Fieldbus Technology and Industrial Automation

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Abstract

All automation systems are now based on fieldbuses. The solutions are numerous due to the number of fieldbuses, which are in turn due to the variety of applications.

This paper traces fieldbus technology from its beginnings, which go back to the first industrial networks in the 1970's. It analyzes the fieldbus requirements, in terms of functions (or services) and of performance (or quality of service). The three following types of quality of service are studied: transport, timeliness and coherence, according to the different types of traffic to ensure (or to operate). The characteristics of periodic and aperiodic traffic are described. The main international standards (IEC, ISO, CEN) are presented regarding these criteria and the main concepts issued from the OSI model. The architecture of applications and the services of the communication system have a mutual influence. This is an important point for the distribution of the application processes, and will be analyzed in regards to the possible application layer models. The architecture of the communication system itself is also studied in the hopes of finding a single system for all applications.

Future developments will be considered, regarding both the end-user needs and the available technologies. And finally, to conclude, we will go back to the title and try to answer the question "Is fieldbus a technology?"

1. Introduction

All automation systems are now based on fieldbuses.

Fieldbuses, in a first approximation, are local area networks dedicated to the connection of sensors, of actuators and of controllers. They are the first level of real time communication in any control architecture, as well as in discrete part manufacturing industry, in robots, in power plants, and in embedded systems in cars, trains, aircrafts, or even in building automation applications.

This technology is not a new one even if new fieldbuses are always in development. But its study is far from completed.

2. The origins

The fieldbus ancestors which stood out the most in industrial automation were Modbus from Modicon (Modicon Bus) and WDPF from Westinghouse (Westinghouse Distributed Processing Family) because of their seniority, their functionalities, and their worldwide acceptance.

Other networks, were already in existence, but did not go beyond a few specific applications or domains. For example, the network ARCNET (Alliance Research Centre Network) started in 1977 and primarily covered office communication needs before being used in data acquisition.

Another network, which was highly used in avionics and aerospace applications was the Military Standard 1553B. In the nuclear instrumentation domain, the CAMAC network, created in the 60s, is considered as the first instrumentation network. Several proprietary networks were in use at the end of the 70s to connect PLCs (Programmable Logic Controllers) (Allen Bradley Data HighWay and Tiway – Texas Instrument Way), as well as in the process industry.

3. Requirements and standardization

The current fieldbuses began to be developed in the 80s after the emergence of factory networks, according to architectures known as MAP, TOP and Mini-MAP or FAIS.

The requirements for the standard covered essentially the physical and performance topics, distances, data rate, insulation, and so on. The notion of application architectures was not really explicit and was often reduced to an operational architecture indicating which devices were interconnected through, or by, which network.

The role of fieldbuses was then identified in the first

levels of CIM architectures, with first the need for decreasing the cost of the wiring, but later as the backbone of the distributed real time systems.

It is this main function which led to a long struggle between contenders in the standardization bodies. The stakes were very high from both a strategic and a profit-making point of view.

This explains the result of the standardization activities: many standards, all incompatible with each other. IEC, ISO and CEN have defined several coherent standards, but there are still many incompatible standards. Several profiles based on Ethernet are now being proposed for standards, for example, Ethernet for plant automation, Etherlink…

4. Quality of service

A great variety of qualities of service are associated to the fieldbuses. As the fieldbuses can be used in any kind of application, and as the required quality of service is directly dependent on the application, then it is only normal (and obvious) that the qualities of service are very different.

The quality of service is related to, evaluated with or measured by different criteria: transport, timeliness, coherence.

Transport is related to the way the sent Protocol Data Units are delivered to the receiver(s). Timeliness is related to the time aspects of the transport, and coherence is related to the simultaneity of actions.

5. MAC-based Fieldbus taxonomy

Different fieldbus taxonomies may be defined, using Medium Access Control, based on the cooperation model (or the application relationships) provided by the application layer.

The usual MAC protocols are based on one of three following classes: controlled access, TDMA or contention. If a control is used, it can be centralized or decentralized. In the case of TDMA, the classification is not so easy, the access is always decentralized, because the decision to send is taken individually by each station, but the clock synchronization function itself may or may not be centralized. In applying such a classification to fieldbus MAC protocols, it is necessary to distinguish the management of periodic and of random traffic. Centralized and decentralized management can be considered for both types of the traffic.

In the case of decentralized management each station must decide, at its allotted time to send, which traffic it should prioritize. In the case of centralized management, a periodic server deals with this problem. A station can ask for an additional right to send when it is periodically polled (special frame on demand) or the server systematically and periodically allots a time slot for aperiodic traffic (time slot in each frame).

6. Application relationship-based fieldbus taxonomy

Application relationships represent how two or more application entities cooperate to obtain a given objective. Two distinct transaction families can be distinguished: the client–server family and the publisher–subscriber, also known under the name producer–consumer.

In the client – server model, two entities cooperate. The server is an entity, which provides a service, *i.e.*, which executes an action on the account of a requester, which is called a *client*. This model is more useful for transmitting state data than event data. Event data detected by a server is only transmitted if the client requests the transfer through a READ service.

The Publisher-Subscriber interactions, involve a single publisher Application Process (AP), and a group of one or more subscriber APs. This type of interaction has been defined to support variations of two models of interaction, the "pull" model and the "push" model.

Based on these basic models, other relationships can be defined, for example: Client – server multi confirmations, Client multi – server, Multi - Publisher Multi – Subscriber, CS mono request multi response.

7. Communication Architectures

The architecture of applications and the services of the communication system have a mutual influence. This is an important point for the distribution of the application processes, and will be analyzed in regards to the possible application layer models. The architecture of the communication system itself is also studied in the hopes of finding a single system for all applications.

The communication architectures have been veritably and explicitly developed according to, and thanks to, the OSI reference model. The first modifications (or extensions) of this model were introduced with the IEEE 802 model and with the MAP-Enhanced Performances Architecture reduced model. Both of these extensions have their own reasons for having been introduced, but arguments for real-time needs were put forward to promote MAP-EPA. It is a known fact that speed alone is not enough to meet the real-time constraints and that, when a minimum amount of resources are available, the scheduling of the tasks and messages within resource allocation is the only solution. That is the main reason for the definition of most of the fieldbus “real-time” MAC protocols including, more or less explicitly, a scheduling of the messages. In parallel, for configuration or maintenance operations (downloading), normal (not real-time) protocols are necessary. In brief, the internal

communications can only be ensured with a two stack architecture. Another reason for a two stack architecture is that the fieldbus needs to communicate with the outside world.

The use of Web technologies and the emergence of Ethernet at the field level contributed to the study of architectures.

8. Towards which future?

Future developments must now be considered, regarding both the end-user needs and the available technologies. Two main axes can classify the research work in this field, firstly the study of new services, of new protocols or mechanisms, such as scheduling for meeting the required quality of service, and secondly, the study of the fieldbus-based applications. This latter case within itself covers two aspects: the design and the building of the applications, in connection with software engineering, and the validation of these applications including the evaluation (or the proof) of the distributed application performances or quality of service, depending, obviously, on the available quality of communication.

And finally, to conclude, we will go back to the title and try to answer the question “Is fieldbus a technology?” We will consider some reasons and criteria to answer this question.