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Field bus: a user approach

J.-C. Orsini

Merlin Gerin
Modicon
Square D
Telemecanique

Schneider Electric

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no. 197

Field bus: a user approach

Jean-Christophe ORSINI

After graduating from the Institut National des Télécommunications in 1987, Mr. Orsini entered into Schneider Electric's Automation activity in 1988. He participated in the development of several communication couplers for Schneider Electric Programmable Logic Controllers (PLCs) on different networks. For the past four years, he has been working on expanding the connectivity of Schneider Electric PLCs.

ECT 197 first issue, March 2000

Lexicon

AS-i (**A**ctuator **S**ensor **I**nterface): Standard for level 0 field buses (or sensor and actuator buses).

ASIC (**A**pplication **S**pecific **I**ntegrated **C**ircuit): Integrated circuit – electronic component – dedicated to a specific application – for example communication protocol management – as opposed to a general circuit, such as a microprocessor.

Automated system object: Modelled and structured representation that describes the functions, offered services and the behaviour of an automated system.

Bandwith: Measures the width of the frequency range in which signals are transmitted with a loss of less than three decibels. By extrapolation, refers to the maximum useful rate of the medium.

CAN (**C**ontroller **A**rea **N**etwork): Group of networks used in very large numbers in the automobile industry, which enable connection at a low cost.

C.I.M. (**C**omputer **I**ntegrated **M**anufacturing): Concept consisting of computerised production units. It defines the hierarchy of used equipment and networks, from the sensors and actuators connected to field buses up to the management computers connected to public networks.

Company network: Local network used in administrative and management applications.

Coupler, or **communication interface:** Electronic device that enables a device to be connected to a network.

Device Net: Field bus based on CAN technology.

Equipment / device: Signifies, in this document, any automated product that is connected to a bus: PLC, variable speed drive, pneumatic distributor, robot, human / machine interface, etc.

Ethernet: Network standard based on the CSMA / CD access procedure to the medium.

FIP (**F**actory **I**nstrumentation **P**rotocol) **/ WorldFIP:** Field bus that covers levels 1 and 2 (European standard EN 50-170).

Frame: A succession of bits or characters emitted in an uninterrupted manner by a device on the network and which constitutes coherent information that can be interpreted by the receiver(s) (messages, questions or answers, value broadcasting, etc.). Frame length (i.e. the number of bits or characters) is always limited.

IB-S: Abbreviation for **I**nter**B**us-**S**.

Industrial LAN: Local network used in an industrial environment (production, etc.).

Interbus-S: Standard for level 0 and 1 field buses.

Java: Object oriented computer language.

LAN (**L**ocal **A**rea **N**etwork): Network that is limited to an area which does not exceed a few kilometres; in general, it refers to networks that are restricted to a building or a company, i.e. which remain in the private sector and do not enter into the public sector; as opposed to WAN (Wide Area Network) for networks such as the Switched Telephone Network or the Internet network.

Medium: Physical communication support (twisted pair, coaxial cable, fibre optic).

Message: Information exchanged on a network via services defined in a messaging protocol: read, write, download memory, files, etc.

Profibus: Field bus included in the European standard EN 50-170, and which covers levels 1 and 2.

Protocol: Relative to an ISO layer, it refers to the dialogue rules between the same layers of communicating units.

Services: Dialogue rules for two adjacent layers. For example, addressing service offered by network layer 3 to the transport layer 4.

TCP (**T**ransport **C**ontrol **P**rotocol) **/**
IP (**I**nternetwork **P**rotocol): De facto standard made popular by the Ethernet and Internet networks that cover ISO layers 4 (TCP) and 3 (IP).

Variable: Structured information, characteristic of a process, and conveyed on a network (motor speed, mobile position, etc.).

WAN (**W**ide **A**rea **N**etwork): As opposed to LAN; network that covers a large area, in general a public network: Switched Telephone Network, Internet, etc. Note: as of a few years ago, the term MAN (Metropolitan Area Network) has been used; this term deals with rapid networks that cover a few dozen, even hundred kilometres (metropolitan areas).

Field bus: a user approach

In the past few years, network technologies of the “field bus” type have surfaced and replace traditional cabling for input / output of programmable logic controllers. Consequently, automated system architectures have considerably evolved. This “Cahier Technique” deals with the “field bus” concept in the manufacturing industry from a user standpoint. Over and beyond cost and performance criteria, it attracts the attention of specifiers and contractors to the importance of the needs concerning interoperability and durability.

Contents

1 Introduction

1.1 Background

To begin with, it is interesting to place the emergence of the field bus in relation to the short history of programmable automated systems:

The appearance of the Programmable Logic Controller

In the 1960's, the cost of electronics dropped to a level low enough so that it could advantageously replace cabled relay logic. Discrete transistor logic modules surfaced, such as the MOG by Merlin Gerin and the Téléstatique 1 by Telemecanique. Very simple to assemble, they seduced automated system technicians. In 1965, germanium for transistors was replaced by silicon and gave birth to the SILIMOG. It is welcomed by the majority of customers up into the 1980's.

In 1968, Modicon invented the programmable logic controller concept. A single device meets the great multiplicity of needs and provides great savings. Thanks to its great operational flexibility, numerous advantages result in all life phases of the installation.

Networks started to pop up here and there as well; at first in the shape of serial links. Protocols formalise exchanges. Since then, Modbus (1979), contraction of MODicon BUS, has become a de facto standard. However they are limited to cases where parallel wiring does not suffice:

- inter-PLC links,
- links with computers,
- monitoring,
- connection of program consoles, etc.

The appearance of field buses

Cost reduction in the field of electronics continued – in particular thanks to the use of ASICs in products – and thus network techniques became advantageous in comparison to point to point links to connect PLC inputs / outputs: These techniques constitute the field bus (see **fig. 1**).

The appearance of standards such as WorldFIP and Profibus as well as the Modbus Plus network followed.

In 1993, Telemecanique marketed its first complete industrial offer based on the WorldFip standard for the remote operation of PLC inputs / outputs (FIPIO) and inter-PLC synchronisation (FIPWAY). Siemens provided a similar offer based on the Profibus standard. During this same time period, Modicon marketed the Modbus Plus network, a true equipment unifier.

1.2 Present evolution

In the past few years, a great number of applications have opted for the field bus. This backbone for automated system architecture appears as an extremely powerful means of exchange, display and flexibility for the equipment included in it.
The field bus has led to a gradual upheaval of architectures:

- the elimination of input / output cables,
- the disappearance of input / output interfaces,
- the disappearance of dedicated serial links.

Aside from these architectural aspects, two other points should be highlighted:

- the decentralisation and distribution of intelligence,
- the arrival of New Technologies (Internet, etc.).

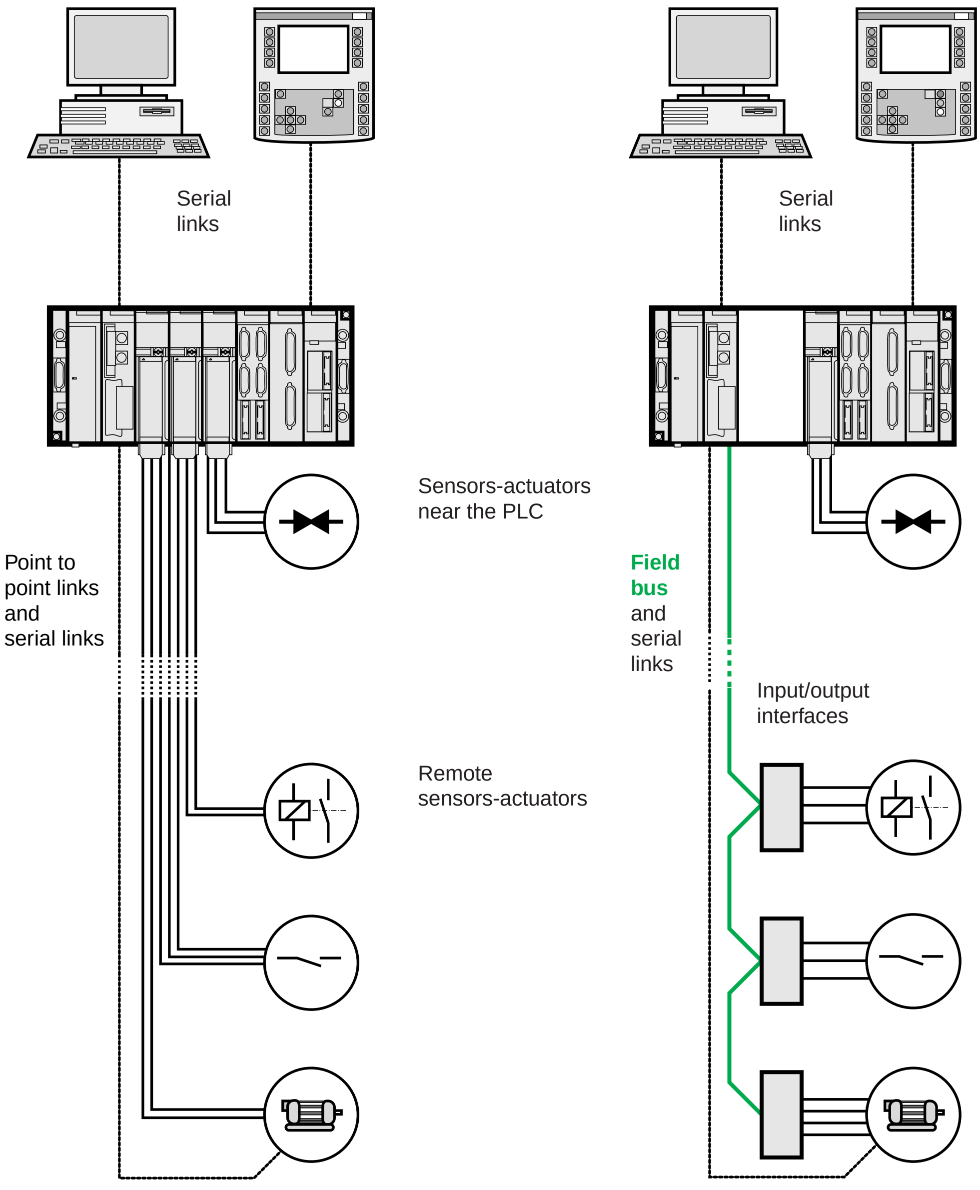


Fig. 1 : connection of input / output interfaces.

