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The FTCSMA/CD Network

Jun-Yao Wang, Wen-Shyang Hwang and Ling-Yang Kung

Department of Electrical Engineering, National Cheng-Kung University,
Tainan, Taiwan, R.O.C.

Abstract-This paper presents a new network model, FTCSMA/CD to provide fault-tolerant capability on IEEE 802.3 (CSMA/CD). This model inserts a sublayer between the LLC (logical link control) sublayer and MAC (medium access control) sublayer, in order to provide the fault tolerance function. That insertion sublayer is called ILM (Interface between LLC and MAC). The new network model adopts two channels as the communication path, but only one of channels is permitted to work at a time. Though the network bandwidth of this network model is not expanded, the network model still reached the goal of network fault tolerant. Further, the network model design is based on the compatibilty with the existent ethernet, so that the original software in the existent network could be used in the fault-tolerant model .

Introduction

In the world, computer network becomes a communication method between computers. Using network makes all programs, data, and equipment available to anyone on the network without regarding to the physical location of the resource and of the users[1]. Workstations connect each other replace the mainframe. This scheme can let many tasks executed by many computers, they are divided into many subtasks by the distributed operation system. These subtasks may be executed by many workstations to reduce execution time of tasks and the cost of the computer system. When we executed our programs or read data from a remote computer in the environment, we hope that our work do not be interrupted even though network fail. Because of these reasons, we always hope that computer system can work normally in any time. Fault-tolerant network is expected in this computer system.

Therefore, we hope to find a model providing fault-tolerant capability in network respect. We select the frequently used network CSMA/CD as our research goal. Because the CSMA/CD oriented network systems (Figure 1) have become widely used and the Ethernet-like approach has been proposed and experimented in developing complex control systems in an industrial environment[2]. Our research focuses on the data link layer in OSI model. Therefore, it will let the upper layer do not need to modify as soon as possible.

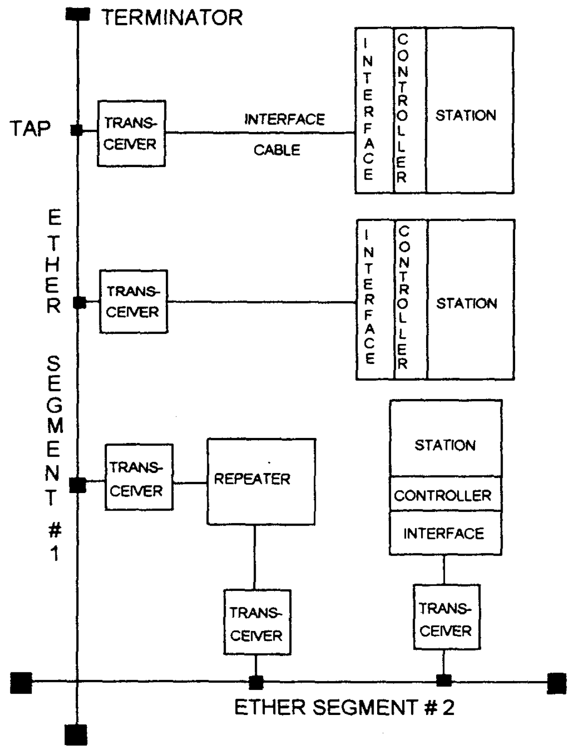

Figure 1. A two-segment Ethernet[3]

The paper begin by showing how the model integrates with original model. The original model is specified by IEEE. Then show the architecture of the model. The input and output of the architecture are compatible with original CSMA/CD architecture. Further, the algorithm of the operation of the architecture is discussed. Finally, the conclusion and the future of the model are presented.

Model Description

The new model increases a sublayer, named ILM (Interface between LLC and MAC), between logical link control (LLC) and medium access control (MAC). Before mentioning the FTCSMA/CD model, illustrate the original model defined by IEEE. The original model is the data link layer in the IEEE 802 LAN standard. The data link layer in the IEEE 802 LAN standard is split into two sublayers. The lower sublayer is the Medium Access Control (MAC)[1]. The upper sublayer is Logical Link Control (LLC). The MAC allow the local LLC sublayer entity to exchange LLC data_units with peer LLC sublayer entities[4]. The LLC sublayer can provide either connectionless or connection-oriented services to network layer. It also provides acknowledged connectionless service[1]. The original model defined by IEEE is in Fig. 2.

