ETHERNET TECHNOLOGY IN AUTOMATION

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Paper deals with Ethernet and particularly with the industrial Ethernet and its extension and transformation from LANs for office to harsh industrial environment. It presents in a short overview existing communication technology for purposes of industrial automation, hence the fieldbuses and lower industrial communication systems that are widely used for purposes of automation. Authors specify requirements of industrial application from machinery as well as from technological processes and basic principles, applied in fieldbuses to fit such requirements. In the second part of the contribution authors expose Ethernet technologies with description of their features. From a comparison of industrial requirements on one hand and Ethetnet TCP/IP parameters and properties on the other hand, authors go to the description of new mechanisms that have extended features of the Ethernet technologies to enable the design development and use of Industrial Ethernet.

Keywords: Industrial Ethernet, industrial communication, standardization

1. INDUSTRIAL COMMUNICATION NETWORK BASICS

The main reasons for wide extension and development of serial industrial networks for purposes of automation were in the beginning of the 1980's the costs of single point cabling between the process instrumentation and PLCs or the first control level of process control systems in machinery and particularly in process control as well as more simple and cheaper commissioning, possibility of remote monitoring, remote parametrization, remote status reading, remote failure localization and information integrity of the all pyramidal control architecture (Fig.1).

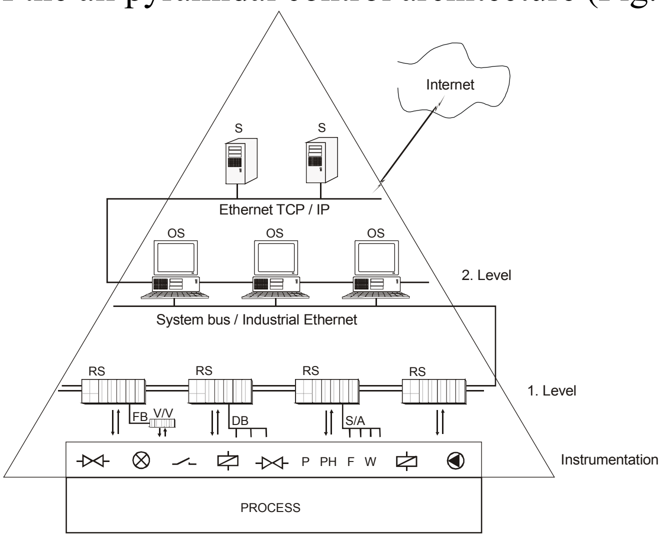

Fig. 1: Control pyramid with hierarchical control levels

For such purposes were developed and since middle of 80's widely used proprietary as well as standardized industrial networks in structure from the Fig.2

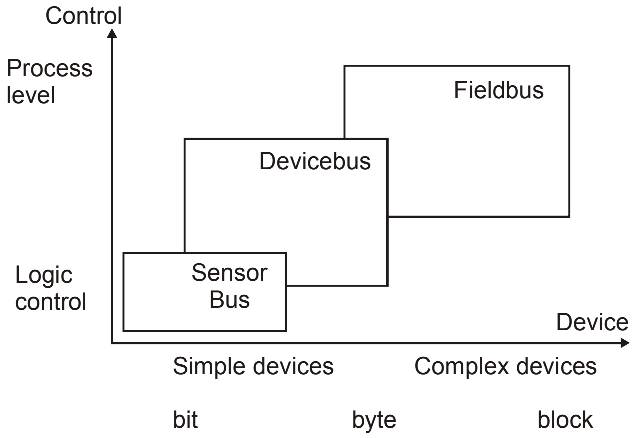

Fig. 2: Comparison of sensor, device and fieldbuses

The lack between necessity of application of serial industrial communication systems on hand side and delay of the procedures of a IEC (International Electrotechnical Commission) standardization of a uniform "world fieldbus" were designed and developed several more or less successful proprietary producer's and problem's oriented simple or more complex serial interfaces and networks. Also national standardization commissions, particularly in Europe had started development of several sophisticated solutions of communication standards for data acquisition and control purposes. Consequences of this process were as expected. There were and are till now many standards and quasi standards in the market of automation. They are less or totally not compatible each other. Producers of devices and other process instrumentation have to develop a set of communication interfaces for one automation device, consumers have difficult choice and are dependent on one or only not many producers of appropriate process instrumentation. The development of distributed automation devices is expensive and redundant.

