CRANE CONTROL NETWORK

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Abstract. This paper summarizes the most important features of the Crane Control Network (CCN) and Fast Multidrive Field bus Link (FMFL) as a part of the Distributed Multidrive System (DMS). The proposed links provide a real-time communication link between various clients or controllers in a complex DMS. CNL is configured as a local overriding communication network and includes FMFL as subnet. CNL and FMFL are designed in accordance with ISO's seven-layer model for Opens System Interconnection (OSI). Both links are used for the time critical, real-time communication within the DMS. DMS, access to the CNL and basic features of the FMFL's protocol are shortly presented.

Keywords. control network, fast multidrive field bus link, distributed multidrive systems, real time communication

1. INTRODUCTION

Within the framework of industrial modernization, increasingly powerful and more flexible control systems for industrial crane application are needed. The CDA (Complex Distributed Applications) based on the control network facilities should be capable to fulfill all these requirements for mentioned modernization. Common control functions are distributed to separate nodes by the use of digital communication. These communication links must ensure high performance, reliability, and availability required by distributed applications. The Crane Control System [fig.1] concept is designed for handling of the complete control and automation of a container crane. The total function is built up of a number of distinct building blocks. These blocks can be installed from the beginning or added on after the delivery of the crane. Many of the building blocks are tightly connected to each other and requires as system designed and built with the total functionality to achieve the right performance. Basic and advance control package are designed to handle the real time processing of the automation functions. CCN (Crane Control Network) is based on open and standardized communication capabilities to enable their complete integration into complex crane production sequences. The basic concept of open system is to enable an exchange of information between application functions implemented on all distributed field devices. That includes defined application functions as a standard user interfaces for communications and a standard transmission medium. Functional specification for the communication protocol is based on an open protocol and supports multi vendor interoperability and interchangeability.

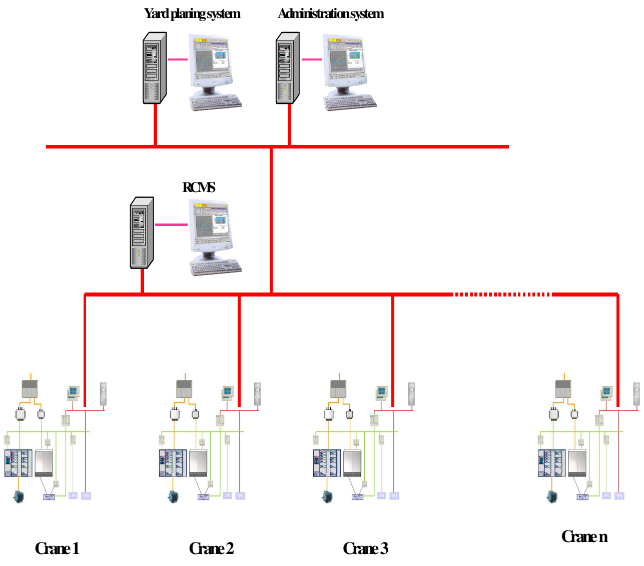
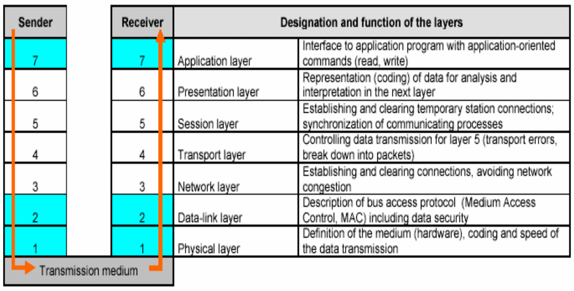


Fig 1. Crane Control System.

Supervisory System for the crane application alias RMCS (Remote Crane Management Server connects all cranes via TCP/IP communication network and optical hubs connected to the Yard Planning and Administration System. The maintenance functionality on the crane is concentrated in the Crane Monitoring and Maintenance System (CMMS) locally.

2. CRANE CONTROL NETWORK

The CCN provides real-time communication link between various clients or controllers in a CDA. These links are local to the respective clients and can only communicate with clients connected to the same bus. CCN is designed in accordance with ISO's seven-layer model for OSI (Opens System Interconnection).