The elimination of Input / Output cables

Cabling costs were first reduced by placing the Input / Output interfaces outside of the programmable logic controller (PLC) so as to place them nearer to sensors and actuators (see fig. 1).

The disappearance of Input / Output interfaces

However, once this step was taken, users quickly understood the benefit of having sensors and actuators themselves directly connected to the bus. It is used as a means for interconnecting devices. This is particularly true for devices that are different since they come from different sources, as well as through their type, such as:

- pneumatic distributors,
- variable speed drives and axis control devices,
- welding or screwing machines,
- various identification devices,
- human / machine interfaces,
- activity specific equipment,
  - weighing,
  - vision, etc.

This connectivity sometimes even justifies the use of a field bus for small distances thanks to its flexibility and upgrading possibilities (see **fig. 2**).

Indeed:

- Some of this equipment (variable speed drives, screwing machines, etc.) simultaneously needs a digital Input / Output link and a serial link to the PLC: the field bus replaces both of these.
- The use in sealed environments of certain other devices made traditional cabling particularly expensive.
- AS-i type buses offer more economical solutions than traditional cabling for the simplest (however also the greatest in number) sensor and actuator connections – pushbuttons, light strips, motor starters, etc. – even for short distances.

The installation becomes a sort of construction game centred around the network cable, which becomes the cabling standard instead of point to point links in 0-24 V or 4-20 mA.

Furthermore, a great deal of diagnostic information, which is detailed on sensors and actuators, is made accessible on all points of the installation thanks to this evolution.

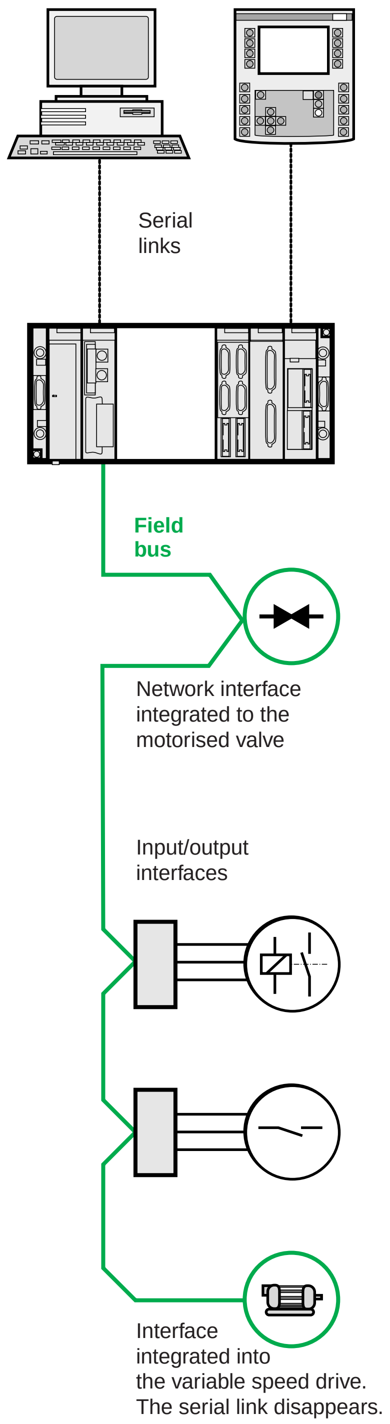


***Fig. 2** : disappearance of input / output interfaces.*

The disappearance of dedicated serial links

With a real communication channel thus created, much greater quantities of information can be conveyed. This led users to use it for functions for which they used dedicated communication means before:

- parameter configuration,
- diagnostic tools,
- programme loading,
- operator interface, etc.

For example, the dedicated serial link used in the past by the operator interface is eliminated and the field bus used in its place. This channel gives it access from every point of the installation, not only to the PLC data, but also to the data of all connected equipment: micro-PLCs, etc. (see **fig. 3**). This of course is limited by the performances of the bus being dealt with: a single type of network cannot satisfy all needs.

The decentralisation and distribution of intelligence

Above and beyond these architectural evolutions, the field bus makes way for decentralisation, or even the distribution of intelligence (refer to these notions in "Cahier Technique" no. 186, § 3.1):

- The decentralisation of intelligence allows for:

□ Greater design modularity. The specialist can treat his field and offer an interface to the designer of the entire system. This modularity is an advantage for the quality of the system and thus for development cost control.

□ Better reactivity of the automated system thanks to the use of nano / pico-PLCs closer to the process.

□ Greater reliability in regard to breakdowns. Degraded functions can be locally planned for certain breakdowns.

- The distribution of intelligence to different devices helps improve performances by allowing each automated device to treat that part of the process for which it is the most capable.

It favours the possibilities for reusing equipment and software modules. It may even go as far as eliminating the central processing unit; however, at present, this is slowed down by the complexity of the mechanisms to be implemented.

New technologies

Nowadays, Internet technologies, through their mass distribution, are revolutionising the computer field. This surge reaches automated systems, triggers desires and overstatements, with possibilities being explored, dealing with CORBA, JAVA, ACTIVE X, etc.

At the network level, two tendencies have surfaced: on the one hand, Ethernet coming down to the field bus levels, on the other hand the position strengthening of a few level 0 buses, such as AS-i. The invasion of widely distributed network components is to be mentioned as well (example: CAN, which came out of the automobile industry).

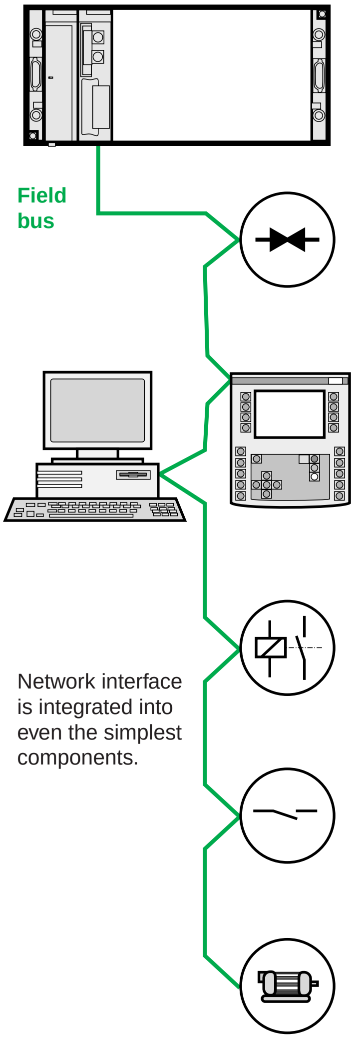


Fig. 3 : disappearance of dedicated serial links.

1.3 Field bus evaluation

But how should the user manage this technological evolution? How can one determine the advantages that it brings and take this into account when choosing automation products?

For a needs and constraints analysis, this document provides a great deal of autonomy to the user for his evaluation.

The questions that an automated system technician asks himself in regard to an application, and which he must transfer to field buses, are centred around four themes:

- cost,
- performance,
- interoperability,
- durability.

Cost

First of all, the possibility of cost savings led to the emergence of the field bus. The first question that the automated systems technician should ask himself is: “Will the use of a field bus in my application be economically advantageous?”

Performance

This is above all a constraint:
“If I determine that x bus is economically advantageous, how can I be sure that its performances will satisfy the requirements of my application?”

Interoperability

If the analysis of the preceding criteria is favourable, it suffices to make sure that the different automated products required for the application can indeed function together depending on the specific needs of this application: what kind of guarantee is available before acquiring and testing the equipment?

Durability

Lastly, once the benefits and feasibility of field bus implementation have been proven, the durability needed for this type of installation must not be overlooked: return on investment requires a certain amount of caution in regard to new technologies. If technologies of the field bus type are at present well established, their multiplicity does not always guarantee that investments will last.

To sum up

The first two criteria, cost and performance, are part of a technical-financial analysis concerning field bus technologies. The latter two, interoperability and durability, depend rather on user confidence: market analysis, builder strategy, the attitude of builders in regard to standards, etc. are to be taken into account.

Of course, market penetration of a standard remains the best indicator of confidence.

2 Performance at the lowest cost

2.1 Cost

In the cost impact analysis of a field bus, it is important to take the life span of an automated system into account, from its design to its disassembly.

Design

Simplicity of the connections to be installed in the case of a field bus (in comparison to traditional cabling) contributes to savings in the cabling diagram. Design modularity (different activities working at the same time) considerably lightens studies.

On the other hand, the introduction of new technology and new types of equipment implies the need for training. It is therefore the source of new expenses. Thus the interest of using different standards or technologies only when it is clearly justified in terms of cost or performance.

Supply, installation and commissioning

When implementing, savings result from:

- reduced cabling costs,
- shorter times, which means savings, through:
  - reducing cabling work,
  - testing modularity,
  - easier / simpler parameter configuration, setting, downloading,
  - increased diagnostic capabilities.

In the case where the bus is used to replace links that were previously dedicated to human / machine dialogue, to diagnostic, programming or parameter configuration tools:

- elimination of certain dedicated communication couplers,
- elimination of dedicated network cables.

However, the additional costs of automated system components must be taken into account.

So as to be able to calculate overall costs, the user must then compare the price of the same automated system component in its traditional version and in its field bus version. He should not forget to take all accessories into account: cables, connectors, special software programmes, implementation costs, etc.
Certain partial data, such as the cost of an ASIC, are sometimes placed first. An analysis that is incomplete to this degree is to be avoided.

Operation (functioning and maintenance)

Simplified maintenance thanks to:

- Reduced cabling and connections

Cable lengths and complex trunkings, as well as the number of connections (all types), which are sources of breakdown, are reduced, thus increasing installation reliability even more. This is subject to the choice of a bus with an immunity that is adapted to industrial electromagnetic disturbances.

