The Fieldbus War: History or Short Break Between Battles?

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Abstract

Understanding the structure of fieldbus standards means knowing their history. This paper reviews the evolution of international fieldbus standards in the area of industrial automation and demonstrates how the present situation of the IEC 61158 standard with its 18 different fieldbus systems came about. While the fieldbus standards seem to have reached a stable state, the upcoming application of Ethernet in the field of automation might create a similar conflict potential. We discuss the current status of Industrial Ethernet and the related standardization efforts.

1. Introduction

The history of fieldbus systems did not start in the mid 1980s, in fact the roots of industrial networks are much older and date back to the early 1970s [1,2]. However, it was only during the 1980s that fieldbus systems started booming. As different as the various application areas were the approaches invented, and from today's point of view it seems that creating new fieldbus systems was a trendy and fashionable occupation for many companies in the automation business. The overwhelming number of different systems appalled rather than attracted the customers, and what followed was a fierce selection process where not always the fittest survived, but often those with the highest marketing power behind them. Consequently, most of the newly developed systems vanished or remained restricted to small niches. Nevertheless, also the big companies soon realised that proprietary fieldbus systems will always have only limited success and that more benefit lies in making the specifications publicly available, so that different vendors may produce compatible devices, which gives the customer back their freedom of choice [3,4,5,6]. Finally, it was this openness that paved the way for the breakthrough of fieldbus systems.

From creating an "open" specification to the standardisation of a fieldbus system it is only a small step. The basic idea behind it is that a standard establishes a specification in a very rigid and formal way, ruling out the possibility of quick changes. This attaches a notion of reliability and stability to the specification, which in turn secures the trust of the customers and, consequently, also the market position. Furthermore, in many countries standards have a legally binding position, which means that when a standard can be applied (e.g., in connection with a public tender), it *has* to be applied. Hence a standardised system gains a competitive edge over its non-standardised rivals. It is therefore no wonder that after the race for fieldbus developments, a race for standardisation was launched. Now this was quite easy on a national level, and most of today's relevant fieldbus systems soon became national standards. Troubles started when international solutions were sought. This caused heavy turbulences and opened a battlefield for politics that gradually left the ground of technical discussion. Table 1 shows the timeline of these "fieldbus wars".

2. The German-French fieldbus war

In the second half of the 1980s, at the beginning of the IEC efforts in the technical committee TC65C, the development of fieldbus systems was mainly a European endeavor, thrust forward by research projects that had still a strongly academic background as well as many proprietary developments. The most promising results were the French FIP and the German PROFIBUS. Both were soon standardized on the respective national level and finally proposed to the IEC for international standardization. Unfortunately, the approaches of the two systems were completely different. PROFIBUS was based on a distributed control idea and in its original form supported an object-oriented vertical communication according to the client-server model in the spirit of the MAP/MMS specification. FIP, on the other hand, was designed with a central, but strictly real-time capable control scheme and with the newly developed producer-consumer (producer-distributor-consumer) model for horizontal communication.

Period	Status of standards	Major activities
1986 - 1990	The claims are staked	Selection of various national standards, German PROFIBUS and French FIP are the main candidates
1990 - 1994	German-French fieldbus war	Attempt of a general specification based on WorldFIP and the Interoperable System Project (ISP)
1995 - 1998	Standardization locked in stalemate	Development of the "American" Foundation Fieldbus (FF) in response to the European approach and formation of the CENELEC standards comprising several fieldbus systems in one standard. Deadlock of the international standard through obstructive minorities.
1999 - 2000	The compromise	The eight type specification becomes a standard.
2000 - 2002	Amendments to reach maturity for the market	The standard is enhanced by more types and the necessary profiles are specified in IEC 61784.

Table 1. Fieldbus standardization timeline from the viewpoint of IEC 61158.

