CS-451 – Distributed Algorithms
Midterm Exam

December 2\textsuperscript{nd}, 2019

Name: __________________________

SCIPER number: ________________

Time Limit: 1:45 hours.

Instructions:

• This exam is closed book: no notes, electronics, nor cheat sheets allowed.

• If you need additional paper, please ask one of the TAs. Write your name and SCIPER on each extra page.

• Read through each problem before starting to solve it.

• When solving a problem, do not assume any known result from the lectures, unless it is explicitly stated that you might use some known result.

• Unless a problem explicitly states otherwise, assume that processes only fail by crashing.

Good Luck!

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<th>Problem</th>
<th>Max Points</th>
<th>Score</th>
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<td>1</td>
<td>5</td>
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<td>2</td>
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1 Terminating Reliable Broadcast (5 points)

(a) (0.5 points) State the interface and properties of Terminating Reliable Broadcast.

(b) (1 point) Discuss the difference between Perfect Failure Detector and Eventually Perfect Failure Detector.
(c) (2 points) Is it possible to implement Terminating Reliable Broadcast, in the presence of one failure, without a Perfect Failure Detector?

- If yes, provide an algorithm that does that, and prove its correctness.
- If no, prove that doing that is impossible.
(d) (0.5 points) State the interface and properties of Consensus.

(e) (1 point) Provide an algorithm $A$ that implements consensus among $N$ processes, subject to an arbitrary number of failures, using at most $N$ instances of Terminating Reliable Broadcast. Prove the correctness of $A$. 
2 Best-Effort Broadcast (5 points)

Complexity & Latency Let $A$ be a distributed, terminating algorithm. We define the following:

- The **maximum per-process communication complexity** of $A$ is the maximum number of messages any process has to exchange (i.e., send + receive) throughout an execution of $A$.

- The **latency** of $A$ is number of units of time $A$ takes to terminate on every process, under the assumption that computation is instantaneous and the delay of every message is one time unit.

(a) (0.5 points) State the interface and properties of Best-Effort Broadcast.

(b) (1.5 points) Provide an algorithm $A$ that implements Best-Effort Broadcast among $N$ processes, subject to an arbitrary number of failures such that: the maximum per-process communication complexity of $A$ if $O(N)$; the latency of $A$ is $O(1)$. Prove the correctness of $A$. 
(c) (2 points) Provide an algorithm $A$ that implements Best-Effort Broadcast among $N$ processes, under the assumption that only the sender process can crash, such that: the maximum per-process communication complexity of $A$ is $O(1)$; the latency of $A$ is $O(\log N)$. Prove the correctness of $A$. 
(d) (1 points) Provide an algorithm \( A \) that implements Best-Effort Broadcast among \( N \) processes, under the assumption that at most \( f \ll N \) of them can crash, such that: the maximum per-process communication complexity of \( A \) is \( O(f) \); the latency of \( A \) is \( O(\log N - \log f) \). Prove the correctness of \( A \).