ASSIGNMENT COVER PAGE

Programme	Course Code and Title
Bachelor of Computer Science (Hons) (UCSE) / Bachelor of Computer Science (Hons) in Computer and Network Technology (UCNT)	COS3043/N System Fundamentals
Student's name / student's id	**Lecturer's name**
0204677 Lim Zhe Yuan	Foo Lye Heng

Date issued	Submission Deadline	Indicative Weighting
22/09/2023 (Week 2)	20/10/2023 (Week 6)	30%
Assignment [1] title	Research report writing	

This assessment assesses the following course learning outcomes

# as in Course Guide	UOWM KDU Penang University College Learning Outcome
CLO1	Explain advanced concepts in system fundamentals theory and implementation
CLO2	Evaluate software design issues for advanced computer systems such as multiprocessors or distributed systems

# as in Course Guide	University of Lincoln Learning Outcome
CLO1	Identify the values of object-oriented design and programming
CLO2	Apply object-oriented principles to the implementation of software programs
CLO3	Apply advanced logical and mathematical techniques in the development of software solutions

Student's declaration

I certify that the work submitted for this assignment is my own and research sources are fully acknowledged.

Student's signature: Zhe Yuan

Submission Date: 20/10/2023

TurnItIn Similarity Report

Asgn1MainReport

ORIGINALITY REPORT

13%	6%	1%	12%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Toronto Business College Student Paper	3%
2	www.ibm.com Internet Source	3%
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4	Submitted to University of London External System Student Paper	2%
5	www.updatesrelates.com Internet Source	1%
6	Submitted to Boston University Student Paper	1%
7	dev.to Internet Source	1%

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Main Report

Part 1: Concept of Virtualization

For starters, a **virtual machine (VM)** is a virtual environment that emulates a functional computer system with its dedicated resources, such as CPU, memory, storage, and network infrastructure, which is created on physical hardware (IBM, n.d.-a; Red Hat, 2022; Sheldon, 2023). Sheldon (2023) describes that VMs functions similarly to actual machines from a user's perspective, and they will not be aware of using a VM in most cases. Under the abstraction of VMs, a hypervisor is needed on the physical computer, known as the host machine, to coordinate between the interaction of VMs, known as the guest machines, with the underlying physical hardware (IBM, n.d.-a). It allows the host to isolate applications and resources from its hardware and manages resources of each VM to accommodate their changing demands (Sheldon, 2023). This enables multiple VMs on the host to run different operating systems and applications independently and have access to the shared pool of resources on the physical hardware (IBM, n.d.-a). Specifically, hypervisors fall into one of two categories: type 1 and type 2. Type 1 hypervisors operate directly on the host machine and have direct access to its hardware, such as Microsoft Hyper-V and VMware ESXi. Oppositely, type 2 hypervisors are installed on top of the host machine OS and handle indirect calls to access hardware resources, such as VMware Workstation and Oracle VirtualBox (Sheldon, 2023). Several use cases of VMs include cloud computing, DevOps support, testing an OS, malware investigation, and executing incompatible software (IBM, n.d.-a).

On another hand, **containerization** is the packaging of application code with its required code libraries and dependencies during software production to create a single lightweight executable, called a container, that runs consistently on any infrastructure. Traditionally, users obtain applications by installing matching application versions to avoid software incompatibility. However, a single software package that is compatible with different computer environments can be created with containerization (AWS, n.d., IBM, n.d.-b). Within the abstraction of containers, container runtimes or engines are responsible for managing container loads, including loading container images from a repository, monitoring local system resources, isolating system resources for container usages, and managing container lifecycles (Aqua Security, 2023). Containerized applications do not bundle an OS copy along with their dependencies but utilize container runtimes as intermediary to communicate to the host OS in a form that it understands. Besides eliminating overhead of running an OS within a container, multiple containers also share common binaries and libraries, making them compact but efficient (IBM, n.d.-b). Several use cases of containerization include cloud migration, microservice architecture adoptions, and IoT applications (AWS, n.d.), and examples of container engines are Docker, CRI-O, and Windows Containers, with Docker being the leading container system. These engines can also additionally work with a container orchestrator like Kubernetes to manage and scale clusters of containerized workloads (Aqua Security, 2023).

