Vidyalankar Institute of Technology Accredited A+ by NAAC	**DEPARTMENT OF COMPUTER ENGINEERING**

Experiment No. 04

Semester	B.E. Semester VIII – Computer Engineering
Subject	Distributed Computing Lab
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Academic Year	2024-25

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Title: Simulate a distributed system with multiple nodes (processes or computers), each with its own local clock.

Explanation:

1. Introduction

In a distributed system, multiple nodes (processes or computers) operate independently, each maintaining its own local clock. Due to hardware variations and environmental factors, these clocks tend to drift apart, leading to discrepancies in timekeeping. Clock synchronization is essential to ensure a consistent notion of time across all nodes, which is crucial for coordinating actions, maintaining event ordering, and ensuring system reliability.

2. The Clock Synchronization Problem

In a distributed system, the absence of a global clock leads to challenges in maintaining a consistent timeline. The two main issues are:

1. **Clock Drift** – The difference in time due to slight variations in hardware clocks.
2. **Clock Skew** – The difference between two clocks at a given instance.

To counteract these issues, synchronization mechanisms are employed to adjust the local clocks of all nodes and bring them into alignment.

3. Clock Synchronization Techniques

There are two primary methods of clock synchronization:

A. External Synchronization

- The nodes synchronize their clocks with a reference time source (e.g., UTC or GPS clocks).
- Example: Network Time Protocol (NTP).

B. Internal Synchronization

- The nodes synchronize with each other without an external reference.
- Example: Berkeley's Algorithm, Cristian's Algorithm.

Since our implementation focuses on **Berkeley's Algorithm**, let's understand it in detail.

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4. Berkeley's Algorithm (Internal Synchronization)

Berkeley's Algorithm is a distributed clock synchronization algorithm designed to achieve internal synchronization in a network of nodes.

Working Mechanism:

1. **Master Node Selection:**
    - One node is designated as the master (coordinator). It is responsible for synchronizing the clocks of other nodes.
2. **Time Collection:**
    - The master node polls all other nodes to get their current local times.
    - Each node replies with its own clock time.
3. **Offset Calculation:**
    - The master calculates the average time of all nodes, ignoring outliers if necessary.

- The offset for each node is determined as the difference between its local clock and the computed average time.

4. **Clock Adjustment:**
   - The master sends an adjustment value to all nodes, instructing them to modify their clocks accordingly.
   - Each node updates its clock by adding/subtracting the given offset.

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5. Implementation of Berkeley's Algorithm in Java

In this implementation, we simulate a distributed system with **multiple nodes** running on separate threads. The **master node** (node 0) gathers time information from all nodes, computes the **average time**, and adjusts the clocks of all nodes accordingly.

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6. Code Implementation Explanation

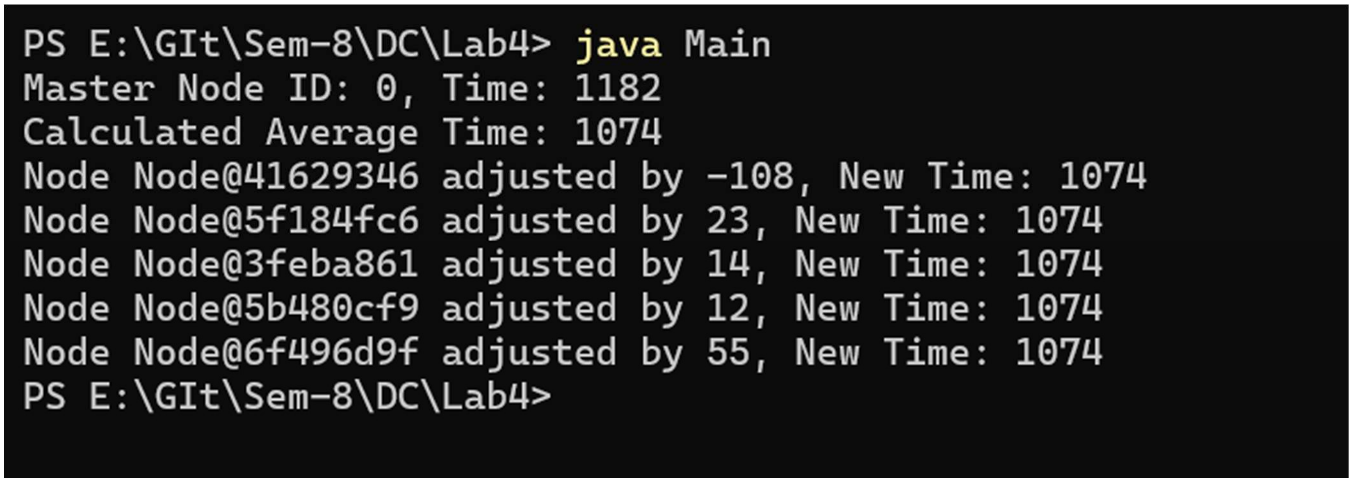
The Java program consists of the following components:

