"Performance Analysis of Local Area Networks"

Final Report

Submitted to:

Mr. John Yin, Manager
Communications and Networks Development Branch
NASA-Ames Research Center, MS 233-18
Moffett Field, CA 94035

Prepared by:

Dr. Hasan S. AlKhatib, PI
and
Ms. Mary Grace Hall, RA
Department of EECS
Santa Clara University
Santa Clara, CA 95053

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This report describes a simulation of the TCP/IP protocol running on a CSMA/CD data link layer. The simulation was implemented using the simula language, an object oriented discrete event language. It allows the user to set the number of stations at run time, as well as some station parameters. Those parameters are the interrupt time and the dma transfer rate for each station. In addition, the user may configure the network at run time with stations of different characteristics. Two types of messages are available, and the parameters of both types are read from input files at run time. The parameters include the dma transfer rate, interrupt time, data rate, average message size, maximum frame size and the average interarrival time of messages per station.

The information collected for the network is the throughput and the mean delay per packet. For each station, the number of messages attempted as well as the number of messages successfully transmitted is collected in addition to the throughput and mean packet delay per station.
INTRODUCTION

The purpose of this simulation is to allow a user to model a network with specific station parameters to see the characteristics of its behavior. In this way, an existing network may be examined, as well as the effect of any change on the network. For example, to see the effects of adding a station to an existing network without actually doing it, the network could be simulated with the added station using this tool. The simulation could be run with varying characteristics of the added station, and the performance of the network under those conditions could be examined.

To implement this simulation, four basic layers were delimitated. They are the host, tcp, ip, and csmacd. (The host layer basically encompasses user and high level characteristics.) Within each layer, the basic functionality of each was modeled using petri nets. For each layer, a transmitter and a receiver entity were defined. Using the petri nets, the possible states were modeled as well as the events that cause state transitions to occur.

Because simula supports the notion of inheritance, common characteristics were grouped together in progressive levels of definition. For example, each entity requires a buffer to store messages in, whether it is part of the host, tcp, ip, or csmacd layer. Therefore, in implementing the lowest level of this simulation (level_0) the class entity was declared with all the common characteristics defined at that level, including the buffer. Subsequent levels were progressively defined based on preceding level class declarations until the specific functions for each layer of the network simulated were implemented.

To allow the user to set variables at run time, this simulation is invoked at the topmost level (network level) after prompting the user for the configuration parameters. These parameters are then passed down to the lower levels as needed, or used as global variables when appropriate.

To sum up, it requires eight entities to represent a single station; a receiver and transmitter for each of the host, tcp, ip, and csmacd layers.
DESCRIPTION OF SIMULATION LEVELS

Because simula supports the notion of inheritance, the software was designed in a series of levels, each one defining structures that are common to the next level. This was done to make the software easier to modify and adapt to future changes, for example modeling a different network protocol. It also maintains the commonality of the software, and helps simplify the design.

The levels designed are level_0, level_1, level_2 and the network level. They are described below.

I. LEVEL_0

Level_0 contains the fundamental building blocks of the simulation, the entity and its supporting structures. The process class entity describes the fundamental process structure that all of the station processes require. That is, all the transmitters and receivers of the host, tcp, ip, and csmacd layers.

Each of these processes require a variable state, used to define the current state of the entity (FREE, SENDING, RECEIVING, etc.). Upon creation, each entity is set to the FREE state. In addition to the state, each entity also requires a buffer for holding messages or frames and a frame pointer. For ease in programming, a variable return_code is defined to hold the return value of procedure calls.

In addition to the declared variables, the process entity is called with several arguments that define station characteristics. This was done to allow these values to be read from an input file. A title is passed in for use in debugging and future plotting. The id number refers to the id number of the station. Although the id number is common to each of the eight entities that represent a station, it must be passed individually to each entity at the time of creation. It is through the id number that each station knows itself. It is used as an array index. For example, tx_ip(id) would activate tx_csmacd(ip) to pass a frame. The dma_xfer_rate and interrupt_time are also station parameters. These are read from the input file, and passed down to the creation of the entity.

The basic class message is also defined in this layer. It contains all the variables required to collect data about the message for later analysis. The basic definition is that of a link class for manipulation in a queue.

The last significant variable defined in this level is the variable u. This variable is used as a random seed generator.
II. LEVEL_1

Level_1 begins the separation of network layers. In the level, the entity classes host, tcp, ip, and csmacd are defined. All aspects that are common to the transmitter and receiver of each network layer are defined here. For example, both the transmitters and receivers of each layer must receive frames from their adjacent layers, so a procedure receive is defined for each entity class.

In addition to the network layer classes, the class window and tcp_timer are defined for use by the tcp layer. The window controls how many messages may be outstanding at once, and the timer is set whenever a transmission is sent.

III. LEVEL_2

Level_2 defines the structure of the network. It contains includes for all the specific entities that define a station (tx_host, rx_host, etc). These entities are described under IMPLEMENTATION OF NETWORK LAYERS. This layer revolves around the variable num_of_stations, which is passed in as a calling argument. The num_of_stations sets the number of stations for the simulation. The entities that define each station are declared as arrays from one to the num_of_stations. In order to declare a variable size array, the array parameter must be passed in as a calling argument. Besides declaring the arrays of entities that compose the stations, the entities are also instantiated and activated. They are instantiated to allow the creation of their support structures, such as their buffers. The activation allows for the initialization of the entities to their first passivation point in the while true loop, which is where they begin to loop on their subsequent states.

Since the simulation allows for more than one type of station at the user's discretion, stations are created using two for loops. The for loops are controlled by the num_typea_stations and num_of_stations. The first loop from one to num_typea_stations configures stations with the variables dma_xfer_rate and interrupt_time. This represents the creation of type a stations.

The second for loop runs from num_typea_stations + 1 until num_of_stations. This creates stations of type b, using the variables b_dma_xfer_rate and b_interrupt_time. This method results in type a stations having the lowest id numbers. For example, if the user chooses to have twenty stations total and five type a stations, then the stations with id numbers from one to five will be the type a stations and the stations with id numbers from six to twenty will be type b stations.

In addition to the declaration of the entities that comprise the stations, a collection queue is also listed as an include file at this level. The collection queue collects all data used to measure performance.
IV. NETWORK

The network level performs two basic functions: it manages all user interface and calls the simulation. In order to call the simulation, all variables required by the simulation must be set. This is accomplished both by absorbing the user inputs and calculating certain key variables. The network level also controls the length of the simulation, based on the number of messages successfully transmitted per station.

The user interface is composed of two parts, prompting the user and writing data collected to an output file. The user is prompted for the number of stations and their type. To choose the type of station, three options are offered: type_a stations, type_b stations or a mix of the two. If a mix of station types is chosen the user is again prompted for the number of type_a stations. If the user chooses to have more type_a stations than the number of stations, the value is automatically reset to the number of stations. No other error checking is performed on the user input.

After the number and type of stations have been defined, the input files are read to obtain the values of station characteristics. There are two station types currently implemented, and the corresponding values of these types are contained in the file "station_typea" and "station_typeb". The names of the input files are directly referenced in the network layer. To add another input file containing station characteristics, the network layer would require modification. The modifications required would be the addition of the new input file, and the definition of new variables for the dma_xfer_rate and interrupt_time, which are currently the only difference between the station types. The new variables would be passed as calling arguments to the simulation.

The format of the input files is identical, regardless of the station type they define. The input files are read using the read_input routine, which assigns the values in the file to the corresponding variables. For this reason, the order of the values in the file is crucial for correct assignment. The read_input routine reads a single value from each line of the input file. The variables read in their assigned order are data_rate, interrupt_time, dma_xfer_rate, aver_arrival_time, prop_delay, max_frame_size, and aver_msg_size. All the values are real except the last two, which are integer.

The output file is written at the end of the simulation. It contains information on the throughput and average delay per frame for the individual stations and the whole network. Also included is the number of successful and rejected messages per station as well as the simulation time required. All values are calculated in the collection_queue routines. The output is written to a file "output" using the print_data routine. The file name is directly referenced in that routine. A modification to the output file would require changes to be made to the print_data routine, and the collection_queue routines that
calculate the data.

After the input files have been read, the value of tau is calculated. The simulation is called with the value of tau and all variables read from the input files as calling arguments. The simulation then loops until each station achieves a minimum number of successful transmissions. The data is then collected, first on a per station basis and then for the network as a whole. It is then printed, and the program terminates.
IMPLEMENTATION OF NETWORK LAYERS

Each of the layers described below represents a network level protocol. They are represented by both a transmitter and receiver entity concerned with the passage of messages. The various states of the entities are listed, along with events that cause a state transition.

I. IMPLEMENTATION OF HOST LAYER

The host layer of this simulation represents all upper layers of network protocol above the tcp layer. In this layer the arrival of new messages is generated and their final reception occurs. This is accomplished by use of message queues, one for the transmitter and one for the receiver.

HOST TRANSMITTER

The host transmitter has no defined states. It loops on generating messages. After a message is generated, the host transmitter checks to see if the tcp transmitter is idle. If it is, it activates it, holds for an interrupt time, and then loops back to generate the next message.

The generate_messages procedure of the host transmitter is responsible for setting message parameters and their arrival rate. It begins by using the global variables aver_arrival_time and u to get a random arrival time. It holds for this amount of time before proceeding to simulate a poisson arrival rate.

The queue length is checked next to see if it is less than MAX_HOST_MESSAGE_COUNT. This is done because of the memory constraints imposed running the simulation. It is desirable to have no restrictions on the number of messages the host transmitter may generate, but since the arrivals of the messages is a poisson process, it has no memory of past arrivals. So the modeling of the arrivals remains valid.

If there is room in the message queue, a new message is created. The time of creation is noted for bookkeeping purposes. A random destination other than its own address is generated. The size of the message is assigned using the global variable aver_msg_size. The message is placed in the queue so that the tcp transmitter may process it. The host transmitter then loops back around to generate the next message.

HOST RECEIVER

The host receiver has two states: FREE and RECEIVING. The FREE state is the idle state, when the host receiver is ready to process the next message. The receiver is capable of receiving more than one message in its queue at once, as compared to the lower layers that process one frame at a time.

When a message arrives, a state transition to RECEIVING occurs. The message is taken out of the queue and discarded,
since all bookkeeping regarding the message is done by the tcp receiver. The state then transitions back to free after holding for an interrupt time.

II. IMPLEMENTATION OF TCP LAYER

The tcp layer is composed of two entities, the transmitter and the receiver as well as a number of supporting structures for the processing of messages. On the transmitter side this layer receives messages from the host, and breaks them into frames for transmission. On the receiving side, it re-assembles the frames back into messages and passes them to the host. The tcp layer is responsible for determining if frames sent have been received. Positive acknowledgements are used to accomplish this. A buffer and a window are used to process messages. Although each of these has a maximum size, if there is not enough room to process the messages, this upper limit is simply increased to accommodate them. To decrease the number of transmissions across the network, positive acknowledgements are resent whenever possible.

TCP TRANSMITTER

The tcp transmitter has three states: FREE, RECEIVING, and SENDING. The FREE state is the idle state, with no messages to process or packets to send. If there are any messages from the host layer of that station to transmit, a state transition to the RECEIVING state occurs, provided that the buffer of the tcp transmitter is not full.

In this state, messages are removed from the host message queue and packetized for transmission. They are also added to a collection queue for easy data retrieval when the transmission is completed.

The tcp transmitter removes messages directly from the host message queue of that station. In addition to transmitting messages, it also transmits acknowledgements and re-transmits packets that have timed out. If there are any acknowledgements, time-outs, or data packets to send a state transition to the SENDING state occurs. In this state, whenever a transmission is sent a timer is set. Should the timer expire before an acknowledgement for the transmission is received, the transmission is resent and the timer reset.

Transmissions are sent on a priority basis. The message with the highest priority is an acknowledgement, followed by a re-transmission of a message that has timed out and lastly a data packet.

TCP RECEIVER

The tcp receiver has two states: FREE and RECEIVING. The FREE state is the idle state, when the tcp receiver is available to receive and has no frame to process. In this state, it activates the ip receiver in case it has any frames to send and then passivates.

When a frame arrives, a state transition to RECEIVING occurs. The type of the frame is checked to see if it is a data
frame and/or an acknowledgement frame. If it is an acknowledgement frame, the procedure ack_message of the transmitter is called to process it. A data frame is processed by the receiver.

Next the frame is removed from the window and the buffer, and the sizes are adjusted accordingly. If the frame is the last data frame of a message, the message is re-assembled and forwarded to the host receiver. The host receiver is then activated to process the message.

