6.02 Practice Problems: MAC protocols

Please read Chapter 15 before trying to solve these problems. Please also solve the problems at the end of Chapter 15.

Problem 1.

Which of these statements are true for correctly implemented versions of stabilized unslotted Aloha, stabilized slotted Aloha, and Time Division Multiple Access (TDMA)? Assume that the slotted and unslotted versions of Aloha use the same stabilization method and parameters.

  A. When the number of nodes is large, unslotted Aloha has a lower maximum throughput than slotted Aloha.

  B. When the number of nodes is large and nodes transmit data according to a Poisson process, there exists *some* offered load for which the throughput of unslotted Aloha is higher than the throughput of slotted Aloha.

  C. TDMA has no packet collisions.

  D. There exists some offered load pattern for which TDMA has lower throughput than slotted Aloha.

Problem 2.

Binary exponential backoff is a mechanism used in some MAC protocols. Which of the following statements is correct?

A. It ensures that two nodes that experience a collision in a time slot will *never* collide with each other when they each retry that packet.

B. It ensures that two or more nodes that experience a collision in a time slot will experience a lower probability of colliding with each ther when they each retry that packet.

C. It can be used with slotted Aloha but not with carrier sense multiple access.

D. Over short time scales, it improves the fairness of the throughput achieved by different nodes compared to not using the mechanism.

Problem 3.

In the Aloha stabilization protocols we studied, when a node experiences a collision, it decreases its transmission probability, but sets a lower bound, p_min. When it transmits successfully, it increases its transmission probability, but sets an upper bound, p_max.

    A. Why would we set a lower bound on p_min that is not too close to 0?

    Show Answer

    B. Why would we set p_max to be significantly smaller than 1?

    Show Answer

    C. Let N be the average number of backlogged nodes. What happens if we set p_min >> 1/N?

    Show Answer

Problem 4.

Consider a shared medium with N backlogged nodes running the slotted Aloha MAC protocol without any backoffs. An idle slot is one in which no node sends data. We will refer to the fraction of time during which no node uses the medium as the "idletime" of the protocol.

    A. If each node has a sending probability of p, what is the idletime? What are the smallest and largest possible values of the idletime?

    Show Answer

    B. Assume N is large. If the Aloha sending probability, p, for each node is picked so as to maximize the utilization, what is the corresponding idletime?

    Show Answer

Problem 5.

True or false?

Assume that the shared medium has N nodes and they are always backlogged.

    A. In a slotted Aloha MAC protocol using binary exponential backoff, the probability of transmission will always eventually converge to some value p, and all nodes will eventually transmit with probability p.

    Show Answer

    B. Using carrier sense multiple access (CSMA), suppose that a node "hears" that the channel is busy at time slot t. To maximize utilization, the node should not transmit in slot t and instead transmit the packet in the next time slot with probability 1.

    Show Answer

    C. There is some workload for which an unslotted Aloha with perfect CSMA will not achieve 100%

utilization.

Problem 6.

Eight Cell Processor cores are connected together with a shared bus. To simplify bus arbitration, Ben Bittdidle, young IBM engineer, suggested time-domain multiplexing (TDM) as an arbitration mechanism. Using TDM each of the processors is allocated a equal-sized time slots on the common bus in a round-robin fashion. He's been asked to evaluate the proposed scheme on two types of applications: 1) core-to-core streaming, 2) random loads.

1) Core-to-core streaming setup: Assume each core has the same stream bandwidth requirement.

2) Random loads setup: core 1 load = 20%, core 2 load = 30%, core 3 load = 10%, core 4 = 5%, core 5 = 1%, core 6 = 3%, core 7 = 1%, core 8 load = 30%

Help Ben out by evaluating the effectiveness (bus utilization) of TDM under these two traffic scenarios.

Problem 7.

Randomized exponential backoff is a mechanism used to stabilize contention MAC protocols. Which of the following statements is correct?

A. It ensures that two nodes that experience a collision in a time-slot will *never* collide with each other when they each retry that packet.

B. It ensures that two or more nodes that experience a collision n a time-slot will experience a lower probability of colliding with ach other when they each retry that packet.

C. It can be used with slotted Aloha but not with CSMA.

Problem 8.

Three users X, Y and Z use a shared link to connect to the Internet. Only one of X, Y or Z can use the link at a given time. The link has a capacity of 1 Megabit/s. There are two possible strategies for accessing the shared link:

- TDMA: equal slots of 0.1 seconds.

- "Taking turns": adds a latency of 0.05 seconds before taking the turn. The user can then use the link for as long as it has data to send. A user requests the link only when it has data to send.

In each of the following two cases, which strategy would you pick and why?

A. X, Y and Z send a 40 Kbytes file every 1sec.

Show Answer

B. X sends 80 Kbytes files every 1sec, while Y and Z send 10 Kbytes files every 1sec.

Show Answer

Problem 9.

Alyssa P. Hacker is setting up an 8-node broadcast network in her apartment building in which all nodes can hear each other. Nodes send packets of the same size. If packet collisions occur, both packets are corrupted and lost; no other packet losses occur. All nodes generate equal load on average.