- New diagnostic capabilities

Even the simplest sensor-actuators can provide a great amount of diagnostic information.

- Better modularity

The distribution of intelligence favours the implementation of more precise and improved self-tests thus of the reliability in regard to breakdowns and evolutions.

- Standardisation of components

The variety of means to route information is thus reduced: couplers common to several products (see **fig. 4** next page), cables and connectors common to different product categories replace various line links, serial links, and high rate networks. The stock of spare parts and thus maintenance costs are reduced.

- Cost of breakdowns

Diagnostic information that is available in products enable for both certain breakdowns to be avoided and to reduce the time needed for repairs. Production shutdown costs linked to breakdowns are thus reduced as well.
However, only well integrated tools and mature technology really give access to these advantages.

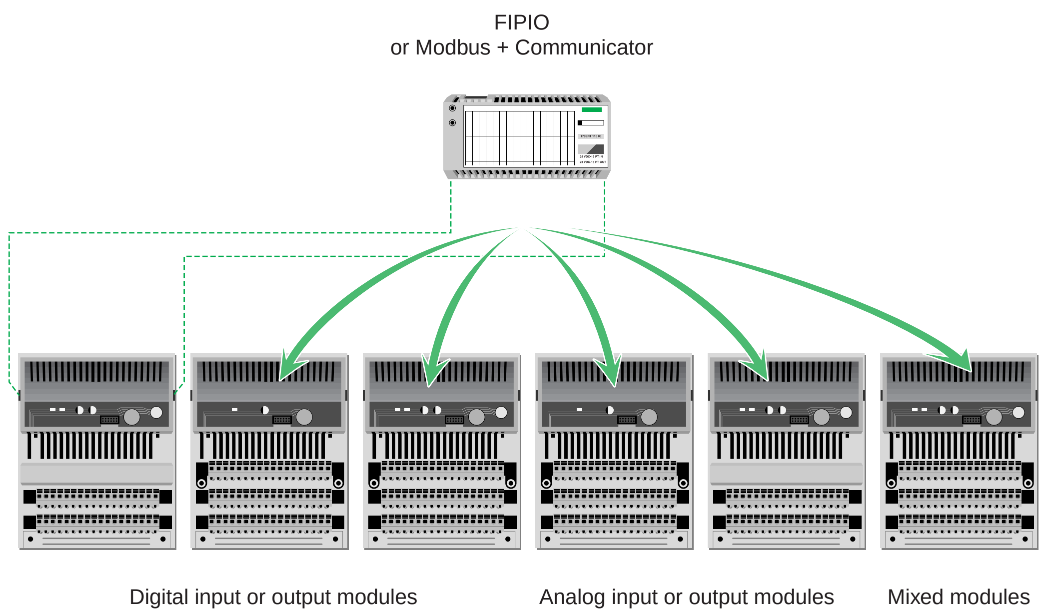


Fig. 4 : a single FIPIO communicator coupler for all the Schneider MOMENTUM modules.

Renovation

Upgrading an application is greatly simplified with the use of a field bus. For example, the entire cabling system of a machine was changed between Friday evening and Monday morning in a large automobile manufacturing plant without production losses. This type of intervention would have been entirely impossible using traditional cabling.

Disassembly

Here too, the use of a field bus helps to reduce costs:

- reduced “de-cabling” costs,
- best possibilities for reusing equipment.

The cost impacts of the different life phases of the installation are shown in the chart in **figure 5**.

Various studies have been published on this subject, as well as the assessment reports of numerous real applications, to which you can refer to acquire a more in-depth view of costs (refer to the bibliography).

However, cost analysis cannot be dissociated from that of performance.

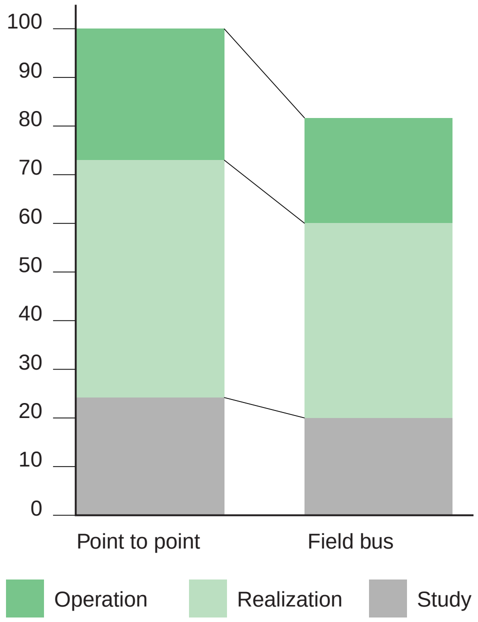


Fig. 5 : impact on costs due to the use of a bus.

2.2 Performance

Types of constraints

Amongst user needs, the following must be distinguished:

■ Constraints linked to the application environment:

□ power supply of connected equipment,

□ number of sensors-actuators,

□ required distances,

□ electromagnetic disturbances,

□ mobile elements,

□ topological constraints,

□ tightness,

□ harsh environment (salt, water, acids, etc.),

□ explosive environment, etc.

The user must write up a complete list of these constraints, to which a manufacturer must be able to commit. Consequently, bus evaluation concerning these aspects does not pose a major problem because the characteristics of this type are in general well identified. For some of them, standards define the level of compatibility to which each one refers. This is particularly true for that which deals with environmental constraints.

■ Time constraints

□ maximum response time, in function of the number of Inputs / Outputs.

□ rate of data needed for the application.

The field bus has underlined the necessity of time performance calculations, which were already taken into account by PLC manufacturers in their traditional architectures, based on cyclic mechanisms. This merits a more in depth explanation.

Automated bus performances

The time requirements of an automated bus are different from those of a company network or a public network (WAN), primarily concerning two aspects:

■ Order of magnitude

Automated systems in the manufacturing industry more often require short delays (from one ms to several dozen ms) to route short information (binary) than high transfer rates for large quantities of information. For large transfers (programme downloading, etc.), a certain slowness is allowed as long as the binary values (valve closing, etc.) continue to be transmitted within the same delays.

Furthermore, in certain cases, specific constraints, such as equipment synchronisation, are also required.

■ Determinism

For the correct operation of an automated system application, the transfer of certain information must be conducted in a limited amount of time. The field bus contributes to this factor.

Even if a page takes a few seconds to appear on a PC screen, for instance 1% of the time, this can be tolerated. This is however not the case when dealing with the information from the safety cubicle of a railway barrier that is closing on a car!

Determinism is a property that authorises the theoretical calculation of the maximum guaranteed transfer times to the bus in function of operating conditions (number of devices, etc.).

Deterministic bus mechanisms are given in the appendix: some of them allow for this determinism to be guaranteed for critical information while also managing less important exchanges (human / machine dialogue, diagnosis, etc.).

The benefit of determinism for networks used in automated applications has been the subject of numerous debates over the past few years. Without questioning its importance, the notions of determinism and safety mechanism must not however be confused. The fact that all applications have a breakdown ratio linked to the equipment, environment, etc. must be taken into account as well. Thus, in the given example, whether or not the bus is deterministic, a safety mechanism stops the barrier in case of a break in the medium. The only risk, with a non deterministic bus, is that the barrier be stopped not because of a break in the medium but rather due to traffic that is too high. To avoid this situation, i.e. so that its probability be less than the allowed breakdown ratio, the load level of the non-deterministic bus must simply be limited. The use of non-deterministic buses is therefore possible with higher rates, which indeed are higher cost factors. Technical evolutions and the effects of volume make it competitive; Ethernet, which is non-deterministic, after having replaced the token bus 802.4 a few years ago, is being considered today on the field bus level for the same cost reasons.

Evaluation criteria

■ What is to be calculated?

The user often has to calculate time performance. He should in particular be concerned with the relevance of the figures that have been provided in regard to his needs.

Different values can be found:

□ medium rate,

□ network cycle time,

□ response time of the automated system concerning a particular action,

□ global response time of the process.

The user should attribute a great amount of importance to applicative data, which are the only ones that are significant for him. He is typically interested in the input / output response time (measure or calculate the amount of time between the activation of an output following the activation of an input), the following being specified each time:

□ the nominal value,

□ the maximum guaranteed value.

Information, such as medium rate or network cycle time, can only be used once a more in depth analysis has been conducted.

■ Performance cycles

Most automated buses operate on cyclic polling principles: information is acquired at the rate of a cycle that is infinitely repeated. Each piece of information is acquired once in the cycle.
In the worst case scenario, if the time of acquisition takes place just before a change in status, the latter is transmitted in the next cycle (see **fig. 6**).

Certain types of buses, such as WorldFIP, allow for a macro-cycle to be defined, which is itself made up of elementary cycles (see Appendix). Certain pieces of information are then exchanged upon each elementary cycle whereas other pieces are only exchanged once every two elementary cycles, or even once per macro-cycle. This allows for the refreshing period for each piece of information to be adapted to required response times.

Likewise, the PLC programme is characterised by a cycle time. Some sensors-actuators contain a software programme that operates according to a cyclic mechanism. Each time an event occurs at the input of one of these cyclic systems, a complete system cycle, at most, must take place, before being able to treat it. The maximum global response time is thus the sum of cycle times. However, a significant difference between this maximum time and nominal performance (events occurring in the middle of a cycle) may arise (see **fig. 7**).

■ The impact of the medium access principle

Depending on the access procedure to the bus medium, the impact of the bus cycle time may be different. For example, depending on the case, transmission of information to a receiver may take place as soon as the information is made available on the bus or may take up to a complete cycle (see **fig. 8**).

Comparisons of buses with characteristics of the medium rate or cycle time type, are thus insufficient – sometimes abusively used – and can lead to false conclusions concerning response times if they are dissociated from the operating principles of the bus.

