CHAPTER 2
LITERATURE SURVEY

In this chapter, the related knowledge to the thesis research is described. This theoretical knowledge consists of the Ethernet protocol, the solutions based on the Ethernet protocol to support time constraints, communication and the solutions based on the Ethernet switch. The flexible time-triggered switched Ethernet (FTT-SE) protocol is also described in this chapter, which is the basis of the proposed solution in the thesis.

2.1 ETHERNET PROTOCOL

The Ethernet is currently a mainstream in the industrial environment as an inherent interface. This protocol is additionally utilized as a part of the production line floor by adding different changes to help the ongoing communication. The Ethernet was produced in the 1970s, and the first Institute of Electrical and Electronics Engineers (IEEE) standard was distributed in 1985 as IEEE 802.3 (Decotignie 2005). The Ethernet protocol utilizes the carrier sense multiple access with collision detection (CSMA/CD) discretion. In the CSMA/CD, a system hub transmits the information to the transport while the transport is free. At that point, the transport checks for the impact, and, if the crash happens, it quits sending the information and sits tightly for an irregular time. In the wake of holding up a particular time, the hub tries to retransmit the information. In this manner, this peculiarity of the CSMA/CD component is an issue with backing hard continuous conduct in the protocol. The protocol Ethernet has been enhanced by including a switch-based structure with an N-port repeater. The switch rehashes the information
received from a port and telecasts to all of the other ports. In the meantime, the switch tries to check the conceivable crash and advises all of the ports if any impact happens (Decotignie 2005). The switch was supplanted by a Medium Access Control (MAC) span, which is called an Ethernet switch because of the switch limits. The primary difference of switch is the point at which the switch recovers the information, sending it to the port in which the end-of-the-line is known.

When a message touches the base at a switch port, it is cushioned, checked as indicated by its end, and moved to the cushion concerning to that terminus port. Although the changing of the Ethernet by including switches enhances the execution of the protocol, later alternate changes have been proposed to help the constant conduct (Decotignie 2005).

2.1.1 FTT – CAN

The Flexible Time-Triggered Communication over Controller Area Network (FTT-CAN) protocol fulfills the time-activated communication plan and backs both the time-activated and occasion-activated traffic with a fleeting separation. The traffic is planned online and, midway in an extraordinary switch, called a master switch, in light of any scheduling strategy. Examples of this are the fixed priority or the earliest deadline policy. The planned messages are transmitted inside fixed -time opening called an elementary cycle (EC). A specific message, known as the trigger message (TM), is indicated from the master switch to all of the distinctive switches at the beginning of the EC to synchronize the transmissions of all the switches (Almeida et al 2002).

Every EC is partitioned into two back-to-back windows known as synchronous and asynchronous windows. Synchronous windows are utilized for intermittent message transmissions, and the asynchronous windows are
committed to aperiodic message transmissions. The planned messages for the current EC are encoded in the TM, and all of the beneficiary switches are permitted to transmit the booked messages into the communication medium. The adaptability, perfection, and efficiency of this protocol has been concentrated (Almeida et al 2002), and the analyses demonstrate that the specified peculiarities are accomplished utilizing flexible time-activated standard in the FTT-CAN protocol.

The communication administrations of the FTT-CAN are performed inside the two sub-frameworks, known as the synchronous messaging system (SMS) and the asynchronous messaging system (AMS). The SMS presents administrations focused around the maker purchaser, while the AMS administrations are shaped by sending and getting the fundamentals.

The SMS deals with the synchronous messages, which are synchronized with the ECs. All of the switches unravel the TM sign to check whether the messages are prepared to be sent by a maker switch. This is performed by checking a local area network message table that comprises the identification of the messages to be created or devoured by this slave switch. Nonetheless, the AMS administrations are mindful to handle the asynchronous traffic. This sub-framework is like the first CAN protocol, which fills in as a necessity-based disseminated assertion instrument. An alternate level of access control is utilized to forestall the impedance between the asynchronous messages and the occasional traffic. This is carried out by authorizing a strict fleeting separation between the two sub-frameworks. The right to gain entrance control sets the starting and ending time of every asynchronous window, and, subsequently, the asynchronous traffic is pending to transmit outside of this window. Promptly, amid the asynchronous window, the switches are allowed to transmit their solicitations (Almeida et al 2002).
2.1.2 EDF Scheduled Switch

