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The Fieldbuses – a Comparative Analysis

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1. The Fieldbus

In different life areas where the achievements of the contemporary informatics are used it is noticed aspiration towards forming specialized groups for fulfilling of certain work and the parameters of the task are placed centralized in a system covering the whole activity of one production, factory, database, bank etc. The results of the work of the specialized group are sent back to the center where the decision for the further activities of the system is made. This means that the separate specialized groups own a certain local intelligence permitting them alone and simultaneously to execute a certain work without engaging for this the central control system. Thus, the central control uses its resources to execute more high intelligent work like analysis of the work of the specialized groups and optimization of the future activities of the system.

The basic activity at the communication between the central control and the specialized groups and also between the groups themselves is taken by the fieldbus or the fieldnetwork. It looks after the data transmission as at the lowest control level of one production – the level of the sensors and the actuators – also for the highest – the ruling level of a plant. This explains the functional variety and the great differences in the exploitation characteristics which exist in the field buses; some of them are created for using mainly when activating the actuators and collecting information from sensors and following groups; and others are specialized for information processing from higher level as for example calculating using a certain algorithm of the future process behavior with the aim its optimal control. In the area of production models exist imaging the information floats in the distributed systems beginning from the sensor/actuator and reaching the plant manager.

The tendencies for development in the field buses are towards the simplification of the configuration and integration of the testing, following and control groups with the communicational ones. The aspiration is to create integral schemes combining all these functions.

The recent research generalizes some characteristics of the fieldbuses. At the comparison many criteria are taken in mind covered in two parts: technical and strategic.

2. Estimation criteria for fieldbuses

In aspect of their creation and application the fieldbuses can be roughly divided in two basic groups: specialized buses and buses with common application. The buses Interbus-S, LON, CAN, ABUS, SERCOS belong to the first group. They usually work on the lower control level and the first two levels are mainly defined in them in the model OSI. BITBUS, FOUNDATION, Profibus, P-Net belong to the second group. They have more complex protocol and usually work at higher level in the hierarchy and in them the other two levels of the model OSI are defined or it is forecasted to be defined. In some cases these levels are grouped and receive a new name or make sublevels (for example the fieldbus FOUNDATION). But the quick distribution of the fieldbuses has erased to a big extent already this division and the buses with special application are used in fact for many and different applications. Sooner we could speak of buses working on the lower level of the production process and such working on the higher levels in the communication hierarchy.

At the choice of a bus for concrete application different in its character criteria are used: functional, economical, production. Most commonly the criteria could be divided in two basic classes: technical and strategic. The technical ones cover the distribution of the buses in the space, their speed characteristics and the organization of the work. They concern the functioning of the buses in their concrete application. The strategic criteria are the production characteristics, the questions about standardization as well as some questions for their distribution and the development perspectives. These criteria make influence upon the economic decisions.

In Fig.1 a classification of the estimation criteria of the fieldbuses is presented. To the group of the space criteria are added the maximum acceptable bus length, the maximum acceptable distance between the stations and the type of topology of the bus. To the group of the time characteristics are added the information transmission speed, the cycle length (when polling in cycle), the synchronization type, the maximum delay when sending messages, the software overhead. To the organization criteria are added the maximum acceptable number of participants (stations, nodes) of the bus, the hierarchy, the way of distributing of the bus between the participants (arbitration), the way of addressing of the participants, the message length (the so called "telegram"), as the system reaction when error arising, the questions of reliability etc.

To the criteria concerning the standardization questions are added the covering of the levels in the standard for an open system (ISO/OSI), the confirmation of certain indicators by international or state standards (compatibility), the giving of certificates. The technological criteria cover the production of the element base, the presence of necessary peripheral modules, software, development devices and diagnostics. The execution of these criteria gives independence for the user from the producers and providers when building the system. Very important for the investments are the suitability of a certain fieldbus for concrete application (typical application area), distribution degree and also the perspectives for development and distribution.

