

**CSCI 5105: Foundations of Modern Operating Systems**  
**Spring 2007**  
**Mid-Term Exam**

**NAME:**

**STUDENT ID:**

**General Instructions:**

- Write your name and student ID clearly above.
- You have 1 hour 15 minutes to write the exam. No extra time will be given.
- The questions in the exam combine for a maximum of 100 points.
- You must write your answers clearly in the space provided for each question. You might use the backside of each page, as well as the additional sheet at the back if required. If you are using additional space, you must clearly label the question no. that you are answering. Any loose sheets must have your name and student ID written clearly.
- The exam is open book/open notes, however, no exchange of materials is allowed. You must use your own notes/book.
- Electronic devices (laptops, notebooks, PDAs, cell phones, ipods, etc.) are strictly prohibited.
- Read each question carefully before answering.
- Good luck with the exam!





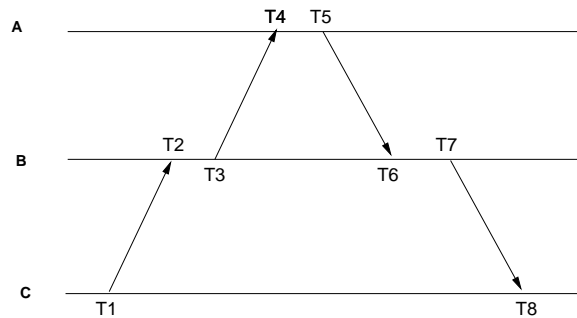
2. Consider a DHT-based overlay network, where the keys are generated from a 6-bit key space. Further assume that an object with key  $k$  is placed on  $\text{successor}(k)$ , where  $\text{successor}(k)$  is the node in the network with the minimum key  $\geq k$  (modulo  $2^6$ ). Assume that the network initially has nodes with the following keys: 2, 3, 5, 8, 13, 21, 34, 55. Based on this information, answer the following questions.
- (a) **(24 pts)** Draw a logical view of the overlay network, showing the finger table for each node.

(b) **(4 pts)** Which nodes hold objects with keys 0, 4, 16, and 32?

(c) **(4 pts)** If you injected a query for key 7 at node 21, which nodes will the query be routed through?

(d) **(2 pts)** If you generated a query at node 2 for an object with a random key, what is the maximum number of hops required to find that object?

3. Consider a client C that needs to synchronize its time to UTC. To do that, it uses an intermediate time server B, which in turn synchronizes itself with another time server A having the UTC time. Suppose that the machines use the following synchronization protocol: C sends a message to B, which then sends a message to A and waits for a response. When B receives a response from A, it immediately corrects its clock by the computed offset, and then sends a response back to C. As part of the protocol, both B and C use Cristian's algorithm for their clock synchronization, and the messages carry the relevant timestamps as specified by Cristian's algorithm. The following figure shows the protocol.



Assume that initially, B is 10 minutes behind UTC, C is 10 minutes ahead of UTC, and A is at UTC. Further assume that each message takes 5 minutes of absolute time to propagate, and there is a 5 minute interval between each successive receive and send of messages (i.e., between T2 and T3, T4 and T5, and T6 and T7).<sup>1</sup> Finally, you can ignore the effects of clock drifts and relativity.

Answer the following questions based on the above information.

- (a) **(16 pts)** Assuming that UTC is 12:00 when C sends its first message to B, what are the timestamp values for T1-T8?

<sup>1</sup>Yes, that's a really slow network and set of machines!

(b) **(6 pts)** What are the clock offset values ( $\theta$ ) calculated by B and C respectively? (Show your calculations as well).

(c) **(8 pts)** After the whole synchronization is over, does C have the correct time? If not, how can you modify the above protocol to fix the problem?

**Additional Page**