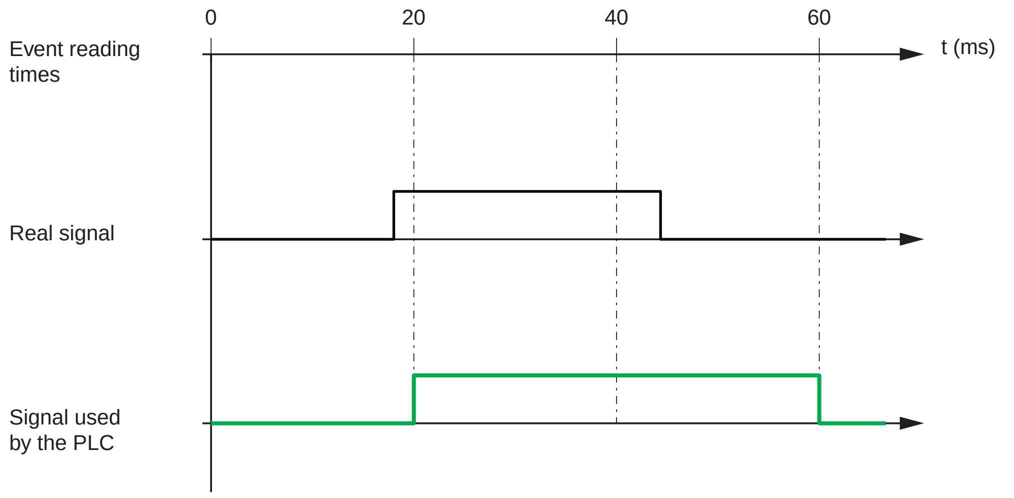
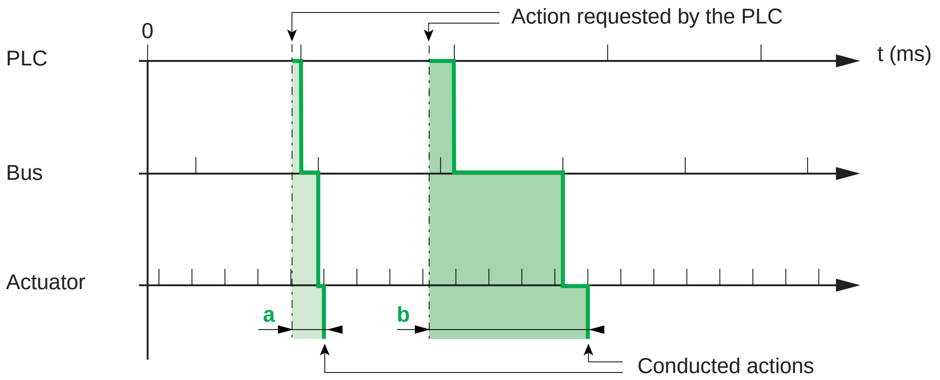


***Fig. 6** : response time fluctuation when using a cyclic mechanism.*

Reliability

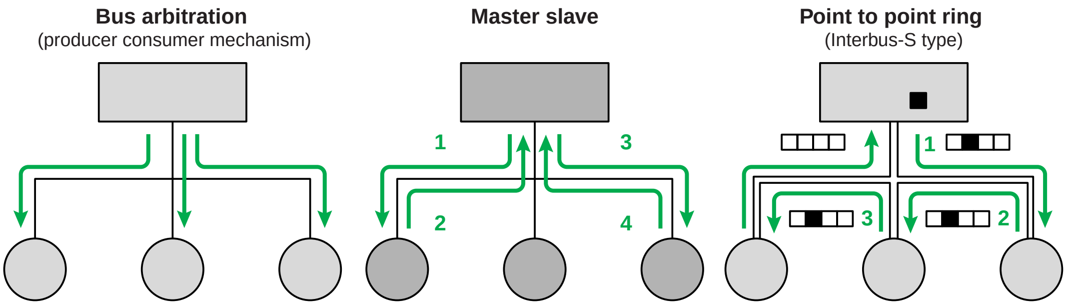
Reliability is a performance criteria. In the field of operational safety, everything or almost everything can be evaluated, and everything, of course, has its price. Total, absolute, reliability would have an infinitely high price. In critical cases, where safety appears as a major project constraint, it is absolutely necessary to conduct an evaluation with a reliability expert, so as to be justifiably confident in the implemented system.

In other cases, a simple evaluation is sufficient. The user should take into account the risks and the means that he has available to cover them. The notion of risk is a synthesis between the cost of a feared event and the probability of it taking place.



a - Minimum delay for taking into account **b** - Maximum delay for taking into account

Fig. 7 : impact of successive cycles on response time.



The information is broadcasted: as soon as it is made available on the bus, it is accessible by all of the connected equipment.

The information, as soon as it is made available on the bus, is accessible to the master (**1** and **2**). However, if it is to be transmitted to another slave, another complete cycle, in the worst case scenario, must have evolved (**3** and possibly **4**).

The information circulates on a single frame that travels from one device to another. A network cycle corresponds to the time needed to conduct a complete loop.
When one device wishes to transmit information, it will wait, in the worst case, for one complete cycle to take place before being able to insert the information into the frame. Then this information will, in the worst case, need one complete cycle before arriving at its destination, and this depending on the respective positions of the emitter and the receiver in the loop.

Fig. 8 : impact of the cycle time on the response time, depending on the access procedure to the medium.

A priori, except for complex architecture that tolerates breakdowns, a bus fault can block the entire application.

Even so, field buses contribute to improving the application availability (and through this to a reduction of the global cost of an automated installation), by:

■ making diagnosis easier (addition of diagnostic information, breakdown search tools, cabling simplicity),

■ separating functions,

■ facilitating (and thus making it more rapid) the replacement of a processing module.

However, not all buses offer the same level of service concerning this point:

■ On the one hand, the quality of the diagnosis varies depending on:

□ the information provided,

□ the means of accessing this information.

■ On the other hand, the continuity of supply in the case of de-energisation, disconnection or breakdown of a device varies from one bus to another.

Certain buses are especially designed to manage availability. For example, Modbus+ allows amongst other things medium redundancy. These characteristics constitute a choice criteria for users. Each person should evaluate their importance in function of his needs.

2.3 Optimising the cost / performance ratio

The technological limits at present

To date, a single network cannot satisfy the needs of all applications, in particular in terms of cost and performance, but also concerning the constraints related to environment, connected products, standardisation, etc.

Present technologies are a satisfactory answer in terms of cost for the connection of simple input / output equipment due to the fact that they only require limited exchanges, in general over limited distances. Inversely, for equipment that needs greater exchange volumes, often over greater distances, the cost, which is higher, of the needed technologies is acceptable in regard to the higher cost of associated equipment.

Cost and performance objectives thus go hand in hand and have led manufacturers to offer technical solutions that are adapted to the required levels. A classification of network solutions has thus been implemented: it joins the C.I.M. pyramid structure.

Field bus classification

The diagram in **figure 9** shows the range covered by each of the main automated system bus standards in this hierarchy. The different aspects are thus correlated:

■ Targeted characteristics

□ volume and type of exchanged information,

□ price of network couplers,

□ required reaction time,

□ maximum network lengths,

■ Associated classification

□ C.I.M. pyramid levels,

□ names of network groups,

□ place in standard architecture.

Of course, all values are but orders of magnitude.

This classification allows for the target of a bus to be quickly understood, or inversely, for a list of buses to satisfy a need. This merits a few explanations so as to be correctly understood and used advisedly:

■ It is not discontinuous. The objective is limited to identifying the zone in which a bus ensures the best response for cost / performance optimisation. The ratio progressively worsens as one moves away from this zone.

■ The user may be enticed by standards that cover several levels. Indeed, the fewer the number of different networks used, the more

□ investment is reduced

- training,

- standardisation of managed equipment, etc.

□ freedom for defining automated system architecture,

- making any device dialogue with any other device in a transparent manner

- avoiding gateways and the writing up of dedicated programmes to manage exchanges, etc.

It is also an indicator of the solution durability. Since it is not too specialised, it is better placed to ensure its own profitability through the volume effect, thus, for that which concerns the user, its durability. This is the case for Modbus Plus, which is remarkable because of its unifying aspect.

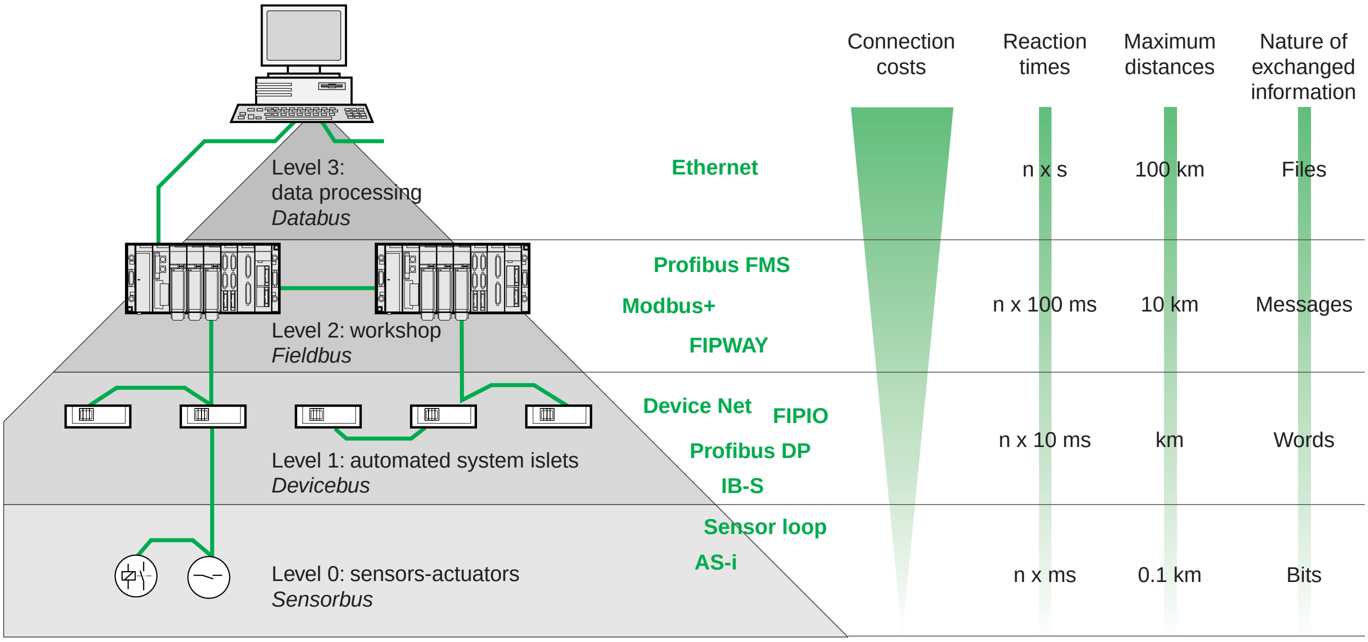


Fig. 9 : field bus classification.

