ISSN 1392 – 124X INFORMATION TECHNOLOGY AND CONTROL, 2007, Vol.36, No.3

MMS IN REAL INDUSTRIAL NETWORK

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Abstract. Copper Institute, Industrial Informatics department, is developing and applying network real time process monitoring and control systems. The kernel of those systems is the microprocessor measuring station - MMS. In hardware and software point of view, MMS is a type of PLC (programmable logic controller) with some of local and remote functional possibilities. In monitoring and control of technological processes in many production plants, occurs a necessity for transfer of information and interaction with the process from remote distances (from control center, for example). It is obvious that for these requirements there should be available monitoring and control systems for operation in network environment. Special attention is paid to communication sub-systems, i.e. development of cost viable and in practice easily applied solution. Some of these systems are already in use. The paper presents hardware and software characteristics and performances, with special regard to network operation and possibilities.

Keywords: Process Control, Distributed Resources, Computer network, Real Time.

1. Introduction

The own monitoring and control system is developed and applicated in some of production plants of Mining & Smelting Complex Bor. Because of long geografical distances it has to be a distributed system based on a network. The solution of network infrastructure has always been faced with a basic problem of communication paths. In spite of the fact that for communication channels telephone line connections have been selected, which represents the least expensive solution in urbane environment, it is frequently very difficult to provide at least one communication line for each device (network node). It must be stressed that in this case leased lines are necessary, since the system involves the process of real time permanent operation, which practically is not possible to realize with switched lines. Systems already developed and in use, correspond to these requirements to a large extent, but they have certain deficiencies, which required introduction of some improvements.

The basic requirement is a real time operation in network environment but with respect of imposed limitation: impossibility to provide leased telephone lines from the control center to each of system units (nodes). A development work has been undertaken with goal to create and perform a synthesis of specific network structure. Hierarchical organization of network management has been adopted, and topographic form has been dictated by practical requirements in the concrete application.

2. Hardware

To gain the proper insight into the picture about the requirements to be satisfied and about performances of realized network, it is useful first to present basic characteristics of nodes in the network and the manner of their operation. Considering that a system is involved for monitoring and control of technological processes, one or more industrial automatic devices (MMS-PLC, Data Logger etc.) are the system basis [1]. For interaction with the process (to check actual state of parameters and execute the action on the process- remote control) a classical PC is used. This means that the simplest network contains one MMS and one PC. In a general case, for "distributed" processes a large number of PLCs are required to perform measurement of process parameters, data acquisition, control and transfer to the host computer (PC). In local control, according to a pre-set algorithm, MMS generates motor signals and transfers them to executive devices for intervention on the flow of technological process [2]. Independently from the fact whether local control is in force or not, data about status of the process are transferred from the place of origin – source (MMS) to decision-making place (PC), and these information we shall simply call data. On PC these data are processed and results presented in corresponding form on the screen and stored in external memory. If the system performs remote control function, depending on the status of the process, from PC to MMS corresponding commands are sent, which effect adequate actions and affect the process flow. This information is called commands. Apart from effects on the process, commands have their effects on MMS itself for testing its functionality, giving information about real time etc [2]. Designed and implemented network must satisfy several basic requirements: to provide correct and efficient manner of data transfer via PLC in the shortest time possible from the time of their origination, to solve uniformly transfer of commands to PLC while the command is active and actual, to provide successive transfer of data from PLC for the case that there are any faults in normal transfer for any reason.

FEP&MSD (Front End Processor and Modem Sharing Device) is a microprocessor device whose function is to ensure solid communication link with belonging PCs, on one hand and to establish, maintain and control network operation of local and remote groups of PLCs, which are called clusters, on the other. It is a central node in the network for practical reasons also (to avoid the necessity for a new pair of modems, apart from other things) it is located next to PC and is directly connected to one of its communication ports (Back-to-Back).

In hardware basis of this device, two components may be differentiated: pre-processor (FEP), which is based on micro-controller M68HC11 [3], and asynchronous modem (base band) with time multiplexing output (MSD). Figure 1 presents its simplified functional diagram.

