CHAPTER 5
MODELLING OF OPTICAL STAR LAN

5.1 INTRODUCTION

Performance evaluation is an essential element in any system, more so for LAN because it involves the use of a lot of hardware and software. The evaluation process implies assessment of appropriate performance parameters. The choice of performance parameters and the method of their evaluation are greatly decided by the objectives set forth for the performance evaluation.

A model, being an abstraction of reality based on the value of some set of attributes observed for each resource in the LAN, provides the conceptual framework for analysing the system. In analytical modelling, the entire system operation is characterised in the form of equations which are used to get the required performance parameters. Simulation modelling techniques are employed when proper behaviour cannot be defined by equations.

The performance parameter is a measure which quantifies the efficiency of a LAN. The measures of performance obtained as a result of the modelling are: Throughput, Delay, Contention Period, Idle Period, Busy Period, Effect of Loading and Effect of Packet Size.
Modelling, particularly analytical modelling, is done only for non-deterministic processes, CSMA/CD being a non-deterministic system needs modelling for the system study [17].

In this chapter, an analysis of CSMA/CD is performed for the Optical Star LAN covering most of the performance parameters, with approximations made to match real-life systems. The performance parameters arrived through with the developed delay and throughput models for non-persistent CSMA/CD with slotted time axis are compared with those of bus configuration.

CSMA/CD is basically a multiple access scheme which can be viewed as a broadcast channel shared by a population of distributed users. For a group of 'M' users, the problems to be addressed by the access protocol will be:

1. To identify the ready users, among the 'M' users.
2. To assign channel access to exclusively one user, if at least one exists.

The second problem can be recognised as a problem of mutual exclusion. The ready users in the system can be considered as customers in a distributed queue. A consequence of the conservation law in queuing theory is that the average message delay of an access protocol is independent of the order
of service but depends mainly upon the amount of time wasted for assigning the channel. Thus, the important question to be answered is how quickly channel access can be assigned to a ready user.

5.2 CSMA/CD PROTOCOL

Because of the bursty nature of traffic in computer communications, performance of an access protocol for a broadcast network depends mainly upon how quickly one of the ready users is identified and given access to the channel. It is more efficient to provide the available communication bandwidth as a single high-speed channel shared by many contending users; thus multi-access system calls for schemes that are purely random in nature. The earliest and the simplest such scheme is the so called Pure-ALOHA. Unfortunately, Pure-ALOHA provides a channel utilisation of 18% as a maximum [19].

Another scheme, called the Carrier Sense Multiple Access (CSMA), has been shown to be highly efficient in environments with propagation delays which are short compared to the packet transmission time [20]. CSMA reduces the level of interference caused by overlapping packets in random due to other users and inhibit transmission when the channel is in use. The packets which are inhibited or suffer collisions are rescheduled for
transmission at a later time according to some rescheduling policy. An extension to this scheme is to detect interference amongst several transmissions (including its own) and abort transmission. This is referred to as Carrier Sense Multiple Access with Collision Detection (CSMA/CD).

CSMA/CD requires that each device with a packet ready for transmission senses the channel prior to transmission. A number of protocols exist which regulate the action to be taken by the terminals after observing the state of the channel. A terminal should never transmit when it senses the channel to be busy. Depending on how the devices try for a transmission, there are categories of CSMA/CD systems: Non-Persistent CSMA/CD, 1-Persistent CSMA/CD, and P-Persistent CSMA/CD [19].

In a Non-persistent CSMA/CD, a terminal with a packet ready for transmission senses the channel and proceeds with the steps shown in the flow diagram of Fig. 5.1 (a).

Under an 1-Persistent CSMA/CD protocol, a terminal which finds the channel busy, persists on transmitting as soon as the channel becomes free, see the flow diagram shown in Fig. 5.1 (b).
The P-persistent CSMA/CD allows the ready terminal to randomize the start of the transmission following the instant at which the channel goes idle, as illustrated in the flow diagram in Fig. 5.1 (c).