Numerous standards thus respond, in good conditions, to the needs of levels 1 and 2, sometimes overflow into the bottom of level 3 and / or the top of level 0.

On the contrary, due to high cost constraints at level 0, the buses located at this level rarely overflow more than a little bit into the bottom of level 1.

The user must be careful to not be fooled by a so-called universal bus that in reality cannot ensure the cost / performance compromise at all levels. It is better to have a gateway that is correctly integrated into the automated system than a bus that is too expensive on one part of the application. Thus, gateways allow for AS-i equipment to be connected to FIPIO or Modbus Plus architecture.

A few precisions need to be made concerning two sources of confusion:

- Communication profiles

In certain cases, variations are hidden in the same standard – communication profiles – that segment the desired cost and performance levels. Between them, the compatibility level varies.

- Technologies

Most buses offer different technical solutions – different ASICs in particular – to connect to the bus at a cost adapted to the connected product and to its performances. Therefore, a component that is particularly adapted to level 1 and another particularly adapted to level 2 can exist. The existence of several well-targeted components allows the manufacturer to offer products with an optimised cost / performance ratio.

The user must have a good understanding of these notions, which will be detailed below. If not, he sometimes discovers too late that behind the same description there are actually two different buses.

Communication profiles

A network standard defines the rules that aim at allowing conform devices to communicate with each other. However, most standards offer, or authorise for lack of precision, operating alternatives that are completely incompatible with each other, each being adapted to a specific utilisation. Simply complying with the standard thus rarely guarantees that what the user is looking for, i.e. inter-device communication.

A communication profile is supported by a network standard and aims at defining, in the framework of this standard:

■ on the one hand, choices (amongst the different alternatives offered by the standard),

■ on the other hand, any eventual additions to the standard, needed to guarantee communication between devices that comply with the profile.

It thus selects all the characteristics in the standard that are adapted to the given utilisation, for example remote connection of PLC Inputs / Outputs (level 1) or synchronisation of PLCs (level 2).

For the user, it is a better guarantee of interoperability. Furthermore, this allows him to benefit from the advantages of the non-multiplication of network types, under the condition, however, of correctly understanding the range of these profiles and associated limits.

In particular:

■ Are cabling tools (cables, connectors, etc.) the same for each profile?

■ To what degree can two devices that are each conform to a different profile, but that have the same bus, inter-operate? If not, is there compatibility for a sub-assembly of the protocol? If the answer is negative, using these profiles is equivalent to using two different buses.

Example of a communication profile

On the basis of the WorldFip standard, two profiles have been defined and are offered on Schneider Electric products:

■ FIPIO, I/O bus for PLCs (level 1),

■ FIPWAY, synchronisation bus (level 2).

The definition of such profiles that are integrated into PLC systems, provide the user with a guarantee of the operating compatibility, without him having to broaden his knowledge of the WorldFip standard.

In this example, FIPIO and FIPWAY equipment cannot be connected to the same network, however:

■ cabling tools are the same in both cases,

■ both profiles are supported by the exchange of variables and messages from the WorldFip standard:

□ the variables are different in both cases: PLC I/Os for FIPIO versus synchronisation information in the case of FIPWAY;

□ the same messages, however, can be routed from one profile to another. The only difference is located in the bandwith that is available for this messaging: weak on FIPIO versus strong on FIPWAY.

This allows:

□ for messaging to transit in a transparent manner from FIPIO to FIPWAY and vice versa,

□ the program consoles to be indifferently connected to FIPIO or FIPWAY,

□ equipment parameters – or operator dialogue connection – that uses messaging, to be indifferently configured on FIPIO or FIPWAY,

□ identical diagnostic tools – e.g. network analyser – to be indifferently used on FIPIO or FIPWAY, thus limiting the need for user training.

For the Profibus standard, Profibus DP and Profibus FMS offer a similar structure.

Technology

This term is used here to indicate the hardware and / or software components that allow for product operation conform to a standard and / or a communication profile to be ensured.

A same standard may be implemented by different technologies (component) that allow for it to best adapt to the communication needs of each device:

■ equipment connected to the lowest levels do not necessarily offer all the proposed functions, however they all have a common core that allows them to dialogue with each other,

■ the significant exchange needs in quantity and diversity of the most complex equipment do not lead to high connection costs for the simplest equipment.

Each device uses technology – a component – that depends on its own exchange needs and not on the bus to connect itself.
This is similar to the profile notion: components are often specified to implement all or part of the profiles in a standard.

Example concerning technologies

The WorldFip standard uses 3 types of components:

■ FULLFIP and FIPIU tolerate all the possibilities in the standard, including the messaging and bus arbitration functions.

■ FIPCO manages the exchange of variables without restrictions (excluding the bus arbitration and messaging functions). It is piloted by a micro-controller.

■ MICROFIP allows for a simple device to be connected (inputs / outputs only) without a micro-controller.

Figure 10 illustrates the use of these different components in the case of a remote input / output bus on a PLC.

The PLC, thanks to the FIPIU or FULLFIP component, thus has all the possibilities offered by the FIP bus, including the bus arbitration function that allows it to manage access to the medium for all of the connected equipment.

Operator dialogue connected using the FIPIU component: this allows it to access, through messaging, all of the PLC memory to display a large variety of information needed by the operator.

Variable speed drive controlled using a few input / output words and the parameters of which can be configured using a few dozen configuration words. It is connected using the FIPCO component that is piloted by a micro-controller from the 8051 family. Exchanges remain rather simple, however are greater in size.

Module that manages 8 digital inputs and 8 digital outputs connected to a bus using the MicroFip component, without a micro-controller. This is a very low cost solution, however the only information that can be exchanged is input / output information.

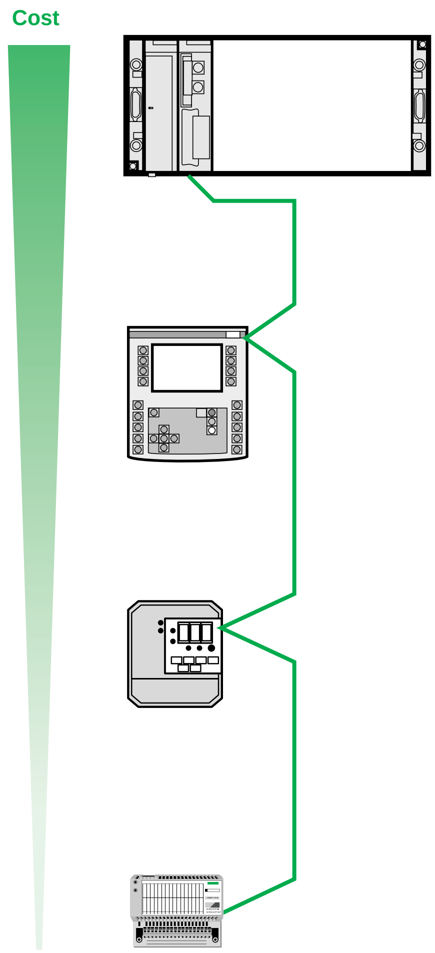


Fig. 10 : cost-performance optimisation through the use of appropriate components.

3 Interoperability

After having chosen a bus according to its characteristics, it is necessary to make sure that the different devices to be connected can function together by performing the exchanges required by the targeted application. The term "interoperability" is used to qualify this "correct operation".

However, before going any further, the terms used in this field must be clarified.

3.1 Definitions

Example

These definitions are illustrated using the example of a variable speed drive that exchanges information with a PLC via a WorldFip network:

- Two variable speed drive input words
  - on / off motor command,
  - set speed.
- Three variable speed drive output words
  - actual status of the motor (on / off),
  - set speed applied to the motor,
  - measured motor speed.

Furthermore, this variable speed drive must receive parameters from the PLC to operate.

Conformity

Conformity with a standard simply indicates compliance with its specifications. This in no way guarantees the correct operation of equipment in the framework of an automated system application:

- The standard can offer several options: the correct operation of two devices implies the choice of the same options or, at least, compatible options.

Example: the medium rate, the type of access to variables (either through a physical address, or through a name) or the list of implemented services can be the object of a choice.

- The standard may contain specification gaps that allow for interpretation by each device. Two devices cannot inter-operate if the same key point has been interpreted differently by manufacturers.
- Certain standards only deal with part of the ISO layers (see Appendix) and therefore cannot alone allow two devices to exchange information. For example, Ethernet (or 8802.3) exclusively processes layers 1 and 2, TCP / IP only layers 3 and 4.

In the given example, conformity of the variable speed drive signifies that it exchanges its inputs / outputs and its parameters through frames that are conform with the WorldFip standard. The parameters, for example, can be exchanged via WorldFip variables or messages: in both cases, the variable speed drive is conform.

Interoperability

Interoperability is the ability of two devices to dialogue with each other. However, this notion needs to be clarified so that a user may make full use of this concept: Indeed, two devices can inter-operate extremely well concerning certain services and not at all for others. The user must determine whether the services and functions, for which the devices inter-operate, satisfy the needs of his application.

So as to facilitate this step, some buses define communication profiles (see § 2.3) that specify the chosen options and exact characteristics of the exchanged information.

