SURVEY OF THE MAP PROJECT

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This paper is intended to give a brief introduction to the MAP and a description of its major functions to the readers that are not familiar with it and the estimation of the state of the project to those readers who already know it. Layer functions are described and commented. Special emphasis is given to the real-time extensions and to the integrated architecture. At the end some comments on MAP 3.0 specification are enumerated.

1. INTRODUCTION

Information is becoming the most important factor in manufactoring industry. It is the fact that the information controls all the levels of production. Following the information flow in the factory, we pass all the crucial points, from the management, planning, finance to the process control management. Optimization of all these points helps us to economize the production which is the final goal of the effort. The technologies enabling this are computer science and microelectronics.

To make the information useful it has to be brought to the places where it is needed. In other words, the providers and the users of information have to be integrated in a system. Studying these problems a new discipline named CIM (Computer Integrated Manufacturing) arose and with right it became very fashionable. CIM became a must in the modern industry.

That is where the problem appears - missing a means for the communication. Computer companies have developed their own methods of transferring data between their products. As a result, different makes of computers are more and more difficult to integrate into the same system and devices need different interfaces to match different types of the data flow. Integration can thus easily mean changing and adopting interfaces to every system, which again means studying all the different systems in the network.

The only way to change this praxis seems to be the making of universaly accepted communication systems to fit the computers and to become a standard.

Persuading computer firms to redesign their products could never succeed. The only thing to do is to make the communication systems to fit the computers, in other words, to work towards an universally accepted communication system to which any make of programmable device could be easily standardized.

2. HISTORY OF THE MAP

The MAP resulted from the operating difficulties of a very large company - General Motors. By the end of 1970s, in the GM, they had 20.000 programmable controllers, 2000 robots and over 4000 intelligent devices in use and only good 10% of them were capable to communicate with each other beyond the limits of their own "island of automation". Making their plans for 1980s they realised that soon the sum of different inteligent stations to be interconnected would reach the number of 300.000.

To solve the problem, in 1980 a group of scientists led by Mike Kaminsky was organised and by 1983 they defined a communication protocol concept named MAP (Manufacturing Automation Protocol). In the beginning, some independed equipment manufacturers, later on a lot of mighty potential users, like Allen-Bradley, Gould, Motorola, IBM, Hewlett-Packard joined them, finding their future problems very much alike to them of GM. The first great success and public appreciation was achieved in 1984 at the National Computing Conference (NCC).

After that the project was supported by some new big companies (Ford, General Electric etc..), and the concept found interest outside USA, in Europe, Canada and Japan. In connection to the MAP, several other protocols were developed, like TOP (Technical Office Protocols) under the leadership of Boeing, real time extensions etc..

The next great event in the history of MAP was the AUTOFACT fair in 1985 in Detroit, where a 10mbit model network connecting several different stations was presented under the standard MAP protocol version 2.1.

The current version 3.0 was published in April 1987, including internetwork communication, TOP, real-time extension, carrier-band version etc.. The version 3.0 is to be left unchanged for the next six years. This should give users the oportunity to get used to it and to show its good and bad sides.

The final proof of the functionality of the MAP was ENE (Enterprise Networking Event), in June '88 in Baltimore, where a network of over 100 different active stations was successfully presented. We could see a little subset of this at the MAP-Sonderschau at SYSTEC'88 in Munich.

3. LAYERS OF THE ISO-OSI MODEL

In 1978, International Standard Organization (ISO) issued its famous seven-layer Reference Model for Open Systems Interconnection (OSI). It suggests a phylosophy of peer-to-peer communication between partners. It is not intended to be a standard, it only offers a way to solve communication problems. It also dues not have to be used in its entirety, the layers that are considered not to be necessary in a particular application can be omitted and their function can be distributed among other layers.

There are two good reasons why to use the layering: first, because of the complexity of the functions required in a comfortable transmission of data and second, it gives a possibility to make functions transparent and independent so it could be modified without disturbing others as long as interfaces are intact.

The idea of the model is to define functions of particular layers and interfaces between them. Portions of data (layer headers) are being added to the information to be transferred from one system in the network to another while travelling from the upper layer of the sender to the lowest - physical layer. The same headers are being unpacked and used while traveling the other way around in the receiver (see Fig.1).

