ΠAΜIBIA UΠIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF COMPUTING AND INFORMATICS

DEPARTMENT OF COMPUTER SCIENCE

QUALIFICATION: Bachelor of Computer Science	
QUALIFICATION CODE: 07BACS	LEVEL: 6
COURSE: Distributed Systems and Applications	COURSE CODE: DSA621S
DATE: November 2022	SESSION: 1
DURATION: 3 Hours	MARKS: 100

FIRST OPPORTUNITY EXAMINATION QUESTION PAPER	
EXAMINER:	Prof. José G. Quenum
MODERATOR:	Prof. Dharm Singh Jat

This paper consists of 3 pages
(excluding this front page)

INSTRUCTIONS

1. This paper contains 5 questions.

2. Answer all questions on the exam paper.

3. Marks/scores are provided at the right end of each question

4. Do not use or bring into the examination venue books, mobile devices and other materials that may provide you with unfair advantage. Should you be in possession of one right now, draw the attention of the examiner officer or the invigilator.

5. NUST examination rules and regulations apply.

PERMISSIBLE MATERIALS

Calculator

Question 1 .... [15 points]

Consider a distributed system with five (05) processes (P_1, P_2, P_3, P_4 and P_5). The processes are involved in a synchronous consensus algorithm. After $k + 1$ rounds the values exchanged by the processes are as follows:

P_1: $\{V_0^1, V_1^1, V_2^1, \ldots, V_{k+1}^1\}$;

P_2: $\{V_0^2, V2_1, V_2^2, \ldots, V_{k+1}^2\}$;

P_3: $\{V_0^3, V_1^3, V_2^3, \ldots, V_{k+1}^3\}$;

P_4: $\{V_0^4, V_1^4, V_2^4, \ldots, V_{k+1}^4\}$;

P_5: $\{V_0^5, V_1^5, V_2^5, \ldots, V_{k+1}^5\}$;

Following the consensus algorithm, what is the decision made by each process? Define the requirement for an agreement to be reached, assuming that no process fails.

Question 2 .... [20 points]

Consider seven (7) processes in a distributed system: P_1, P_2, P_3, P_4, P_5, P_6 and P_7. Here, the higher the process identifier, the higher the resources attached to it. As such, process P_7 is the current leader. However, P_3 just detected that the leader has crashed. It then started an election algorithm using the Bully algorithm. Describe step-by-step the execution of the algorithm until the election of a new leader. Note that P_2 also crashed during the election algorithm.

Question 3 .... [25 points]

(a) Consider four (04) processes (P_1, P_2, P_3 and P_4) as part of a distributed system. The   [15]
following events (listed in order) have occurred at each process:

P_1: e_0, e_1, e_2, e_3, e_4 and e_5

P_2: $\imath_0$, $\imath_1$, $\imath_2$, $\imath_3$ and $\imath_4$

P_3: $\jmath_0$, $\jmath_1$, $\jmath_2$ and $\jmath_3$

P_4: ℓ_0, ℓ_1, ℓ_2 and ℓ_3

In addition, we have the following observations:

- Event $\imath_1$ resulted from a message exchange between P_1 and P_2 after event e_2;
- Event e_4 resulted from a message exchange between P_2 and P_1 after event $\imath_2$;
- Event $\jmath_0$ resulted from a message exchange between P_1 and P_3 after event e_1;
- Event $\imath_4$ resulted from a message exchange between P_3 and P_2 after event $\jmath_1$;
- Event e_3 resulted from a message exchange between P_4 and P_1 after event ℓ_0;
- Event ℓ_1 resulted from a message exchange between P_3 and P_4 after event $\jmath_2$;
- Event e_5 resulted from a message exchange between P_4 and P_1 after event ℓ_2;
- Event ℓ_3 resulted from a message exchange between P_3 and P_4 after event $\jmath_3$.

Using a diagram represent the vector clocks corresponding to the logical clock for each event in the system.

(b) In order to capture the global state of the system, P_2 records its state after event $\imath_1$. [10]
Using the Snapshot algorithm define a consistent cut that represents a global state of
the system with $\imath_1$ as part of the frontier. For each event in the cut, you will justify why
it is included.

Question 4 . . . . [25 points]

(a) A client application wishes to access the byte range $402718322 - -470718322$ from a [5]
file (file1.dat) in Google File system (GFS). What chunk index(es) does the byte range
correspond to?

(b) Describe in detail the read operation of the byte range from GFS. [8]

(c) The byte range how now been modified. Describe in detail the write operation in GFS. [12]

Question 5 . . . . [15 points]

Two processes $S_\imath$ and $S_\jmath$ are involved in remote invocation with $S_\imath$ acting as the caller, while $S_\jmath$
acts as the callee.

(a) Highlight the underlying request-reply protocol using its primitives. [6]

(b) The request issued by $S_\imath$ was not replied to on time. Explain the steps taken by both [9]
processes using the at-least-once semantics.