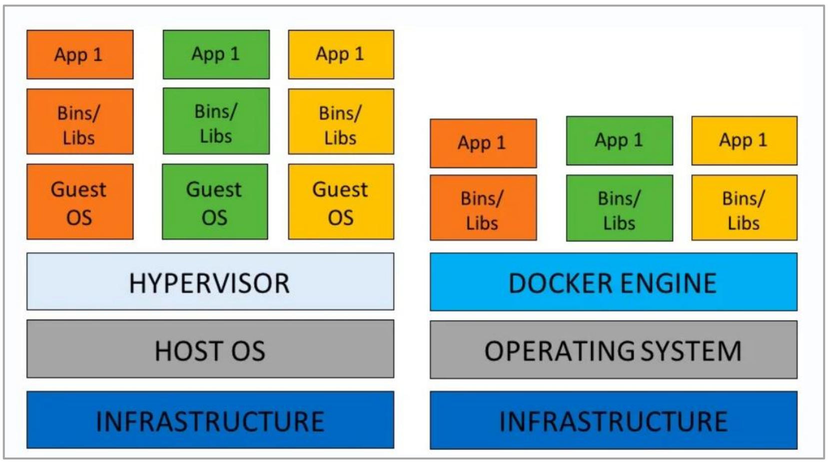

***Figure 1**: Architecture difference between virtual machines (left) and containerization (right) (Murillo,2019)*

VMs and containerization works similarly in terms of diverting attention from the physical hardware and enabling multiple types of software to run on a single environment. However, the main difference lies in their architecture, where containers virtualize only the OS and not the rest of the underlying hardware unlike VMs (Sheldon, 2023), which is mainly for making applications adaptive to the host OS instead of establishing different environments. It is easier to understand containers as lighter VMs as they adapt to the host OS and share the kernel with other containers instead of managing their individual guest OS like VMs did (Murillo, 2019).

Part 2: Benefits and Limitations for the Virtualization technologies

Due to similarities between both technologies mentioned above, it was discovered that they also share common benefits and limitations that target their corresponding architecture design. The tables below contrast some, but not all benefits and limitations that can be found in these technologies.

Benefits:

Characteristics	Virtual machine (VM)	Containerization
Efficiency	VMs enable multiple operating systems to run simultaneously on the same host by utilizing existing computing resources efficiently, which also eliminates the need to invest in new hardware resources for additional environments, resulting in lower business expenses and maximizing returns of investment (IBM, n.d.-a).	Multiple application containers can share and coexist on the same host machine's OS kernel, thus eliminating dedicated guest OS overhead. Higher server efficiencies can be achieved by speeding up bootup times as there is no OS to boot (IBM, n.d.-b).
Portability	VMs can be relocated to other physical computers in a network. This makes it possible to allocate workloads to servers that have spare computing power. VMs can even move between on-premises and cloud environments, making them useful for hybrid cloud scenarios (IBM, n.d.-a).	A container creates an executable package of application software that is independent of the host OS, and hence, is portable and able to run uniformly and consistently across any platform or cloud (IBM, n.d.-b).
Fault isolation	Each VM is completely self-contained with their own guest OS resource allocation and management capabilities (Narang, 2023). Even if a VM is damaged by malware or unexpectedly crashes, they do not affect processes on the host or other guest OS (Totounji, 2022).	Containerized applications are isolated and operate independent from each other on a host OS. One container failure does not affect the continuation of any other containers and development teams can resolve any technical issues within one container without causing any downtimes (IBM, n.d.-b).

Limitations:

Characteristics	Virtual machine (VM)	Containerization
Single point of failure	If the host machine fails, all VMs running on it will also be destroyed unless a failsafe mechanism is in place (Narang, 2023).	Containers share the host OS kernel, so containers will consequently become vulnerable as well if the kernel is compromised (Guyton, 2019).
Complexity	Virtualization can be complex to set up and manage, especially when multiple VMs are involved. It may also require additional tweaks and customization to fulfill task preferences (Narang, 2023).	Containers can also be complex to set up and manage as applications should be designed in a way that is interpretable by container engines. Container orchestration tools, such as Kubernetes, adds another layer of complexity despite being used for simplifying container management (Xcube Labs, 2023).
Software	Hardware capabilities emulated by VMs are limited by the hardware resources available on the host (Narang, 2023).	Containers are designed to be stateless, meaning they avoid storing data or state. This makes managing persistent data, such as databases, a difficult endeavour within a container environment (Xcube Labs, 2023).

Part 3: Challenges of Virtualization technologies

It is also notable that virtual machines and containerization encounter common challenges because of their semblance.

