adopted an internal architecture standard very similar to the Cisco-Rockwell Automation CPwE.

But the needs of the secondary plants made this standardization a challenge. There were two major issues: First, educating their secondary plant stakeholders to the potential value of Ethernet networking. This was especially true for packaging operations which had normally been deployed sans network. The second issue was how to inculcate their network design processes into their procurement process, which consisted of many distinct projects and purchases.

The education process has been ongoing. Their principal benefit derives from remote support and access to these systems. A secondary value comes from automated data collections, which feeds into their manufacturing analytics. While well established in the bulk plants, analytics are less mature in some secondary areas. The value of new data will justify the infrastructure investment in many cases, but not all. Furthermore, the investment decision is often made during a capital project, where the TCO factors that weigh during the operating life of the system may not be visible or well quantified. Their solution to this problem has been to add external technical reviews to the project work process.

Formal project reviews, including network infrastructure, have been adopted to promote wise CPwE investment decisions in capital projects.

The company calls this step its “Technical Architecture Review Process”, known as TARP (until the US Treasury’s program gave this acronym a bad name). The review is a required step in all capital projects of a certain size, and may take place more than once on any project. The review is conducted by people outside of the project team, but it is not binding. All the decision-making is still performed by the project team itself.

The review focuses on:

- Project Scope
- Related Equipment/Production Units
- Supporting Applications (MES, DNS, AutoID, Historian, etc.)
- Project Objectives
- Milestone Dates
- Human Operator Interaction
- Control System Architecture
- Anticipated loading
- Network Isolation, Performance, and Security
- Remote Access
- Safety

Dozens of prescribed questions are answered during the review. Deviations from the standard architecture are identified and the disposition of these is chosen by the project team. “We do not command compliance to the network reference architecture”, said the executive interviewed by ARC, “In some packaging applications, the team might decide to bring a whole packaging line in with non-industrial Ethernet switches and they opt to run the line isolated from the manufacturing network. If the line anticipates running at less than capacity, they may be OK with that.” Asked what improvements he would make to the TARP program, he responded that “We need to be engaged at the design and specification stage of projects. I would make the TARP review dependent more on the technology being used rather than just project size. If we are introducing new technology to the production system, a small project may well merit a full review, especially since it may be the first of many.”

Decentralization Challenges Standards at Food Manufacturer

ARC also interviewed a North American manufacturing executive of a major multi-billion dollar global food company, with a huge US presence. This company moved toward standardized plant Ethernet architecture several years ago. According to the executive, “In our early days, we didn’t specify very much about plant Ethernet networks. As they grew and proliferated with only minimal oversight, we had a couple instances where we experienced significant downtime as a result of network disruptions. At that point we instituted common design practices.”

He reported that in his company there is not really an internal network “standard” document, but rather a set of accepted practices covering required infrastructure to support networked applications like HMI, data Historians, MES, etc.

The economic justification for these practices in most cases is production equipment reliability. This focuses infrastructure spending on the most critical production areas, but does not guarantee uniformity. It has resulted in consistent network implementation for their critical production systems.

The firm finds that greater reliability of production equipment is the most frequent justification for their investments Ethernet infrastructure.

The downtime caused by haphazard Ethernet network engineering has been eliminated.

They do not employ these practices universally for two reasons: slack resources and organizational. Slack arises as a barrier in the case of less critical

systems or those with excess capacity. Here an unplanned shutdown can be remedied by simply scheduling additional production during what would otherwise be idle time. However the capital savings come at the cost of remote machine visibility, diagnostics, and service.

The organizational issue is non-technical and more complex. It stems from the decentralized operational philosophy they have adopted as their operations have grown organically and through significant M&A activity, as they have recently inherited a large number of additional plants through M&A. As the executive reports:

“The mode of operation today is not for central engineering staff to dictate policies to the business units. Five years ago that might have been the case, but today the business units operate with greater autonomy. Staff engineering makes some decisions, and they participate as stakeholders, but most questions are decided by the business. Ultimately this makes network infrastructure investment a business unit decision for us. One consequence of this policy is that as an enterprise we are less consistent from a systems and infrastructure design standpoint.”

