

“Just in Time”

through decentrally control technology networked through Ethernet



→ At Ford Europe's Belgian factory at Genk a fast Ethernet backbone with 100 Mbaud in full-duplex operation connects 130 BC9000 Bus Terminal Controllers made by Beckhoff. These control a complex transportation system known as the tunnel, which handles the clocked provision of components and systems from five suppliers. The tunnel owners themselves invested about 7 million € in hardware, software and network technology.

Ethernet connects tunnel controllers

The new Ford Mondeo is produced at the Ford factory at Genk in Belgium. Each day more than 1,650 vehicles are said to roll off the conveyor belt in three shifts. Depending on the order and equipment the expected estimated annual production totals 350,000 units. Ford relocated a suppliers' park slightly on factory grounds. The suppliers' park houses important "Just-In-Time" and "Just-In-Sequence" system components. These products are delivered to the assembly area located in the C halls on the factory grounds using a transportation system known as the tunnel. This tunnel acts as a high-level viaduct from the park, transporting components as far as the assembly stations within the factory. The 1 km long transportation portion of the system consists of approximately 7 km of the con-

veyor track. There are two directional routes. The main one, including the extension from the suppliers' park, leads directly into the factory arriving at transfer stations on the assembly line. From there, they return from the factory along two main routes. About 30 million € were invested on the complete system, of which about 7 million € went on the complex automation technology. Significantly the owner of the Tunnel is not Ford, but the ASG (Automotive Service Genk) company, in which the firm of GTI Electro Thijs from Genk also has a financial interest. GTI is responsible for the entire electro-technical equipment relating to the project. MULTIPROX, Beckhoff's exclusive representative in Belgium, offers additional support. ASG, as a joint venture with the equipment firms of Eisenmann and LRM (Limburgse Reconvertie Maatschappij), set up the CSG (Con-

The suppliers SML, Lear, Textron and TDS Essers are connected directly to Ford Mondeo's assembly halls via the overhead transportation system consisting of 7 km of conveyor track.

veyor Services Genk) operating company. Essentially, the conveyor tunnel is being paid in terms of piece production of each completed vehicle. Thus, both operators and suppliers ensure Ford's "trouble-free" standards of product and system transfer.

The decision to construct the tunnel was made in 1999. "Ford wants the suppliers to be closer to the production location" was how project leader Ivan Guillems from GTI Electro Thijs proposed the tunnel project. Initial plans for the tunnel began in October 1999. The first construction measures began in December. Simultaneously, design and implementation strategies took place for equipment and its manufacture, i.e. the conveying technology, which was supplied by the firm of Eisenmann from Böblingen. By the end of April commissioning work began. On August 15, 2000 the first series of 8 hour operational test runs started. A week before the official start of production in September, the conveying equipment was subjected to uninterrupted operation lasting 100 hours. Since then Ford continues to increase production of the Mondeo. As a result, the transportation output rises steadily, thereby increasing the demands to guarantee "Just-in-Time" and "Just-in-Sequence" deliveries of the necessary parts and system components. For this reason the control program of the conveying equipment is being continually improved.

Previously at its plant located at Saarlouis, Ford finds the close proximity location of the suppliers' park, and linking the conveyor technology of the suppliers with that of their own assembly line, creates purpose and concept with the following expectations:

- | All necessary parts and system components are delivered with time precision,
- | Delivery is controlled by individual order and therefore takes place dependent upon the specific equipment version,
- | Intermediate storage is not necessary in the delivery chain,
- | Packaging is not necessary during transportation,
- | Damage will not occur as a result of or during transportation.



Linked to the system are the following suppliers: SML (complete vehicle engines), Lear (car seats), Textron (dashboard and tank systems) and TDS Essers (exhaust equipment, cable trees etc.). Each of the four suppliers is connected to the transportation system through its own lifting station. The components or systems, which are ready for delivery, are placed in special carriers (vehicles or supports). After determination of parts to be dispatched, in accordance with transportation requirements, the expedition process begins. Parts are usually lifted from the station in the hall of the supplier in question, using the complex lifting stations, and attached to the tunnel conveyor system. This procedure is carried out using the relevant lifting stations and points. The carriers are returned to the supplier's hall in the reverse manner, i.e. before a loaded carrier is attached, the unloaded carrier is transferred to the supplier's transportation system, following the lowering of the lift. Every "empty" carrier can in addition be individually checked or maintained at a special station.