III. IMPLEMENTATION OF IP LAYER

The ip layer implementation is composed of two entities, the receiver and transmitter. It is a very simple layer that receives a pointer to the buffer contents and passes it to the next appropriate layer. Both entities receive packets through their receive routines. In this layer, the frame pointer is checked directly rather than the state of the buffer. Only one packet is required for the entity to activate itself.

**IP TRANSMITTER**

The ip transmitter has three possible states: FREE, READY, and SENDING. FREE represents the idle state, with no frame in the buffer. When a frame is received, a state transition to the READY state occurs. At this stage, the ip transmitter is ready to transmit a frame to the csmacd layer. It calls the receive routine of the csmacd transmitter for that station, and attempts to pass the frame. It loops in that state until the frame is successfully passed to the csmacd transmitter.

When the frame is successfully passed, the state transitions to SENDING. At this point the ip transmitter activates the transmitter entities of the tcp and csmacd layers for that station, and resets itself.

The ip transmitter also allows for a failed transmission. If the csmacd layer of that station is unable to transmit the frame, it calls the routine transmit_failed. This routine in turn calls the transmit_failed routine of the tcp transmitter of that station.

**IP RECEIVER**

The ip receiver has two states: FREE and BUSY. The FREE state corresponds to the idle state, when the receiver is available to receive and has no current frame. In this state, the receiver of the csmacd layer for that station is activated in case it has a frame to send to the ip receiver. If the ip receiver receives a frame, it transitions to the BUSY state. It loops in that state until it successfully transmits the frame to the tcp receiver. Whether the transmission is successful or not, it activates the receiver of the tcp layer to allow any possible state transitions of that layer to occur.

After a successful transmission to the tcp receiver, the frame pointer is reset to none and the state is set to FREE.
IV. IMPLEMENTATION OF CSMA/CD LAYER

The csmacd layer implementation is based on the petri net model of the csmacd. It is composed of two entities, the receiver and transmitter as well as the definition of a class channel_csmacd. The entities are processes that have the capability of activating and passivating themselves. Class channel_csmacd, on the other hand, is a simple class definition that basically consists of a queue. The buffer for the csmacd layer is actually implemented as a characteristic of the csmacd receiver and transmitter. That is to say, both the transmitter and the receiver each have their own buffer.

Both entities receive packets through their receive routines, which check to see if the buffer is available. If it is, it accepts the incoming packet and sets the buffer state to FULL. Only a single packet is required to set the buffer state to FULL. If the buffer is FULL when an incoming packet arrives, it is ignored.

Each csmacd entity is designed as a forever true loop. If there is an incoming message in the buffer or a state transition has occurred, it loops determining through the next state procedure if another transition can occur. When all possible state transitions have been exhausted, it passivates. To be awakened, the csmacd transmitter must be called by the ip transmitter. The csmacd receiver, on the other hand, may be awakened either by a sending csmacd transmitter or by its ip receiver layer.

For each possible state shown on the petri net, there is a subroutine. The state subroutines are contained in csmacd_txs for the transmitter, and csmacd_rxs for the receiver. These subroutines check for potential transitions, and return a boolean value of true if a transition of state occurs.

CSMA/CD TRANSMITTER

The csmacd transmitter has five possible states: DISABLED, FREE, WAIT_FOR_RE_TX, ATTEMPT_TX, and ACQUIRE_CHANNEL. Each of these states will be described below.

The FREE state represents the idle state, when the transmitter is not engaged. In this state, for a transition to occur, the buffer must be full and the channel must be free. If this is the case, the state transitions to ATTEMPT_TX. If the buffer is full, but the channel is not free the transmitter waits in the channel queue until the channel becomes free.

The ATTEMPT_TX state represents the transmitter attempting to transmit a packet. In this state, the transmitter holds for a period of tau, and then checks the channel_state variable to see if it is zero. If it is, it increments the channel_state variable and holds for another tau. It then checks to see if the channel_state variable is greater than one. If it is, a collision has occurred. If not, it ends the collision window and
transitions the state to ACQUIRE_CHANNEL. If a collision occurs, the state is set to DISABLED. So, from the ATTEMPT_TX state there is always a state transition to either ACQUIRE_CHANNEL or DISABLED.

The DISABLED state represents the period when a station realizes it has collided with one or more stations and must jam transmissions. Each station involved in a collision will independently realize the event by checking the channel_state variable. In this way, the channel remains a passive element and the individual stations are the active determinants of their state.

When a station realizes it is disabled, it holds for a jam time of two tau and then changes state to WAIT_FOR_RE_TX. It decrements the channel_state variable and checks to see if the variable has returned to zero. This indicates that the jam is over, and all stations involved are ready to wait for retransmission. If the jam is over, the station will check the channel queue to see if there were any stations that were waiting for the channel. If so, it wakes them up. In this way, preference for new transmissions over transmissions involved in a collision is preserved.

In the WAIT_FOR_RE_TX state, the station checks to see if it has attempted to send the transmission more than max_tries (sixteen attempts). If it has, it retrieves the frame from the buffer and calls the transmit_failed routine of the station's ip layer. The csmacd transmitter is reset for the next transmission and the ip transmitter is activated.

If the csmacd transmitter has not exceeded max_tries, it increments a binary backoff variable n, and generates a random number in the window of $2^n - 1$. It holds for that time times tau, and then transitions back to the FREE state to attempt to transmit again.

The ACQUIRE_CHANNEL state represents the station transmitting. In this state, the collision window has ended and the station definitely has the channel. The transmission time is calculated based on the bits per packet divided by the data rate. The transmitter simply sends the message by calling the receive routine of the destination csmacd receiver, and then activating it. No attempt is made to determine if the transmission is successfully received. The csmacd receiver is then reset (the buffer is empty and the state is FREE) and the ip transmitter is activated.

CSMA/CD RECEIVER

The csmacd receiver has three possible states: DISABLED, FREE, and RECEIVING. Because it is impossible for a receiver to receive an unsuccessful transmission in this simulation, only the FREE and RECEIVING states are modeled. These states are described below.

The FREE state represents the idle state of the csmacd
receiver. In this state, the receiver checks to see if the buffer is full. If it is, it resets the state to receiving. If not, it does nothing.

The RECEIVE state attempts to pass the buffer contents to its ip receiver. It calls the ip receive routine to pass the buffer contents, and holds for rx_delay. The ip receiver is activated, and the csmacd receiver is reset (the buffer is empty and the state is FREE). If the csmacd receiver is unsuccessful in attempting to pass its buffer contents to the ip receiver, it passivates until re-awakened by the ip receiver or a csmacd receiver.

CSMA/CD CHANNEL

The csmacd channel is not a process class, but a simple class definition. It is composed of a queue and a class state variable. The queue is used for stations wishing to transmit when the channel is already in use. When the channel becomes free (after a successful transmission or at the end of a jam) the stations in the queue are all activated at once and allowed to contend for channel acquisition. If more than one station is in the queue, this generally results in a collision with normal contention resolution. In this way, the behavior of the csmacd protocol is preserved.

Access to the channel is controlled by the channel state variable. If the channel state variable is zero, the channel is free and a station may transition state to ATTEMPT_TX. If it is not zero, the station enters the channel queue.

To simulate the collision window, two possible cases are considered. After a station has transitioned states from FREE to ATTEMPT_TX, it holds for a period of tau. It next checks the channel state variable to see if it is still zero. If it is, no collision has occurred yet and it continues to attempt to gain the channel. If it is not, the station has collided with another station and it holds for another tau and follows the collision protocol.

If no collision occurs within the first tau period, the station attempting to transmit increments the channel state variable and holds for another tau. It then rechecks the channel state variable to see if it is greater than one. If it is, another station is also attempting to transmit and a collision has occurred. If not, it has successfully gained the channel.

At the end of a successful transmission, the station decrements the channel state variable and it returns to zero, thus leaving the channel in a free state. In the case of a collision, as each station completes the hold for the jam time, it decrements the channel state variable and checks to see if it has returned to zero. If it has, all stations involved in the collision have now completed their jam and the channel is free. Any stations in the channel queue are now awakened to compete for the channel. If the channel state variable is not zero, all station involved in the collision have not completed their jam and the channel is not free.
MAKEFILE DESCRIPTION

A makefile is available to compile all code required by the simulation. By typing make, an executable called network will be built. Since the system file that contains the grammar rules used by make does not include the simula language, all dependencies and rules for construction must be explicitly stated. This is difficult to implement in simula, since compiling a ".sim" file results in the creation of a ".o" file and a ".s" file. The ".o" file contains the object code, and the ".s" file is used by the assembler phase of compilation. To make use of the make utility, it was decided to state dependencies based on the ".o" files alone, since the ".s" files are automatically generated with the compilation anyway.

To add a new simula file to the list of files to be compiled, the following format should be used:

```
new.o: new.sim
       $(SIM_COMP) $*
       $(SIM_ASM) $*.o $*.s
```

To add a simula file that will be used as an include file in another simula file, the dependency is listed directly:

```
old.o: new.sim
       other_include.sim
```

The above steps will insure that the dependencies are always correct, so that recompilation of the appropriate files is automatic after any modifications.

The makefile contains two targets, the network executable and a debug executable. To use the debugger, code must be compiled with the debug option and thus it is included. To make a debug executable, type "make dnetwork". This will compile the code with a debug option.

When one simula file is used as an include file in another simula file, no separate ".o" file is created for the included ".sim" file. Instead, the simula code in the include file is incorporated in the ".o" file generated for the master file. That is why the included ".sim" file is listed as a dependency for the master ".sim" file rather than its ".o" file that one might think should be created.
CONCLUSION

In its current state of implementation, this simulation models only LAN composed of stations. A logical progression would be to implement bridges to allow for a more complex LAN. This could be accomplished by creating another layer above the network layer to call the simulation. Since the network layer as currently implemented is a simulation call, it would have to be modified so that there is a single simulation running rather than a series of network simulations.

Another area of future development is the user interface. Currently, a simple menu is presented to the user and they type in the letter corresponding to their choice of station type. As the user definable parameters increase, a graphical menu interface may be more appropriate.
this file contains the lowest level declarations required in this simulation. Most of the following classes are either inherited or referenced by succeeding classes.

SIMULATION CLASS level_0;
BEGIN

INTEGER u;  ! seed number for random number generator;

HEAD CLASS message_queue(title);
VALUE title; TEXT title;
BEGIN
END;

.dataunit CLASS dataunit;
BEGIN
INTEGER bytes, dest_addr, source_addr;
END;

dataunit CLASS message;
BEGIN
INTEGER type, id;
long real createtime, donetime;
long real time_per_message;
BOOLEAN rejected;
  createtime := 0.0;
  donetime := 0.0;
  time_per_message := 0.0;
  rejected := FALSE;
END;

message CLASS frameunit;
BEGIN
REF(message) msgptr;
INTEGER seqnum, acknum, setwindow;
BOOLEAN ack, fin;
  ack := FALSE;
  fin := FALSE;
END;

HEAD CLASS buffer;
BEGIN
REF(frameunit) front, tail, current, msgtail;  ! buffer ref. frame pointers;
INTEGER maxsize, cursize;
INTEGER state;
front := NONE;
tail := NONE;
current := NONE;
msgtail := NONE;

END;

PROCESS CLASS timer;
BEGIN
INTEGER status;

END--of--timer;

PROCESS CLASS entity(title,id,dma_xfer_rate,interrupt_time);
VALUE title; TEXT title;
INTEGER id;
long real dma_xfer_rate;
long real interrupt_time;
BEGIN
  REF(buffer) buf;
  REF(frameunit) frame;
  INTEGER state;
  INTEGER return_code;

procedure reset;
BEGIN
  reset the variables_
  state := 0_ _ this sets it to free;
  frame := none
  actions: ;
  resets the entity variables;
end;

main body, set variables;
BEGIN
  ! get buffer,set buffer state to EMPTY;
  buf := new buffer;
  buf.state := 0;
  ! set state of entity to FREE
  state := 0;
END

END entity;***
! main program of simulation;
BEGIN
   u := 1000003;         ! initialize seed;
END***MAINPROGRAM***;
END***SIMULATION***;
level_1.sim - subclass of level_0

this file inherits all knowledge of level_0 simulation and declares classes that define common characteristics of the layers modeled in this simulation.

external CLASS level_0;

level_0 CLASS level_1;
BEGIN
%INCLUDE define_def.sim

entity CLASS host;
BEGIN
ref(message_queue) msg_queue;
ref(message) host_msg;

END OF HOST;

tcp CLASS tcp;
BEGIN
REF(window) win;
REF(frameunit) lastsent;
REF(timeout_queue) timeoutq;
BOOLEAN timed_out, next_msg;
INTEGER timeout_count;
INTEGER buf_space, last_byte_sent;

integer procedure receive(recvframe);
REF(frameunit) recvframe;

! This procedure handles the addition of frames to the tcp buffer. If there is room in the buffer the frame is added and the buffer parameters and pointers are updated, otherwise the receive fails.