In the architecture of CSMA/CD protocol shown in Fig. 5.2, the transmit side of a station will be invoked whenever it is required to transmit. The transmit data encapsulation sublayer constructs a frame by supplying a preamble, start of frame delimiter, a source address, a destination address, a medium access control bit, the message proper, padding and a frame check sequence. The message is obtained from the logical link control sublayer and the transmit link management ascertains whether the medium is free and initiates the transmission. The transmit data encoding sublayer takes the bit serial string from the link management and generates electrical signals to be placed on the medium. On the receiving side the receive data decoding sublayer converts the data on the medium into a bit stream and passes it on to the receiving management, to establish that the received frame is valid. The receive data encapsulation sublayer recognise the frame's destination address and determines whether it matches with its own, disassembles the frame and passes the message part along to the logical link control sublayer.
5.3 QUEUEING THEORY

The mathematical foundation for most analytical models for computer networks is queueing theory, which is a powerful abstraction for modelling system. Different queue models can be assumed to tackle a given problem. In computer networking the M/G/1 discipline is widely used and hence for the present analysis of OSLAN also a M/G/1 is adopted. This is because, when the number of users in the network is fairly large the arrival of users at the server can be assumed to a Poisson distribution. The service time requirement by each user cannot be predicated with good certainty, since each user may have different requirements and no specific assumptions can be made on this parameter. Hence a general distribution 'G' is used. The number of servers used in the network is assumed to be '1', and hence the third parameter in the queue model is unity.

For the M/G/1 queue embedded Markovian chain is being used. A Markovian chain is a random sequence which has a finite number of states and which has certain memoryless properties. In M/G/1 queue, the points chosen are the instants when there is a completion in service and a consequent departure from the queue, at which points the Markovian chains are said to be embedded.
The simple queue model for a LAN is as shown in Fig. 5.3, individual nodes store up the packets to be transmitted and continually monitor the activity at the hub.

5.4 THROUGHPUT MODEL

In this section the throughput model of the OSLAN is developed, with the assumption that the time axis is slotted and the duration of each slot is of one unit. It is further assumed that the number of users using the system is fairly large and they collectively form an independent Poisson source with an aggregate mean packet generation rate of \( \lambda \) packets/second. Collisions are detected at the central hub and the time required by the hub to detect an already occurred collision is denoted by \( \delta \), where the duration \( \delta \) is very small compared to the propagation time.

The chain of activities that follow a collision in a CSMA/CD protocol with slotted time axis is shown in Fig. 5.4. If station A starts transmitting at \( t = 0 \), for a collision to occur, station B must also start at the same instant. This is because, in a slotted version of CSMA/CD all the stations start transmitting at the beginning of the slot. Since the slot width 'T' is greater than the propagation time, a collision can occur only if two stations start transmitting at the beginning of the slot. In Fig.
5.4. the factor 'a' denotes the ratio of the propagation time to the transmission time, and factor 'b' denotes the duration for which the central hub generates the jamming signals. The bus contention period 'r' can be determined from Fig. 5.4. as

\[ r = \frac{a}{2} + \delta + \frac{a}{2} + b \]  

or, \[ r = a + b + \delta \geq a + b \]  

assuming '\delta' to be small compared to the factors 'a' and 'b'. Fig. 5.5 shows a typical contention period.

The throughput of a system, \( S \), can be given by: [19]

\[ S = \frac{\bar{U}}{\bar{B} + \bar{I}} \]  

wherein the factor \( \bar{U} \) denotes the average channel utilisation time without collisions, \( \bar{B} \) denotes the average busy period and \( \bar{I} \) is the average idle time. Let \( P_s \) denote the probability of a successful transmission. Therefore,

\[ P_s = \text{[Probability that there was a packet during the last slot of preceding idle period/some arrival occurred]} \]
i.e., \( P_s = \frac{P_1}{1 - P_0} \)  \( (5.4) \)

If \( G \) is the offered load, and if a Poisson's distribution is assumed, then

\[
P_0 = \frac{e^{-aG} (aG)^0}{0!} = e^{-aG} \quad (5.5)
\]

\[
P_1 = \frac{e^{-aG} (aG)^1}{1!} = e^{-aG} aG \quad (5.6)
\]

\[
P_s = \frac{aGe^{-aG}}{1 - e^{-aG}} \quad (5.7)
\]

Therefore, the utilisation of the channel without collisions, \( \bar{U} \), can be obtained as:

\[
\bar{U} = P_s \cdot \text{(slot duration)} \quad (5.8)
\]

\[
\bar{U} = P_s \cdot T \quad (5.9)
\]

\[
\bar{U} = \frac{aGe^{-aG}}{1 - e^{-aG}} \quad (5.10)
\]