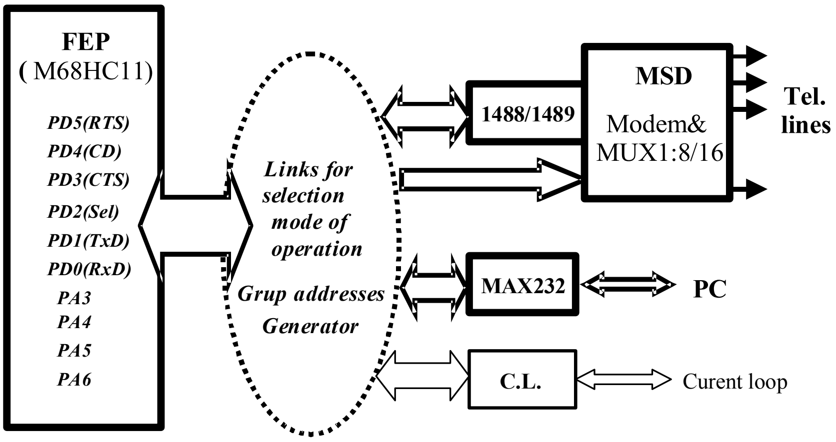

Figure 1. Simplified block diagram of FEP&MSD device

In EPROM of the device there is a monitoring and control and operating program, while RAM is used for buffers for each particular PLC, i.e. for temporary storage of messages sent to PC. The manner of operation of FEP&MSD is described in basic part of software and its physical connection with PC and local modem is achieved through two mutually dependent ports. According to time-sharing principle active port is selected, i.e. alternative port is disabled (Enable/Disable), by generating corresponding output PD signals.

Other nodes in the network are MMS, microprocessor devices – Microprocessor Measuring Station (MMS) or Universal Measuring Station – UMS [6], type of PLC, which perform acquisition of data from the process and generate motor signals for affecting the flow of technological process. For the network operation, the usage has been made of capabilities of the processor M68HC11 (which is used in our case) to communicate serially in asynchronous regime [4]. Physical connection between nodes is realized with two-wire leased line. For conditioning of transfer signal simple assemblies are used as line amplifiers. Only the first one in the group (cluster) is slightly more complex and is directly connected to the modem. In concrete case, a modem LD1900 in basic range is used, of own construction, for asynchronous regime of operation on two-cord leased line. Mutual connections of nodes within one group (cluster) is performed with two lines in multipoint and may extend about 2.5 km from the first to the last measuring station. One group (cluster), theoretically, contains up to 128 nodes (MMSs) but in practice only 16 has been used. FEP&MSD device may support up to 16 clusters. Considering the distance involved, PC is connected in the network with three-cord interface cable (RxD,TxD and Gnd). Figure 2 represents a simplified structure of a complex network.

3. Software solutions

To gain an insight into controlled process in real time, to issue commands in real time to a particular device and store the data for successive analyses and processing, it is necessary that PC exists in the network and operates under the corresponding application program. Due to the limited central memory of FEP and for other reasons, it is not rational that information from measuring stations is accepted if it can not be transferred to PC and connection with other nodes in the network is not established if stable communication between FEP and PC does not exist.

The network is centrally controlled, but regarding the control two versions have been provided: first in which start of each transfer is initiated by FEP and second in which PC determines the speed of communication with pre-processor and accordingly timing of complete network [4].

In the first solution, independent timer in PC generates instructions for interrupts (Timer IRQ) in uniform time intervals, duration of which is defined by conditions of operation of measuring stations and transfer time, i.e. requirements of system response. This parameter (Scanning Rate) is imposed as an external parameter and its value in practice amounts from 100 ms to several seconds. In one time interval (between two timer interrupts) FEP first establishes connection with PC and after acknowledgement of correct state (check of status of PC programs and accuracy of transfer in both directions) breaks the connection and establishes communications with the first successive PLC in the list of logical addresses of nodes in the network. As a result of successful transfer, a message is received from secondary node (MMS), which mandatory contains information about status of the node and quality of transfer to and from FEP and useful data about process parameters, if this actual information is available. That message FEP transfers to PC in the first successive "communication". The network functions on the principle master/slave, where FEP is a primary node and each MMS within groups (clusters) a secondary node. PC is "privileged" secondary node, since FEP "calls" it immediately before establishment of connections with other nodes in the network [4]. It is obvious that in the case of communication break between FEP and PC, network is functionally broken. Then each node continues with autonomous local operation until spontaneous establishment of network function, after which accumulated remainder of messages is transferred.