This system that backs both constant and non-continuous messages is focused around the Ethernet switch which is produced by Hoang et al. In the proposed construction modelling, both the switch and end switches require the expansion of an ongoing layer. This continuous layer is in charge of building an ongoing channel, an affirmation control, time synchronization, and a message transmission control in the system. The switch and the end switch construction modelling in the proposed result are shown in Figure 2.1. The transmission is completed inside the continuous channels in which the data transfer capacities are now held. when a switch needs to send constant information, it sends an appeal to the switch to demonstrate the source and the end-of-the-line switches.

![Figure 2.1 Layers of switch](image-url)
On the off chance that the appeal is achievable from the switch perspective, the switch advances the solicitation to the end switch. The target switch checks the state of accepting a message, too. When the ongoing channel is built, the switch analyse the source switches to demonstrate the channel stronghold. The practicality dissection is proposed in Hoang et al (2006), considering the Earliest Deadline First scheduling (EDF) strategy and considering the overhead of control messages and non pre-emptive traffic control.

2.1.3 EtheReal

The EtheReal protocol is an alternate system, which is focused around the Ethernet switch, with timeliness ensuring the protocol helps both the constant and non-ongoing messages. In this result, a few administrations are executed on the switch to back up the protocol. These administrations are available to the switches as client level libraries. Along these lines, the transfer speed reservation solicitation sends to set up the constant association, and the switch checks the assets to meet the QoS necessities of the continuous association (Varadarajan & Chiueh 1998). when an ongoing application tries to set a continuous association, it sends the reservation demand, known as the real-time communication daemon (RTCD), to a client level of the switch, which is dependable in building the constant association. The RTCD packet contains the destination IP address, the QoS parameters, and the EtheReal association ID. All of the switches included in the association make new association ID from the last switch that interfaces with the end switch. When the ongoing association appeal is acknowledged, all of the switches along the way make a steering table with relating the QoS and the association ID data. At last, the RTCD furnishes a proportional payback IP location to the sender application to demonstrate the association establishment. At that point, the
sender switch begins to transmit the ongoing information through the attachment that the application opens (Varadarajan & Chiueh 1998).

The traffic forming and policing have been utilized in EtheReal protocol to blanket the smooth packet landing time in the switch and switches. Additionally, the traffic policing is utilized to guarantee the QoS prerequisites amid the run-time (Pedreiras et al. 2005).

2.1.4 FTT-Empowered Ethernet Switch

The FTT-empowered Ethernet switch is a protocol that is focused around the FTT standard and master/slave system; however, the master is actualized inside the switch. In this protocol, the switch is not the Commercial Off-The-Shelf (COTS) switch. There are different benefits; for instance, the straightforwardness of the asynchronous traffic deals with and stretches the uprightness of the skeleton, which is consolidated in this protocol (Santos et al. 2009).

In the FTT protocols, there are three types of traffic: intermittent and constant traffic, aperiodic or sporadic ongoing traffic, and the non-continuous traffic (Santos et al. 2009). The periodic and aperiodic traffic is initiated by the master. In the asynchronous traffic, the application with every switch enacts them. The channel station system is utilized within a request to ensure the convenient behaviour of the system. To set a continuous channel for exchanging the messages, all of the switches in the way of the message structure source to a goal switch are included. When a switch requires communicating something specific, it needs to set up the ongoing channel by sending a solicitation to its switch. The parameters of the message, such as a source switch, an end-of-the-line switch, a necessity, and an execution time, is sent with the appeal. All of the connections between the sources to the goal switches check the practicality and furnish a proportional payback as an
achievement or a reject signal. In the event that the solution to the source switch is an achievement, the message will be transmitted through the created ongoing channel.

