A Review on PROFINET Fieldbus System

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Abstract - Networked control system is acting as the most important limb of the distributed control system. The various fieldbus standards have been developed for industrial automation. The main theme of the fieldbus system in industrial control system is plant system integration. This article provides the OSI standard communication model and review of the experimental articles in the field of PROFINET.

Key Words: Programmable Logical Controller, OSI, Fieldbus, PROFINET-IO and PROFINET-CBA.

1. Introduction

In big industries, the control system design is getting to be more and more complex and distributed in nature. The major reason of their complexity is number of variables involved in its control, non-linearity, interaction with different system etc. The distributed control strategy involved in the control system design even play major role. The Fieldbus system makes it possible to establish the distributed control possible. The Fieldbus system is developed to establish the communication which involves sharing of the control, monitoring and safety signals within the controller, with sensor and controller and in controller to actuator. There are a lot of fieldbus systems presents in the industrial control market. Some of them are listed in the IEC standard. The major differences between commercial office networks and industrial networks are provided in the [1]. This clearly shows that industrial communication networks are more complex.

Programmable logic controller is the most important controlling device in the industrial domain due to its ruggedness, easy programming, maintains and industrial environment friendly design. PROFIBUS, PROFINET-IO, ModBus, CAN Bus, and INTERBUS are some of the fieldbus protocols.

This article provides the review on the PROFINET standards. The OSI (open system interconnect) is described first. It describes different isolated layers involved in the communication link. The PROFIBUS and PROFINET are taken into consideration after words.

2. Open System Interconnect

The OSI involves seven different isolated layers which are defined in order to establish the co-operation between different control devices [2] so that the information exchange became possible.

2.1 Physical Layer

Mechanical links, optical and electrical means are major concerns in this layer of OSI model which helps in data

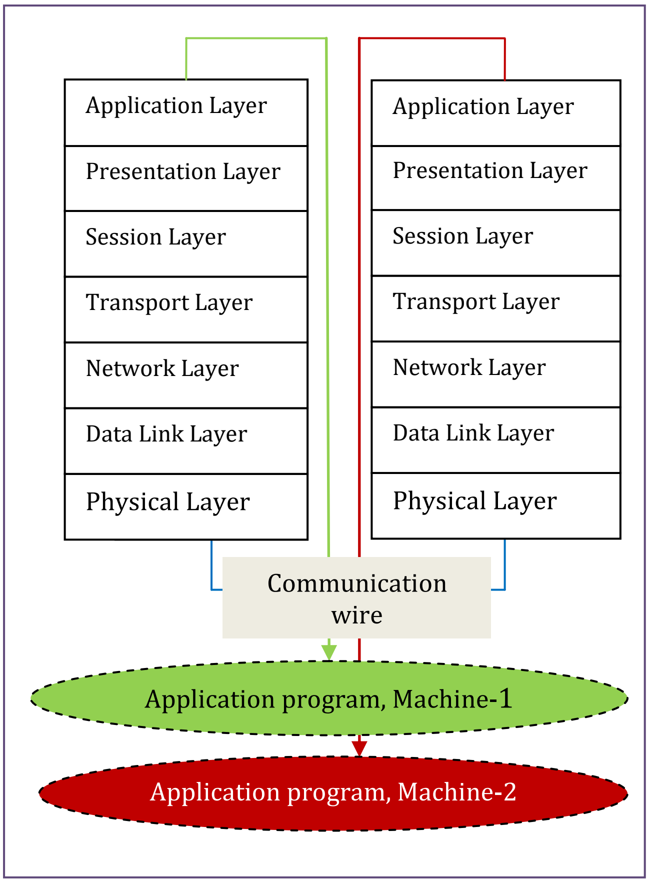

Fig. 1 OSI Reference Model

transmission between communicating partner. This plug and play option enhances accessibility but it must be required that the devices must be compatible for this task. The real information obtained from sensor module or processed information shared with the control element is down through this layer. The variant of physical layer could be found in the IEC-1158 standard.

