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Stable Ethernet TCP/IP Real Time Communication In Industrial Embedded Applications

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ABSTRACT: *A stable Ethernet communication link in industrial embedded applications and networking are possible at all levels of industrial automation, especially in the controller level whereby the data exchanges in real-time communication is mandatory. Designing a Robust and Reliable Industrial Communications Infrastructure with Ethernet has traditionally been used to network enterprise workstations and to transfer non-real-time data. The success of Ethernet in the desktop world has been due to its simplicity, expandability, robustness, and affordable implementation. Based on Ethernet's success as a data network, embedded soft real-time communication networks are being implemented with standard 100 Mbit/s Ethernet for economy, familiarity, and compatibility with enterprise networks. By using TCP/IP on top of Ethernet, embedded systems can become globally accessible from enterprise networks. This connectivity and interoperability is possible, and affordable using commodity off-the shelf (COTS) hardware and software, which has led to a recent surge in interest in embedded Ethernet.*

Keywords – *EtherCat, Industrial Ethernet, OSI, Switched Ethernet ,TCP/IP Ethernet*.

I. INTRODUCTION

In this paper review of various parameters based on Ethernet is seen. Ethernet is the most widely used local area network technology. Despite originally not being designed for industrial communication, some of its properties, such as easy integration with Internet, inherent compatibility with the management networks used at higher levels in hierarchical industrial systems, and low price make its use in industrial context very attractive. However, the stochastic bus arbitration mechanism adopted by traditional. Ethernet (CSMA/CD) has remained a main obstacle for its extensive use in factory floor in the past decade. Currently, using switch technology to enable Ethernet support real-time communication is rapidly becoming a hotspot. The switched Ethernet eliminates data collisions on the network and can be used to transmit real-time data. When Ethernet adopts micro-segmentation with full duplex transmission mode, each station in it has separate collision domain. The collision problem in IEEE802.3 network is eliminated and simultaneous sending and receiving of data are possible, so the real-time performance of Ethernet is significantly improved [1].

Recognizing that Ethernet is the leading networking solution, many industry organizations are porting the traditional fieldbus architectures to Industrial Ethernet. Industrial Ethernet applies the Ethernet standards developed for data communication to manufacturing control networks,Figure1[4]. Using IEEE standards-based equipment, organizations can migrate all or part of their factory operations to an Ethernet environment at the pace they wish. The fieldbus data structure is applied to Layers 5, 6, and 7 of the OSI reference model over Ethernet, IP, and TCP/UDP in the transport layer (Layer 4). Industrial Ethernet networks can be classified into three main classes, according to the protocols they use and, consequently to the performance they can provide. The first class uses standard, unmodified Ethernet hardware as well as standard TCP/IP software stacks for process communication. In this case real-time performances are limited by unpredictable delays in infrastructure components like switches or software stacks (TCP/UDP/IP) [2].

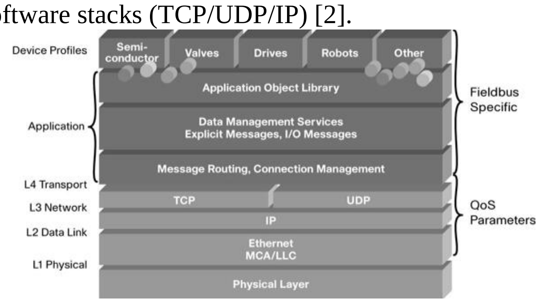

Figure1. OSI reference model

II. Switched Industrial Ethernet

2.1 Priority

Scheduling is introduced into switches as well as source nodes to get as much real-time performance as possible, at the same time as the use of standard protocols like TCP/IP and Ethernet is preserved**.** The priority scheduling based on IEEE802.1p is a good choice to enhance the real-time performance of switch industrial Ethernet, which can prevent real-time data from delayed due to contending for the same MAC output with non-real-time data. Inserting a deadline field into real-time frames to achieve EDF queuing feature in real-time queues, which is a desirable feature in industrial communication.[1]

2.2 Delay

The delay analysis of switched Ethernet: The delay at Ethernet switch includes: (a) The destination table look-up time and switch fabric set-uptime, which are the basic delay of Ethernet switch; (b) The queuing time a frame must wait in buffer when the MAC output is busy; (c) The forward time, which depends on the forward mode that Ethernet switch adopts. When store and forward mode is adopted, the forward time is in direct proportion to the frame length. We also combine the last two items and call them the buffer response time of a frame at Ethernet switch. Traditional switched Ethernet does not provide effective priority transfer mechanism for industrial communication. Because non-real-time data generally have long frame, when a real-time data arrives, if there happens to be a mass of non-real-time data waiting for service, then the real-time data will be delayed significantly. The buffer response time of a frame at source node or Ethernet switch is easily

$$d_{response} = \frac{l_i + \sum_{w=1}^{i-1} l_w}{c},$$

derived as where , $l_i = m_i + \mu$, $l_w = m_w + \mu$, m_i and m_w *i m* and *w m* are frame lengths of the considered frame and queued frames, respectively, μ is the minimum Ethernet inter-frame gap, and *c* is the MAC output rate. Because the event variables and messages are sporadic, the number of queued frames *w* is uncertain when the frame *i* reaches the MAC buffer. Therefore, the maximum buffer response time of cyclic variables is not bounded[1].