1. **Node Class (Callable<Integer>)**
   - Each node has a **local clock** initialized with a random drift.
   - Implements call() method to return its clock time.
   - Provides a method to **adjust its time** when synchronization occurs.
2. **Clock Synchronization Process:**
   - The **master node (node 0)** collects times from all nodes.
   - Computes the **average time** from collected values.
   - Determines the required **offset** for each node.
   - Adjusts the clocks to achieve synchronization.

CODE:

```java
import java.util.Random;
import java.util.concurrent.*;

class Node implements Callable<Integer> {
    private int nodeId;
    private int localTime;
    private Random rand = new Random();

    public Node(int nodeId) {
        this.nodeId = nodeId;
        this.localTime = 1000 + rand.nextInt(200); // Simulating different local times
    }

    public int getTime() {
        return localTime;
    }

    public void adjustTime(int offset) {
        localTime += offset;
    }

    @Override
    public Integer call() {
        return localTime;
    }
}

public class Main {
    public static void main(String[] args) throws InterruptedException,
ExecutionException {
        int numNodes = 5;
        ExecutorService executor = Executors.newFixedThreadPool(numNodes);
        Node[] nodes = new Node[numNodes];

        for (int i = 0; i < numNodes; i++) {
            nodes[i] = new Node(i);
        }

        // Master node is node[0]
        Node masterNode = nodes[0];
        System.out.println("Master Node ID: 0, Time: " + masterNode.getTime());

        // Collect times from all nodes
        @SuppressWarnings("unchecked")
        Future<Integer>[] futures = new Future[numNodes];
        for (int i = 0; i < numNodes; i++) {
            futures[i] = executor.submit(nodes[i]);
        }

        // Calculate average time offset
        int totalTime = 0;
        for (Future<Integer> future : futures) {
            totalTime += future.get();
        }

        int avgTime = totalTime / numNodes;
        System.out.println("Calculated Average Time: " + avgTime);

        // Synchronize all nodes
        for (Node node : nodes) {
            int offset = avgTime - node.getTime();
            node.adjustTime(offset);
            System.out.println("Node " + node + " adjusted by " + offset + ", New Time:
" + node.getTime());
        }

        executor.shutdown();
    }
}
```

Output:



```
PS E:\GIt\Sem-8\DC\Lab4> java Main
Master Node ID: 0, Time: 1182
Calculated Average Time: 1074
Node Node@41629346 adjusted by -108, New Time: 1074
Node Node@5f184fc6 adjusted by 23, New Time: 1074
Node Node@3feba861 adjusted by 14, New Time: 1074
Node Node@5b480cf9 adjusted by 12, New Time: 1074
Node Node@6f496d9f adjusted by 55, New Time: 1074
PS E:\GIt\Sem-8\DC\Lab4>
```