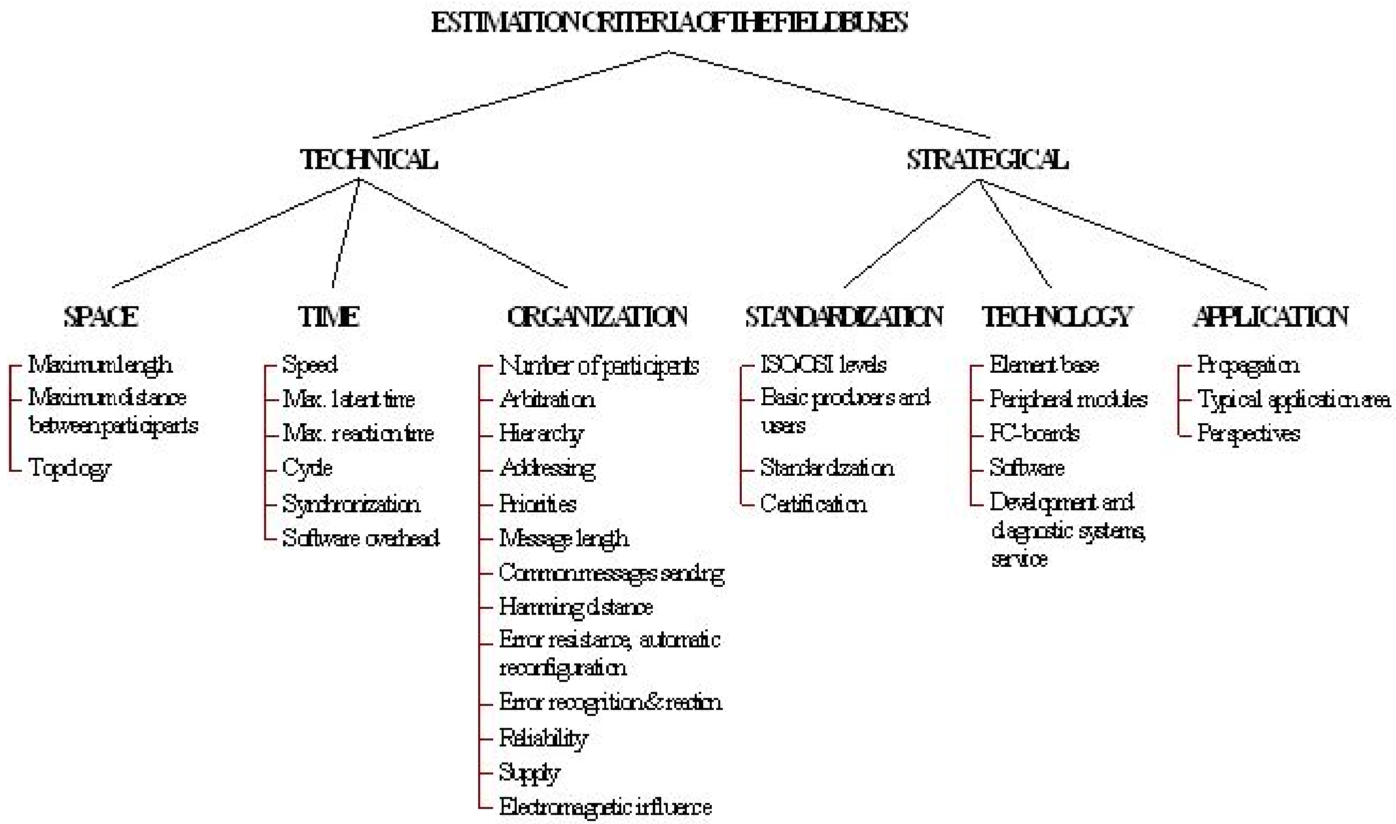

Fig. 1. Estimation criteria of the fieldbuses

3. Comparison analysis of chosen fieldbuses

In Table 1 are presented some of the most important characteristics for the most famous and with the biggest distribution fieldbuses.

The bus **ARCNET** is the "oldest", but not by occasion is used until today. It can spread in distance up to 6 000 m and has high transmission speed - up to 2.5 Mbit/s. It is used mainly for local networks as all stations are with equal rights. The master for the moment is determined by the method "Token Passing".

Sensor-actuator bus (ASI) is spread only on 100 m and the transmission speed is not big. It works on the lowest level in a distributed system and the addressing can be done in two ways: by polishing from the master or by a special device.