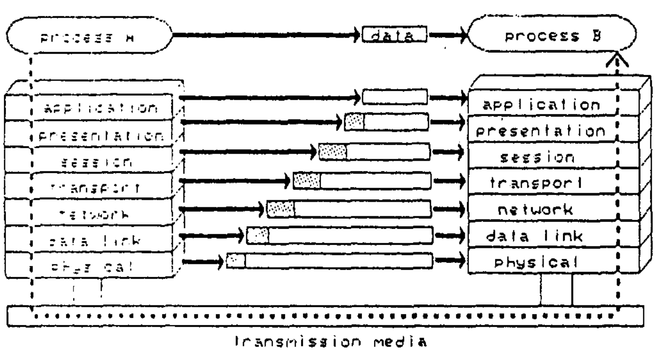

Fig.1. Data transmission between the processes in different nodes

Each node on the network is equipped with this layer mechanism, and each layer plays its part in data transfer, communicating with its alter ego in the partner node. The only direct link between nodes is the network cable, connecting all the nodes on the level 1.

The OSI architecture offers a possibility of connecting non-compatible nodes or networks, providing they support OSI reference model. It uses special nodes to adopt data up to the layer that is still common. Depending on this layer, the nodes are named repeaters (connecting distant equivalent networks or nodes), bridges, routers or gateways (universal coupling node). The principle is shown in the Fig.2.

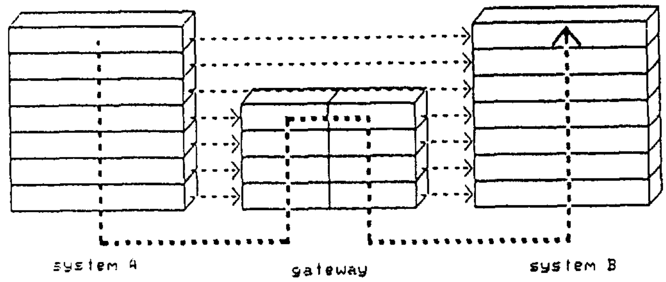

Fig.2. Connecting up to the layer 1 incompatible nodes

4. CHARACTERISTICS OF THE MAP

In the following chapter we shall describe major characteristics of the MAP protocol going through all the layers of the reference OSI model which is in its entirety implemented in the MAP.

The Physical Layer

provides the physical medium for transmitting data between two nodes. It provides the communication hardware, connects and disconnects, modulates and demodulates and drives data on the network.

MAP specifies two alternatives for the transmission medium, both conforming the IEEE 802.4, according to the application:

- for backbone networks and other multi-channel applications it recommends 10 Mbit/s broadband technology on co-axial cable,

- to suit less sophisticated applications it allows the use of carrierband 5 Mbit/s technology on co-axial cable.

The broadband means multi-channel, unidirectional, high-rate transmission. It allows multiplexing with other communication signals in the factory, data, voice and video transmission simultaneously on the same carrier. The carrierband means single-channel, bidirectional, low-cost, potentially more reliable transmission. It avoids the problems of broadband (head-end remodulators, precise tunning to the channels, no delay in remodulating between transmission and reception frequencies etc.), but it is slower in transmission rate and restricted to the cable length of 700m and a maximum of 30 nodes per segment.

The next version of MAP will probably add the third option - fibre optics in the near future. It has some very convenient properties: light-weight, suitable for long distance connections, very low attenuation, very high data rates, immune to electrical noise, safe in hazardous environments, unaffected by lightning, secure from unautorised tapping, electrically totally insulated connection - no grounding problems. But, in the field of fibre optics technology there is still not enough experience and no stable standards to lean on. The MAP mentions fibre optics in an addendum and will include it into the standard, as soon as conditions will be met.

The Data-Link Layer

The data-link layer means a communication link between the nodes, being responsible for assembling data to the frames, giving them adresses, gaining access to the network, checking the data and the medium for errors etc. IEEE802 divides the layer 2 into two independent sub-layers: the Logical Link Control (LLC) sub-layer and the Media Access Control (MAC) sub-layer. LLC does transfer, sequencing, error checking, and addressing and thus enabling the error free path between nodes. MAC manages the access to the physical medium.

MAC in MAP supports IEEE 802.4 token-bus configuration. It guarantees access to the network within a definite time (as opposite to e.g. the CSMA/CD).

LLC, using ISO 8802.2, offers three options to control the traffic: connectionless (type 1), connection oriented (type 2) or acknowledged connectionless (type 3). The connection oriented option organizes a virtual connection between communicating nodes. The connectionless one means sending data without any feedback information, and acknowledging one means no connection, but a possibility to confirm a succesfull receipt of a message. The connectionless transfer is very rapid, but without confirmation, error recovery and flow control. When using connection oriented option, one first has to establish a connection. After that any data can be sent with options of flow control, error recovery etc.. Finally, the connection has to be broken. The connectionless acknowledged type of LLC is used in real time extension of MAP (the MiniMAP), where connections can not be built up because of the time, but data have to be confirmed or an immediate answer is needed.