Sender	Receiver	Designation and function of the layers	
7	7	Application layer	Interface to application program with application-oriented commands (read, write)
6	6	Presentation layer	Representation (coding) of data for analysis and interpretation in the next layer
5	5	Session layer	Establishing and clearing temporary station connections; synchronization of communicating processes
4	4	Transport layer	Controlling data transmission for layer 5 (transport errors, break down into packets)
3	3	Network layer	Establishing and clearing connections, avoiding network congestion
2	2	Data-link layer	Description of bus access protocol (Medium Access Control, MAC) including data security
1	1	Physical layer	Definition of the medium (hardware), coding and speed of the data transmission

Fig 1. The OSI Reference Model

It is used for the time critical, real-time communication within the distributed control system [1]. The majority of open distributed applications are based on the client-server communication model. This means that client or application process accessing and using server as remote file system. A single server process supports access requests from a distributed community of clients concurrently. When two or more networks are involved in an application, the mode of working is normally refereed to as internetworking [1], [2]. The term Inter-network or Internet is used to refer to the composite network. Each constituent network is referred to as a subnet. It is assumed that each network is of a different type and hence that the router will have a different set of network protocols associated with each network part. Control network based on Internet is assumed as a subnet. For this particular application, CCN is a private IP network. This means that all communication handling will be the same, regardless of network type or connected devices. CNL is scalable from a very small network with a few nodes to a large network containing a number of Network Areas with addressable nodes (there may be other restrictions such as controller performance). CCN uses the MMS (Manufacturing Message Specification) communication protocol on Ethernet to link workstations to controllers. MMS is an ISO 9506 standard. In order to support CNL on RS-232C links, the PPP (Point-to-Point Protocol) could be used. The RNRP (Redundant Network Routing Protocol) handles alternative paths between nodes and automatically adapts to topology changes. MMS and RNRP are described in Fieldbuses such as FOUNDATION Fieldbus H1 (according to ISA SP50), PROFIBUS-DP (according to IEC 1158-2 and EN 50170). CCN uses the MMS protocol and a reduced OSI stack with the TCP/IP protocol in the transport/network layer, and Internet and/or RS-232C as physical media. MMS (Manufacturing Message Specification) is an ISO 9506 standard. This means that all communication handling will be the same, regardless of network type and connected devices. CCN identified by its network ID, normally covers one manufacturing plant. A large CCN can be divided into network areas or sub-networks, for example to keep most of the time-critical communication within smaller areas, thereby improving performance. The CCN can contain up to 32 network areas, each with a maximum of 500 addressable nodes (different number series can be used for different plant areas and check must be done regarding the controller performance for restrictions on the total number of nodes that can be used). Sub-networks are not permitted within a network area. Network areas must be interconnected by controllers (used as routers). A controller running the RNRP protocol with two Internet ports having the same node number connected to different network areas, has router capability. If the node detects that it is connected to more than one network area, it automatically starts routing without any need for extra configuration data. The CCN must be protected from foreign traffic that can be a security risk and also cause undesired load on both the nodes and network. To avoid these risks the Control Network should be physically separated from the Plant Intranet and protected by servers and/or firewalls. In large configurations such separation may also be desirable between the Control Network and client/server networks. CCN can be connected to the network via communication interface units.

Together with CCN, part of the distributed application could be DMS (Distributed Multidrive System) as a basic drives concept. Direct integration of variable speed drives into the overall process control system by way of CCN and FMFL (Fast Multidrive Fieldbus Link), brings about a number of advantages, such as simplified connections, consistent operator supervision or control and improved application program legibility. In DMS, several APC (Application

Controllers) are interconnected by FMFL where each drive is used as separate node.