CPwE Enables New Production Systems

ARC spoke about Converged Plantwide Ethernet with a manufacturing executive of a major global fast-moving consumer goods (FMCG) company. This company has been using Cisco and Rockwell Automation CPwE refer-

ence architectures in North America for three years. Their reasons for standardizing on the architecture depend on the business unit involved.

Their manufacturing operation supports two major business units in North America. One is a traditional and mature product business. The other business features much newer products that evolve and change rapidly, and are manufactured on some of the most complex IACS equipment that the company operates.

There are values to the CPwE Architecture that are shared across both businesses. These include reduced risk derived from greater network manageability. They call one of their biggest pain points “enterprise desktop push” – this occurs when enterprise network changes impact manufacturing systems. The reference architecture enables a more controlled patching process with less disruption, resulting in better OEE from greater uptime and availability. The manufacturer was unable to specifically quantify these benefits, but stated that to follow a software update schedule driven by IT needs was simply incompatible with their need for high production rates and rapid, predictable production execution.

Their more modern product business has several additional drivers for CPwE. These pertain to the highly complex equipment and systems that build the products. The company has used a CPwE architecture combined with highly standardized application engineering to develop a vastly stronger MES capability for this business. In fact, the MES data collection and roll-up is now entirely automated, because of the standard architectures used. This automation enables them to analyze the MES situation several times each day, rather than once every few weeks – over 100x more often than some of their other businesses can do this. This more current information is critical, because maintaining OEE is an important challenge for this business. The operation needs to push the production systems toward their engineering and operating limits. They need to know how far they can push production while maintaining quality and uptime, and gain granular visibility into the causes of lost machine speed or availability.

The company has embedded the network infrastructure decisions in its project development process. The extra investment required does result in some management push-back. “Many of today’s networks and systems do not enable us to identify the root causes of machine down-time. In cases like this, it is difficult to articulate the benefits during the CapEx process,

though they are there. On the other hand, you cannot simply force one architecture onto every asset at every site. But if a project does its network planning early, we can work out a plan based on their anticipated services.”

The firm also plans to move Ethernet down to the device layer as much as possible in order to get greater capacity and speed. In these cases, “the new infrastructure needs to assure the isolation and quality of service of these networks”, he says. These will be provided by using CPwE as the design principle even for device-level networks.

ARC Recommendations for Manufacturers

Based on our discussions with these 3 manufacturers, here are recommendations ARC makes for similar firms:

- Develop standard reference architectures for Ethernet networking within your plants and production areas. These should be developed with input from production management, IT, and your firm’s critical suppliers such as OEMs, automation and IT suppliers, and system integrators.
- These new reference architecture standards should support specific business benefits and application requirements, with a view toward future enterprise needs for plant access and information.
- Include formal review points in your capital project process, especially for large production systems or new plant technology. These reviews should focus on the networked equipment associated with the project, and should detail the anticipated network services and the expectations for supporting network infrastructure. The first of these reviews should be done as early as practical in any project.
- In capital projects, negotiate a match between the required functionality/performance and the need for new supporting network infrastructure, rather than imposing a single network design on each project.
- Machine builders and system integrators must anticipate end user demands for further system integration, deeper machine diagnostic and performance information, and more remote services. These demands will require high-performance communications and networks internally and externally.

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The Converged Plantwide Ethernet Design and Implementation Guide and associated Rockwell Automation whitepapers, presentations, and educational material are available at <http://www.ab.com/networks/architectures2.html>.

The Cisco Ethernet to the Factory (EttF) solution, including the Converged Plantwide Ethernet Design and Implementation Guide, case studies, and whitepapers is available at http://www.cisco.com/web/strategy/manufacturing/ettf_overview.html.