The Network Layer

Sometimes, for different reasons we have to connect two or more sub-networks into one system. The network layer has a task of routing messages between two nodes in the network, regardless whether they are in the same or an interconnected sub-network. This task includes finding the best communication route between the two nodes, and determining the physical address in the new environment.

The MAP uses CLNS (Connectionless Network Service). The internal organisation of the network layer is devided into three parts, the Sub-Network-Independent Convergence Protocol (SNICP), the Sub-Network-Dependent Convergence Protocol (SNDCP), and the Sub-Network Access Protocol (SNAcP). The SNICP encounters the required standard and service to the service above and to the user, the SNAcP is an interface to the Data-Link Layer, and the SNDCP converts the SNAcP services to and from the form (if) required for the SNICP.

The task of this layer is also naming. That is one of the crucial points in the network design. Variables and other names in the network that are local to a node should not be transparent to the others, and vice versa. This layer also defines a routing model and standard address formats which is one of the greatest contributions of the MAP.

The Transport Layer

Using the services given by lower layers, the transport layer enables to higher layers a reliable end-to-end data transfer. It controls data exchange, organizes access to the network, segments messages to a restricted length, and reconstructs coming segmented data and corrects errors occuring during transmission, if possible and necessary.

The MAP uses a very wide option of the suggested layer 4 specification to compensate rather limited choice (connectionless service) in network layer. It includes the basic functions - connection, segmentation, reassembling and disconnection - and adds some more sophysticated service - for example multiplexing of the connections (sharing one link to different connections in multi-network use), flow control, error detection etc..

The Session Layer

The session layer is the first of the three more sophisticated layers, which are application oriented. Its function is to set up and manage a dialogue between application processess. It ensures that exchange of data on Transport layer is structured and synchronised. It allows establishing and releasing session connections and transfers synchronisation signals.

In the MAP, the layer is broken into three parts; the Kernel Functional Unit, supporting the mandatory session services required to establish a session connection, transfering normal data and releasing the connection, the Duplex Functional Unit, supporting a two-way simultaneous transfer service, and the Resynchronise Functional Unit, allowing the session users to synchronise the transmission of data between asynchronuous nodes.

The Presentation Layer

The Presentation Layer is responsible for the presentation of the data among the nodes taking part in the session. There are two types of the notation in the OSI model. Abstract syntax is a notation for the formal description of data types and values associated with the representational formats used by computer systems. This form is then ready to be encoded into a bit level transmission format using transfer syntax. On the receiver side, the data must be translated from the transfer format to the abstract format.

The presentation layer makes transparent the existance of the transfer syntax, and provides for the conversion to and from it.

In previous versions of the MAP, the Presentation Layer was null. MAP 3.0 defines translation services and protocols and thus supports services of the application layer.

The Application Layer

The layers below the Application Layer were designed to be as much transparent to the network users as possible. The Application Layer prowides an interface between the user and the network. Because of the diversity of applications to support, the Application Layer can not be a universally valid standard. It is a set of procedures for each significant type of application. Information, the application layer is dealing with, concerns data, text, graphics etc.. Other layers deal with anonimous frames of data.

Standards provided by the Application layer are divided into two groups. The first, ACSE (Association Control Service Elements, former CASE), provides services for the establishment and termination of Application Associations. It is a common service for the communication, specifying service primitives like Associate request/indication/response/confirm; Release request/indication/response/confirm; Abort request/indication etc.

The second, called ASE (Application Service Elements) is there to provide the type of service required by the particular application. It includes four elements, Directory Services, File Transfer, Access and Management (FTAM), Network Management and Manufacturing Message Standard (MMS).

Directory Services:

To gain the access to data in remote nodes, all the nodes in network need information about all directories. This is enabled by the Directory Service. It has three major participants: the Directory User Agent (DUA), the Directory Service Agent (DSA) and the Directory Information Base (DIB). In the DIB the information about the directories is stored. The user gets this information from his Directory Service Agent that communicates with Directory Service Agent. Only the DSA has the access to data in DIB. The Directory Information Base can be stand-alone or distributed.

