Ethernet-Networking Technology: A Surface Review on Current Issues

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Abstract – *Ethernet has evolved throughout the years and still remains relevant in modern communication applications. Its reliability and easy configurability is one of the most liked feature for device communications. Hence, in this paper a surface review upon Ethernet is carried out. Several aspects of Ethernet and its application is investigated on its current researches and achievements. Ethernet applications is used in leading design technologies in the automotive and aviation industry another popular application of it is in the industrial sector. The energy usage of Ethernet and its common issues are also reviewed. From the reviews done, it can be clearly seen that the role of Ethernet in modern network technology is still important as its features are desirable and its flaws consistently being overcome despite the issues of the Ethernet.*

Keywords*: Ethernet, Ethernet based technologies, Ethernet technologies in automotive*

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I. Introduction

From past till present, Ethernet has been favored by scientists and professionals from several fields. One of the fields that make Ethernet a focus, is in the automotive communications such as car, aviation and others. This is due to the requirements of low power consumption, light weight, low wire count and low deployment costs of the new automotive features such as advanced driver assistance systems, parking aids, lane departure systems, infotainment systems and blind-spot detection systems [1]. From the research and study of Y.B. Pradeep, networking technology – Ethernet is suitable and has been used in automotive communications as done by BMW in 2008. There are several advantages of automotive network based on Ethernet such as, low cost in mass production, bandwidth scalability with no negative impact on safety and functionality, connectivity options both inside and outside the vehicle and galvanic isolation due to transformer coupling. For example, it is used in energy efficient Ethernet (EEE) features and supports by Ethernet MAC [1].

These advantages of Ethernet can be proven by comparing it to the existing Controller Area Network (CAN) protocol. There are several automotive functional domains in automotive communication field such as powertrain, body and control, driver assistance, infotainment and entertainment [2]. These functional domains feature different requirements and specific constraints [2]. Since the applications of automotive communications increases rapidly nowadays, the demand for inter-ECU (Electronic Control Units) or the demand of larger bandwidth is required by the On-Board Diagnostics (OBD). Therefore, Ethernet is more suitable and better which can replace CAN in future for the reprogramming and diagnostics of automotive Electronic Control Units [2] since CAN's biggest busses is of 500kbps (100kbps-500kbps) [3] while Ethernet has 100Mbps busses which significantly larger than CAN. Other than that, Ethernet supports communication among applications with diverse real-time and safety requirements [2]. In the future, Ethernet will replace CAN with thanks to the Diagnostics over Internet Protocol (DoIP) standard that allows for seamlessly interfacing vehicles to a network [2].

The leading technology that used in automotive application is the Audio Video Bridging (AVB). Audio Video Bridging is the in-vehicle systems (such as multimedia, camera-based driver assistance and on-board diagnostics). Nowadays, there are AVB and AVB-ST based on Ethernet (IEEE). Both these technologies are advanced in the audio and video systems of vehicles with

advantages such as open specification, significant savings on cabling costs, thickness and weight. However, there are still differences among the performance of both AVB and AVB-ST. Lucia from University of Catania did a comparison of the performance in the approach of dealing scheduled traffic presented in realistic between the two technologies. From the result obtained (Table 2, [4]), we found that AVB-ST has lower latency and jitter (micro-seconds) than AVB for cameras, DVD player and also CD audio player. Thus it can be concluded that AVB-ST is more efficient and suitable in future works since it results in lower and bounded latencies to scheduled traffic under low and high SR traffic load [4].

