FIP NETWORK

GENERAL INTRODUCTION

ALS 50249 b-en

1st issue: 05 / 1990
Revision 02 / 2000

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FIP NETWORK
GENERAL INTRODUCTION

REFERENCE No.

ALS 50249 b-en

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REVISION TABLE

Index letter	Date	Nature of revision
b	02-2000	ALSTOMISATION

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1. INTRODUCTION

The FIP time critical bus is a field bus network involving the lower levels of control process systems and discrete piece manufacturing.

At this level, the data exchanged are of different types :

- values sampled from the process by means of sensors for processing by the control systems,
- commands produced by the control systems and feedback to the process by actuators,
- information exchanged between control systems in the context of an application involving equipment such as programmable controller class or smart sensors and actuators class,
- information required for monitoring, control, command and maintenance.

The first three types of exchanges can be described as horizontal trafics since they involve information to be shared between sensors, actuators and control equipment (programmable controllers).

These exchanges should take place taking into account the particular requirements of distributed real time applications, mainly concerning compliance to the exchange periods.

The last type of exchange can be described as vertical since they involve the information necessary for control and monitoring of the processes. These exchanges cannot be foreseeen and, in general, are less stringeant from the timing point of view.

FIP has been designed to simultaneously satisfy the requirements of periodic communication in critical time and those of aperiodic communication with the higher levels.

2. GENERAL PRINCIPLES

2.1. REVIEW OF THE ARCHITECTURE

In a production system, the control functions are ensured by a control system supported by various decentralized items of equipment interconnnected by a communication system.

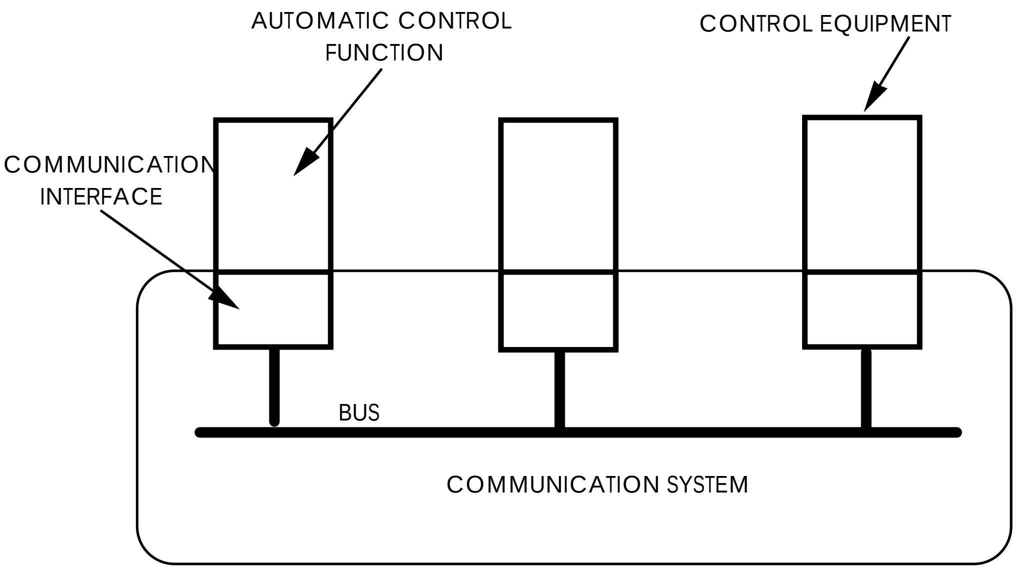


Figure 2.1.1: Architecture of a process control system

Control equipment simultaneously ensures the functions of automatic control and the functions of communication enabling information exchanges with the other equipment.

The communication interface has a layered structure with the functions of each layer resting on those offered by the lower layers.

2.2. STRUCTURE OF THE FIP COMMUNICATION SYSTEM

The FIP communication system is divided into three layers whose respective functions correspond to the OSI (Open System Interconnection) model of the ISO (International Standard Organization) :

1 : physical layer,
2 : data link layer,
7 : application layer.

It is covered in France by the following UTE standards :

- C 46-604 Physical layer in base band on shielded twisted pair
  (certified)
- C 46-607 Physical layer in base band on optical fibre
  (provisional)
- C 46-603 Data link layer
  (certified)
- C 46-602 Application layer - Periodic and aperiodic services
  (certified)
- C 46-606 Application layer - Message transport service
  (being developed)
- C 46-601 General presentation architecture
  (being developed)
- C 46-605 Network management
  (provisional)

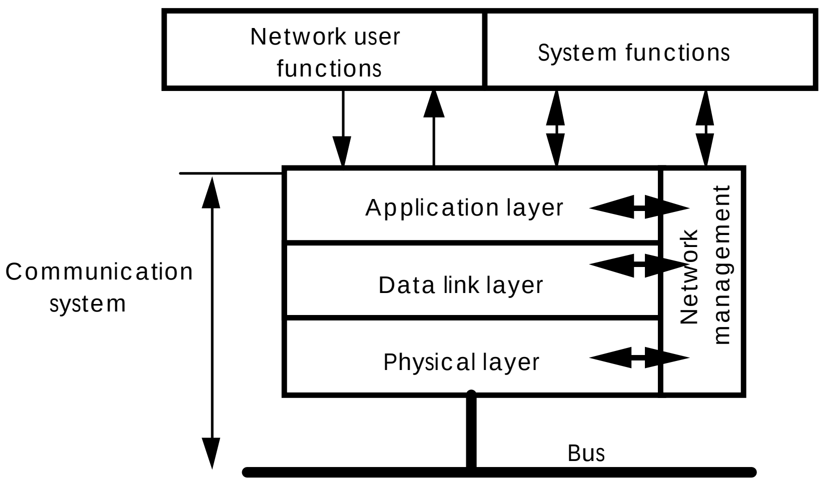


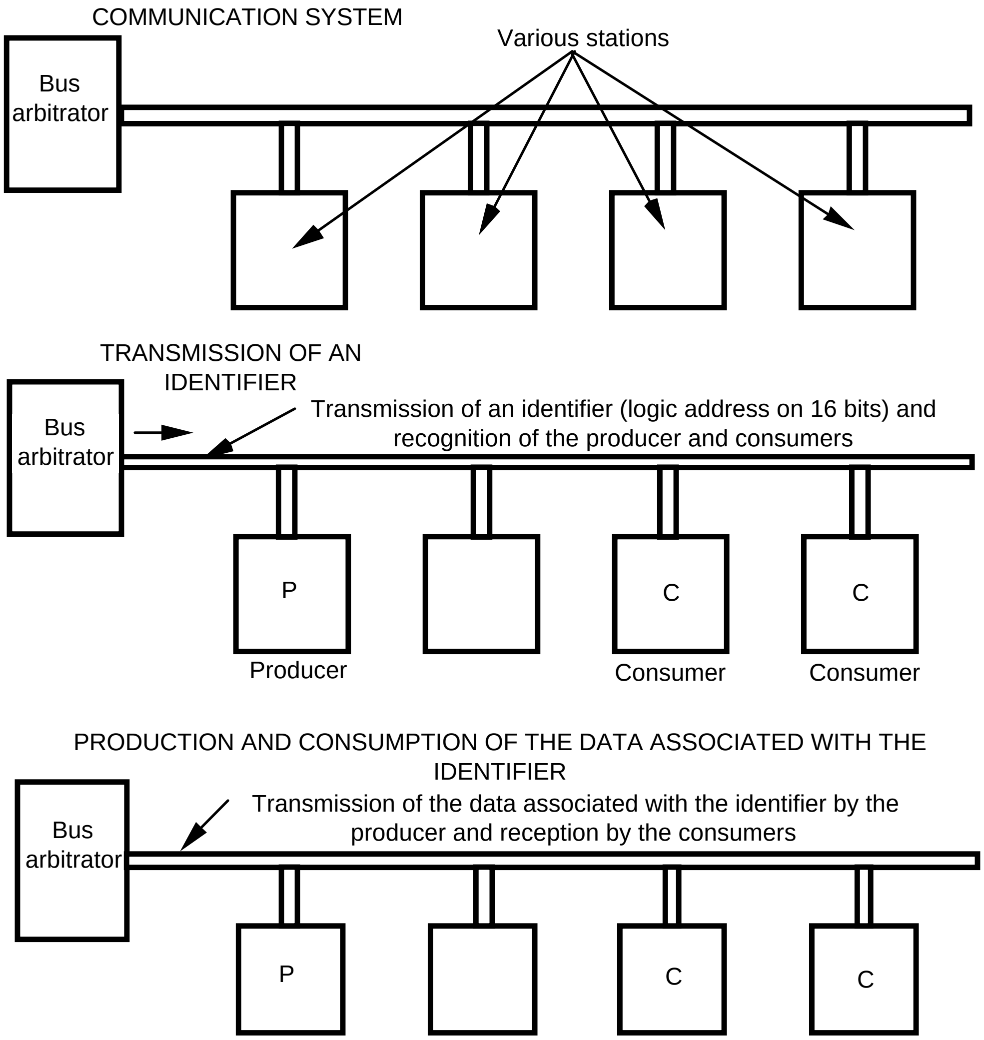
Figure 2.1.2 : Structure of the FIP communication system

2.3. OPERATING PRINCIPLES

Through the FIP network circulate the values of listed and identified variables such as the measurements from a sensor, commands to actuators, programmable controller variables, etc. All the variables and associated values form the data. An item of data or information transmitted by its "producer" is identified with the help of a single name. A producer is informed at transmission of the information which he possesses by the reception of the code of the corresponding variable. He then sends the corresponding value on the bus. This mechanism is called source addressing.