2.1.5 Multi-Switch FTT-SE Network

The FTT-SE with various switches alongside the single master switch joined with the root switch was proposed at one time in Behnam et al 2012. In this approach a system making a few Ethernet switches, which are joined together as tree topology, was considered. All transmitted messages are controlled through one master switch which is joined with the root switch. As per the FTT-SE protocol, all messages are transmitted in a fixed time space known as Elementary Cycle (EC). The master switch filters all occasional messages in a table to check if any prepared message accessible to be booked. Assuming this is the case, the prepared message is embedded into a prepared line which is sorted as per the scheduling strategy, for example, Fixed Priority or Earliest Deadline First. The scheduler gets first message from the prepared line and registers in the event that fits with the specific transfer speed inside the EC. All messages which are planned by the master switch are encoded in a specific message known as Trigger Message (TM). The TM is sent at the start of the EC and the beneficiary slave switches unravel the TM and transmit the scheduled messages.

2.2 REAL TIME SWITCHED ETHERNET

2.2.1 Protocols

Ethernet switches are generally tuned to provide a high throughput, as required for Internet traffic and so have poor support for timeliness. Several techniques have been proposed to enhance their timing properties. One class of technique is to use traffic shapers in each node to limit the burstiness, and the amount of load submitted to the network, thus preventing
memory overflows. Master/slave systems might likewise be utilized to accomplish ongoing conduct, since the master launches each transaction and hence has complete control over the heap submitted to the network. For example, the Ether CAT protocol uses this technique together with specialized switches and an open-ring topology. Another example is the ETHERNET Power link protocol (EPL), where a master node explicitly triggers each transaction according to a cyclic scheduling table. Transactions are always broadcast in such protocols thus they cannot exploit the available parallel forwarding paths. Foundation HSE is a layer protocol, based on standard Ethernet equipment that uses a high-level communication scheduler to reduce contention by preventing devices from concurrently generating data. Similarly, Ethernet/IP relies on COTS Ethernet equipment, i.e., switches, network interface cards and IP stacks. Avoiding overloads and achieving timely behavior in this case requires a careful analysis by the system designer since there are no specific run-time enforcement mechanisms. Finally, it is also possible to enhance the switch with traffic control and scheduling capabilities. For example, Hoang et al (2006) proposes the inclusion of EDF traffic scheduling and on-line admission control inside a switch. The EtheReal protocol presents a similar architecture, also based on a modified Ethernet switch. Isochronous Real Time (IRT) (Hwang & Shih 2009) and PEAC (Pedreiras et al 2005) employ a distributed cyclic time-slottning scheme encompassing a deterministic time-triggered phase and an asynchronous phase for non-real-time traffic. Recently, Wang et al. proposed a new switch design that supports the features of real-time traffic, providing low latency. However, the switch configuration, such as in PROFINET-IRT, is carried out off-line and thus cannot be used for dynamic situations in arriving and departing streams and/or adaptation of the existing ones. In general, using customized switches has the disadvantage of lower (possibly no) availability of equipment and higher costs but has the potential for higher efficiency and robustness. It is thus a choice that the system architect must consider.
Comparing with the techniques above, FTT-SE follows a Master-slave approach, too, but uses polling on a cycle basis rather than message basis, reducing the overhead substantially. But, more important to our purpose, is that it is the only protocol explicitly providing guaranteed on-line traffic scheduling services, with support for arbitrary scheduling policies, while only using Ethernet COTS equipment.

2.2.2 Real-Time Ethernet

The Ethernet protocol has an assertion instrument focused around CSMA/CD which was the primary hindrance of supporting constant applications in Ethernet. A few strategies have been created for applying the continuous behavior in Ethernet communication. These routines are recorded as underneath:

- **CSMA/CD based systems**: These systems utilize the standard Ethernet connectors and the impact in the system is identified with traffic properties. Actually, the probability of impact in the system is identified with the traffic properties, for example, usage variable and message length (Kopet 1997). In these strategies the traffic properties are utilized to figure the probabilities of deadline misses.

