UNIVERSITY COLLEGE LONDON
DEPARTMENT OF COMPUTER SCIENCE
3035/GZ01: Networked Systems
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Individual Coursework 1
Distributed: 17th October 2013; Due: 24th October 2013, 4:05 PM

Instructions: Answer all of the following problems. Either handwritten or typeset solutions are fine, but if you write by hand, please ensure your answers are legible. Please show all work! We cannot award credit for correct answers if their complete derivation isn't shown. Please state clearly all assumptions you make while solving a problem. This coursework is worth 8% of the total marks for 3035/GZ01.

Please monitor the 3035/GZ01 Piazza site during the period between now and the due date for the coursework. Any announcements (*e.g.,* helpful tips on how to work around unexpected problems encountered by others) will be sent to the list.

Hand-in instructions: Hand in hardcopy for your solutions at the start of lecture at 4:05 PM on the 24th of October. There is no provision for electronic submission of this coursework. Any late submissions should be handed in at the 5th floor reception desk in the CS department (in MPEB).

Collaboration: Collaboration is *not permitted* on this problem set; you may not discuss the problems or their solutions with anyone else (whether or not the other person is taking the class), apart from the instructors and teaching assistants. All work you submit must be your own. You may of course refer to all lecture notes and readings, and any other materials you wish (textbooks, papers, or material found on the Internet).

Late days: If you wish to use any late days on this assignment, you *must* state how many days you wish to use clearly at the top of the first page. If your written assignment does not include a request to use late days, you will not be permitted to use date days on the assignment later. (Full late-day policies are stated on the 3035/GZ01 web site.)

1. **Catching Burst Errors with the CRC**

   In class we stated that the CRC will detect a burst error of length at most $g-1$ bits, provided that $G(x)$ contains the terms 1 and x^{g-1}.

   (a) Let's begin with the example case of a single burst error of two bits occuring at the end of a four-bit packet with generator $G(x) = 1 + x^2$.

      i. What are the resulting generator bits for $G(x)$?

      [1 mark]

      ii. What are the resulting bits of the error polynomial $E(x)$?

      [1 mark]

      iii. Show all steps of the long division to argue that the CRC will detect this particular burst error.

      [2 marks]

   (b) Now let's reason about any single burst error of length $k \leq g-1$ occuring i bits from the end of the frame. Recall from lecture that an error goes undetected whenever $E(x) = G(x) \cdot Z(x)$ for some polynomial $Z(x)$.

i. What is the error polynomial $E(x)$ for this error pattern? (Your answer will be a polynomial in x involving i and k).

[2 marks]

ii. Argue that in order for $E(x)$ to equal $G(x) \cdot Z(x)$, $Z(x)$ must contain the term x^i.

[2 marks]

iii. Why therefore can $E(x)$ never equal $G(x) \cdot Z(x)$? (Hint: Note that by your answer to the above question, $G(x) \cdot Z(x)$ must contain the term x^{i+g-1}.)

[2 marks]

2. **Implementing the CRC in Software (P & D 2.20)**

The CRC algorithm discussed in lecture requires lots of bit manipulations, for which a hardware design excels, but it is, however, possible to efficiently implement the CRC in software. Our approach will be to perform polynomial long division using a table-driven method, taking multiple bits at a time. We'll investigate the strategy here for long division three at a time, but in practice we would divide 8 or 16 bits at a time, and the table would have 256 or 65,536 entries.

p	$q = p.000 \div G$	$G \times q$
000	000	000 000
001	001	001 101
010	011	010 ___
011	0__	011 ___
100	111	100 011
101	110	101 110
110	100	110 ___
111	___	111 ___

Let the generator polynomial $G(x) = x^3 + x^2 + 1$, or 1101 in bits. To build the table for $G(x)$, we take each three-bit sequence p, append three trailing zeroes, and then find the quotient $q = p.000 \div G$, ignoring the remainder. The third column is the product $G \times q$, the first three bits of which should equal p.

(a) Verify, for $p = 110$, that the quotients $p.000 \div G$ and $p.111 \div G$ are the same; that is, it doesn't matter what the trailing bits are.

[2 marks]

(b) Fill in the missing entries in the table.

[3 marks, ½ mark per entry]

(c) Use the table to divide 101 001 011 001 100 by G.

Hint: the first three bits of the dividend are $p = 101$, so from the table the corresponding first three bits of the quotient are 110. Write the 110 above the second three bits of the dividend, and subtract $G \times q = 101110$, again from the table, from the first six bits of the dividend. Keep going in groups of three bits. There should be no remainder.