The notice is transmitted by the bus arbitrator which thus manages the communication rights of all the parties involved. This bus arbitrator periodically transmits the names of variables and, for this purpose, has the list of all the variables (drawn up from the application specification).

Each subscriber has a personal buffer memory identified by a logic address encoded on 16 bits whose various variables correspond to the identifiers ; there are thus 65536 addresses and as many buffer memories possible. The bus arbitrator sequentially transmits a list of identifiers on 16 bits ; the producer identifying its number transmits the corresponding information on the network.



<u>Figure 2.3.1</u> : Operating principle of the FIP network

The transmitted information is **broadcast** to all the subscribers connected to the network and can thus be used by one or several consumers recognizing the identifier of this information as forming part of their list.

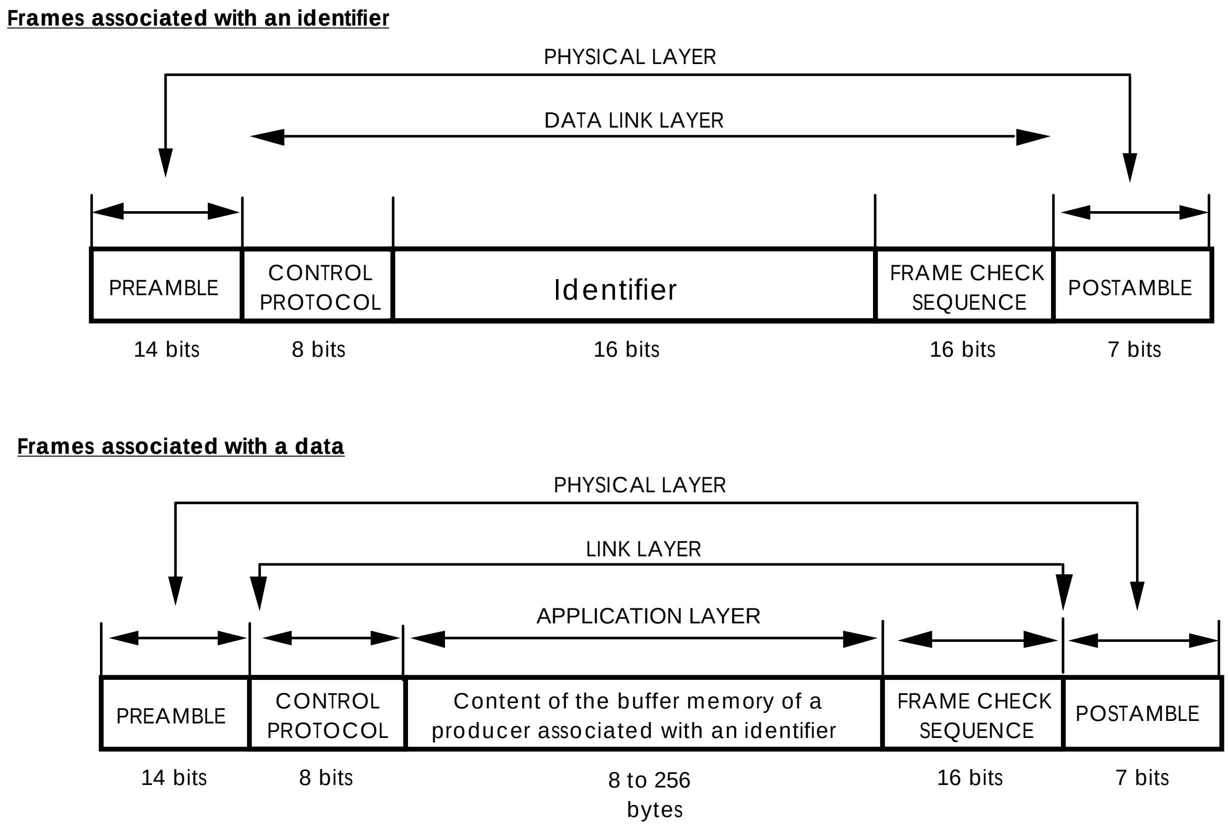
This basic service is generally performed without acknowledgement. The consumers only perform an error detection on the data frames, based on the observance of the time constraints during the exchange. The choice of this procedure is based on the fact that the data has, in all cases, a limited lifetime.

FIP thus ensures, for each subscriber, a **periodic** refreshment of the data included in the bus arbitrator list. In this sense, the FIP forms a real time updating system for a **distributed data base**.

Other needs have lead us to define a random traffic for updating of identified data (for example, transmission of an event) which could take place in the dead time between periodic communication. This is the **aperiodic** communication.

Besides, message transmission services for general use are available as random communication. They are described in a following chapter.

The frames transmitted on the bus are represented in Figure 2.3.2.



<u>Figure 2.3.2</u> : FIP frames

2.4. MAIN SERVICES

The services and protocols offered by the data link layer and the application layer are of two types :

- the periodic/aperiodic services (they are called MPS at the application layer level and A/P at the data link level),
- the message transmission services (they are called SUB-MMS at the application layer level and MSG at the data link level).

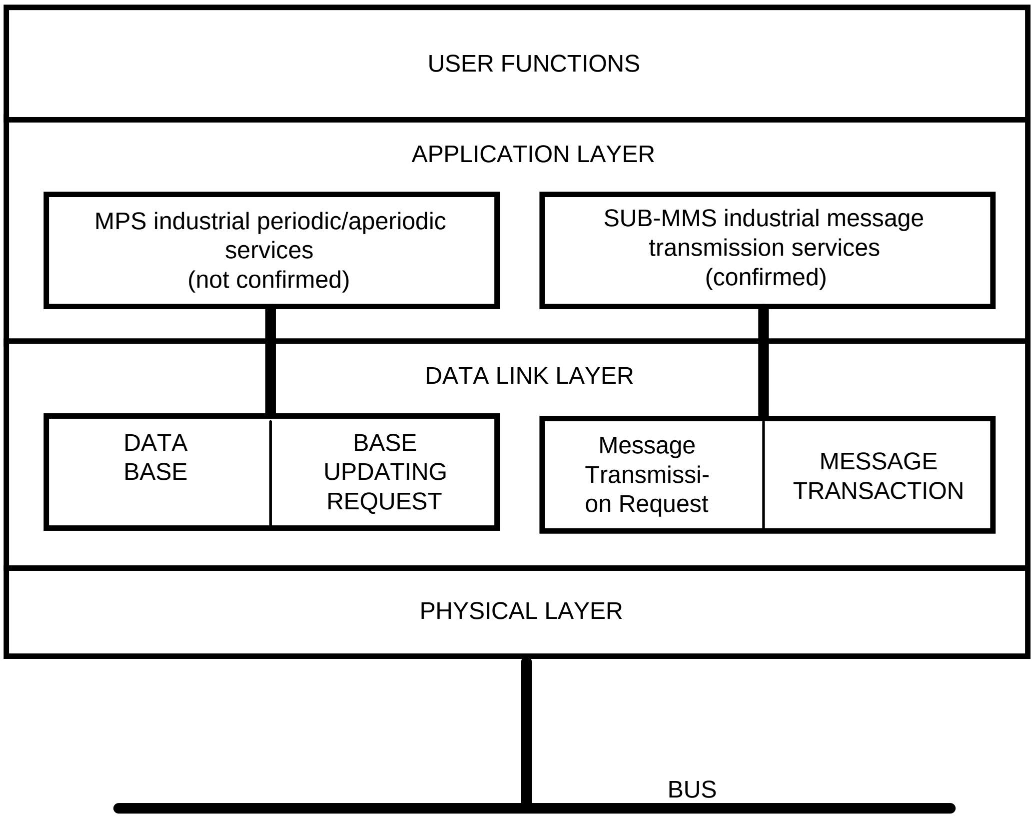


Figure 2.4 : Block diagram of the FIP services

The LOS periodic/aperiodic services are specially adapted to the real time requirements of a real time distributed. They are used to :

- periodically update the data base distributed between the various items of equipment of the control system,
- update, on request, of an item of this data base,
- calculate the time coherence status associated with the base data,
- calculate the consistency status associated with the base data sets.

