

# Industrial Real-Time Ethernet

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## ***Preface***

This project is a Master's degree thesis and concludes the program Master of Science in Computer Systems Engineering with a profile in Innovation and Entrepreneurship at the School of Information Science, Computer and Electrical Engineering (IDE-section) at Halmstad University. The project was initiated in January 2000 and was concluded in January 2001. The project was made at the Halmstad University campus in collaboration with HMS Industrial Networks.

This report is part of a masters thesis report and has been written as an overview of the final thesis. The full report can be obtained by contacting Anders Kallerdahl (see below for contact address).

## ***Introduction***

Ethernet networks have not been suitable for industrial environments due to the nature of the undeterministic handling of communication-traffic. The traffic in, e.g., an industrial fieldbus network is usually time-constrained and requires therefore real-time services that Ethernet not has been able to provide. Today the prices of Ethernet hardware have fallen, transmission speed has increased, and the Ethernet standard (IEEE 802.3) has been extended with new features such as full duplex, flow control etc. Taking advantage of the mentioned progress, we have now developed a network concept (including novel methods) for which sophisticated support for real-time traffic is offered. The network includes an Ethernet switch with some specific hardware and software, while end nodes is only complemented with some additional software. We call our developed network concept Industrial Real-Time Ethernet. Significant features of the Industrial Real-Time Ethernet include:

- ✍ Real-time support for cyclic traffic with cycle duration as short as ca 1 ms.
- ✍ Worst-case latency down to ca 1 ms (can be shorter than the cycle duration).
- ✍ Dynamic configuration/set-up of real-time channels with guaranteed performance (Quality of Service; QoS). Static configuration at system design/start-up is also possible.
- ✍ Transparent support for reliable UDP/IP traffic, such as for standard TCP/IP but with much better timing properties.
- ✍ High transmission capacity (switched 100 Mbit/s full duplex).
- ✍ Clock synchronisation which can be utilised by, e.g., applications and/or operating systems.
- ✍ Remote maintenance of industrial applications via Internet.
- ✍ Support for multiple logical real-time channels from each node.

- ✍ Eliminates use of traditional complex industrial communication systems.
- ✍ Real-time support for standard UDP/IP Internet traffic.
- ✍ Support for co-existing non-real-time standard TCP/IP and UDP/IP Internet traffic without disturbing the real-time traffic.
- ✍ In addition to switched networks, Industrial Real-Time Ethernet can be extended with some support for real-time traffic over a shared-medium topology too.
- ✍ Real-time support can be given to applications without any modifications of them. Using an Industrial Real-Time Ethernet API (Application Programming Interface) will, however, give the opportunity of setting up and specify real-time channels more dynamically.
- ✍ Non-real-time nodes (nodes without Industrial Real-Time Ethernet drivers) can co-exist in the network without disturbing the real-time traffic.

In summary, we offer better support for industrial real-time traffic over Ethernet compared to existing solutions on the market and published research results. The solution brings cost advantages by, e.g., the use of cheap standard Ethernet mass-market components, remote maintenance, and coexistence of maintenance and real-time traffic.

### ***The proposed solution***

Industrial Real-Time Ethernet is based on an 100 Mbit/s Ethernet switch supporting hard real-time traffic with bit rate and latency guarantee, i.e. a predefined amount of data delivered before a deadline. The guarantee is upheld by real-time channels, which can be created and closed dynamically. A real-time channel can be considered as a virtual wired connection between two nodes connected to the switch, with a guaranteed bit rate and a guaranteed maximum latency. The nodes, which are connected to the switch, can either be real-time nodes or non real-time nodes depending on which level quality of service is required. Non real-time nodes are nodes without Industrial Real-Time Ethernet drivers.

In the proposed solution there are no modifications of the Ethernet hardware on the network interface cards. The real-time communication support in the nodes and the switch is handled by software added between the network layer and the link layer, in the OSI reference model. Some additional hardware in the switch, compared to a standard Ethernet switch, might also be needed. The switch has the overall responsibility both for set-up of real-time channels and for online control of packets passing through the switch. The software in the end nodes will include API and simple regulation of the traffic passing through the protocol suite and out of the node.

To mention some details of the solution, it is based on, e.g., cyclic resource allocation with relaxed synchronisation requirements, earliest deadline first algorithm, and control messages with synchronisation, acknowledgement and access control information. More details on the proposed solution can be given by the inventors (see the end of this document for contact information).