In the given example, even though they are both conform to the standard, the variable speed drive and PLC cannot inter-operate, if:

- the variable speed drive receives its parameters through the messaging frame,
- the PLC only manages variables.

Interchangeability

Interchangeability implies the possibility of replacing one device with another of the same type, and which ensures the same functions and offers the same services on the bus: for example, a variable speed drive can, or not, be replaced by another without modifying the automated system application, i.e. without touching the applicative programme of the PLC in the given example. On top of the interoperability between the PLC and each of the variable speed drives, this requires that the nature and type of information that is exchanged with the PLC be identical no matter which drive is being used.

This notion requires more than simply being conform to the network protocol. Indeed, it implies the definition of the list, the structure and the characteristics (nature and type) of the information managed by all of a certain type of equipment. This notion deals with equipment profile.

Coming back to the given example, let us suppose that the variable speed drive exchanges the status of its inputs using a WorldFip variable that contains first of all the on / off command, then the speed data.

Another variable speed drive exchanges its inputs using the same variable but in which the speed data comes first and the on / off command second. This variable speed drive too inter-operates with the PLC. However its information is not interchangeable with the first variable speed drive. An equipment profile, which defines the semantics of each of the input / output words of a drive, allows for interchangeability to be ensured. On the other hand, this prevents the user from benefiting from specific functions that are available on certain products. Moreover, some manufacturers see it as an obstacle to the possibility of enriching their offer. On the contrary, some users see in it the possibility of interchangeability.

It is clear that, for complex equipment such as variable speed drives, the number of parameters that need to be taken into account, especially real time behaviour, make interchangeability a goal that is difficult to reach.

Equipment profiles can be defined independently from the used network: then all that needs to be specified for each network are the communication objects used (frame types: messages, variables, etc.) to exchange functional objects defined in the equipment profile.

Schneider Electric variable speed drives are conform with the DRIVECOM equipment profile.

3.2 What are the operational guarantees?

Objective

The user should obtain guarantees in regard to:

- interoperability, above anything else, to ensure the correct operation of the targeted application,
- conformity with a bus standard so as to ensure that correct operation is not limited to the utilisation being dealt with and to offer the best guarantees in the case of upgrading: use of new services, change in product, etc.
- interchangeability, if need be, to have the possibility to change products, even suppliers, for example for upgrade or maintenance purpose.

What are the means for obtaining these types of guarantees? This is detailed in the following paragraphs.

Associations

Most field buses are promoted by an association that groups together the manufacturers of products connected to the bus (or which may be connected). Some of these associations also regroup users, which is clearly an advantage. For example, associations have been set up for the Profibus, WorldFip, Device Net, Interbus-S, and AS-i standards.

These associations contribute to promoting their standard and associated technologies and guarantee compliance with the standard by each of their members.

However, the quality of their internal functioning varies. Many of them are primarily animated by a big PLC manufacturer and to which peripheral product manufacturers adhere.

The advantage is the associated manufacturer guarantee, which is the best indicator of the good functioning of an association. This also eliminates any risk of difference of opinion amongst its members. However, the probability of this standard becoming a common standard for several big PLC manufacturers is low. A special case is that of the Interbus-S club animated by Phoenix, which manufactures peripheral products but not PLCs.

Among these associations, the good functioning of the AS-i consortium, in which Schneider Electric and Siemens partake, is to be noted. This association groups together major manufacturers that are not only members, but that also offer large catalogues of competitive products. It has been able to manage standard evolutions and product compliance with it.

Some associations offer certificates of conformity. This contributes to limiting risks, but does not guarantee interoperability.

Organisations for standardisation

Certain buses are conform to international (ISO, IEC, etc.) or national (IEEE, UTE, etc.) standards. This constitutes a quality guarantee for the user and can be of importance in regard to public markets.

Since, however, bus technologies constantly evolve, it is often difficult to make them compatible with the consensus and thus with the delays needed to draw up a standard.

Setbacks concerning standards are numerous. In the world of automated systems, the MMS standard must be cited. Requested by users, implemented above Ethernet by the vast majority of suppliers, it never really left the ground. Despite minor problems due to its novelty, it correctly satisfied the needs of a good number of applications. Today, virtually all applications use proprietary messaging. Was standardised messaging really needed?

Notoriety

Many proprietary networks have become “de facto standards”. This has been true in the industrial world for the past few years for Modbus / Jbus, Unitelway, etc. This is also true for the computer world with de facto standards such as TCP / IP which have been largely developed to the detriment of equivalent ISO standards.

The appearance of a de facto standard through technology penetrating in a market (industry in general, significant industrial sector i.e. automobile, etc.) is clearly an indicator of correct operation of products that comply with it. For example, CAN components, from the automobile sector, are interesting for the automated systems industry because of their low cost.

Likewise, a certain number of technologies from the computer industry, which represents a much greater market than the automated systems market, have penetrated into the industrial world. This is for example in another field, the case of PCs which have replaced the consoles dedicated to programming PLCs.

Likewise, the ISO 8802.4 standard, dedicated to automated systems for level 2 networks, was not able to withstand the Ethernet penetration (ISO 8802.3). The few advantages of 8802.4 for automated systems were not convincing facing:

- the enormous Ethernet network base already installed in factories for data processing needs,
- cost reductions and the multiplicity of tools available for Ethernet, induced by the effects of volume that are unique to the data processing market.

In brief, the notoriety of a standard, synonymous with volume, and therefore feedback, is for the user an indicator of good functioning. The volume of the compatible product catalogue is a good indicator for it.

Manufacturer guarantees

Lastly, one of the best guarantees for correct operation of heterogeneous equipment in the framework of a distributed installation remains the guarantee by a big manufacturer. This of course implies that such a manufacturer is willing to open its architectures. This is the case today of the main PLC manufacturers – Rockwell, Schneider Electric and Siemens – which master a field bus technology, integrated in a privileged manner into their offers:

- PLC CPUs, with integrated bus connection,
- wide range of digital and analog IP20 and IP65 I/O modules,
- a large number of connected devices by the manufacturer and partners, which are sometimes competitors:
  - pneumatic distributors,
  - position encoders,
  - variable speed drives and axis control products,
  - robots,
  - identification: bar code readers, inductive readers, etc.
  - Human-machine dialogue products,
  - products specific to an activity: screwing, welding, etc.
  - display systems,

- I/O exchanges and diagnosis transmission that are harmoniously integrated in the programming language and programming and diagnostic tools for PLC manufacturers products as well as for partners products.

For this, manufacturers have set up partnership programmes to accompany automated system product manufacturers that are likely to connect to their bus. Thus, Schneider Electric, with its Modconnect programmes for Modbus Plus, and Fipconnect for FIP, today merged into Schneider Alliances, offers its partners equipment and software solutions to simplify the development of their connections as well as interoperability tests that provide common customers with all the guarantees for correct operation.

True, it is preferable in this context that the field bus technology backed by the manufacturer be a standard that is guaranteed by an official organisation and supported by a club or association in which many companies participate, including users. Likewise, the credibility of this "opening-up" strategy implies that it authorises the connection of products that are in competition with this manufacturer. However if there is technical and financial implication by a major manufacturer:

- that provides guarantees for bus operation which it masters, in particular concerning systems aspects, and global performance, which is impossible with solutions that are too heterogeneous,
- for which it can ensure all the necessary technical support,
- with devices that it has validated, including third-party devices,

this makes the motivation to satisfy him more believable to the customer.

This implication helps limit the situations, which are frequent when dealing with networks, in which each network connection product supplier blames the other for malfunctions.

Lastly, this solution limits the multiplication of suppliers to the real need only, i.e. even calls upon a new supplier when it has a new and specific competency in a given activity, for example:

- The use of a pneumatic or welding product when the PLC manufacturer does not offer this type of product.
- The choice of a product that is in competition with the product of the PLC manufacturer when the competitor's product has functional, technical or financial advantages in comparison to the equivalent product from the PLC manufacturer.

Based on the construction logic of an automated system architecture offered by a big PLC manufacturer, it allows for costly adaptations for equipment, training and global control to be avoided:

- multiple gateways,
- heterogeneous tools, etc.

Interoperability today

In the near past, interoperability and conformity preoccupied and for a reason users who were confronted with malfunctions.

Today, this is no longer the case:

- Maturity of network technologies in the industrial world.
- Taking these risks into account by the manufacturers through more rigorous testing (conformity and interoperability with various equipment, including that of competitors).
- Better defined standards.
- Often, the guarantee by a big manufacturer of technology that it masters.

As for interchangeability, it is but at its beginnings.

4 Durability

4.1 Stakes

Once, one or several field bus technologies having been identified on the basis of cost and performance criteria, and the guarantees obtained for correct operation of the automated system application targeted by this technology, the user should ensure himself of the durability of the application, and in particular of the durability of the chosen field bus technology.

For the automated system technician, it deals with the guarantee that the products that he uses will have a life span (commercialisation then maintenance) that is compatible with his needs.

Automated system products represent in general a small part of global installation costs. This installation investment is high and is not intended to be replaced in the near future: life spans are in the region of 10 to 20 years. Yet, automated system products are more and more based on – in particular following the introduction of the field bus – electronic and computer technologies, the life spans of which are clearly smaller and which constantly evolve. In sight of the constant progress in the field of electronics, who can predict with certitude that anyone of the present technologies will still be used 20 years from now?

4.2 Tendencies

Before dealing with durability, it is necessary to specify the directions in which techniques evolve.

Three tendencies take shape today:

Rise in the field of application for buses

The first tendency is the increasing capacity of buses to cover several levels of the C.I.M. pyramid. Each bus attempts to evolve so as to broaden its field of application, therefore, in a pragmatic manner, its potential market. This is the answer, within the limits of technology, to the ideal request from users who would like to have a single, universal network that meets all of their needs.

Taking into account the present technical possibilities, the main tendency consists of extending level 0 buses to the bottom of level 1, while extending level 3 buses towards level 2.

