The Future of CAN / CANopen and the Industrial Ethernet Challenge

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Industrial Ethernet technologies are a formidable challenge to CANopen as the low-cost industrial networking technology of choice. Ethernet technologies will eventually replace the majority of CANopen applications, at least in regards to new developments.

For many years, Controller Area Network (CAN) and CANopen, a higher-layer protocol based on CAN, represented the best choice for low-cost industrial embedded networking. However, since the official introduction of CAN in 1986, there has been a quest to replace CAN and CANopen to overcome the most obvious shortcomings such as limited baud rate and limited network length.

Industrial Ethernet technologies are currently the most formidable challenge to CANopen as the low-cost industrial networking technology of choice. Ethernet technologies will eventually replace the majority of CANopen applications, at least in regards to new developments, starting at this very moment in certain areas such as industrial control including motion control and, especially, robotics. Ironically, CAN - the underlying hardware layer of CANopen - has a far greater lifetime expectancy in the North American market than CANopen as a higher layer protocol.

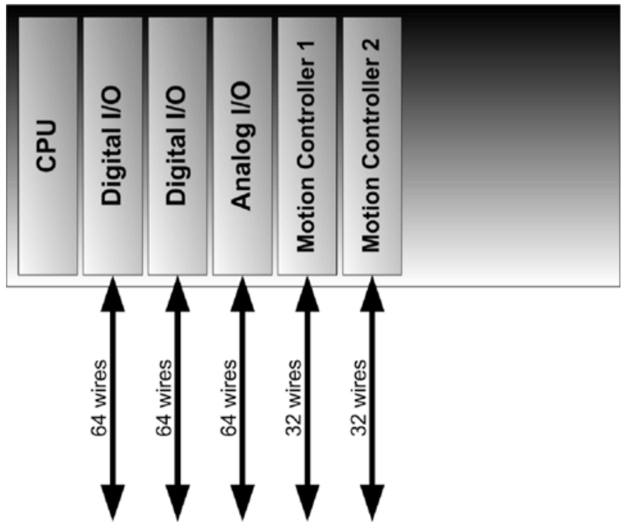
However, there can be too much of a good thing, and that is definitely the case when it comes to Ethernet-based fieldbus technologies. There are currently more than 20 different industrial Ethernet solutions available, all with their distinctive advantages and disadvantages, making a pro/contra decision difficult. The major question, besides the technical aspect, is which of these technologies will survive in the market, and how do they support the current need for control components. In all consequence, the battle between these technologies is a mere marketing battle.

This article will elaborate on the future of CAN and CANopen in the North American market. It will also address the need for faster fieldbus systems and narrow the field of potential winners in the Ethernet race.

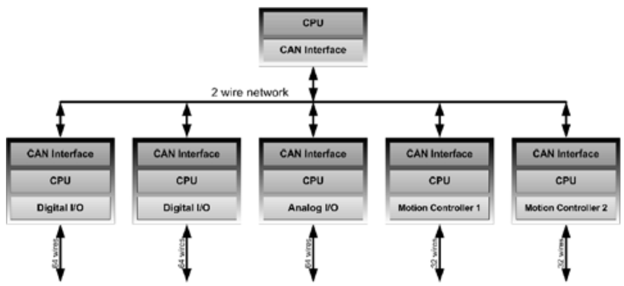
Distributed vs. Central Control

Over the years, CAN and CANopen, due to their economical implementation combined with an extremely high level of reliability, have proven and established their dominance as a fieldbus system for embedded solutions. They were, however, never intended to effectively penetrate the huge North American market for simple industrial I/O, namely the PLC market.

Conventional industrial controls, especially PLC, are based on *Central Control* where a single CPU is responsible to control the application tasks, resulting in high performance requirements for the CPU. Another downside is the great amount of wiring resulting in a considerable impact on service and maintenance.



Central Control
(Distribut vs Central Control 1.jpg)



Distributed Control
(Distribut vs Central Control 2.jpg)

Established serial communication technologies for embedded solutions such as RS-485, CAN, TCP/IP, etc. support a *Distributed Control* architecture in form of Master/Slave or Client/Server configuration. The most obvious advantages are the saving in wiring plus the increased performance of a multi-processor system. There are more benefits resulting from the savings in wiring such as increased system reliability, improved service and maintenance, and, most importantly, reduced downtime and reduced operating costs.

