TDA596 / DIT240 (2nd academic period 2014/2015)

Exam: Distributed Systems

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Means allowed: Nothing except paper, pencil, pen and English - xx dictionary.

Please answer questions 1 to 6

General information: All questions should be answered in English. Write clearly and use the pages in a structured way so your answers are easy to read. Each question answer should be started on a new sheet of paper. All answers should be motivated, explained, elaborated, detailed, precise and accurate.

Important suggestion: Read all questions before answering. Plan your time so that you can (at least) write a brief answer to all questions (and sub-questions). Please notice the weight that is given to each question (and sub-question).

Grading: GU: G 24p, VG 48p ; CTH: 3:a 24p, 4:a 36p, 5:a 48p of maximum 60 points.

Review: Please keep your exam code. Information about individual exam review will be published on the course website.

Department of Computer Science and Engineering
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1. Basics about Distributed Systems (10 points)

1 a) (1 points) Define the term "Distributed System". Be brief and precise.

1 b) (1 points) The following statement is attributed to Thomas J. Watson, Chairman and CEO of International Business Machines (IBM), in 1943: "I think there is a world market for maybe five computers". Please state the key consequences for distributed systems if this sentence had been the correct vision.

1 c) (2 points) Centralized Systems (e.g. Client Server Systems) vs. Decentralized Systems (e.g. Peer-To-Peer Systems): We discussed the differences between the centralized architectures and the decentralized architectures. Note two advantages for each system and explain each briefly.

1 d) (4 points) We discussed the Dining Philosophers Problem: N silent philosophers sit at a round table with bowls of spaghetti. Forks are placed between each pair of adjacent philosophers. Each philosopher must alternately think and eat. However, a philosopher can only eat spaghetti when he has both left and right forks. Only one philosopher can hold each fork and so a philosopher can use the fork only if no other philosopher is using it. After he finishes eating, he needs to put down both forks so they become available to others. A philosopher can take the fork on his right or the one on his left as they become available, but cannot start eating before getting both of them. Note, eating is not limited by the amount of spaghetti left; an infinite supply is assumed. (Text adapted from Wikipedia).
Sketch in pseudo code a solution to this problem that is deadlock free, starvation free, and distributed (i.e., does not require a central entity for coordination). Briefly explain why your solution is deadlock free and starvation free.

1 e) (2 points) Ethical challenges: Certain distributed systems such as BitTorrent and TOR trigger ethical challenges. List and briefly discuss two ethical challenges for each of these two systems.

2. Mutual Exclusion and Election and Naming (10 points)

2 a) (1 points) Define the terms “Mutual Exclusion” and “Election”, as used in the context of this course. Be brief and precise.

2 b) (3 points) Token Ring for Mutual Exclusion.

i. Please describe how the Token Ring algorithm works.
ii. List at least two limitations of its design.

2 c) (3 points) Any algorithm for mutual exclusion must fulfill two goals: safety and liveness.

i. Please define these two goals, be brief and precise.
ii. Explain how the Token Ring algorithm achieves these.

2 d) (3 points) In the lecture we discussed the concept CAN. CAN is a Distributed Hash Table (DHT). Answer the following questions about CAN:

i. What topology do the nodes form?
ii. What operations does a DHT, e.g., CAN, provide?
iii. How is redundancy in CAN achieved?
iv. In CAN, how many hops does it take at most to lookup a data item? (Assume that the number of nodes is “n”, and dimensions are “d”).
v. How does a node join a CAN DHT?
vi. Neighbor Table: Which nodes are stored in a neighbor table of a node in the CAN DHT?

3. Time and Synchronization (10 points)

3 a) (1 points) In the course we discussed the concept of clock synchronization for physical clocks. Why is clock synchronization important in Distributed Systems that rely on physical clocks?

3 b) (3 points) Assume we need to synchronize the physical clocks of "n" nodes but do **not** have access to a reference clock.

i. Which algorithm would you choose and why?

ii. Briefly illustrate that algorithm. You can draw a figure to support your argumentation.

3 c) (3 points) Assume we need to synchronize the physical clocks of "n" nodes to an accurate reference clock.