The transportation system consists of a telfer system, which has a total length of about 7 km, with 110 points and a total of 35 lifting stations. The telfer system transports 450 supports. During the course of three-shift operation some 45,000 parts are conveyed to the assembly points on the Mondeo assembly line. The cycle time on the Mondeo assembly line amounts to 45 seconds. As a result every 45 seconds the equipment versions required specifically for the customer's



GTI Electro Thijs from Genk is responsible for the complete electrotechnical equipment of the "Conveyor Suppliers' Park". They are supported by MULTIPROX, the exclusive Beckhoff agency in Belgium.

GTI in Belgium comprises 4 companies, grouped into GTI Holding Belgium nv, a division of the larger GTI Holding. With a turnover of

approximately 160 million € and 1200 permanent staff, GTI in Belgium is one of the biggest suppliers in the technical services market. This technical service comprises design, management and installation, as well as maintenance and control of all technical disciplines.

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www.gti-group.be

MULTIPROX

MULTIPROX is the Belgian daughter of the TURCK holding, one of the leading groups in industrial automation technology. Initially specialized in sensors, Multiprox now offers solutions for the whole range of applications, i. e.:

- | Sensor technology for the periphery
- | Processor controlled switching and monitoring devices in user-friendly designs,
- | Systems technology for fieldbuses.

With relation to the fieldbus technology, the exclusive distribution of Beckhoff was an important step forward. The complete system solutions, offered by Beckhoff with the fieldbus independent Bus Terminals and TwinCAT, made possible a break-through in the market of the larger installation and machine constructors.

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order must be at the installation point. When the car body is called onto the Mondo assembly line the order data containing performance and equipment versions is notified to the supplier via a network of logistics computers. Exactly 78 minutes later the required parts, systems and components must be at the assembly line. The suppliers therefore have approximately 34 minutes for final assembling and for checking and preparing the required parts for dispatch. Transportation lasts a maximum of 24 minutes and the programmed buffer time amounts to about 6 minutes. Demonstratively, the precise and accurate "timetable" places extremely high demands upon the system and the whole concept of the transportation system.

Modularity of the telpher system including control technology

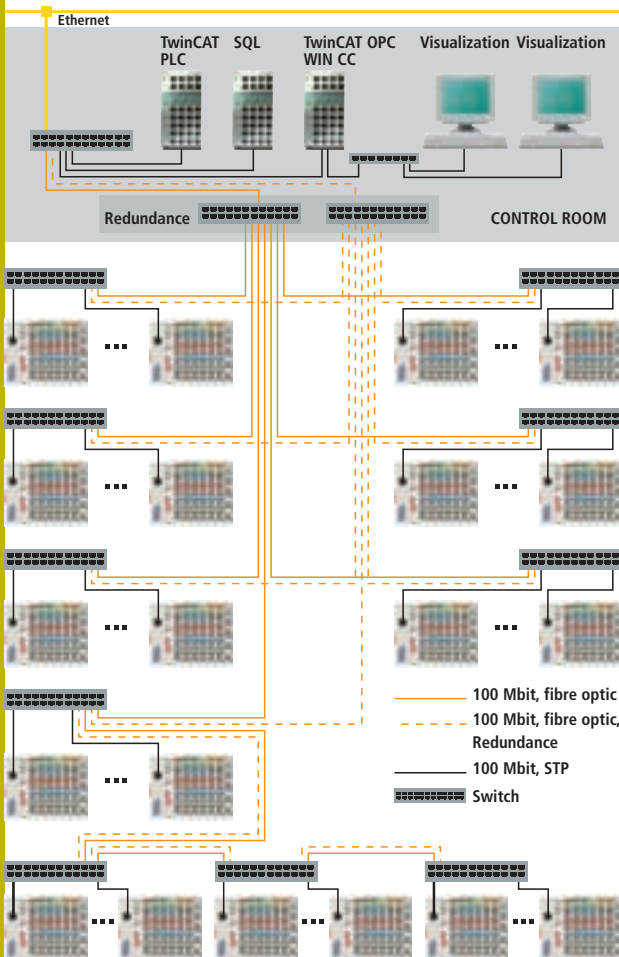
A modular design for the transportation system was conceived during the planning stage of the plant. From an engineering standpoint, this modularity is provided by the lifting stations (reception and transfer) and points. However, regarding control technology, a choice of either a distributed I/O control with central intelligence or a control system using distributed intelligence was required. The planners at GTI Electro Thijs compared these two systems and decided in favor of a solution using distributed intelligence. Project leader Ivan Guilliams explained the decision as follows: "Modularity has great advantages overall. For instance, it enables us to bring into operation simultaneously autonomous areas of the factory providing greater operational security. In that, a fault in one area of the factory does not have an adverse effect upon the whole conveyor system". There are also solid advantages in the translation of the practice for the concept of distributed intelligence control. Referring to this Bart Claes of GTI Electro Thijs, project engineer responsible for the realization of software and hardware, considers these to clarify part solutions in question and gives reason for the multiple use of software solutions. "With 110 points to be controlled and 35 lifting stations there is a great deal of uniformity in the local control systems, so that these may be easily modified and can be easily maintained in their totality", states Claes.