For examples see the list of only the most frequently used industrial networks and protocols pro automation purposes from the end of the 90's:

- Profibus DP, PA, FMS
- FIP, WorldFIP
- P-Net
- CAN
- DeviceNet
- ControlNet
- Foundation Fieldbus
- BACNet
- Interbus
- AS-Interface
- HART, and others

On the other hand the above mentioned industrial networks are developed appropriate for industrial application and have no ambitions to be used for other (IT) purposes. They fit very well following industrial requirements on communication subsystem:

- reliability
- robustness (EMC, mechanical robustness)
- real – time (timeliness and synchronism)
- closed – security from principal
- possible enhancement in the sense of safety

It is not the aim of the contribution to present industrial networks in details. It is well known since the 80's and 90's. Nevertheless let us associate the most used single protocols and serial networks from above list into the Fig.3 and specify their main feature, area of use and perspectives. The absolutely most successful sensor and device bus is Profibus DP, followed by AS-interface. The Profibus is one of the three fieldbuses standardized it the EU 50170 standard since the 90's. Profibus DP is on a large scale extended all over the automation application in machinery, small and big applications all over the world. It shows more then 10 million DP nodes. The Interbus is popular in German machinery, particularly for motion control in the level of sensor - control system - actuator communication. The FIP (WorldFIP) is intended to be a fieldbus for factory automation, it is a part of the EN 50170 standard and lives particularly in the Nord America industry. The last part of the EN 50170 standard is the P-Net, the less important European fieldbus, limited for the Danish process industry. The most advanced classical fieldbus seems to be the Foundation Fieldbus (shortly fieldbus), the youngest fieldbus, initiated by the SC65C working group of the IEC and implemented experiences and ideas from both, the Profibus and FIP standards. The existing standard of the unique world fieldbus as the 15 years standardization activity of the IEC (predominatingly working group SC65C) is depicted in the Fig.3.

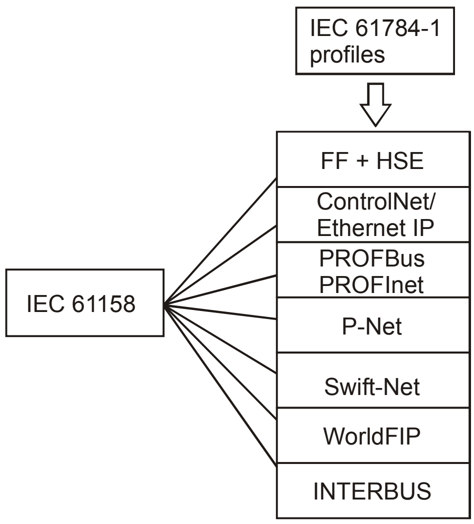

Fig. 3: World fieldbus standardization in the end of 90's

The 7 fieldbuses and their communication and automation profiles are specified in both the IEC 61158 standard and the associated IEC 61784-1 as the successful results of the long standardization process of the SC65C working group of the IEC.

2. INDUSTRIAL ETHERNET

In the second half o the 90th began an interesting development in the industrial communication. The Ethernet technology – the de facto standard in communication in LANs – due to the wide extension of Internet and IT (information technologies) become more and more cheaper, faster and widely used. Due to the use of switches the collision domains became less critical, throughput of Ethernet became greater, response time became shorter and Ethernet technology, originally specified by IEEE 802.3, but being under a continuous development in IT, made several steps (switching, full duplex, 100Mbit/s and more) to become more deterministic. It was a big challenge for automation to use Ethernet technology for purposes of industrial communication.

In the end 90th many producers and professional associations from industrial automation branch came to the conclusion that Ethernet technology will be very perspectives also for the automation world and began with development, specification, and application of more or less proprietary solution of industrial Ethernets. In this way were developed new communication systems on the Ethernet technology principles and physics: Ethernet IP, Ethernet PowerLink (EPL), Modbus TCP, EtherCat, Profinet, Sercos III and next are under development. The IEC had no chance to have the quick development of the industrial Ethernets under control and decided to standardize already existing successful solution of Industrial Ethernets.

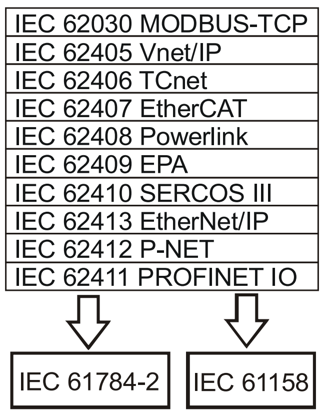

Fig. 4: Profiles of the IEC 61158 standard - communication profiles

2.1 Industrial Ethernet Basics

There are significant differences between requirements on communication system for industrial automation purposes and principal features of the IEEE 802.3 standard Ethernet and particularly Ethernet TCP/IP with the family of application protocols. The office and IT world has particular requirements on robustness (EMC, mechanical as well as robustness against internal and external failures), shows a small set of communication entities (PCs), Ethernet TCP is full sufficient for purposes of Internet

IP technologies. The industry word has much more strong requirements: high mechanical robustness (to the class IP65, IP67), high EMC – higher then in IT world, deterministic media access of communicating entities, high requirements on safety communication from the functional safety point of view (specified by the IEC 61508 standard), the same security requirements as the bank operations information system, real – time or hard real - time requirements on control and communication systems reactions.