2.1. CCN based on TCP/IP protocol

The protocol defines communication messages transferred between controllers as well as between the engineering station and the controller (e.g. downloading an application or reading/writing variables). It has been developed especially for industrial applications. The Internet protocol is one protocol associated with the complete protocol stack and it is known as TCP/IP protocol (Transmission Control Protocol/Internet Protocol). Protocol is now widely used in many commercial and research Internets and includes transport and application layers. Networking protocols layers are responsible for a different facet of the communication. A protocol suite for used TCP/IP protocol is the combination of different protocols at various layers and is considered to be a minimized OSI 4-layer system. The data link layer or network interface layer includes the device driver in the operating system and corresponding network interface module. This module, handle all the hardware components of physically interfacing to the network Media. Network layer or Internet layer supports the movement of packets around the network as well as routing of packets. Internet Protocol, Internet Control Message Protocol together with Internet Group Management Protocol provides the network layer in the TCP/IP protocol suite. Transport layer supports a flow of data between two hosts. TCP/IP protocol includes two different transport protocols: TCP (Transmission Control Protocol) and UDP (User Datagram Protocol). TCP and UDP are two predominant transport layer protocols and both use IP as the network layer [4], [5]. TCP provides a reliable transport layer while UDP sends and receive datagrams for applications. The application layer is direct interface to the user application program and could include: Telnet, FTP (File Transfer Protocol), SNMP (Simple Network Management Protocol), SMTP (Simple Mail Transfer Protocol). Telnet provides services to enable a user application program to log on to the operating system of remote device. User can communicate interactively with another application process as if the user terminal was connected directly to it. FTP enables user application program to access and interact with remote file system. Access to a remote file server is a basic requirement in many distributed control applications. SMTP manages the transfer of mail from one system mail to another. SNMP is concerned with management of all the communication protocols and supports the total network environment. API (Application programming interface) for application using the TCP/IP protocols called sockets and TLI (Transport Layer Interface). A socket is end-point for communications that get bounds to the UDP or TCP port within the node. One application layer creates a TCP stream socket and binds it to a particular well-known port number. Next application layer in the host device creates another stream socket which one will request connection to the previous socket by specifying its host Internet address and port number. Once the two TCP sockets have been thus connected, there is a virtual circuit set up between them. Up to five different protocols or sockets could be created. The socket layer contains a certain number of paired "calls" and these routines protect code that accesses data structures shared between the socket layer and the protocol-processing layer. The board communication software support package uses a client-server communication model. The main server reads requests and, if requested, sends a reply back to the client. The client builds the request according to the specific application layer, sends message and waits for a reply to be sent back. The CNL Medium Access Control (MAC) standard together with associated physical media specification (contained in the IEEE 802.3 Carrier Sense Multiple Access with Collision Detection (CSMA/CD) standard's document) are implemented [7], [8].

3. FIELDBUS PROTOCOL

Field buses are industrial communication systems that use a range of media such as copper cable, fiber optics or wireless, with bit-serial transmission for coupling distributed field devices [fig.2]. These devices could be a different type of sensors, actuators, transducers or complex drive systems.

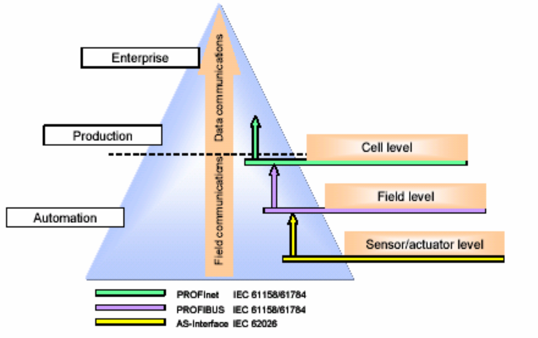


Fig 2. Profibus in automation

Most of the today PLC (Programmable Logic Controller) controllers support different type of Fieldbus protocols (MasterBus 300, SattBus, COMLI, MODBUS or PROFIBUS). Profibus protocol is used in many industrial applications today.PROFIBUS [fig.3] is a vendor independent, open fieldbus standard for a wide range of applications in manufacturing, process and building automation. Vendor independence and openness are guaranteed by the PROFIBUS standard EN50170. With PROFIBUS, devices from different manufacturers can inter-communicate. Suitable interfaces exist for PLCs, which include the Siemens, Mitsubishi and Allen Bradley range. Vendor controllers support the PROFIBUS-DP variant of the PROFIBUS protocol, which is designed especially for communication between automatic, control systems and distributed I/O at the device level. It is most often used to allow a central PLC or PC based control system to use external 'slave' devices for I/O or specialized functions. The principal advantage is that these devices may be distributed around a machine, thereby saving on the cost of point-to-point wiring. The 'open' nature of the network also permits equipment from different manufacturers to be mixed on the same bus. Additionally, the off-loading of complex and specialized tasks such as PID temperature control lessens the processing load on the central PLC so that its other functions may be carried out more efficiently and requires less CPU memory.

