Chapter 6

13. *M* terminals are attached by a dedicated pair of lines to a hub in a star topology. The distance from each terminal to the hub is *d* meters, the speed of the transmission lines is *R* bits/second, all frames are of length 12500 bytes, and the signal propagates on the line at a speed of 2.5 (10^8) meters/second. For the four combinations of the following parameters {d = 25 meters or d = 2500 meters; R = 10 Mbps or R = 10 Gbps}, compare the maximum network throughput achievable when the hub is implementing: Slotted ALOHA; CSMA/CD.

Solution:

L = 12500 x 8 bits, $t_{prop} = d$ / (2.5 x 10^8 meters/sec), $a = t_{prop} R/L$

Values for a:

R/d

	2x25	2x2500
1.00E+07	2E-05	2E-03
1.00E+10	2E-02	2E+00

Maximum Throughput for Slotted ALOHA:

R/d

	2x25	2x2500
1.00E+07	0.367879	0.367879
1.00E+10	0.367879	0.367879

Maximum throughput for CSMA-CD:

R/d

	2x25	2x2500
1.00E+07	0.999872	0.98736
1.00E+10	0.886525	0.07246

15. A wireless LAN uses polling to provide communications between *M* workstations and a central base station. The system uses a channel operating at 25 Mbps. Assume that all stations are 100 meters from the base station and that polling messages are 64 bytes long. Assume that frames are of constant length of 1250 bytes. Assume that stations indicate that they have no frames to transmit with a 64-byte message.

Solutions follow questions:

d = 100 m between the base station and the stations
$v = 3 \times 10^8$ m/sec
$t_{prop} = 100 / (3 \times 10^8) = 0.33\ \mu sec$
R = 25 Mbps
X_{frame} = 10000/25Mbps = 400 μsec
X_{poll} = 512/25Mbps = 20 μsec
R = 2.5 Gbps
X_{frame} = 10000/2.5Gbps = 4 μsec
X_{poll} = 512/2.5Gbps = 0.2 μsec
$X_{end} = X_{poll}$

a. What is the maximum possible arrival rate that can be supported if stations are allowed to transmit an unlimited number of frames/poll?

$\rho_{max} = 1$ and $\rho = \lambda X$
R = 25 Mbps
λ_{max} = 1/400 μsec = 2,500 frames/sec

b. What is the maximum possible arrival rate that can be supported if stations are allowed to transmit N frames/poll?

$$\rho_{max} = \frac{MNX_{frame}}{M\{NX_{frame} + X_{end} + X_{poll} + 2t_{prop}\}} = \frac{1}{1+\frac{20+20+0.66}{400N}} \approx \frac{1}{1+\frac{0.1}{N}}, \quad \lambda_{max} = \frac{\rho_{max}}{X}$$ as N increases, ρ_{max} approaches 1.

R = 25 Mbps
N = 10, ρ_{max} = 99%
λ_{max} = 1/400μ = 2,500 frames/sec

c. Repeat parts (a) and (b) if the transmission speed is 2.5 Gbps.

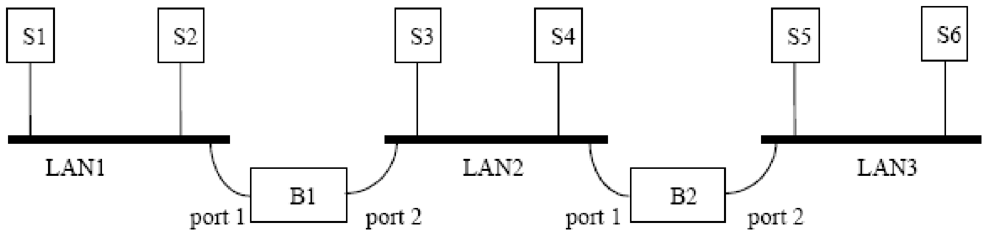
(a) R = 2.5 Gbps
ρ_{max} = 1
λ_{max} = 1/4 μsec = 250,000 frames/sec

(b) R = 2.5 Gbps

$$\rho_{max} = \frac{1}{1+\frac{0.2+0.2+0.66}{4N}} \approx \frac{1}{1+\frac{0.26}{N}}, \quad \lambda_{max} = \frac{\rho_{max}}{X}$$