Returns: OK, FAILED

Globals: buf (current buffer)

begin
integer rc;
    if buf.state = EMPTY then
        begin    ! buffer is empty, receive the frame & update pointers:
            recvframe INTO(buf);
            buf.state new(buf);
            if buf.space = EMPTY then
                rc = FAILED
            else
                rc = OK;
        end;
    else
        rc = FAILED;
end;
received frame;
buf.current := recvframe;
buf.tail := recvframe;
buf.state := NENF;  \
! update the state of the buffer
next_msg := TRUE;  \
! set flag to indicate message ready to send
rc := OK;  \
! set the return code to indicate success
end

else if buf.state = NENF then
begin  \
! buffer is not empty, not full, check size of frame
if (buf.maxsize >= buf.cursize + recvframe.bytes) then
begin  \
! okay to receive frame, receive it & perform updates
recvframe. INTO(buf);
buff.tail := recvframe;
if (buf.current == NONE) then
begin
buf.current := recvframe;
end
rc := OK;
goto Return;
end
else begin  \
! no room for frame, set buffer to FULL & fail receive
buf.state := FULL;
rc := FAILED;
goto Return;
end
end
else if buf.state = FULL then
begin  \
! buffer FULL, receive fails
rc := FAILED;
goto Return;
end
end
return:
begin
receive := rc;
if (rc = OK) then
begin  \
! if status okay, update the buffer's current size
buf.cursize := buf.cursize + recvframe.bytes;
end
end
end--of--receive;

procedure reset_buffer;
! procedure reset_buffer
! This procedure reset all the buffer parameters to their
! initial (empty) state.
! Globals: buf (current buffer)
begin
buf.front := NONE;
buf.current := NONE;
buff.tail := NONE;
buf.state := EMPTY;
buf.cursize := 0;
end

integer procedure outofbuf(msg_id);
INTEGER msg_id;
! procedure outofbuf

This procedure removes all the frames of a given message from the tcp buffer and performs the required updates to keep the buffer current.

Returns: OK

Globals: buf_space, buf, next_msg, return_code

begin
  REF(frameunit) outofptr, currentptr;
  integer count;
  count := 0;
  currentptr := buf.FIRST;  ! start at the beginning of the buffer(buf);
  return_code := FAILED;
  
  while currentptr=/=NONE do
  begin
    count := count + 1;  ! trace through the loop for debug
    if currentptr.id=msg_id then
    begin
      ! take all matching id #'s out of buf
      outofptr := currentptr;
      currentptr := (currentptr).SUC;
      outofptr.OUT;
      return_code := OK;
      buf_space := buf_space + outofptr.bytes;
    end else
    begin
      ! no match, update current pointer to next
      currentptr := (currentptr).SUC;
    end;
  end;
  if (return_code = OK) then
  begin
    buf.front := buf.FIRST;  ! update pointers if frames removed from buf;
    if (buf.front /= NONE) then
    begin
      next_msg := TRUE;  ! if another message in buf, set flag to send;
    end else
    begin
      reset_buffer;  ! no more frames to send, reset the buffer;
    end;
  end;
  outofbuf := return_code;
end--of--outofbuf;

boolean procedure reserve_buffer_space(addbytes);

procedure reserve_buffer_space

! This procedure checks the space in the buffer to see if
! the entire message will fit. If so, the space is reserved;
! and TRUE is returned, else FALSE is returned. This
! prevents partial messages in the buffer.
!
! Returns: TRUE - success, FALSE - failure
!
! Globals: buf (current buffer), buf_space
!
integer addbytes;
begin
  integer bytes_left;
  bytes_left := buf_space - addbytes;

if (bytes_left >= 0) then
begin
  buf_space := bytes_left;
  reserve_buffer_space := TRUE;
end else begin
  buf.state := FULL;
  reserve_buffer_space := FALSE;
end;

integer procedure set_donetime(msgptr);

  ! This procedure sets the donetime parameter of the message to indicate that the message has been sent and acknowledged. This is done for data collection statistics purposes.

  ! Returns: OK, FAILED

  ! Globals: buf (current buffer)

begin
  if msgptr /= NONE then ! check for valid message pointer
  begin
    msgptr.donetime := TIME; ! set the current time to message donetime
    set_donetime := OK; ! status of procedure is okay
  end else begin
    set_donetime := FAILED;
  end;
end;

begin
  ! main; ! set up parameters and instantiate window;
  win := new window;
  win.state := EMPTY;
  win.maxsize := 10240;
  win.cursize := 0;
  timeoutq := new timeout_queue;
  timeout_count := 0;
  timed_out := FALSE;
  next_msg := FALSE;
end--of--main;

TCP++OF++TCP;

entity CLASS ip;
BEGIN
  BOOLEAN csmacd_rc;

  ! lean procedure receive(recvframe);
  Ref(frameunit) recvframe;

  begin
    if (state = FREE) and (frame == NONE) then
    begin
      state := READY;
      frame := recvframe;
      receive := TRUE;
    end;
  end;

END++OF++TCP;
end else begin
    receive := FALSE;
end;

END;

entity CLASS csmacd;
BEGIN
    boolean change_state;    ! flag for change of state;
    boolean buffer_interrupt;  ! flag for frames in the buffer;

    ref( frameunit ) procedure get_frame_from_buffer;
    called by: csmacd_txs_acquire_channel,csmacd_rxs_idle;
    calls: none;
    returns: ;
    a pointer to the frame from the buffer;
    if the buffer is empty,pointer to none;
    globals used: ;
    buf - the current buffer;
    actions: ;
    takes a frame out of the buffer;
    should set the buffer state to empty;
    does not do so because of integrity of;
    buffer during transmission,i.e., buffer;
    should not be released until frame is ;
    transmitted;

    ref( frameunit ) procedure get_frame_from_buffer;
begin
    ref( frameunit ) out_frame;

    ! initialize the variables;
    out_frame := none;

    ! if the buffer isn't empty,get the frame out;
    if ( buf /= none ) then
    begin
    if ( not ( buf.empty ) ) then
    begin
        ! get the frame from the buffer ;
        out_frame := buf.first;
        out_frame.out;

        ! set the buffer state;
        !buf.state := EMPTY;
        end;
        end;
    ! set the return variable;
    get_frame_from_buffer := out_frame;
procedure clear_buffer;

! called by: reset;
! calls: none;
! returns: none;
! globals used: ;
! see below;
! actions: ;
! resets the csmacd buffer variables;

procedure clear_buffer;
begin
  ! set variables back to zero;
  buf.state := FREE;
  ! reset buffer interrupt;
  buffer_interrupt := false;
  ! reset the frame pointers;
  buf.clear;
end;

! main body for csmacd;
begin
  change_state := false;
  buffer_interrupt := false;
end;

CLASS window;
BEGIN
REF (dataunit) current, front, back;
INTEGER maxsize, cursize;
INTEGER state;
INTEGER rc; !rc -- return code;

integer procedure rxtcp_outof(frameptr);
REF(frameunit) frameptr;
begin
  cursize := cursize - frameptr.bytes;
  if (cursize > 0 ) then
  begin
    state := NENF;
    front := front.SUC;
  end else begin
    reset_window;
  end;
  rxtcp_outof := OK;
end--of--rxtcp_outof;
REF(frameunit) frameptr;
begin
end--of--tcp_outof;

procedure reset_window;
begin
state := EMPTY;
cursize := 0;
front := NONE;
current := NONE;
back := NONE;
end;

boolean procedure reserve_space(bytes);
integer bytes;
begin
if maxsize >= (cursize + bytes) then
begin
   cursize := cursize + bytes;
   reserve_space := TRUE;
end else begin
   reserve_space := FALSE;
end;
end;

procedure cancel_reserve_space(bytes);
integer bytes;
begin
   cursize := cursize - bytes;
end;

boolean procedure addto(frameptr);
REF(frameunit) frameptr;
begin
if state = FULL then
begin
   addto := FALSE;
   go to Return;
end;
if state = NENF then
begin
   if maxsize >= cursize then
   begin
      state := NENF;
      current := frameptr;
      back := frameptr;
      addto := TRUE;
      go to Return;
   end;
   if maxsize < cursize then
   begin
      state := FULL;
      addto := FALSE;
      go to Return;
   end;
end;
if state = EMPTY then
begin
   state := NENF;
   front := frameptr;
   current := frameptr;
   back := frameptr;
end;
end;
addto := TRUE;
go to Return;
end;

begin

**** window - main program ****;

state := 0;
end;

BEGIN++OF++WINDOW;

-READ CLASS timeout_queue;
begin

-INK CLASS timeout_unit;
begin
  REF(tcp) layer;
  REF(tcp_timer) timerptr;
  REF(frameunit) frameptr;
  long real time_up;
  integer event;
  integer status;

  status := NOT_SET;
end;

-timer CLASS tcp_timer;

-end

-INK (timeout_unit) tcp_event;
long real currtime;

- procedure setup(timeout_event);
  REF(timeout_unit) timeout_event;
begin
  tcp_event := timeout_event;
  tcp_event.status := SET;
end;

- procedure start;
begin
  hold(tcp_event.time_up);
  timeout_occurred;
end;

- procedure timeout_occurred;
begin
  (tcp_event.layer).timeout_count := (tcp_event.layer).timeout_count + 1;
  tcp_event.status := FRAME_TIMED_OUT;
  (tcp_event.layer).timed_out := TRUE;
  reactivate(tcp_event.layer);
end;

begin

  start;
end;

END;

! main body;
%INCLUDE define_assign.sim
END.
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NCC2-554

PERFORMANCE ANALYSIS OF LAN ;

!***************************************************** ;

external CLASS level_1;
level_1 class level_2(num_of_stations,tau,prop_delay,interrupt_time,
data_rate,dma_xfer_rate,aver_arrival_time,
max_frame_size,aver_msg_size,b_interrupt_time,
b_dma_xfer_rate,num_typea_stations);

integer num_of_stations;
integer tau;
long real prop_delay;
long real interrupt_time;
long real data_rate;
long real dma_xfer_rate;
long real aver_arrival_time;
integer max_frame_size;
integer aver_msg_size;
long real b_dma_xfer_rate;
long real b_interrupt_time;
integer num_typea_stations;

BEGIN
integer msg_count; ! unique message id number;

%INCLUDE collection_queue.sim
%INCLUDE rx_host.sim
%INCLUDE tx_host.sim
%INCLUDE tcp.sim
%INCLUDE ip.sim
%INCLUDE tx_csmacd.sim
%INCLUDE rx_csmacd.sim
%INCLUDE channel_csmacd.sim

ref(rx_csmacd) array srx_csmacd(1:num_of_stations);
ref(tx_csmacd) array stx_csmacd(1:num_of_stations);
ref(channel_csmacd) schannel_csmacd;

REF (tx_tcp) array stx_tcp(1:num_of_stations);
REF (tx_ip) array stx_ip(1:num_of_stations);
REF (rx_host) array srx_host(1:num_of_stations);
! REF (rx_tcp) array srx_tcp(1:num_of_stations);
REF (rx_ip) array srx_ip(1:num_of_stations);
REF (tx_host) array stx_host(1:num_of_stations);
REF (collection_queue) collectionq; ! collection queue for network;

INTEGER i;
BEGIN

! initialize variables;

for i := 1 step 1 until num_typea_stations do
begin

! create entities;

srx_host(i) :- new rx_host("rx_host",i,
   dma_xfer_rate,interrupt_time);

stx_tcp(i) :- new tx_tcp("tx_tcp",i,
   dma_xfer_rate,interrupt_time);

srx_tcp(i) :- new rx_tcp("rx_tcp",i,
   dma_xfer_rate,interrupt_time);

srx_ip(i) :- new rx_ip("rx_ip",i,
   dma_xfer_rate,interrupt_time);

stx_ip(i) :- new tx_ip("tx_ip",i,
   dma_xfer_rate,interrupt_time);

srx_csmacd(i) :- new rx_csmacd("rx_csmacd",i,
   dma_xfer_rate,interrupt_time);

stx_csmacd(i) :- new tx_csmacd("tx_csmacd",i,
   dma_xfer_rate,interrupt_time);

end;

! configure type b stations;
for i := (num_typea_stations + 1) step 1 until num_of_stations do
begin

