International Institute of Information Technology, Hyderabad

(Deemed to be University)

CS3.301 Operating Systems and Networks – Monsoon 2024

Mid Semester Examination

Max. Time: 1.5 Hr **Max. Marks: 35**

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 seven questions with four MCQs and carries total of 35 marks. For MCQs you can select one or more options (if necessary). Please refrain from writing long explanations for MCQ questions. **Keep the explanations short and to the point.**
4. In general, for descriptive questions keep the explanations short and to the point. Long answers do not necessarily indicate higher marks.
5. Feel free to make meaningful **assumptions**. However, please **state them clearly**.

Good Luck

Congrats on your new startup VirtualizeIt!!

Congratulations on founding your own startup, 'VirtualizeIt,' which specializes in building a modern, lightweight operating system designed for cloud environments. As the founder and lead architect, you've recently recruited a team of enthusiastic junior developers who are eager to learn and contribute to the core features of the OS. Your team is divided into small groups, each tasked with implementing key aspects: process virtualization, memory virtualization, and the transport layer of network communication based on the OSI model. Your role is to guide these junior developers, explaining how to design efficient virtualized environments for processes and memory, while ensuring that the transport layer handles network data transfer reliably and efficiently. As their mentor, you'll need to review their designs, troubleshoot challenges, and help them understand the impact of these components on overall system performance. The future of 'VirtualizeIt' depends on how well you can impart your expertise and ensure the team builds a world-class operating system.

As the CEO you have 90 minutes to help the team with different problems which will help in upskilling your team. Each task is assigned a specific number of points, and the cumulative score of all the tasks will determine the skill level of the employees (based on total points), with a maximum of 35 points.

1. The group working on memory virtualization has decided to use paging as the approach for memory management. The team is dealing with a 32 bit address space with 4 KB pages. The team was able to identify the table with the mapping between the page numbers and frame number given as the following:

Virtual Page Number	Frame Number
0x00001	0x00004
0x00003	0x00007
0x00004	0x00002

However, the team is unclear about different aspects related to the address translation and they require your support in making them understand: **(7 points)**

a. The team printed the address of a couple of variables during the program execution and they obtained the addresses as: i) 0x000032AC and ii) 0x00001A3B. The team believes that this is the actual address. But you are claiming that this is not the actual address. Why do you think this is not the actual address? For each of the virtual addresses what will be the actual address? (5 points)

b. During your interaction you noticed that some team members feel that it would have been better to use segmentation for memory virtualization in general as it allows to allocate memory as per the requirement of each segment of the process. What is your opinion on this statement? (2 points)

2. As the team started working with paging using linear page table as the way forward for memory virtualization, they started noticing some challenges. The team noticed that the processes are taking more time to execute and they are unclear why this is happening. As a starting point the team wanted to get an idea of how many processes are executing in the system and they noticed that there are about 500 processes that the system is executing on average. Further, they were also able to estimate that each entry in the page table is consuming about 4 bytes. They have raised this issue to you and you noticed that there are some issues with the manner in which paging has been implemented which is impacting the overall efficiency and effectiveness of translations. **(10 points)**
   a. In your opinion what will be the memory overhead (in MB) of using paging (based on the given scenario) and what is a solution the team can consider to improve this situation. **(3 points)**
   b. You also noticed that for each translation, the mechanism is searching through the entire page table in the physical memory which is making address translation less efficient. You identified that the team is missing the use of a hardware component. What do you think the team can do to improve this situation? Further do you feel such a solution can contribute towards effective process virtualization considering that there are many processes that use the network and/or I/O? **(4 points)**
   c. As a final step, you felt that some more improvements can be done. In order to support processes with larger address space, the team has implemented a FIFO page replacement policy while using a cache size of 3 considering a set of access to pages: 0, 1, 2, 0, 1, 3, 0, 3, 1, 2, 1. What is your opinion on the page replacement policy used **(3 points)**

3. In order to support process virtualization, the team working on process virtualization has planned to use Multi-Level Feedback Queue (MLFQ) as the scheduling policy. The team is planning to use 100 queues to implement MLFQ. However, some of the team members are not aligned with this decision and they would like to get your inputs on the impact of configuring a MLFQ scheduling algorithm with 100 queues. In your response, try to address the following aspects: **(6 points)**
   a. How does the use of 100 queues affect the granularity of priority control and the handling of process priorities? (1.5 points)
   b. What are the implications for process starvation, particularly for those starting in lower-priority queues? (1.5 points)
   c. Explain the potential scheduling overhead and its effect on overall system performance (1.5 points)
   d. Analyze how responsiveness for interactive tasks might be influenced by this configuration. (1.5 points)

4. The team working on the transport layer has developed a simple web application to test their implementation. The web application is responsible for sending video stream over the network and the team has decided to use a connection-less protocol for the data transfer. Considering that the initial data sent to the process is 01100110 10101010 11110000 00001111. What do you suggest is the mechanism that the team needs to consider for using on the transport layer of the receiving machine to check for errors? **(3 points)**
   a. Acknowledgement number and checksum
   b. Sequence number and checksum
   c. Only use checksum
   d. Use sequence number and acknowledgement number
   e. None of the above

5. As the team completed working on the implementation of support for connection oriented protocol, they noticed that whenever a process has completed the data transfer to the server process, the connection is getting terminated abruptly without the server process acknowledging the termination. The team is confused and requires your suggestion. What do you think could be the problem? **(3 points)**
   a. Using connection oriented protocol like UDP provides no guarantee
   b. The process might be auto setting FYN bit at the end of data transfer
   c. The process might be auto setting RST bit at the end of data transfer
   d. The process is not making proper use of acknowledgement number
   e. The process might not be setting SYN bit at the end of the data transfer

6. The transport layer team has built a file transfer application that uses connection less protocol for communication. Given this context, the team wanted to discuss a scenario with you. Assume that during the communication, the sending or receiving process undergoes context switch. What will happen if the context switch introduces a significant delay in processing? **(3 points)**
   a. The protocol will retransmit lost packets automatically after the context switch
   b. The packets may arrive out of order or be lost, and no recovery will occur at the transport layer
   c. The operating system will save and restore the protocol connection state
   d. Protocol will start a new session after the context switch
   e. None of the above

7. As a final step, the team is having a debate related to the role of various components and layers of the network stack (implemented as per the OSI model). Assuming the scenario that data needs to be sent from Process A in Machine 1 located at 192.168.20.12 to process C in Machine 20 located at 172.196.16.2, what are the key components that are responsible for determining the best path and further for final hop-to-hop delivery? **(3 points)**
   a. Router at Layer 3 for optimal path supported by IP and Switch at Layer 2 for hop-to-hop using MAC
   b. Router at Layer 4 for optimal path using IP and Switch at Layer 3 for hop-to-hop using port number
   c. Host at Layer 7 for optimal path supported by IP and port number and Router at Layer 3 supported by MAC
   d. Router at Layer 3 for optimal path supported by IP and Hub at Layer 4 for hop-to-hop supported by MAC
   e. Switch at Layer 3 for hop-to-hop supported by MAC addressing followed by Router at Layer 2 for end-to-end supported by IP