High performance Ethernet

ABB broadens its range of Ethernet-compatible devices

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Industrial control systems comprise a large number of different embedded devices (eg, sensors, actuators, controllers) and a number of computers that work together to control a physical system. Such systems can control an enormous variety of installations, including process plants, power generation and distribution systems, car manufacturing factories and air condition systems in shopping malls. ABB supplies control systems and a huge number of embedded devices designed for use in such applications. While some applications require only low-tech control, based on individual components that work in isolation, more and more customers require devices that are able to communicate with each other, exchanging information and providing operators with data and status updates on demand.

Good communication solutions are as much a part of ABB devices as their ease of use and their reliability. Customers can choose their device based on the needs of their system and assume that ABB quality and efficient communications will be provided as standard. As the market moves towards an increased use of Ethernet to provide for its communications needs, ABB is enhancing its range of Ethernet-compatible devices.

The trend towards Ethernet in industrial plants is partly motivated by its high performance to cost ratio and its ability to support fiber optics, electrical cables and wireless technologies in a single system. Another attraction is that Ethernet's associated TCP/IP (transmission control protocol/internet protocol) technologies provide a network infrastructure that can be managed in a unified way. This streamlines infrastructure deployment and maintenance, providing savings on training and spare part supply.

The communications needs of the office world differ from those of industry, as do the needs of the embedded devices in different industrial applications. One typical industrial requirement is for real-time control responses. If communication solutions are involved in a control loop, response time is critical. The acceptable delay in response time is determined by the physical or chemical laws governing the process under control. When controlling high voltage AC currents, for example, acceptable delays could be only a few milliseconds, and in mechanical motion control, the tolerance could be less than a millisecond. In chemical reactions, which tend to be much slower, a one-second delay of the actuator action might be acceptable, but meeting strict deadlines is still required because once it has started, a chemical reaction will never wait. Communications solutions must accommodate this range of requirements, either in a single solution, or by combining multiple technologies.

Throughput and reliability

The throughput and reliability of a communications system are also critical factors in choosing a communications solution. Again, different applications have different requirements. Throughput demands can influence the real-time abilities for a system, since heavy loadings can destroy real-time responses. The physical element of a communications solution defines primary design choices. Ethernet on copper cables and optical fibers is an extremely efficient system, with very little noise and small losses due to noise. Wireless communication is less reliable and a significant number of data packets can be lost. Protocol software will ensure that lost packets are re-sent, but this reduces throughput and real-time responses. If, on the other hand, the cable or fiber is seriously damaged, no software will get the message through. This problem can be solved only by building physical redundancy into the communication interfaces in the form of a second or even third cable or fiber. However, the introduction of redundancy can lead to complication of the user interface.

Over the past few years, the convention in the automation market has been to use Fieldbus for connecting to process equipment and Ethernet for connecting terminals, servers and controllers. The trend now is to extend the use of Ethernet beyond controllers, moving it closer to the field and imposing greater demands in terms of real-time requirements, reliability and safety. This requires the provision of good Ethernet-compatible embedded solutions and standardized protocols for the communication of data on Ethernet. A number of protocols are currently in use, the most promising of which are FF HSE, PROFINET, EtherNet/IP, Modbus TCP and certain specialized solutions intended for motion control.

The theoretical limit on throughput of data using Ethernet cables and fibers is not a serious problem in most automation applications. However, the capacity of the central processing units (CPUs) of embedded devices can form a bottleneck in the flow of communication on the network, and this problem must be given serious attention. The efficiency of stack implementation in an embedded device is the single most important issue for throughput. If the limiting factor is the processor's ability to parse a protocol, upgrading a very small CPU in a device close to the field level from 10 Mbit/s Ethernet to 1 Gbit/s Ethernet might not increase throughput at all. A bandwidth of 10 Mbit/s is normally sufficient for such a device. To provide the required efficiency in stack traversal, some of the standard protocols that are typically used with Ethernet office applications must be modified or used in combination with other protocols.

