International Institute of Information Technology, Hyderabad

(Deemed to be University)

CS3.301 Operating Systems and Networks – Monsoon 2025

End Semester Examination

Max. Time: 3 Hr **Max. Marks: 60**

Instructions to the students:

1. Answers written with pencils won't be considered for evaluation.
2. Please **read the descriptions** of the questions (scenarios) **carefully.**
3. There are a total of nine questions with five MCQs and carry total of 60 marks. For MCQs, you can select one or more options (if necessary). Please refrain from writing long explanations for MCQs. **Keep the explanations short and to the point. Note that explanations are mandatory for MCQs.** There is an additional bonus question, which will be counted towards the overall course bonus.
4. Please **state any assumptions** made clearly.
5. Use pseudocode when necessary (you are not required to provide the exact C implementation).

Good Luck

The "AgentOS" Initiative

AgentOS is one of the first operating systems designed to natively support *agentic* AI workloads. Built on a Unix-based foundation, its goal is to provide a seamless, chat-like user interface through which users can issue natural language commands, via text or voice. These commands are then interpreted and handled by different AI agents within the system to complete tasks on behalf of the user. After six months of development, the engineering team has discovered several critical issues in the underlying Unix implementation. To move forward with the planned launch, they urgently need expert support.

You have been recruited as a Systems Intern because you have just completed the Operating Systems and Networks (OSN) course. The AgentOS engineering team now relies on your understanding of OS mechanisms, network behavior, and systems reasoning to help them resolve these issues.

You are given **180 minutes** to analyze the scenarios and answer the tasks that follow. Each task carries a specific number of points. Your **total score, out of 60 points,** will determine your contribution to the stability and readiness of AgentOS for release.

1. The AgentOS team is evaluating whether Round Robin (RR) is a suitable scheduler for their workloads. They consider three processes: P1, which arrives at time 0 ms and requires 5 ms of CPU time; P2, which arrives at 1 ms and exhibits mixed behaviour with a 2 ms CPU burst, followed by a 4 ms I/O operation, and then another 2 ms CPU burst; and P3, which arrives at 3 ms and requires 4 ms of CPU time. The team simulates these processes under Round Robin scheduling with a 1 ms time quantum and no context-switch overhead, and they want to determine the resulting average turnaround time. What is the correct value and why? **(3 points)**

   a. 10.00 ms

   b. 8.66 ms

P1	P2	P1	P2	P3	P1	P3	P1	P2	P3	P1	P3	P

c. 11.33 ms
d. 9.00 ms

2. The AgentOS team was testing the networking stack when they observed significant network jitter and decided to inspect the TCP timeout behavior. **At time, t the system's internal state** is EstimatedRTT: 50 ms and DevRTT: 4ms. For the most recent packet, the RTT was 60 ms. Assuming the standard TCP parameters of $\alpha = 0.125$ and $\beta = 0.25$, what should the TCP Timeout Interval be updated to for the *next* transmission and why? **(3 points)**
   a. 67.25 ms
   b. 72.00 ms
   c. 51.25 ms
   d. 70.75 ms

3. The AgentOS team was considering using segmentation as the approach for memory virtualisation. The underlying system uses 16-bit Virtual Addresses. The memory management hardware uses the top 2 bits of the address to select the segment. The current Segment Table is configured as follows:

Segment	ID (Binary)	Base Address (Physical)	Limit (Size)
Code	00	0x2000	0x1000
Heap	01	0x9000	0x2000
Stack	10	0xE000	0x1000

The team is also not clear about how the address translation is happening and would like your support on that. A process generates the Virtual Address 0x5100. What is the corresponding Physical Address and why? **(3 points)**

   a. 0x3100
   b. 0xA100
   c. 0xF100
   d. Segmentation Fault

4. After the above translation, the AgentOS team is more informed about the challenges when using segmentation and wants you to lead the design and development of a subsystem of a new Kernel. The team wants the system to utilize Demand Paging with a software-managed TLB for memory management. There may be scenarios where the page translation is not present in the TLB and a TLB miss occurs. Further, post TLB miss, the page may not be present in the physical memory as well. Given this constraint, they want you to do the following **(10 points):**
   a. Design an algorithm/pseudocode for the OS Trap Handler to resolve conditions where the page is not in memory. Your algorithm must sequentially detail the lifecycle of this event from the moment the trap occurs to the moment the process resumes. You

must explicitly account for CPU efficiency: The CPU cannot sit idle while the disk spins. (5 points)

b. The members of the AgentOS team taking care of the Persistence aspect, have completed the development of the virtual memory subsystem, but they are facing performance issues when memory becomes full. They need you to design the Page Replacement Policy by considering two constraints: i) The hardware does not support a timestamp register for every page access; ii) The hardware provides a single Reference Bit per page table entry. Outline the algorithm for the *evictPages()* routine that decides which pages to evict. Does your algorithm degenerate to FIFO under specific circumstances? (5 points)

5. As part of diagnosing intermittent network failures in AgentOS, the networking team asks you to verify whether the system is correctly following the TCP three-way handshake. A TCP client module P in AgentOS initiates a connection to a remote TCP service *Q*. Let *Np* denote the ***sequence number*** in the *SYN* sent from P to Q, and let *Nq* denote the *acknowledgement* ***number*** in the SYN-ACK sent from Q back to P. Based on standard TCP behaviour, which of the following statements is/are *CORRECT* and why? **(3 points)**
   a. The sequence number *Np* is randomly chosen
   b. The sequence number is set to *0*
   c. The acknowledgement number is $Nq = Np$
   d. The acknowledgement number is $Nq = Np + 1$