Thus, the AS-i bus evolves to be able to manage analog information whereas the use of Ethernet, very present at level 3, is called up by level 2, even level 1.

Studies have been conducted concerning the ability to meet the needs of these levels, so as to benefit from cost reduction due to the mass distribution of this technology.

An Ethernet coupler is already available for Input / Output modules in the MOMENTUM range by Schneider Electric. Simultaneously, level 1 and 2 field buses, which are widely implanted in industry and which adequately satisfy users' needs, evolve to cover a wider field of application:

- rise in the medium rate, for better performances and to better cover level 2 even the bottom of level 3;
- new components, connectors, etc. that are less expensive and simpler to use, to expand towards the top of level 0;
- an always more complete catalogue of products adapted to special environments:
  - tight products,
  - modules compatible with explosive environments,
  - cables that withstand all types of harsh environments (salt, acid, oil, solar radiation, …) etc.
- taking into account the TCP / IP protocol to open up to Internet and take advantage of the technology wave at a low cost, while preserving characteristics adapted to the industrial environment.

It is therefore difficult today to say in which direction this will evolve. Different possibilities are being studied by the manufacturers.

Equipment profiles

Today, field bus technologies are widely used and already provide more than the benefits initially expected. The market is thus ready to move on to the next phase, if the users find new advantages in it, in particular a way to make new savings. Standardisation work concerning equipment profiles is underway and in which Schneider Electric participates. It will deal with an increasing number of equipment categories. A multiplication of equipment solutions for equipment profiles can thus be expected. Furthermore, these profiles allow for high-level automated system objects to be defined. They will facilitate users' work:

- programming,
- maintenance,
- interoperability,
- interchangeability, etc.

Distribution of intelligence

Lastly, after having enabled inputs / outputs to be placed at a distance, and having often contributed to the decentralisation of intelligence, the field bus today opens the way to the distribution of intelligence.

Indeed, in the beginning, the programmable logic controller was above all the idea of a computer that contains input / output interfaces. If these interfaces can as of now communicate with the computer via a network, the PLC – simply fitted out with a network interface, like all computers today – looses all its particularities.

True, this reasoning is a bit simplified. As such, a PC does not integrate certain PLC operational values such as reliability or durability. However, PLC cards already exist for PCs, which allow advancement in this direction without a break in operational continuity, (all the while keeping durability in mind) and the use of field buses amplifies this tendency even more.

Automated system architecture is thus reduced to a field bus upon which the following can be connected:

- different automated components that integrate all or part of automated intelligence,
- Human-machine interfaces,
- the programming terminal, which via the bus distributes the programme to the different automated components,
- possibly, a central unit in a PLC, which is present and available when automated components are not able to integrate all the needed processing intelligence (see **fig. 11**).

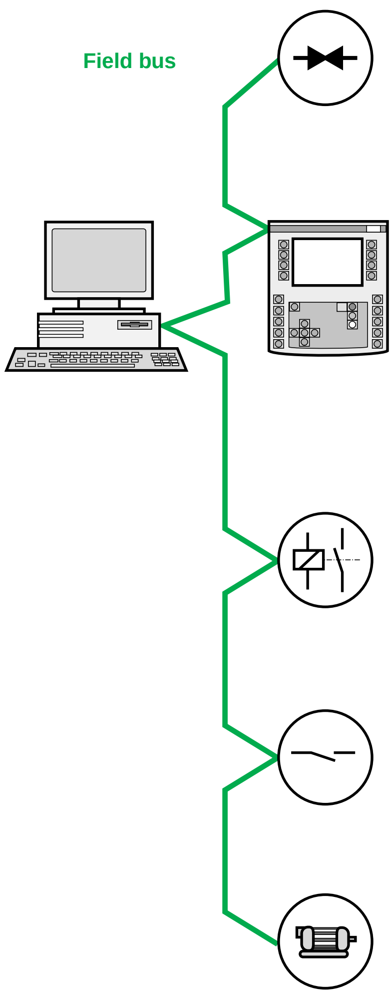


Fig. 11 : intelligence distributed to automated system components.

4.3 Guarantees for durability

The notoriety of a standard has already been mentioned as one of the guarantees of correct operation. The appearance of de facto standards that have widely penetrated the market also constitute an indicator of durability. However, any standard, even widespread, will eventually evolve or even become obsolete. This can be seen on a daily basis in the computer field where even the most widespread standards are abandoned because durability is not a strong requirement in this field.

Facing evolutions, simultaneous mastering of programming workshops and used network technologies have more than ever become fundamental in the world of automated systems. The user should be supported by a company that is capable of providing, with its partners, a complete system ensuring its correct operation and both corrective maintenance and upgrading. Facing the multiplication of heterogeneous equipment and the present technological path, needs concerning durability remain. PLC manufacturers, aware of this major need, know that the answer lies in long-term marketing and maintenance. Despite the ongoing evolution of technologies upon which they base themselves, they also know, when need be, how to ensure the “gentle migration” to these new technologies by using all sorts of solutions:

- automated application conversion,
- gateways,
- maintaining former technology in parallel with new technology on new products.

As an example, there is no equivalent life span in the computer world for communication protocols such as Modbus.

The functioning of companies, the activity of which is not based on supplying global solutions for automated systems nor the need for durability that goes along with these solutions, and which only master one type of product and not necessarily buses to which the product is connected, may lead the user to have to deal alone with this obsolescence at extortionate prices.

In a broader fashion, equipment and software tools used by automated system technicians have necessarily become commonplace through the arrival of technologies stemming from the Internet world. However, in this context, technicians’ needs for a credible interlocutor are even greater. This interlocutor has to be able to master both this new supply of equipment and software and the constraints linked to this activity.

5 Conclusion

The programmable logic controller has revolutionised the activity by introducing electronic and computer technologies into the heart of control systems for automated processing. The field bus has become yet another revolutionary component by spreading these same technologies as well as network techniques, up into sensors and actuators. Included in the processing assembly, they are at the basis of an enormous potential for evolution:

- They have already, by successive steps, revolutionised architectures, providing advantages that were not always expected in the beginning. Technical-financial compromises still maintain for the moment traditional solutions in parallel.
- Beyond this, processing itself has been questioned: decentralisation then distribution of intelligence. On top of technology, this leads to the need for standardisation: it is already underway and will continue in the next few years.
- Lastly, it brings with it an infinite number of innovations that could revolutionise automated systems: Java, Corba, internet, Active X, etc.

Along with the evolutions brought by technology, a certain rationalisation of the offer can be expected: the user will congratulate himself on this. A rise in bus performance and thus their field of application is inescapable even if the universal bus capable of meeting all types of needs will probably never exist.

Facing this upheaval, the user must of course be cautious and keep in mind the constraints specific to his activity (environment, durability, etc.). However he should also be careful to not miss the boat.

In particular, durability should not be confused with standstill. For the user, durability means:

- a guarantee that products will be available in the long-term,
- as well as (and maybe even above all) “gentle migration” solutions when he considers that new technology may be profitable for him.

Through investment in field bus based technologies,

- he can already profit from the advantages recognised today (cost reduction, flexibility, diagnostic ability, etc.)
- he will be better informed to be able to judge for himself each of the upcoming evolutions, have an influence on them, even ask suppliers for them, rather than simply passively accepting them.

Appendix

Access procedures to the medium

This paragraph explains the basic principle behind a few of the most common procedures for access to the mediums. Deterministic procedures (see § 2.2) and non-deterministic procedures can be distinguished.

Deterministic procedures

■ Master-slave

In a medium access procedure of the master-slave type, a single device, the master, initiates all exchanges; the other devices, the slaves, simply answer the requests of the master. This principle can be found on a significant number of networks that are based on a serial link of the RS 485 type with protocols such as Modbus. In this case, exchanges are programmed by the user, and if random applicative events are likely to trigger such exchanges, the network is not of the deterministic type. However, this procedure can serve as the base for defining cyclic polling of information by the master on a defined number of devices.

The time needed to poll all the devices makes up a cycle time, which is the maximum delay for each device to convey its information. This is the principle used for example with the AS-i bus.

■ Bus arbitration

The procedure is quite similar to the preceding one (master-slave procedure with a definition of the equipment polling cycle) since a single bus-arbitrating device allows each of the other devices to “speak” in turn. The main difference is that when a device “speaks”, it can address information to any other device or to all of them at the same time (broadcasting).

This is the principle used for example with the WorldFIP bus.

■ Token ring

This type of procedure is defined by the 8802.4 standard. A token, which corresponds to the right to speak, goes from station to station according to a predetermined order. Each station can emit to any other station as long as it has the token, however it can only keep it for a limited time, defined during configuration. This is the principle used by the Modbus Plus network.

Non-deterministic procedures

■ CSMA / CD - Carrier Sense Multiple Access / Collision Detection

This is the access principle to the medium used in buses of the Ethernet type (ISO 8802.3 standard). A device that wants to send a frame, attempts to transmit it then verifies that no collision occurred (i.e. that another device tried to send information at the same time). In the case of a collision, it tries again after waiting a certain amount of time, which is randomly determined.

Thus, frame transfer time is linked to a delay after which a collision is avoided: it is therefore a static function of the number of devices that try to send frames, thus of the network load.

Sharing the bandwith

Certain buses can guarantee transfer delays for certain information (typically remote PLC inputs / outputs) while preserving part of the bandwith to convey information for which the transfer delays are not critical.

Illustration using WorldFIP

The WorldFIP bus is based on processing a network cycle or macro-cycle, through equipment that has the bus arbitration function. This cycle is made up of elementary cycles of the same length and which have an identical structure.

The length of an elementary cycle is structured on time frames allotted to:

■ cyclic (periodic) traffic of variables and / or messages,

■ acyclic traffic of variables,

■ acyclic traffic of messages,

■ maintaining all elementary cycles synchronised.

Each portion of the cyclic traffic is allotted once and for all to a process datum: for example equipment Inputs and Outputs. Contrarily, acyclic traffic corresponds to an allotted time but is only used upon request (see **fig. 12**).