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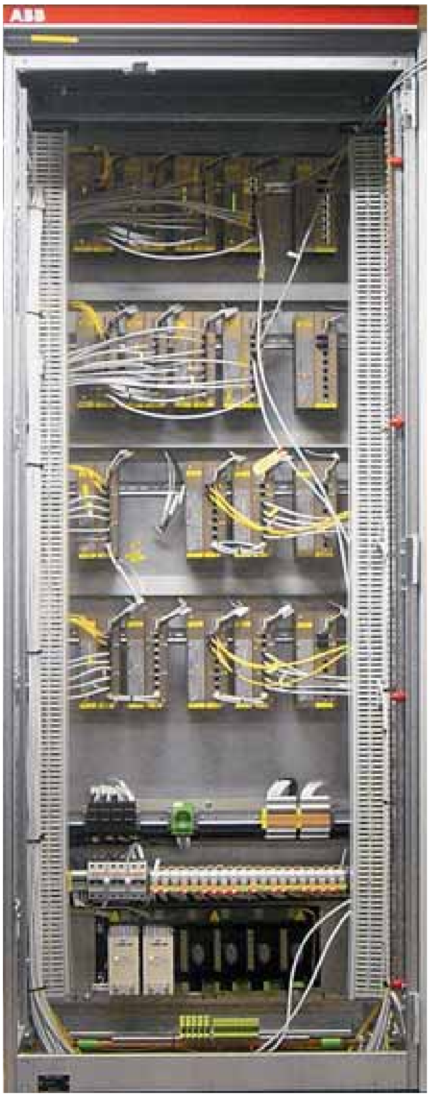
A comparison of the measured delay time for UDP/IP traffic on Windows XP operating systems running on a 2.5 GHz Pentium processor 1 shows that, even with such a fast processor, the majority of time is spent handling the message in the processor. With a 1-Gbit/s Ethernet, the network delay is very short indeed.

Real-time requirements

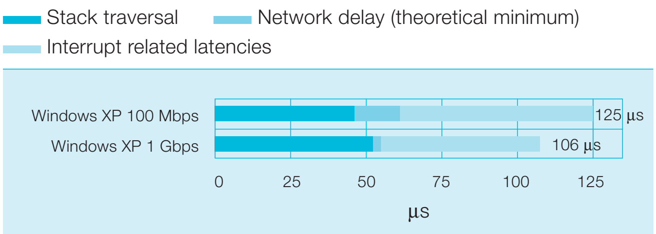
Real-time requirements pose a particular problem for "old-fashioned" Ethernet systems that are based on coaxial cables or hubs. Such systems were equipped with collision detection such that, if two devices tried to send data simultaneously (or near simultaneously), both data packets would be lost and each device would attempt to resend after a quasi-random waiting time. If a number of such collisions occurred consecutively, then the delay would become significant and hard to predict. New Ethernet systems, however, are based on full-duplex switch technology, in which such collisions do not occur. Each device has a dedicated physical line to a switch, and switches will store and forward all data packets. If the port to the next switch or device happens to be in use, the switch will put the packet in a queue and send it when the port becomes available. This technology provides real-time responses that are adequate for the vast majority of industrial applications. For more demanding applications, such as motion control, it is possible to alter the Ethernet low-level protocol to produce a highly deterministic time-slotted system. This can be achieved using the



PROFINET IRT, EtherCAT, Ethernet POWERLINK and SERCOS III technologies.