The established Ethernet TCP/IP protocol, theoretically 100 times faster than CAN or CANopen, never had the potential to be fully accepted as an industrial protocol, because it is non-deterministic, i.e. it does not support real-time control. Consequently, Ethernet TCP/IP was never a threat to existing CAN and CANopen applications. New Ethernet technologies, such as EtherCAT, Powerlink, Ethernet/IP, etc., however, do have the potential not only to replace existing fieldbus systems, but also to play a major role in the North American PLC market.

Advantages and Disadvantages of CAN and CANopen

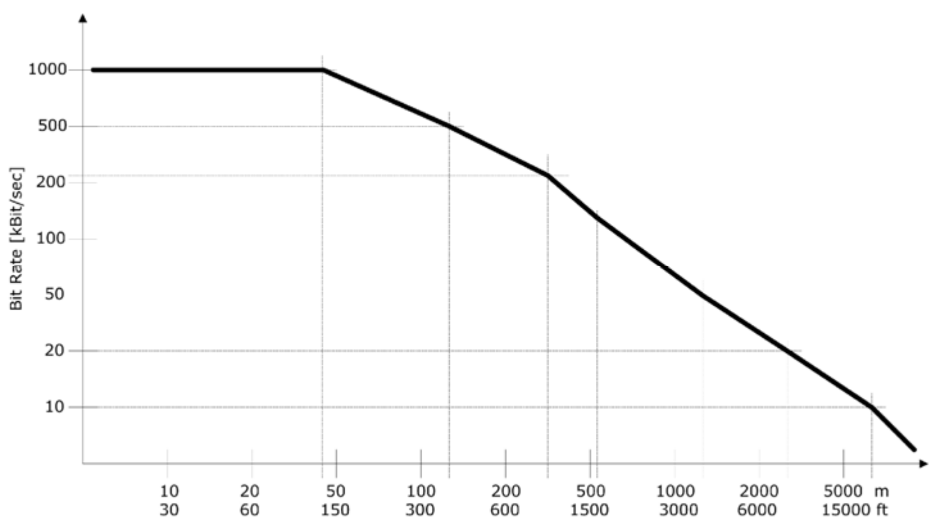
CAN and CANopen, used as fieldbus systems for embedded solutions, combine a number of advantages that cannot be matched by Ethernet TCP/IP. They are:

- Extreme Reliability and Robustness
- No Message Collision
- Very Low Resource Requirements
- Low-Cost Implementation
- Designed for Real-Time Applications
- Very Short Error Recovery Time
- Support of Device Profiles (CANopen only)

However, there are some disadvantages of using CAN and CANopen, the biggest being the limited network length (~120 feet at a 1 MBit/sec baud rate). The disadvantages are:

- Limited network length (depending on baud rate)
- Limited baud rate of 1 MBit/sec
- Limited bandwidth

The following picture demonstrates the relation between baud rate and supported network length:



CAN Bus 4.jpg

CANopen is basically a software add-on to provide network management function to CAN. The side effect is a reduced CAN bandwidth. The degree of bandwidth loss depends primarily on the use of Service Data Objects (SDO) and Process Data Objects (PDO). Only a meticulous "housekeeping" can guarantee the best possible performance.

In all fairness, the limited bandwidth is not a major problem, since CANopen handles only the communication means between multiple processors (nodes); the major control tasks take place within the nodes, and they do not necessarily effect the bus communication.

Houston, we have a solution…

(Uhm… We're looking for the problem…) In all consequence, the current excitement about new Ethernet technologies is based on a mere marketing hype. The matter of the fact remains that more than 95% of all industrial control applications are sufficiently covered by technologies that were established many years ago. It is nevertheless also the case that these new Ethernet technologies are developing steadily closer toward the lower price level of conventional components, and "why buy a compact car when you can get a large hybrid SUV with four-wheel drive and better gas mileage for nearly the same price?"

While it is true that the costs for Ethernet technologies show a tendency to lower prices, the statement "nearly the same price" can only be regarded as another marketing statement. A tough reality check will reveal that the costs are currently several times higher than those of a conventional system such as CANopen (the estimated factor is somewhere between 3 and 20).