2.3 Topology: The performance of the switched networks with the linear bus and the tree topologies with respect to the control cycle time, the number of switches required, and the required buffer size. The linear bus topology has the advantage that it has a similar topology to the control networks and the required buffer size is small compared to the switched networks with the tree topology, it requires longer control cycle time than the networks with the tree topology[3].

III. Industrial Ethernet Technologies

3.1 Classification:

Industrial Ethernet networks can be classified into three main classes, according to the protocols they use and, consequently to the performance they can provide. The first class uses standard, unmodified Ethernet hardware as well as standard TCP/IP software stacks for process communication. In this case real-time performances are limited by unpredictable delays in infrastructure components like switches or software stacks (TCP/UDP/IP). In this category we can find Modbus/TCP, a very popular network based on a simple protocol that can be easily implemented. It is a messaging structure used to establish master-slave/client-server communication between intelligent devices. The last version is based on TCP/IP and the performance is primarily determined by such a protocol stack. Another solution in this class is Ethernet/IP, a network communication standard that uses an open protocol at the application layer.

The second class approach still uses standard, unmodified hardware, but it does not use TCP/IP for process data communication. A dedicated process data protocol unit is introduced, which is transported directly in the Ethernet frame. For example Ethernet Powerlink uses a master-slave technique on top of the native Ethernet Medium Access Control. Basically, a master station (called Managing Node) sends poll requests to each slave (called Controlled Node) which then answers with a response. In these networks, TCP/IP traffic may still exist, but typically it is controlled and limited by real-time Ethernet protocol. Finally, networks belonging to the third class typically make use of dedicated hardware (at least by the slave devices) and, in such a way, they allow to achieve the best performance with data transfer times in the order of some tens of microseconds or even less[2].

3.2 An example of Industrial Ethernet-EtherCat:

The behavior of EtherCAT networks by means of Opnet simulations by using basic models for both master and slave devices are deduced. The performance of an EtherCAT system, and consequently its cycle time, depend on the particular considered network configuration, It is worth to underline that the only two physical topologies allowed for an EtherCAT network are the binary tree topology and the simpler line topology, which is actually a particular binary tree without any branch. Nevertheless the logic topology of an EtherCAT system is always a ring. The presence of more slaves that is 10 results in a major frame size, Figure2 results for simpler line topology, with 10 slaves the time is greater than with 3 slaves. Also the binary tree topology, Figure3 for EtherCat are comparable with those relevant to the line topology [2].

3.3 Effect Of Different Parameters On The Real Time Performance Of The Network:

Simulations in OPNET showed the effect of different parameters on the real time performance of the network. Parameters like (packet length, number of nodes and packet production rate) have minor effect on the network performance, while the others (packets processing rate and FTP traffic transferred to an industrial node) could affect seriously on the network behavior. The addition and removal of the headers which belong to layers : four (TCP layer), layer three (IP layer) and layer two (Data link layer).This also includes all necessary calculations on different levels, such as check sum calculation (layers 4 & 3), CRC (layer 2) and all other activities relating to the packet creation procedure. The action and reaction activities made by different protocols on the different layers in the (TCP/IP) stack are. 1) The value of the packet processing rate depends mainly on the speed of the node's processing unit, operating system efficiency and other node's architectural components. 2) Varying packet length, number of sensors and sensor's sampling rate has minor effects on latency. 3) Packet processing rate of nodes has a great influence on latency and care should be paid to enhance the industrial node's ability in this field. The value of the packet processing rate depends mainly on the speed of the node's processing unit, operating system efficiency and other node's architectural components. The results obtained from running the simulation model are shown in Figure4 [5].

3.4 Solutions To Enhance Real Time Performance Of Industrial Ethernet:

Different techniques is introduced to modify Industrial Ethernet performance and to enhance its stability under different load conditions. FTP traffic shaping, Multicasting/VLAN and network delay solutions combined together and result are shown in figure5 [6]. The model configured with the presence of non industrial nodes in the network which exchange TCP packets at a rate of (100 Mbps) on the line. The network divided into several Multicast/VLAN groups to enhance node operation. Also, FTP traffic shaping method used the same values of segment size and Inter request period. Modified EtherChannel technology can used to protect the network performance against high load conditions.