! create entities;

srx_host(i) :- new rx_host("rx_host",i,
   b_dma_xfer_rate,b_interrupt_time);

stx_tcp(i) :- new tx_tcp("tx_tcp",i,
   b_dma_xfer_rate,b_interrupt_time);

srx_tcp(i) :- new rx_tcp("rx_tcp",i,
   b_dma_xfer_rate,b_interrupt_time);

srx_ip(i) :- new rx_ip("rx_ip",i,
   b_dma_xfer_rate,b_interrupt_time);

stx_ip(i) :- new tx_ip("tx_ip",i,
   b_dma_xfer_rate,b_interrupt_time);

srx_csmacd(i) :- new rx_csmacd("rx_csmacd",i,
   b_dma_xfer_rate,b_interrupt_time);

stx_csmacd(i) :- new tx_csmacd("tx_csmacd",i,
   b_dma_xfer_rate,b_interrupt_time);

end;

for i := 1 step 1 until num_of_stations do
begin

! activate the entities;
activate srx_csmacd(i);
activate stx_csmacd(i);
activate srx_ip(i);
activate stx_ip(i);
activate srx_tcp(i);
activate stx_tcp(i);
activate srx_host(i);
activate stx_host(i);


end;
! declare a channel;
schannel_csmacd :- new channel_csmacd;
collectionq :- new collection_queue;
msg_count := 1;
END;
END;
begin

external class level_2;
%INCLUDE prompt_user.sim
%INCLUDE read_input.sim
%INCLUDE get_tau.sim

integer num_of_stations;
integer num_typea_stations;
integer max_frame_size;
integer aver_msg_size;
long real prop_delay;
long real tau;
long real interrupt_time;
long real b_interrupt_time;
long real data_rate;  ! data transmission rate, Mbp secs;
long real dma_xfer_rate;  ! data transmission rate, Mbp secs;
long real b_dma_xfer_rate;  ! data transmission rate, Mbp secs;
long real aver_arrival_time;  ! mean time between message arrivals;

! get the user input;
prompt_user;

! get the station parameters;
if (num_typea_stations = num_of_stations) then begin
  read_input("station_typea");
  b_interrupt_time := 0.0;
  b_dma_xfer_rate := 0.0;
end
else if (num_typea_stations = 0) then begin
  read_input("station_typeb");
  b_interrupt_time := interrupt_time;
  b_dma_xfer_rate := dma_xfer_rate;
  interrupt_time := 0.0;
  dma_xfer_rate := 0.0;
end
else begin
  read_input("station_typeb");
  ! save the interrupt time and dma_xfer_rate;
  b_interrupt_time := interrupt_time;
  b_dma_xfer_rate := dma_xfer_rate;
  ! get type a input parameters;
  read_input("station_typea");
end;

! calculate tau:
tau := get_tau;

! start the simulation;
! el_2(num_of_stations,tau,prop_delay,interrupt_time,
data_rate,dma_xfer_rate,aver_arrival_time,
max_frame_size,aver_msg_size,b_interrupt_time,
b_dma_xfer_rate,num_typea_stations)

begin
ref (message) cur_message; ! test variable;
long real sim_start_time; ! starting time for simulation;
long real sim_end_time; ! ending time for simulation;
integer i;

%INCLUDE print_data.sim

! assign the start time;
sim_start_time := time;

! check for successful messages;
while ( collectionq.total_message_success < MIN_NUM_PER_STATION * num_of_stations ) do
begin
   hold(10);
end;

! assign the end time;
sim_end_time := time;

! collect the data;
collectionq.get_station_data;

! get the network throughput;
collectionq.get_network_data(sim_start_time,
sim_end_time);

! print_data;
print_data;

end;
end
integer procedure get_num_of_stations;
called by: network;
returns the number of stations;
globals used: none;
actions: queries the user for number of stations;

integer procedure get_num_of_stations;
begin
! get the number of stations;
outtext(" Please input the number of stations");
outimage;
get_num_of_stations := init;
procedure read_input

called by: network

calls: none

action: reads the data for stations
opens and closes the input file

variables used: data_rate,
interrupt_time,
aver_msg_size,
max_frame_size,
aver_arrival_time
prop_delay

**************************************************************************;
procedure read_input(input_file);
text input_file;
begin

ref(infile) in_file;

! open the input file;
in_file := new infile(input_file);
in_file.open(blanks(80));

! get station data;
data_rate := in_file.inreal; in_file.inimage;
interrupt_time := in_file.inreal; in_file.inimage;
dma_xfer_rate := in_file.inreal; in_file.inimage;
aver_arrival_time := in_file.inreal; in_file.inimage;
prop_delay := in_file.inreal; in_file.inimage;
max_frame_size := in_file.inint; in_file.inimage;
aver_msg_size := in_file.inint; in_file.inimage;

! close the file;
in_file.close;

**************************************************************************;
integer procedure prompt_user;

called by: network;

returns the number of stations;

globals used: none;

actions: queries the user for number of stations;

begin
integer response;

! get the number of stations;

outtext(" Please input the number of stations");
outimage;
outimage;

num_of_stations := inint;

outtext(" Please choose station configuration");
outimage;
outimage;
outtext(" TYPE A TYPE B");
outimage;
outtext(" Please choose interrupt time 1.0 0.5");
outimage;
outtext(" dma transfer rate 40.0 80.0");
outimage;
outtext(" maximum frame size 1500 1500");
outimage;
outtext(" average interarrival time 0.000004 0.000004");
outimage;
outtext(" average message size 5000 5000");
outimage;
outtext("PLEASE ENTER CHOICE");
outimage;
outtext(" TYPE A 1");
outimage;
outtext(" TYPE B 2");
outimage;
outtext(" MIXTURE 3");
outimage;

! get the response;
response := inint;
if ( response = 1 ) then
begin
    num_typea_stations := num_of_stations;
end
else if ( response = 2 ) then
begin
    num_typea_stations := 0;
end
else
begin
    ! wants a combination of types;
    ! get the number of type A stations;
    outtext(" Please input the number of TYPE A stations");
    outimage;
    num_typea_stations := inint;
    ! make sure we got an o.k. number;
    if ( num_typea_stations > num_of_stations ) then
begin
    num_typea_stations := num_of_stations;
end
else if ( num_typea_stations < 0 ) then
begin
    num_typea_stations := 0;
end;
end;
procedure print_data

called by: network

calls: none

action: prints the data for stations and networks. Opens and closes the output file.

variables used: collection_queue variables

**************************

begin

! open the output file;
out_file := new outfile("output");
out_file.open(blanks(80));

! print station data;
out_file.outtext("station # ");
out_file.outtext(" throughput ");
out_file.outtext(" aver delay / frame ");
out_file.outtext(" success ");
out_file.outtext(" reject ");
out_file.outimage;

for i := 1 step 1 until num_of_stations do
begin

out_file.outint(i,5);
out_file.outtext( " ");
out_file.outreal(collectionq.throughput(i),10,20);
out_file.outtext(" ");
out_file.outreal(collectionq.aver_delay_per_frame(i),10,20);
out_file.outtext(" ");
out_file.outint(collectionq.message_success(i),5);
out_file.outint(collectionq.message_not_sent(i),5);
out_file.outimage;
end;

! print the network characteristics;
out_file.outtext(" network_throughput = ");
out_file.outreal(collectionq.network_throughput,10,20);
out_file.outimage;
out_file.outtext(" aver_delay_per_frame = ");
out_file.outreal(collectionq.network_aver_delay,10,20);
out_file.outimage;
out_file.outtext(" simulation time ");
out_file.outreal((sim_end_time - sim_start_time),10,20);
out_file.outimage;

! close the file;
out_file.close;

end;
long real procedure get_tau;

called by: network;

returns tau;

globals used: ;
  long real max_net_length;
  long real prop_delay;

actions: calculates tau;

end;

long real max_net_length;

! assign variables;
max_net_length := 2.5; ! max length of network;

get_tau := max_net_length * prop_delay;

end;
HEAD CLASS collection_queue

defines the queue used to collect data
called by: level_2.sim - allocates collection queue
tx_tcp.sim - puts messages into queue
calls: none
actions: defines collection queue
         initializes collection queue variables

HEAD CLASS collection_queue;
BEGIN

integer array total_num_of_bytes(1:num_of_stations);
   ! total num_of_data bytes;
integer array total_num_of_messages(1:num_of_stations);
   ! total num_of_data messages;
integer array total_num_of_frames(1:num_of_stations);
   ! total num_of_frames sent;
integer array message_success(1:num_of_stations);
   ! number of messages successfully received;
integer array message_not_sent(1:num_of_stations);
   ! number of messages not sent;
long real array total_through_time(1:num_of_stations);
   ! total time traveling through;
long real array throughput(1:num_of_stations);
   ! total # bytes / total time ;
long real array aver_delay_per_frame(1:num_of_stations);
   ! total time per message / total # frames ;
long real network_throughput;
long real network_aver_delay;
integer total_message_success;
integer i;

%INCLUDE collect_data.sim
%INCLUDE get_station_data.sim
%INCLUDE get_network_data.sim

! main body;
! initialize variables;
for i := 1 step 1 until num_of_stations do
begin
   total_num_of_bytes(i) := 0;
   total_num_of_messages(i) := 0;
   total_num_of_frames(i) := 0;
   message_success(i) := 0;
   total_through_time(i) := 0.0;
   throughput(i) := 0.0;
   aver_delay_per_frame(i) := 0.0;
end;

network_throughput := 0.0;
network_aver_delay := 0.0;
total_message_success := 0;

END;

END;
integer procedure get_frames_per_message;

called by: collect_data;

returns the number of frames per message;

globals used: message.bytes;

actions: calculates frames per message;

**************************************************************;

integer procedure get_frames_per_message(integer num_of_bytes);
integer num_of_bytes;

begin

integer bytes_remaining;
integer num_of_frames;

! initialize variables;
bytes_remaining := num_of_bytes;
num_of_frames := 0;

while( bytes_remaining > 0 ) do
begin

! increment frame count;
num_of_frames := num_of_frames + 1;

! decrement bytes_remaining;
bytes_remaining := bytes_remaining -
     BYTES_PER_FRAME;
end;

get_frames_per_message := num_of_frames;

end;
procedure collect_data;

called by: collection_queue;

collects station data for messages;

globals used:
  message.createtime;
  message.donetime;
  message.totaltime;
  message.rejected;
  dataunit.bytes;

actions: collects data statistics for messages;
  sets msg.time_per_message;
  collects time per station;
  collects frames per station;
  collects the # of useful bytes ( data bytes );
    per station;

procedure collect_data(cur_message);
ref (message) cur_message;   ! current message examined;
begin
%INCLUDE get_frames_per_message.sim
%INCLUDE inc_message_count.sim

! did we get a message;
if ( cur_message /= none ) then
begin
  ! do we have a data message;
  ! if so, collect data;
  if ( cur_message.type = DATA ) then
  begin
    ! was this a successful transmission;
    if ( cur_message.donetime <> 0.0 ) then
    begin
      if ( not cur_message.rejected ) then
      begin
        ! collect data;

        ! increment the message count;
        inc_message_count(cur_message.source_addr);

        ! get the time it took to send the message;
        cur_message.time_per_message :=
          cur_message.donetime -
          cur_message.createtime;

        ! add it to sending station time;
        total_through_time(cur_message.source_addr) :=
          total_through_time(cur_message.source_addr) +
          cur_message.time_per_message ;
  end
end
! increment the number of messages;
total_num_of_messages(cur_message.source_addr) :=
  total_num_of_messages(cur_message.source_addr) + 1;

! collect the number of bytes;
total_num_of_bytes(cur_message.source_addr) :=
  total_num_of_bytes(cur_message.source_addr) +
  cur_message.bytes;

! get num_of_frames per message;
total_num_of_frames(cur_message.source_addr) :=
  total_num_of_frames(cur_message.source_addr) +
  get_frames_per_message(cur_message.bytes);

end;
end;
end;
end;

! take the message out of the queue;
cur_message.out;
end
else
begin
  outtext(" Error in get_data. msg is NULL pointer");
  outimage;
end;
( 1;
procedure inc_message_count;

called by: collect_data;

returns none;

globals used: message_success;

actions: increments the number of successful messages per station. If the number of messages per station is less than MIN_NUM_PER_STATION, then the total number of messages per network is incremented.