- **Modified CSMA protocols**: This protocol utilizes the CSMA system properties; however some modifications have been added to get the constant behavior. These modifications, for example, back off and retry components are executed to enhance the fleeting behavior of the system. Two fundamental modifications in this class of the protocols are postponing the transmission to diminish the crash probability and control the impacts. The system known as Virtual Time CSMA is created...
as per the first approach which defers the transmission to acquire the worldly behavior. Alternate solutions, for example, CSMA/DCR are displayed as per the second approach.

- **Time Division Multiple Access (TDMA) system:** In this framework, the time openings are relegated to the messages and a casing of time spaces transmitted occasionally. More often than not, an uncommon instrument has been utilized to synchronize the message transmission between switches in the system (Pedreiras et al 2005).

- **Master/Slave procedure:** In this procedure there is a specific switch known as master switch which controls the traffic in the system among slave switches. Fundamentally, ace switch surveys all slave switches and they got consent to send information. Besides, ace switch utilizes a specific motion as control message to survey all the slaves.

- **Switched Ethernet:** Utilizing switches within the system diminish the non-deterministic behavior of Ethernet. Fundamentally, a switch buffered the entry message and checks the goal location of the message. The yield ports have yield buffer and the request of message sending is based on priority.

2.3 **SCHEDULABILITY ANALYSIS**

Concerning switch traffic schedulability analysis, much work has been carried out since the early 90s. Two main frameworks have been used, Network Calculus (NC) (Mifdaoui et al 2010, Marau et al 2006) and response time or utilization-based analysis (RTA) (Santos et al 2009, Hoang et al
Santos et al (2009) present a comparison of both approaches for the case of fixed priority packet scheduling. Basically, Network Calculus is more flexible to use, relying on a more general traffic model, while providing more pessimistic delay bounds. This is the motivation for the response-time analysis for switches in Georges et al (2002) that also considers the impact of FCFS queues. Despite the relatively large amount of work on network-induced delay caused by switches, particularly Ethernet switches (Lenzini et al 2006, Georges et al 2002), less attention has been devoted to utilization-based tests. Curiously, the same has happened in the real-time scheduling community, with more work dedicated recently to response-time analysis. The use of utilization-based tests is further complicated by the presence of FCFS queues in the switch. The works that consider such tests build upon modified switches that carry out different scheduling policies. Conversely, FTTSE overrides the effect of FCFS queues and supports any scheduling policy on COTS switches. Thus, we will use the FTT-SE protocol to execute RM and EDF scheduling and take advantage of the respective schedulability utilization bounds with a proposed general adaptation to cope with release jitter. This will enable the deployment of dynamic QoS management, which requires such tests to perform on-line bandwidth reclamation and redistribution. We believe that the results in this model can also find applicability in other scopes, such as pipeline scheduling. Moreover, our results also allow eliminating the release jitter from the utilization-based tests by upper bounding its impact with utilization terms. Finally, the recent work in Davis & Burns 2008 also includes a pseudo utilization-based schedulability test that accounts for release jitter but:
• It considers all tasks simultaneously affected by their release jitter being substantially more pessimistic than considering the maximum release jitter once for the set of tasks as in our case.

• Does not directly reflect bandwidth.