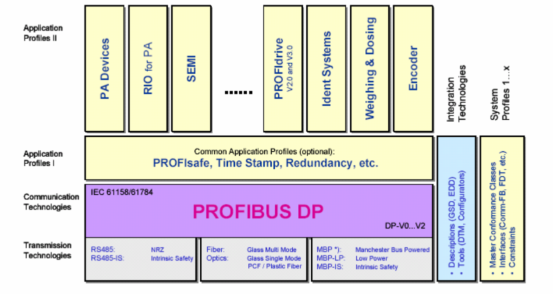

Application Profiles II
PA Devices
RIO for PA
SEMI
......
PROFIdrive V2.0 and V3.0
Ident Systems
Weighing & Dosing
Encoder
Integration Technologies
System Profiles 1...x
Application Profiles I
Common Application Profiles (optional):
PROFIsafe, Time Stamp, Redundancy, etc.
Communication Technologies
IEC 61158/61784
PROFIBUS DP
DP-V0...V2
Transmission Technologies
RS485: NRZ
RS485-IS: Intrinsic Safety
Fiber: Glass Multi Mode
Optics: Glass Single Mode
PCF / Plastic Fiber
MBP *): Manchester Bus Powered
MBP-LP: Low Power
MBP-IS: Intrinsic Safety
• Descriptions (GSD, EDD)
• Tools (DTM, Configurators)
• Master Conformance Classes
• Interfaces (Comm-FB, FDT, etc.)
• Constraints

Fig 3. Profibus structure

PROFIBUS-DP is described in DIN 19245, and forms part of EN 50170 with P-Net and World FIP. However it is important to note that P-Net and World FIP are wholly incompatible with PROFIBUS, using different wiring and transmission technologies. The PROFIBUS-DP network uses a high-speed version of the RS485 standard, permitting baud rates of up to 12Mbaud. A maximum of 32 PROFIBUS-DP stations (nodes) may be contained within a single network segment. Use of RS485 repeaters allows a total of up to 127 stations. PROFIBUS-DP is a multi-master, master-slave, and token passing network.

PROFIBUS is available in two other types, aimed at different application areas, as follows [fig.4]:

- PROFIBUS-PA is designed especially for process automation. It permits sensors and actuators to be connected on one common bus line even in intrinsically safe areas. PROFIBUS PA permits data communication and power over the bus, using intrinsically safe, 2-wire technology according to the international standard IEC 1158-2, but may also be used on the standard RS485 cabling for non-intrinsically safe applications.
- PROFIBUS-FMS is the general-purpose solution for communication tasks at the cell level. Vendor controllers may be used on 'combi' networks, which combine DP and FMS, but may only be used for PA when the intrinsically safe physical medium is not used.

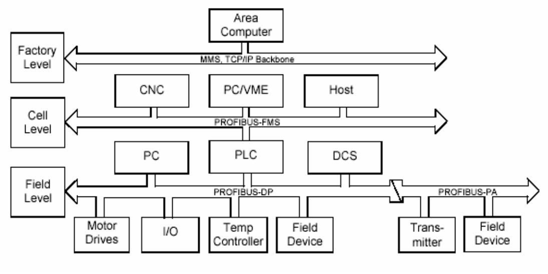


Fig 4. Profibus family

PROFIBUS-DP distinguishes between master devices and slave devices. It allows slave devices to be connected on a single bus thus eliminating considerable plant wiring typical with conventional communications systems. Master devices determine the data communication on the bus. A master can send messages without an external request when it holds the bus access rights (the token). Masters are also called active stations in the PROFIBUS protocol. Slave devices are peripheral devices. Typical slave devices include input/output devices, valves, motor drives and measuring transmitters. They are intelligent slaves and this means they will only respond to a master when requested to do so.