These methods have a number of advantages: 1) The latency values are minimized to the lower possible limits. 2) The system performance is absolutely stable.3) The various techniques give immunity against sudden changes in network conditions.4) · The network can be used to carry control data as well as ordinary data (multi-purpose network) in an efficient manner.5) · No change is made to the Ethernet standardization.

IV. Conclusion

An Ethernet switch operates at the data link layer of the OSI model to create a separate collision domain for each switch port. Ethernet is of the type multiple-access network but can easily be implemented as a pure switched network by adding more switches in an intelligent manner. The adoption of Ethernet technology for industrial communication between controllers, and even for communication with field devices, supports direct Internet capability. Industrial Ethernet networks that use intelligent switching technology can offer a variety of advantages compared to traditional industrial networks. The technology can be deployed using a switched Ethernet architecture and has proven successful in multiple critical applications in different markets. Because the technology is based on industry standards, Industrial Ethernet enables organizations to save money by moving away from expensive, closed, factory floor optimized networks. Using standard Ethernet technologies also reduces overall risk and provides investment protection, as manufacturers and automation vendors can take advantage of continued industry investment and innovation in compatible technologies. By providing a scalable platform that can accommodate multiple applications, Ethernet-based automation systems can increase flexibility and accelerate deployment of new applications in the future. At the same time, Ethernet delivers the network security, performance, and availability required to support critical manufacturing applications.

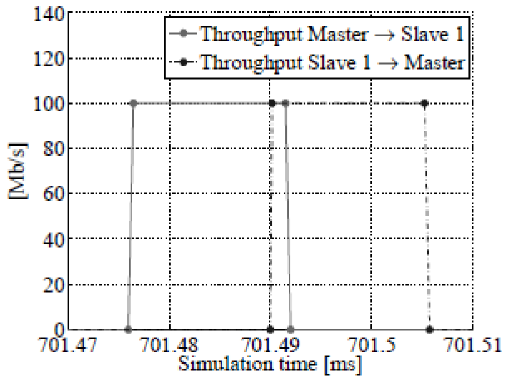

Figure2: Result for line topology with 10 slaves.

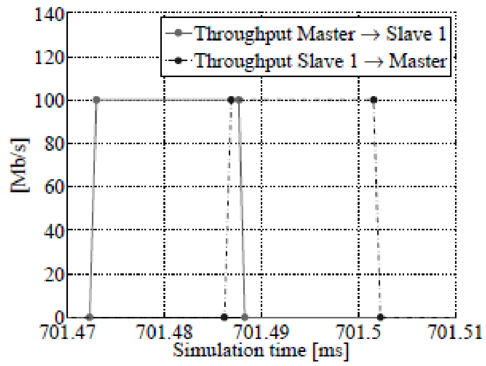

Figure3: Result for tree topology with 10 slaves.

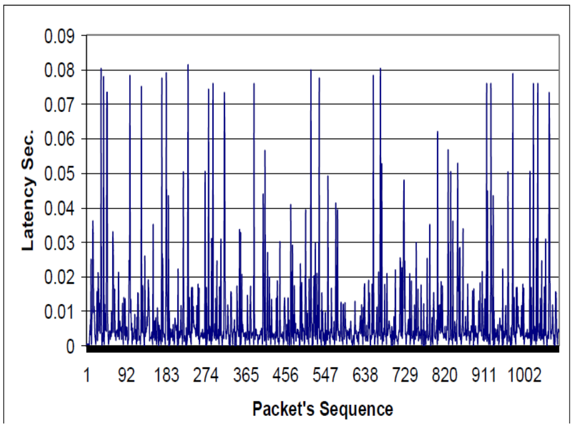

Figure4: Result of Packet processing rate of nodes on latency.

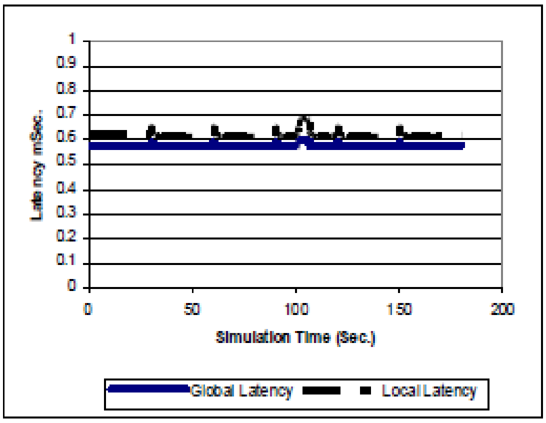

Figure5: Different techniques is introduced to modify Industrial Ethernet performance

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