The literature on switched Ethernet is inconceivable and there have been numerous works tending to its amleness to constant communication. We can discover from generally old analysis recommendations, for example, Ethereal (Decotignie 2005) and the EDF Scheduled Switch, both focused around channel reservations underpinned on improved switches. For example, the upgraded switches proposed in Hoang et al (2006) that consolidate synchronous and asynchronous movement with rate security. In the then, numerous answers for continuous Ethernet really made it to the business, for example, TTEthernet and PROFINET IRT, both streamlined for time-activated operation, and Ethernet, improved for snappy sending with on-the-fly upgrade of the Ethernet edges while navigating the hubs. AFDX is additionally in this classification, with upgraded sending and rate control focused around static sending tables and rate channels, and has been utilized predominantly within aeronautics. Another standard has been made, named Ethernet AVB (Audio-Video Bridges), which backings channel reservations with limited end-to-end idleness, with out any business help. These arrangements utilizing upgraded switches present enhanced execution yet bring about high cost and lower accessibility than current COTS Ethernet switches (IEEE802.1d). In this manner, a few arrangements were additionally looked into and in the long run promoted, in light of overlay protocols that control the movement submitted to COTS switches. This is the situation of Ethernet POWERLINK and FTTSE, both expert/slave approaches, the recent of which will be utilized within this model because of its unrivalled transmission capacity effectiveness and activity planning adaptability.
Concerning the timing analysis of multi-switch Ethernet a few routines are accessible. Network Calculus is utilized within Kopet (1997) to break down the end-to-end. It defers in FTT-SE utilizes a solitary expert multi-switch topology and in Lo Bello et al (2000) utilizing for systems of standard Ethernet switches. The work in Marau et al (2007a) presents three routines to determine the end-to-end movement defers in a multi switch AFDX system, specifically utilizing Network Calculus, system recreation and model checking. Among this Network Calculus shows higher cynicism. A tighter timing investigation for AFDX systems can be attained utilizing the trajectory approach as reported in Marau et al (2010). System analytics are likewise utilized (Marau et al 2007a) to infer end-to-end activity delays for Ethernet AVB, demonstrating a careful investigation focused around a car infotainment framework. The work in Mifdaoui et al (2010) presents a more pessimistic scenario delays confirmation of in-vehicle Ethernet systems utilizing the same systematic schema to produce upper limits and weighing them against tests in most pessimistic scenario situations. An alternate methodology is followed in Marcellin et al (2000) and Pedreiras & Almeida (2005) that determine end-to-end postponement limits for a solitary stream in FIFO multiplexed sink-tree systems utilizing an altered Network Calculus skeleton. These works use dividing of a system topology into a set of coherently differentiated sink-trees having departure hubs at the root and entrance hubs at the clears out. The movement is totalled in hubs by presenting a FIFO arrangement called accumulated booking.

A class of administration bends is acquainted with focus to the administration that is gotten in a total planning system. Moreover, the work in Pedreiras et al (2002) used the said technique to research a confirmation control in sink-tree systems. As can be seen from the concise study above, most detrimental possibility reaction time investigation of systems of standard Ethernet switches is unexplored to an extensive degree. In this model we
further investigate this sort of dissection connected to an expert slave system of switches, running the FTT-SE protocol with one expert controlling the movement at each switch, and we demonstrate that we can get tighter results than with Network Calculus.

2.4 COMPRESSION STANDARDS

Multimedia compression standards and multimedia transmission are used to identify redundant data, e.g., groups of pixels of similar color, to reduce the data size. Different compression standards such as JPEG (with baseline, progressive, hierarchical and lossless profiles), JPEG2000, MPEG-2, H.263 and MPEG-4 (part 10, also known as H.264 or MPEG-4 AVC) allow the system to cope with the requirements posed by the different classes of applications. Two main types of compression are applied during transmission: image compressors and video compressors. An image compressor compresses between frames, while a video compressor uses the redundancy of images in a sequential manner. Depending on the application being used, one must choose the compression technique. In recent years, many image compressor standards like JPEG and video compressor standards like MPEG are applied during multimedia transmission. In contrast, video coding is a compression technique that is performed by the application. The result is higher compression rates, which use less bandwidth during transmission when the load of the network can be affected by various parameters. The video coding technique maintains image quality at a constant rate. This is not suitable for industrial applications where the image quality changes often. In image compression, all images are independent, so if any, loss occurs in one image during transmission, nothing affects the subsequent images being transmitted. In turn, video transmission uses different frame types, namely, I-frames, which are independent, but also P-frames, i.e., inter-frames coded depending on previous frames, and sometimes B-frames that depend on following frames. Only I-frames are self-
contained; thus, the loss of a frame or part of it may have an impact on several of the following frames, until the arrival of another I-frame. But in another important characteristic of video transmission in industrial applications is that the images of different streams are sometimes captured at low rates and multiplexed together in the same channel. In this situation the compression level is redundant.