Thus, three types of exchanges share the bandwith on a WorldFIP network:

■ Cyclic variables, for critical time control and monitoring functions.

■ Acyclic variables, transmitted upon request and on status changes.

■ Messaging, acyclic as well, for downloading and maintenance functions.

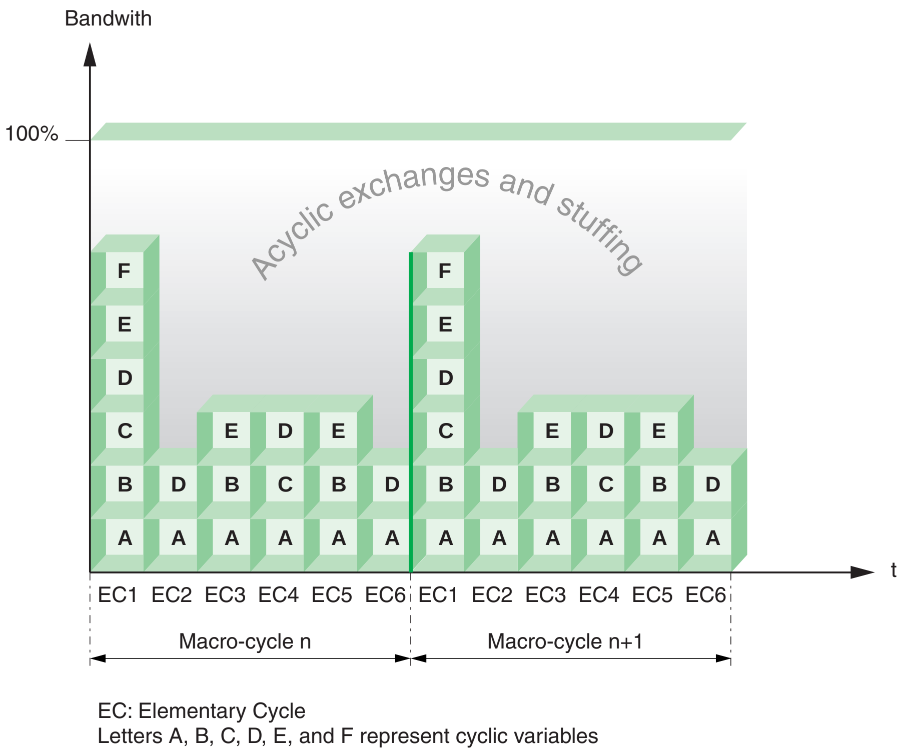


Fig. 12 : the WorldFIP macro-cycle.

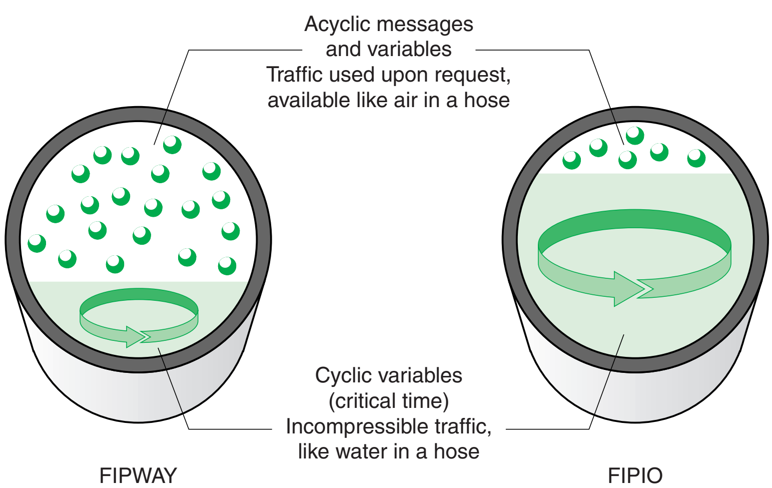


Fig. 13 : WorldFIP: a hose at the adjustable water level. Illustration: FIPIO and FIPWAY.

The portion of the bandwith that is allotted to each of these flows is an important element in a WorldFIP configuration. By privileging one type over another, networks are specialised for an application of the reflex PLC type or for co-ordination between monitoring and operator dialogue devices.

Thus, a WorldFIP network can be compared to a hose through which different types of data flow, the "level" of each data type is determined by its configuration (see **fig. 13**).

Illustration using Interbus-S

This is a “point-to-point ring” mechanism, a single frame travels from one device to another:

When the frame passes, the device reads the part that contains the values of its inputs and writes on the part that contains its output values. On top of this, the frame contains from 0 to 4, 16-bit words that can contain a message fragment (in general, four words does not suffice to transmit a message), that allow for such a fragment to be transmitted at each bus cycle.

For example, for a messaging channel of 1 word, the rate per slave is 256 octets / sec. If the cycle has 32 slaves and 1024 I/O.

Illustration using MODBUS PLUS

Likewise MODBUS PLUS simultaneously offers functions that need a deterministic procedure, such as cyclic updating of inputs / outputs, and other functions that do not need this, such as on-line programming. “Logic sessions” ensure proper mechanics and thus are dedicated to these different functions.

The AS-i case

On AS-i, a contrario, all exchanges are cyclic: equipment inputs / outputs flow once every 5 ms whereas the parameters of each device flow once every 31 cycles. It is not possible to add additional traffic to this. Due to this, AS-i cannot tolerate messaging. This is clearly not its goal.

The OSI model by ISO

The OSI model (Open System Interconnection) defined by ISO (International Standard Organisation) segments functions of a system that communicates using 7 layers. These layers range from functions nearest the network (cable, etc.) to functions nearest the communication needs of devices (nature and meaning of exchanged information, etc.) (see **fig. 14**):

The main objective of this structure is to allow for the standard of a layer to be changed independently from the others. Thus, for example, a twisted pair link can be locally replaced by a fibre optic link to travel across a zone that is subjected to electromagnetic disturbances, all functions of the other layers remaining the same: information content, messaging addressing, access procedure to the medium, etc.

Nevertheless, not all networks use all the layers. This is the case in particular for field buses that are primarily based on a 3-layer structure: 1, 2 and 7. This simplifies the operation of communication couplers and authorises high performances and low costs.

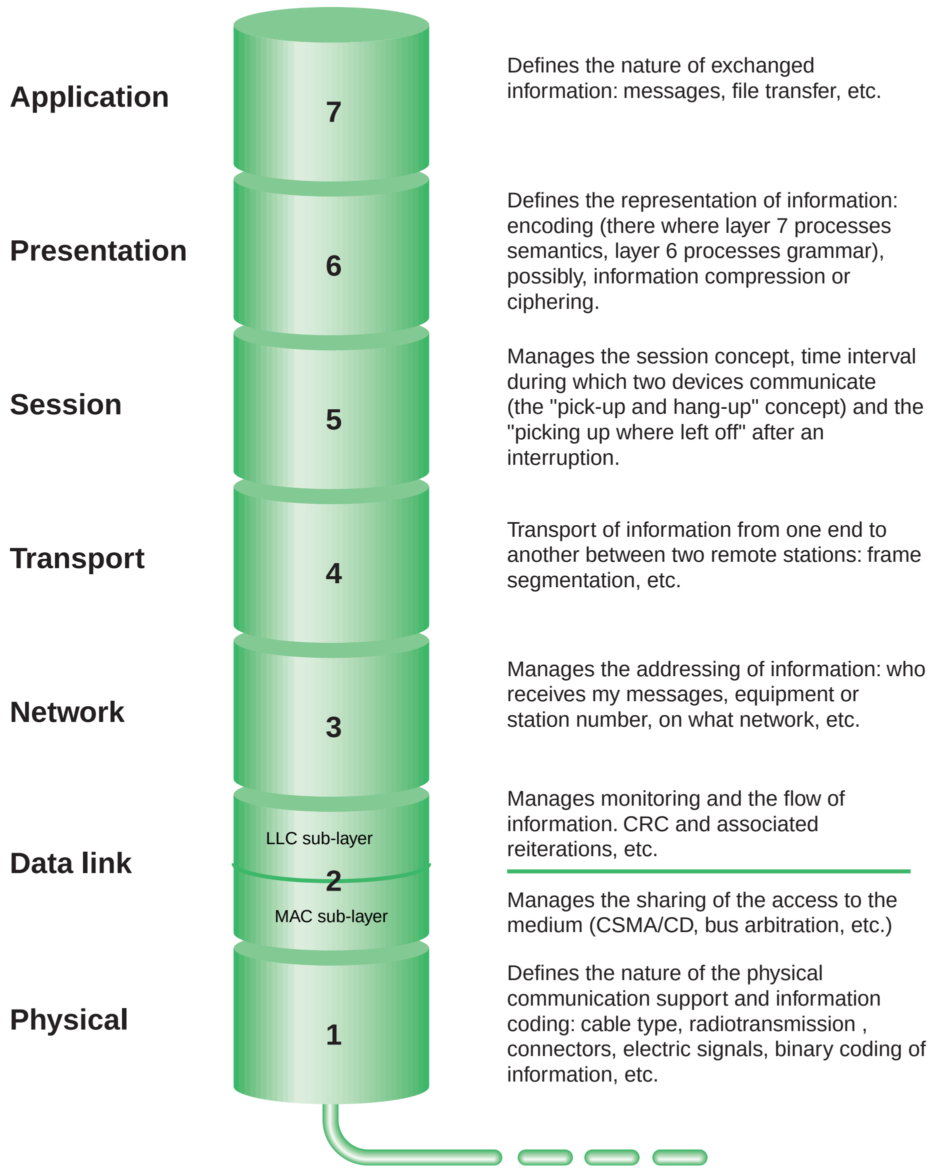


Fig. 14 *: the OSI model.*

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Schneider Electric

Direction Scientifique et Technique,
Service Communication Technique
F-38050 Grenoble cedex 9
Fax: 33 (0)4 76 57 98 60

DTP: AXESS - Saint-Péray (07).
Edition: Schneider Electric
Printing: Imprimerie du Pont de Claix - Claix - France - 1000
- 100 FF -