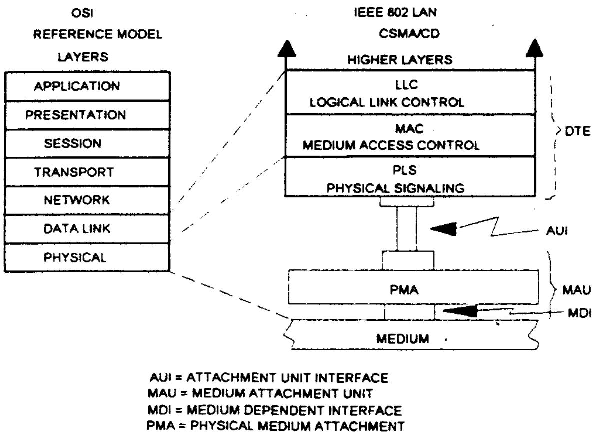

Figure 2. Service Specification Relation to the LAN Model [4]

Two services provided to the LLC Sublayer by the Media Access Sublayer are transmission and reception of LLC frames[4]. For the compatibility with the original model, the ILM must provides same services to the LLC in FTCSMA/CD model.

Functions:
TransmitFrame
ReceiveFrame

The FTCSMA/CD model is in figure 3. In the model, the data link layer is split into three sublayers. The upper sublayer is LLC sublayer. The lower sublayer is ILM sublayer. The lowest sublayer is constituted by two MAC sublayers.

The ILM sublayer schedules which MAC is responsible to frames for transmitting these frames. The ILM is provided services by MAC and provides service for LLC. Three services provided to the LLC by ILM are transmission, reception of LLC frames and test the MACs.

Functions:
TransmitFrame
ReceiveFrame
TestMac

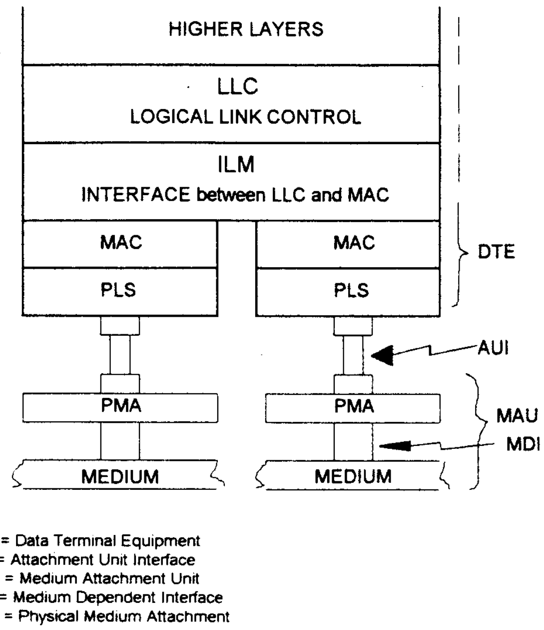

Figure 3 The FTCSMA/CD model

These functions make fault-tolerant MAC transparent to LLC because it doesn't need to know which MAC is responsible to transmit frames and which MAC receives frames. For the LLC sublayer, it can think its lower layer is a MAC sublayer because the ILM sublayer is not existing for it, that is, the ILM sublayer is transparent for the LLC sublayer.

The LLC transmits a frame by invoking TransmitFrame:

function TransmitFrame (
destinationParam: AddressValue;
sourceParam: AddressValue;
sourceParam: AddressValue;
lengthParam: LengthValue;
dataParam: DataValue): TransmitStatus;
type TransmitStatus = (transmitOK, excessiveCollisionError);

The LLC knows that two channels collide together when TransmitFrame returns excessiveCollisionError condition.