Alyssa observes a utilization of 0.5. Which of the following are consistent with the observed utilization?

A. True/False: Four nodes are backlogged on average, and the network is using Slotted Aloha with stabilization, and the fairness is close to 1.

Show Answer

B. True/False: Four nodes are backlogged on average, and the network is using TDMA, and the fairness is close to 1.

Show Answer

Now suppose Alyssa's 8-node network runs the Carrier Sense Multiple Access (CSMA) MAC protocol. The maximum data rate of the network is 10 Megabits/s. Including retries, each node sends traffic according to some unknown random process at an average rate of 1 Megabit/s per node. Alyssa measures the network's utilization and finds that it is 0.75. No packets get dropped in the network except due to collisions.

C. What fraction of packets sent by the nodes (including retries) experience a collision?

Show Answer

Problem 10.

Note: this problem is useful to review how to set up and solve problems related to Aloha-like access protocols, but the calculations shown in the answer are more complex than we would ask on a quiz.

Consider a network with four nodes, where each node has a dedicated channel to each other node. The probability that any node transmits is p. Each node can only send OR receive one packet at a time. What is the utilization of the network? Assume each packet takes 1 time slot. Assume each node has 3 queues -- one for each other node -- and that each is backlogged.

Show Answer

Problem 11.

Suppose that there are three nodes seeking access to a shared medium using slotted Aloha, where each packet takes one slot to transmit. Assume that the nodes are always backlogged, and that each has probability p_i of sending a packet in each slot, where i = 1, 2 and 3 indexes the node. Suppose that we assign more the sending probabilities so that

p_1 = 2(p_2) and p_2 = p_3

A. What is the utilization of the shared medium?

Show Answer

B. What are the probabilities that maximize the utilization and the corresponding utilization?

Show Answer

Problem 12.

Suppose that two nodes are seeking access to a shared medium using slotted Aloha with binary exponential backoff subject to maximum and minimum limits of the probability pmax = 0.8 and pmin = 0.1. Suppose that both nodes are backlogged, and at slot n, the probabilities the two nodes transmit packets are p_1 = 0.5 and p_2 = 0.3.

A. What are the possible values of p_1 at slot n+1? What are the probabilities assocated with each possible value?

Show Answer

B. What are the possible values of p_2 at slot n+1? What are the probabilities associated with each possible value?

Show Answer

Problem 13. Bluetooth is a wireless technology found on many mobile devices, including laptops, mobile phones, GPS navigation devices, headsets, and so on. It uses a MAC protocol called Time Division Duplex (TDD). In TDD, the shared medium network has 1 master and N slaves. You may assume that the network has already been configured with one device as the master and the others as slaves. Each slave has a unique identifier (ID) that serves as its address, an integer between 1 and N . Assume that no devices ever turn off during the operation of the protocol. Unless otherwise mentioned, assume that no packets are lost.

The MAC protocol works as follows. Time is slotted and each packet is one time slot long.

In every *odd* time slot (1, 3, 5, …, 2t–1, …), the master sends a packet addressed to some slave for which it has packets backlogged, in round-robin order (i.e., cycling through the slaves in numeric order).

In every *even* time slot (2, 4, 6, …, 2t, …), the slave that received a packet from the master in the immediately preceding time slot gets to send a packet to the master, if it has a packet to send. If it has no packet to send, then that time slot is left unused, and the slot is wasted.

A. Alyssa P. Hacker finds a problem with the TDD protocol described above, and implements the following rule in addition:

From time to time, in an odd time slot, the master sends a "dummy" packet addressed to a slave even if it has no other data packets to send to the slave (and even if it has packets for other slaves).

Why does Alyssa's rule improve the TDD protocol?

Show Answer

Henceforth, the term "TDD" will refer to the protocol described above, augmented with Alyssa's rule. Moreover, whenever a "dummy" packet is sent, that time slot will be considered a <u>wasted</u> slot.

B. Alyssa's goal is to emulate a round-robin TDMA scheme amongst the N slaves. Propose a way to achieve this goal by specifying the ID of the slave that the master should send a data or dummy packet to, in time slot 2t–1 (note that $1 \leq t \leq \infty$).

Show Answer

Henceforth, assume that the TDD scheme implements round-robin TDMA amongst the slaves. Suppose the master always has data packets to send only to an arbitrary (but fixed) subset of the N slaves. In addition, a (possibly different) subset of the slaves always has packets to send to the master. Each subset is of size r, a fixed value. Answer the questions below (you may find it helpful to think about different subsets of slaves).

C. What is the *maximum possible* utilization of such a configuration?

Show Answer

D. What is the *minimum possible* utilization (for a given value of r) of such a configuration? Assume that r > N/2. Note that if the master does not have a data packet to send to a slave in a round, it sends a "dummy" packet to that slave instead. A dummy packet does not count toward the utilization of the medium.

Show Answer

6.02 Introduction to EECS II: Digital Communication Systems
Fall 2012