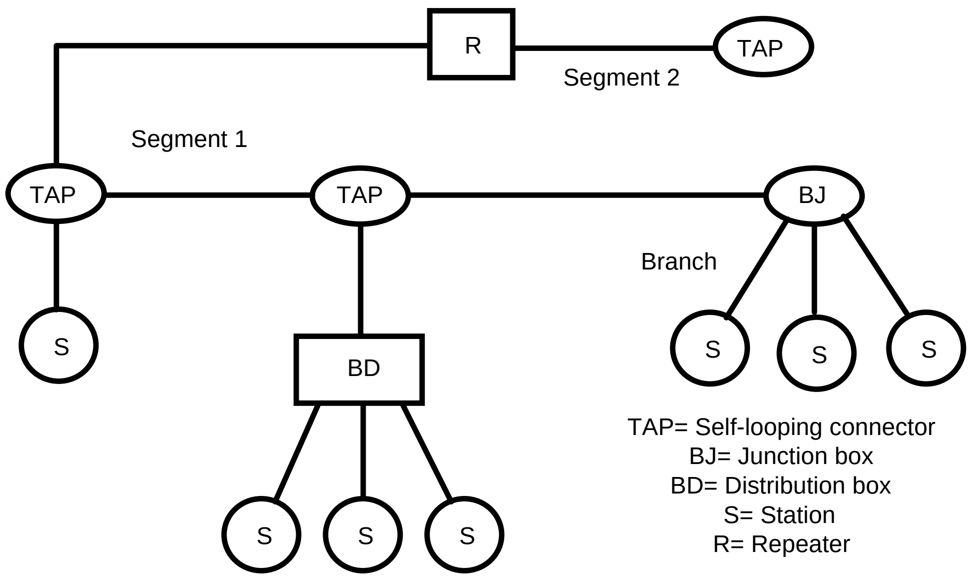
The MMS message services are mainly used for the requirements of the real time distributed application operating modes and its configuration.

2.5. PERFORMANCES AND TOPOLOGY

Data transmission takes place at speeds of 31.25 kb/s, 1 Mb/s or 2.5 Mb/s, on a shielded twisted pair divided into segments whose length depends on the selected speed, with a maximum of 32 connection points by segment and a maxium of 256 stations for the system. For example, at 1 Mb/s, a segment will measure 500 m maximum.

A distribution box, which is a particular repeater, is used to connect eight subscribers to a single connection point. The segments are interconnected by a repeater. There cannot be more than 3 repeaters between any two subscribers.

The transmission can also take place through optical fibre, with the stations interconnected in active optical star networks.



<u>Figure 2.5</u> : Example of the topology of a FIP network

Operating safety at the physical layer level is obtained by a coding of the Manchester type and frame delimiters. At this level, FIP also ensures redundancy of the medium : transmission takes place on both buses, but the listening is selective on one or the other of the media, with the help of a local procedure.

2.6. ADVANTAGES OF THE FIP SOLUTION

- Savings in wiring and in design

  As a field bus network, FIP simplifies the building of a distributed automatic control system by replacing the conventional point-to-point wiring between sensors/actuators and the processing unit by a multi-point wiring network which is cheaper and simpler, while preserving the response time, the safety and the operating simplicity of a centralized automatic control system.

- Facility in modification, extension, setting into service and maintenance

  FIP can be used for interconnection and connection to the automatic control equipment of intelligent sensor and actuators, whatever their location. It thus gives this equipment the possibility of using any of these sensors/actuators as input-output and perform its remote parametering, remote adjustment and remote setting and, in maintenance, to perform remote troubleshooting.

- Opening

  FIP is a standard solution accessible to all manufacturers or internal users. The adoption of FIP is an inportant step towards interoperation and interchangeability of products.

3. THE FIP MODEL : DISTRIBUTED REAL TIME DATA BASE

Automated systems ensure multiple functions. Some are conventional : regulation, sequential control, axis control on a robot. The others are less conventional but ensure an ever greater productivity in the broad sense (production follow-up, help in maintenance, management of operating modes).

Each of these functions is hierarchically structured in so far as it is possible, at a certain level, to define the services independently of the manner in which they are physically built. These functions are not independent from one another. The links between them take the form of data exchanges which can be described in the form of models.

3.1 CLIENT/SERVER MODEL

Most existing communication systems, whether standardized or not, favour point-to-point communication between applications distributed over various sites. In this case, if more than two applications should interact, the network user has the responsibility of organizing the interactions.

That is why, the client/server model is often used to describe this interaction mode between two processes. A process, the client, has the initiative of the communication and the other process, the server, executes the customer's requests.

This model is adapted to vertical communication required by the same function between entities of different levels. The request can come either from the upper level, for example to read a list of data, or from the lower level, to provide information concerning a fault or an alarm.

This model privileges the viewpoint of the actions described in a function. But it neglects the fact that the same data can be exchanged, used, and shared by different functions.

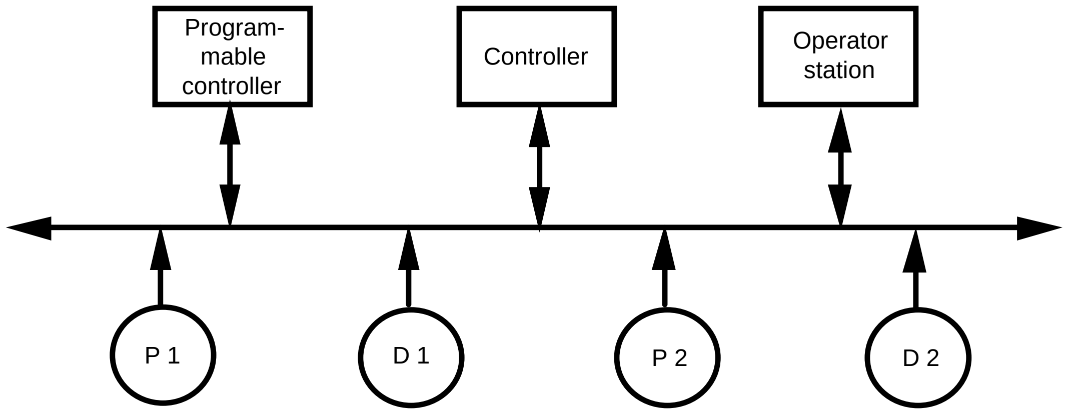
For example, in this model, the MMS variable reading service allows any application to obtain access to a variable owned by another. But if two applications use this service to access the same variable, they have no guarantee that the values returned will be the same.

To meet the requirements associated with horizontal communication, in particular the period of validity and the consistency of data, it is necessary to define another model. This model is called PDC, after Producer, Distributor, Consumer.

Before dealing with it, we shall treat the essential notion of data consistency which can have several different aspects.

3.2. DATA CONSISTENCY

Figure 3.2 gives an example of an application which implies data consistency. The measurements are provided by two pressure sensors, P1 and P2 and two flowrate sensors D1 and D2. The controller periodically requires this data. The programmable controller and the operator station also use this data.



<u>Figure 3.2</u> : Example requiring data consistency

- Temporal consistency of production

  This property means that the data values have been produced in the same time slot. This helps to ensure that all the values have been sampled at the same instant. This can be necessary for the coherence of the algorithm of the user application.

- Time coherence of transmission

  This property indicates that the data reaches the consumer in the same time slot and is thus available when the application algorithm should be executed.

- Space consistency of variable values

  This property concerns the use of lists of identical variables by distinct applications on different stations. It indicates to users of the same list that the copies of variable values are identical with all users.

3.3. PRODUCER/DISTRIBUTOR/CONSUMER MODEL

The Producer of an item of data is an application responsible for the production of the data which can be periodical or not, synchronized or not, with other productions or other applications.

The Distributor of data is responsible for the transfer of data from the producer of that data to all the consumers.

The Consumers of data are applications which, to be executed, require data. The use of data can be periodic or not, and synchronized or not with other applications.

The distribution of data should guarantee the temporal characteristics of the productions with respect to the consumption and making available of this data according to the consumer's requirements. The distribution can thus be periodical or not and synchronized or not with other applications.

The PDC model thus privileges consumers. Besides, the distribution function, statically designed and configured, can be modified in operational service to satisfy the temporal requirements of consumers. This model is well adapted to horizontal exchanges and can also satisfy some vertical communications.

3.4. STRUCTURE OF VARIABLES

A variable is defined as an abstract item of information (or object) designated by a unique name in the control system. Attributes are associated with this name, corresponding to its main characteristics (see Figure 3.4) :

- General attributes such as the identification number or the type of variable. The types of variables can be simple (boolean, integer, decimal, etc.) or complex (tables, structure).