The communication at **BITBUS** is done on higher level because of the local intelligence of the bus participants. The bus may reach the distance from 132 km and the information exchange speed - up to 2.4 Mbit/s. But the typical transmission speed is 375 kb/s. These characteristics permit the usage of BITBUS in systems with distributed control and the separate system modules may be placed even in different buildings. This is necessary when producing big and complex products containing modules with essentially differing production technology.

The bus **CAN** (Control Area Network) initially was designed for usage in mobile devices and that is why its maximum length is not big. But its suitability for work in real time is of big importance. These qualities and its high reliability and the very good arbitrating scheme of the access bring to its extremely quick distribution by the automation too, where very often the possibility to work in real time is a basic requirement. Its speed and the availability of a good and easily realized way of determination of the priority of the separate nodes make it very suitable for application in complex automatic production systems.

The **DIN-MeЯbus** is distributed in Germany and as it is obvious from its name is designed mainly for collecting data from test and control groups for the aims of tests. That is why only the first two levels in the model ISO/OSI are defined.

For the Japanese bus **FAIS** there is no much information. It is used mainly for data collection from input/output devices and control devices. It is not distributed in Europe and America.

The French bus **FIP** is one of the most commonly spread. It is used mainly on sensor/actuator level and that is why its maximum length is not big. Its way of addressing is original. It is object oriented: the variables (objects) are polished in a cycle from one of the stations in which the process "master" is situated. It is possible for the stations to give a request for transmitting of additional messages or for acycle polishing of a given object. The work speed is 1 Mb/s, but at certain conditions it can reach up to 5 Mb/s.

The fieldbus **FOUNDATION** is the result of the efforts of several big producers to create an universal fieldbus. Initially these "warring" between themselves producers create a foundation, which to make a standard for the fieldbus. Later the work upon the standardization leads to creating of the new bus, owning the understandings of this foundation for a fieldbus answering to all requirements of the standard. But the result is not very encouraging. The designed speed is 31.25 kb/s (a twisting couple) on a distance1900 m, but two more are forecasted: 1 Mb/s and 2.5 Mb/s. The master uses a list of the participants in the communication, which contains the moment for declaring of certain data necessary for the work of certain stations. When this moment comes the master requires from the device containing this data to declare them by broadcast.

Interbus-S permits work on great distances but the transmission speed is quite low. The peripheral devices have identification numbers by which the master ad-

Table 1*. Characteristic indicators of the most famous field buses

Fieldbus	Length	Speed	Number of participants	Arbitration	Addressing	Priority	Standardization
ARCNET	6 000 m	2.5 Mb/s	255	Token Passing			
ASI	100 m	167 kb/s	1 master, 31 slaves	Master / Slaves	Addressing device, master-polishing	-	wanted
BITBUS	13.2 km	62.5 kb/s - 2.4 Mb/s, typical 375 kb/s	1 master, 250 slaves	Master / Slaves Orientation on the messages	Addresses from 1 to 250	-	1, 2, 7 accepted from ANSI
CAN	1 000 m	1 Mb/s	32 for RS 485, 2032 log. limited	CSMA / CR, undestroyable, bitwise	Object oriented; 2 032 participants	2032	1, 2, 7
DIN-M	500 m	1 000 Mb/s	1 master, 31 slaves	Master / Slaves		-	
FAIS		10 Mb/s		Token Ring			
FIP	2 000 m	typical 1 Mb/s; up to 5 Mb/s possible	256	Master / Slaves	Object oriented: 65 536 variables, 16 000 messages	2	1, 2, 7
FOUNDATION	1900 m generally*	31.25 kb/s; foreseen 1 Mb/s, 2.5 Mb/s	up to 32	Centralized Master / Slave, decentralized Token Passing			
Interbus-S	12.8 km, up to 80 km	500 kB/s	1 master, 256 peripheral devices	Master / Slaves	Identification number	-	1, 2, 7
LON	6.1 km	1.25 Mb/s	32 385	predicative persistent CSMA / CD	Oriented to the participants, 5 types	128	1 - 7
P-Net	n*1 200 m	76.8 kb/s	125 (32 masters)	Master / Slaves Token-Passing		-	
PROFI-BUS	4 800 m	0.5 Mb/s; for DP 1.5 Mb/s	127 masters	Centralized: Master/Slave & Polling, decentralized Token Passing	addresses from 0 to 126	2	1, 2, 7

* The deviation length can reach up to 120 m and depends on the number of the included devices (see Table 2)

Table 2. The ratio between the number of devices included in one deviation and the length of the whole deviation (fieldbus FOUNDATION)

Number of devices in the deviation	Deviation length
25 32	1 m
19-24	30 m
15-18	60 m
13-14	90 m
1-12	120 m

dresses them. This bus works also on level sensor/actuator, but is designed for productions, where the controlled objects are situated on great distances and has no high requirements towards the transmission speed.