Different as they were, the two systems were suited for complementary application areas. Evidently, a universal fieldbus had to combine the benefits of both, and an expert group came up with a new proposal [7]. In an extension of FIP towards WorldFIP, the functionality of the client-server model was added. On the other side, the ISP (Interoperable System Project) attempted to demonstrate how PROFIBUS could be enhanced with the publisher-subscriber communication model which is about the same as the producer-consumer model of FIP. Strange enough, the ISP was abandoned in 1994 before reaching a mature state because of strategic reasons [8].

In the meantime, the leading role in the standardisation efforts on IEC level had been taken not by the Europeans, but by the work of the committee SP 50 of the Instrumentation, Systems and Automation Society (ISA), who had been much more efficient during the late 1980s and exerted an important influence on the layer structure of the standard as we have it today [9,10]. Still, by the mid 1990s, the IEC committee had not produced any substantial outcome for more than eight years. The only exception was the definition of the Physical Layer, which was adopted as IEC 61158-2 standard already in 1993. This part is the one that has since been used very successfully mainly in the process automation area. On top of the physical layer, however, the standardization drafts became more and more comprehensive and overloaded with all kinds of communication and control principles imported from the different systems. In the Data Link Layer specification, for example, three different types of tokens were introduced: The "scheduler token" determines which station controls the timing on the bus, with the "delegated token" another station can temporarily gain control over the bus, and the "circulated token" is being passed from station to station for bus access. The problem with these all-inclusive approaches was that a full implementation of the standard was too expensive, whereas a partial implementation would have resulted in incompatible and not interoperable devices (a problem which was encountered also in the early implementations of, e.g., PROFIBUS-FMS, where significant parts of the standard are optional and not mandatory).

3. The international fieldbus war

In 1995, after long years of struggles between German and French experts to combine the FIP and PROFIBUS approaches, several mainly American companies decided to no longer watch the endless discussions. With the end of the ISP project, they began the definition of a new fieldbus optimized for the process industry: the Foundation Fieldbus (FF). This work was done outside the IEC committees within the ISA, and for some time, the IEC work seemed to doze off.

Following the failure to find an acceptable draft for a universal fieldbus, the Europeans feared that it might be impossible to get their national standards into an international one. By that time, the standardization issue had ceased to be a merely technical question. Fieldbus systems had already made their way into the market, much effort and enormous amounts of money had been invested in the development of protocols and devices, and there were already many installations. Nobody could afford to abandon a successful fieldbus, hence it was – from an economical point of view – impossible to start from scratch and create a unified but new standard which was incompatible to the existing national ones. Within CENELEC, the national committees found after lengthy discussions a remarkable and unprecedented compromise: All national standards under consideration were simply compiled "as is" to European standards [11]. Every part of such a multi-part standard is a copy of the respective national standard, which means that every part is a fully functioning system. Although this approach is very pragmatic, it took a long time to reach it, and the contents of the individual CENELEC standards still reflect the strategic alliances that had to be formed by the

CENELEC standards part	Contained in IEC standard	Brand name
EN 50170-1 (Jul. 1996)	IS 61158 Type 4	P-Net
EN 50170-2 (Jul. 1996)	IS 61158 Type 1/3/10	PROFIBUS
EN 50170-3 (Jul. 1996)	IS 61158 Type 1/7	WorldFIP
EN 50170-A1 (Apr. 2000)	IS 61158 Type 1/9	Foundation Fieldbus
EN 50170-A2 (Apr. 2000)	IS 61158 Type 1/3	PROFIBUS-PA
EN 50170-A3 (Aug. 2000)	IS 61158 Type 2	ControlNet
EN 50254-2 (Oct. 1998)	IS 61158 Type 8	INTERBUS
EN 50254-3 (Oct. 1998)	(IS 61158 Type 3)	PROFIBUS-DP (Monomaster)
EN 50254-4 (Oct. 1998)	(IS 61158 Type 7)	WorldFIP (FIPIO)
EN 50325-2 (Jan. 2000)	IS 62026-3 (2000)	DeviceNet
EN 50325-3 (Apr. 2000)	IS 62026-5 (2000)	SDS
EN 50325-4 (under vote)		CANOpen
EN 50295-2 (Dec. 1998)	IS 62026-2 (2000)	AS-Interface

Table 2. Contents of the CENELEC fieldbus standards. The dates given in brackets are the dates of ratification by the CENELEC Technical Board.

national committees to get "their" standard into the European one.