- Static attributes defined mainly during configuration and concerning the mechanisms locally associated with a variable such as the synchronization, the producer or the consumer.

- Dynamic attributes characterizing the data itself as well as possible associated information to evaluate the validity such as "updating" or "promptness" in time.

The addressing of the variables is done by their global symbolic name which makes possible the unique identification of the local image of that variable. The addressing is global for the whole system within the framework of the distribution mechanism.

The data base is thus distributed over all the equipment connected to the network and the same name designates the local images of the same variable in the system.

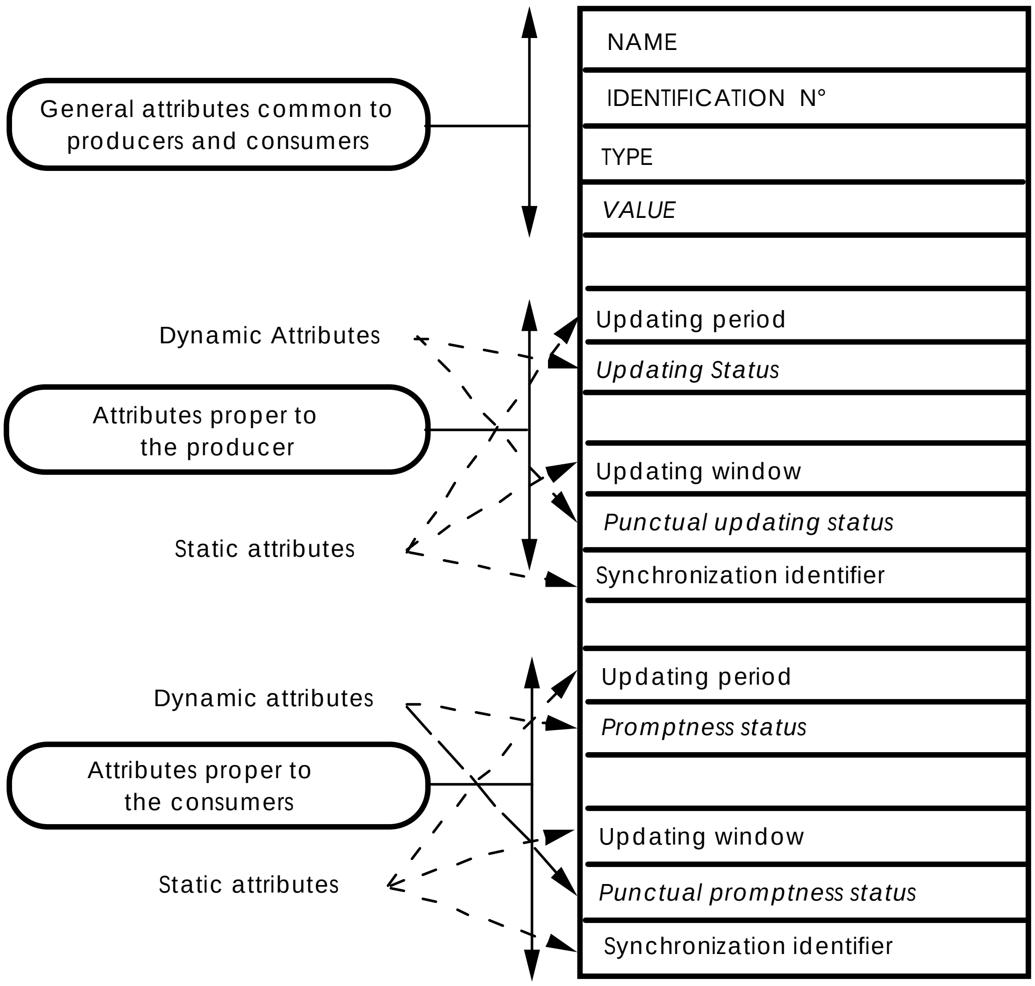


Figure 3.4 : Description of a variable

4. SHORT TECHNICAL DESCRIPTION OF THE SERVICES OFFERED BY FIP

4.1. PHYSICAL LAYER

The data conveyed on the transmission bus is encoded in Manchester II (split-phase code, represented in Figure 4.1.1). This code has the advantage of simultaneously conveying the clock and the data.

The Manchester code should be capable of encoding logic "0"s and "1"s, representing the information to be transmitted, positive (V+) and negative (V-) violations used to limit the frames as well as the equalization bits (EB+ and EB-) used to restore the line status after transmission of a delimiter and to limit the periods without transition.

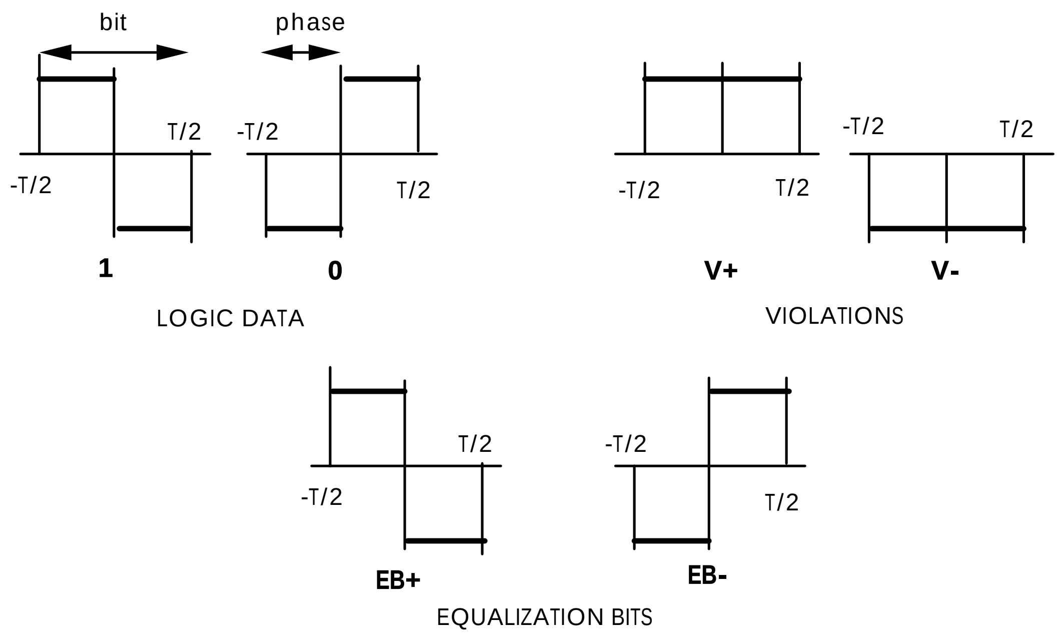
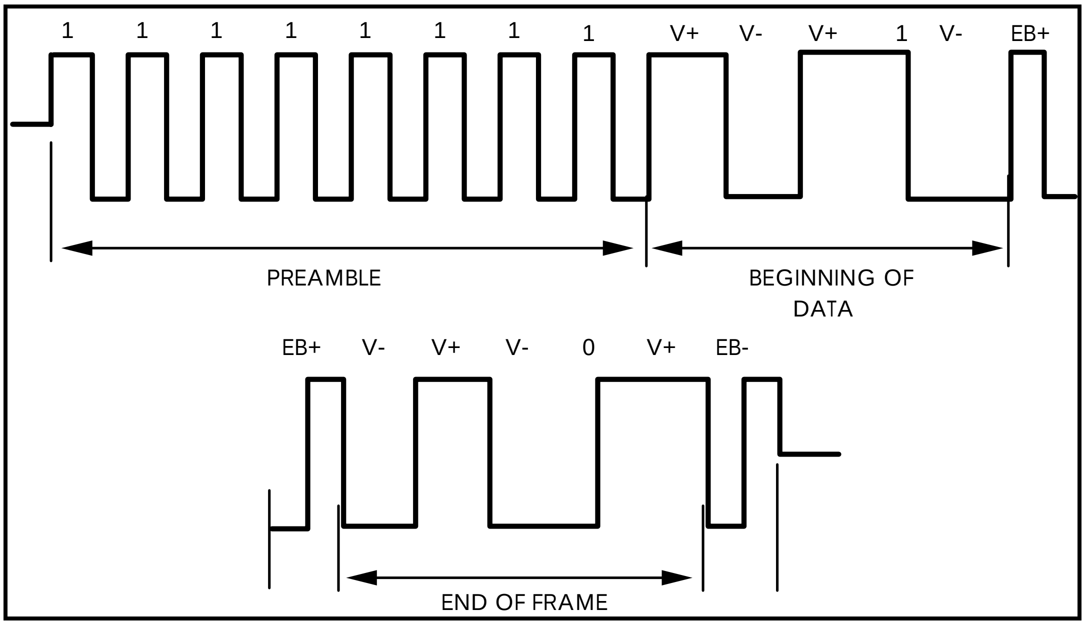


Figure 4.1.1 : Data encoding

For example, Figure 4.1.2 describes the signals at the beginning and end of a FIP frame in Manchester II.