The question of the system coupling was also clarified by the fundamental decision to opt for distributed intelligence, resulting in a decision for networking with Ethernet TCP/IP. "There is a great deal of logistical data to communicate and less I/O data", again Bart Claes. It was, therefore, a question of implementing an efficient communication system, to maintain the distributed control systems with appropriate capacity. In addition a decision had to be made on the appropriate control concept. The answer: The BC9000 Bus Terminal Controllers with integrated Ethernet interface together with the TwinCAT Software PLC as the main control system and link to the WinCC visualization system. "We opt for the most technically convincing solution", said Claes. He adds, the BC9000 the integrated Ethernet interface and the comprehensive Bus Terminal program, and Bus Terminals with serial interfaces for coupling identification reading stations and programming in accordance with IEC 61131-3, gave it the edge.

Ethernet is the soul, but not the backbone

130 BC9000 Bus Terminal Controllers are used in the whole tunnel project. Networking of the control system is carried out using Fast-Ethernet TCP/IP (100 Mbaud). The whole Ethernet connection of Switches bears a beneficial redundant ring. Therefore, should a fault occur on any one of the fiber optic sections between the total of 11 Fast-Ethernet Switches (Cisco Systems), the "disconnected" Switch can always be reached via the opposite section. The connection between the "managed" Switches takes place in full-duplex operation, so that the network is almost capable of working in real-time. From the 24 ports, each per switch, coupled to the star constructed BC9000 is by screened cable connection – first to a socket in the control cabinet and thereafter by patch-cable to the RJ45 plug of the BC9000.

From a control technique point of view, each of the connected mini-PLCs works autonomously, i.e. no irrelevant I/O data is communicated via the Ethernet but only the data about the components to be transported, and is specific to the order. If, in spite of its redundant design, the Ethernet connection should fail, up to 500 order records can be stored in one BC9000. Only then would any additional data be lost. It is important, however, that all equipment relating to the convey-



130 BC9000 Bus Terminal Controllers are connected with the PC based control unit via a redundant Ethernet network.



Project leader Ivan Guilliams and the project engineer Bart Claes from GTI Electro Thijs.

ing technology should not be switched off because of a failure of the Ethernet. The fitted BC9000 mini-PLC makes available 128 kbyte data memory, 96 kbyte program memory and 4080 byte for remnant data.

Bus Terminal Controllers in the form of mini-PLCs take over distributed control tasks

The BC9000 Bus Terminal Controllers are Bus Couplers with integrated PLC functions and Ethernet connection. In the tunnel project the BC9000 Controller is fitted as distributed intelligence in the Ethernet network with the function of an intelligent slave. Apart from the Bus Terminal Controller, a BC9000 contains any number of up to 64 of the 2- and 4-channel Bus Terminals. Programming is carried out with the TwinCAT programming system in accordance with IEC 61131-3. The configuration/programming interface on the BC9000 is used to load the PLC program. As an alternative, as is the case in Genk, the PLC program can also be loaded via the Ethernet network using the TwinCAT PLC Software.

If necessary, each Bus Terminal can essentially use the KS2000 configuration software, in such a way that it can exchange data directly with a higher-level automation device via the fieldbus – in the application described with the TwinCAT PLC. Similarly, pre-processed data can be exchanged between the Bus Terminal Controller and the higher-level controller via the fieldbus.

