ENHANCING THE HIGH PERFORMANCE OF PROFINET

Leading the World in
Industrial Networking
and Communications

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EXECUTIVE SUMMARY

PROFINET is an 'all-encompassing' Industrial Ethernet solution for automation, offering superior performance across a wide range of applications and industries. As well as delivering real-time IO performance it fully supports the sub-millisecond demands of advanced Motion Control. It can easily connect to other networks, in particular existing fieldbus systems and process automation networks.

PROFINET therefore means that current equipment and systems can remain in use, ensuring skills, assets and investments are protected. PROFINET also offers easy integration across the enterprise because it is fully compatible with standard Ethernet.

Used in automation, Ethernet requires enhancement to achieve 'real-time' performance. Broadly, three ways of doing this have emerged:

1. Using TCP/IP as a real-time protocol. This is typified by Modbus/IDA, Ethernet/IP and FOUNDATION Fieldbus HSE.

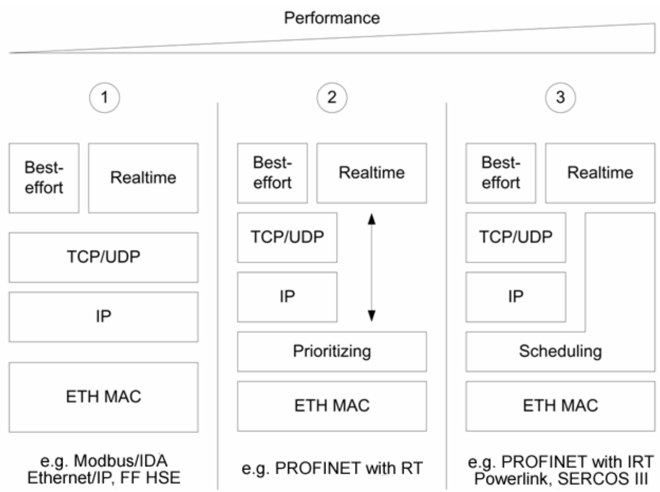
2. Prioritization of transmissions and sharing Ethernet bandwidth. This is typified by PROFINET with RT.

3. Time scheduling of Ethernet traffic, and reserving of Ethernet bandwidth. This is typified by SERCOS III, PROFINET with IRT, and Powerlink.

The time scheduling solution offers the highest performance potential, although different implementations have emerged. A recent report undertook a comparison of two such implementations: the 'summation frame' approach and the 'individual frame' approach. The report found that the 'individual frame' technique of PROFINET is significantly better for almost all automation applications today. However, the 'summation frame' approach suits some simple networks better. The project partners are now developing a way to enhance PROFINET for simple networks and plan to demonstrate the results at Hanover Fair, 2008.

REAL-TIME ETHERNET - AN ANALYSIS

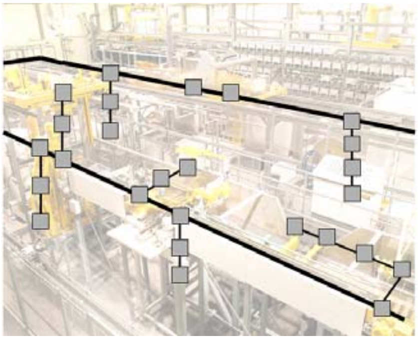
For manufacturing plants there is a range of real-time Ethernet approaches available. From the point of view of achievable performance these can be divided into three categories, as shown in the diagram below.



During the BMBF (German Federal Ministry of Education and Research) project "*Real-Time Ethernet for Sensor/Actuator Networks*", the question of which approach offers the greatest performance potential was examined, sponsored separately by the participating vendor companies.

It was decided to put the main emphasis on category 3 systems since they offer cycle times in the sub-millisecond region, thanks to appropriate real-time extensions to Ethernet. Within category 3, two main principles can be discerned: on the one hand there is the 'summation frame' process in which one frame supplies several nodes with data at the same time. On the other hand, there is the approach of transmitting data in 'individual frames' to each node.

Typical Automation Structures



Modern manufacturing plants are typically based on a combination of line and branch network structures. This is because a factory floor often requires many production units to be linked together, while the individual units themselves have localized needs based on the requirements of the process and the machine or cell design.

In the example shown above, the factory floor consists of 6 separate processes, each with its own sensor/actuator requirements. In simple applications – say a single production unit – this can often be a line structure. One of the biggest advantages of Ethernet is its capability to easily link horizontally to peer group networks enabling production cells to work cooperatively and connect vertically to higher level IT systems, enabling data to be shared across the enterprise. It is also a fact that automation systems are becoming increasingly complex, with larger amounts of data being transferred across longer and longer distances to meet the needs of a growing range of uses. Simple line structures cannot meet the needs of these more complex and flexible automation systems.

All of which means that Industrial Ethernet solutions such as PROFINET are becoming very important in manufacturing. PROFINET offers easy peer-to-peer and vertical integration and is suitable for both discrete and process applications. PROFINET can also embrace legacy networks easily – including popular fieldbuses such as PROFIBUS - to protect existing investments in systems and equipment. The question this White Paper focuses on is: what are the performance differences between the 'summation frame' and the 'individual frame' solutions in IO applications?