<u>Figure 4.1.2</u> : Timing chart of the beginning and end of a frame

The physical layer also defines the transmission channel redundancy mechanisms as well as the interconnections.

4.2. DATA LINK LAYER

All the exchanges on the bus are managed by a bus arbitrator.

The function of the **bus arbitrator** (BA) consists in giving a turn to each information producing subscriber taking into account the services required by the application.
It thus has three functions :

- Periodic scanning of variables.
- Scanning of variables on request.
- Transmission of messages on request.

Besides, the BA can ensure a synchronization function to guarantee the constant duration of a scanning cycle.

Each type of scanning takes place respectively in a periodic window, an aperiodic window for variables, an aperiodic window for messages and a synchronization window (see Figure 4.2.1). The four windows form an elementary scanning cycle. The elementary cycle and its duration are defined by the consumer during configuration.

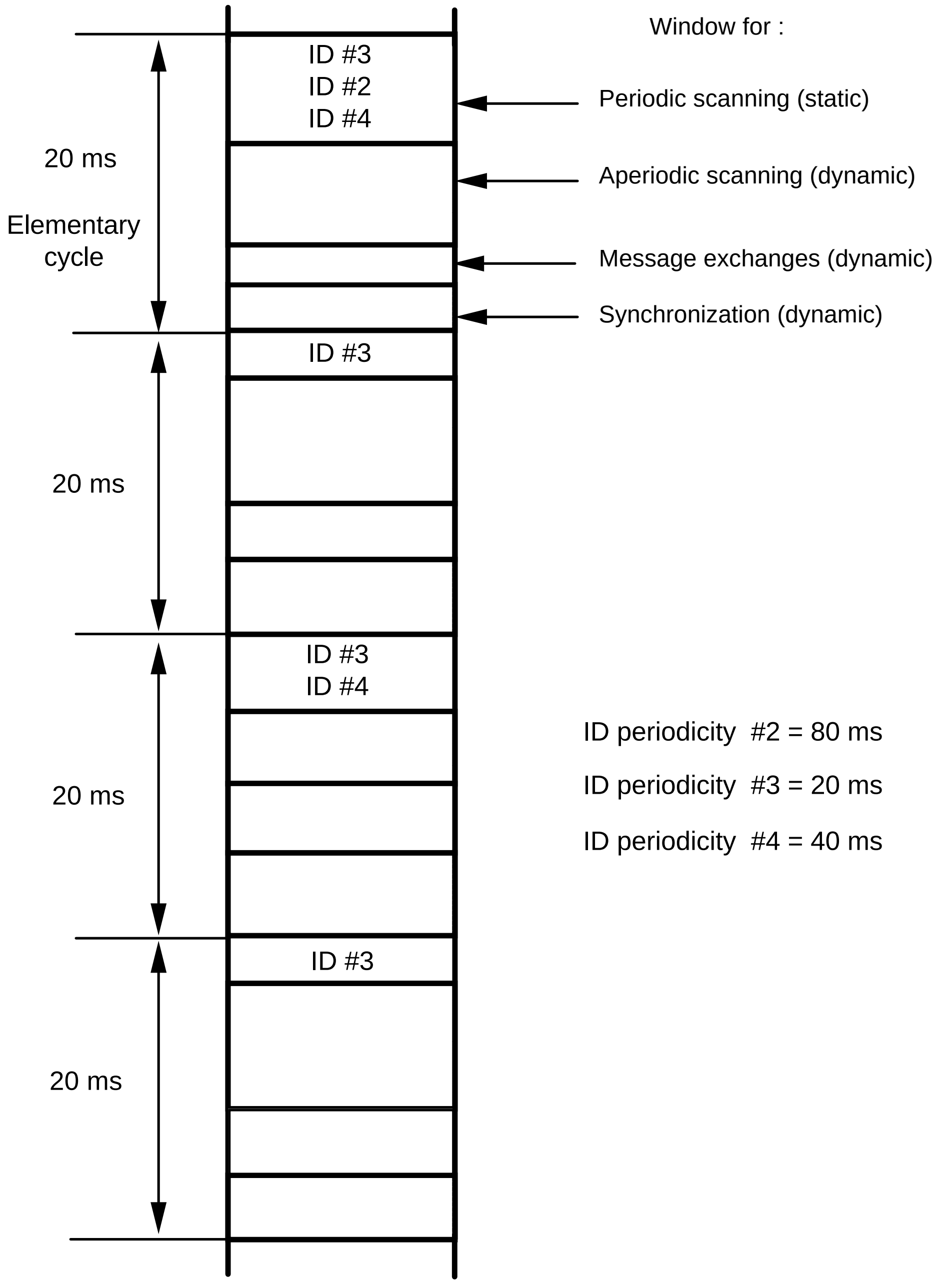
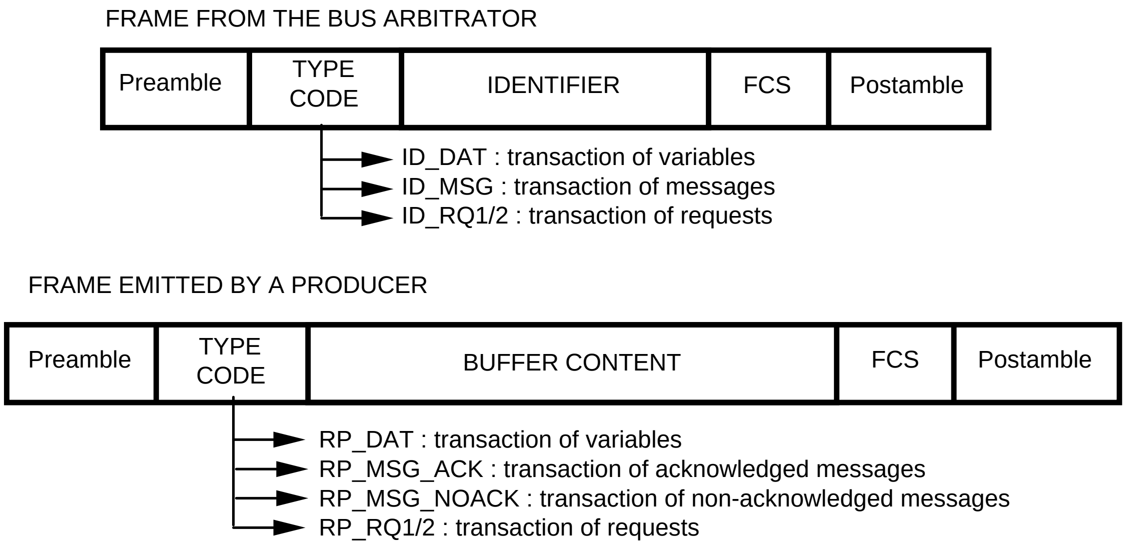


Figure 4.2.1 : Example of a bus arbitrator scanning table

An elementary transaction consists of the succession of frames concerning the same service. The management of elementary transactions consists in controlling the succession of frames composing a transaction.

The format of the frames associated with the different types of transaction is given in Figure 4.2.2.



FCS is the transmission control field.

Figure 4.2.2 : Frame formats

We shall examine the mechanisms of these exchanges in the three following cases out of all the possible cases :

- periodic transaction of variable,
- request and aperiodic transaction of variable
- request and transaction of acknowledged message.

Periodic transaction of variable (Figure 4.2.3) :

After transmission of a variable identifier frame (ID_DAT), the BA sets a time out and waits for a variable response frame :

- If the received frame is a variable response (RP_DAT), the BA passes to the following identifier to be scanned.

- If the received frame is a variable response completed by an aperiodic transfer request (RP_DAT_RQi), the BA stores the identifier producing this demand in the queue of the aperiodic requests with the required priority and passes to the following identifier to be scanned (i = 1 urgent request ; i = 2 standard request).

- If the received frame is a variable response completed by a message transfer request (RP_DAT_MSG) the BA stores the identifier producing this request in the message queue and passes to the following identifier to be scanned.

- If the received frame is a variable response completed by an aperiodic transfer request and by a message transfer request (RP_DAT_RQi_MSG), then the BA stores the identifier producing this request in the corresponding files and passes to the following identifier to be scanned.

