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.

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.

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

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. RELATED WORK

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 acquisition 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,
diverters, 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
analog 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 synchronized way in order
to online 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
EtherCAT has 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 the steel 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 and monitoring 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 sensors using 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 introduced into data acquisition system as it has low maintenance cost, rapid installation 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 EtherCAT technology 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] its 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 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. EtherCAT 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 the industrial automation trends. 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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