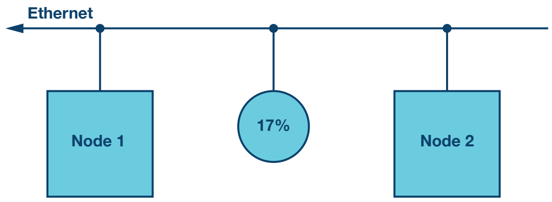
Why It Is Worth It to Explore Ethernet for Motion Control



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Motion control is one of the most demanding applications within the typical automation and control system, as we have noted before in several other articles. For years it was largely the province of legacy fieldbuses such as CANopen, as well as conventional peripheral component interconnect cards. These technologies had their fair share of limitations (for example, relatively meager bandwidth) but were generally reliable and inexpensive to implement.[1] However, a move toward industrial Ethernet protocols, including PROFINET®, as well as EtherNet/IP®, EtherCat®, and many others began in earnest years ago, as Ethernet was modified to address its biggest shortcomings, notably the lack of determinism in its standard office incarnation.

Over time, Ethernet has become preferable to these technologies for several reasons:

- It opens up the possibility of converging disparate networks into one, creating a common connection between the factory floor and enterprise IT that does not require juggling a bunch of different protocols. This is especially important for motion and machine control, both of which have historically been divided among multiple fieldbuses like DeviceNet, SafetyBUS p, and others.
- It has staying power. Despite being commercially introduced decades ago, Ethernet is still by far the most popular set of standards for office networking, and it is also growing faster than fieldbus in factory settings. An early 2015 survey found that Ethernet nodes were growing at a 17% annual rate, compared to 7% for traditional fieldbus.[1]
- It is widely supported and not just in the automation industry. Parts are manufactured in mass quantities and, as such, are typically more cost-effective than the specialized pieces of equipment needed for operating fieldbus and conventional PCI network infrastructure. Installation and maintenance are also simpler; multiple trainings on separate technologies are not necessary and standard components can be used.

Most importantly, Ethernet can also now provide the determinism that is central to any motion control application. A series of advances such as the replacement of CSMA/CD with full-duplex switching and isolated collision domains, as well as the ongoing refinement of the IEEE 1588 precision time protocol have set Ethernet on the path to being a predictable network for industrial systems. A universal standard such as time sensitive networking (TSN), which incorporates parts of the IEEE 802.1 and 802.3 specifications, was not fully available as of early 2016, but industrial Ethernet protocols already provide viable solutions for deterministic, cost-effective, and scalable motion control. Industrial Ethernet protocols can handle demanding motion control applications.

Different Ways of Achieving the Same Goal

Let's look briefly at how each one provides the determinism needed for motion and machine control applications:

PROFINET

The standard TCP/IP stack can be bypassed via the PROFINET IRT channel, which can be defined in several ways:

- One option is via ASICs that synchronize nodes; under this setup, each PROFINET IRT device has a special ASIC for handling node synchronization and cycle subdivision, and incorporates an intelligent 2- or 4-port switch.[2]
- Another possibility is to use a solution such as a standard REM switch that can be configured for multiple industrial Ethernet protocols, including IRT.

Overall, PROFINET IRT is built for systems that require deterministic, submicrosecond clock synchronization. Less than 1 millisecond is the target baseline for cycle times, while under 1 microsecond is the ideal for jitter accuracy.[3] To hit these marks, PROFINET IRT uses full-duplex, fast Ethernet for network segmentation. It defines a *fast lane* for its traffic via its features for bandwidth reservation, scheduling, and separation of time domains for different types of Ethernet traffic.

EtherCAT

EtherCAT utilizes on-the-fly processing to allow frames to pass through slaves with only negligible time delay before being returned to the master. This is in contrast with standard Ethernet, which sends out frames to multiple devices and waits for all of them to respond and be updated, often with lots of delays along the way. An EtherCAT slave instead extracts data as it arrives and writes a response.[4]

The EtherCAT protocol also allows for bandwidth optimization by combining incoming and outgoing data for numerous devices to be consolidated into a single Ethernet frame. In this way, it reduces transmission overhead and provides much needed support for networks that are heavily loaded with I/Os, drives, and other devices. Multiaxis servo control requires a lot of bandwidth and EtherCAT frees it up in droves. According to numbers cited by *Machine Design*, a network using EtherCAT could sample and update 64 drives and a few additional I/Os in less than 250 microseconds.

EtherNet/IP

EtherNet/IP maintains standard Ethernet layers, including TCP/IP and UDP/IP. This is quite convenient for plant operators since they can utilize unmodified Ethernet components throughout their networks. However, it makes several key additions, through extensions, that close the determinism between Ethernet and traditional fieldbus.

CIP Sync maps the IEEE 1588 precision time protocol onto the intuitive object-oriented model used by the common industrial protocol (which is the basis for EtherNet/IP in addition to the older CompoNet, DeviceNet, and ControlNet fieldbuses). This allows for precise clock synchronization across devices.

CIP motion provides a set of application profiles that enable torque, speed, and position loops to be closed within servo, variable frequency, and/or vector drives. It can coordinate a large number of axes with a motion planner update that takes a mere 1 millisecond.

ODVA, the organization overseeing the development of both CIP and EtherNet/IP, continues to update these extensions to address critical requirements such as controller-to-drive interfaces and intercontroller communications. EtherNet/IP as a whole remains an appealing option for motion control using standard, unmodified Ethernet.

"CIP Motion has punched a hole in an urban myth of industrial automation"[5] explained Paul Brooks of Rockwell Automation in an article for *Industrial IP Advantage*. "The myth: Standard Ethernet cannot be used for motion control and so something needs to be developed that is based on Ethernet; adding time slice algorithms to the firmware or hardware of devices, or simply building a proprietary network with CAT5 cables and a gateway to standard Ethernet."

As these three protocols demonstrate, motion control is a challenging task that can nevertheless be addressed effectively with industrial Ethernet. Fieldbuses have not gone away, but they have serious competition as more enterprises look to simplify their networks and prepare for the Industrial Internet of Things.

References

[1] Wilfred Voss. "The Future of CAN/CANopen and the Industrial Ethernet Challenge." *ESD Electronics Inc.*

[2] "Fieldbus Market Is Still Twice as Big as Industrial Ethernet." *Drives & Control*, January 2015.

[3] Paula Doyle. "Introduction to Real-Time Ethernet II." *The Extension*, 2004.

[4] Jason Goerges. "EtherCAT Enables High Performance Motion Control." *Machine Design*, November 2010.

[5] Paul Brooks. "Using EtherNet/IP for Motion Control." *Industrial IP Advantage*, October 2015.

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