N = 10,
ρ_{max} = 97.4%
λ_{max} = 0.788/4μ = 243,700 frames/sec

52. Six stations (S1-S6) are connected to an extended LAN through transparent bridges (B1 and B2), as shown in the figure below. Initially, the forwarding tables are empty. Suppose the following stations transmit frames: S2 transmits to S1, S5 transmits to S4, S3 transmits to S5, S1 transmits to S2, and S6 transmits to S5. Fill in the forwarding tables with appropriate entries after the frames have been completely transmitted.



Station	Port

Station	Port

Solution:

Station	Port
S2	1
S5	2
S3	2
S1	1

Station	Port
S2	1
S5	2
S3	1
[redacted]	
S6	2

Chapter 4

10. Suppose a multiplexer has two input streams, each at a nominal rate of 1 Mbps. To accommodate deviations from the nominal rate, the multiplexer transmits at a rate of 2.2 Mbps as follows. Each group of 22 bits in the output of the multiplexer contains 18 positions that always carry information bits, nine from each input. The remaining four positions consist of two flag bits and two data bits. Each flag bit indicates whether the corresponding data bit carries user information or a stuff bit because user information was not available at the input.

a. Suppose that the two input lines operate at exactly 1 Mbps. How frequently are the stuff bits used?

In this case, the stuff bits are always used because the information bits alone only provide an aggregate bit rate of 1.8 Mbps.

b. How much does this multiplexer allow the input lines to deviate from their nominal rate?

This multiplexer provides either 9 or 10 bits for each stream per 22-bit frame. Thus, it allows either of the two input streams to transmit as low as 0.9 Mbps and as high as 1.0 Mbps.

12. SONET allows positive or negative byte stuffing to take place at most once every four frames. Calculate the minimum and maximum rates of the payload that can be carried within an STS-1 SPE.

Solution:

STS-1 rate = 51.84 Mbps

Payload rate = 50.112 Mbps

Frame = 125 μsec

Drifts = (8 bits) / (4 x 125 μsec) = 0.016 Mbps

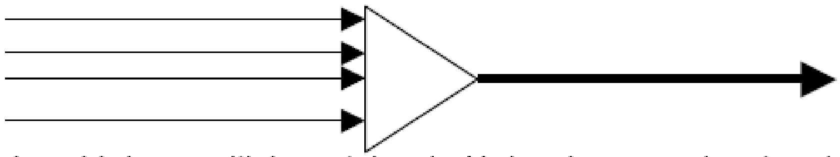
Maximum payload rate = 50.112 + 0.016 = 50.128 Mbps

Minimum payload rate = 50.112 – 0.016 = 50.096 Mbps

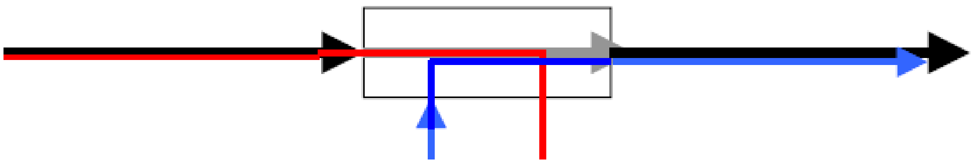
25. Compare the operation of a multiplexer, an add-drop multiplexer, a switch, and a digital cross-connect.

Solution:

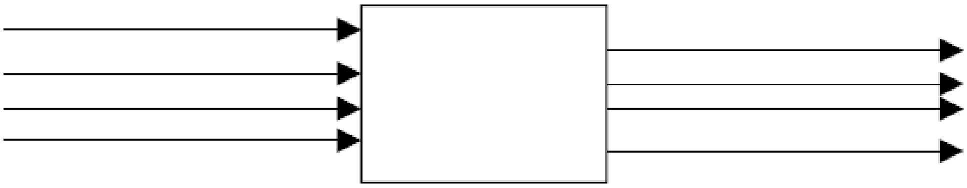
A multiplexer is a 1:*N* device. It takes *N* separate signals on *N* different inputs and combines them into one higher rate signal on one output port.