For the simulation to be successful in data collection, every station must have a guaranteed minimum throughput.

begin

! increment the number of station messages;
message_success(id) := message_success(id) + 1;

! should we increment the net success messages?
if ( message_success(id) <= MIN_NUM_PER_STATION ) then
  total_message_success := total_message_success + 1;
end;
procedure get_station_data;
called by: network ( call to simulation );
collects station data for messages;
globals used: ;
total_time;
total_through_time;
total_num_of_bytes;
total_num_of_messages;
dataunit.bytes;
actions: collects data statistics for messages;
collects time per station;
collects the # of useful bytes ( data bytes );
per station;

integer i;

loop through the stations:
for i:= 1 step 1 until num_of_stations do
begin
  check for zero divide;
  if ( total_through_time(i) <> 0.0 ) then
  begin
    calculate the throughput for this station;
    throughput(i) := total_num_of_bytes(i) /
                       total_through_time(i) ;

    calculate average delay per frame for this station;
    aver_delay_per_frame(i) := total_through_time(i) /
                                 total_num_of_frames(i) ;
  end;
end;
procedure get_network_data;

called by: network ( call to simulation );

collects station data for messages;

globals used: 
  network_throughput;
  calculates network time from sim_end - sim_start;

actions: collects data statistics for network;
  calculates throughput per network;
  calculates average packet delay per network;

procedure get_network_data(sim_start_time, sim_end_time);

long real sim_start_time;  ! starting time of simulation;
long real sim_end_time;  ! ending time of simulation;

begin

  ! collection variables;
  integer net_total_num_of_bytes;  ! total num_of data bytes;
  long real net_total_through_time;
  long real net_total_aver_delay;
  long real throughput;
  integer i;

  ! initialize variables;
  net_total_through_time := sim_end_time - sim_start_time;
  net_total_num_of_bytes := 0;
  throughput := 0.0;
  net_total_aver_delay := 0.0;

  ! loop through the station collection queue;
  for i := 1 step 1 until num_of_stations do
    begin
      ! collect the number of bytes;
      net_total_num_of_bytes := net_total_num_of_bytes +
                              total_num_of_bytes(i);

      ! collect the average delay per frame;
      net_total_aver_delay := net_total_aver_delay +
                             aver_delay_per_frame(i);
    end;

    ! calculate the throughput for this network;
    if ( net_total_through_time <> 0.0 ) then begin
      network_throughput := net_total_num_of_bytes /
                           net_total_through_time ;
    end;

    ! calculate mean delay per frame;
    if ( net_total_num_of_bytes <> 0.0 ) then begin
      mean_delay_per_frame := net_total_aver_delay /
                             num_of_stations ;
    end;
end;
begin
    network_aver_delay := net_total_aver_delay / num_of_stations;
end;
end;
TX_HOST - transmitter host

STATES: Not Applicable

Actions: Use station statistics to generate the arrival and lengths of new messages. The messages are put into a host message queue and the corresponding TCP layer is notified (activated) to allow action if its state/buffer permits.

Globals Used: U - the random seed number used as input to all random number generations.
message_count - unique id numbers for the messages, for tracking and debugging primarily.

History
1/11/89 mhall change random number generator from randint to negexp

1/19/89 mhall put a check for MAX_MESSAGE_COUNT before creating message. keep track of rejected attempts when queue is full

2/17/89 mhall changed code to use aver_msg_size

host CLASS tx_host;
BEGIN
long real arrival_time; ! time until arrival;
integer message_status;

procedure generate_messages;
begin
  ! generate arrival of a message
  arrival_time := negexp( aver_arrival_time, u);

  hold(arrival_time); ! no action until message arrival time

  ! can we generate another message?
  if ( msg_queue.cardinal < MAX_HOST_MESSAGE_COUNT ) then begin
    ! create and initialize the new message
    host_msg := new message;
    host_msg.createtime := TIME;
    host_msg.id := msg_count;

    ! this parameter is used primarily to allow
    ! for tracking of messages, a unique id#
    msg_count := msg_count + 1;
  end
end
! assign source and destination address;
host_msg.source_addr := id;

! get a destination other than itself;
host_msg.dest_addr := randint(1, num_of_stations, u); while host_msg.dest_addr = id do begin
  host_msg.dest_addr :=
    randint(1, num_of_stations, u);
end;

host_msg.type := DATA;

! get a size for the message;
! host_msg.bytes := randint(min_bytes, max_bytes, u);
host_msg.bytes := aver_msg_size;

! into the message queue;
host_msg.into(msg_queue);

else
begin
  ! keep track of the ones that don't get in;
collectionq.message_not_sent(id) :=
    collectionq.message_not_sent(id) + 1;
end;

! this layer doesn't passivate on initialization;
msg_queue := new message_queue("tx_host");

! set characteristics of station message;
! if (id <= (num_of_stations/2)) then begin
begin
  minbytes := 50;
  maxbytes := 150;
end else begin
  minbytes := 8000;
  maxbytes := 10000;
end;

while TRUE do begin
  ! generate messages forever;
begin
  ! generate messages;
generate_messages;
  if stx_tcp(id).IDLE then begin
    activate stx_tcp(id);
  end;
  hold(interrupt_time);
end--of--while;

END;
RX_HOST - receiver host

STATES: FREE, RECEIVING

Actions: Receive a completed message from the TCP layer. Delay to simulate the DMA transfer of data. Reset to be ready to receive the next message.

host CLASS rx_host;
BEGIN

procedure dma_transfer(no_bytes);
!
This procedure executes a hold to simulate a dma transfer.
It used the number of bytes passed to it to determine the actual length of the hold.
!
Globals: dma_xfer_rate
!
integer no_bytes;
begin
  hold(no_bytes * 8 / dma_xfer_rate);
end;

boolean procedure receive(recvmsg);
REF(message) recvmsg;
begin
  recvmsg.INTO(msg_queue);
  dma_transfer(recvmsg.bytes);
  receive := TRUE;
end;

begin
  ! RX_HOST MAIN
  ! initialize the rx_host entity
  msg_queue := new message_queue("rx_host");
  host_msg := new message;
  ! passivate after creation;
  passivate;
  while TRUE do
    ! loop until the simulation ends
    begin
      if (msg_queue.EMPTY) then
        ! no action required, do nothing
      begin
        !
      end;
    end;
  end
end
passivate;
end
else
begin
! message queue not empty, begin processing ;
state := RECEIVING;
! receive a message from TCP layer ;
host_msg := msg_queue.SUC;

if (host_msg /= NONE) then
! NONE test to avoid runtime errors ;
begin
! simulate processing time ;
hold(interrupt_time);
state := FREE;

! remove the message from the queue ;
host_msg.OUT;
! discard the message
host_msg := NONE;
end;
end;
end;

END++of++rx_host;

(
TX_TCP - transmitter tcp

STATES: FREE, SENDING

Actions: Fetch message from host message queue, packetize, add to buffer, send the message. Send acknowledgments, and piggybacked data/ack frames

```
tcp CLASS tx_tcp;
BEGIN
REF(buffer) ackq;
REF(message_queue) host_msg_queue;
INTEGER rc;
BOOLEAN ack_to_send, piggyback;

begin

procedure dma_transfer(no_bytes);
!
procedure dma_transfer
!
This procedure executes a hold to simulate a dma transfer.
It used the number of bytes passed to it to determine the actual length of the hold.
!
Globals: dma_xfer_rate

integer no_bytes;
begin
   hold(no_bytes * 8 /dma_xfer_rate);
end;
!
procedure packetize(msg);
!
This procedure divides the message referenced by MSG into frames.
The frames are put into the tcp buffer by the netservice level procedure RECEIVE. The final frame is marked by setting the FIN bit.
This procedure is called only after space within the buffer has been reserved for the entire message size. A partial message will not be packetized.
!
begin
   REF(frameunit) tcpframe;
   integer temp, msg_size;
   i = 1;
```

---
begin
  temp := msg.bytes;
  msg_size := max_frame_size;
  while temp > 0 do
    begin
      tcpframe := new frameunit;
      tcpframe.id := msg.id;
      tcpframe.bytes := msg_size;
      tcpframe.dest_addr := msg.dest_addr;
      tcpframe.source_addr := msg.source_addr;
      tcpframe.type := DATA;
      tcpframe.seqnum := msg_size * i;
      tcpframe.msgptr := msg;
      if tcpframe.seqnum >= msg.bytes then
        begin
          tcpframe.fin := True;
          tcpframe.bytes := temp;
          tcpframe.seqnum := msg.bytes;
          if tcpframe.bytes < 65 then begin
            tcpframe.bytes := 65;
            tcpframe.seqnum := msg.bytes + (65 - temp);
          end;
        end;
      buf.msgtail := tcpframe;
      end;
      temp := temp - msg_size;
    end;
  return;
end--of--packetize;

procedure ack_message(ackframe);
  begin
    tempframe := win.front;
    while tempframe /= NONE and tempframe.dest_addr=ackframe.source_addr
      and tempframe.seqnum<=ackframe.acknum do
      begin
        tempframe := tempframe.next;
      end;
    win.state := EMPTY;
  end--of--ack_message;
kill_timer(tempframe);  ! cancel the timer for the acked frame;
  ! adjust the window size
  windowsize := win.cursize - tempframe.bytes;
if tempframe.fin then  ! when the last frame in message
begin
  ! remove the message from buffer
  msgptr := tempframe.msgptr;
  win.front := tempframe.SUC;
  if (outofbuf(tempframe.id) = OK) then
  begin
    ! Mark the message with current time
    ! indicating the time the message
    ! acknowledgement was received. Call
    ! for data collection.
    if (set_donetime(msgptr) = OK) then
      begin
        ! get the data from this successful message;
        collectionq.collect_data(msgptr);
      end;
  end;
if win.front=NONE then
begin
  win.reset_window;
  goto Break;
end else begin
  win.state := NENF;
  tempframe := win.front;
  goto Break;
end;
begin
  win.front := tempframe.SUC;
  if win.front=NONE then
begin
  win.reset_window;
  goto Break;
end;
end;
end;
end--of--ack;

procedure copyframe(source, dest);
REF(frameunit) source, dest;
!
! This procedure makes a copy of the frame being sent, since SIMULA 
! will not allow a given Link class object to exist in more than one 
! set (ie. a frame cannot be in more than one buffer at any given time).
! To allow the frame to stay in the transmitter’s buffer until it is 
! acknowledged, a copy of the frame must be sent.
!
begin
  dest.id := source.id;
  dest.bytes := source.bytes;
  dest.dest_addr := source.dest_addr;
  dest.source_addr := source.source_addr;
  dest.type := source.type;
  dest.seqnum := source.seqnum;
  dest.acknum := source.acknum;

procedure copyframe(source, dest);
dest.fin := source.fin;
dest.msgptr := source.msgptr;
end;

boolean procedure transmit(frame);
REF(frameunit) frame;

! This procedure copies the frame to be sent and calls the IP RECEIVE
! procedure. If IP receives the frame, activate the IP entity.
!
! Returns: TRUE - frame received by IP
! FALSE - frame not received by IP
!
begin
REF(frameunit) sendframe;
sendframe := new frameunit;  ! create new frame_unit template to send;
copyframe(frame, sendframe);  ! copy info from old frame to new copy;
if ( stx_ip(id).receive(sendframe) ) then
begin
transmit := TRUE;  ! frame received by IP, it's on its way;
activate stx_ip(id);  ! IP has something to do, so wake it up;
end else begin
transmit := FALSE;  ! the frame couldn't be sent yet
end;
end--of--transmit;

REF(timeout_unit) procedure find_timeout;

! This procedure searches the timeout queue to find the frame that
! timed out, i.e., the frame in which the FRAME_TIMED_OUT flag is set.
!
! Returns: reference to the first timeout_unit found which meets the
! condition FRAME_TIMED_OUT, otherwise NONE.
!
begin
REF(timeout_unit) current, next;
boolean found;
find_timeout := NONE;
found := FALSE;  ! flag to indicate if timeout was found;
current := timeoutq.FIRST;  ! start at the beginning of the timeoutq;
while (not found) do
begin
if (current /= NONE) then  ! search until end of queue
begin
if (current.status = FRAME_TIMED_OUT) then
begin
find_timeout := current;
found := TRUE;
timeout_count := timeout_count -1;
end else begin  ! didn't find one, get the next timeout
current := current.SUC;
end;
end else begin  ! have searched the entire queue
found := TRUE;  ! break out of the loop
timed_out := FALSE;
timeout_count := timeout_count -1;
end;
end;
if (timeout_count = 0) then timed_out := FALSE;
end;
procedure update_buffer;

! This procedure updates the necessary buffer pointers after a frame is transmitted.

begin
    lastsent := frame;
    buf.current := (buf.current).SUC;
end--update_buffer;

boolean procedure receive_ack(ackframe);

REF(frameunit) ackframe;

! This procedure receives an acknowledge frame for transmission from the TCP Receiver. Comparisons are made to determine:
! - if the frame is to be piggybacked
! - if an previous ACK for the same message exists and should be updated to reflect the current status of the message
! - if this ACK should be added to the acknowledgement queue