To make the CENELEC collection easier to handle, the various fieldbus systems were bundled according to their primary application areas. EN 50170 contains "General purpose field communication systems", EN 50254 "High efficiency communication subsystems for small data packages", and EN 50325 comprises different solution based on the CAN technology. In the later phases of the European standardization process, the British national committee played the part of an advocate of the American companies and submitted also FF, DeviceNet, and ControlNet for inclusion in the European standards. Table 2 shows a compilation of all these standards, as well as their relation to the new IEC standard. For the sake of completeness, it should be noted that a comparable, though much less disputed standardization process took place also for bus systems used in machine construction (dealt with by ISO) as well as building automation (in CEN and more recently in ISO).

While the Europeans were busy standardizing their national fieldbus systems and sort of neglected what happened in IEC, the Fieldbus Foundation prepared their own specification. This definition was modeled after the bus access scheme of FIP and the application layer protocol of PROFIBUS-FMS. The FF specification naturally influenced the work in the IEC committee, and consequently the new draft evolved into a mixture of FF and WorldFIP. When this draft was put to vote in 1996, the actual fieldbus war started, and the casus belli was that PROFIBUS was no longer represented in the draft. Given the strict European standardization rules where international (i.e., IEC) standards supersede opposing CENELEC standards, the PROFIBUS proponents feared that FF might gain a competitive advantage and "their" fieldbus might lose ground. Consequently, the countries where PROFIBUS had a dominant position managed to organize an obstructive minority that prohibited the adoption of the standard by a narrow margin. The fact that the IEC voting rules make is easier to cast positive votes (negative votes have to be justified technically) was no hindrance, as there were still inconsistencies and flaws in the draft that could serve as a fig-leaf. However, the FF empire (as it was seen by the PROFIBUS supporters) struck back with legal tricks to save the standard. They launched an appeal to cancel negative votes that had not sufficient technical justification, which would have turned the voting result upside down. They even proposed that the members (i.e., the respective national mirror committees) should decide about the (non-)acceptance of the incriminated votes – a procedure which is not in conformance with the IEC rules and caused substantial exasperation. In the course of subsequent voting processes, things grew worse: countries voting – both in favor and against – that had never cast a vote before; votes not being counted because they were received on a different than the designated fax at the IEC and thus considered late; rumors about presidents of national committees who high-handedly changed the conclusions of the committee experts, and finally the substantial pressure exerted by leading companies on the national committees. By and large, the obstruction of the standard remained unchanged, and the standardization process had degenerated to an economical and political battle, which was apt to severely damage the reputation of standardization as a whole.

4. The compromise

On the 15th of June 1999, the "Committee of Action" of the IEC decided to go a completely new way to break the stalemate. One month later, on the 16th of July, the representatives of the main contenders in the debate (Fieldbus Foundation, Fisher Rosemount, ControlNet

Standards part	Contents	Contents and meaning
IEC 61158-1	Introduction	Only Technical Report
IEC 61158-2	PhL: Physical Layer	8 Types of data transmission
IEC 61158-3	DLL: Data Link Layer Services	8 Types
IEC 61158-4	DLL: Data Link Layer Protocols	8 Types
IEC 61158-5	AL: Application Layer Services	10 Types
IEC 61158-6	AL: Application Layer Protocols	10 Types
IEC 61158-7	Network Management	Must be completely revised
IEC 61158-8	Conformance Testing	Work has been cancelled

Table 3. Structure of IEC 61158 fieldbus for industrial control systems.