The slot period \( T \) is assumed to be of unit time. The average busy period is given by:
\( B_1 \) = Probability of successful transmissions x
Average successful period +
Probability of unsuccessful transmission x
Average contention period

\( s_1 \) = \( P_s(1 - a) + (1 - P_s)(r) \) \( \text{(5.12)} \)

\( s_2 \) = \( P_s(1 - a) + (1 - P_s)(a + b) \) \( \text{(5.13)} \)

The average idle period \( I \) is given by:

\[ I = \frac{\text{Probability of no arrivals of messages}}{\text{Probability of some occurrence}} \times \frac{a}{1 - e^{-aG}} \] \( \text{(5.14)} \)

This is because \( \frac{a}{1 - e^{-aG}} \) represents the number of slots which
are geometrically distributed with a mean of \( \frac{1}{1 - e^{-aG}} \) \( [19] \).

Therefore the expression for throughput is obtained as

\[ S = \frac{aG e^{-aG}}{a e^{-aG} + b \left(1 - e^{-aG} - aG e^{-aG}\right) + a(1-e^{-aG} + Ge^{-aG})} \] \( \text{(5.15)} \)
5.5 DELAY MODEL

A slotted version of non-persistent CSMA/CD is considered in which the time axis is slotted. Packets are assumed to be of fixed length and all terminals are synchronised to start transmission only at the beginning of a slot and then operate according to the protocol.

Considering a general case of an user population consisting of M users, each user can be in one of the two slots, backlogged or thinking. In the thinking state, the user generates a new packet in a slot with a probability \( \sigma \), whereas the user in the backlogged state cannot generate a new packet for transmission. A device is said to be backlogged if its packet had either a channel collision or was blocked because of a busy channel. A backlogged device remains in the state until it completes successful transmission of the packet, at which time it switches to the thinking state.

The rescheduling delay of a backlogged packet is assumed to be geometrically distributed in that each backlogged user is scheduled to resense the channel with a probability \( \gamma \). It is also assumed that the terminal learns about its success or failure instantaneously at the end of its transmission period.
Let $N^t$ be a random variable, called the channel backlog, representing the number of backlogged users at the beginning of slot $t$. The channel input rate at time $t$, defined as the average number of packets generated by the users at time $t$, is denoted by $S^t$. Further, it is assumed that $M$, $\sigma$ and $\gamma$ to be time-invariant. Consider a Markov chain embedded at approximate points representing the message arrival. The state of the system is the number of messages in the system. Consider the embedded slots in the idle period. The intervals of time between two consecutive embedded slots are defined as cycles. These cycles are of random length. Consider one such cycle:

Let $t_e$ denote the first slot and $N^{te}$ denotes the state of the system at $t_e$. Let $I$ denote the length of the idle period. It is assumed that $M$ users in the system form a Markov Chain. Actually a Markov Chain consists of a finite number of states and these states can be represented by a transition matrix $R$ which includes both the probabilities of success and failure in transmission. In order to arrive at a delay model we assume an arbitrary slot $(t_e + I - 1)$ which has $i$ users and the next slot $(t_e + I)$ with $k$ users. We find all possible conditions of success, $S_{ik}$ and failure, $F_{ik}$ with respect to these two slots.

In Fig. 5.6 no terminal is ready during the interval $[t_e, t_e + I - 2]$; at least one terminal becomes ready in
the last slot of an idle period, i.e., at $t_e + I - 1$. The vertical arrows represent the number of arrivals. The probability that some terminal is ready, $P_r$, is given by

$$P_r \text{[some terminal ready / } N^{te} = i]$$

$$= 1 - (1 - \gamma)^i (1 - \sigma)^{M-i}$$  (5.16)

We seek the transition probability matrix $P$ between consecutive embedded points. $P$ is the product of several single-slot transition matrices which are to be defined. $N^{te}$ is invariant over the entire idle period except over the slot $t_e + I - 1$. We denote by $R$ the transition matrix for slot $t_e + I - 1$ and by $Q$ for all remaining slots of the busy period. Since the length of the busy period depends on the number of devices which become ready in the slot $t_e + I - 1$, the factor $R$ can be given as:

$$R = S + F$$  (5.17)

where the $(i, k)^{th}$ elements of $S$ and $F$ are defined as

$$S_{ik} = Pr \text{[}[N^{te+I} = k] \text{ and transmission is successful / } N^{te+I-1} = i]$$  (5.18)

$$F_{ik} = Pr \text{[}[N^{te+I} = k] \text{ and transmission is unsuccessful / } N^{te+I-1} = i]$$  (5.19)
For any slot in the busy period the probability matrix, \( Q \), simply reflects the addition to the backlog from the \( M - N^{te} \) thinking devices and so \( Q_{ik} \) is defined as:

\[
Q_{ik} = P_r \left[ N^{te+1} \mid N^{te+1-1} \right]
\]  \hspace{1cm} (5.20)