File Trasfer, Access and Management:

The FTAM includes services for information transfer between processes and file stores. It supports binary and text files. The main services available are creating and deleting files, transfering entire files, reading and modifying file attributes, erasing and searcing for the file contents etc.. It enables every node the use of all the files in the network as if they were its own.

Network Management

The network Management has three main roles: gathering information on the usage of the network media by the network devices, ensuring the correct operation of the network and providing reports. It manages configuration, name, performance and faults

Manufacturing Message Format

The Manufacturing Message Format standardises the format and semantics of a list of mnemonic instructions and messages covering all the operating information required by manufacturing devices. It is a simple, limited vocabulary designed to control the widest range of all kinds of the intelligent machines like NC devices, robot controllers, programmable controllers, PC systems etc. Messaging services for factory floor devices requiring device-specific information are defined in four companion specifications covering numerical control devices (EIA specification), programmable controllers (NEMA specification), robot controllers (RIA specification) and process-control specification (ISA specification).

4. MAP AND THE HARD REAL TIME

The MAP with its seven layer topology can not assure data transfer quick enough for time-critical applications like hard real time. On the other hand, this kind of communications does not need time-costly comfortable services.

For that reason there are two extensions in MAP to cope with time-critical data transfer, one is MAP-EPA, the other Mini-MAP.

The MAP-EPA (Enhanced Performance Architecture) is a dual-architecture node, incorporating a full seven-layers MAP node at the one side, and a reduced version, consisting only of the layers 1,2 and 7, on the other (see fig.3). The node can use a full architecture to communicate with other full-MAP nodes or a reduced side architecture for rapid access to the same nodes, provided they are on the same network segment.

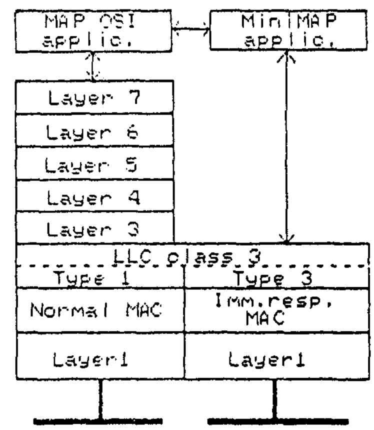

Fig.3: MAP-EPA architecture

The MiniMAP has the same architecture as the reduced side of MAP EPA architecture. It enables a rapid data transfer, but it is not an OSI- compatible device and hence can not communicate with full 7 layer nodes, only with nodes with the same architecture. That comprises its use in so called production cell networks. They have access to the backbone network over a MAP-EPA node, being in both networks and serving as a bridge.

The real-time communication needs to be very quick, but also very reliable. But, reliability takes time, so the two demands exclude each other. Reliability in communication is improved by acknowledging a successfull receipt of a message, but it takes time to gain control over the media. Reduced architecture resolves this problem introducing immediate responding. The transmitting node, possessing the token, passes it to the receiving one. If the message was received uncorrupted, receiver acknowledges it or provides the answer immediately if required. After that, the token is returned to the original transmitter.

5. INTEGRATED COMMUNICATION SYSTEM

In Fig.4 the communication system for Computer Integrated Manufacturing is shown. For the backbone, the full MAP factory-wide broadband network is proposed, connecting subnetworks and bigger systems and possibly serving for other communication needs in the factory (e.g. video and voice and other data transmission).

Subnetworks are tied to the backbone with some coupling devices, routers, bridges or gateways, depending on similarity of design. These are office, business and technical design dedicated subsystems, like TOP or other CSMA/CD