The LLC accepts incoming frames by invoking ReceiveFrame:

function ReceiveFrame (
var destinationParam: AddressValue;
var sourceParam: AddressValue;
var lengthParam: LengthValue;
var dataParam: DataValue): ReceiveStatus;

type ReceiveStatus = (receiveOK, length error, frameCheckError, alignmentError);

The TestMAC function provides the LLC to test which MAC is in collision. The function makes user know which channel should be checked. So, the LLC tests channel by invoking TestMAC:

function TestMAC:MACStatus;
type MACStatus = (MAC_OK, channel1CollisionError, MAC_Error);

The MAC_Error means that two channels are in excessive collision.

Two services provided to ILM by MAC1 and MAC2 are transmission and reception of LLC frames.

Functions:
TransmissionFrame1;
ReceiveFrame1;
TransmissionFrame2;
ReceiveFrame2;

Use these functions to let MACs think that they get frames from LLC and send frames to LLC. The ILM is transparent to MACs.

The ILM transmits a frame by invoking TransmitFrame1 or TransmitFrame2:

function TransmitFrame1(2) (
destinationParam: AddressValue;
sourceParam: AddressValue;
lengthParam: LengthValue;
dataParam: DataValue): TransmitStatus;
type TransmitStatus = (transmitOK, excessiveCollisionError);

The ILM receives a frame by invoking ReceiveFrame1 or ReceiveFrame2:

function ReceiveFrame1(2)(
var destinationParam: AddressValue;
var sourceParam: AddressValue;
var lengthParam: LengthValue;
var dataParam: DataValue): ReceiveStatus;
type ReceiveStatus = (receiveOK, length error, frameCheckError, alignmentError);

These services provided to LLC by ILM and provided to ILM by MACs make frames coming from LLC transmitting in normal way, that is, these frames don't modify or add additional fields for the additional sublayer, ILM. For examples, when LLC wants to transmit frames, it invokes TransmitFrame(). When ILM receives the frames coming from LLC, it directly invokes TransmitFrame1(2) to transmit these frames. In these processes, LLC doesn't modify any frames. LLC directly send these frames coming from LLC to MAC for transmitting these frames.

ILM Architecture

The difference between the FTCSMA/CD model and original model defined in IEEE 802 is the ILM. The interfaces of the ILM with LLC and with MAC are defined in previous section. This section illustrates the architecture of the ILM. The architecture of ILM (in figure 4) has three status registers, three memory areas, six queues, and a ILM processor. The three status registers are MAC1(2)_Status and visual MAC_Status. The three memory areas are SFA and RFA1(2). The six queues are SFQ, RFQ, MRQ1(2) and MSQ1(2). The MAC1(2)_Status that are written by MAC1(2) is used for recording the status of individual MAC and the visual MAC_Status written by ILM processor is used for recording the status of MACs of entire architecture. These statuses includes TransmitStatus, ReceiveStatus and some additional statuses. The status also includes TestMAC_Status for visual MAC_Status.

The SFQ and RFQ are written by LLC and ILM. They record the address of frame that will be sent or has been received. The MRQ1(2) and MSQ1(2) record the address of frames which MAC1(2) will transmit or have received. The SFA and RFA1(2) store these frames that will transmit or have received.

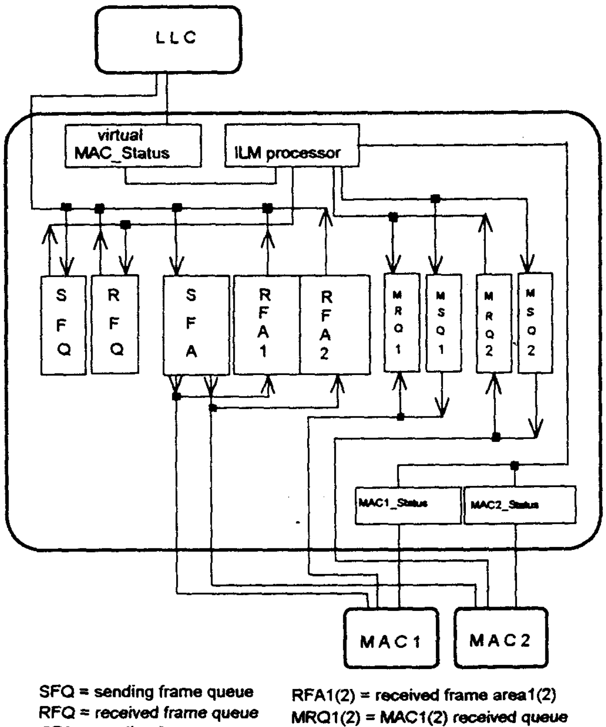

Figure 4. The architecture of ILM

The transmitting algorithm of the architecture is below:

1. *The ILM checks SFQ whether any frame requests to be sent.*
2. *IF the check is true, the ILM stores the address of the frame to MSQ1. Meanwhile, the frame wait to be sent by MAC1.*
3. *The ILM processor checks MAC1_Status to inspect whether MAC1 is excessiveCollisionError. If check is true, ILM restores these addresses that stored in MSQ1 to MSQ2 and*

- *sets the virtual MAC_Status to channel1CollisionError. Meanwhile, these frames wait to be sent by MAC2.*
4. *If MAC1 and MAC2 are excessiveCollisionError, the ILM processor sets the virtual MAC_Status to MAC_Error.*
5. *If two conditions are not happened, the ILM sets the virtual MAC_Status to MAC_OK.*

If a frame will be sent, the LLC must store the frame in SFA and its address in SFQ. If the LLC wants to know whether the channel is in excessiveCollisionError or not, it can read the virtual MAC_Status to get the message. The MAC1 must also check MSQ to know whether any frames request to be sent. If it is true, MAC read the address of these frames from MSQ and sends these frames from SFA. If the network has any status (e.g., excessiveCollisionError), MAC must write the status to MAC1(2)_status.

The model's received algorithm is below:

1. *The ILM checks MRQ1(2) whether any frames are received by MAC1(2).*
2. *If the check is true, the ILM gets the addresses of frames from MRQ1(2) and stores these addresses to RFQ.*
3. *The ILM gets ReceiveStatus from MAC1(2)_Status and writes these statue to virtual MAC_Status.*
4. *Meanwhile, these frames wait to be received by LLC*

In the model, if a frame is received from MAC1(2), the MAC1(2) must store the frame to RFA1(2) and the address of the frame to MRQ1(2). The MAC1(2) must also store the ReceiveStatus to MAC1(2)_Status. The LLC must check RFQ whether any frames are received from MAC. If it is true, the LLC reads the address of frame from RFQ, the frame from RFA1(2) and ReceiveStatus from virtual MAC_Status.

From the two algorithms, we can know that MAC2 is used for transmitting or receiving frames only when MAC1 is in excessiveCollisionError condition. Though the network model (in figure 3) is not better than existent network in the bandwidth, the network model reaches the goal of network fault tolerant. We can know that the network model (in figure 5) is compatible with existent ethernet from its transmitting and received algorithms, so that we can use it very easily.

FTCSMA/CD Network Structure

From above explanation, the FTCSMA/CD network structure is obtained in figure 5. It is a general network. It has three hosts having fault-tolerant network capability and one host only having traditional network capability. From the topology, it is realized that the fault-tolerant capability of segment #1 can connect with the fault capability of segment #2 by repeater. So, the network fault tolerant capability can expand and the fault-tolerant capability of the entire fault-tolerant network system can build by connecting these segments having fault-tolerant capability. Certainly, the fault-tolerant capability can be selected for any hosts. So, the degree of fault-tolerant capability versus cost can be varied throughout the network to achieve an optimal cost/fault-tolerant capability mix.

The FTCSMA/CD provided fault-tolerant capability by dual channel. Figure 6 illustrates a FTCSMA/CD bus segment consisting of three singly connected node (N1, N2, N3). Node N1 and N2 connect with the channel (FC and SC). N3 only connect with one channel (FC). Node N1, N2 are the fault-tolerant nodes and node N3 is traditional node not providing fault-tolerant capability. In the structure, network operation can be spilt into two operations, normal operation and fault operation. During normal operation (i.e., no faults on the first channel), these nodes use the first channel (FC) for transmission and reception of data . The second channel (SC) is inactive. During fault operation, these nodes use SC for transmission and reception of data. FC is inactive.