Alternatively, the stringent real-time requirements for motion control can be met by synchronizing local clocks 2. This can be achieved using normal Ethernet packets, though it does present some challenges for implementation. One node is designated the "time master" and it provides time information to all other nodes, where it used to use to set local clocks. The dominant standards for synchronization are NTP (Network Time Protocol), SNTP (Simple Network Time Protocol) and PTP (Precise Time Protocol, IEEE 1588). A number of ABB products support these standards. For example, the industrial DCS controller AC800M supports SNTP and the PicMaster Robot supports IEEE 1588. The main source of inaccuracy in time synchronization is the jitter in the execution of the software that timestamps the arrival of an Ethernet telegram at the node. It is important to make timestamping as fast as possible. It should occur in the first interrupt routine for Ethernet, or even earlier, ie, in the hardware before the operating system of the embedded units start. Good software implementation can gain a few microseconds in this process, while a hardware solution might bring accuracy down to 100 nanoseconds.

1 A measurement of the delay time for UDP/IP traffic on Windows XP operating systems running on a 2.5 GHz Pentium processor [1]



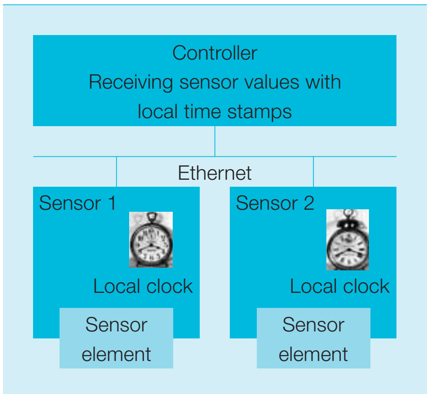
The efficiency of stack implementation in an embedded device is the single most important issue for throughput.

Safety

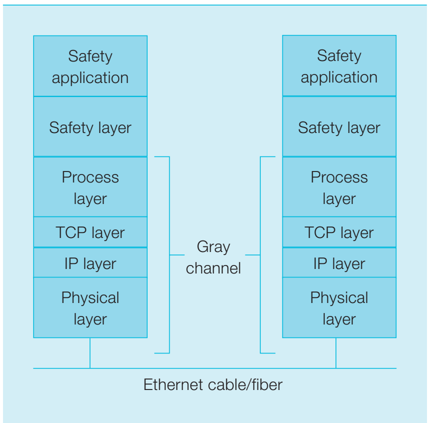
If the system under control poses a threat to human health or the environment, governments require proof that adequate safety and emergency equipment is in place. Such safety control systems must comply with international standards, such as IEC 61508, which is based on the SIL (safety integrated level) categories for equipment and communication. SIL 2 and SIL 3 are usually demanded in chemical, petrochemical and off-shore oil installations, and in mechanized industries.

Ethernet systems can also be certified for safety. Since it would be impractical to impose the IEC 61508 safety standard on all software and hardware involved in an Ethernet system, safety certification relies on the concept of "gray" channels. This can be, for example, TCP/IP with a process-specific layer on top 3, creating a new layer in the communication protocol. This "safety layer" has very high quality implementation and can discover all relevant errors that could occur in the gray channel. For PROFINET, this layer is the PROFIsafe layer and for EtherNet/IP, this is the CIP safety layer.

2 Stringent real-time requirements for motion control can be solved by synchronizing local clocks



3 The layers of a typical communication protocol



Implementation

A standard Ethernet board is adequate for some products, but in ABB devices, Ethernet is usually integrated into specially designed hardware. Ethernet-compatible processors, which may be required to work at particular temperatures or under other specialist conditions, are available from a number of suppliers, eg, PowerPCs (from Motorola or IBM), ColdFire processors, and ARM-based chips. The functional requirements will determine the choice of processor – many variations are available, with differing levels of communication support. Specialized chips are now becoming available to support the special motion control variants of Ethernet. These are either an ASIC, typically with an ARM CPU built in, or an FPGA to handle the lower level Ethernet protocols.

The future

Ethernet is an important emerging trend in the industrial market. It is already supported by a number of existing ABB products but, as its importance grows, more of ABB embedded devices will be developed to support this high-performance communications system.

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Reference

[1] G. Prytz, S. Johannessen. "Real-time Performance Measurements using UDP on Windows and Linux", ETFA 2005.