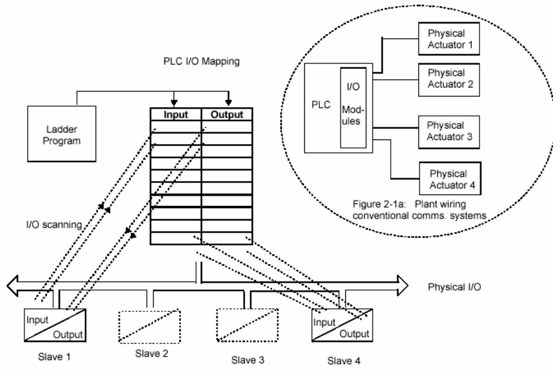


Fig 5. Profibus cyclic scan

PROFIBUS-DP is based around the idea of a 'cyclical scan' of devices on the network, during which 'input' and 'output' data for each device is exchanged [fig.5].

The process of reading the inputs and writing to the outputs is known as an I/O data exchange. Typically, the parameters from each slave device will be mapped to an area of PLC input and output registers, or a single function block, so that the controlling ladder logic or program interfaces with the device as if it were an internally fitted module. It is NOT necessary, therefore, for the programmer to know anything about the physical network. The process of network configuration is usually performed using a PC based program, which allows the devices on the network to be defined and device parameters to be mapped into the PLC registers or function blocks. The cyclical scan occurs in the following order:

- Values from each slave device, 'Input Data', are first scanned over the network into a pre-defined set of input registers in the master controller. Such values might be a set of digital input readings for a digital input unit, or the measured temperature and alarm status from a PID controller.
- The master then runs its control program, (such as a ladder logic program) using the input data read from the slave devices.
- The master writes output values (output data) into a pre-defined set of output registers. For example, one of the digital inputs read in the input data might be used to select one of a set of set points to be sent to the PID controller.
- These outputs are then written to each slave device, and the scan-process-write cycle repeats.
- Typically no more than 32 bytes of input data and 32 bytes of output data are exchanged for each device during the data exchange. Some PLC masters allow no more than this, although the PROFIBUS-DP standard provides the possibility of transferring 236 bytes in each direction. The input and output data lengths for a given device are variable and it is possible to have devices with only input data, only output data, or both.
- The input and output data mixture used by a given slave device is defined by what is known as a GSD file. See Chapter 5 for more details. For simple devices such as digital or analogue I/O blocks, this is fixed. However, since more complex devices often have a much wider choice of possible values to send, it is usually possible to edit the GSD file to change the mapping of device parameters onto Profibus inputs or outputs. This is the case with most Eurotherm implementations, which also allow access to parameter data not in the GSD Input/Output data file.
- The GSD file is imported into the PROFIBUS Master Network Configuration software before the network is created.

4. FAST MULTIDRIVE FIELD BUS LINK

The Multidrive concept gives users of drive systems with a number of different possibilities to solve their engineering problems. A new concept for engineered drive applications includes: built-in distributed application control, open communication and advanced PC based tools for application programming, commissioning, trouble shooting and drive monitoring support.

