Medium Access Control (MAC) Layer

Prof Vijay Ukani
CSE Department
Institute of Technology
Nirma University

Probability

Q. A disadvantage of a broadcast subnet is the capacity wasted when multiple hosts attempt to access the channel at the same time. As a simplistic example, suppose that time is divided into discrete slots, with each of the n hosts attempting to use the channel with probability p during each slot. What fraction of the slots are wasted due to collisions?

Ans. Distinguish total events into n+2 events.

Events 1 through n consist of the corresponding host successfully attempting to use the channel, i.e., without a collision. The probability of each of these events is $p(1-p)^{n-1}$.

Event n+1 is an idle channel, with probability $(1-p)^n$.

Event n+2 is a collision.

Since these n+2 events are exhaustive, their probabilities must sum to unity. The probability of a collision, which is equal to the fraction of slots wasted, is then just

$1 - np\,(1-p)^{n-1} - (1-p)^n$.

Probability

Q. In some networks, the data link layer handles transmission errors by req uesting damaged frames to be retransmitted. If the probability of a frame's being damaged is p, what is the mean number of transmissios required to s end a frame? Assume that the acknowledgements are never lost.

Ans. The probability Pk, of a frame requiring exctly k transmissions is the pr obability of the first k-1 attempts failing, and k^{th} attempt is successful is

p^{k-1} x (1-p)

The mean number of transmission is then just

$$\sum_{k=1}^{\infty} kPk = \sum_{k=1}^{\infty} k.p^{k-1}(1-p) = \frac{1}{1-p}$$

Aloha

- Consider the delay of pure ALOHA versus slotted ALOHA at low load. Which one is less?

Ans. With pure ALOHA, transmission can start instantly. At low load, no collisions are expected so the transmission is likely to be successful. With slotted ALOHA, it has to wait for the next slot. This introduces half a slot time of delay.

Aloha

- A large population of ALOHA users manages to generate 50 requests/sec, including both originals and retransmissions. Time is slotted in units of 40 msec.

(a) What is the chance of success on the first attempt?

(b) What is the probability of exactly k collisions and then a success?

Ans. With 25 slots/second and an average or 50 requests/second, we have G = 2. Then use the slotted Aloha formula for efficiency.

(a) With G = 2 Poisson's Law gives a probability of e^{-2}.

(b) $(1 - e^{-G})^k e^{-G} = 0.135 \times 0.865k$.

probability of success : e^-G

CSMA/CD

- A 1-km-long, 10-Mbps CSMA/CD LAN (not 802.3) has a propagation speed of 200 m/μsec. Repeaters are not allowed in this system. Data frames are 256 bits long, including 32 bits of header, checksum, and other overhead. After a successful reception, receiver sends a 32-bit acknowledgement frame. What is the effective data rate, excluding overhead, assuming that there are no collisions?
- Ans. The RTT of the cable is 10 μ sec. A complete transmission has six phases:

x2

1. Transmitter seizes cable (10 μ sec)
2. Transmit data (25. 6 μ sec) 256/10^7
3. Delay for last bit to get to the end (5. 0 μ sec) (10^3/200) * 10^-6
4. Receiver seizes cable (10 μ sec)
5. Acknowledgement sent (3. 2 μ sec) 32/10^7
6. Delay for last bit to get to the end (5. 0 μ sec)

The sum of these is 58. 8 μ sec. In this period, 224 data bits are sent, for a rate of about 3.8 Mbps. 224/58.8*10^-6

start ACK transmission + Data transmission + ACK + end ACK transmission + ACK sent + ACK

CSMA/CD

Q. What is the length of a contention slot in CSMA/CD for
(a) a 2-km twin-lead cable (signal propagation speed is 82% of the signal propagation speed in vacuum)?, and
(b) a 40-km multimode fiber optic cable (signal propagation speed is 65% of the signal propagation speed in vacuum)?.

Ans. (a) Signal propagation speed in twin lead is 2.46×10^8 m/sec. Signal propagation time for 2 km is 8.13 μ sec. So, the length of contention slot is 16.26μ sec.

(b) Signal propagation speed in multimode fiber is 1.95×10^8 m/s. Signal propagation time for 40 km is 205.13 μ sec. So, the length of contention slot is 410.26 μ sec.

CSMA/CD ☆

Q. How long does a station s, have to wait in the worst case before it can start transmitting its frame over a LAN that uses the basic bit-map protocol?