In the start-up phase the TwinCAT PLC Software controls the configuration of the Ethernet network for the distributed control technology via function blocks (FB) for the whole transportation system. The TwinCAT PLC Software allows upload of distributed generated configuration data in order to manage and store them centrally. This means it is not necessary to carry out the setting procedure again if a Bus Terminal is exchanged. The TwinCAT PLC Software carries out the desired setting automatically after switching on. For processing the PLC program, which is about 1 MB in size, TwinCAT requires only 1.3 ms for the processing operation on the central PC (Pentium III, 500 MHz). That is 17% of the NT computing power.

Control security through rapid processing cycles

Each of the 130 distributed BC9000s, which are fitted in the tunnel transportation system, is autonomous. The mini-PLCs usually have 40 to 50 I/O connections, in the case of points or with lifting stations there are more than 80 I/Os. In addition, almost every BC9000 has a reading station for the identification system connected via a Bus Terminal with serial interface; in the case of the lifting stations, two reading stations are connected. In some cases the control stations have a text display attached, which report on the current status of the application or station.

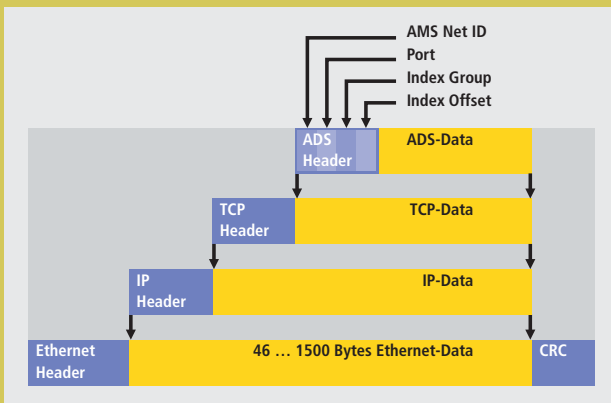
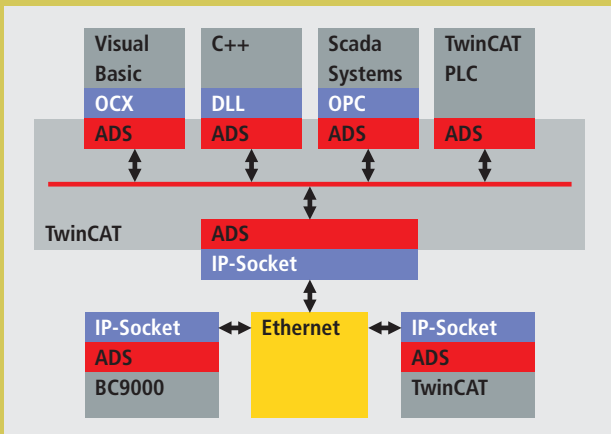
Each carrier contains an identification carrier, which stores the order and target data. Finally, all stored data determines the route taken by the carrier through the total of 110 points to the transfer station in the Ford assembly plant. From a technical control point of view this means the data read from the identification carrier is important for adjusting the points and therefore for the track. In the case of two carriers arriving simultaneously, the FIFO principle determines which has precedence in the setting of the points. Thus there are no priorities within the control programs.

Although the task settings for the BC9000 are comparatively complex, there are no problems with the cycle time. The following values have so far been registered for the cycle time including interface processing:

- | 5 ms for BC9000 without attached reading station
- | 8 ms with a reading station connected
- | 10 ms for a BC9000 controlling two points
- | 20 ms for a BC9000 for a lifting station with more than 80 I/Os (including serial interface)

Since the distributed control systems work simultaneously and as if in parallel, the cycle time is no "Achilles heel" of the whole project unlike what happens with a control solution with central intelligence.





As one of the pioneers in the field of PC based control, Beckhoff have long been involved in the open interfaces of the IT world, and therefore also with Ethernet, the most widely used IT network. TCP/IP principles are the model for ADS, the Automation Device Specification developed by Beckhoff. The ADS routing functionality permits communication over any kind of connecting channel – between tasks and software module within a TwinCAT controller, between PCs via Ethernet, or even over the more important fieldbuses directly to the distributed automation devices. The Bus Terminal Controllers connected to the fieldbus can be programmed, and even debugged, online over the bus and then on over an Ethernet network.