The industrial networks (fieldbuses, device buses and sensor/actuator buses) match the requirements well. The standard Ethernet TCP/IP as the IEEE 802.3 standard with regard to the CSMA/CD medium access methods didn't match requirements on determinism, real – time and particularly requirements on hard real time features, required in the motion control of cooperating axes in machinery. But the recent Ethernet is no more the initial IEEE 802.3 standard of 80th. Due to the continuous development in cabling, use of switches and hubs use of full duplex communication and some other enhancements, the recent Ethernet shows better properties in term of real time and determinism. Nevertheless the really deterministic features reaches really only true Industrial Ethernets (Ethernet PowerLink, EtherCat, Profinet I/O, Profinet V3, Sercos III, Ethernet IP).

2.2 Real-time over Industrial Ethernet

Let us to determine mechanisms to enhance real – time capability (determinism, synchronism) of Ethernet technology. They are priorities in the MAC mechanism, full duplex, UDP instead of TCP, producer-consumer and publisher- subscriber message addressing, switching, segmenting and routing messages into real time and non real time domains, high speed communication and communication planning. Some of them appear already by the Ethernet for office and IT (full duplex, switching, UDP/IP, high speed communication, communication planning). Nevertheless the isochronous communication modus, that is an imperative condition for a high-speed motion control is not possible without an appropriate synchronization mechanism. The most advanced Industrial Ethernets use the Precision Time Protocol (PTP) by the IEEE 1588 that goes out from distributed synchronized time clocks in cooperating entities (e.g. control systems of synchronized mechanical axes in machinery) and is cheap and powerful enough. It is said that PTP enables to keep the deadline with a jitter lower then 1 microsecond, that is better result then by fieldbuses, especially developed for such a purposes. In the Fig. 8 to 11 there are principals of mechanisms to enhance real-time capabilities of the Ethernet technology.

Let us present three basic principals of communication model of recent industrial Ethernets:

1st model - both the real-time and non-real-time data exchange is carried out through the same way - TCP/UDP/IP stack by encapsulating the real-time data in the application sub layer (Fig. 5a).

2nd model - the time critical data flows over a real-time SW bypass parallel to the TCP/UDP/IP, time no-critical data and messages are carried out over the TCP/UDP/IP (Fig. 5b).

3rd model - real-time data are carried out by a HW bypass of the TCP/UDP/IP stack, non real-time critical data flow over the standard Ethernet TCP/UDP/IP, special Ethernet HW is unavoidable (Fig. 5c)

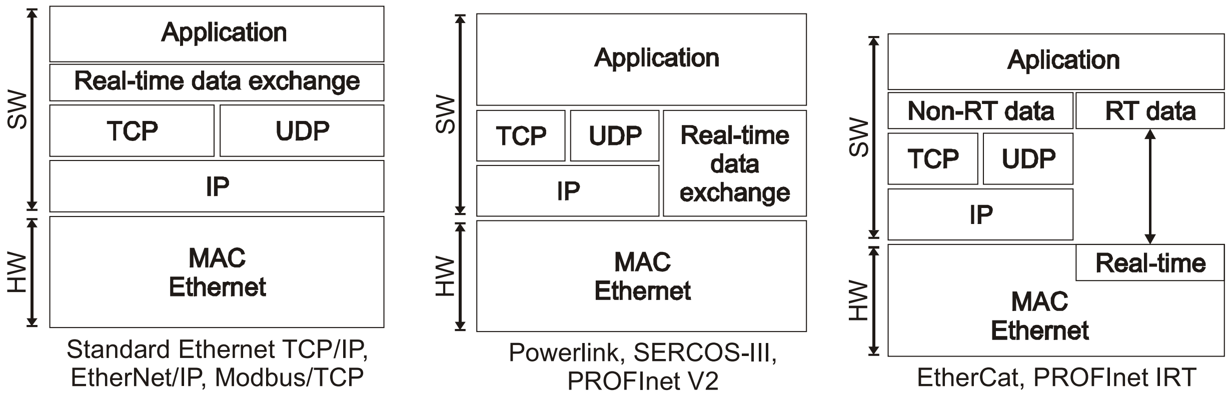

Fig. 5a,b,c: Industrial Ethernet solutions

3. CONCLUSION

Author's aim was to provide an introduction into the recent development in industrial communication with particular attention to the standardization process due to penetrating of Ethernet technology. It was unavoidable to make a short overview in industrial communication networks, in specification of requirements a state of the art in standardization process of the "world fieldbus". Authors presented basic development of Ethernet technology in its way to the most perspective technology for industrial communication in the future. Basics of Industrial Ethernets that enables enhancement of real-time have been introduced.

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