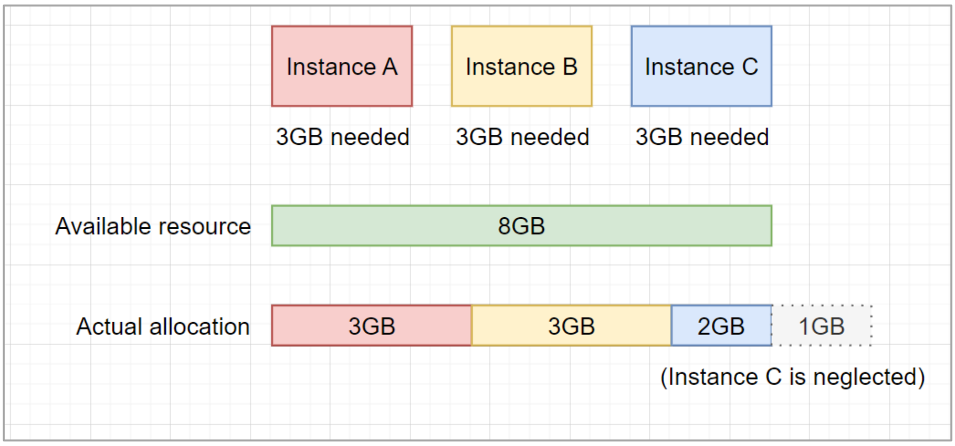

Figure 2: *Demonstration of inefficient resource distribution in virtualization*

Firstly, both technologies suffer from difficulties of distributing computing resources in terms of memory and processor scheduling and management. Regardless of the virtualization of OS or the whole bare metal machine, allocating computing resources enough to appropriately run and maintain the operation of multiple instances of these technologies prove to be a massive challenge. Virtualization may partition system in a manner where some processes might function spectacularly, but others might not obtain enough access to computer resources to meet their needs. Resource distribution problems often occur in virtualization migrations and can be fixed with capacity planning before the environmental shift (GDH, 2018).

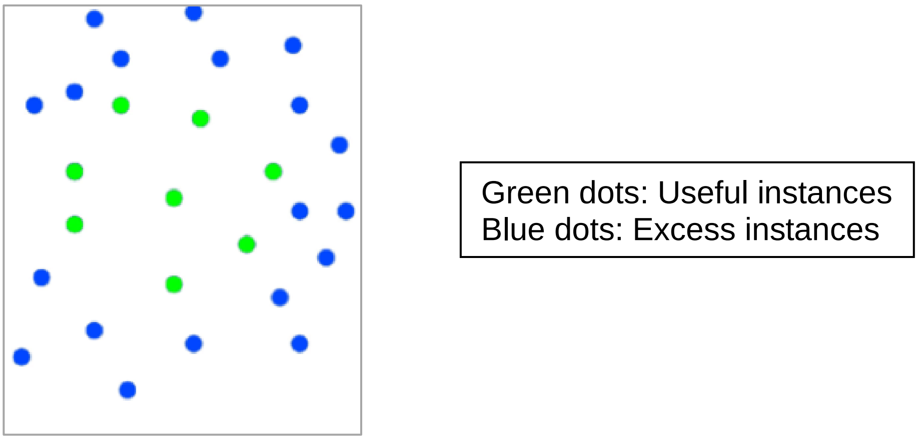

Figure 3: *Demonstration of cloud sprawl*

In terms of device emulations, the management of multiple virtualization instances also presents a major challenge. Factoring in the possible complexity of managing these technologies, a considerable amount of time and effort is required to ensure the availability of managed instances if there are many (Rodriguez, 2021). Furthermore, server or cloud sprawl may also occur, which is the uncontrolled proliferation of instances and services (Bigelow, 2021), as VMs and containers can be initialized quickly and abused by users unintentionally. Cloud sprawl not only causes problems in instance monitoring, but also in efficiency as excess instances exacerbate resource distribution and bottlenecks performance (GDH, 2018; Rodriguez, 2021).

