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Sistemas Distribuídos - MEEC **2023-11-09**
Exam (with handwritten cheat sheet) **Duration: 90 min**

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1. **Justify all your answers.**
2. **Please answer to questions 1 and 2 in one sheet, and to the remaining questions in another sheet.**
3. **Please answer to all questions either in Portuguese or in English.**

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1 [3v] - Concerning Distributed Systems:

1.1- Explain the operation of **distributed** and **centralized** clock synchronization.

1.2- Explain the **Producer-Consumer** middleware model and give at least one example.

2 [7v] - An **IoT system** is installed in a smart city and captures environmental parameters from several **hundreds** of sensor nodes. These sensors send information **periodically** to a cloud on the Internet. A **server** running in the cloud **receives** the sensing values and **processes** them, acknowledges the processing back to the sensors and logs the results in a temporal database in the cloud. **Users** can subscribe to a number of **notification services** running in the cloud and be notified automatically once those services detect **relevant events** in the database.

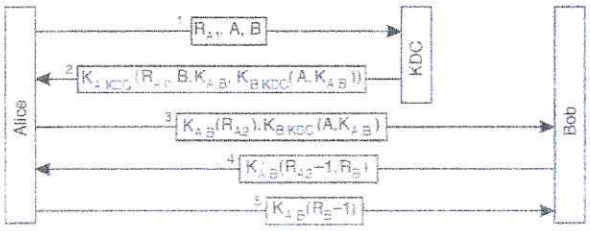
2.1- The sensors connect to the server using **TCP channels** to send their values and wait for the server acknowledgement. When designing the server, which would be the most adequate **internal architecture** (iterative, thread-based or event-driven)?

2.2- Which **middleware model** (client-server, producer-consumer, publisher-subscriber, shared-memory) would be more adequate to the communication between **users** and **notification services**?

2.3- Consider that the sensors transmit **periodically** with a period of **1min**, but they are **asynchronous** and have drift-rates (but much smaller than the transmission period). Assume the server tags every received sensor reading with a **local timestamp**. What is the **maximum time difference** (in the server clock) between the latest values of any two sensors? Show the situation with a **time diagram**.

2.4- Consider now that the server is also a **time server** and that the sensors get a **server timestamp** with the acknowledgement of each sensor communication. The **jitter** affecting these communications (acknowledgements) is upper bounded by **5ms** and the **drift-rate** of the sensors local clocks is upper bounded by **10ppm** (10 parts per million). Which is the **best precision** that can be **guaranteed** to the global clock in the sensors? Justify your computations.

3 [3v] - The figure shows a secret key authentication protocol.



3.1- Would it be possible to do direct authentication, i.e. without the KDC? If yes, what would its disadvantage be? If not, why?

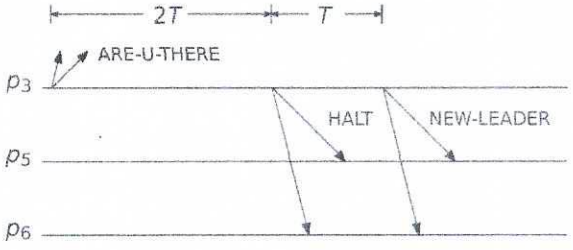
3.2- Assume that in message 2, the KDC did not include Bob's id, **B**. What could go wrong? Explain.

4 [2v]- In the lectures, we argued that the **two-phase commit** protocol solves the atomic commitment problem in the crash failure model, as long as processes recover.

4.1- What if processes may have only a finite number of omission failures? Justify.

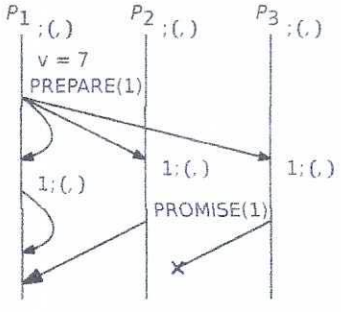
4.2- What if the processes may exhibit byzantine behavior for single time interval of finite duration? Justify your answer.

5 [2v]- Consider a simple execution of the Bully election algorithm.



Explain what might go wrong if p_3 sent a NEW_LEADER message instead of the HALT message 2T time units after sending the ARE-U-THERE message

6 [3v]- The figure on the right shows a partial execution of Paxos, the consensus algorithm.



6.1- Complete it so that the value 7 is not decided at the end of the second phase, in spite of the leader sending the message `ACCEPT_req (1,7)` to a majority of the participants. Justify.

6.2- Consider the use of Paxos in the implementation of State Machine Replication and the following statement:

> If the "leader" starts the second phase of Paxos instance after deciding the command of the previous instance, the participants (replicas) can apply the command of each instance as soon as they learn the decided value.

Is this statement true? If not, explain why. If yes, explain why, in spite of that possibility, it may be advantageous that the leader starts the second phase of a Paxos instance, before deciding the command of previous instances.