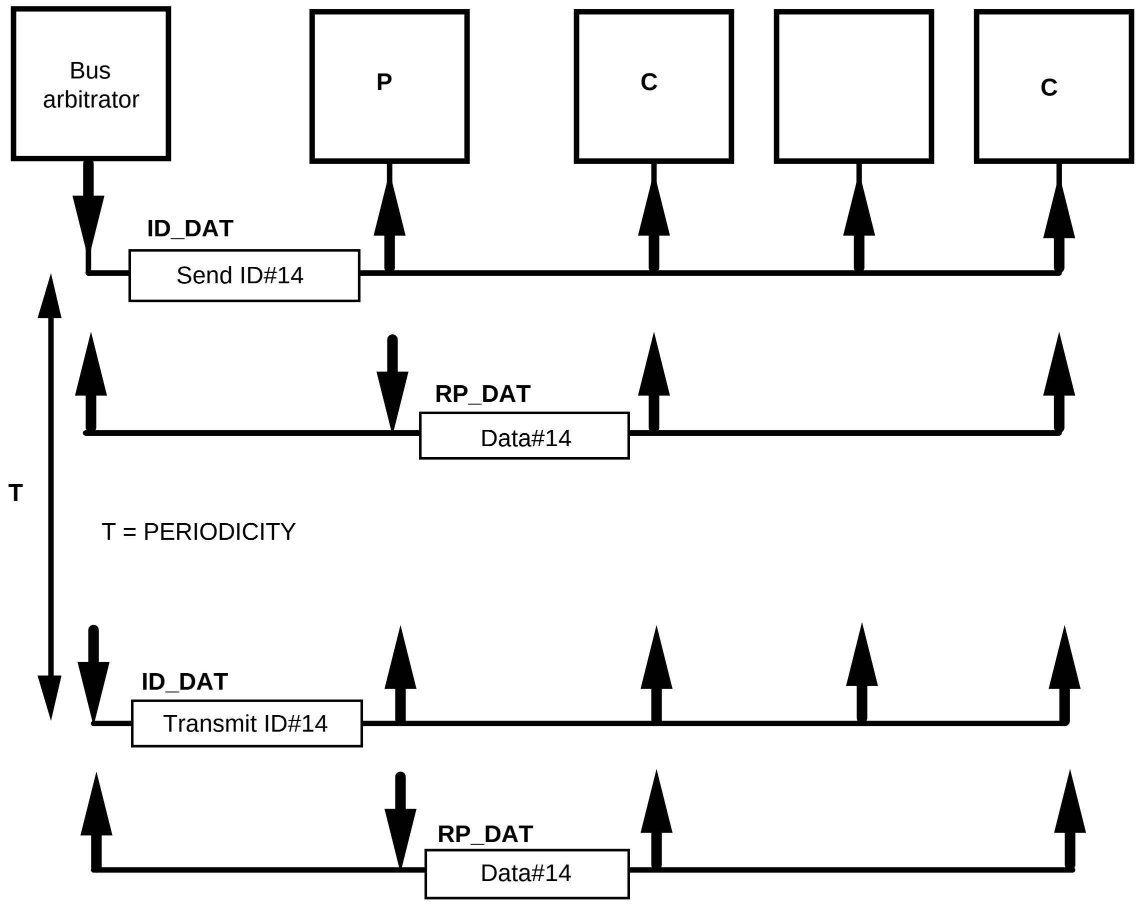


Figure 4.2.3 : Timing chart of the periodic exchange

Request and aperiodic transaction of variable (Figure 4.2.4) :

When the periodic scanning is ended, the BA collects the list of requests to be served. It transmits the first request identifier frame (ID_RQ1), from the urgent aperiodic queue. If this queue is empty, the BA transmits the first "request" identifier frame (ID_RQ2) from the standard aperiodic queue, if it is not empty, sets a time out and waits for a request response frame. The producer which has recognized its idenfication transmits in an RPQi frame the list of IDs of variables which it wishes to exchange on the bus, whether it is producer, consumer or neither one nor the other.

The BA stores the series of identifiers requested by the response frame (RP_RQi) in the queue of explicit requests, and passes immediately to the first requested variable identifier.

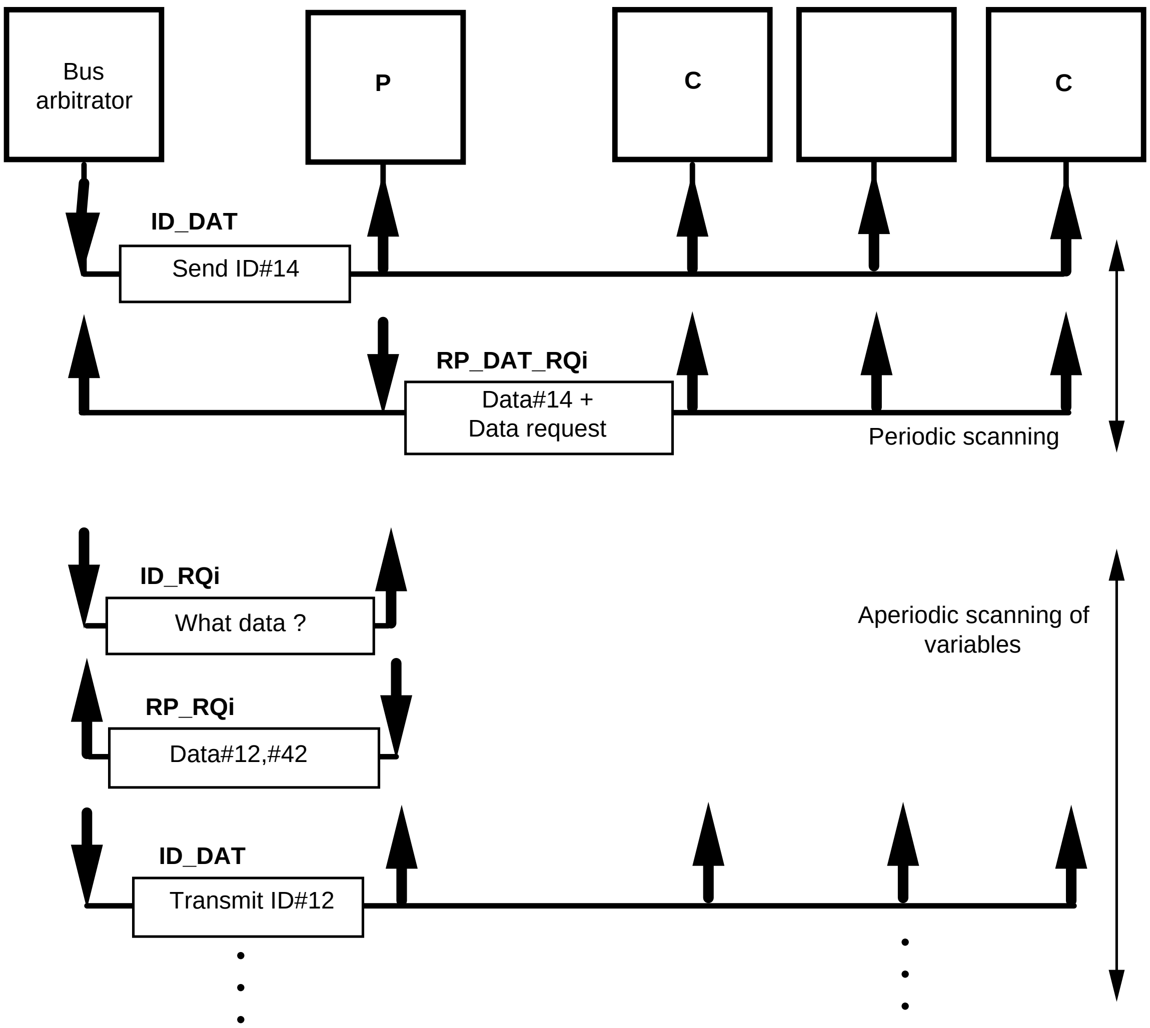


Figure 4.2.4 : Aperiodic communication timing chart

Request and transaction of acknowledged message (Figure 4.2.5) :

When the aperiodic scanning is over, the BA has collected the list of message requests. It transmits the first "message" identifier frame (ID_MSG) from the message queue if it is not empty, sets a time out and waits for an "End of transaction" response frame.

The equipment which has recognized its identification transmits the first message of its list in the form of an RP_MSG_ACK. This response contains the address of the addressee, which recognizes its identification and sends back an RP_ACK frame. When the source has received the acknowledgement or has performed several retransmissions without effect, it sends back an RP_FIN frame to the arbitrator.

* If the received frame is an end-of-transaction message (RP_FIN) the BA passes to the following identifier to be scanned.

* If the received fame is a message with acknowledgement (RP_MSG_ACK) or an acknowledgement response frame (RP_ACK), the BA sets an additional time out and waits for an end-of-transaction response frame (RP_FIN).