International, Rockwell Automation, PROFIBUS user organization, and Siemens) signed a "Memorandum of Understanding", which was intended to put an end to the fieldbus war. The Solomonic resolution was to create a large and comprehensive IEC 61158 standard accommodating all fieldbus systems [12]. However, other than CENELEC, where complete specifications had been copied into the standard, the IEC decided to retain the original layer structure of the draft with physical, data link, and application layer, each separated into a services and protocols part (Table 3). The individual fieldbus system specifications had to be adapted to so-called "types" to fit into this modular structure. In a great effort and under substantial time pressure the draft was compiled, submitted for vote, and released as a standard on December 31st, 2000.

It was evident that the collection of fieldbus specifications in the IEC 61158 standard is useless for any implementation. It needs a manual for the practical use showing which parts can be compiled to a functioning system and how this can be accomplished. This guideline was compiled later on as IEC 61784 as a definition of so-called "profiles". At the same time, the specifications of IEC 61158 have been corrected and amended. The drafts of these documents are currently under vote and can be expected to be put into operation by the end of this year. These profiles show that the international fieldbus today consists of seven different main profiles that in turn can be subdivided (see Table 4). All important fieldbus systems from industrial and building automation are listed here, and the world's biggest automation companies are represented with their developments.

FF consists of three profiles. The H1 bus is used in process automation, whereas HSE is planned as an Ethernet backbone and for industrial automation. The H2 is a remainder of the old draft. It allows for a migration of the WorldFIP solution towards FF, but in the profile description it is explicitly noted that there are no products available. From the PROFIBUS side, the two profiles DP and PA are present, even the new PROFInet has been included. Interestingly, the experts did it not consider worthwhile to list the original version of PROFIBUS, the FMS, which is a strong sign for the diminishing importance, if not abandonment of this hard-

IEC 61784 Profile	IEC 61158 Protocols			CENELEC	Brand names
	Phy	DLL	AL		
CPF-1/1	Type 1	Type 1	Type 9	EN 50170-A1 (Apr. 2000)	Foundation Fieldbus (H1)
CPF-1/2	Ethernet	TCP/UDP/IP	Type 5	-	Foundation Fieldbus (HSE)
CPF-1/3	Type 1	Type 1	Type 9	EN 50170-A1 (Apr. 2000)	Foundation Fieldbus (H2)
CPF-2/1	Type 2	Type 2	Type 2	EN 50170-A3 (Aug. 2000)	ControlNet
CPF-2/2	Ethernet	TCP/UDP/IP	Type 2	-	EtherNet/IP
CPF-3/1	Type 3	Type 3	Type 3	EN 50254-3 (Oct.1998)	PROFIBUS-DP
CPF-3/2	Type 1	Type 3	Type 3	EN 50170-A2 (Oct.1998)	PROFIBUS-PA
CPF-3/3	Ethernet	TCP/UDP/IP	Type 10	-	PROFInet
CPF-4/1	Type 4	Type 4	Type 4	EN 50170-1 (Jul. 1996)	P-Net RS-485
CPF-4/1	Type 4	Type 4	Type 4	EN 50170-1 (Jul. 1996)	P-Net RS-232
CPF-5/1	Type 1	Type 7	Type 7	EN 50170-3 (Jul. 1996)	WorldFIP (MPS,MCS)
CPF-5/2	Type 1	Type 7	Type 7	EN 50170-3 (Jul. 1996)	WorldFIP (MPS,MCS,SubMMS)
CPF-5/3	Type 1	Type 7	Type 7	EN 50170-3 (Jul. 1996)	WorldFIP (MPS)
CPF-6/1	Type 8	Type 8	Type 8	EN 50254-2 (Oct. 1998)	INTERBUS
CPF-6/2	Type 8	Type 8	Type 8	EN 50254-2 (under vote)	INTERBUS TCP/IP
CPF-6/3	Type 8	Type 8	Type 8	EN 50254-2 (under vote)	INTERBUS Subset
CPF-7/1	Type 6	Type 6	-	-	Swiftnet transport
CPF-7/2	Type 6	Type 6	Type 6	-	Swiftnet full stack

Table 4. Profiles and protocols according to IEC 61784 and IEC 61158.