2.2 Data Link Layer

The data link layer of OSI model deals with the group of bits normally organized in a stream of eight bits. This layer helps in detecting an error in the information and implement possible correction algorithm. The cause of error in it could be due to interferences of physical medium. This layer is most important from programmer design view, as it helps in defining real time behavior, valuable speed etc. The data link layer helps in defining the data transmission format on the network and it includes the information of data packet checksum, source and destination addresses. The Media Control Access (MAC) address is different for all communicating device. With MAC address a particular device can be accessed on the Ethernet.

2.3 Network Layer

This layer is used to establish the route between the source and destination devices and also take care of the traffic problems. The Internet Protocol is used to establish the network interface. The network layer breaks large size data streams in smaller one. The receiving device has to take care of combining the data stream back to its original form, so that important information can be extracted from it. A datagram comprises of data field with the information of header/footer (logical network address, routing information), data stream and flow control. It helps in internetworking, routing of devices in the network and network control.

2.4 Transport Layer

Major contribution of this layer is in error recognition and data recovery. This layer make sure that the long data stream be broken into smaller data fragments at the source station and recombined back at the destination station. The Transport Control Protocol (TCP) and User Datagram Protocol (UDP) are two variant that occupy whole transport layer. TCP establish the communication link between devices using the socket which are determined using the port number and IP address. UDP has low overhead but it possess less error checking and more prone to overcome from the crash. The network delays are also handled in this layer. If data stream does not reaches to the destination accurately, then this layer initiate either the retransmission of data or informs the user and proceed further based on user action.

2.5 Session Layer

This layer performs three main tasks that are establishing the connection between devices, use that connection for data stream exchange between them, and end that session. It helps in organizes and synchronizes the transfer of data between two applications. The Remote Procedure call (RPC) which is built on the TCP and UDP are very well known session protocol. The duration of connection for data stream exchange is also handled by this layer.

2.6 Presentation Layer

The presentation layer make sure that two machine which tries to communication with each other can have same data format so that each machine can able to understand data accurately. Indeed, this layer makes sure that different data formats can be put in some common form which each machine can understand easily. This layer provides security sensitive information and also large size data.

2.7 Application Layer

This layer uses specific networking application to provide all the means that are necessary for two applications to transfer data within them. The various functions can be expressed with this layer as explained in [2]. Identification of intended communication partner, current availability of that, establishing authority, taking care of privacy, determination of useful resources and its quality, recovery from error, identification of restriction that are put on the data syntax such as character set and data structure etc. are some of the intended functions of application layer.

In industrial domain, there are a large number of active nodes on a single network at the same time and meeting their time requirement is critical task [3]. The basic idea of industrial communication network and an overview of popular protocol could be found in the [1]. Normally, the networking strategies developed for the office are also work well in the industrial domain for interconnecting the devices. They are star topology, ring topology and bus topology. Each device connecting topology has its advantages and disadvantages.

Due to the timing constrains the whole layer of OSI are not followed in the design of control network system. Some layers are skipped in order to enhance the timing issues of the real time application and shorter the respond time.

3. PROFINET

PROFINET is based on the distributed automation architecture which means that control nodes can be easily defined, connected to one-another and use repeatedly. It is based on the Ethernet link. But it fulfills the deterministic and real time communication constraints of industrial automation very well [4, 5].

PROFIBUS supports two protocols named as PROFINET-IO and PROFINET-CBA. This categorization is based on the time critical issues. In order to support real time and TCP/IP traffics simultaneously at the same time, PROFINET defines Non-Real Time (based on the UDP/IP, used only configuration phase), and two Real time communication classes (i.e. Real Time i.e. used to communicate with standard field devices and Isochronous Real Time i.e. dedicated to hard real time application example motion control)[6]. Table 1 provides brief detail of them. Where P_CBA represents PROFINET Component Based Automation (CBA) and P_IO represents PROFINET-IO respectively.