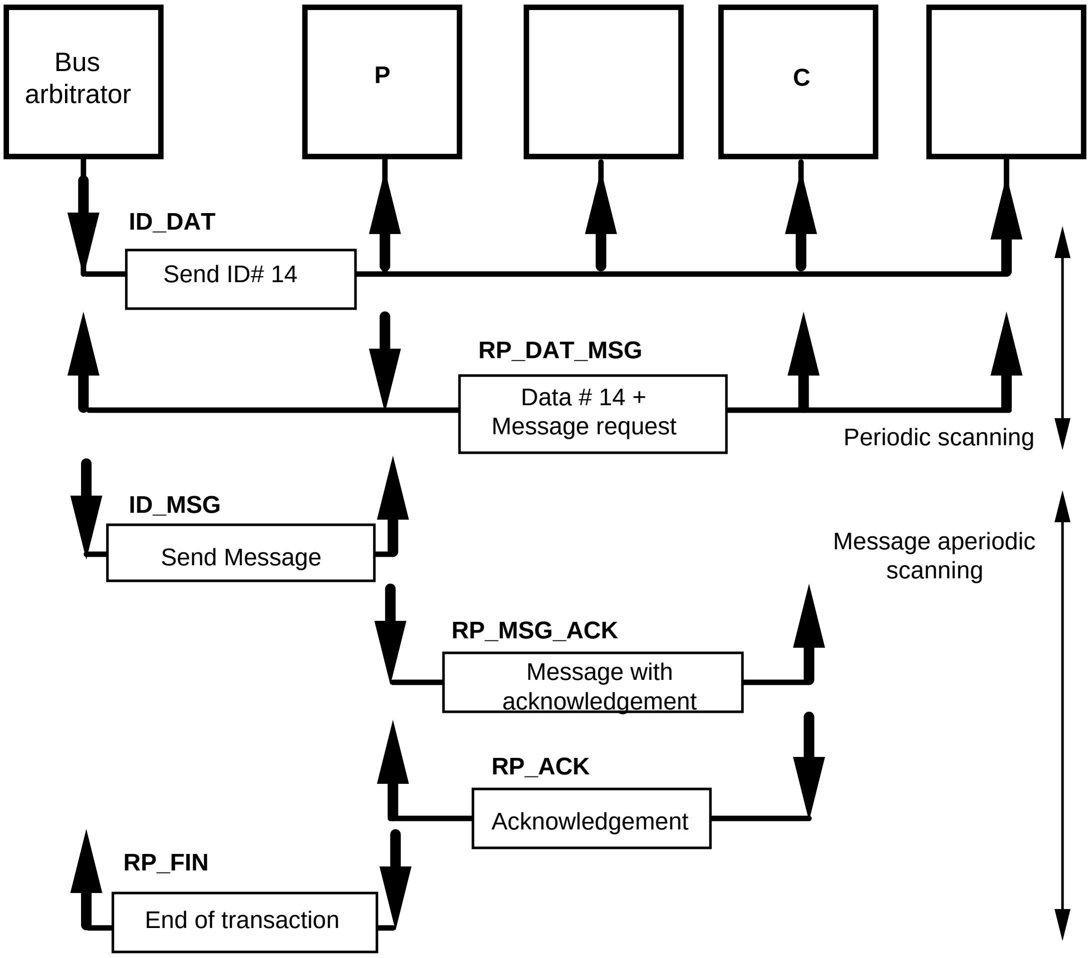


Figure 4.2.5 : Timing chart of the message transfer with acknowledgement

In these three types of exchanges :

- If the received frame is of a different type, the BA detects an error and passes to the following identifier to be scanned.

- If the response frame includes an incorrect control field (FCS), the BA detects a transmission error and passes to the following identifier to be scanned.

- If the time out expires, the BA detects a loss of the response frame and passes to the following identifier to be scanned.

The queues include an "antiduplication" device to prevent its filling by the same request which has not yet been answered.

Synchronization :

During the synchronization window, the BA performs a waiting loop until the end of the elementary cycle time out, to pass to the following cycle. This loop is performed by repeated transmission of a variable identifier which has neither producer nor consumer and which thus has no response.

4.3. APPLICATION LAYER

The various services of the application layer enable access to the variables and the synchronization of the user applications of several items of equipment.

Local reading and writing

The automatic control functions have, at their communication interface, a local image of the produced or consumed variables. By means of local read and write services, they can handle these local images.

There is no 2-way exchange of information between the subscribers connected to the bus. The consumed value, for local reading, is that from the last updating by the distribution mechanism managed by the distributor. The value produced for local writing is placed at the disposal of the distributor communication system which takes charge of the distribution to all the consumers (Figure 4.3.1).

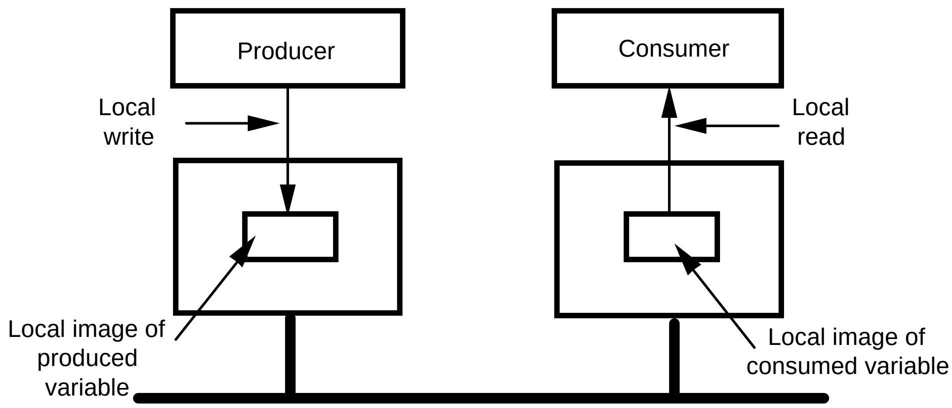


Figure 4.3.1 : Local read and write

The local reading and writing are mechanisms independent from the network activity.

The local reading gives access to a list of variables which can come from various items of equipment.

Remote reading and writing

The remote reading service allows a consumer to know the value of a variable present at a producer subscriber. The value thus received by its communication interface, source of the request, as well as for all consumers of this variable, corresponds to the latest value produced.

Figure 4.3.2 illustrates this mechanism :

1 - Remote read request.
2 - Update request transmitted through the distributor.
3 - Search for the producer.
4 - Broadcast of the value by the producer.
5 - Confirmation of remote reading.

On indication of reception, the consumers of the variable can obtain the last value produced.

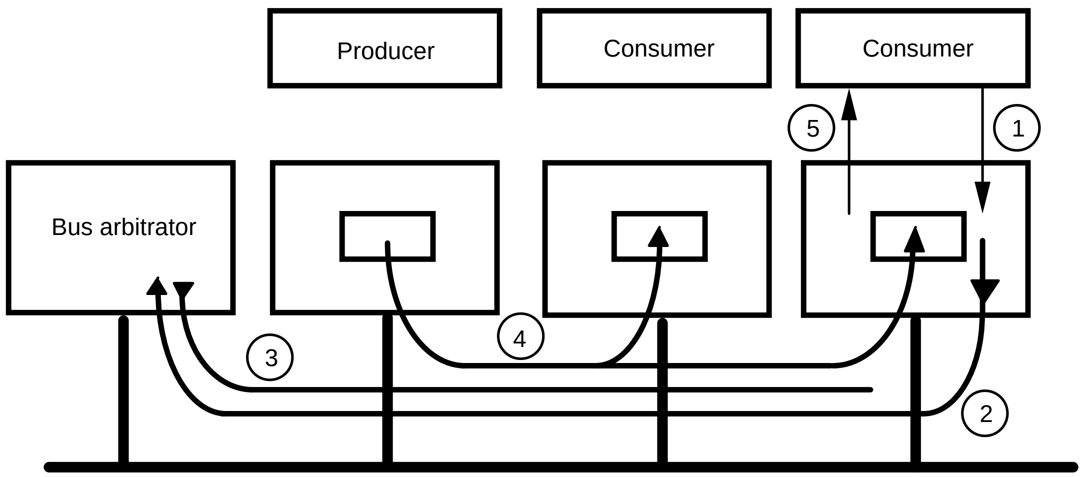


Figure 4.3.2 : Remote reading

Remote writing applies the same principle, except that in this case the producer initializes the distribution. Reading of lists is also available.

Update services

The local write or read requests are respectively initialized by the producers and consumers of a variable. An updating service is available, enabling a subscriber, called third party, to make an updating request for a variable. The third party can be producer or user of the variable but need not be concerned with consumption nor with production.

Indication services

Optional indication services inform the consumers of the reception of a consumed variable value in their communication interface or inform a producer of the transmission of a produced variable.
This can be used to check the correct operation of the communication interface as well as to synchronize the subscriber applications from reception or transmission of certain variables.

Service quality

To inform the consumer of the validity of the produced and consumed data, boolean information, produced at the application layer, is added. This information consists of updates and prompts.

- Validity of production : the update statuses

  These are states produced by the application layer of the producing item (produced variable). A true status informs a consumer that the information producer has observed a delay called production period. The information handled in the communication system is thus of the form <type, value, status>.

