



**PAMIBIA UNIVERSITY**  
**OF SCIENCE AND TECHNOLOGY**

**FACULTY OF COMPUTING AND INFORMATICS**  
**DEPARTMENT OF SOFTWARE ENGINEERING**

<b>QUALIFICATION:</b> BACHELOR OF COMPUTER SCIENCE	
<b>QUALIFICATION CODE:</b> 07BCMS, 07BAIT	<b>LEVEL:</b> 6
<b>COURSE:</b> DISTRIBUTED SYSTEMS AND APPLICATIONS	<b>COURSE CODE:</b> DSA612S
<b>DATE:</b> OCTOBER 2025	<b>PAPER:</b> THEORY
<b>DURATION:</b> 3 HRS	<b>MARKS:</b> 80

<b>FIRST OPPORTUNITY EXAMINATION QUESTION PAPER</b>	
<b>EXAMINER(S)</b>	<b>Ms. NDINELAGO NASHANDI</b>
<b>MODERATOR:</b>	<b>PROF JOSE QUENUM</b>

**THIS QUESTION PAPER CONSISTS OF 8 PAGES**  
(Including this front page)

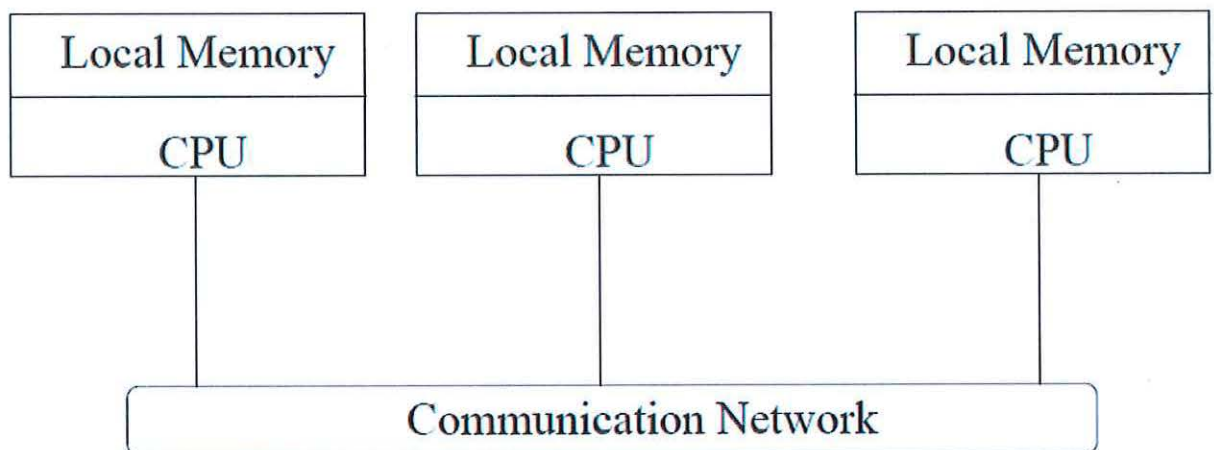
### INSTRUCTIONS TO STUDENTS:

1. Read all the questions, passages, scenarios, etc., carefully before answering.
2. Answer all the questions.
3. Number each answer clearly and correctly.
4. Write neatly and legibly.
5. Making use of any crib notes may lead to disqualification and disciplinary action.
6. Use the allocated marks as a guideline when answering questions.
7. Looking at other students' work is strictly prohibited.
8. This paper consists of eight (**8**) pages, including the cover page.
9. The paper consists of 3 sections: A, B and C.

**SECTION A: 5 marks**

**Multiple Choice Questions (WRITE the correct letter)**

1. Which of the following best describes a distributed system? [1 mark]
  - A. A single computer running multiple applications simultaneously.
  - B. A collection of independent, autonomous hosts connected through a communication network.
  - C. A computer system that shares memory, clock, and operating system among all nodes.
  - D. A single operating system managing multiple interconnected computers.
  
2. Consider the diagram below and the description of a distributed system. [1 mark]



Which of the following statements about a distributed system is **correct**?

- A. A distributed system consists of multiple processors that share memory and a common clock.
- B. In a distributed system, all processors operate under a single operating system with shared global memory.
- C. A distributed system consists of multiple independent processors with local memory communicating via a network.
- D. In a distributed system, processors cannot exchange messages over a network.

3. Why should replicated files be placed on failure-independent machines?
  - A. To improve system speed
  - B. To ensure they do not fail together
  - C. To reduce memory usage
  - D. To eliminate consistency issues
  
4. Which of the following best describes the purpose of logical clocks in distributed systems?
  - A. To synchronise all system clocks to a universal time reference.
  - B. To establish a total ordering of events across all distributed processes.
  - C. To ensure causality by allowing a partial ordering of events in a distributed system.
  - D. To measure the time elapsed between any two events in a distributed system.
  
