Review Paper on Ethernet for Control Automation Technology Ether CAT

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***Abstract*—Nowadays reliable communication is necessary in the field of automation and other real time applications which require systems with accurate time synchronization and high data throughput. Real-time Ethernet (RTE) protocols have recently emerged as the leading solution in the automation industry. EtherCAT is a real-time industrial field bus technology for precise motor control applications with excellent performance at relatively low cost. EtherCAT was first introduced and developed by Beckhoff Automation. The EtherCAT protocol is standardized as IEC standard IEC61158. EtherCAT can meet the requirements of both the hard and hard and soft real time systems in automation technology and many other real time applications.**

Keywords—Synchronization; High-speed; Topological-flexibility; less-jitter; less cycle-time

I. INTRODUCTION

The adoptability rate of EtherCAT is increasing due to its high data transfer rates, excellent performance and low cost. The limitations of traditional Ethernet can be overcome by using EtherCAT technology [24]. At every connection the Ethernet packet is not received, interpreted and copied as process data, instead the data is processed on the fly. This means that the transmission of the new EtherCAT packet start as soon as possible before completely receiving the incoming data packet. EtherCAT master transmits the frame which contains a number of datagrams and each datagram holds the process data for particular slave.

II. ETHERCAT PROTOCOL

A. Technology overview

EtherCAT network consists of one master and many numbers of slaves in a network as shown in Fig 1. Without any additional communication processor the master can be implemented by a standard Ethernet Media Access Controller (MAC) [19]. This MAC should provide a full-duplex 100 Mega bit/second interface. A standard PC with the necessary software can act as anEtherCAT master[21]. The EtherCAT technology is based on the principle of processing the data on the fly. EtherCAT uses standard Ethernet frame to transport the process data using the ethertype 0x88A4. The addressing of the nodes in the network is independent of the physical order of the nodes in the network. EtherCAT supports the broadcast and multicast communication between the slaves if initiated by the master device. The newly developed FMMU (fieldbus memory management unit) in each input output (I/O) terminal reads the data addressed to it, whilst the telegram continues through the device [18]. The data is exchanged when the telegram passes through each frame. The telegrams are only delayed by a few nanoseconds.

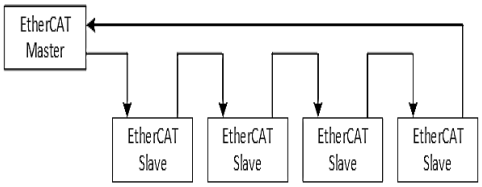

Fig. 1. EtherCAT network

B. Layers of EtherCAT slave

1) Physical layer: This is the lowest layer that receives and transmits the electrical network signals. The PHY (PHYsical) circuits convert EtherCAT frames into internal logic signals which read from, or write to DPRAM (Dual-Port RAM) memory. This is done on the fly and completely in hardware with no delays or connection to internal firmware.

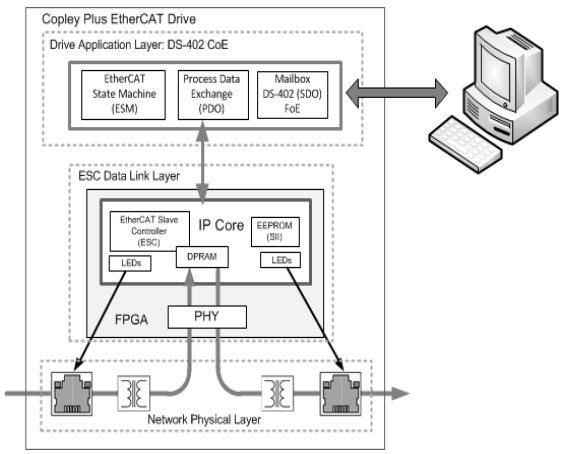

Fig. 2. Can Open Over EtherCAT

2) ESC (EtherCAT Slave Controller) Data Link Layer: The DPRAM information is read/written by the firmware. Data written into DPRAM will be transferred to the next datagram passing through on the network. And data transferred to the DPRAM from the network is available to

read by the firmware at any time between successive write operations. An EEPROM (Electrically Erasable Programmable Read Only Memory) is implemented in the FPGA and the networks status LEDs are controlled by the IP core.

3) Drive application layer: This is the layer that is actively exchanging data with the EtherCAT master which is running an application for an overall machine-control function. This is the level at which Can open over EtherCAT (CoE)applies as shown in Fig 2.

4) CANopen, EtherCAT, and CoE: CoE is the abbreviation for CANopen application protocol over EtherCAT [13]. A Protocol defines a message format and the rules for the exchange of data[20].