One of the most interesting fieldbuses is **LON** (Local Operating Network). Initially it is created for control of buildings (lightening, heating, closing and opening of doors and windows, water providing, lift movement etc.), and later it is spread in other fields. That's why the maximum possible number of participants is quite big. The way of arbitrating is similar to that in the bus CAN, but with LON a special algorithm is used for determining the possibility of successful transmission of messages on the network as the maximum number of priorities is limited to 128. At the same time an interesting scheme for the hierarchical structuring of the network is used which gives great freedom at its configuration. Besides LON is maybe the only field bus for which the whole 7 levels are defined in the model ISO/OSI, and software products are offered which help the development. As a shortcoming could be said that the number of the nodes in the network is given beforehand when creating of the concrete application and can not be changed after that.

P-Net is created in Denmark and is with universal application. Its speed is not big and the length is determined by the number of its nodes. The distance between two nodes could reach maximum 1200 m. The maximum number of participants is 125, but only 32 from them can be masters. When having more than one master the arbitrating is done by the method "Token Passing".

Profibus is a German bus and is distributed mainly in Germany. Its speed is not very high (500 kb/s), and the protocol is quite heavy. On the bus there could be up to

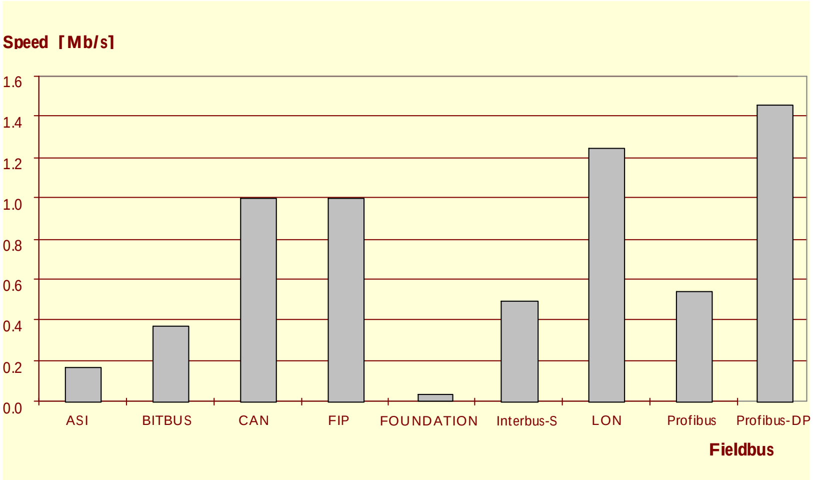

Fig. 2. Transmission speeds for some famous buses

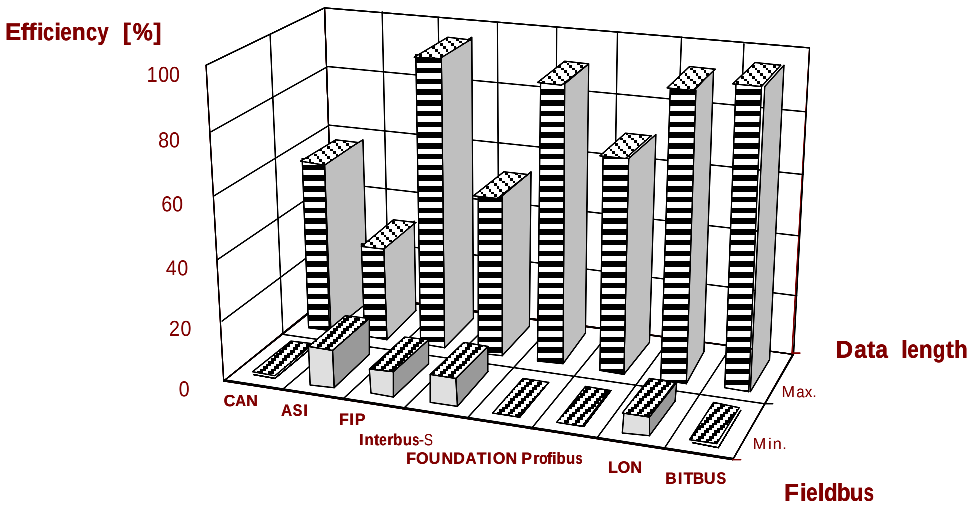

Fig. 3. Effectiveness of some of the most distributed fieldbuses

127 masters, and between them the active at the moment is determined by the method Token Passing". To each master there are slaves, which are polished by the master when it receives the token. The levels 1, 2 and 7 according to the model ISO/OSI are defined beforehand.

Because the proposed by Profibus speed is not high enough for some applications (level sensor/actuator), the firm Siemens has modified the bus using only a subset from its functions. At this modification (**Profibus DP** - Dezentrale Peripherie) the speed can reach 1.5 Mb/s. But already devices are presented working with a speed from 12 Mb/s. The modification is used at quick data exchange between central automation systems and easy peripheral devices (slaves).

On figure 2 the ratio between the transmission speeds for the used at the comparison fieldbuses could be seen.

An important characteristic of the buses is the transmission effectiveness i.e. the ratio between the common length of one message and the length of the useful information in it. On figure 3 these ratios of the separate buses are presented graphically. Most ineffectively the short messages are transmitted of course. But they are used comparatively often. The optimal effectiveness is reached when the maximum possible length for useful information is used. But this happens rarely especially by the buses, which permit very big lengths. The typical messages in the network LON for example are with length of 2 bytes (11% effectiveness), while the highest effectiveness is reached with length of 228 bytes (93%). In this aspect the buses like CAN for example appear more effective. They do not offer big lengths of useful information (8 bytes only), but they are with comparatively constant loading. In them messages with 0 bytes length are barely sent although such possibility exists. In fact their effectiveness moves between 14.5% and 58%.