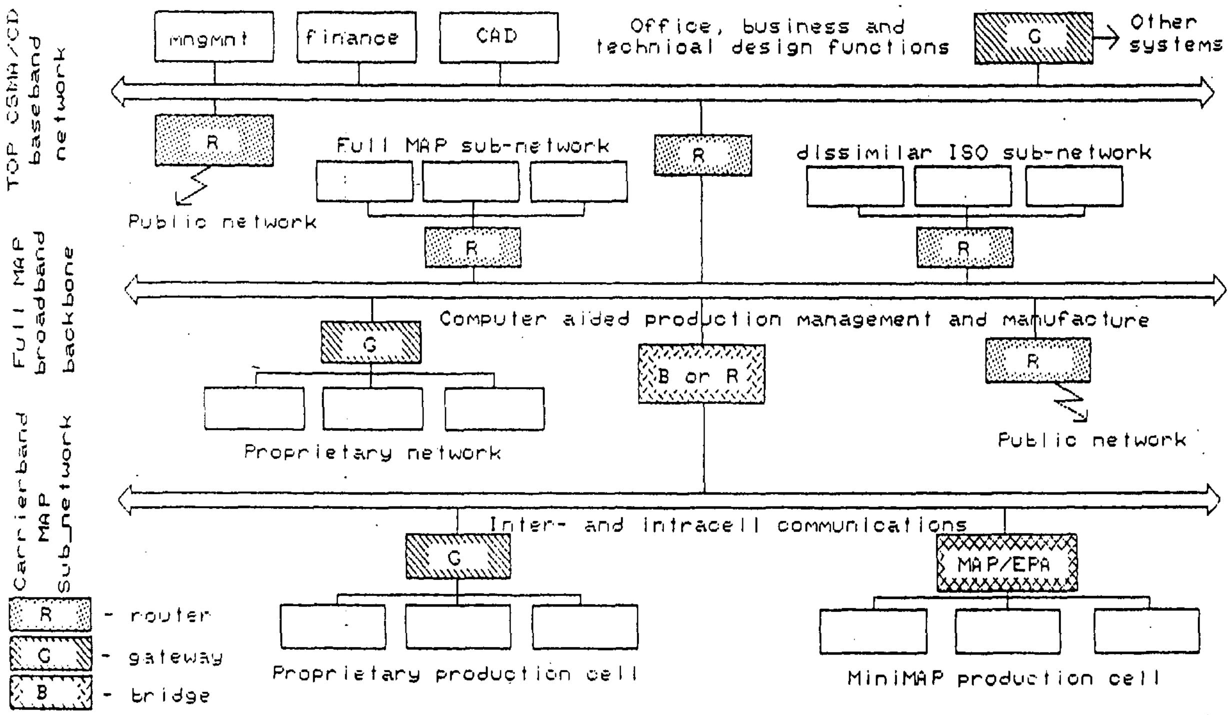

Fig.4. MAP integrated communication system (example from /6/)

networks on the one side, and production cells in real-time networks on the other. These networks can be proprietary, existing process control distributed systems or MiniMAP-like systems.

6. PRESENT STATE OF DEVELOPMENT

This chapter is meant to present the state of the MAP project as it was at the time of SYSTEC'88 at the end of October 1988 in Munich.

There were about 20 MAP vendors and users taking part in MAP Sonderschau. Information about Enterprise Networking Event in Baltimore in June '88 was also given where more than 100 different participants were connected to a MAP backbone network.

The MAP Sonderschau was initiated by the European MAP Users Group (EMUG). Its aim was to prove that MAP is operable and ready to integrate a lot of different products and even net-

