Electrical and Information Technology

Communication and Networks

Problems Link Layer

2016

Problems

1. Consider a network applying a slotted Aloha access system. The assumption for this is that all nodes are perfectly synchronised and that the slot time is T, which is also the packet duration time. Packets arriving to a node for transmission will be transmitted during the next slot. In average there are G packets transmitted arriving to nodes in the network during a slot, meaning that this is also the average number of transmitted packets during a slot. With many nodes in the network it is reasonable to assume packets arrive according to a Poisson distribution, which gives the probability of k packets in a slot as

$$P(k) = \frac{G^k e^{-G}}{k!}$$

   (a) What is the probability for a packet to be successfully transmitted (and received) over the network?

   (b) What is the throughput over the network? The throughput is the expected number of successfully transmitted packets per slot.

(c) Derive the maximum throughput in an Aloha system.

(d) In un-slotted Aloha the nodes are not synchronised, and will start transmitting as soon as a packet arrives at the node. For that case the probability of success changes a bit. Redo the derivations in problem a-c for this case.

2. For a pure ALOHA, it can be proved that if the number of frames generated during one frame transmission time is G, then the average number of successful transmissions is $S = G \times e^{-2G}$. Consider a network using pure ALOHA that transmits 150-bit frames on a shared channel of 300 kbps. What will be the throughput if the number of frames produced in a second is 1500?

3. Below is a printout of an Ethernet frame taken from a sniffing tool. The preamble, SFD and CRC is not included in the trace.

```
0000 ff ff ff ff ff ff 08 60 6e 7a a6 a4 08 00 45 00
0010 00 44 0e 79 00 00 80 11 91 11 82 eb c9 48 82 eb
0020 cb ff c5 aa 07 9b 00 30 8e 01 50 5a 38 70 61 6d
0030 48 38 7a 65 5a 74 74 4f 6f 7a 58 65 36 4e 42 52
0040 6b 44 4c 49 73 65 49 52 75 77 4c 64 6b 36 73 75
0050 38 41
```

(a) What is the destination address? Which station(s) is it aimed for?

(b) What is the source address?

(c) What does the type/length field tell us?

(d) What is content of the first and the last byte of the payload?

4. What is an Ethernet II frame's maximum and minimum efficiency? Include all control fields as well as preamble and SFD in your calculations.

5. The maximum length of a 10BASE5 link is 2.5km. What is the minimum length of an Ethernet II frame in worst case so that collision detection works? The propagation speed in a coaxial copper cable is approximately 60% of the speed of light in vacuum.

6. Six channels, each with a bandwidth of 150 kHz, have to be multiplexed together using FDM. A guard bandwidth of 10 kHz is needed between any two adjacent channels to prevent interference. What should be the minimum bandwidth of the link in order to enable the communication?

7. Consider a simple telephone network consisting of two end offices of one intermediate switch with a 1 MHz full-duplex trunk between each end office and the intermediate switch. Assume a 4 kHz channel for each voice call. The average telephone is used to make four calls per 8 hour workday, with a mean call duration of 6 minutes. Ten percent of the calls are long distance. What is the maximum number of the telephones an end office can support?

8. (a) Instead of LLC, could HDLC be used as a data link control protocol for a LAN? If not, what is lacking?

   (b) An asynchronous device, such as a teletype, transmits characters one at a time with unpredictable delays between characters. What problems, if any, do you foresee if such a device is connected to a LAN and allowed to transmit at will (subject to gaining access to the medium)? How might such problems be resolved?

9. A baseband has 5 stations equally spaced at 500 m from one another. The data rate of the bus is 50Mbps and the propagation speed is 10^5 km/s.

   (a) What will be the total time taken to send a package of 2KB from any station to its adjacent station, measured from the beginning of transmission to the end of reception?

   (b) What will be the total time taken to send the package from a station at one end to the station at the other end, measured from the beginning of transmission to the end of reception, if the delay of each intermediate node is 10^{-5} seconds?

   (c) If two adjacent stations begin to transmit at exactly the same time, when will their packets interfere with each other?