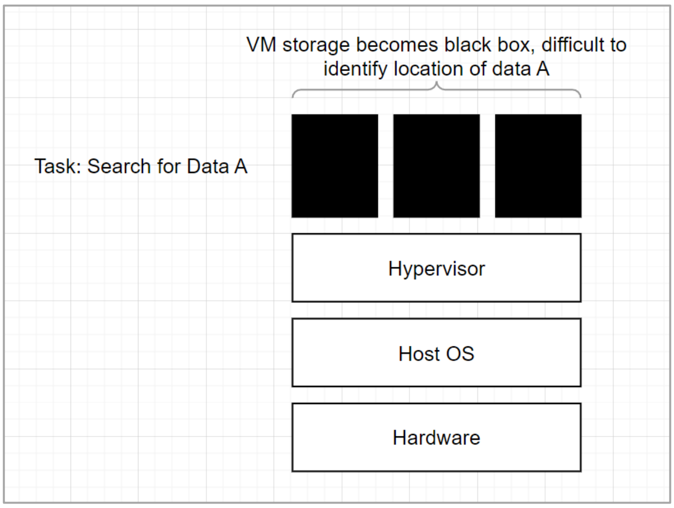

Figure 4: *Demonstration of lack of data visibility in VM*

Determining the appropriate data management practice for storage is also another challenge for these virtualization technologies. As virtualization becomes more inclusive with heterogeneous environments, especially with the adoption of containers, problems regarding about a lack of visibility to where business-critical instances and data reside becomes more prevalent (Rodriguez, 2021). This makes organizations vulnerable and increases chances of data loss. According to GDH (2018), creating and accessing backups is also difficult as there is no actual hard drive for data to be relocated on, and external backup programs are required to simplify and centralize the process.

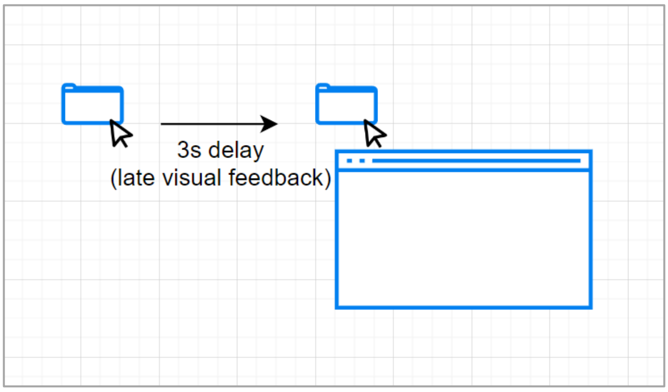

Figure 5: *Demonstration of possible delayed I/O response of a virtual instance*

One challenge to virtualization for I/O is ensuring their performance and minimizing latency. McDougall and Anderson (2010) mentioned that a virtualization platform must provide excellent performance, such that an instance running in a virtual environment must perform on-par with a native instance. This have not been entirely the case as it was also mentioned that I/O performances displayed is still directly dependent on the capabilities and availability of the hardware (Danciu & Metzker, 2010). This issue is evident as a VMware vSphere (2019) article has documented a problem where the host took longer to complete I/O requests and VMs displayed unsatisfactory response time.

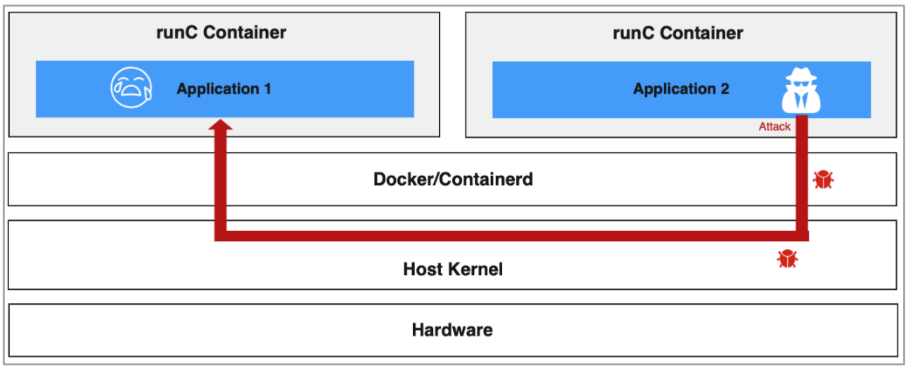

Figure 6: *Demonstration of a possible security breach between containers (Alibaba Cloud, 2023)*

Last but not least, ensuring security in virtualization technologies from data and legal perspectives is another challenge. VMs and containers may be compromised if no access control is configured in place, which may happen due to human errors or system bugs (Rodriguez, 2021). According to Rodriguez (2021), there are reports of hackers who gained access to sensitive data in a Kubernetes server without password protection. The ability to virtualize environments unconditionally also raises questions about licensing compliance. Some software licenses may not give consent or require an additional license payment for usages on additional virtual instances (Narang, 2023).