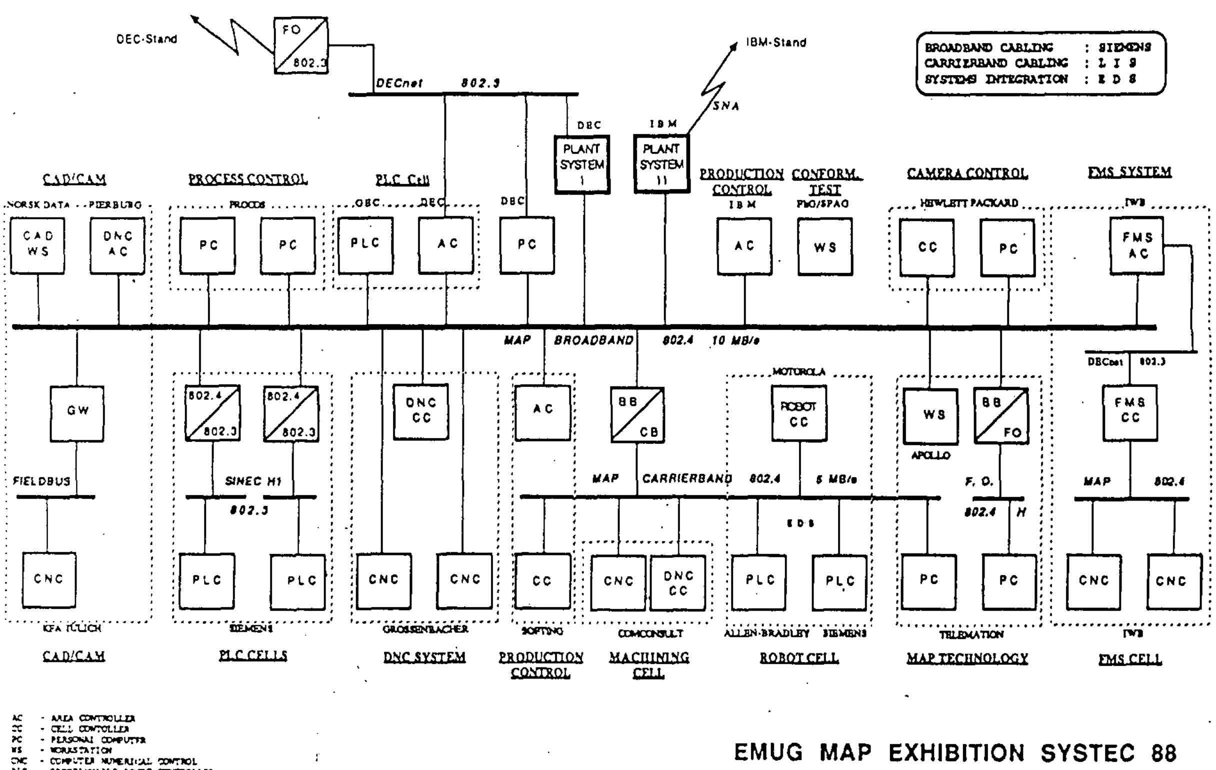

Fig.5: Network at the MAP Sonderschau at Systec '88 in Munich (from /4/)

works into an interoperable system. On the MAP Broadband 802.4 10 MB/s backbone different nodes and sub-networks were connected, including TOP, MAP Carrierband 802.4, fiber optic carrierband of Telemation, DECnet 802.3, multi-vendor production cells and robots, CAD systems and even a separate video camera and a monitor system on its own channel. On the same broadband cable different versions of MAP, the 3.0 and the 2.1 are possible to show the upgrade possibility in the future. (see Fig.5)

Looking over the MAP products on ENE we must state that by Summer '88 only a few vendors could present them. The fairs in spring '89 will show if the promise that the number of MAP producers is increasing will be fulfilled. MAP board-level products were shown by Concord (PC-bus and Multibus products) and Motorola (VME-bus products). Some other announced new products. MMS software producers are also very rare: Motorola for its VME boards and SISCO for DOS versions. Support for other operating systems is announced. Knowing this, the fact that more than 100 nodes from different vendors at the ENE in Baltimore were interoperable is not so astonishing, as most of the vendors used the same Concord boards and Sisco software.

Another fact shown at ENE are the prices. They felt to the range of 2000 USD for one node, what is very near to the proposed price.

One of the less encouraging facts is that the biggest computer manufacturers, like DEC and IBM, still stand aside of the business as observers or producing their own OSI-compatible networks with an option to connect to MAP. It is certainly not that, what other dedicated MAP members would like to see. The development in early 1989 will show their intentions, which will be crucial for further progress of MAP. The latest news from DEC is not very encouraging.

7. CONCLUSION

Devotees are delighted: ENE was a triumph of MAP. It showed that numerous vendors were capable to communicate with each other. It is no doubt that MAP represents efforts of the largest group of computer manufacturers working together on one goal - to be able to transmit data over a network. The result of this collaboration is the widest all-embracing communication standard and everybody is waiting how it will prove.

Looking at the MAP critically, we can state some facts. First of all, some crucial topics are still not standardised, like network management. There exist several versions of some topics or they are not accepted by whole group. On the other hand, there are some parts of standards, that proved inconsistent or less suitable in the first applications, like immediate response option in real-time version.

To give the vendors and users enough time to implement their solutions they have frozen MAP 3.0 specification for the next 6 years. This period is very long in such a dinamic field like distributed computing, especially if the standard is not validated long enough. Deficiencies will have to wait too long to be included into a standard that would have to be a living structure.

The major disadvantage of MAP architecture are its real-time extensions. Introducing immediate response solves problems on the lowest level, it acknowledges the integrity of received data, not that of the message. There are troubles with error management since there is no higher-level mechanism. It allows no broadcasting and there is no clock synchronisation provided.

One of the greatest problems of the real-time MAP extensions is that it has no fault tolerant concept, what is crucial in modern process-control networks. Malicious node can not be located and excluded by the protocol.

In spite of all there are some very good and universally applicable standards in MAP that will survive regardless of long-term destiny of the whole project. One of the most important is doubtless Manufacturing Message Standard in the Application layer that defines semantics of communication language.

Some most important fairs in the near future will show the success of the proposed standard. The greatest computer manufacturers that are not convinced of the effectiveness of it are still standing by, leaving their door to the MAP open, but using mostly their own networks.

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