Due to the requirements of low latency, requirement on real-time strictly in automotive application, time sensitive networking (TSN) as an upcoming set of Ethernet has been introduced. TSN specifies new quality of service mechanisms in the form of different traffic shapers to address those requirements stated. There are three shapers namely, burst-limiting shaper (BLS), time-aware shaper (TAS), and peristaltic shaper (PS). Where TSN/BLS allows bursts of limited size without prior blocking [4]. To verify the efficiency and functionality of TSN/BLS, comparison of TSN/BLS against Ethernet AVB and standard Ethernet (IEEE 802.1Q) have been done by Daniel and Rolf (University Braunschweig). From the results obtained, unshaped traffic (Ethernet without TSN) sometimes have lower worst-case latency guarantees than the shaped traffic, TSN/BLS. Moreover, the results tell us that IEEE 802.1Q has the lowest worst-case latency guarantees [5]. Thus it can be concluded that TSN/BLS has the higher worst-case latency guarantees than unshaped traffic for AVB systems in automotive communication.

In addition to the automotive communication systems, National Aerospace Laboratory NLR currently uses Ethernet based Flight Test Instrumentation (FTI). Instead of the conventional IRIG-PCM point-to-point data connections, NLR chose to use Ethernet network in application of FTI. There are two projects that have been highlighted which are FTI system in F-16BM ”Orange Jumper” test aircraft has been updated to an Ethernet-based master-slave data acquisition system [6] and the Generic Instrumentation System for the Defence Helicopter Command based on Ethernet components [6]. Both of these projects resulting in the Ethernet-based systems allow significant savings on costs and real-time efficiency [6]. For example, main functions of FTI system is divided into two which are functions of aircraft part and ground-based part. With the use of Ethernet-based FTI system, every component is interfaced with Ethernet Local Area Network (LAN) [6] in both parts that stated before. This is the reasons that Ethernet-based FTI system is cheaper than IRIG-PCM connections. These projects show the advantages of Ethernet and motivate the further working on Ethernet-based systems.

II. Industrial Sector

With improvement of technology, new schemes are adopted in industrial sectors to improve efficiency by monitoring and controlling in real-time. It must be noted that communication network in industrial differ significantly from traditional enterprise networks mainly due to the requirements of the industrial sector [7]. The differences can be overcome by introducing a standard which will then allow people with basic knowledge of computer networks be able to work in either sectors [8]. In the industrial sector, a fast and reliable communication network is preferred. Network can be divided into two part, one is local area networks (LANs) and another is wide area networks (WAN). Ethernet is Network technologies for local area networks (LANs) that can transfer data at a rate as high as 10 Mbps [9]. Nowadays, Ethernet is widely used in industrial automation for monitoring and control of industrial process parameters. It is because Ethernet can distribute measurement and control unlimitedly and inexpensively, with relatively high speed network and low delay that support many applications. Besides that, installation of Ethernet is easy with low cost payment. In comparison with other technologies like Bluetooth, Zigbee, IR, RF-ID and GSM, Ethernet have a very high speed, safe and reliable but low response [9]. The upgradation to an ICT communication network improved flexibility of the electrical protection and control system of the tested North American Refinery [10]. Ethernet network implementation, also eases future expansion and any changes to the infrastructure of the refinery as the Ethernet is easily configurable [10]. It is also crucial to consider the worst-case scenario of Ethernet timing. A research is done on the timing of Ethernet AVB using both simulation and a formal worst-case analysis based on Compositional Performance Analysis known from embedded computing systems. From the results, the worst-case latencies were quite high and well above the low-latency target of 250µs which indicates unmodified Ethernet AVB has issues for low-latency Ethernet in industrial automation [11].

III. Energy Consumption

The growing use of communication technology is increasing exponentially, and almost everything today relies on it. This then creates an issue regarding the power consumption of the communication system that affects its industry at providing high speed data transfers at a low cost. Towards the scope of Ethernet, 41% of all systems in the TOP500 use Gigabit Ethernet as of June 2012 for its low cost and competitive performance [12]. This has spark the need to reduce its energy consumption for a greener and cost effective solution to the communication industry. One of the measures taken is the implementation standard IEEE 802.az, Energy Efficient Ethernet (EEE), approved in 2010 which reduces energy consumption by