## **Vision**

Industrial Real-Time Ethernet has a broad target market including application areas such as: (i) industrial communication industry with products used in, e.g., manufacturing industries and where our partner, HMS (HMS Industrial Networks), is one of the world's leading companies in the fieldbus technology sphere, (ii) communication in embedded systems like radar signal processing systems for which we have good contacts in one of the world leaders (Ericsson Microwave Systems), (iii) broadband access networks, (iv) traditional local area networks (LANs) where, e.g., enhanced support for multimedia traffic is needed, and (v) storage area networks (SANs) for the hot area of distributed storage. The work this far has been focused on the first two application areas (for which we have got very good indications of market interest from our partner and contacts) but we see no reason to exclude the other application areas since they have very similar demands of real-time traffic support.

Industrial Ethernet ([www.industrialethernet.com](http://www.industrialethernet.com)) is an example of an organisation that is adapting Ethernet hardware to the industrial environment. Despite of the recent trends towards high-speed networks such as ATM, the predominant architecture for local area networks is still based on Ethernet. The standardisation work on industrial Ethernet, where HMS is a founding member of IndustrialEthernet.com and board member of IAONA (Industrial Automation Open Networking Alliance), has, however, not lead to sophisticated support for real-time traffic such as in Industrial Real-Time Ethernet.

There has been much discussion recently regarding the applicability of using Ethernet at various levels in industrial applications. Since Ethernet is so prevalent and frequently used in the office it would be natural to use Ethernet in the industrial plant-floor in industrial networks. Eric Byres, Artemis Industrial Networking, January 1998, quoted in Intech Magazine: "I think we may see Ethernet completely take over the industrial bus and network market in the next ten years". This is one reason that the development of Industrial Real-Time Ethernet was started.

Currently existing field-busses on the market have a maximum bit rate of 12 Mbit/s (Profibus with advanced transceivers) but the majority of the field-busses have bit rates from 200 kbit/s to 500 kbit/s. Industrial Real-Time Ethernet will use 100 Mbit/s due to the fact that future industrial systems require higher bit rates to allow the network to connect to the outside world (Intranet/Internet) and more complex systems. The connection to intranet/Internet makes, e.g., web based maintenance possible to coexist with the real-time traffic which is highly desirable. It will be possible to browse an industrial computer via the Internet for status control or for software updating and at the same time guarantee that this will not hazard the important real-time traffic.

There is a rapid increase of the need of online storage, such as network connected hard discs. Storage of data through a network needs reliable communication. Future industry trends says that future capital investments in storage will be 75 % of all capital investments in corporate data centres ["Network attached storage architecture", *Communications of the ACM*, Nov. 2000]. More market advantages with Industrial Real-Time Ethernet are treated in the introduction.

Our vision of a company based on Industrial Real-Time Ethernet, makes its money on selling the Ethernet switches with real-time support. Software drivers will probably be

shipped free of charge. Our partner in the project, HMS, has an established world-wide sales organisation which advantageously can be used.

### ***Current state of the project***

This project has been running as a master's thesis work at the University of Halmstad involving two master degree students, Ulrik Hagström and Anders Kallerdahl, and a supervisor, Ph.D. Magnus Jonsson. This project started in January 2000 and was finished in January 2001.

The goal of this project was to develop a specification for real-time communication over Ethernet via a switched network without modifying any Ethernet hardware in the end nodes. The reason not to modify the Ethernet hardware in the end nodes is that the market is conservative and in order to support inclusion of existing systems.

The status of the project is that a specification of the switch and nodes exist. The specification includes algorithms handling the scheduling of the communication and protocols for, e.g., channel set-up and error-handling. No hardware, software or simulation implementation has been done. Instead the main focus have been to make the proposal as generally applicable as possible and to get good knowledge of the state of the art in the area.

The first stage of future work will primary be software development and construction of a hardware demonstrator. We believe that the hardware can be developed based on standard components available on the market. The next stage will be to get funding for commercialisation.

### ***Rewards***

- ✍ This project has been chosen by Chalmers School of entrepreneurship to be a masters thesis project as this project was seen as a promising idea to apply for a patent and build a company on.
- ✍ This project has been rewarded with the best masters project award of 2000 by the company Innovation Team. ([www.innovationteam.se](http://www.innovationteam.se)).
- ✍ This project has been rewarded as the best master thesis by SNART (Swedish National Real-Time Association) 2001. (<http://www.docs.uu.se/snart/>)

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