Equation 5.20 denotes the probability of \( k \) and \( i \) messages in the \((I + t_e)\) and \((I + t_e - 1)\) slots, respectively.

The stationary probability matrix, \( J \), will represent the fact that a successful transmission decreases the backlog by one; its \((i, k)\)th elements being defined as:

\[
J_{ik} = 1 \text{ for } k = i+1
\]

\[0 \text{ otherwise.}\]

If the transmission is successful, the transmission has length \( T+1 \); if it is unsuccessful, its length is \( r+1 \). The transition matrix \( P \) is therefore expressed as [17]

\[
P = SQ^{T+1} J + FQ^{r+1}
\]

The conditions for the transition probability matrices are indicated below:
Conditions for $S_{ik}$

i) $k < i-1$

This case arises when the number of messages in $t_e + 1$, (i.e., $k$), is less than that of $(t_e + I - 1)$ slot (i.e., $i$). The probability of a successful transmission is zero. This is because the number of messages after successful transmission should not be less than $i-1$. Therefore,

$$S_{ik} = 0$$ \hspace{1cm} (5.21)

ii) $k = i-1$

The number of messages in the $t_e + 1$ slot is equal to that of $t_e + I - 1$ slot. The probability that a successful transmission will occur indicates that there are no new arrivals but one backlogged terminal transmits. Therefore,

$$S_{ik} = \frac{iv (1 - \gamma)^{i-1} (1 - \sigma)^{M-1}}{[1 - (1 - \gamma)^i] [1 - \sigma]^{M-1}}$$ \hspace{1cm} (5.22)

where $iv (1 - \gamma)^{i-1}$ indicates that one of the backlogged stations transmitted. $(1 - \sigma)^{M-1}$ indicates that there are no new arrivals in the thinking device. And the factor $[1 - (1 - \gamma)^i] [1 - \sigma]^{M-1}$ denotes the probability that some terminal is ready.
iii) \( k = i \)

Here the number of messages in \( t_e + I - 1 \) and \( t_e + I \) slots are equal. This occurs when there is one new arrival and one backlogged station transmits.

\[
S_{ik} = \frac{\sigma ((M - i)(1 - \sigma)^{M-i-1}) i \gamma (1 - \gamma)^{i-1}}{[1 - (1 - \gamma)^i][1 - \sigma^{M-i}]} \tag{5.23}
\]

\((M - i)(1 - \sigma)^{M-i-1}\) denotes one new arrival and \(i \gamma (1 - \gamma)^{i-1}\) denotes one backlogged device has transmitted.

iv) \( k = i+1 \)

This condition states that there are \(i+1\) messages in the \( t_e + I \) slot. This occurs when there is one arrival and no transmissions.

\[
S_{ik} = \frac{\sigma ((M - i)(1 - \sigma)^{M-i-1}) (1 - \gamma)^i}{[1 - (1 - \gamma)^i][1 - \sigma^{M-i}]} \tag{5.24}
\]

v) \( k > i+1 \)

i.e., if the number of messages in the \( t_e + I \) slot exceeds \( i + 1 \) messages then there is no successful transmission. This
condition will occur because if the number of messages are 
more than i+1 then there will be a collision and the transmission 
will not be successful.

Therefore, we have

\[ S_{ik} = 0 \text{ for } k = i + 1 \]  \hspace{1cm} (5.25)

Conditions for \( F_{ik} \)

i) \( F_{ik} = 0 \) if \( k < i \)

This is because the transmission is unsuccessful and the 
umber of messages in the \( t_e + I \) slot should not be less than 
the number of messages in the \( t_e + I - 1 \) slot. So the probability 
of unsuccessful transmission is zero.

ii) \( k = i \)

If the number of messages in the \( t_e + I \) slot is the same 
as the number of messages in the \( t_e + I - 1 \) slot, then there 
are no new arrivals and one or two or more of the backlogged 
stations have transmitted.