5. In the Network Files System (NFS) architecture, which layer provides the abstraction that allows multiple operating systems to access files uniformly?
  - A. RPC client stub
  - B. Virtual File System (VFS) layer
  - C. Local file system interface
  - D. System call layer

**SECTION B: 8 marks**

- *Answer all the questions in the provided booklet.*
- *The section consists of 2 questions.*

1. Give FOUR reasons that would make a corporate organisation shift from centralised systems to distributed systems. [4 marks]
2. Distributed systems security is fundamentally more complex to implement than in standalone systems. Identify the four broad components of security as they apply in distributed systems. [4 marks]

**SECTION C: [27 marks]**

- *Answer all the questions in the provided booklet.*
- *The section consists of 4 questions.*

1. Distributed File Systems (DFS) provide several key supports such as remote information sharing, user mobility, availability, and diskless workstations. Discuss how these supports contribute to system reliability, user flexibility, and performance in a large-scale distributed environment. Use relevant examples to support your answer [9 marks]
2. Provide and explain the architecture of the Google File System. (9 marks)
3. Explain how a client write operation is performed in the Google File System. (5 marks)
4. Explain how GFS copes with failures. (4 marks)

**SECTION D: [16 marks]**

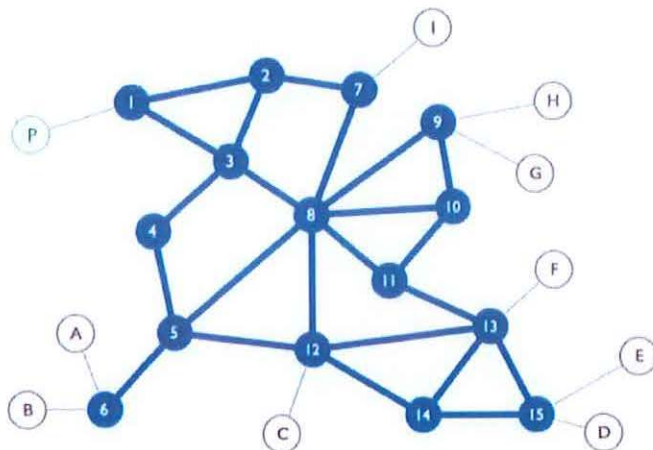
- Answer all the questions in the provided booklet.
- The section consists of 2 questions.

1. With the aid of a diagram, explain how the Publish/Subscribe communication model operates. Discuss why this paradigm is considered a promising approach for modern distributed systems, highlighting the functionalities and system requirements it addresses.

[10 marks]

2. Consider the following Event Notification System (ECN) for a publish/subscribe system:  
The event space is represented by a single numerical attribute  $X$ , which can assume real values.  
Subscriptions can be expressed using operator  $\langle = \rangle$

Table 1 Event Notification Network



Subscribers have issued the following content-based subscriptions.

Table 2 Subscription table

Subscriber	Subscription
A	$y > 28$
B	$y < 5$ OR $y > 95$
C	$y < 45$
D	$y > 30$ AND $y < 65$
E	$y > 10$ AND $y < 23$
F	$y > 10$ AND $y < 15$
G	$y > 20$ AND $y < 25$
H	$y < 17$
I	$y > 55$

Given the following routing table, compute and sketch the path followed by event  $Y=17$  published by Publisher P through the ECN. Use the filter-based event routing model [6 marks]  
 Hint: Broker 1 can forward to either interface 2 or interface 3, or both, depending on their subscriptions (content-based address).

Table 3 Routing Table

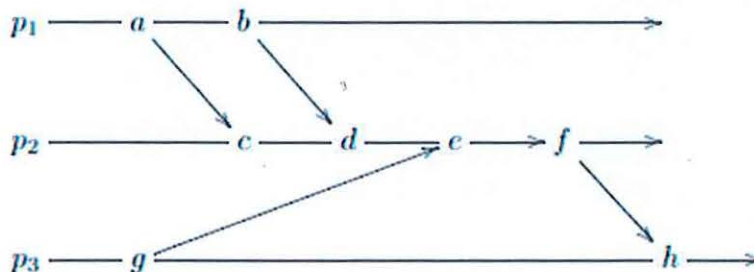
Broker	Interface	Content-based address
1	2	$y > 55$
1	3	$y > 28 \text{ OR } (y < 5 \text{ OR } y > 95) \text{ OR } y < 45 \text{ OR } (y > 30 \text{ AND } y < 65)$
2	7	$y > 55$
3	4	$y > 28 \text{ OR } (y < 5 \text{ OR } y > 95)$
3	8	$y < 45 \text{ OR } (y > 30 \text{ AND } y < 65)$
4	5	$y > 28 \text{ OR } (y < 5 \text{ OR } y > 95)$
5	6	$y > 28 \text{ OR } (y < 5 \text{ OR } y > 95)$
8	10	$y < 17 \text{ OR } (y > 20 \text{ AND } y < 25)$
8	11	$y > 10 \text{ AND } y < 15$
8	12	$y < 45 \text{ OR } (y > 10 \text{ AND } y < 23) \text{ OR } (y > 30 \text{ AND } y < 65)$
10	9	$y < 17 \text{ OR } (y > 20 \text{ AND } y < 25)$
11	13	$y > 10 \text{ AND } y < 15$
12	14	$(y > 10 \text{ AND } y < 23) \text{ OR } (y > 30 \text{ AND } y < 65)$
14	15	$(y > 10 \text{ AND } y < 23) \text{ OR } (y > 30 \text{ AND } y < 65)$

**SECTION E: [24 marks]**

- Answer all the questions in the provided booklet.
- The section consists of 2 questions.

1. Individual computers and servers in distributed systems incorporate a physical clock for timing and sequencing purposes. Discuss how the individual clocks are synchronised to serve the function of a single distributed system. [10 marks]

2.



Three processes,  $p_1, p_2, p_3$ , communicate as shown in the diagram, with events labelled  $a, b, c, d, e, f, g, h$ .

- a. Assign a Lamport timestamp to each event. [4 points]
- b. Assign a Vector timestamp to each event. (start at  $[0,0,0]$ ) [6 points]
- c. Define what it means for two events to be concurrent. State the relationship between their Lamport timestamps. [4 points]

\*\*\*\*\* End of the Paper \*\*\*\*\*