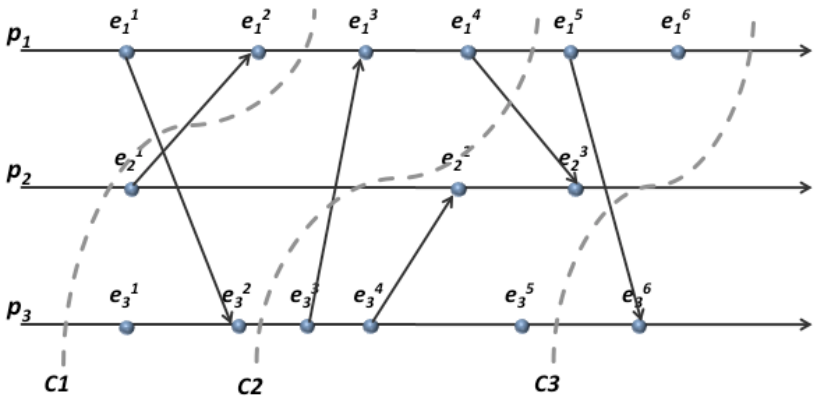
i. Which two algorithms did we discuss in the course that could you choose and why?

ii. Briefly illustrate one of the two algorithms. You can draw a figure to support your argumentation.

3 d) (3 points) We discussed the concept of consistent and inconsistent cuts.

i. Please explain this concept briefly and define the term consistent cut.

ii. Please note for each cut (C1, C2, C3) depicted below whether it a consistent or inconsistent cut. Explain your reasoning briefly



4. Consistency and Replication (10 points)

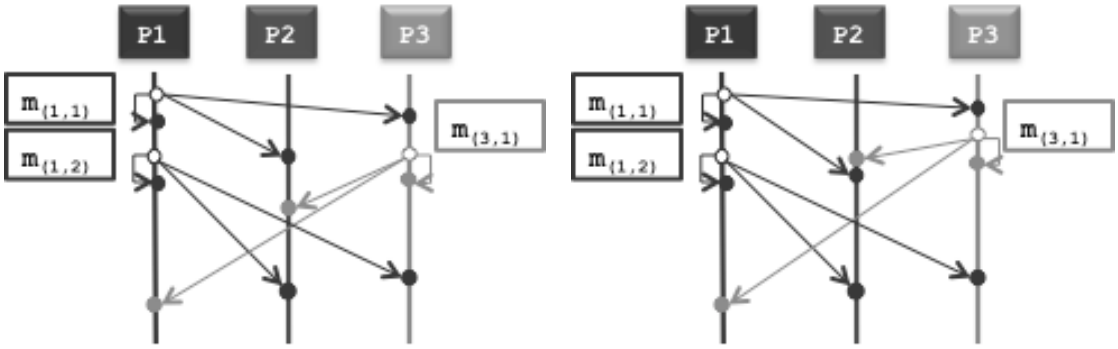
4 a) (1.5 points) In the lectures we discussed the concepts of "Replication", "Consistency" and "Eventual Consistency".

i. Please define the term "Replication"
ii. Please define the term "Consistency"
iii. Please define the term "Eventual Consistency"

4 b) (1.5 points) List three benefits that replication provides. Explain these benefits briefly.

4 c) (4 points) We discussed the concepts of Total Ordering, Sequential Ordering, and Causal Ordering

i. Briefly explain each concept.
ii. Below you see two figures. For each figure, please note weather it describes Total Ordering, Sequential Ordering, and Causal Ordering. Briefly describe your decisions.



4 d) (3 points) We discussed the concept of Active Replication.

i. Briefly explain this concept. You can draw a figure to support your argumentation.
ii. Active replication uses a central entity for parts of its operations. Briefly explain why this is a reasonable design.

5. Fault Tolerance (10 points)

5 a) (2 points) Failure Models: In the lecture we discussed different failure models. Please note four of them and describe each briefly.

5 b) (4 points) We discussed the "Byzantine Generals Problem".

i. In the "Byzantine Generals Problem" there are honest generals and dishonest generals (traitors). What is the goal of the honest generals? What is the goal of the traitors?

ii. In the lecture we introduced an algorithm with multiple phases to enable consensus among the generals. Explain the algorithm and its different phases.

iii. Under what conditions can the generals achieve consensus. How many honest generals are required, assuming that there are k dishonest ones?

5 c) (4 points) We discussed the "Two Phase Commit" Protocol. As the name states, it consists of two phases.

i. Please name and describe phase 1 briefly.

ii. Please name and describe phase 2 briefly.

6. Applications

6 a) (5 points) We discussed TOR, which enables, for example, anonymous Internet browsing.

i. Briefly explain how TOR provides anonymous Internet browsing. You can draw a figure to illustrate your argumentation.

ii. TOR also allows so called hidden services. Please briefly explain what a hidden service is and how TOR enables it. You can draw a figure to illustrate your argumentation.

6 b) (5 points) Describe the MapReduce algorithm. Split it into its phases. For each phase include: what it does and who is responsible (the MapReduce framework or the programmer).