The probability of no new arrivals is \((1 - \sigma)^{M-1}\).
Probability of one or two or more of backlogged terminals will 
transmit is given by

\[
= [1 - i\gamma (1 - \gamma)^{i-1} - (1 - \gamma)^i]
\]
therefore,

\[
F_{ik} = \frac{(1 - i \gamma (1 - \gamma)^{i-1} - (1 - \gamma)^i) (1 - \sigma)^{M-i}}{[1 - (1 - \gamma)^i (1 - \sigma)^{M-i}]} \tag{5.27}
\]

\(\text{iii) } k = i+1\)

Number of messages in the \(t_{e} + 1\) slot is \(i+1\). This condition will occur if there is one new arrival and one of the backlogged terminals transmitted. The probability of a new arrival is given by

\[
\sigma(M - i) (1 - \sigma)^{M-i-1}
\]

The probability of one of the backlogged stations has transmitted is given by

\[
[1 - (1 - \gamma)^i]
\]

Therefore, we have,

\[
F_{ik} = \frac{\sigma(M - i) [1 - \sigma]^{M-i-1} [1 - (1 - \gamma)^i]}{[1 - (1 - \gamma)^i (1 - \sigma)^{M-i}]} \tag{5.28}
\]

\(\text{iv) } k > i+1\)

If \(k > i+1\) there are \(k-i\) messages arriving at \(M-i\) stations which are in the thinking state. The probability for this
condition is given by

\[ F_{ik} = \frac{\binom{M-i}{k-i}(1-\sigma)^{M-k}(\sigma)^{k-1}}{[1-(1-\gamma)i(1-\sigma)^{M-i}]} \quad (5.29) \]

On the other hand all ready terminals in the interval 
\([t_e + I - 1, t_e + I]\) will sense the channel busy and will be blocked for transmission; these terminals remain in the backlogged state if they were already backlogged or switched to backlogged state if they are in the thinking state. For any slot \(t\), 
\([t_e + I - 1, t_e + I]\) probability of \(i\) users in the previous slot and \(k\) number of users in the current slot and is defined by \(Q_{ik}\), single-step transition matrix which is given by:

\[ Q_{ik} = Pr \left[ \frac{N^{te+I}}{N^{te} + I - 1} \right] \quad (5.30) \]

**Conditions for \(Q_{ik}\)**

1) \(k = i\),

\[ Q_{ik} = 0 \quad (5.31) \]

The two necessary neighbouring slots cannot have the same number of terminals.
ii) $k > i,$ 

$$Q_{ik} = \binom{M-i}{k-i} (1 - \sigma)^{M-k} \sigma^{k-i} \tag{5.32}$$ 

The average stationary channel throughput is computed as the ratio of the time, the channel carries successful transmission during a cycle (an idle period followed by a busy period) averaged over all the cycles, to the average cycle length [17].

The probability of channel carrying successful transmission during a cycle with $N^{te} = i$ is given by

$$P_s(i) = \frac{\sigma \left[ (M-i) (1-\sigma)^{M-i-1} (1-\gamma)^i + i \gamma (1-\gamma)^{i-1} (1-\gamma)^{M-i} \right]}{(1 - (1 - \gamma)^i) (1 - \sigma)^{M-i}} \tag{5.33}$$

The first term in the numerator indicates that there will be successful transmission if there is a new arrival and no backlogged transmission.

The second term in the numerator indicates only one of the backlogged stations transmits and all others remain silent. The denominator indicates that some terminal is ready.
Distribution of the length of Idle Period

Since the state of the system remains unchanged during the idle period,

\[ \delta_i = (1 - \gamma)^i (1 - \sigma)^{M-i} \]

is the probability that the system remains unchanged during the idle period given \( N^{te} = i \).