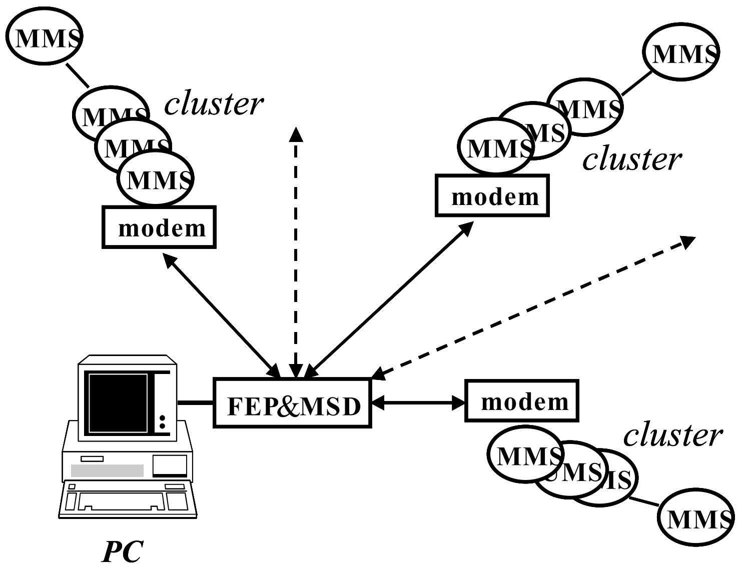

Figure 2. Block diagram of network structure

Second solution differs basically from the first one, only in the part of initial establishment of communication FEP-PC. In this case, PC by execution of its operating (application) program performs the program sequence of establishment and control the communication session with FEP. After successful two-way transfer of corresponding messages, FEP continues with "calling" of other nodes in the network, analogous to the above described procedure.

The first manner of network control has been realized at the time of intensive usage of DOS operating system and assumes sufficiently synchronized and time determined sequence, controlled by a stable real time clock in pre-processor. On PC corresponding actions are required in operation with communication port and interrupt controller and modification of interrupt vector table is also carried out, i.e. a separate routine (Interrupt Driven) is executed for reception of message. The basic advantage of this solution is manifested in uniform definition of scanning time and expiry of time interval (timeout) of each of secondary nodes, by which very precise synchronization is enabled for operation of complete network. The main disadvantage lies in the necessity for changes in interrupt control, by which some of capabilities of PC are limited.

Usage of WINDOWS has conditioned new, second solution. Control of serial port is now more difficult without special routines (drivers) because of which new manner of communication control has been adopted. Compared to the comfort presented by WINDOWS environment and ease of programming, this disadvantage may be negligible in practice.

Because of complexity of network structure, it is possible to differentiate communication software at all levels: PC, FEP and MMS. On PC, when it operates under DOS operating system, very complex programming solution is used for communication support, for the case that FEP is the primary node in the network. During "Booting" of operating system a resident program for reception of characters from port and modification of interrupt vector table is loaded into

RAM. This program is written in C language. Application program itself is written, in majority of cases, in Turbo Pascal with modules for exchange of information in network, which contain short assembly language procedures. In WINDOWS environment, application programs are written mainly in Delphi and operation with communication ports is made significantly easier.

Basically, FEP contains programming solutions for control of accuracy of its own operation (Self Test) and operating programs for establishment of network function, monitoring and control of its operation. Since nodes in network are specific devices (MMSs), own communication protocol has been developed. This protocol defines manner of establishment and breaking of connection between nodes, message format and manner of control of transfer accuracy. All program modules are written in assembly language for MC68HC11 [3], optimized as regards duration and contained as resident software in EPROM. RAM is used for some of side parameters and for messages. For specific requirements it is possible to transfer the code from PC to FEP (teleloading) and its storage in RAM, which is mainly used in program testing stage.

MMS (PLC) device executes supervision and control of technological process and its operating program is adjusted to concrete requirements. Apart from diagnostic and testing program module and operating program, each PLC must also contain communication program because of its dependence in operation (it must be sent a command, real time clock value etc.) and due to the requirement that measurement data should be transferred to host computer. Functions of message reception, control of transfer accuracy and sending of answers are contained in a special procedure, which is activated by hardware interrupt from communication port. Since here a secondary node in the network is involved FEP initiates these actions and they do not disturb basic functions of PLCs, which are measuring, control and data collection.

4. Message format and timing

The designed computer network operates based on asynchronous transfer [6]. To be able to establish and break efficiently connections between network nodes and to achieve optimal speed and maximal accuracy of transfer, a standard message format has been designed, which is presented in Figure 3.