However, the technological advantages of Ethernet based fieldbus systems, whether needed or not, are compelling, and they contribute to a higher acceptance level worldwide. The advantages are:

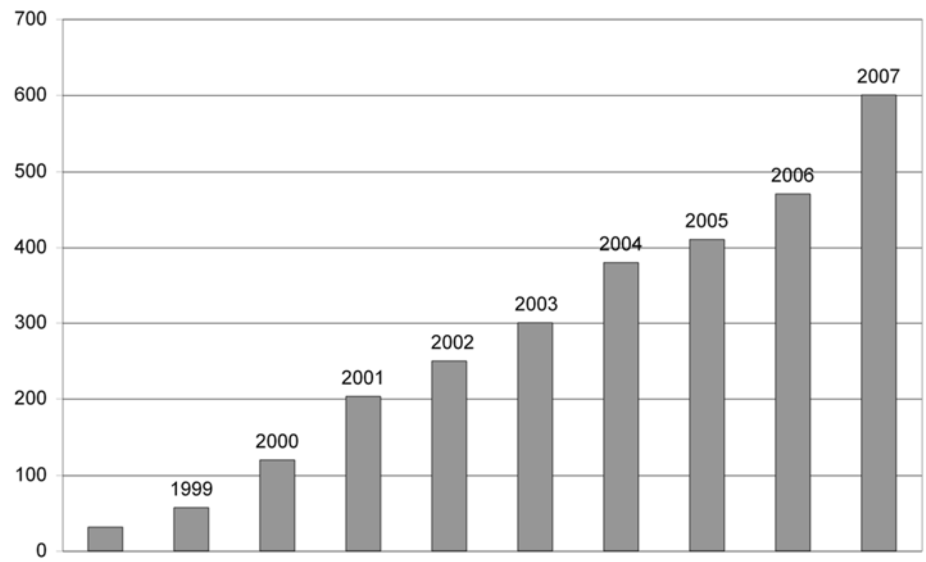
- Speed! (Currently 100 MBit/sec)
- Unlimited network length
- Use of established HW components (RJ-45, Switches, Hubs, etc.)
- Increased system performance

Note: There is currently no information on how Ethernet based fieldbus technologies compare to the high level of reliability and robustness as provided by Controller Area Network.

The Future of CAN and CANopen

The future of CAN - as the physical layer - and CANopen - as a higher layer protocol based on CAN - in the North American market must be seen separately.

The use of Controller Area Network is still dominated by its vast use in the automobile industry, and there are no indications that CAN will be replaced in short-term. Another stronghold is the use as a physical layer for the SAE J1939 protocol, and CAN will remain the most cost-sensitive fieldbus solution for small, embedded systems.



CAN Nodes Sold in Millions
Source: CAN-in-Automation
(CAN Nodes Sold.jpg)

In summary, the use of CAN will continue in:

- Automobiles and Trucks
- Aerospace (e.g. satellites)
- SAE J1939
- Small Embedded Solutions
- Legacy Applications

CANopen, however, is facing a much tougher battle, since its major application range is now being attacked by the new Ethernet technologies. These CANopen legacy applications are:

- Motion Control
- Industrial Machine Control

Other applications not necessarily effected by Ethernet technologies are:

- Niche Applications (Lifts, Escalators, Gambling Machines, Telescopes, Specialty Vehicle Systems, Cost-Sensitive I/O Control, etc.)
- MilCAN

The MilCAN standard, mainly used by the British Army for their military vehicles, allows CANopen and SAE J1939 devices to access the same bus.

The Medical industry is still the biggest supporter of CANopen in the North American market, but here, too, are tendencies to look into Ethernet technologies due to the vastly increased data throughput that these technologies offer.