In recent years, multimedia real-time transmission over the Internet (Marcellin et al 2000) has generated a significant amount of research interest. Typical solutions have been based on the transmission control protocol (TCP), the user datagram protocol (UDP), or the Internet protocol (IP) stack, complemented by other protocols, such as real-time protocol (RTP)/real-time control protocol (RTCP), real-time streaming protocol (RTSP), or session initiation protocol (SIP). These protocols measure key network parameters such as bandwidth usage, packet loss rate, and round-trip delays to control the load put on the network. The calculation of the required bandwidth for storing video as well as live video (video streams). The efficiency of the quality results is highly dependent on the delay allowed by the particular application. This is one of the main limitations of these technologies. Some of the algorithms presented in Pedreiras et al (2002) called buffer smoothing algorithms, use the buffers to accept and smooth the variations of bit rate. Studies presented in Jasperneite et al (2009) and Silvestre et al (2006) presented another technique called content-based network resource allocation. In these approaches, the latency can be very high since they employ relatively large image buffers in the sender and are based on standard IP networks, using traffic smoothing techniques. In addition, some preliminary processing stages are needed before performing the compression. An increase in latency causes high computational overhead on the sender's side. In video transmission latency comes from video code and network delay or losses. The video coding technique significantly reduces the latency effect of image
coding and network delay, which can also be reduced by using RTCP. With these protocols the VBR Streams match with the available bandwidth provided by the communication channels during the transmission. This matching can be done by adopting some parameters like changing frame rate, which results in a frame dropping and low quality frame resolution. To avoid this, we can use some approaches that reserve channel capacity for the maximum bandwidth required by the multimedia content. However, this causes high bandwidth losses with no frame loss. One possible option that can be used to solve this problem is to reserve the channel capacity for the average bandwidth required for the content. This option also causes high network losses/delay, but with efficient utilization of bandwidth.

The main drawback of existing technologies, with regards to their use of industrial communications, is the latency introduced. For example, smoothing video algorithms use memory buffers between the producer and the consumer to smooth the bit-rate variations. Estimates of the required bandwidth and buffering can be handled offline for storing video or, for live (i.e., non-interactive) video streams, can be based on a few images buffered before their transmission. However, the quality of the results depends on the delay allowed by the application. Similar limitations are found in the content-based network resource allocation schemes presented in Motai &Kosaka (2008), Silvestre et al (2007). In these approaches, the latency can be high since they employ relatively large image buffers in the sender and are based on standard IP networks, using traffic smoothing techniques. In our proposed model we concentrate on fitting VBR into CBR streams and associated challenges. The QoS model uses the FTT-ESE protocol, which obtains the required bandwidth for real-time multimedia transmission. The goal of this model is to reduce frame loss and utilized bandwidth efficiently with respect to QoS parameters for each stream used in the transmission. Our model takes as input various performance aspects such as allocated bandwidth,
compression level, and utilization of network resources for each multimedia source.

Moreover, they require a complementary processing stage before compression in order to adapt the compression to the image content. Thus, the latency is further increased and high computational overhead is incurred by the sender nodes. The latency problem is addressed by the low-delay rate control algorithms that achieve a high performance for videophone and video-conference applications.

### 2.5 CONCLUSION

The main drawback of existing technologies, with regards to their use of industrial communications, is the latency introduced. For example, smoothing video algorithms use memory buffers between the producer and the consumer to smooth the bit-rate variations. Estimates of the required bandwidth and buffering can be handled offline for storing video or, for live (i.e., non-interactive) video streams, can be based on a few images buffered before their transmission. However, the quality of the results depends on the delay allowed by the application. Similar limitations are found in the content-based network resource allocation schemes presented in existing works. In these approaches, the latency can be high since they employ relatively large image buffers in the sender and are based on standard IP networks, using traffic smoothing techniques. In our proposed model we concentrate on fitting VBR into CBR streams and associated challenges. The QoS model uses the FTT-ESE protocol, which obtains the required bandwidth for real-time multimedia transmission. The goal of this model is to reduce frame loss and utilized bandwidth efficiently with respect to QoS parameters for each stream used in the transmission. Our model takes as input various performance aspects such as allocated bandwidth, compression level, and utilization of network resources for each multimedia source.