10. Consider the transfer of a file containing one million 8-bit characters from one station to another. What is the total elapsed time and effective throughput for the following cases:

(a) A circuit-switched, star-topology local network. Call setup time is negligible and the data rate on the medium is 64 Kbps.

(b) A bus topology local network with two stations a distance D apart, a data rate of B bps, and a frame size of P with 80 bits overhead per frame. Each frame is acknowledged with an 88-bit frame before the next is sent. The propagation speed on the bus is 200 m/μs. Solve for:

1. $D = 1$ km, $B = 1$ Mbps, $P = 256$ bits;
2. $D = 10$ km, $B = 1$ Mbps, $P = 256$ bits;
3. $D = 1$ km, $B = 50$ Mbps, $P = 10,000$ bits.

Solutions

1. (a) For a packet to be successfully transmitted there must be one packet transmitted in that slot. If there is zero packets, of course zero packets will be received, and if there are more than one packet there will be a collision and no packets are received. So

$$P(\text{success}) = P(k=1) = Ge^{-G}$$
$$P(\text{no success}) = 1 - Ge^{-G}$$

(b) The throughput is the number of successes per slot,

$$\rho = E[\text{success}] = 1 \cdot Ge^{-G} + 0 \cdot (1 - Ge^{-G}) = Ge^{-G}$$

(c) Maximisation gives

$$\frac{\partial}{\partial G} Ge^{-G} = (1-G)e^{-G} = 0 \quad \Rightarrow \quad G_{\text{opt}} = 1$$

Hence,

$$\rho_{\text{opt}} = e^{-1} \approx 37\%$$

(d) Assume the same settings as before, i.e. the packet duration is T and the probability for k packets in that time is is $P(k) = \frac{G^k e^{-G}}{k!}$. In an un-slotted system a node starts transmitting as soon as it a packet arrives. So for a successful transmission the channel must be empty when a packet arrives (say time $t = 0$). That means there should be no other packets arriving during time T before this. There should also be no other packets arriving until after time T. These two event are independent, thus,

$$P(\text{success}) = P(0 \text{ pkt in } -T \le t < 0) \cdot P(1 \text{ pkt in } 0 \le t < T)$$
$$= e^{-G} Ge^{-G} = Ge^{-2G}$$
$$P(\text{no success}) = 1 - Ge^{-2G}$$

The throughput is

$$\rho = E[\text{success}] = Ge^{-2G}$$

and maximisation gives

$$\frac{\partial}{\partial G} G e^{-2G} = (1 - 2G)e^{-2G} = 0 \quad \Rightarrow \quad G_{\text{opt}} = \frac{1}{2}$$

Hence,

$$\rho_{\text{opt}} = \frac{1}{2} e^{-1} \approx 18\%$$

2. Frame transmission time = Frame size/Bit rate = $150/(300 \times 10^3) = 0.0005$ s.
   Number of frames produced in a second = 6000.
   Number of frames produced in a frame transmission time, $G = 1500 \times 0.0005 = 0.75$.
   Hence, $S = G \times e^{-2G} = 0.75 \times e^{-2\times 0.75} = 0.167$ or 16.7%.

3. (a) The destination is the broadcast address, thus all stations must act as receivers.
   (b) `08 60 6e 7a a6 a4`
   (c) The type/length field contains `08 00`. This is > 1500 so it cannot be a frame length. Thus it indicates that the field is type field and that this ethernet frame is of type Ethernet II. Type `08 00` tells us that the payload is an IPv4 datagram.
   (d) The first payload byte contains `45` (like most IPv4 datagrams) and the last byte contains `41` (CRC is not included).

4. Control fields, preamble and SFD make up $8 + 14 + 4 = 26$bytes. Minimum frame size is $64 + 8$ bytes even if the frame carries only 1 byte of data. Thus, the efficiency in this case is $1/72 = 1,4$%. The maximum payload size is 1500 bytes giving an efficiency of $1500/1526 = 98$%.