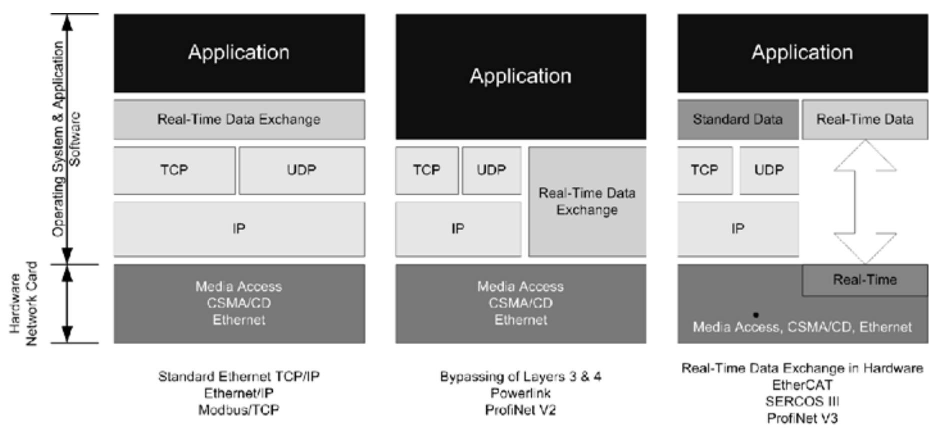
The Ethernet Challenge

There are currently more than 20 different industrial Ethernet solutions available in the marketplace, all with their distinctive advantages and disadvantages, making a pro/contra decision for the end-user difficult. The major question, besides the technical aspect, is which of these technologies will survive in the market, and how do they support the current need for control components. As a matter of fact, the battle between these technologies is not necessarily based on technological advantages; it is a mere marketing battle.

Out of the 20+ Ethernet based industrial protocols remains a much shorter list of candidates that realistically have a chance to penetrate the American market significantly. They are:

- EtherCAT
- Powerlink
- Ethernet/IP
- Modbus/TCP
- ProfiNet

The following picture demonstrates the differences between these systems in an overview:



Ethernet Protocols Comparison.jpg

The picture also demonstrates the major difference between Ethernet/IP and Modbus/TCP on one side and EtherCAT, Powerlink, and ProfiNet on the other. Realistically speaking, neither Ethernet/IP nor Modbus/TCP is deterministic (i.e. not suited for hard real-time control); they do not support a direct connection between the physical layer and the application.

Especially Modbus/TCP – basically Modbus over Ethernet - with a cycle time between 5 and 10 milli-seconds must be considered too slow for real-time control. It is nevertheless extremely easy to implement, which explains its wide usage.

While Ethernet/IP may not be the optimum choice in regards to real-time control, it is nevertheless the strongest player in the North American market due to the “political” support by Rockwell Automation. The same is true for ProfiNet (supported by Siemens). A downside for ProfiNet may be the high performance requirements by the standard, making an implementation for third-party vendors somewhat difficult.

There are only three protocols that provide a direct hardware connection between the physical layer and the application, i.e. they require a specific controller chip. These protocols are:

- EtherCAT
- Sercos III (limited presence in North America)
- ProfiNet V3 (current status unknown)

EtherCAT and Powerlink also support CANopen device profiles to provide a certain level of portability for existing CANopen applications.

The current problem with the Powerlink standard seems to be the transition from Powerlink V1 (a B&R proprietary version; B&R is the creator of the Powerlink protocol) to the Powerlink V2 standard as agreed by the members of the Ethernet Powerlink Specification Group (EPSG), and there are strong indications that the support for the Powerlink standard is waning.

The following provides an overview of the various Ethernet protocols.

	EtherCAT	Ethernet/IP	Powerlink	Modbus/TCP
Vendor Organization	EtherCAT Technology Group	Open DeviceNet Vendor Organization	Ethernet Powerlink Specification Group	Modbus-IDA Group
Homepage	www.ethercat.org	www.odva.org	www.ethernet-powerlink.org	www.modbus-ida.org
Availability of Specification	Members signing an NDA	Free	Members	Free
Availability of Technology	Example Code, ASIC, FPGA	Example Code	Standard Ethernet Chips	Example Code
Products Available Since	2003	2000	2001	1999
Interaction Structure	Master/Slave	Client/Server	Master/Slave	Client/Server
Communication Method	One frame for all communication	Message Oriented	Message Oriented	Message Oriented

	partners			
Ether Data Transfer Rate	100 MBit/sec	100/10 MBit/sec	100 MBit/sec	100/10 MBit/sec
Physical Topology	Line, Daisy, Chain, Tree	Star	Star	Star, Tree
Logical Topology	Open Ring Bus	Bus	Ring	Bus
Infrastructure Components	Switches between different segments	Switches (Hubs are possible, but not efficient)	Hubs, no switches	Hubs, Switches
Device Profiles	CANopen, SERCOS	DeviceNet, ControlNet	CANopen	None

Note:

- Ethernet/IP and Modbus/TCP are open to increased speed standards, i.e. there would be no need for hardware upgrades. All others would be subject to hardware changes.
- The use of switches and/or hubs increases wiring costs and lowers system reliability.
- The use of hubs may impact real-time performance (Does not apply to Powerlink due to timing control preventing message collision).