  Figure 4.3.3 shows the True or False status of the asynchronous update with respect to the value production times. A time out is set at the production of a value with a duration corresponding to the production period. The status is True as long as the time delay is set and becomes False on its expiry.

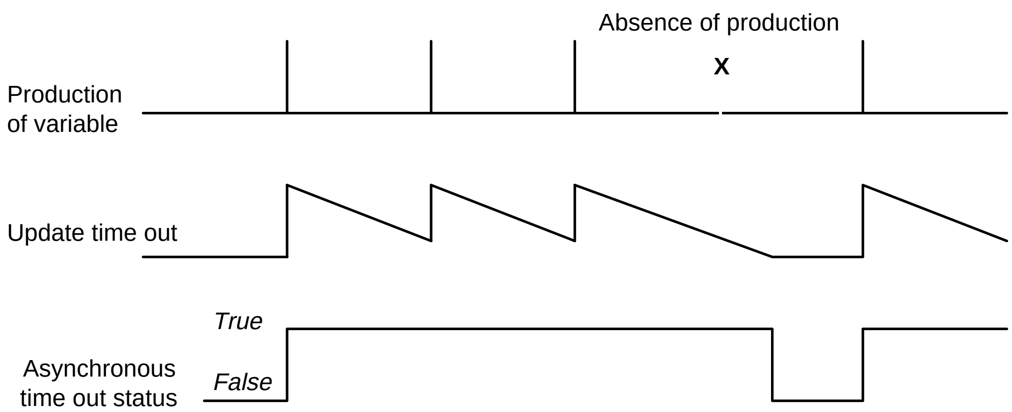


Figure 4.3.3 : Asynchronous update status

  The update statuses can be asynchronous, synchronous or punctual. A true synchronous update status informs a consumer that a synchronization variable has been received and that, after this variable, the information producer has observed the production period.

- Transmission validity : the promptness statuses

  The prompt statuses are produced by the application layer of the communication interfaces of the user entities (consumed variable). A promptness status with the True value indicates to a consumer that the associated variable has been transmitted by the network at a time earlier than the transmission time.

  Figure 4.3.4 shows the asynchronous prompt statuses with respect to the reception time of a variable.

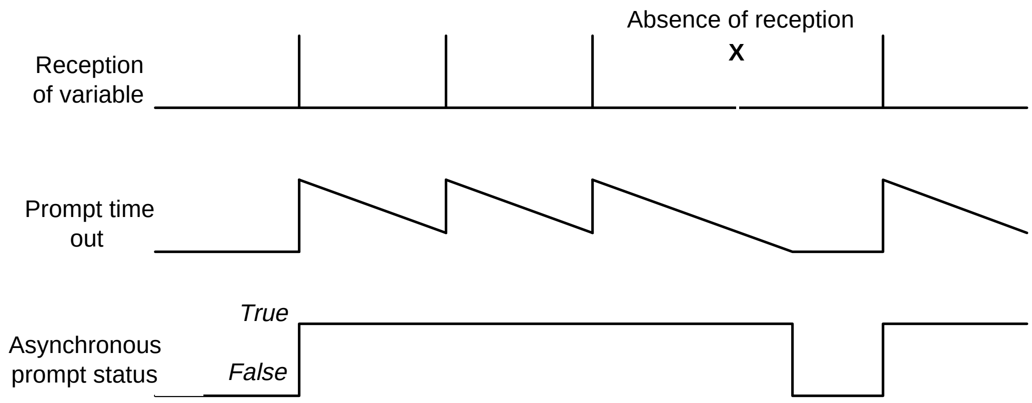


Figure 4.3.4 : Asynchronous prompt status

The prompt statuses can be asynchronous, synchronous or punctual. A true synchronous prompt status, for example, informs the user application that a synchronization variable has been received and that, consecutively, the associated variable has been received within a time lower than the transmission period.

Synchronization mechanism

An asynchronous application function is a function whose execution is independent of the network. Inversely, an application function is synchronous or synchronized if its execution is related to an indication from the network.

The functions composing an application can be synchronous or asynchronous. In the latter case, a synchronization mechanism enables them to participate in a synchronized time-sharing application.

In this mechanism a variable is associated , a second buffer at the application layer. This private buffer is exclusively accessible to the user functions. It is accessed by asynchronous local read or write operations. The public buffer is only accessible via the network.

Figure 4.3.5 shows the resynchronization mechanism which consists in transfering the content of one buffer to the other at a synchronization command from the network like, for example, a particular identifier.

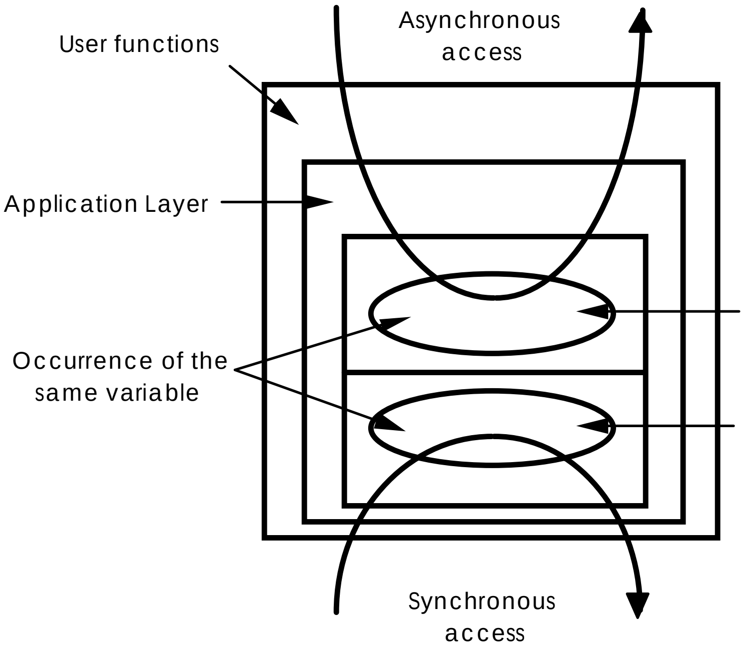


Figure 4.3.5 : Resynchronization mechanism

These synchronization commands are positioning pulses for the resynchronized consumed variables and the snapshot pulses for the resynchronized produced variables.

Other services are available like the access to the lists of variables with their associated consistency statuses. For more details concerning these services, consult standard C 46-602.

4.4. NETWORK MANAGEMENT

The network management is a set of tools and services used for :

- management of the installation, the configuration and its modification,
- management of the various communication operating states,
- evaluation and counting of faults and performances.

These functions are installed in each item of equipment of the system in the form of a set of management services enabling operation in the FIP environment.

Management of the system includes all the steps required for operation of a network from the electrical connection of equipment to the bus up to complete setting into service of the communication necessary for the application requirements.
This operating chronology is represented in Figure 4.4.

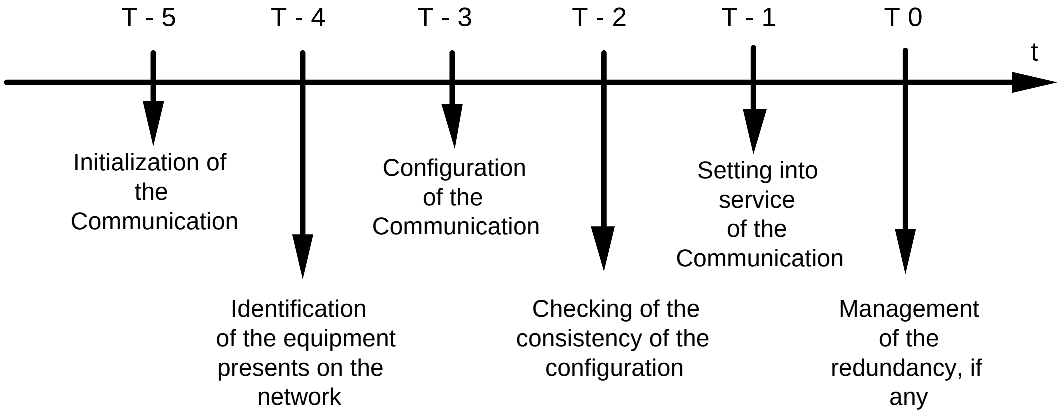


Figure 4.4 : Chronology of the operation of a network

The main steps are :

- Initialization of the communication of the equipment, which consists of the assignment of an item number and addresses to each station in order to make it accessible within the system.

- Identification of the equipment used to check if the type of equipment present on the network is in conformity with the requirements of the application.

- Configuration of the communication by installation of the data base necessary for the requirements of the consumer application.

- Checking of the consistency of the installed configuration in order to determine the possible incompatibility between the various configurations of the system equipment.

- Setting into service of the communication which finally places at the consumer's disposal the means which he requires to communicate.

- After operation has begun, fault detection, evaluation of performances, redundancy check of the medium and arbitration if these options are selected.