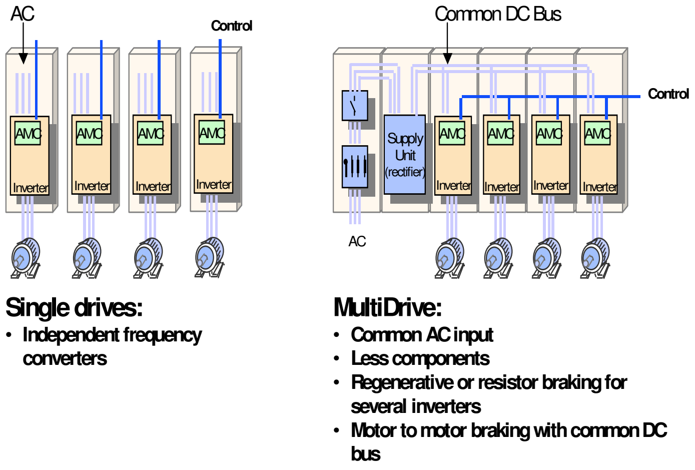


Fig 1. Multi drive concept

The Application Controller (APC), common for both DC and AC drives, is basically a single board controller with all the software and hardware facilities needed to handle the application specific functions. The Digital Drive Controller (DDC) software is fixed but various functions and operating modes can be selected via parameters. Either a torque or a speed reference provided by the APC controls the DDC. In a distributed multi drive systems, several application controllers are linked by the fast communication link where each drive can be used as a node. Common control functions are distributed to separate nodes by the use of digital communication. APC can communicate with external systems with communication boards, as well. APCs are interconnected by FMFL where each drive is connected as separate node. High Level Data Link Control (HDLC) protocol is an international standard (defined by ISO for use on both point-point and multi-drop data links) and is used in this application. It supports Layer 2 of the seven-layer OSI model and is called data link layer. HDLC uses a bit-stuffing process to ensure that bit pattern of the delimiter flag does not occur in the fields between flags. The HDLC frame is synchronous and physical layer provides a method of clocking and synchronizing the transmitter/receiver. It uses both data and control messages carried in a standard format frame. Address field carry the frame's destination address. The length of this field is commonly 0 or 8 bits, depending on the data link layer protocol. The content of the address field depend on the mode of operation. The 8 or 16-bit control field provides a flow control and defines the frame type. Data is transmitted in the data field, which can vary in length. Error control is implemented by appending a Cyclic Redundancy Check (CRC) to the frame. For this application 16-bits long CRC is used. Three classes of frame are used in HDLC protocol: Unnumbered, Information and Supervisory frames. Unnumbered frames are used for Link Management (LM) for example to establish a logical connection between APCs and any DRC. All data (packed in information frame) is transfer under the control of the master station (application controller). In a multidrop application LM procedure for Normal Response Mode (NRM) and Asynchronous Balanced Mode (ABM) are used (Fig.5), [1].

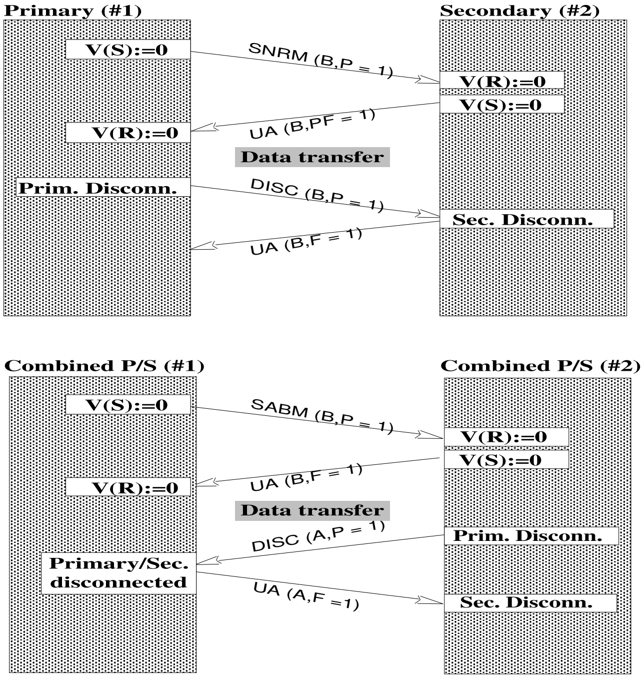


Fig.5. HDLC Link Management

5. ACCESS TO CCN AND FMFL

MC68EN360 Quad Integrated Communication Controller (QUIC), [10], supports communication module [fig.6]. The QUICC is a versatile one chip integrated microprocessor with peripheral combination. It is the logical extension of MC68302 design and includes communication processor, two IDMA controllers and four general-purpose timers. Communication module (Fig. 4) is based on glueless system design. For the Ethernet LAN capability of the QUICC, additional SIA transceiver is required. Ethernet serial MC68160 EEST supports connections to the attachment unit interface or twisted-pair. The QUICC supports the Ethernet/IEEE 802.3 protocol.