Profile	Name	Industry	Special features	Processing	Bus access	Nodes per segment
CPF-1/1	FF (H1)	Process	Function blocks for decentralized control	central decentral	producer-consumer with distributor	max. 32
CPF-1/2	FF (HSE)	Factory Process		decentral	CSMA/CD	max. 30
CPF-1/3	FF (H2)	Factory		central decentral	producer-consumer with distributor	max. 32
CPF-2/1	ControlNet	Factory	Optimized for factory applications	central	producer-consumer	max. 99
CPF-2/2	EtherNet/IP	Factory				max. 30
CPF-3/1	PROFIBUS-DP	Factory	Optimized for Remote I/O	central	master-slave with token-passing	max. 126
CPF-3/2	PROFIBUS-PA	Process	Optimized for Process Control	central		max. 32
CPF-3/3	PROFInet	Factory	Distributed Automation Objects	decentral	producer-consumer	max. 30
CPF-4/1	P-Net RS-485	Factory Shipbuilding	Multi-net capability	central	master-slave with token-passing	max. 32
CPF-4/1	P-Net RS-232					
CPF-5/1	WorldFIP	Factory	Distributed realtime database	central decentral	producer-consumer with distributor	max. 256
CPF-5/2						
CPF-5/3						
CPF-6/1	INTERBUS	Factory	Optimised for remote I/O	central	single master with synchronised shift register	max. 256
CPF-6/2	INTERBUS TCP/IP					
CPF-6/3	INTERBUS Subset					
CPF-7/1	Swiftnet transport	Aircraft	Optimised for aircraft	decentral	producer-consumer with distributor	max. 1024
CPF-7/2	Swiftnet full stack					

Table 5. Technical characteristics and domain of application of the different profiles.

to-engineer fieldbus which is currently only contained in the EN 50170-2. The Danish fieldbus P-Net was taken over like all definitions and variants of WorldFIP and INTERBUS. In the latter case, also the extensions for the tunneling of TCP/IP traffic have been foreseen in the standard. A newcomer in the fieldbus arena is Swiftnet, which is widely used in airplane construction (Boeing). The correct designation of a IEC fieldbus profile is shown for the example of PROFIBUS-DP: Compliance to IEC 61784 Ed.1:2002 CPF 3/1. Table 5 shows some technical characteristics and the main fields of application for the different systems. Low-level fieldbus systems for simple I/Os such as the ones based on CAN or the AS-Interface are not part of IEC 61158, it is planned to combine them in IEC 62026.

5. New challenges: Industrial Ethernet

In recent years, Ethernet has become increasingly popular in automation. And like in the early days of fieldbus systems, this boom is driven mainly by the industry – on an academic level, the use of Ethernet had been discussed decades ago. Hence the initial situation is comparable to that 15 years ago, and there is enough conflict potential in the various approaches to use Ethernet in automation.

The future role of Ethernet in the automation area is not clear. Initially, Ethernet was considered inappropriate because of its lack of real-time capabilities. With the introduction of switched Ethernet and certain modifications of the protocol, however, these problems have been alleviated. And even if there are still doubts about the predictability of Ethernet [13], its the penetration into the real-time domain will influence the use of fieldbus-based devices and most likely restrict the future use of fieldbus concepts. Today, Ethernet takes the place of mid-level fieldbus systems, e.g., for the connection of PLCs. There exist first applications in manufacturing and building automation where no other fieldbuses than Ethernet are installed. To replace the existing fieldbuses by Ethernet TCP/IP, these communication protocols must also fit into one single ASIC. These requirements of price and size is mandatory for simple devices connected to modern fieldbuses today. At the moment fieldbus connection circuits for simple devices, often only one ASIC, are still cheaper than Ethernet connections. Nevertheless, there exist different solutions to make Ethernet and TCP/IP meet the (real-time) requirements of industrial applications [14]. The different approaches can be classified in different groups (Figure 1):

- tunnelling of a fieldbus protocol over UDP/TCP/IP
- definition of new real-time enabled protocol
- reduction of the free medium access in standard Ethernet
- tunnelling of TCP/IP over an existing fieldbus