In many cases the effectiveness depends on the participants number (for example by the Interbus-S) or on the message type (transmission of variables or of service messages on the fieldbus FIP), so the comparisons can not be made at absolutely equal. The comparison of the transmission speeds is also difficult because the carrying media is different. It must be accounted also that some of the buses can work with different carrying media. Beside the distance, which the bus covers, can also influence the speed (the fieldbus CAN).

For the aims of the comparisons made in the article the aspiration was to be used the best shown results in practice.

4. Conclusion

The contemporary tendencies when creating distributed systems enforce architectures of module type and the bus plays an important role. It connects the separate modules in one whole and many requirements appear towards it:

– possibility for widening, changing or decreasing of the system configuration
– possibility for including of modules of different producers
– possibility for connecting with other buses
– possibility to form a bus hierarchy- speed, corresponding to the functionality of the distributed system
– reliability in aspect of disturbances, etc.

A great variety of field buses exist on the market. From one side this makes the things easier for the users because it gives them the possibility to use the most suitable system. From the other side the confirmation of the standards and the producers aspiration for their execution assures possibilities for communication between the different buses. The discussions on these questions are hot and the standardization is slow.

The development of the field buses and networks is quite rapid as in aspect of the protocol and structure also in technological aspect. In the near future many achievements are expected in technological and structural level. It is not already utopia for anybody the whole management of plants and concerns – beginning from the production process level and reaching the administration. Hierarchical network systems are created in which different types of buses participate – field, local and even global. Some possibilities are thought of for fieldbuses with the network of integrated services ISDN and for creating of super great networks on the base of the technology ATM.

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Полевые магистралы – сравнительный анализ

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В данной статье осущевляется анализ характеристик множества наиболее распространенных полевых магистралей. Представлена также классификация критериев их оценки. Критерии в основном разделены на две группы - технические и стратегические. Подробно рассмотрены характеристики множества наиболее известных полевых магистралей с точки зрения предсталвеных критериев. Для анализа подбраны магистрали различных классов (общего и специального приложения), охватывающие полную палитру полевых магистралей: работающие на низких и высоких уровнях (в соответствии с моделью OSI). Построены сравнительные таблицы и диаграммы, отображающие важные для магистральей показатели (скорость, эффективность) и насколько любая из представленых магистралей “покривает” наиболее важные из обсужденных критериев.