SmartEdge Platform – Industrial Ethernet

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Introduction

Industrial control systems are essential parts of industry facilities. They usually rely on mature field buses because of their safety and reliability. However, these field buses are being replaced with industrial Ethernet protocols in recent years, since they provide higher throughput, standard components, flexibility and seamless integration of the factory floor into IT infrastructure.

Automation Pyramid

The industrial control systems consist of four layers: the field level, control level, management level and enterprise level.

The field level contains sensors and actuators. Its purpose is to sense physical quantities and pass the data to the upper level, and get the control data from the upper level and adjust the actuators accordingly. It does not perform any decision. On the other hand, it must perform its tasks reliably, despite harsh industrial environment.

The control level contains devices like programmable logic controllers (PLC) and human-machine interfaces (HMI). Its purpose is to perform closed-loop control of particular industrial processes, thus there are hard real-time requirements at this level. If the number of control loops is large, the system is usually implemented as a distributed control system (DCS).

The management level sits above the control level and serves as a supervisor of all tasks at that level (Supervisory Control & Data Acquisition, SCADA). There are no real-time requirements.

Enterprise level (ERP systems) is the top level. Its purpose is to perform production planning and quality management. It is part of the IT infrastructure, rather than Operation technology (OT).

Communication Diversity

Requirements on communication systems differ for the levels mentioned above.

The communication between the field level and control level and at the control level itself is usually based on field buses. The critical parameters are robustness, communication latency and determinism, which are essential for closed-control loop systems. Another typical requirement is power supply over the same bus. Throughput is rather low, in order of 100kbps to 1Mbps, but it is sufficient due to low amount of data transferred at this level (a few bytes) and very lightweight communication protocols.

The communication between management and enterprise level is based on common Ethernet and TCP/IP protocol. It provides high throughput, usually in order of 100Mbps to 1Gbps, very low-cost due to commercial-grade devices and dozens of application protocols built on top of the TCP/IP protocol.

Devices at the control level interface with both levels mentioned above – they use the robust, deterministic and expensive field buses at one side and fast, cheap, but nondeterministic Ethernet at the other side.

Unification

The idea behind the Industrial Ethernet is to unify the protocols at the control level. That protocol shall provide high data rate and low cost of the Ethernet and, at the same time, low latency and determinism of the field buses. High data throughput is already a feature of the Ethernet. Low cost can be achieved through use of standard Ethernet components, like bridges and software stacks. The last requirements, determinism, can be fulfilled only through proper modification of the Ethernet and/or TCP/IP protocols.

Industrial Ethernet

Industrial Ethernet is a modification of common Ethernet to meet requirements of the control level, especially low latency and determinism. Several Industrial Ethernet standards were introduced. These standards are unfortunately incompatible. They can be classified according to the OSI layers that were modified in particular standard however, and common hardware implementation can be proposed for some classes.

OSI Layers

The communication systems are described using models with several abstraction layers. Each layer provides services to the layer above it and uses services from the lower layer below, but does not depend on implementation of that particular layers. The Open System Interconnection (OSI) model is the most generic model, while the TCP/IP model, shown below, describes the current most common network architecture.

OSI Layer	Data Unit	Protocols	Resources
Application	Data	HTTP, SSH, SMTP, RDP	Software
Transport	Stream/Datagram	TCP, UDP	Software
Internet	Packet	IP	Software
Network Access	Frame, bit	Ethernet	Hardware

Types

The industrial Ethernet protocols differ in the scope of changes in standard TCP/IP network layers.

Some protocols, like EtherNet/IP or Modbus/TCP reuse common Network Access layer, Internet layer and Transport layer, and define a new application protocol on top of that. It allows the use of most COTS hardware components and software libraries. On the other hand, it has limited performance due to unpredictable network delays, which are caused especially by software components.

Other industrial Ethernet protocols, like Ethernet Powerlink or Profinet RT, reuse common hardware components only and rely on modification of all the software layers above that.

Finally, some industrial Ethernet protocols, like EtherCAT, Profinet IRT or Sercos III, use both special hardware components and special software libraries. This option provides the highest performance, i.e. low latency and determinism.

Implementation

Legacy Approach

Implementation options depend on the type of industrial Ethernet protocol detailed earlier.

The industrial Ethernet protocols that modify the application layer only usually use common hardware implementation of the network access layer and common software libraries. The hardware part consists of a dedicated IC for physical layer (PHY) and hardware implementation of the data link layer (MAC), usually embedded in MCU IC. The software implementation consists of common TCP/IP stack and specific Industrial Ethernet libraries.

The industrial Ethernet protocols that are built on top of the network access layer may use the same hardware as above but requires a specific software implementation of all layers above that. This software implementation may need high processor performance and large RAM memory, which constrains the choice of MCU system.

Finally, the industrial protocols that redefines all the layers, both hardware and software, may use common PHY IC, but all other parts, like data link layer (MAC) and software stack, are fully custom.

SoC

Use of the custom SoC allows higher level of integration - the processor, memories, MAC and PHY can be implemented in a single device.

The processor is available as soft IPs, and its choice depends on requirements of particular application.

The common data link layer controllers (MAC) are available as soft IPs as well, both with and without support for precision time protocol (PTP, IEEE 1588).

The PHY is available as a hard macro for most common application specific integrated circuit (ASIC) technology processes.

SmartEdgeTM Platform

Industrial Ethernet is being adopted as a standard for automation control networks. Integration of several components – processor and memory for software protocol stack, Ethernet controller and physical layer for lower Ethernet layers, in addition to other application specific modules, allows to reduce BOM and the cost.

Renesas, formerly Dialog’s SmartEdge^{TM} platform incorporates all the Sensor AFE (Analog Front End), Calibration, Control, Security and Industrial Communication elements of a smart edge device, all integrated onto a single cost-effective chip. With more than 20 years’ experience designing advanced embedded mixed-signal chips for hundreds of customers in every major region, our ASIC & IP division delivers a new breed of design-centric semiconductor supplier capable of optimising its designs for every customer, yet achieving cost economies not thought possible with custom chips designs until now

Revision History

Revision	Date	Description
1.0	Mar 01, 2018	Initial release
1.1	Dec 22, 2021	Re-brand