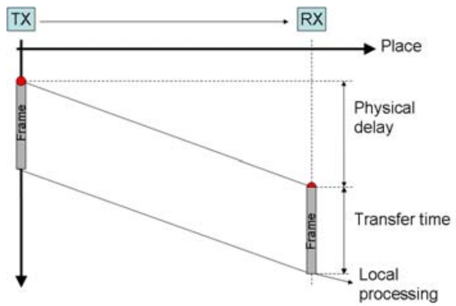
THE TWO APPROACHES IN OUTLINE

The 'summation frame' approach consists of multiple-node messages that, in effect, travel cyclically around a network visiting each node address in turn. Relevant data is dropped - or picked up - at each node according to the way the network is engineered. An analogy is a railway train visiting many stations on a single track. The approach is an efficient method of delivering small payloads across a simple line structure.

PROFINET, which is scalable across many different application types, keeps to the Ethernet principle of transmitting data to different node addresses during each successive Ethernet cycle. The addresses can be handled in any order. PROFINET can also share the Ethernet bandwidth so that standard TCP/IP data can co-exist with automation data in the same cycle. PROFINET with IRT can further split each real-time Ethernet message into 'time slots' using a technique called time scheduling. This technique can be extended by using high speed, configurable Ethernet switches that allow more than one node to be accessed during this real-time portion – a technique that is primarily for multiple-axis, motion control applications.

The flexibility offered by the choice of operating modes, and the individual node addressing principle, make PROFINET an all-encompassing Industrial Ethernet solution.

Factors Affecting Performance

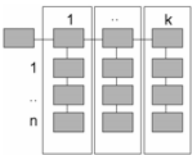


The two most important factors influencing the performance of an Ethernet network are the physical delays in the cable/hardware and the frame transfer times – see left. Although the physical delays for present-day fieldbus systems have become negligible compared to the frame transfer times, this component is more dominant in Ethernet-based solutions, particularly under high bit rate conditions.

An analysis of various plants has shown that so-called 'comb' (or 'crest') structures, i.e. main lines with branches, provide optimum cabling costs and conditions. These configurations also best support automation because modularization of plants often requires different update times for different field devices. For simple sensor/actuator networks (say within a single machine) a plain line structure may be the better choice.

TEST CONDITIONS

For the purposes of comparing the performance of each approach, two network types were defined, as shown below. Both were then tested under laboratory conditions across a range of transmit and receive scenarios using fast Ethernet to transmit a range of data packet sizes:

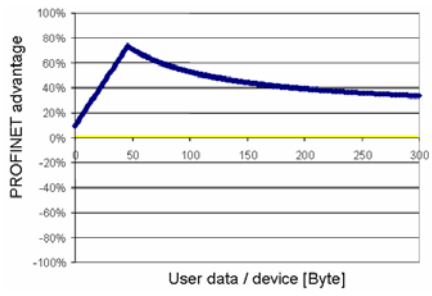


Comb structure: Main line with k = 8 stations in every bus cycle; plant components with n = 10 users in every 8th cycle; distance between users = 50 meters in both cases.

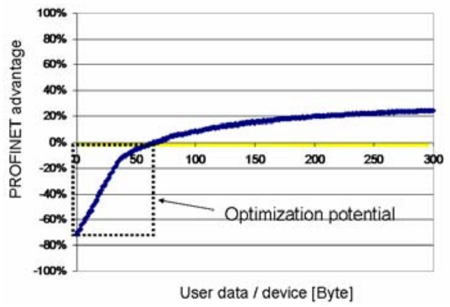
Line structure: Line with 50 stations, each 50 meters apart. Asymmetry factor of 30% to represent the fact that inputs and outputs are not equal.

TEST RESULTS

Test results were computed and displayed in a comparative format (see the diagrams below) indicating the 'ratio of advantage' of each approach.



'Comb' structures: Here, it was shown that PROFINET reacts more flexibly and faster across virtually the entire case spectrum with, broadly, a 40% speed advantage. In comb structures, 'summation frames' always have to go through each node twice (they have to follow the branches out and back again) so the physical delay is long compared to directly addressing the nodes. It can be shown mathematically that the absolute difference of the cycle times increases quadratically in proportion to the number of nodes involved.



Line structures: Here, it was shown that PROFINET has the advantage for larger data packet sizes. However, at smaller packet sizes, the 'summation frame' approach reacts faster.

In essence, the results indicate that the 'summation frame' approach has benefits when simple sensor/actuator networks in line structures are involved. However, in almost all other cases, PROFINET is superior.

THE 'ALL-ENCOMPASSING' PROFINET

The results indicate that there is potential for optimizing PROFINET for smaller data packet sizes and line structures. To enhance PROFINET's position as the 'all-encompassing' Industrial Ethernet solution, a special project has been initiated by the report's partner companies.

The project aims to reduce two main time components of the PROFINET cycle - i.e. the physical delay and the frame transfer time, utilizing:

- Algorithmic forwarding that reduces forwarding time and frame overhead.

- Optimizing support for the 'slipstream effect', whereby Ethernet frames are transmitted to the node that is physically last first.

- Optimizing the ratio of payload and overhead information within the Ethernet messages to achieve shorter bus cycle times.

Reference

Jasperneite, Jürgen; Schumacher, Markus; Weber, Karl: '*Limits of Increasing the Performance of Industrial Ethernet Protocols*'. 12th IEEE Conference on Emerging Technologies and Factory Automation, Patras, Greece, Sep 2007.

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Phone: +49 721 / 96 58 590; Fax: +49 721 / 96 58 589; E-mail: info@profibus.com