DAD	SAD	EAD	CODE	CST	Text	EOM	BCC

Figure 3. Format of Message

DAD – Destinations Address
SAD – Source Address (Message Originator)
EAD – End Address (Address of end destination node)
CODE – Status or Command
CST – Communications status (Previous transfer quality)
Text – Useful information
EOM – End of Massage
BCC – Block Check Character

It is obvious that given characters (total 7 bytes without information useful for process control) represent an overhead which must always be transferred in each communication. Duration of the transfer of this message header and control characters may be represented in the following manner:

$$t_h = 7 \times Tr, \qquad (1)$$

where Tr is the physical transfer speed (Transfer Rate). Due to some realistic conditions of operation, in practice, transfer rates of 9600 bps and 19200 bps are used, so that t_h = 7.3 ms, and t_h = 3.65 ms, respectively. It is obvious that higher transfer rate must be selected whenever possible, but present limitations must be taken into consideration, which are conditioned by the quality of transfer routes (telephone lines) and distance between nodes. For normal maintenance of network in operation, for control of presence of nodes in the network and control of their state it is sufficient that such (null) message is transferred from PC to any secondary node and that answer is received back. Each of the characters in the message has its significance at two bit levels, so that diagnostic of network operation is done by their analysis. A part of message containing useful information (text) has a variable length, but for the case of commands from PCs, 5 bytes are sufficient for any action on MMSs or during control process.

Accordingly, command message length has been standardized to the length of 12 bytes, i.e. its transfer time is 12.5 ms or 6.25 ms, respectively.

MMS, in its standard configuration supports 64 analogue and 128 bit inputs. During the operation, sampling of input channels is performed and after corresponding controls, a message is formed for sending to the host computer. The length of this message may be represented in the following manner:

$$D_p = 3 + 64 \times 2 + 22 = 153 \text{ bytes}. \qquad (2)$$

Each message contains origination time (first three characters) and since measuring data are one byte numbers and transfer obeys certain rules of ASCII code (Etx = \$03 etc.), it is necessary to carry out adjustment for the transfer, so that total length of useful information is 153 bytes, and the time required for its transfer is:

$$t_t = 153 \times Tr. \quad (3)$$

With given transfer rates, with the inclusion of one start and one stop bit, the maximal transfer time for the message is:

$$T_p = t_h + t_t, \quad (4)$$

which practically amounts to 166.6 ms or 83.3 ms, respectively for transfer rates of 9600 bps and 19200 bps.

When complete exchange of information is taken into consideration, i.e. command sent to MMS and command sent to PC, physical transfer itself lasts 180 ms or 90 ms, respectively. If it is known that each information must be transferred from PC to FEP and then to secondary node and reversibly, it is obvious that this transfer time should be doubled. Accordingly, for message exchange time interval must be provided of 350, or in a more favorable case, of 175 ms. If it is known that all other actions on MMS and especially on PC (including measuring, logical control, analysis and preparation of messages, i.e. display on the screen and generation of command codes) last significantly shorter, it may be concluded that for servicing one secondary node, 400 ms, or 200 ms is required. What does it mean in practice? Optimal response time of such network including about 50 nodes is in the range of 10 seconds. In case of issuing commands it may be very slow. Due to this, an algorithm has been developed for forced establishment of connection between selected nodes, so that servicing of urgent requirements can be done in the shortest time interval (about 200 ms). After that scanning of other nodes is performed according to their logical addresses.

In real situations frequent faults occur on particular nodes and they are out of operation for a shorter or longer time interval or without communication with FEP. To improve network performance (to shorten response time), these nodes are excluded from the network and only after remedy of faults their operation is resumed. This procedure has been called dynamic network configuration and it functions efficiently in practice. Criteria for exclusion of nodes from network and their re-connection are sufficiently "broad" and may be easily changed [5].

5. Conclusion

First impression is that realized network, by its characteristics, does not belong to the group of high performance solutions. The megabit transfer rate is a standard performance of present networks. But the development and application of this described solution has its practical aim. Its application solves a group of requirements (problems) in real time environment. Processes and events, which are monitored and controlled by such system, are relatively slow (town central heating system, water supply network, electrolytic copper refinery plant, meteorology and air pollution control etc.). Actual information about the state of these processes is generated in one-minute intervals or more rarely, so that efficiency of communication system can not been questioned. Apart from favorable price/performance ratio, functioning of realized network has shown to be very efficient, reliable and especially resistant to poor communication conditions, thanks to solid transfer quality control and possibility of dynamic network reconfiguration.

There are a couple of installed systems with satisfactory performances in real operational environment.

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Received May 2007.

DOI: 10.5755/j01.itc.36.3.11882