Ans. The worst case is where all stations want to send, s is the highest-numbered station out of the N stations (who sends last in the cycle), and s becomes ready to send just after the bitmap has passed. Station s must wait $(N - 1) \times d$ bit times for the transmission of the other stations before a new contention cycle begins, N bit times for a contention bitmap, and $(N - 1) \times d$ bits for transmission of other frames before its frame starts. The total is $N + 2(N - 1)d$ bit times. This is worse than the delay in steady-state when all stations want to send; each station must then wait $N + (N - 1)d$ bit times after its frame for all other stations and a contention bitmap until it begins to send again.

CSMA/CD ☆

- An IP packet to be transmitted by Ethernet is 60 bytes long, including all its headers. If LLC is not in use, is padding needed in the Ethernet frame, and if so, how many bytes?
- Ans. The minimum Ethernet frame is 64 bytes, including both addresses in the Ethernet frame header, the type/length field, and the checksum. Since the header fields occupy 18 bytes and the packet is 60 bytes, the total frame size is 78 bytes, which exceeds the 64-byte minimum. Therefore, no padding is used.

CSMA/CD

Ethernet frames must be at least 64 bytes long to ensure that the transmitter can detect collisions. A faster Ethernet has the same minimum frame size but can transmit 10 times faster. How is it possible to still detect collisions?

Ans.

In order to detect collisions, the station must be still transmitting when the first bit reaches the far end of the cable. As the network speed goes up, the minimum frame length must go up or the maximum cable length must come down proportionally.

Indeed, let: u=speed of signal, l = length of the cable, and s=data rate (bps)

Then the minimum frame size is: $x=s*l/u$.

Thus, since x is the same for both Ethernet and Fast Ethernet, and s in Fast Ethernet is 10 times as much as in Ethernet, l, the wire length, must be 1/10 as long as in Ethernet.

CSMA/CD

Assume CSMA/CD protocol. Find the minimum frame length for a 1Mbps bit rate and maximum network span of 10 kilometers with no repeaters. Assume a medium propagation delay of 4.5 nanoseconds per meter. Is CSMA/CD a reasonable protocol for a network of this span and bitrate

•Ans.

Minimum frame size for CSMA/CD is 2 * $T_{pr.}$

Propogation Delay: $T_{pr} = (4.5 * 10^{-9})*(10 * 10^{3}) = 4.5 * 10^{-5}$ sec

Thus, Min frame length = $1 * 10^{6} * 9 * 10^{-5}$) = 11.25 bytes

CSMA/CD would be a very reasonable protocol for a network of this span and speed since the minimum frame size is not " excessive" (e.g. larger than 64 bytes)

Limited Contention Protocol

Sixteen stations, numbered 1 through 16, are contending for the use of a shared channel by using the adaptive tree walk protocol. If all the stations whose addresses are prime numbers suddenly become ready at once, how many bit slots are needed to resolve the contention?

Ans. Stations 2, 3, 5, 7, 11, and 13 want to send. The contents of each slot being as follows:

Slot 1: 2, 3, 5, 7, 11, 13

Slot 2: 2, 3, 5, 7

Slot 3: 2, 3

Slot 4: 2

Slot 5: 3

Slot 6: 5, 7

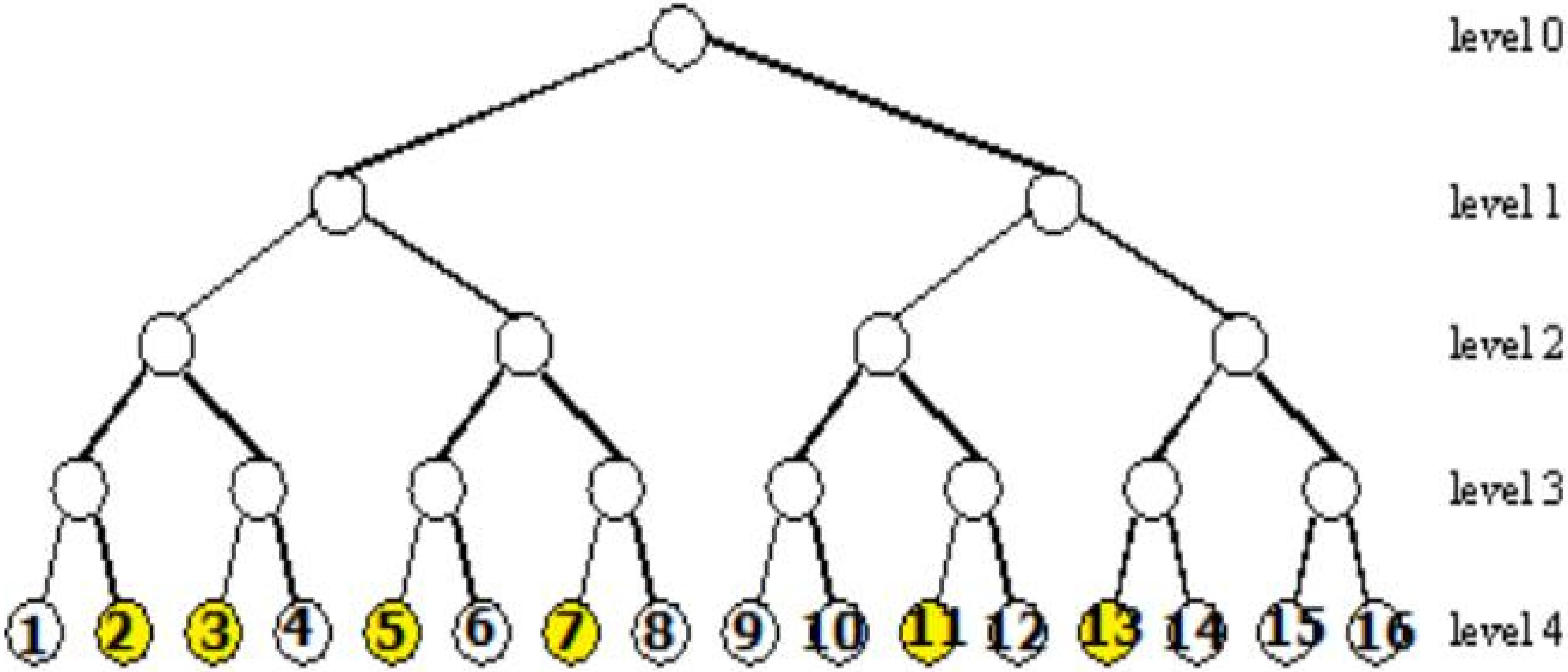
Slot 7: 5

Slot 8: 7

Slot 9: 11, 13

Slot 10: 11

Slot 11: 13



Total 11 slots are needed to resolve the contention

Wireless LAN

Consider five wireless stations, A,B,C, D, and E. Station A can communicate with all other stations. B can communicate with A, C and E. C can communicate with A, B and D. D can communicate with A, C and E. E can communicate A,D and B.

(a) When A is sending to B, what other communications are possible?

(b) When B is sending to A, what other communications are possible?

(c) When B is sending to C, what other communications are possible?

Ans. For successful communication we require that the sender can reach (communicate with) the receiver, and that there be no other sender who can reach (now interfere with) the receiver. Also, a station cannot send and receive at the same time.

a)Since all stations will see A's packet, it will interfere with receipt of any other packet by any other station. So, no other communication is possible in this case.

b)B's packet will be seen by E , A and C, by not by D. Thus, E or C might try to send to D at the same time. However, E and C can communicate with A, so this would interfere with B's transmission to A. Thus no other communication is possible.

c)B's packet will be seen by E , A and C, by not by D. Thus, E or A might try to send to D at the same time. Of these two possibilities, A can communicate with C, so this would interfere with B's transmission to A. But E can safely send to D since it will not interfere with C 's reception.

Wireless LAN

Six stations, A through F, communicate using the MACA protocol. Is it possible for two transmissions to take place simultaneously?

Ans. Yes.

Imagine that they are in a straight line and that each station can reach only its nearest neighbors. Then A can send to B while E is sending to F .

Wireless LAN ☆

Suppose that an 11-Mbps 802.11b LAN is transmitting 64-byte frames back-to-back over a radio channel with a bit error rate of 10^{-7}. How many frames per second will be damaged on average?

Ans.

A frame contains 512 bits. The bit error rate is $p = 10^{-7}$.

The probability of all 512 of them surviving correctly is $(1 - p)^{512}$, which is about 0.9999488. The fraction damaged is thus about 5×10^{-5} .

The number of frames/sec is $11 \times 10^{6} /512$ or about 21,484.

Multiplying these two numbers together, we get about 1 damaged frame per second.

Wireless LAN

Bluetooth uses FHSS with 1600 hops per second. What is the dwell time?