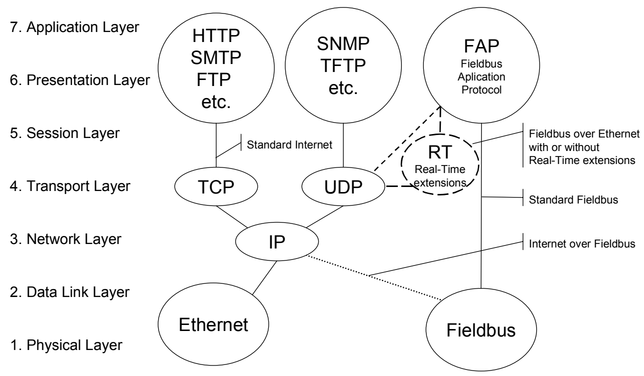

Figure 1. Structures of Ethernet and Fieldbus combinations.

5.1. Ethernet in IEC 61158

Standardization has not intensively dealt with the question of Industrial Ethernet yet. Still, in the wake of the fieldbus wars, several solutions based on Ethernet and TCP/UDP/IP have made their way into the IEC 61158 standard without much fighting (see also Tab. 4):

- High Speed Ethernet (HSE) of the Foundation Fieldbus
- Ethernet/IP of ControlNet and DeviceNet
- PROFInet defined by PROFIBUS International
- TCP/IP over INTERBUS

HSE and Ethernet/IP (note that here IP intelligently stands for "Industrial Protocol" to make confusion perfect) are two solutions with a fieldbus protocol being "tunnelled" over TCP/IP. To be specific, it is no real tunnelling, where data packets of a lower fieldbus OSI layer are wrapped in a higher layer protocol of the transport medium. Instead, the same application layer protocol which is already defined for the fieldbus is also used over the TCP/IP or UDP/IP protocol stack. In the case of ControlNet and DeviceNet, this is the Control and Information Protocol [15]. This solution allows the device manufacturers to base their developments on existing and well-known protocols. The implementation is without any risk and can be done fast.

The idea behind PROFInet is more in the direction of implementing a new protocol. For the actual communication, however, it was decided to use the COM/DCOM mechanism known from the Windows world. This solution opens a wide possibility of interaction with the office IT software available on the market. The possibility to use fieldbus devices like objects in office applications will increase the vertical connectivity. On the other hand, this also includes the risk of other applications overloading the network, which has to be avoided. Basically, the COM/DCOM model defines an interface to use modules as black boxes within other applications. PROFInet offers a collection of automation objects with COM interfaces independent of the internal structure of the device. So the devices can as well be virtual, and so-called proxy servers can represent the interfaces of any underlying fieldbus. This encapsulation enables the user to apply different implementations from different vendors. The only thing the user has to know is the structure of the interface. Provided the interfaces of two devices are equal, the devices are at least theoretically interchangeable. Although this proxy mechanism allows to connect Ethernet to all types of fieldbus systems, it will not be a simple and real-time capable solution. A second problem is that in order to achieve portability, the COM/DCOM mechanism has to be reprogrammed for different operating systems. DCOM is tightly connected to the security mechanisms of Windows NT, but there is also the possibility to use WIN95/98 systems or – with restrictions – some UNIX systems. To simplify this, the PROFInet runtime system includes the COM/DCOM functionality, and the standard COM/DCOM functions inside the operating system have to be switched off if PROFInet is used.

The solution of tunnelling the TCP/IP protocol over a fieldbus requires some minimum performance in terms of throughput from the fieldbus to be acceptable. Normally, throughput of acyclic data (the transport mechanism preferably used in this case) is not the strongest point of fieldbus systems. Nevertheless, INTERBUS defines the tunnelling of TCP/IP over its acyclic communication channel [16]. The benefit of this approach is the parameterisation of devices connected to the fieldbus with standard Internet services. However, this forces the manufacturer of the field device to implement also the complete TCP/IP stack on the device and the installation personnel to handle the configuration of the IP addressing parameters for the connected field devices.