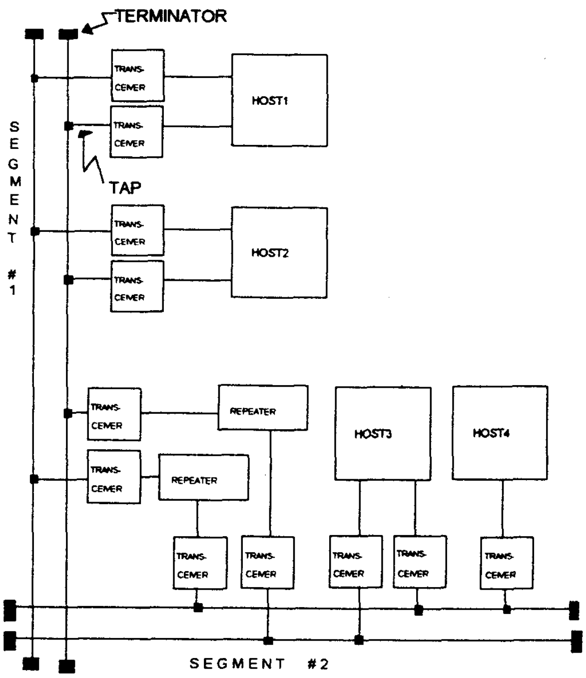

Figure 5. The FTCSMA/CD Network

During normal operation (in fig. 6) , node N1 wants to transmit data to node N2 or N3 through FC. When N1 broadcast its packet to the channel, it monitors FC to make sure no fault was happened on FC (i.e., excessive collision or N1 not connect to FC). N1 continue to transmit its packets through the channel if no fault was happened on FC. N2, N3 receive N1's packet through FC. If a fault was happened on FC, nodes on the segment are changed to the fault operation state (fig. 7). When N1 is on fault operation, it switch its transmitting packets through SC. N2 will receive these packets through SC. During fault operation, N3 will can't receive any packets from N1 because it doesn't connect with SC. During the operation, N1 transmits its packet through SC, and continuously check whether FC it is normal or not. If N1 find FC is normal, N1 will switch to normal operation state. In the fault operation state, N1 find FC is normal by checking whether FC can transmit normally the packet waiting to transmit when network switched from normal operation to fault operation or not. If FC is normal, N1 returns to normal operation.

In the FTCSMA/CD structure, a node wants to have fault-tolerant capability must connect with dual channel. It also proves that every node on the network can select the fault-tolerant capability.

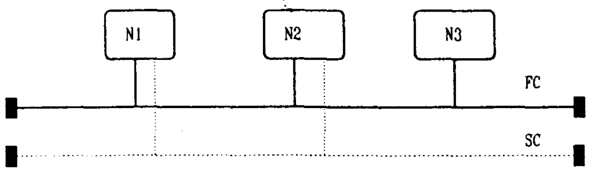

Figure 6. network on the normal condition

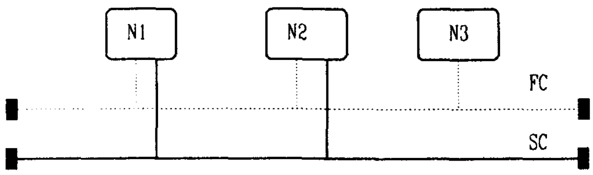

Figure 7. network on the fault condition

Conclusion

The FTCSMA/CD network use dual-channel approach for achieving fault-tolerant ability. The network is compatible with ETHERNET. Every host (or nodes) on network can have the right to select the fault-tolerant ability. It let the cost be distributed for the fault-tolerant capability.

From the ILM structure, we known some payment for fault-tolerant capability. First, some delay is generated because the system must decide the transmission messages to transmit through which channel and the system must check whether the system has been recovered after the fault had happened. Second, some extra cost must be spent , e.g. the ILM, two channels, and so on. The performance reduction and extra cost is the price paid for improved the fault-tolerant ability of the network.

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