An add-drop multiplexer takes in *N* signals on one input port and replaces one of them with a new signal from a separate input port. The new aggregate signal is routed to an output port and the signal that was replaced is "dropped" to a separate output port.



A switch takes in *N* inputs and routes them to *N* different outputs. Frequently each input to a switch contains a number of multiplexed connections. These connections can be demultiplexed and routed to different output ports where they are aggregated prior to exiting the switch. Generally, switches are configured using signaling that establishes paths across the network.



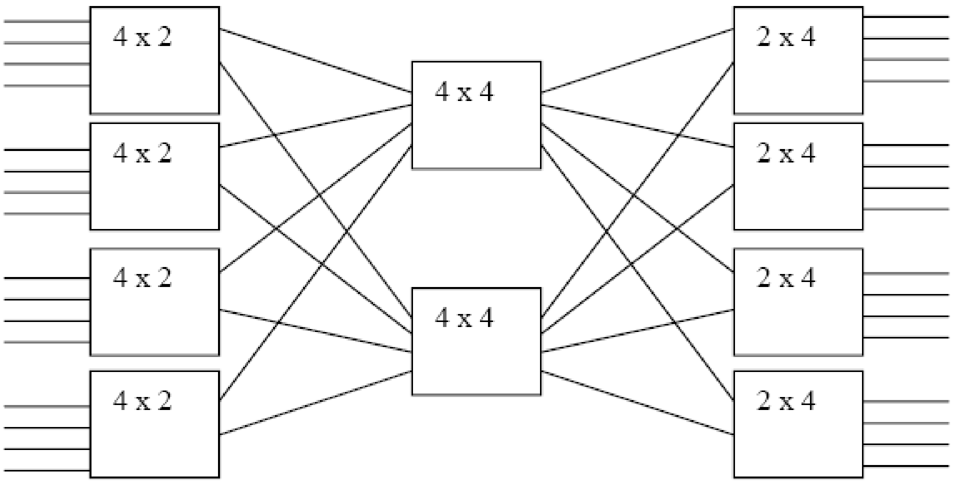
A digital cross-connect is similar to a switch except that it is semi-permanent, usually configured by network operators rather than signaling processes. Their configuration is also done on a larger time scale (days or weeks). Digital cross-connects provide a basic network topology on which routing can be applied.

27. Consider the multistage switch in Figure 4.35 with $N = 16$, $n = 4$, $k = 2$.

Solutions follow questions:

a. What is the maximum number of connections that can be supported at any given time? Repeat for $k = 4$ and $k = 10$.

For $N = 16$, $n = 4$ and $k = 2$, we have the following switch architecture:



Thus, the second stage is the bottleneck, and blocking can occur in the first stage. Thus, eight connections can be supported at a time.

If $k = 4$, then blocking will occur if we are not allowed to rearrange connections. It can be shown that in this case blocking can be avoided if we are allowed to rearrange the connection pattern every time a new connection request is made.

If $k = 10$, then there are ten 4 x 4 switches in the second stage. Since there are only 16 inputs and 16 outputs, the switch can accommodate any set of connections without blocking.

b. For a given set of input-output pairs, is there more than one way to arrange the connections over the multistage switch?

As shown in the picture in part (a), it is clear that each input-output pair can be connected through any one of the k second-stage switches. Thus, there are k ways to arrange the connections over a multi-stage switch.

29. Consider the multistage switch in Figure 4.35 with $N = 32$. Compare the number of crosspoints required by a nonblocking switch with $n = 16$, $n = 8$, $n = 4$, and $n = 2$.

Solution:

For any switch to be non-blocking, we require $k_{nb} = 2n - 1$. The total number of crosspoints is $2Nk + k(N/n)^2$. The resulting number of crosspoints necessary for different values of *n* is shown below.

N	*n*	*k*	Number of Crosspoints needed
32	16	31	2108
32	8	15	1200
32	4	7	896
32	2	3	960

For a one-stage *N* x *N* switch with $n = 32$, we would require 1032 crosspoints. Thus we see that, just as was noted in question 26c, for *k* much less than *n*, multistage switches can provide good hardware economy while remaining non-blocking.