TDA596 / DIT240 (2nd academic period 2016/2017)

Exam: Distributed Systems

16. August 2017

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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.

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1. Basics about Distributed Systems (10 points)

1 a) (2 points) Define the term “Distributed System”. Be brief and precise.

1 b) (2 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) (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 d) (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. Naming (10 points)

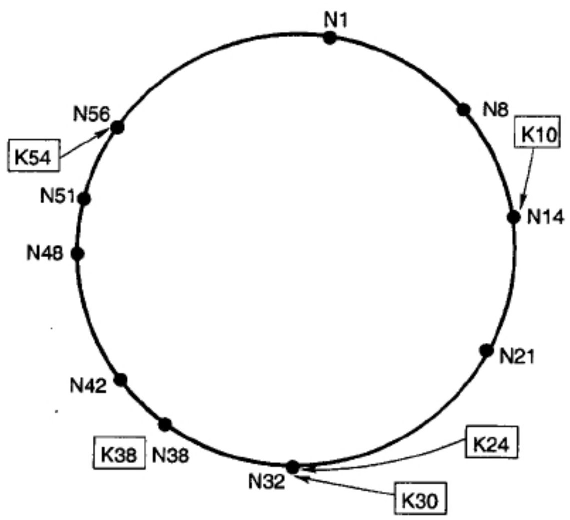
2 a) (2 points) Define the terms "naming" and "name resolution" in Distributed Systems in your own words. Be brief and precise.

2 b) (3 points) In the course we discussed two concepts for name resolution: Iterative and recursive name resolution. Briefly describe each concept and highlight their key differences.

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

- What topology do the nodes form?
- What operations does a DHT, e.g., Chord, provide?
- How is redundancy in Chord achieved?
- In Chord, how many hops does it take on average to lookup a data item? (Assume that the number of nodes in the Chord is "n").
- How does a node join a Chord DHT?
- Neighbor Table: Which nodes are stored in a neighbor table (called finger table in Chord) of a node in the DHT?
- Dynamo introduces the concept of virtual nodes, what are they used for?

2 d) (2 points) Finger tables in Chord: Below you find a picture of a Chord ring, with nodes N1, N8, N14 etc. Please list the finger table of node N8, i.e., list to which nodes the figures point and explain your reasoning and calculations. Note: in this example, the finger table size is 6.



3. Mutual Exclusion & Election (10 points)

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

3 b) (4 points) Bully Algorithm for Leader Election.

- Please describe how the algorithm works.
- How does the algorithm deal with nodes failing during election?
- What message complexity does the algorithm have and why?

3 c) (4 points) In the course, we discussed the Ricart & Agrawala algorithm for Mutual Exclusion.

- Please explain this algorithm.
- What is the message complexity (please explain).
- Please define the terms centralized algorithm, decentralized algorithm, and distributed algorithm.
- Is Ricart & Agrawala a centralized, decentralized, or a distributed algorithm? (please explain).

4. Consistency and Replication (10 points)

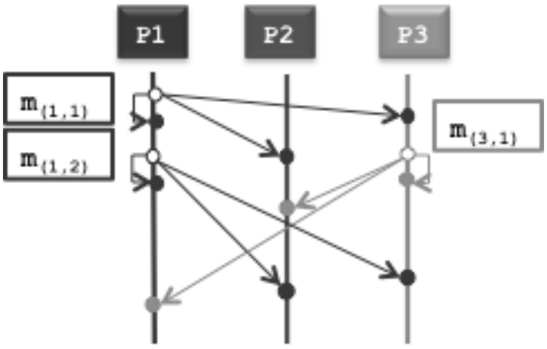
4 a) (2 points) In the lectures we discussed the concepts of “Replication”, “Consistency” and “Eventual Consistency”.

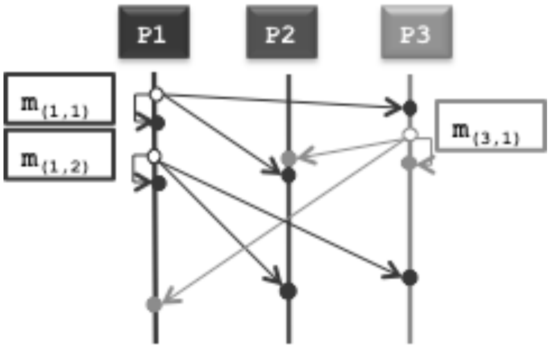
i. Please define the term “Replication”
ii. Please define the term “Consistency”
iii. Please define the term “Eventual Consistency”

4 b) (2 points) List three benefits that replication provides. Explain these benefits briefly.

4 c) (3 points) We discussed the concepts of Total Ordering, Sequential Ordering, and Causal Ordering

- Briefly explain and formally define each concept.
- 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 a Centralized Active Replication Protocol.

- Briefly explain this concept. You can draw a figure to support your argumentation.
- 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) (3 points) Orphans: A client might crash while the server is performing a corresponding computation requested by the client. Such an unwanted computation is called an *orphan* (as there is no parent waiting for it after done).

- What problems do orphans cause?
- In the course, we discussed four strategies to deal with orphans. Please explain each of them.

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

- 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?
- In the lecture, we introduced an algorithm with multiple phases to enable consensus among the generals. Explain the algorithm and its different phases.
- Under what conditions can the generals achieve consensus. How many honest generals are required, assuming that there are *k* dishonest ones?

5 c) (3 points) We discussed the "Two Phase Commit" Protocol. As the name states, it consists of two phases.

- Please name and describe phase 1 briefly.
- Please name and describe phase 2 briefly.
- Please discuss what happens in case of a failure during *phase 1*, i.e., a node not replying because it crashed.
- Please discuss what happens in case of a failure during *phase 2*, i.e., a node not replying because it crashed.

6. Applications

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

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