! Returns: TRUE if the acknowledgment is successfully handled
! FALSE if there is an error in the processing

begin
    REF(frameunit) tempframe;
    boolean set_piggyback;

    set_piggyback := FALSE;
    if (lastsent =/= NONE) then
        begin
            tempframe := lastsent.SUC;
        end else begin
            tempframe := NONE;
        end;

        if (not set_piggyback) then
            begin
                if (tempframe =/= NONE) then
                    begin
                        if tempframe.dest_addr = ackframe.dest_addr then
                            begin
                                piggyback := TRUE;
                                set_piggyback := TRUE;
                                tempframe.ack := TRUE;
                                tempframe.acknum := ackframe.acknum;
                            end;
                        else if (not set_piggyback) then
                            begin
                                if (ackq.EMPTY) then
                                    begin
                                        ackframe.INTO(ackq);
                                    end else begin
                                        tempframe := ackq.SUC;
                                    end;
                                while (tempframe =/= NONE) and (ackframe=/= NONE) do
                                    begin
                                        if (tempframe.id=ackframe.id) and
                                            (tempframe.acknum < ackframe.acknum) then
                                            begin
                                            end;
                                        end
                                    end;
                            end;
                        end;
                    end;
                end;}
tempframe.acknum := ackframe.acknum;
ackframe := NONE; ! ack frames combined, discard
! ack not used
end else begin ! match not found, look at next ack
  tempframe := tempframe.SUC;
end;

if (ackframe=/=NONE) then ! no matching ACK found in ACKQ
begin
  ackframe.INTO(ackq); ! put ack into the ack queue
end;

ack_to_send := TRUE;
receive_ack := TRUE;
end--of--receive_ack;

procedure transmit_failed(frameptr);
REF(frameunit) frameptr;

! This procedure removes the entire message from the buffer and window
! when transmission at the csmacd layer has failed.
!
! Assumptions:
! - only one message in the transmission window at any given time

begin
  (frameptr.msgptr).rejected := TRUE; ! mark the message as rejected
  return_code := outofbuf(frameptr.id);
  win.reset_window;
end;

procedure create_timeout_ref(timeout_frame);
REF(frameunit) timeout_frame;

! This procedure creates a timeout_unit for placement into the timeout
! queue. It initializes the parameters of the timeout_unit.
!
! Returns: Reference to a new timeout_frame
!
! NOTE: TCP actually calculates the time_up value using a weighted
! average of the actual times to send and receive an ACK.
! This feature has not been implemented in this version.

begin
  REF(timeout_unit) timeout;
  timeout := new timeout_unit; ! create a new timeout template
  ! initialize all of the variables
  timeout.layer := stx_tcp(id); ! set reference to the entity
  timeout.frameptr := timeout_frame; ! set reference to specific frame
  timeout.time_up := 28000.0;
  create_timeout_ref := timeout;
end;

procedure kill_timer(timeout_frame);
REF(frameunit) timeout_frame;

! This procedure searches the timeout queue for the reference to the
! transmitted frame. If found it is cancelled and removed from the

timeout q. If it is not found no action occurs. The search ends with the first match found. There is only one timeout_frame for any frame transmitted, including any re-sends of the same frame for whatever reason.

begin
  REF(timeout_unit) current;
  current := timeoutq.FIRST;
  while (current=/=NONE) do
    begin
      if (current.frameptr==timeout_frame) then
        begin
          cancel(current.timerptr); ! cancel the timeout process
          current.OUT; ! remove timeout_unit from queue
          goto Break; ! exit the loop
        end;
    current := current.SUC; ! frame match not found, get next unit;
  end;
Break:
end;

procedure start_timer(timeout);
REF(timeout_unit) timeout;

begin
  REF(tcp_timer) new_tcp_timer;
  new_tcp_timer := new tcp_timer; ! create a new timer process
  timeout.timerptr := new_tcp_timer;
  new_tcp_timer.setup(timeout); ! initialize the timer process
  timeout.INTD(timeoutq); ! put in q (keep a reference to it)
  activate new_tcp_timer; ! start the timer
end;

begin ! main program portion of tx_tcp;
  REF(frameunit) ackframe;
  REF(message) msg;
  REF(timeout_unit) timeoutptr;
  boolean xmit_failed;

  xmit_failed := FALSE;
  ackq := new buffer;
  msg := new message;
  buf.cursize := 0;
  buf.maxsize := 20480;
  buf_space := buf.maxsize;
  msg := none;
  lastsent := none;
  piggyback := FALSE;
  ack_to_send := FALSE;

  // Initialize the parameters
  // set tcp buffer size for station
  // initialize loop flags

  // Reference to ack frame used in MAIN;
  // reference to a message used in MAIN;
  // reference to a timeout used in MAIN;
  // parameter used to determine the status of attempted transmission; if TRUE, the layer passivates waiting for a state change in an adjacent layer to retry.
passivate;

! assign the host message queue to local pointer;
host_msg_queue := stx_host(id).msg_queue;

while TRUE do  ! DO FOREVER LOOP
begin
    while (host_msg_queue.EMPT OR buf.state = FULL)
    and not (ack_to_send OR timed_out OR next_msg) do
        begin
            passivate;
        end;
    if (ack_to_send OR timed_out OR next_msg) then
        begin
            state := SENDING;
            if (ack_to_send) then
                begin
                    if (piggyback) then
                        begin
                            piggyback := FALSE;  ! Reset piggyback flag
                            frame := buf.current;
                            if (frame =/= NONE) then  ! NONE test to avoid runtime error
                                begin
                                    if (win.reserve_space(frame.bytes)) then
                                        begin
                                            if (transmit(frame)) then
                                                begin
                                                    if (win.addto(frame)) then
                                                        begin
                                                            timeoutptr := create_timeout_ref(frame);
                                                            start_timer(timeoutptr);
                                                            update_buffer;
                                                        end
                                                    end else begin  ! set flag to passivate at end of loop;
                                                        xmit_failed := TRUE;
                                                    end--addto;
                                                end--transmit;
                                            end else begin  ! reserve
                                                xmit_failed := TRUE;
                                            end--reserve;
                                        end;
                                    end else begin
                                        ackframe := ackq.FIRST;  ! assign a reference to first ack;
                                        if (ackframe =/= NONE) then  ! NONE test to avoid runtime error
                                            begin
                                                if (transmit(ackframe)) then  ! send the acknowledgement
                                                    begin
                                                        ackframe.OUT;  ! remove the ack from the queue
                                                        if (ackq.EMPT) then
                                                            ack_to_send := FALSE;
                                                    end else begin
                                                        xmit_failed := TRUE;  ! Transmit returned FALSE, set the
                                                    end--transmit;
                                                end else begin  ! the xmit_failed flag so that the
                                                    xmit_failed := TRUE;
                                                end;
                                            end--ackframe;
                                        end;
                                    end;
                                end;
                            end--frame
                        end;
                    end;
                end;
        end;
    end;
if (ackq.EMT) then
begin
  ! verify there are no acks in queue;
  reset the ack_to_send flag
end;
end;
end;
end else begin
  ! ack_to_send is FALSE, check other flags;
if (timed_out) then
begin
  timeoutptr :- find_timeout; ! find the timed out unit from q;
  if (timeoutptr /= NONE) then
begin
    ! timeout unit found, resend by the frameptr;
    if (transmit(timeoutptr.frameptr)) then
begin
      timeoutptr.status := SET; ! start a new timer for frame;
      start_timer(timeoutptr);
      timeout_count := timeout_count - 1;
    end else begin
      xmit_failed := TRUE; ! set flag to cause passivate;
    end;
  end else begin
    timed_out := FALSE; ! No timeout found, reset the flag;
  end;
end else begin
  timed_out := FALSE; ! No timeout found, reset the flag;
end;
end else begin
  if (next_msg) then
begin
frame :- buf.current;
if (frame /= NONE) then
begin
  if (win.reserve_space(frame.bytes)) then
begin
    ! reserve space in the xmit window;
    if (transmit(frame)) then
begin
      ! transmit the frame to IP;
      if (win.addto(frame)) then
begin
        ! officially add the frame to the win;
        ! create/start the timer;
        ! update the buffer pointers;
        timeoutptr :- create_timeout(frame);
        start_timer(timeoutptr);
        update_buffer;
        if lastsent==buf.msgtail then
begin
          ! send only one message at a time;
          next_msg := FALSE;
        end;
end else begin
      xmit_failed := TRUE;
      win.cancel_reserve_space(frame.bytes);
    end;
end else begin
      xmit_failed := TRUE;
      win.cancel_reserve_space(frame.bytes);
    end;
end else begin
  xmit_failed := TRUE;
end;
end else begin
next_msg := FALSE;
end;
end;
end else begin
end;
end
if (xmit_failed) then

  Xmit_failed flag indicates that some condition exists to attempt a transmit, and that the attempt failed. The transmitter will passivate, waiting for a change in the conditions, so that the next transmit might succeed. The loop will be executed from the beginning after TX_TCP is activated so that whatever is highest priority will be done first.

begin
  xmit_failed := FALSE;
  passivate;
end;

end else begin

begin
  if (not host_msg_queue.EMPTY) and (not buf.state=FULL) then
  begin
    state := RECEIVING;
    msg := host_msg_queue.SUC;
    ! add message to tcp buffer only if there is room for the entire message
    ! buf_space indicates space remaining
    if (reserve_buffer_space(msg.bytes)) then
      begin
        msg.Out;
        ! Message is taken out of host queue and added to the data collection queue.
        msg.INTO(collectionq);
        dma_transfer(msg.bytes);
        ! Hold for dma xfer of data bytes;
        packetize(msg);
        ! Prepare the msg for sending, add to buffer as individual frames to be transmitted.
      end;
      state := FREE;
    end;
  end;
hold(interrupt_time); ! Hold for tcp processing time, needs refinement;
end--of--while;

end--of--main;
END++of++TCP;
RX_TCP - receiver tcp

STATES: FREE, RECEIVING

Actions: receive message from IP, update the buffer, send ACK in response to data message, update parameters in response to CTRL, pass complete message up to host

NOTE: For this simulation it is assumed that there is room in the receiver BUFFER for any arriving frame. The WINDOW size will be checked for availability.

tcp CLASS rx_tcp;
BEGIN
REF(message) msg;
REF(frameunit) summaryptr, temp;
REF(buffer) buf_rc;

procedure dma_transfer(no_bytes);
! procedure dma_transfer
! This procedure executes a hold to simulate a dma transfer.
! It used the number of bytes passed to it to determine the actual length of the hold.
! Globals: dma_xfer_rate

integer no_bytes;
begin
  hold(no_bytes * 8 / dma_xfer_rate);
end;

integer procedure rx_receive(recvframe);

REF(frameunit) recvframe;
! This procedure receives a frame at the tcp level. It updates window and buffer sizes to reflect the size of the frame received.

begin
  boolean win_rc;
  win_rc := FALSE;
  return_code := FAILED;

  if (win.maxsize < (win.cursize + recvframe.bytes)) then
    begin
      ! set win.maxsize so never fails for WINDOW too small;
      win.maxsize := win.cursize + recvframe.bytes;
    end;

  receive message "from ip, update the buffer"
  send ACK in response to data message, update parameters in response to CTRL, pass complete message up to host

  return_code := SUCCESS;
end;
if (win.reserve_space(recvframe.bytes)) then
  begin
    ! reserve space in the window for the frame
    if (buf.maxsize < (buf.cursize + recvframe.bytes)) then
      begin
        ! set buf.maxsize so never fails for BUFFER too small;
        buf.maxsize := buf.cursize + recvframe.bytes + 1;
      end;
    win_rc := win.addto(recvframe);
    buf_rc := receive(recvframe);
  end
else begin
  win.cancel_reserve_space(recvframe.bytes);
end;
if (win_rc) and (buf_rc = OK) then
  begin
    return_code := OK;
  end;
if (buf.current == NONE) then
  begin
    buf.current := recvframe;
  end;
rx_receive := return_code;
end--of--rx-receive;

procedure ctrl_message;
begin
  ! This procedure can be used as a starting point to implement the ;
  ! control messages of TCP.
end--of--ctrl;

procedure reassemble_message;
begin
  ! This procedure creates a new message and copies all of the ;
  ! information from the summary frame to the message preparing to ;
  ! pass the message up to the host.

  msg := new message;
  ! create a new message and copy info
  msg.id := summaryptr.id; ! from the summary frame
  msg.dest_addr := summaryptr.dest_addr;
  msg.source_addr := summaryptr.source_addr;
  msg.bytes := summaryptr.bytes;
end--of--reassemble_message;

ref(frameunit) procedure get_summary_frame;
begin
  REF(frameunit) bufptr;
  bufptr := buf.FIRST;
  while (bufptr /= NONE) do
    begin
      if (frame.id=bufptr.id) then
        begin
          ! matching frame found, assign
          break;
        end;
    end;
  end;
end--of--get_summary_frame;
get_summary_frame :- bufptr; go to Break; end else begin bufptr :- bufptr.SUC; ! no match-check next buf entry; end; Break: end--get_summary_frame;

integer procedure last_contiguous_byte;
! This procedure will search through the buffer updating the summary frame until no more updates are possible. The buffer pointers are updated and combined frames are removed from the buffer.