Table1. PROFINET Brief Real Time Idea

S. No	Supported Traffics	Cyclic time/ jitter (in %)	Supported type
1	Non real time	≥100 ms/ ≥ 100	P_CBA
2	Real Time	≥ 5 ms/ ≥15	P_CBA & P_IO
3	Isochronous Real Time	≥ 250 µs/ ≥ .4	P_IO

The PROFINET channel takes care of all the data traffic that occurs on it [8]. In PROFINET-IO, the Time Division Multiplexing is used to transport the NRT, RT and IRT data on the same channel. It is based on the IEEE-1588 standard that ensures the accuracy in data exchange in sub-microseconds [6]. Fig.2 describes the data structure for communication.

PROFINET-CBA protocol is defined for the integration in plant at higher level, such as data exchange among various production lines. It solves the engineering effort very well in which user have to connect the devices with simple joining the input and output with simple links. Critical network are not handled by it. DCOM over TCP/IP for non-real time communication applications and Real Time class-1 protocol for medium performance real time application are two standard supported protocols in it.

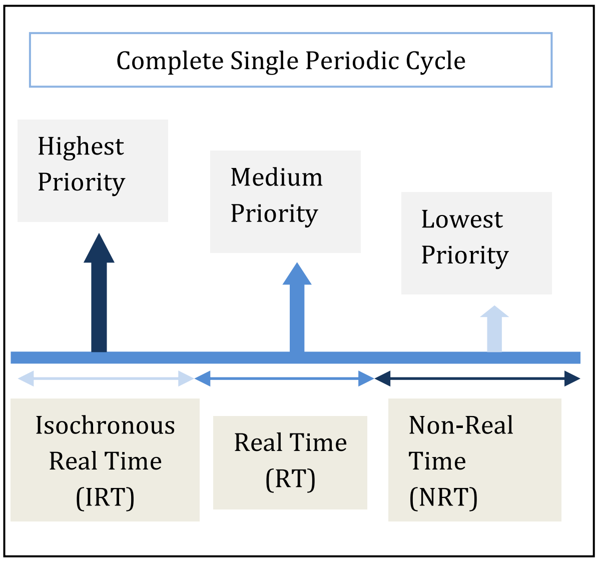

Fig.2 Structure of PROFINET-IO Single Cycle

The timing performances of the PROFINET-CBA are based on the "QoS" concept which indicates the latency (i.e. maximum time required to transmit the source information to the destination) in transmission. TCP/IP stack delays, application delays and fieldbus cycles are some of the elements that are not considered in the PROFINET Control and can degrade its performance drastically. DCOM and RT based communication details are found in [7].

In Ethernet LAN based networks, the network switch plays essential role in the networking and its behavior significantly affects the overall network performance as mentioned in [9]. Table 3 provides concluded details of switches topologies. Determinism is not guaranteed in case of heavy traffic conditions due to uncertainty in data packaging which results in fluctuation in propagation delay. For more experimental results on PRFINET-IO and PROFINET-CBA user may prefer [7].

Table3. Switch Topologies and Corresponding T_d & T_{sid} values on 100baseT Ethernet Network

Switching Topologies	T_d (delay due to packet buffering)	T_{sid} (internal delay due to component elaboration)
Store and Forward	$5.76<T_d<122.08$ µs	Several microseconds
Cut Through	1.12 µs	> 1 microsecond
Fragment-Free Switch	5.76 µs	-

3. CONCLUSIONS

The PROFINET plays major role in the Network Control systems which are normally seen in industrial automation. The time delay constraints for soft real time control system are within required range in PROFINET fieldbus. The paper lists most important aspects of fieldbus system.

a) More Stress is put in PROFINET fieldbus adoption in industrial domain due to no addition device need for establishing communication link in different industrial control architecture.
b) In Real time control systems, the delay and jitter problems which are in µs range is well defined under Isochronous Real Time class.
c) Non time critical control systems are put in hard real time class where delay and jitter problems are not more prompting.

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