dynamically turning off unused links to save interconnect power [12]. The EEE is able to adapt its power consumption to the actual traffic demand thus solving energy consumption of a single network connection [13]. The standard set is due to in nearly all of the Ethernet based systems, the receiver and transmitter is operating at full power regardless of data transmission [12]. To further improve the energy saving EEE on High Performance Computing (HPC) a "Power-Down Threshold" scheme is proposed to be used as an add-on to EEE to mitigate its on/off transition overhead which results in a 7.5% of power save in comparison to the standard EEE system [12]. The reduction of power consumption in HPC is of great interest as it consumes a significantly large amount of power. Another scheme to increase energy efficiency is by optimum traffic allocation. Link aggregation is commonly used to increase capacity of a network connection which increases power consumption if all links are used without optimal loads. Hence, a proposed sharing method of load among the links is used, whereby the link is only activated to transmit traffic when the previously links in the aggregate are being used at its maximum allowed load [13]. The result from synthetic and real traffic traces test when the proposed sharing algorithm applied see a maximum energy consumption reduction of 50% [13].

Another approach in high performance energy saving data transfer is by applying EEE on Optical Ethernet such as Passive Optical Networks (PONs) as its usage has also grown due to its capabilities in comparison with its copper transceivers [14]-[15]. In order to estimate the energy consumption of a link that uses a sleep-mode power saving mechanism an analytical model is used, which provides key answers as to whether the complexity of optical component outweighs its energy saving scheme making it negligible [15]. An interesting result obtained from optical transceiver with 10Gb/s EEE on medium traffic load is the significant relative energy saving achieved at any load given that the transition time is below 1μs [15]. For further energy saving scheme for PON based on downstream Packet Scheduling (ESPS) in Ethernet PON (EPON), an algorithm and a rule for downstream packet scheduling at the inter- and intra-ONU levels to reduce delay and a hybrid sleep mode that contains ONU deep sleep mode and independent sleep modes for transmitter and receiver [14]. From the simulation results, the ESPS is better than the traditional Upstream Centric Scheduling (UCS) in terms of energy usage and average delay in both real and non-real time packets downstream.

In addition to aid energy conservation of Ethernet, the transceiver needs to be consistently improved as to sustain high data transfer of Gigabit per second (Gbps). A low-power 100 Gigabit Ethernet transceiver IC compliant with IEEE802.3ba 100GBASE-LR4 in 40nm CMOS is incorporated with a multidrop clock distribution scheme with single on-chip transmission-line (T-line) and quadrate RX and TX scheme without CML logic gates for reduction of power. The transceiver IC proved to be successful in providing high power efficiency of 3.9mW/Gb/s, which by comparison to recently published 25 GB/s transceiver is the best [16].

IV. Issues About Ethernet

With the extensive growth of Ethernet, there are several issues faced in order to meet the demands of a faster and more efficient data transfer. One of the current issues is the scalability of the Ethernet Datacenter Network (DCN). The problem was investigated and a method of topology-independent software-defined edge control framework, FRINGE was introduced [17]. FRINGE reduces the number of rules in network devices and suppress the useless broadcast packets in the DCN. Other than the above, the quality of network has also becomes a major issue as user's demands increases in the aspect of cost effectiveness and user experience. The method employed to overcome the issue is by using Maximum Transmission Unit (MTU) of Ethernet to divide the large data into small packets [18]. The small packet sizing improves overall performance in most of the parameters investigated. As we all know, the standard Ethernet does not provide a fault-tolerance capability. For that, various fault-tolerant Ethernet (FTE) protocols for power applications were developed. Seamless Ethernet switches can provide seamless redundancy with zero recovery time and without modification to the standard Ethernet frame layout[19]. It also reduces traffic to 50% in comparison to the standard HSR protocol which also leads to a more free bandwidth. There is also an issue of congestion that occurs when links are oversubscribed and traffic is beyond normal limits.

There are problems that make Quantized Congestion Notification (QCN) cannot enter into the sliding mode motion (SMM) [20]. For that, sliding mode congestion control (SMCC) is introduced so that it can enter into the SMM pattern under any conditions. Experiments on the NetFPGA platform verify that SMCC is stable and can achieve shorter response time than QCN.