Returns:
Integer value of the highest contiguous byte received

begin
integer last_byte;
boolean updated;
REF(frameunit) bufptr, tempptr;
lst_byte := 0; ! set last_byte in case first frame not received;
updated := TRUE;
while (updated) do
begin ! search the list again after each update, until no more updates;
bufptr :- summaryptr.SUC; ! start search after the summary frame;
updated := FALSE;
while (bufptr /= NONE) do ! search until the end of the buffer;
begi!n
if (summaryptr.id=bufptr.id) then
begin ! the frames have the same id number;
if (summaryptr /= bufptr) then
begin ! the pointers point to different frames;
if (bufptr.seqnum= (summaryptr.bytes+ bufptr.bytes)) then
begin ! contiguous frame found, combine them;
summaryptr.seqnum := bufptr.seqnum;
summaryptr.bytes := summaryptr.bytes+bufptr.bytes;
last_byte := summaryptr.bytes;
summaryptr.fin := bufptr.fin;
updated := TRUE;
end;
end;
end;
if (updated) then
begin ! update the buffer pointers and remove the frame;
! that was just combined with the summary frame;
tempptr :- bufptr;
bufptr := bufptr.SUC;
if (tempptr==buf.current) then
begin
buf.current:-(buf.current).PREV;
end;
tempptr.OUT;
tempptr:= NONE;
end else begin
bufptr := bufptr.SUC;
end;
end--while;
end--while;
if (summaryptr.bytes == summaryptr.bseqnum) then

begin
  last_byte := summaryptr.bytes;
end;
last_contiguous_byte := last_byte;
end--of--last-contiguous-byte;

procedure acknowledge(aframe);
  REF(frameunit) aframe;

  ! This procedure creates an acknowledgment for the last contiguous Byte
  ! of the same message as the frame received. The ACK is put
  ! into the acknowledgement queue of the transmitter.

begin
  ref(frameunit) ackframe;
  ackframe := new frameunit_ ! create new frame for the ack
  ackframe.dest_addr := aframe.source_addr; ! initialize the frame
  ackframe.source_addr := aframe.dest_addr;
  ackframe.id := aframe.id;
  ackframe.ack := TRUE;
  ackframe.type := ACK;
  ackframe.bytes := 65; ! set ack bytes to minimum packet size
  ackframe.acknum := last_contiguous_byte; ! find the byte to ack
  ackframe.setwindow := buf.maxsize - buf.cursize;
  if not (stx_tcp(id).receive_ack(ackframe)) then
    begin
      end--of--acknowledge;
end