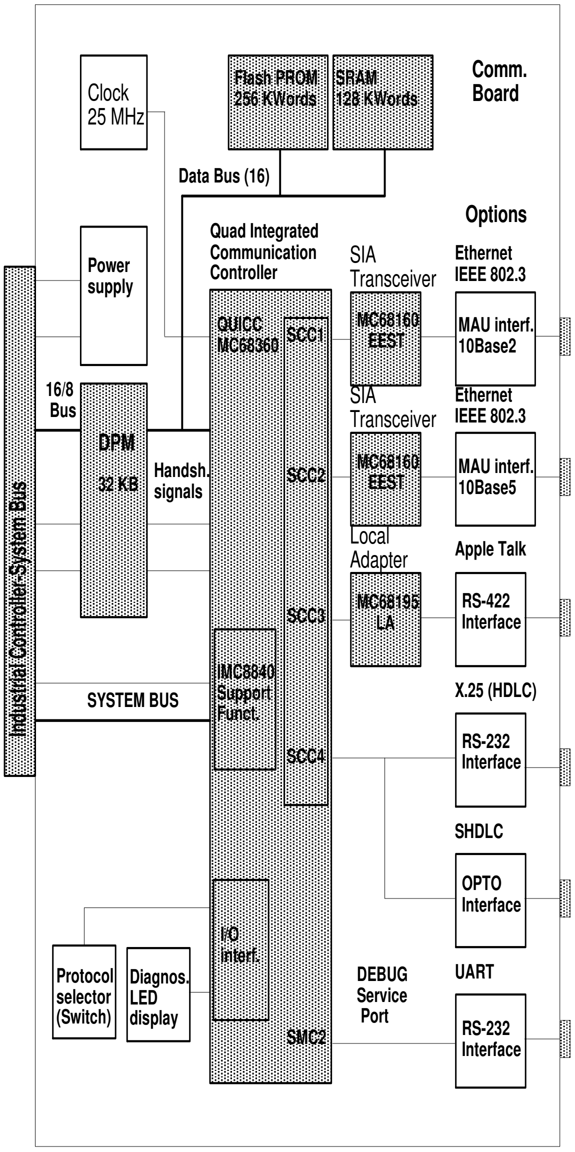


Fig.6. Communication module

High-performance real-time operating system (VxWorks developed by Wind River Systems) is adapted for this communication board [9].VxWorks includes a fast, scaleable run-time system, testing and debugging facilities, and a UNIX cross-development package.

Universal communication module supports access to the Ethernet/IEEE 802.3 control network, HDLC/SDLC local LAN and UART used as service channel.

6. CONCLUSION

The CCN provides real-time communication link between various clients or controllers in a DMS application. These networks are local to the respective clients and they are used in the complex DMS to integrate a variable speed drives into overall process control system application. The CCN is based on the Ethernet/IEEE 802.3 (TCP/IP) protocol and provides a connection-oriented data stream service between the two-end points of user application process. The term stream is used since it treats all the user data associated with a sequence of request and response messages. Communication module supports access to the CCN and creates a direct logical interface to the CCN protocol suite via different sockets. The stream socket layer maps protocol-independent requests from application layer to the protocol-specific implementation. Up to five different protocols or sockets could be selected and serviced within less then 20 ms. The FMFL is based on the HDLC protocol and is used in multi-drop configuration. It supports Layer 2 of the seven-layer OSI model and is called data link layer. Guaranteed data exchange between different clients should be less then 2 ms. DMS, access to the CCN and FMFL then some hardware capabilities of the new communication module are shortly presented.

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Analphabetic list of important shortcuts:

APC	**Appl**ication **C**ontroller
API	**A**pplication **P**rogramming **I**nterface
BA	**B**us **A**dministrator
CMMS	**C**rane **M**onitoring and **M**aintenance **S**ystem
CNL	**C**ontrol **N**etwork **L**ink
CSMA	**C**arrier **S**ense **M**ultiple **A**ccess
DDC	**D**istributed **D**rive **C**ontroller
DMS	**D**istributed **M**ultidrive **S**ystem
FMFL	**F**ast **M**ultidrive **F**ieldbus **L**ink
FTP	**F**ile **T**ransfer **P**rotocol
HDLC	**H**igh level **D**ata **L**ink **C**ontrol
MAC	**M**edium **A**ccess **C**ontrol
OSI	**O**pen **S**ystem **I**nterconnection
SMTP	**S**imple **M**ail **T**ransfer **P**rotocol
SNMP	**S**imple **N**etwork **M**anagement **P**rotocol
TCP/IP	**T**ransmission **C**ontrol **P**rotocol/**I**nternet **P**rotocol
TLI	**T**ransport **L**ayer **I**nterface
UDP	**U**ser **D**ata **P**rotocol