Lastly an interesting issue found is Ethernet security against malware and hackers. Problems are related to Address Resolution Protocol and to self-configurability. There are several solutions provided like accepting Ethernet's insecurity and circling it with firewalls, creating a logical separation between the switches and end hosts, and centralized cryptography based schemes. In short, the security of Ethernet can be relatively high, but not without its setbacks like loss of simplicity and ero-configurability [21].

V. Ethernet Improvement And Advancement

The constant increase in demand of a better communication network has led to the improvement of the Ethernet to be a competitive choice of communication networks. One of the recent research done for Ethernet is CUCKOOSWITCH [22]. CUCKOOSWITCH is a new forwarding information base (FIB) design for software-based Ethernet switch. The researches had shown that CUCKOOSWITCH can process about 92.22 million minimum sized packets per second on a commodity server equipped with eight 10 Gbps Ethernet interfaces while maintaining a forwarding table of one billion forwarding entries.

Ethernet is a non-real-time communication system while Controller Area Network (CAN) is a deterministic real-time communication system. The researchers studied about the combination of it to become CAN-Ethernet architectures for Real-Time applications [23] which then allows a real-time communication using Ethernet. However, the combination creates several other problems, one of which the researchers addressed is the collision control due to jitter by implementing a time-triggered on Carrier Sense Multiple Access (CSMA/CD) [23]-[24]. The results obtained from their research is that transmission delays of Ethernet are bounded and the respect of CAN traffic deadlines can be guaranteed. Following the research done on CAN-Ethernet architectures for real-time application, another research on low cost and a deterministic real-time control communication using Ethernet is carried out. Two schemes are introduced, the Binary Exponential Backoff (BEB) and Linear Backoff schemes, with the aim of reducing jitter and delay [24]. From their simulation, it is proven that jitter and delay can minimize the packet transmission time jitter by up to 50%. This reduction in collision helps to improve the real-time communication of the Ethernet.

The step of improvement of Ethernet to real-time usage has difficulties such as real-time Ethernet POWERLINK being unable to implement cross-communication which is deemed crucial [25]. By overcoming this obstacle, cross-communication will expand with the increase rate of transmission of a network. Therefore, it is proposed for a scheme based on mastering the real-time Ethernet POWERLINK to implement cross-communication. It is seen from their experiments that the scheme is proven successful in improving the data transmission efficiency of the network to a certain extent.

Another evolution is the change of Mobile Broadband Backhaul Network Migration from TDM to Carrier Ethernet due to the drastic increase in demand due to the introduction of high speed data transmission like LTE and 4G [26]. This is because Ethernet transport infrastructure (MPLS and carrier grade Ethernet) will be deployed and maintained at a lower total cost of ownership than legacy TDM transport infrastructure [26], which basically means increasing utilization of network while maintaining a low cost. However, there is no one solution for a complete fix, as it will be highly dependent on the network.

VI. Conclusion

From the surface review done, the prospects of Ethernet technology in the automotive and aviation industry is very bright as it is highly preferred in the latest designs of automotive and aviation models. While in the industrial sector, Ethernet is a preferred choice as the application of monitoring and control requires a fast yet reliable mean to transmit data. The easy configurability is also a main factor as factories tend to undergo upgradation for better efficiency. As for its energy usage, with the new EEE standard Ethernet technology, it has reduced significant amount of energy consumption. In addition to that, the implementation of the standard has sparks interest in researchers to further reduce energy consumption as the communication network continuously grows and consumes larger amount of power. It can be concluded that energy usage of Ethernet will be further reduced, with a new better schemes and better transceiver and receiver parts for higher rate of communication transfer. Despite all the wide usage of Ethernet, future issues will arise as the demand for a faster and more secure means of communication network continuing to grow. Hence, future upgrades of Ethernet are always an on-going process with a wide variety of improvements to be a silver bullet for all problems although it is unlikely. In conclusion, the Ethernet network is proven relevant in today's network communication and can still be developed further.

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