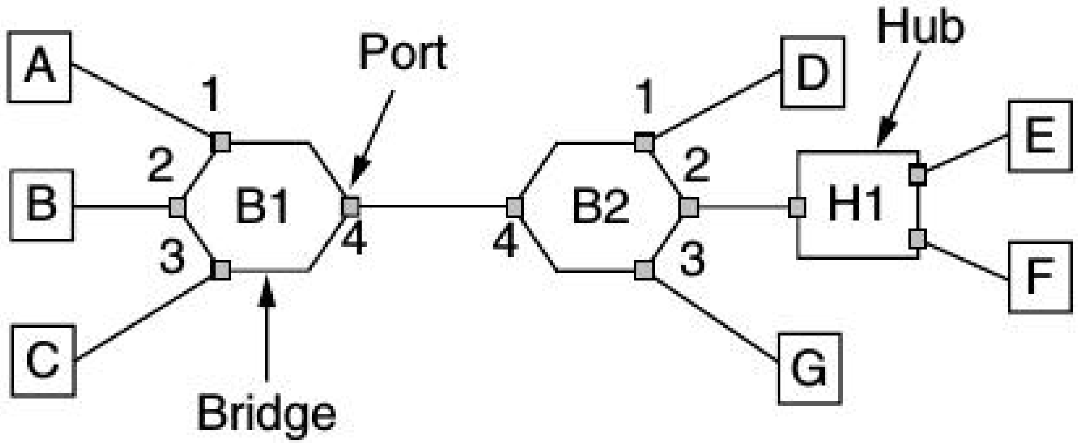
Ans.

Dwell time is time spent on each frequency channel. Since in Bluetooth network the hopping rate is 1600 hops per second, time spent on each channel is 1/1600 sec

Bridges

Suppose the hash tables in the two bridges are empty. List all ports on which a packet will be forwarded for the following sequence of data transmissions:

a)A sends a packet to C.
b)E sends a packet to F.
c)F sends a packet to E.
d)G sends a packet to E.
e)D sends a packet to A.
f)B sends a packet to F.

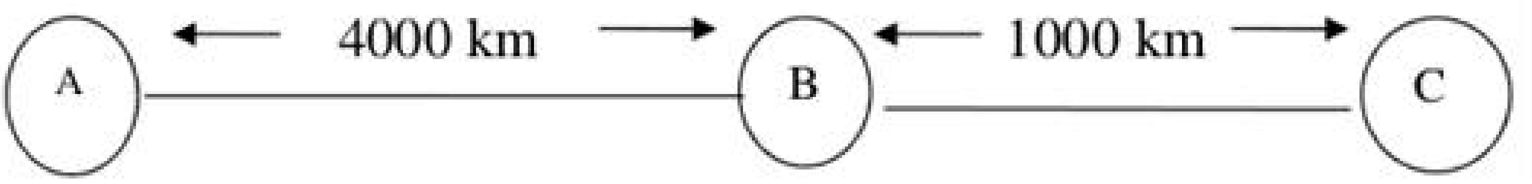


Ans. (a) B1 will forward this packet on ports 2, 3, and 4. B2 will forward it on 1, 2 and 3.
(b) B2 will forward this packet on ports 1, 3, and 4. B1 will forward it on 1, 2 and 3.
(c) B2 will not forward this packet on any of its ports, and B1 will not see it.
(d) B2 will forward this packet on port 2. B1 will not see it.
(e) B2 will forward this packet on port 4 and B1 will forward it on port 1.
(f) B1 will forward this packet on ports 1, 3 and 4. B2 will forward it on port 2.

☆ Forwarding (1)

In following figure frames are generated at node A and sent to node C through node B. Determine the minimum transmission rate required between nodes B and C so that the buffers at node B are not flooded, based on the following:

- The data rate between A and B is 100 kbps.
- The propagation delay is 5 μsec/km for both lines
- There are full--duplex, error--free lines between the nodes.
- All data frames are 1000 bits long; ACK frames are separate frames of negligible length.
- Between A and B, a sliding-window protocol with window size 3 is used.
- Between B and C, stop and wait is used.



Forwarding (2)

In order not to flood the buffers of B, the average number of frames entering and leaving B must be the same over a long interval.

- A -> B: Propagation time = 4000* 5 μsec = 20 msec
- Transmission time per frame = 1000/(100*10 3) = 10 msec.
- B -> C: Propagation time = 1000* 5 μsec = 5 msec
- Transmission time per frame = x = 1000/R
- R = data rate between B and C (unknown)

- A can transmit three frames to B and then must wait for the acknowledgement of the first frame before transmitting additional frames. The first frame takes 10 msec to transmit; the last bit of the first frame arrives at B 20 msec after it was transmitted and therefore 30 msec after the frame transmission began. It will take an additional 20 msec for B's ack to return to A. Thus A can transmit three frames in 50 msec.
- B can transmit one frame to C at a time. It takes 5 + x msec for the frame to be received at C and an additional 5 msec for C's acknowledgement to return to A. Thus, B an transmit one frame every 10 + x msec, or three frames every 30 + 3x msec.
- Thus: 30+3x=50 x= 6.66 msec and R = 1000/x = 150 kbps.