The Ethernet solution using the Bus Terminal Controller

All the Bus Terminal Controllers connected to the central PC control system via the Ethernet network communicate with each other using the TwinCAT ADS (Automation Device Specification) communication system. The ADS protocol runs on top of the TCP/IP or UDP/IP protocols. It allows the user within the Beckhoff environment to use almost any connecting route to communicate with all the connected devices and to parameterize them. The ADS connecting mechanism consists of four functional groups:

- | The AMSNetID providing a reference to the device to be addressed.
- | The port refers to a particular area within the device, such as the process data, the registers, etc.
- | The index group is a 4 byte variable (long or UDINT) that accesses data within the port.

The offset, like the index group, is also a 4 byte variable. It indicates the offset at which the variable is to be read or written.

The TwinCAT PLC/NC software, capable of running under Windows NT 4.0 or Windows 2000, makes the drivers and the ADS protocol available. In order to establish a connection to the BC9000 Ethernet Bus Coupler, TwinCAT must be installed together with the ADS drivers. The Bus Terminal Controllers' hardware connection is carried out as with "classical" fieldbus equipment via TwinCAT's System Manager. The ADS functions provide a method for accessing the Bus Terminal Controller information directly. ADS function blocks can be used in TwinCAT PLC Control for this. The coupling of Scada-systems with TwinCAT is carried out via the ADS-OCX, ADS-DLL or OPC.

Ethernet TCP/IP Bus Coupler BK9000

- | Protocols TwinCAT ADS, Modbus TCP (others in preparation)
- | Digital peripheral signals 256 I/Os, analog peripheral signals 128 I/Os
- | Automatic recognition of the transmission rate (10/100 Mbaud)
- | Bus connection via Ethernet standard RJ45

Ethernet TCP/IP Bus Terminal Controller BC9000

- | Based on the Bus Coupler BK9000, the BC9000 contains integrated PLC functionalities
- | Programmable with TwinCAT according to IEC 61131-3 via the programming interface or via Ethernet
- | Program/data memory 96/128 kbyte, remanent flags 4080 bytes
- | PLC cycle time approx. 1.5 ms at 1000 instructions
- | Status messages via e-mail and function blocks (SMTP)
- | IEC library for individual protocol implementation

For about 2 years now, Ethernet has been discussed as a possible substitute fieldbus, even down at the sensor-actuator level. A number of groups and consortia have made their mark here with a number of "Ethernet flavors". The most important approaches are briefly introduced in this summary.

Profinet

Profinet represents an answer from the Profibus User Organisation (PNO – Profibus Nutzer Organisation) to the "Ethernet hype". The main thrust of this approach is the retention of Profibus as the bottom level fieldbus (the device or sensor/actuator level), while Ethernet is used as a means of higher-level communication. Profinet defines gateways between Ethernet and Profibus. These gateways translate Ethernet remote procedure call requests to the Profibus cyclic process data services (DPV0, perhaps later enhanced to acyclic Profibus DPV1 services).

Ethernet Flavors – an Overview

Profibus nodes can be addressed from any local Ethernet device – these nodes do not have to deal with Ethernet protocols, since they only communicate over Profibus services. Profinet is thus not (so far) a “Profibus on Ethernet”, but is rather a defined Ethernet interface to a conventional Profibus network. The remote procedure calls (RPC) here use TCP/IP. DCOM here provides the interface to the RPC client, although Microsoft are no longer continuing development, since it is not fully compatible with the Internet (e.g. firewall penetration).

Work has in the meantime started in the PNO on a dedicated protocol, with which field devices should be able to communicate directly via Ethernet (i.e. without Profibus). This approach will then place them in direct competition with the Open DeviceNet Vendor Association (ODVA) and with ControlNet International (CI), who, with

Ethernet/IP

are actually replacing the physical DeviceNet and ControlNet fieldbusses with Ethernet. In this context, IP does not stand for “Internet Protocol” (as it does in TCP/IP), but for “Industrial Protocol”. This is again a matter of protecting investment – while the PNO are “protecting” the Profibus as a whole, Ethernet/IP is preserving the common higher protocol levels of DeviceNet and ControlNet for the brave new world of Ethernet. Control and Information Protocol (CIP) is the name of the common denominator, and it embraces the entire object model, and therefore also the DeviceNet and ControlNet device profiles. Ethernet/IP forms the CIP services on TCP/IP and UDP/IP: The acyclic parameter services (explicit messaging) are based on the connection-oriented TCP/IP protocol, while the process data