!******** RX_TCP --- MAIN **********************************************;
begin
  buf.cursize := 0;
  buf.maxsize := 10240; ! set tcp buffer size for station;
  ! info set up in a file;
  passivate;
  while TRUE do
    begin
      if buf.current /= NONE then ! frame to receive in buffer, start;
        begin
          state := RECEIVING;
          frame := buf.current;
          ! control not implemented - 12/88
          if frame.type = CTRL then ctrl_message;
            ! pass ack info to tx_tcp for updates;
          if frame.ack then stx_tcp(id).ack_message(frame);
            ! receive data information
          if frame.type = DATA then
            begin
              ! Find the summary frame for message,
              ! should return a pointer to the 1st
              ! frame found for the same message.
              ! Either a previously received frame
              ! or the current frame if no previous;
              ! frame exists should be returned.
              summaryptr := get_summary_frame;
              if (summaryptr==NONE) then ! debug message
                begin
                  end
```
acknowledge(frame);

! remove frame from receiver window;
return_code := win.rxtcp_outof(frame);

if (buf.current /= NONE) then
  buf.current := (buf.current).SUC;
if (summaryptr /= NONE) then
  begin
    if (summaryptr.fin) and 
      (summaryptr.bytes = summaryptr.seqnum) then
      begin
        ! last frame, message complete;
        reassemble_message;

        ! send message to the host;
        while not (srx_host(id).receive(msg)) do
          begin
            if (srx_host(id).idle) then
              activate srx_host(id);
          end;

        dma_transfer(msg.bytes);
        activate srx_host(id);

        ! remove frames from buffer;
        return_code := outofbuf(summaryptr.id);
      end;
    end;
  else
    begin
      ' update buffer for CTRL or ACK frames;
      return_code := win.rxtcp_outof(frame);
      temp := frame;

      if (buf.current /= NONE) then
        buf.current := (buf.current).SUC;

      if (temp /= NONE) then
        begin
          buf_space := buf_space + temp.bytes;
          temp.OUT;
          temp := NONE;
        end;
    end;
  end;
else
  begin
    ' no frame to receive, passivate;
    state := FREE;
    activate srx_ip(id);
    passivate;
  end--of--if;
frame := None;

! simulate processing time with hold;
hold(interrupt_time);
end--of--main;
END++of++RXTCP;
}
RX_IP - IP Receiver

STATES: FREE, BUSY

ACTIONS: Receives a frame pointer (REF) from its station's
rx_csmacd layer, calls the tcp receive function
RX_RECEIVE to put the frame into rx_tcp's buffer.

ip CLASS rx_ip;
begin
passivate;
while TRUE do
begin
while frame==NONE do
begin
state := FREE;
activate srx_csmacd(id); ! give dependent layer a
! chance to react to state change;

passivate;
end;
if frame/=NONE then
begin
state := BUSY;
return_code := FAILED; ! initialize value of return_code;
while (return_code = FAILED) do
begin
return_code := srx_tcp(id).rx_receive(frame);
if (return_code = OK) then
begin
activate srx_tcp(id);
frame := NONE;
end;
if (return_code = FAILED) then
begin
activate srx_tcp(id);
end;
end;
frame := NONE; ! reset the ip receiver parameters;
state := FREE;
end;
hold(interrupt_time); ! simulate the processing time of IF;
end;
end;

TX_IP - IP Transmitter

STATES: FREE, SENDING, READY

ACTIONS: Receives a frame pointer (REF) from its station's
tx/tcp layer, calls the csmacd receive function to put the frame into tx_csmacd's buffer.

CLASS tx_ip;
begin

procedure reset_tx_ip;
begin
    frame := NONE;
    state := FREE;
end;

procedure transmit_failed(frameptr);
REF(frameunit) frameptr;
begin
    stx_tcp(id).transmit_failed(frameptr);
end;

begin
passivate;
while TRUE do
begin
    while frame==NONE do
begin
        passivate;
    end;

    state = FREE, no frame to send;
    ! state = READY, have frame; state set in receive procedure;

    Attempt to pass frame to csmacd, if attempt fails then passivate... will try again when activated by csmacd or tcp. Will not succeed until csmacd actually receives the frame.

    while (not stx_csmacd(id).receive(frame) ) do
begin
    passivate;
end;

    state := SENDING;
    if stx_csmacd(id).IDLE then
begin
    activate stx_csmacd(id);
end;
reset_tx_ip;
activate stx_tcp(id);
hold(interrupt_time);
end--while--true--do;
end;
end++TX_IP;
process class tx_csmacd;

substructure of: class protocol;

calls: ( state routines );
csmacd_txs_acquire_channel;
csmacd_txs_attempt_tx;
csmacd_txs_idle;
csmacd_txs_wait_for_re_tx;
csmacd_txs_disabled;

returns: none;

globals used: 
loops on state and change_status;
this indicates if a change of state has occurred;

actions: mimicks the transmitter of the csmacd;

! declare entities for the csmacd layer;

csmacd class tx_csmacd;
begin

attributes;
integer n;
long real tx_delay;
long real total_delay;

state routines;
determine if a transition will occur;
return a boolean true if transition occurs;

! files that contain the state subroutines and specific procedures;
%INCLUDE csmacd_txs.sim
%INCLUDE csmacd_tx.sim

! main body;
begin

initialize attributes;
n := 0;

loop forever;
while true do
begin
if (( not change_state ) and
       ( not buffer_interrupt )) then
begin
  passivate;
  change_state := true;
end
else
begin

! reset the transition;
change_state := false;

! identify the state;
if ( state = DISABLED ) then
begin
  change_state :=
  csmacd_txs_disabled
end
else if (state = WAIT_FOR_RE_TX ) then
begin
  change_state :=
  csmacd_txs_wait_for_re_tx;
  ! have we waited max tries;
  if ( not change_state ) then begin
    ! reset the variables;
    reset_tx_csmacd;
    ! wake up ip;
    activate stx_ip(id);
  end;
end
else if (state = FREE ) then
begin
  change_state :=
  csmacd_txs_idle
end
else if (state = ATTEMPT_TX ) then
begin
  change_state :=
  csmacd_txs_attempt_tx
end
else if (state = ACQUIRE_CHANNEL) then
begin
  ! get the frame to;
  ! send from the buffer;
  frame :=
  get_frame_from_buffer;
  ! if we got the frame ;
  ! send it on ;
  if(frame /= none ) then
  begin
    change_state :=
    csmacd_txs_acquire_channel(frame);
    ! wake up ip after transmission;
  end
end
if ( change_state ) then
begin
  ! calculate total delay;
  total_delay :=
      prop_delay + tx_delay;

  ! activate the csmacd_rx;
  activate srx_csmacd(frame.dest_addr);
end;
end;

! reset the flag;
reset_tx_csmacd;

! wake up ip layer;
activate stx_ip(id);
end
else
begin
outtext(" ERROR IN IDENTIFYING C_TX_STATE");
outint(state,5);
outimage;
end;
end;
boolean procedure csmacd_txs_disabled;
begin
  boolean return_code; ! true if transition occurs;
  long real jam_time; ! amount of time for jam;
  return_code := true;
  jam_time := 2 * tau;
  hold (jam_time);
  ! call end jam for transition state;
  csmacd_tx_end_jam;
  ! always return true, since there's always a transition;
  csmacd_txs_disabled := return_code;
end;

boolean procedure csmacd_txs_wait_for_re_tx;
begin
  procedure csmacd_txs_wait_for_re_tx;
  called by: process class tx_csmacd;
  calls: csmacd_tx_end_of_delay;
  returns: true if n <= 16, false otherwise;
  ! globals used: checks the value of n declared in tx_csmacd;
  ! actions: if n <= 16, calls csmacd_tx_end_of_delay;
  !
  boolean procedure csmacd_txs_wait_for_re_tx;
end;
boolean return_code;
integer max_tries;                ! max number of attempted tx;

max_tries := 16;

! call the transition if n <= max_tries;
if ( n <= max_tries ) then
begin
    return_code := csmacd_tx_end_of_delay;
end
else
begin
    ! return frame pointer to ip;
    frame := get_frame_from_buffer;
    stx_ip(id).transmit_failed(frame);
    return_code := false;
end;
csmacd_txs_wait_for_re_tx := return_code;

procedure csmacd_txs_idle;
called by: process class tx_csmacd;
calls: csmacd_tx_attempt_send;
returns: true if transition occurs, false otherwise;
globals used: 
    buf.state;
actions: represents the idle state;

boolean procedure csmacd_txs_idle;
begin

    boolean return_code;

    ! initialize return code;
    return_code := false;

    ! is there a possible transition;
    ! if the buffer is full tx;
    ! attempt to send;

    ! is there something in the buffer to send;
    if ( buf.state = FULL) then
    begin
        return_code := csmacd_tx_attempt_send;
    end;
csmacd_txs_idle := return_code;
end;
procedure csmacd_txs_attempt_tx;
  called by: process class tx_csmacd;
  calls: csmacd_tx_end_of_collision_window;
          csmacd_tx_collision;
  returns: true if transition occurs, false otherwise;
  globals used: tau ;
  actions: represents attempting to transmit state;
           checks the channel variable to see if collision;
           has occurred between attempt_to_send and now;
           if not, holds for two tau total before checking;
           to see if collision has occurred. This is the;
           collision window time;

boolean procedure csmacd_txs_attempt_tx;
begin
  boolean return_code;
  return_code := true;

  if ( schannel_csmacd.csmacd_channel_state = 0 ) then begin
    schannel_csmacd.csmacd_channel_state :=
      schannel_csmacd.csmacd_channel_state + 1;

    hold (tau);
  end
  else begin
    if(schannel_csmacd.csmacd_channel_state > 1 ) then begin
      csmacd_tx_collision;
    end
    else begin
      csmacd_tx_end_of_collision_window;
    end;
  end
end;
csmacd_txs_attempt_tx ::= return_code;

procedure csmacd_txs_acquire_channel;
called by: process class tx_csmacd;
calls: csmacd_tx_end_of_tx_message;
returns: true if transition occurs, false otherwise;
globals used: ;
    tau;
actions: represents the transmit state;
    calculates the tx_delay and the transmit_time;

begin

    long real transmit_time;
    long real transmit_rate;
    boolean return_code;

    return_code := false;

    ! calculate transmit time;
    tx_delay := sending_frame.bytes * 8 / data_rate;
    transmit_time := tx_delay - 2 * tau;
    if ( transmit_time < 0 ) then
        transmit_time := 0.0;
    hold (transmit_time);

    ! is this the end of the transmission message;
    return_code := csmacd_tx_end_of_tx_message(sending_frame);

    csmacd_txs_acquire_channel := return_code;
end;
procedure csmacd_tx_end_jam;

called by: csmacd_txs_disabled;
calls: none;
returns: none;
globals used: state := WAIT_FOR_RE_TX;
schannel_csmacd.csmacd_channel_state :=
schannel_csmacd.csmacd_channel_state - 1;

actions: ends the jam;
transitions the transmitter to wait for re-tx.;
changes channel state to free by decrementing states;
checks channel_queue with last transmitter in jam;

procedure csmacd_tx_end_jam;

begin

! from disabled state;
! owns the transition from disabled to wait;
! for re-transmission;
! (jam over );

! reset state variables;
! transmitter waits for re_tx;

state := WAIT_FOR_RE_TX;

! decrement the channel;

schannel_csmacd.csmacd_channel_state :=
schannel_csmacd.csmacd_channel_state - 1;

! was this the last transmitter in the jam? ;
if ( schannel_csmacd.csmacd_channel_state = 0 ) then
begin

! check to wake up channel queue;

csmacd_tx_check_channel_queue;

end;
end;

procedure csmacd_tx_end_of_delay;
boolean procedure csmacd_tx_end_of_delay;
begin
boolean return_code;
long real wait_time;
integer wait_max;

! initialize variables;
return_code := true;
n := n + 1;

! get a wait max value based on n;
if ( n > 10 ) then
begin
    wait_max := 1023;
end
else
begin
    wait_max := ( 2 ** n - 1 ) - 1;
end;

! get the wait time;
wait_time := randint ( 0, wait_max, u );
hold( wait_time * tau );

! reset state variable;
state := FREE;

! check to see if we're over 16 attempts;
if( n > 16 ) then
begin
    return_code := false;
end;
csmacd_tx_end_of_delay := return_code;
end;

procedure csmacd_tx_attempt_send;
called by: csmacd_txs_idle ;
calls: none;
returns: always true;
globals used: 
state := ATTEMPT_TX;
schannel_csmacd.csmacd_channel_state:=;
schannel_csmacd.csmacd_channel_state + 1;
channel_queue;
actions: try to gain control of the channel;
transitions the transmitter from idle to attempt_tx;
if not possible, goes into channel queue;

boolean procedure csmacd_tx_attempt_send;
begin
boolean return_code;
! from idle state;
! owns the transition from idle to attempting to send;
! initialize variables;
return_code := true;

! is the channel free;
! reset state variables;

! can we get the channel;
if (schannel_csmacd.csmacd_channel_state = FREE) then begin
! we can get the channel;
state := ATTEMPT_TX;
end
else begin
! wait for the channel;
! no change of state, passivate in queue;
wait(schannel_csmacd.channel_queue);
end;

! assign return value;
csmacd_tx_attempt_send := return_code;
end;

procedure csmacd_tx_end_of_collision_window;
called by: csmacd_txs_attempt_tx;
calls: none;
returns: none;
state := ACQUIRE_CHANNEL;

actions: ends the collision window;
transitions the transmitter to end of collision window;
owns the transition from attempting to;
transmit to acquiring channel;

procedure csmacd_tx_end_of_collision_window;
begin
! from attempting to transmit state;

! reset state variables;
state := ACQUIRE_CHANNEL;
end;

procedure csmacd_tx_collision;
called by: csmacd_txs_attempt_tx;
calls: none;
returns: none;
globals used: state := DISABLED;

actions: ends the jam;
owns the transition from attempting to;
transmit to global collision;
transitions the transmitter to disabled.;

procedure csmacd_tx_end_of_Tx_frame;
called by: csmacd_txs_acquire_channel;
calls: none;
returns: true if frame received, false otherwise;
globals used: ;
schannel_csmacd.csmacd_channel_state - 1;

; actions: ends of transmission;
; calls the rx_csmacd receive routine;
; decrements the channel state variable;
; checks the channel queue for entities waiting;
; for the queue;

;

boolean procedure csmacd_tx_end_of_tx_message(sending_frame);
ref( frameunit) sending_frame;
begin
  boolean return_code;
  return_code := true;
  ! from transmitting state;
  ! owns the transition from transmitting to;
  ! idle;

  ! change the receiver message pointer;
  return_code := srx_csmacd(sending_frame.dest_addr).receive(frame);

  ! decrement the channel variables;
  channel_state :=
    channel_state - 1;

  ! do we have anybody in the channel queue;
  csmacd_tx_check_channel_queue;

  ! set the return code;
  csmacd_tx_end_of_tx_message := return_code;
end;

procedure csmacd_tx_check_channel_queue;
called by: csmacd_tx_end_of_tx_message;
calls: none;
returns: none;

globals used:
  schannel_csmacd.channel_queue;

actions: checks the channel queue to see if anybody;
  waiting;
  takes any transmitters waiting out of the;
  queue and activates them;

;
begin
next_transmitter := schannel_csmacd.channel_queue.first;
next_transmitter.out;
activate next_transmitter;
end;
end;

procedure reset_csmacd
begin
reset entity variables;
reset;

reset the tx_csmacd variables;
n := 0;
tx_delay := 0;
total_delay := 0;
change_state := false;
clears the buffer;

actions:
resets the csmacd_tx variables;

procedure dma_transfer(no_bytes);

This procedure executes a hold to simulate a dma transfer.
It used the number of bytes passed to it to determine the
actual length of the hold.

Globals: dma_xfer_rate

integer no_bytes;
begin
hold(no_bytes * 8 / dma_xfer_rate);
boolean procedure receive;

called by: csmacd_txs_idle,csmacd_rxs_idle ;

calls: none;

returns: ;
true if frame entered into buffer;
false otherwise;

globals used: ;
buf - current buffer;
buffer_interrupt - set when frame enters buffer;

actions: ;
takes a frame and puts it into the buffer;
sets the buffer state to full;
sets buffer_interrupt to true;
holds for dma_xfer time;

boolean procedure receive(in_frame);
ref(frameunit) in_frame;
begin
boolean return_code;
return_code := false;

if ( not ( buf.state = FULL )) then
begin
! put the frame in the buffer ;
in_frame.into(buf);

! set the buffer state;
buf.state := FULL;

! set the buffer interrupt;
buffer_interrupt := true;

! hold for transfer time;
dma_transfer( in_frame.bytes );

return_code := true;
end;
receive := return_code;
end;
process class rx_csmacd;

substructure of: class protocol;

calls:  
csmacd_rxrs_idle;
csmacd_rxrs_receiving;

returns: none;

globals used:  
loops on the state and change status boolean

actions: mimicks the receiver of the csmacd;
activates rx_ip when appropriate;

attributes; 
long real rx_delay; in usecs;

state routines;
! determine if a transition will occur;
! return a boolean true if transition occurs;

files that contain the state subroutines and specific procedures;
%INCLUDE csmacd_rxrs.sim
%INCLUDE csmacd_rx.sim

main body;
begin
rx_delay := 10.0;

initialize attributes;

loop forever;
while true do
begin
! do we check for a transition;
if (( not change_state ) and
( not buffer_interrupt )) then
begin
passivate;
change_state := true;
begin
else
begin

! reset the transition;
change_state := false;

! identify the state;
if (state = FREE ) then
begin
change_state :=
csmacd_rxs_idle ;
end
else if (state = RECEIVING ) then
begin
change_state :=
csmacd_rxs_receiving ;

! is the buffer full receiving;
if ( change_state ) then
begin
! wake up the ip layer;
activate srx_ip(id);

! reset the variables;
reset_rx_csmacd;
end;
end
else
begin
outtext(" ERROR IN IDENTIFYING C_RX_STATE");
outint(state,5);
outimage;
end;
end;
end;
procedure csmacd_rxs_idle;
called by: process class rx_csmacd;
calls: csmacd_rx_frame;
returns: true if transition occurs, false otherwise;
globals used: buf.state;
actions: represents the idle state;

procedure csmacd_rxs_receiving;
called by: process class rx_csmacd;
calls: csmacd_rx_buffer_full;
returns: true if transition occurs, false otherwise;
globals used: none;
actions: represents receiving state;
checks to see if the buffer's full;
boolean return_code;
return_code := false;

! check to see if we have a transition;
return_code := csmacd_rx_buffer_full;

! hold for a receiving time;
hold(rx_delay);

csmacd_rxs_receiving := return_code;

end;
procedure csmacd_rx_frame;

called by: csmacd_rxs_idle;
calls: none;
returns: always true;
globals used: none;
actions: changes the state from idle to receiving;
owns the transition for receiving message;

procedure csmacd_rx_buffer_full;

called by: csmacd_rxs_receiving;
calls: none;
returns: none;
true if frame was sent to rx_ip;
false otherwise;
globals used: frame (frame pointer);

actions: imitates the receiving state;
owns the transition for receiving buffer full;

begin
boolean return_code;
return_code := true;

! reset state variables;
state := RECEIVING;
! set the return value;
csmacd_rx_frame := return_code;
end;

begin
boolean return_code;
return_code := true;

begin
boolean return_code;
return_code := true;

begin
boolean return_code;
return_code := true;
! get the next frame to send;
! or loop on the last one;
if ( frame == none ) then
begin
    frame := get_frame_from_buffer;
end;

! if we got the sending frame, pass it up;
if ( frame /= none ) then
begin
    if ( srx_ip(id).state = FREE ) then
    begin
        ! set the frame pointer for the ip layer;
        return_code := srx_ip(id).receive(frame);
    end
else
    begin
        return_code := false;
    end;
end
else
begin
    return_code := false;
end;

! set the return value;
csmacd_rx_buffer_full := return_code;

procedure reset_rx_csmacd;
called by: rx_csmacd;
calls: reset;
clear_buffer;
returns: none;
globals used: 
    change_state := false;
clears the buffer;
actions: 
    resets the rx_csmacd variables;
procedure reset_rx_csmacd;
begin

    ! reset entity variables;
    reset;

    ! reset the rx_csmacd variables;
    change_state := false;

    ! clear the buffer;
    clear_buffer;
}
procedure dma_transfer(no_bytes);

This procedure executes a hold to simulate a dma transfer. It uses the number of bytes passed to it to determine the actual length of the hold.

Globals: dma_xfer_rate

integer no_bytes;
begin
  hold(no_bytes * 8 / dma_xfer_rate);
end;

boolean procedure receive;

called by: csmacd_txs_idle, csmacd_rxs_idle;
calls: none;
returns:
  true if frame entered into buffer;
  false otherwise;

globals used:
  buf - current buffer;
  buffer_interrupt - set when frame enters buffer;

actions:
  takes a frame and puts it into the buffer;
  sets the buffer state to full;
  sets buffer_interrupt to true;
  holds for dma_xfer time;

boolean procedure receive(in_frame);
ref(frameunit) in_frame;
begin
  boolean return_code;
  return_code := false;

  ! if the buffer isn't full, put the frame in;
  if ( not (buf.state = FULL) ) then begin
    ! put the frame in the buffer;
    in_frame.into(buf);

    ! set the buffer state;
    buf.state := FULL;

    ! set the buffer interrupt;
    buffer_interrupt := true;
  end;

  return return_code;
end;
! hold for transfer time;
dma_transfer( in_frame.bytes );

    return_code := true;
end;
receive := return_code;
end;

process class channel_csmacd;
substructure of: class protocol;
calls: none;
returns: none;
globals used: initializes channel variables;
csmacd_channel_state := 0 (FREE);
channel_queue := new head;
actions: mimicks the channel;

********************************************
class channel_csmacd;

vin

! attributes;
integer csmacd_channel_state;
ref (head) channel_queue;

! main body;
! initialize attributes;
begin
  csmacd_channel_state := 0;
  channel_queue := new head;
end;

don;}
10.0  ! data_rate;
1.0   ! interrupt_time;
40.0  ! dma_xfer_rate;
4000040  ! aver_arrival_time;
5.0   ! prop_delay;
1500  ! max_frame_size;
5000  ! aver_msg_size;
10.0  ! data_rate;
0.5   ! interrupt_time;
80.0  ! dma_xfer_rate;
      ! aver_arrival_time;
5.0   ! prop_delay;
1500  ! max_frame_size;
5000  ! aver_msg_size;
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<th>throughput</th>
<th>aver delay / frame success reject</th>
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<td>1.8610000008&amp;+003 14 0</td>
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aver_delay_per_frame = 3.383071488&+003
simulation time 3.387300000&+006
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simulation time = 5.0243100000+006
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<th>reject</th>
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simulation time = 4.318140000e+06