The idle period distribution is assumed to be a geometric distribution with a mean of \( 1 / (1 - \delta_i) \) for any two successive slots. Therefore, the average idle period is given by

\[ \frac{1}{1 - \delta_i} \]  \hspace{1cm} (5.34)

The throughput averaged over all cycles is given by

\[ S = \frac{\sum_{i=0}^{M} \pi_i P_s(i) T}{\sum_{i=0}^{M} \frac{1}{1 - \delta_i} + [1 + P_s(i)T] + (1 - P_s(i)\gamma)} \]  \hspace{1cm} (5.35)

The average channel backlog is computed as the ratio of the expected sum of backlogs over all slots in a cycle to the average cycle length [17]. The sum of all the slots includes both the idle and busy periods. The average idle period is given by \( 1/(1 - \delta_i) \).
The average backlog over the idle period is given by sum of backlog the system will encounter:

$$\sum_{i=0}^{M} \pi_i \left( \frac{i}{1 - \delta_i} \right)$$

(5.36)

The average busy period backlog will be obtained by the expected sum of backlogs over all slots in the busy period with $\tilde{N}_{\text{te}} = i$. In this case for each state we have to add the backlog for the entire busy period. So for each state the backlog for the entire slots in the busy period is calculated for $\tilde{N}_{\text{te}} = i$.

The average backlog $A_{(i)}$ can be obtained by summing all the states [18]:

$$A_{(i)} = \sum_{l=0}^{T} \sum_{j=1}^{M} [SQ^1]_{ij} + \sum_{l=0}^{T} \sum_{j=1}^{M} [FQ^1]_{ij}$$

(5.37)

It is obtained for the various possible cases of $S$ and $F$ for different $Q$'s. And now, the average channel backlog is computed as the ratio of the expected sum of backlogs over all slots in a cycle (averaged over all cycles), to the cycle length [17, 18, 20]. Therefore we have,

$$\frac{\sum_{i=0}^{M} \pi_i \left( \frac{i}{1 - \delta_i} + A_{(i)} \right)}{\sum_{i=0}^{M} \pi_i \left[ 1 - P_S(i) (1+r) + P_S(i) (T+1) + \frac{1}{1 - \delta_i} \right]}$$

(5.38)
By Little result [17, 18] the average packet delay (normalised to $T$) is defined as the time lapse from the instant the packet is first generated until it is successfully received by the destination device, and is expressed as:

$$D = \frac{N^1}{S}$$

Substituting $N^1$ and $S$, we get, the average packet delay as:

$$D = \frac{1}{M} \sum_{i=0}^{M} \frac{\pi_i \left[ \left( \frac{1}{1 - \delta_i} \right) + A_{(i)} \right]}{\sum_{i=0}^{M} \pi_i \left[ (1 - P_S(i)) (1 + r) + P_S(i) (T + 1) + \frac{1}{1 - \delta_i} \right]}$$

$$= \frac{1}{M} \sum_{i=0}^{M} \frac{\pi_i \left[ (1 - P_S(i)) (1 + r) + P_S(i) (T + 1) + \frac{1}{1 - \delta_i} \right]}{\sum_{i=0}^{M} \pi_i \left[ P_S(i) T \right]}$$

$$= \frac{1}{M} \sum_{i=0}^{M} \frac{\pi_i \left[ \left( \frac{1}{1 - \delta_i} \right) + [1 + P_S(i).T] + [1 - P_S(i).r] \right]}{\sum_{i=0}^{M} \pi_i \left[ \left( \frac{1}{1 - \delta_i} \right) \right]}$$

(5.40)

5.6 CONCLUSION

In this chapter a detailed modelling for the delay and throughput has been developed based on the slotted version of CSMA/CD for an Optical Star LAN using the Queueing theory and Markovian process. The analytical modelling was performed
to obtain the performance parameters. From the equations of the models, the performance parameters such as throughput, average packet delay, average backlog, and channel utilization can be found out and compared with that of bus network. The bus contention period for a star network is shown to be \((a+b)\), which can be compared to the bus contention period of the bus network with identical geometric dimensions, namely \((2a+b)\). Thus the star network has better performance parameters than that of the corresponding bus network.

The delay and throughput comparison for star and bus topology is carried out for a wide range of values 'a', and is discussed in Chapter-6.
BEGIN TRANSMISSION

Fig 5.1(b) 1-PERSISTENT CSMA/CD PROTOCOL ALGORITHM

Fig 5.1(a) NON-PERSISTENT CSMA/CD PROTOCOL ALGORITHM

Fig 5.1(c) P-PERSISTENT CSMA/CD PROTOCOL ALGORITHM
Fig 5-2  ARCHITECTURAL MODEL OF CSMA/CD ACCESS METHOD
Fig 5.3 QUEUE MODEL FOR STAR LAN
Fig 5.4 COLLISION PROCESS IN CSMA/CD STAR
Fig 5.5 CONTENTION PERIOD IN OSLAN