6. A node running AgentOS connects to a network without having any IP address assigned. Immediately after joining, a user process attempts to send an HTTP request to http://anotherdomain.com (server IP: 179.20.10.6). The AgentOS team requires your help in understanding the end-to-end sequence of steps from the moment the node connects until the HTTP request is ready to leave the link layer and move toward the next hop. **(10 points)**
   a. Describe what the Operating System must provide to enable network communication. (2 points)
   b. Explain the mechanisms the node uses to acquire its own IP address and to resolve the destination server's IP address. (4 points)
   c. Describe the activities at the Application, Transport, and Link layers that prepare the HTTP request for transmission toward the next hop (excluding network-layer routing details). (4 points)

7. The AgentOS team recently encountered an issue related to concurrency in one of its subsystems. Three concurrent processes X, Y, and Z execute different critical code segments that update shared variables. Process X performs Wait(a), Wait(b), and Wait(c) before entering its critical section; process Y performs Wait(b), Wait(c), and Wait(d); and process Z performs *Wait(c), Wait(d), and Wait(a)* before entering its critical section. After completing their respective critical sections, each process executes Signal() on the same three semaphores in the same order. All semaphores are binary semaphores initialized to 1. Which one of the following represents a deadlock-free order of invoking the Wait() operations? **(3 points)**
   a. X: Wait(a) Wait(b) Wait(c) Y: Wait(b) Wait(c) Wait(d) Z: Wait(c) Wait(d) Wait(a)
   b. X: Wait(b) Wait(a) Wait(c) Y: Wait(b) Wait(c) Wait(d) Z: Wait(a) Wait(c) Wait(d)

c. X: Wait(b) Wait(a) Wait(c) Y: Wait(c) Wait(b) Wait(d) Z: Wait(a) Wait(c) Wait(d)

d. X: Wait(a) Wait(b) Wait(c) Y: Wait(c) Wait(b) Wait(d) Z: Wait(c) Wait(d) Wait(a)

8. The AgentOS media engineering team is designing a custom file system, *SL-FS*, *optimized for a high-throughput video streaming server. The underlying storage cluster consists of 16 TB (Terabytes) of raw disk space. The SL-FS design specifications are as follows: i) Block size: 8 KB (8192); ii) Pointer size: 64-bit (8 bytes) addresses are used for all block pointers; iii) inode size: 256 bytes; iv) inode structure: To optimize for large media files, the inode contains 12 direct pointers, 1 single-indirect pointer, and 1 double-indirect pointer. Further, for metadata allocation, the system reserves exactly 2% of the total disk capacity specifically for the inode Table (where inodes are stored). The remaining 98% is for data blocks. Given this, help the team with the following* **(10 points):**
   a. Given the allocation policy above, what is the maximum number of files that can be stored in this file system? *Scenario:* If the users strictly store small text logs of size 1 KB each, will the system run out of Data Blocks or inodes first? Justify your answer mathematically. (3 points)
   b. Calculate the maximum file size (in GB or TB) that a single file can reach in SL-FS. *(Show your derivation for Direct, Single-Indirect, and Double-Indirect capacities separately. You may assume 1 KB = 2^{10} bytes, 1 MB = 2^{20} bytes, etc., for calculation simplicity).* (3 points)
   c. The team decides to move the file system onto a Network Attached Storage (NAS) array consisting of 8 disks of 4 TB each. They are debating between using RAID 1 and RAID 5. They want your suggestion on what to use, considering the need for high storage efficiency and the fact that the system is expected to have a larger number of random small writes. *Reason by calculating the usable capacity under both RAID setups and demonstrating performance under write/read workloads. (4 points)*

9. The AgentOS team is in the process of developing a firmware for a high-end Core Router placed at the edge of an Autonomous System (AS). This router maintains a massive *Global_Routing_Table* in shared memory. The router has two critical tasks running as concurrent threads: i) Hundreds of threads representing incoming packets. They need to read the *Global_Routing_Table* to find the "Next Hop" interface. Speed is critical; multiple readers must access the table simultaneously; ii) A background process that receives *BGP_UPDATE* messages from other ISPs. When a route changes (e.g., a cable cut in some location), this daemon must acquire *exclusive access* to modify the table to prevent readers from routing packets into a black hole. **(15 points)**
   a. Write pseudocode *Lookup_Route(Dest_IP)* and *Update_BGP_Route(New_Path)* using *Semaphores and Mutexes.* (8 points)
   b. The router described above is in an Autonomous System (AS 300). Considering a node with a public IP address 179.81.26.18 in this autonomous system wants to send data to another node in another autonomous system (AS 700) with an IP address 17.65.21.89. Given this scenario:
      i. Explain how such a communication can work using different protocols. (4 points)
      ii. Do we need different protocols like OSPF and BGP, or will one protocol suffice for the entire internet routing? Explain (3 points)

10. **Bonus Question**: Many CPU-scheduling algorithms are parameterized. For example, the RR algorithm requires a parameter to indicate the time slice. Multilevel feedback queues require parameters to define the number of queues, the scheduling algorithms for each queue, the

criteria used to move processes between queues, and so on. These algorithms are thus really sets of algorithms (for example, the set of RR algorithms for all time slices, and so on). One set of algorithms may include another (for example, the FCFS algorithm is the RR algorithm with an infinite time quantum). What (if any) relation holds between the following pairs of algorithm sets? **(4 points)**

a. Priority and SJF
b. Multilevel feedback queues and FCFS
c. Priority and FCFS
d. RR and SJF

Time slice

*****************Now it's time to wait for final points*****************