C. EtherCAT State Machine

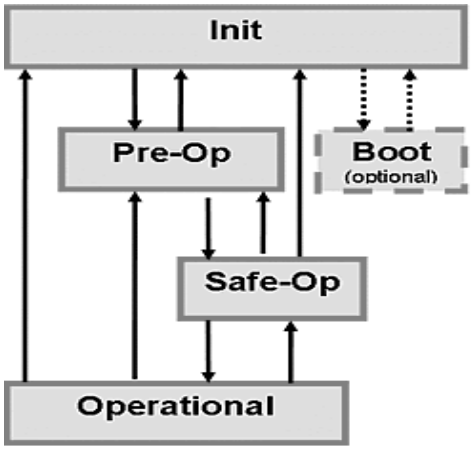

Fig. 3. EtherCAT state machine

There are five different states in EtherCAT as shown in Fig 3.

1) Initialization (Init): EtherCAT slave when switch-on it will be in the Init state. When the device is in initialization state mailbox and process data communication is not allowed.

2) Pre-Operational (Pre-Op): Verifies whether the mailbox was initialized correctly. In Pre-Op state there will be mailbox communication but no process data communication.

3) Safe-Operational (Safe-Op): Checks for the availability of the sync manager channels for process data communication. In Safe-Op both mailbox and process data communication are viable

4) Operational (Op): In the OP state process data and mailbox communication are achievable. At this state the slave copies the contents from master .

5) Boot: In the Boot state firmware update can be done.

III. RELATEDWORK

According to Dafa [9], wind power system requires a field bus technology with improved channel capacity and should be independent of topology. Other field bus technology has very less channel capacity. The control system of wind power system is of high importance as it can guarantee accurate control and operating state. The tasks of the main control system (master) of a wind turbine generator include acquirement of current parameters of the unit, yawing, variation in propeller pitch and synchronization. The wind turbine generator with EtherCAT technology includes control subsystems (slaves) like current converter control unit, yawing control subsystem, variable propeller pitch control subsystem, and monitoring subsystem etc. Real-time EtherCAT is the natural solution to these problems as a result of increased channel capacity and topological flexibility.

As per Xuepei [1] Industrial communication network is the key factor that enables technological advances in automated Baggage Handling System (BHS). BHS refers to a type of conveyor and sorter system installed in airports that transports baggage from check-in areas to the departure gates. In order to achieve the above goal, the system should be capable of performing the following functions like baggage transportation, screening, tracking, sorting, early storage, etc. Critical functional equipment in BHS can be classified as transportation conveyor, queuing conveyor, vertical sorter, diverter, etc. Each controller is in charge of a particular zone and the size of the data periodically exchanged between controller and motor drives in BHS is typically small. In analogy to other industrial Ethernet technology EtherCAT's unique "processing on-the-fly" principle offers better communication efficiency over other RTE protocols when payloads are small.

In the analysis made by Mingxin on multifinger dynamics for Robot hands [5] were developed to give robots the ability to grasp objects with varying physical properties. Here EtherCAT Master and Slave system has been developed ensuring good synchronization [23] and online computing. The EtherCAT communication efficiency is very high (up to 90%) which achieves very short cycle times. Besides efficiency, another feature that makes EtherCAT appealing in the application of motion control is the mechanism that enables robots to operate in a synchronizedway in order toonline compute the complexity of multifinger dynamics effectively.

In 2012 paper[7] the discussion is with respect to the role of real time Ethernet in smart substations. Power industries need Smart Substation to complete the function of information collection, status monitoring, controlling and regulation etc. to meet the requirement of automation and intelligence. Comparing to other field bus technology EtherCAThas high transmission rate, low cost and good security. Therefore the communication of smart substation should also meet real-time requirements. Hence EtherCAT technology is very much preferred to the application of substations.

Bin Jiao describes the superior performance of EtherCAT in the paper[8] of steel plate loading and unloading system. Loading and unloading system of steel sheet has length and weight restrictions which need multiple simultaneous operations to complete. This requires synchronization operation of multiple driver motor and high precision motor speed control. Here PC is the master and the drive which load and unload thesteel is the slave. EtherCAT is the connection between the PC and the driver. Other traditional fieldbus has more jitter and less synchronization compared to EtherCAT. As EtherCAT provides good

synchronization and superior performance, this can be used in steel plate loading and unloading.

In 2011 paper [6], the author says EtherCAT is also compatible with any other fieldbus system. Serial Real time Communication Specification (SERCOS) over EtherCAT provides accurate position, good synchronization and smooth rotation for the motor control system .SERCOS interface is also known as a universal motor control interface [18]. By introducing state machine mapping the SERCOS state machine, its service channel and all other telegram can be used. The SoE (SERCOS over EtherCAT) model ensures the transmission of real-time motion control data in a maximum speed. SERCOS interface with the advantages of EtherCAT shows outstanding real-time behavior and the jitter is less.