[3 marks]

3. **Odd or even?**

   Argue convincingly that if the CRC generator polynomial $G(x)$ contains the factor $(1+x)$ then a CRC using $G(x)$ correctly flags packets containing *any* odd number of bit errors as incorrect.

   Hint: Remember that the CRC misses an error whenever the error polynomial $E(x) = G(x) \cdot Z(x)$ *for some* $Z(x)$*. What happens when you substitute 1 for x in this equation?*

[5 marks]

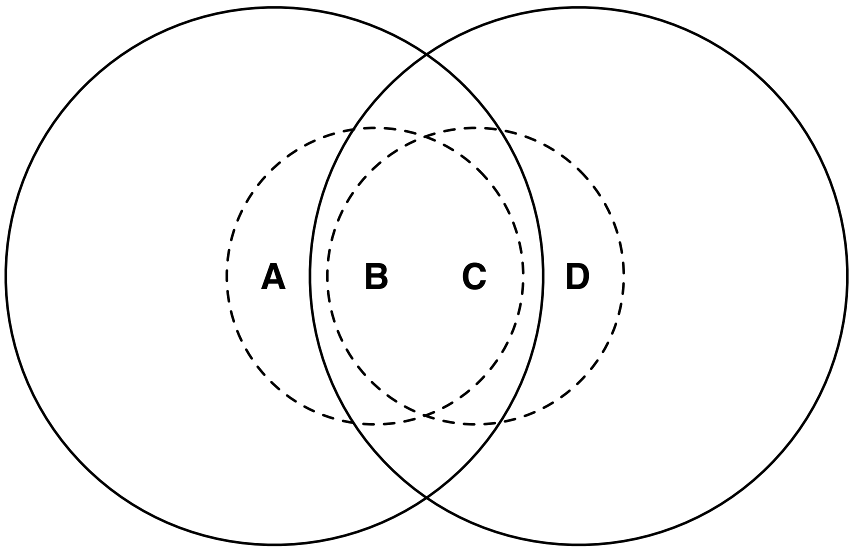
4. **Reordering in rdt v3.0**

   Networked Systems student Louis Reasoner has just studied `rdt3.0`, the stop-and-wait reliable transfer protocol with a one-bit sequence number described in lecture. Louis thinks that rdt3.0 would function even when the network reorders packets. Is he right? If so, argue informally why. If not, provide a counterexample timeline in the style of the timelines presented in lecture, showing sender and receiver states, and packet contents.

[5 marks]

5. **Wireless Medium Access Control**

   When a radio transmits using higher power, its range increases. Consider the below wireless topology, in which all nodes use omnidirectional antennas:



   Nodes A and D in the figure transmit with high power, while nodes B and C transmit with low power. There are four circles drawn in the figure. Each circle represents the **transmit** range of the node on which it is centered. The solid circles represent the transmit range of nodes A and D, while the dashed circles represent the transmit range of nodes B and C.

   Assume that collisions occur when more than one transmission concurrently reaches the receiver, where the transmission range of a sender is determined by the circle centered on it. Assume further that only collisions cause packet losses. Finally, ignore ACKs in all parts of this question.

(a) i. Suppose node A transmits to node B. List all potential hidden terminals with respect to A *in either direction,* (*i.e.,* for cases where A sends first *and* cases where the other hidden terminal sends first. Note that a hidden terminal with respect to A need not also be sending to B—it may be sending to some other node.
In your answer, justify why each node you list is hidden with respect to A.

[2 marks]

ii. Again, suppose node A transmits to node B. List all potential exposed terminals with respect to A. Justify why each node you list is exposed with respect to A.

[2 marks]

iii. Now suppose node B transmits to node C. As before, list all other nodes hidden with respect to B, in either direction, justifying why each is hidden.

[2 marks]

iv. Again, suppose node B transmits to node C. As before, list all other nodes exposed with respect to B, justifying why each is exposed.

[2 marks]

(b) Suppose A sends to B and C sends to D. Both senders send at the same fixed bit-rate. Assume that this bit-rate always decodes successfully when either link is used alone, and never decodes successfully if a collision occurs.

i. Assume that no mechanism is used to detect or avoid collisions. What is the throughput of each transfer as a fraction of its sending rate?

[2 marks]

ii. Now suppose the same two senders send to the same two receivers, but that they use the MACAW MAC protocol discussed in lecture. Assume that any control packets sent by MACAW are short, and thus consume negligible link bandwidth. What is the throughput of each transfer as a fraction of its sending rate?

[2 marks]

[Problem set total: 40 marks]