5. Worst case is if two stations are connected to the extreme ends of the link and the station in one end starts transmitting just as the signal from the other station reaches this end. Also consider that there is no ARQ method deployed in Ethernet; a sending station has to transmit a packet long enough for a collision to be detected otherwise there is no way for the sender to know that the current frame has been destroyed. So the sender must still transmit for the time a frame front has reached the other end of the

link and a collision occurring in that has reached this sender. The one-way propagation time is $2500/180 \times 10^9 = 13.8 \times 10^{-6}$ seconds, thus the time a sender has to keep sending is $2 \times 13.8 \times 10^{-6} = 27.6 \times 10^{-6}$ seconds. One bit time is $1/10 \times 10 \times^6 = 0.1 \times 10^{-6}$ seconds. The sender has to send at least $27.6/0.1 = 276$ which is $276/8 = 34.5$ bytes. Alas, sending a frame with only 1 byte as payload is not enough.

6. Minimum bandwidth of the link = $(6 \times 150) + (5 \times 10) = 950$ kHz.

7. Each telephone makes 0.5 calls/hour at 6 minutes each. Thus a telephone occupies a circuit for 3 minutes per hour. Twenty telephones can share a circuit (although this 100% utilization implies long queuing delays). Since 10% of the calls are long distance, it takes 200 telephones to occupy a long distance (4 kHz) channel full time. The interoffice trunk has $10^6/(4 \times 10^3) = 250$ channels. With 200 telephones per channel, an end office can support $200 \times 250 = 50,000$ telephones.

8. (a) HDLC has only one address field. In a LAN, any station may transmit to any other station. The receiving station needs to see its own address in order to know that the data is intended for itself. It also needs to see the sending address in order to reply.

   (b) Each individual character could be sent out as a separate packet, resulting in tremendous overhead. This problem could be overcome by buffering characters and only sending out blocks of characters.

9. (a) Distance between adjacent stations is 500 m,
   total Time = transmission time + propagation time
   = size of packet/data rate + distance/propagation speed
   = $(2 \times 1024)/(50 \times 10^6) + 500/(100 \times 10^5) = 90.96\mu$s.

   (b) Number of hops = 5-1=4.
   Number of intermediate nodes = 3.
   Time taken for traversing 1 hop = 90.96μs.
   Delay at each hop = 10^{-5} s = 10μs.
   Total time = $4 \times 90.96 + 3 \times 10 = 393.84\mu$s.

(c) As both the packets have same traversing speed, they will collide at a distance of $500/2 = 250$m from any end. As collision occurs when the first bits of the packets meet, only propagation time is considered:
Time = distance /propagation speed = $250/(100 \times 10^5) = 25\mu$s.

10. (a) $T = (8 \times 10^6 \text{ bits})/(64 \times 10^3 \text{ bps}) = 125$ seconds.

(b) Transfer consists of a sequence of cycles. One cycle consists of:
Data Packet = Data Packet Transmission Time + Propagation Time
ACK Packet = ACK Packet Transmission Time + Propagation Time
Define:
C = Cycle time
Q = data bits per packet
T = total time required
Td = Data Packet Transmit Time
Ta = ACK Packet Transmit Time
Tp = Propagation Time
Then:
Tp = $(D)/(200 \times 10^6$ m/sec)
Ta = (88 bits)/(B bps)
Td = (P bits)/(B bps)
T = (8×10^6 bits $\times C$ sec/cycle)/(Q bits/cycle)
$C = Ta + Td + 2Tp$
$Q = P - 80$
Therefore,

1. $C = (88)/(10^6) + (256)/(10^6) + (2 \times 10^3)/(200 \times 10^6) = 354 \times 10^{-6}$
   $Q = 176$
   $T = (8 \times 10^6 \times 354 \times 10^{-6})/(176) = 16$ seconds.
2. $C = (88)/(10^6) + (256)/(10^6) + (2 \times 10^4)/(200 \times 10^6) = 444 \times 10^{-6}$
   $Q = 176$
   $T = (8 \times 10^6 \times 444 \times 10^{-6})/(176) = 20$ seconds.
3. $C = (80)/(50 \times 10^6) + (10^4)/(50 \times 10^6) + (2 \times 10^3)/(200 \times 10^6) = 211.6 \times 10^{-6}$
   $Q = 9,920$
   $T = (8 \times 10^6 \times 211.6 \times 10^{-6})/(9920) = 0.17$ seconds.