5.2. Alternative approaches for Industrial Ethernet

Outside the approaches that are already part of the IEC standard, other solutions are proposed, which not yet entered the standardization process. IDA (Interface for Distributed Automation) is proposing a completely new protocol for real-time communication over Ethernet and UDP/IP. It describes the model elements and interfaces in an automation architecture without standardizing the engineering tools, device functions, or their implementation. Instead, it aims at supplying an object-oriented infrastructure for modular, distributed, and reusable automation solutions based on three main technological pillars: an object-oriented software model for mapping an interoperable engineering and runtime architecture, a seamless system-independent connection level for all classes of communication, from I/O devices through the control system to the management, the integration of channels for safety technology based on Ethernet TCP/IP, and finally a standard browser-based Human Machine Interface for all components of a heterogeneous automation solution through the use of web technologies.

The principle of tunneling is also used for MODBUS/TCP [16] or BACNET. Like with CIP, the existing fieldbus application layer is transported over the UDP/TCP/IP protocol. The integrator of a multi-vendor installation uses Ethernet TCP/IP as a common transport network, but he is still forced to implement all the proposed application layers in his SCADA (Supervisory Control And Data Acquisition) or controller system. Unfortunately, there exists not just one single standard Application Programming Interface (API).

All the approaches to use Ethernet and UDP/TCP/IP for industrial networking assume, that Ethernet is low loaded or fast Ethernet switching technology is used, in order to get a predictable performance. Switching technology does eliminate collisions, but delays inside the switches and lost packages under heavy load conditions are unavoidable also with switches. This gets worse if small switches are used in a multi-level hierarchy, and results in jitter in cyclic communication. As an alternative, a consortium under the lead of Bernecker & Rainer proposed an "Ehernet Powerline". This solution puts a master-slave communication protocol on top of the standard Ethernet, which avoids all collisions. If used without any switches, it gives fast cycle times (400 µs) and very low jitter. Ethernet can therefore be used for the synchronization in motion control. For this solution, however, the free medium access has to be modified. Additionally, the standard TCP/IP protocol is only allowed in the time slice reserved by the master for acyclic data transmission.

In view of the different approaches, the IAONA organization has set to itself the goal to coordinate all these activities and to end up with one Ethernet solution for the automation world. At the moment, though, it is not visible how this can be reached, as there are different major key player like PROFIBUS International who do not participate in IAONA, while others do just follow the debate without real participation. Inside the IAONA organization the DEFIA working group (Deterministic Ethernet for Industrial Automation) has created a new proposal for a real-time protocol extension to Ethernet. Finally, it appears that there are at least as many proposals for industrial Ethernet as fieldbus standards exist already today.

6. Summary and outlook

In the past, we have seen more than ten years of fierce struggles to get the current fieldbus standard. Now, after a short break, it seems we are entering a new phase. The point of discussion is which solution will be adopted for Industrial Ethernet, which is heavily pushed by the industry. But have the contenders learned their lesson from the fieldbus wars? To date there are at least four different solutions available in the international standards, and all major manufacturers of automation devices have put in their solutions. Most of the possible principles of combining fieldbus and Ethernet are already included in the new standard IEC 61158.

Other innovative solutions are being proposed by different organizations. All of them have one major disadvantage: They create more degrees of freedom for the manufacturers and implementers of automation devices to add more and proprietary versions. The only proposition which goes in the opposite way is the initiative of the OPC Foundation: The development of OPC DX offers for the first time the possibility of combining solutions from different manufacturers and protocol families into one system. This approach is, however, not capable of handling real-time traffic.

What will happen with the set of different approaches? Like with every industry-driven trend it is up to the market to decide which technical solution will be adopted best. As there are already some solutions in the international standard, we can anticipate that the potential for conflicts is somewhat reduced. It is therefore probable that the next battle will be only on the market and not inside the standardization bodies, a situation we had in the fieldbus area before the war about the international standards began.

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