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COS3043/N System Fundamentals Marking Rubric
ASSIGNMENT [1] Individual Report Writing (Weighted Marks: 30%)

REPORT COMPONENT (100%)

LEARNING OUTCOME	MARKING CRITERIA	SCALE: Failed (0% to 49%)	3rd class (50% to 59%)	2nd lower (60% to 69%)	2nd upper (70% to 79%)	1st class (80% to 100%)	YOUR MARKS/COMMENTS
CLO 1: [Explain advanced concepts in system fundamentals theory and implementation.] CLO2: [Evaluate software design issues for advanced computer systems such as multiprocessors or distributed systems.]	**1.Elaboration on understanding regarding advanced concepts of virtualization (30%)**	Students demonstrate a superficial understanding towards advanced concepts of virtualization,	Students demonstrate the acquisition of new content from significant learning experiences. Report entry provides evidence of gaining knowledge, making sense of new experiences, or making linkages between old and new information related to advanced concepts of virtualization.	Students demonstrate thoughts about or challenges to beliefs, values, and attitudes of self and others. Report entry provides examples of self-projection into the experiences of other, sensitivity towards the values and beliefs of others, and/or tolerance for differences related to advanced concepts of virtualization.	Students demonstrate the application of learning to a broader context of personal and professional life. Report entry provides evidence of student's use of readings, observations, and discussions to examine, appraise, compare, contrast, plan for new actions or response, or propose remedies to use in and outside structured learning experiences related to advanced concepts of virtualization.	Students demonstrate examination of the learning process, showing what learning occurred, how learning occurred, and how newly acquired knowledge or learning altered existing knowledge. Report entry provides examples of evaluation or revision of real and fictitious interactions related to advanced concepts of virtualization.	
	2. The depth of analysis writing on the benefits and limitations of virtualization technologies (30%)	No analysis or meaning-making related to the benefits and limitations of virtualization technologies.	No analysis or meaning-making. Shows some thinking and reasoning but most ideas are underdeveloped and unoriginal related to the benefits and limitations of virtualization technologies.	Little or unclear analysis or meaning-making. Analysis indicates thinking and reasoning applied with original thought on a few ideas related to the benefits and limitations of virtualization technologies.	Some analysis and meaning-making. Critical thinking is weaved into points. Analysis indicates original thinking and develops ideas with sufficient and firm evidence related to the benefits and limitations of virtualization technologies.	Comprehensive analysis and meaning-making. Reveals a high degree of critical thinking. Analysis indicates synthesis of ideas, in-depth analysis and evidence of original thought and support for the topic related to the benefits and limitations of virtualization technologies.	
	3. Evaluation of the challenges of virtualization (30%)	No analysis or meaning-making related to the challenges of virtualization	No analysis or meaning-making. Shows some thinking and reasoning but most ideas are underdeveloped and unoriginal related to the challenges of virtualization.	Little or unclear analysis or meaning-making. Analysis indicates thinking and reasoning applied with original thought on a few ideas related to the challenges of virtualization.	Some analysis and meaning-making. Critical thinking is weaved into points. Analysis indicates original thinking and develops ideas with sufficient and firm evidence related to the challenges of virtualization.	Comprehensive analysis and meaning-making. Reveals a high degree of critical thinking. Analysis indicates synthesis of ideas, in-depth analysis and evidence of original thought and support for the topic related to the challenges of virtualization.	
	4. References, Sources &Citation (10%)	Some sources are not accurately documented. Diagrams and illustrations are not accurate OR do not add to the reader's understanding of the topic. Missing or no citation and major flaws in the format.	All sources (information and graphics) are accurately documented, but many are not in the desired format. Some diagrams and illustrations are not accurate OR do not add to the reader's understanding of the topic. A very minimal amount of cited works, with incorrect format.	All sources (information and graphics) are documented, but an adequate amount is not in the desired format. Diagrams and illustrations are neat and accurate and sometimes add to the reader's understanding of the topic. An adequate amount of cited works, both text and visual, are done in the correct format. Inconsistencies evident.	All sources (information and graphics) are accurately documented, but a few are not in the desired format. Diagrams and illustrations are accurate and add to the reader's understanding of the topic. All, both text and visual, are done with minimal errors in the format.	All sources (information and graphics) are accurately documented in the desired format. Diagrams and illustrations are neat and accurate, and they add to the reader's understanding of the topic. All cited works, both text and visual, are done in the correct format with no errors.	
						Total (100%)	