(I/O messaging) is based on UDP/IP which, not using connections, is faster. Since the object model and the protocol principles of Ethernet/IP, DeviceNet and ControlNet are largely the same, comparatively simple routers can be used between the various busses – these are not as complex as Profinet gateways. The elements of the Ethernet/IP specification have been part of the ControlNet specification for 2 years. Since April 2001 it has been possible to download the complete specification free of charge from the ODVA website. An example of source code for a slave device is also available there.

IDA

the “Interface for Distributed Automation” is being developed by a consortium of firms founded at the initiative of Kuka GmbH. The inspiration is provided by the vision of creating a comprehensive standard for Ethernet-based automation technology. The formation of a dedicated user organization, the IDA Group e.V., has recently begun. The consortium has set itself some ambitious goals. The IDA protocol under development is intended to be capable of real-time operation, permitting, for instance, high-precision drive synchronization over Ethernet, device parameterization via web servers is to be standardized, machine security implemented via Ethernet, and Plug and Play mechanisms provided for field devices. IDA are using NDDS Middleware, a software product that, similarly to Ethernet/IP, utilizes the TCP/IP protocol services for parameter communication and UDP/IP, following the publisher/subscriber principle, for process data communication. The IDA group also plan to make the specification and source code available free of charge. A first version of the specification has been published in time for the Hanover exhibition.



Martin Rostan, Product Manager
Fieldbus Systems at Beckhoff.

ModbusTCP

is likely to be the most widely used Ethernet automation protocol – it is simply very easy to implement. The well-known serial Modbus protocol is packed into TCP/IP segments. ModbusTCP operates in accordance with the master/slave principle: The master sends its request to the slave, and can transmit output data at the same time. The slave replies with its input data. The polling procedure is easily managed, and uses TCP/IP's connection monitoring. Only a few services are needed, and the achievable performance is more than adequate for many applications. Simple example programs can be found on the Internet or obtained from Beckhoff – a ModbusTCP master can very quickly be implemented on a TCP socket interface.

IAONA

Establishing Ethernet as an automation standard is the aim of the Industrial Automation Open Networking Alliance (IAONA). Initially founded as IAONA USA, IAONA Europe was created at the end of 1999 – and with about 130 members it is at present by far the more active association. After the unsuccessful attempt to declare the IDA concept as IAONA's only protocol and to merge IAONA with the IDA consortium, a more open, global approach was adopted: IAONA now consider themselves to be a neutral umbrella organization for industrial Ethernet. This new role for IAONA acknowledges the

fact that there has now come to be a number of significant, yet mutually incompatible, protocol solutions for industrial Ethernet. IAONA is now attempting to prevent the various de facto standards from drifting further apart. In November 2000 a memorandum of understanding between IAONA Europe, IAONA US, the IDA Group and ODVA was signed, in which ODVA and IDA declare their willingness to agree future development steps with one another under the aegis of IAONA. Thus, for instance, guidelines are to be developed jointly for cabling, message priorities, web server use, Plug and Play mechanisms and safety aspects. Other interest groups are invited to participate.

IAONA has adapted its structure to the changed environment, and has introduced a Technical Steering Committee (TSC) that will set up joint working groups and will guide and coordinate their work. Beckhoff has been elected as the representative of the European members of IAONA in the TSC.

Beckhoff and Ethernet

As was mentioned at the start, Beckhoff have for years been seriously involved in the application of Ethernet to controller networking. Using the BK9000 Bus Coupler and the programmable BC9000 Bus Terminal Controller, the entire Bus Terminal range can be directly connected to Ethernet. Protocols available to these distributed Ethernet I/O stations presently include both ADS (based on TCP/IP or UDP/IP) and ModbusTCP – the modular structure of the Ethernet protocol stack permits the integration of a number of versions in one firmware (and in one hardware). Other protocol versions will follow, according to their significance to the market: Beckhoff Ethernet I/O devices can handle all the relevant flavors of Ethernet!