The high speed performance of the EtherCAT in smart grid is explained in 2011 paper[4]. In smart grids power quality monitoring is of high importance. A smart grid consists of monitoring terminal (node), communication network andmonitoring center. Monitoring terminal collect very high speed data and show the power quality in real time. Communication network exchange the data between the monitoring terminal and monitoring center using EtherCAT. By analyzing the data from monitoring center power quality can be monitored.

In 2015 paper [3] the author narrates the improved performance of Data Acquisition System (DAS) using EtherCAT. An EtherCAT based data acquisition system (DAS) is acquiring the data from the field sensorsusing slaves. It consists of any standard PC to be used as an EtherCAT Master and communicate to the slave devices that make sensors data to be connected to I/O devices available for the master[17]. Each slave processes the incoming telegram directly and extracts/insert the relevant user data and transfer the telegram to the next EtherCAT slave. The EtherCAT slave sends the whole processed telegram back, so that it is returned by the first slave to the control as an EtherCAT master [22]. EtherCAT is a highly flexible and high-performance industrial Ethernet network protocol. Industrial Ethernet was introducedinto dataacquisition system as it has low maintenance cost, rapidinstallation and diagnosis in comparison to other field bus technology.

The performance of a real time network is based on cycle time and network latency. Vinh Quang and Jae wook [10] explains the significance of network latency in embedded PLC. When the PLC command processing speed is shorter than the network latency the system becomes unstable hence, distributed clock solution can be applied to overcome network latency.

C.L Toh [11] illustrates the performance of EtherCATtechnology for the reduction of the propagation delay introduced in a high speed ring network, which is demanded to simplify the wiring network in a complex modular multilevel converter. EtherCAT's unique clock distribution mechanism and cable redundancy manage to meet the proposed synchronization jitter in Modular multilevel Converter (MMC).

In paper[2] the authors specify the application of EtherCAT in open Computer Numerical Control (CNC). The superior performance of EtherCAT allows it to be used in Numerical Control (NC) field. EtherCAT has extraordinary communication ability, flexible topology and reduce the cost of CNC system.

In paper [12] itis observed that the EtherCAT datagrams can be transmitted in a network without cable redundancy. Suppose there are networks with cable redundancy the extended algorithm prevents the need to modify the master's network structure which was created by an automatic device scan. This may reduce the probability of errors and saves time.

In field bus communication, network topology plays an important role in the evaluation of system performance. Compared to line and tree topology in switched Ethernet the shortest communication cycle times can be efficiently achieved using EtherCAT network. Topology is an important aspect in automation industry for improved performance. From this paper[14] it is observed that line, tree and ring topology achieves shortest communication cycle.

The paper[15] reveals the importance of EtherCAT in entertainment industry. The instruments used for movie control results in accurate, noise free and reliable system. Other advantages of EtherCAT include low cost, extreme fast control strategy and simplification of complex system.

The paper [16] explains the design and analysis on networked motion control. Networked motion control is used widely in the areas like printing, packing and textile semiconductor production. As the number of device increases the distributed network must access the information from any location. But the traditional fieldbus communication and serial communication failed to provide high quality of information and changing cycle times. Ethernet has high speed but no real time capability. EtherCAT is the promising technology to overcome the above problem as it has accurate synchronization, high efficiency and less jitter.

In paper the author has researched three different field buses for override trip system. Firstly, the protection using RS485 serial communication was studied but it has low communication rate and high error rate. Secondly, CAN bus also failed to meet the distance and channel capacity. Finally, Ethernet was preferred and it failed to meet the real time requirements. EtherCAT technology overcomes the above disadvantages and can be used in preventing override trip system for high voltage power grid of coal mine.

IV. CONCLUSION AND FUTURE WORK

From the above survey it is apparent that the EtherCAT technology meets all the requirements of industrial communication like real time capability, high speed of communication, very good synchronization, short cycle times, less jitter and low cost. Development of real-time EtherCAT, reduces the cost of automation equipment, improves the real-time response speed and conforms to theindustrialautomationtrends. Finally the author concludes that the EtherCAT is the best real time Ethernet for factory automation especially for motion control, numerical control and other real time applications in automation industry. From the above survey it is clear that EtherCAT technology is the best Real time Ethernet for motor drive applications hence, the future work include the development of EtherCAT communication between Beckhoff PLC and Hexmoto drives.

ACKNOWLEDGMENT

The author would like to thank Mr. Venkatraya Prabhu, Mr. Anantha Saligram, Mr. Krishna Prasad; Managing Directors of Hexmoto Controls Private Limited, Mysuru and Professor V Nattarasu, Professor B A Sujatha Kumari; Professor T Srikanth, Professor Yashwanth S D;S.J. College of Engineering, JSS Science and Technology University, Mysuru for their advice and assistance in the preparation of this contribution.

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