**Examination Information**

The submission deadline for this assessment is **6th June 2020, 11:00 BST**.

**Answer all 3 questions**.

Use this template document to report your written answers to the questions.

Ensure your answers fit in the space available under the questions. **DO NOT** modify the template.

Submit a single PDF file via the **Gradescope** submission point.

Support for the assessment is available via the module Yammer group.

You are permitted to use your lecture notes while completing this assessment.

The number in brackets [ ] indicates the marks available for each question or part question.

You are reminded of the need for clear presentation.

The total number of marks for this assessment paper is **60**.

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**Question 1**

**(a)** State the similarities and differences between traditional computing clusters and computing clouds, considering the following technical and economic aspects:

(i) Hardware, software, and technical support

(ii) Resource allocation and provisioning methods

(iii) Infrastructure management and protection

(iv) Support of utility computing services.

**[6 marks]**

*Answer:*

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| In the aspect of the hardware. Both computing use CPU, GPU, memory bank, etc. However, cloud computing would need to present such heterogeneous hardware to IaaS cloud computing user in abstractions while providing isolation. The software runs on traditional computing would run on it’s Operating System (OS). And for cloud computing, it would create several Virtual Machines (VM) on one single physical machine. So the hardware would share among VMs as well as applications. Or the cloud computing would use containers, it would be more independent, but still, it shares the hardware, and the software would run in an isolated environment. Also, the software in cloud computing can be redeployed to another server along with it’s VM or containers. There is a virtualization layer between hardware and VM. In this case, cloud computing would use hypervisor technology to manage VMs. For containers, it would be a container engine, which is a container manager between container and hardware layer. As for traditional, the manager is manual and runs beyond OS layer, and all cluster run the same applications run on it.  Cloud computing would have resource management and scheduling. Decide how to allocate resources of a system, in the aspect of hardware and network, between users and tasks. It also has to fulfil the Service Level Agreement to ensure the service requirements can be satisfied. There are two ways for provision, one is under-provision, another is over-provision. As for traditional computing, it would make the best effort to find the resources in the cluster. The allocation depends on its hardware to allocate.  For cloud computing, it’s using virtual infrastructure management, like OpenNebula and Openstack. To manage, dynamic deployment of VM on a different physical server. As for its physical server, it’s always in a massive data centre with thousands of machine in the server racks. To protect them, would need a firewall to prevent the attack from Internet hackers. And it’s harder to protect multi-tenant than single user. Traditional computing management would be more focus on the local area network. And its also has to maintain it’s hardware. Cloud computing support pay-per-use model and provide personalized service for each customer, which also support utility computing. As for tradition service, it would be hard to support utility computing and pay-per-use model. |

**(b)** A company is interested in enterprise cloud computing adoption and is considering the following scenarios:

(i) The company has peak customer demand for its IT services in the month of April. It has enough IT resources to handle off peak demand but not peak load. Explain briefly what the best approach is for handling this situation. **[2 marks]**

*Answer:*

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| Use the resource management and scheduling method. The admission control method can handle peak load and prioritize workloads of high-value customers. It’s also has resource throttling methods to handle workload bursts. And service orchestration and workflow schedulers. Auto-scaling techniques. Multi-cloud load balancers to spread the load of an application across multiple clouds. |

(ii) The company wants to build a test environment to test software updates and new solutions. The test environment should mirror the production environment, be secure and inaccessible from outside the company network. The company does not want to invest in infrastructure that may be idle for a significant amount of time. Which cloud computing model will satisfy all these requirements? **[2 marks]**

*Answer:*

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| *Virtual private cloud would satisfy these requirements. They provide private service so that they can only access their data inside their company network. When there is no test, the part of the cloud resources allow outside users to access, so it won’t waste too much resources.* |

(c) You are designing an application that requires both data acquisition and pre-processing of raw data for event filtering on the cloud. Moreover, you have the freedom to describe the underlying hardware to perform the pre-processing. Which hardware architecture would you choose for such an application? Justify your answer. **[5 marks]**

*Answer:*

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| *I would like to use the Application specific instruction set processors (ASIPs) as my hardware architecture. I only need to design one application on the hardware so that the application specific processors would be enough. And it’s better to compare with the general purpose processors. And ASIP is instruction set, micro architecture and memory system are customised for an application. So it would be flexible to design my application to pre-processing raw data would be filtering for specific event filter on the cloud. More importantly, it has even better performance, lower cost and lower power consumption. It would be suitable to perform the pre-processing.*  *Alternatively, with the help of GPU also another fine option. As an accelerator, it can deal with parallel applications and process lots of data very fast.* |

(d) A cloud computing company, Clouds4U, wants to introduce a cloud brokerage service. The role of the cloud broker can be either:

(i) intermediary role, or

(ii) virtual service provider.

Which role should the company go for? Explain your reasoning. **[5 marks]**

*Answer:*

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| *As the role of intermediary, it will help the cloud computing company to search for cloud resources or deploy VM or containers across multi-clouds. There are so many infrastructure providers out there. Therefore the company would need the cloud brokerage service to find which infrastructure provider would be more suitable for the deployment. The role for that can be a third party that enables a user to dynamically search for cloud services that match a given profile within a predefined budget. Another role is to provide service, like facilitating the deduplication, encryption and transfer of the customer’s data to the cloud and assisting with data lifecycle management. All in all, the intermediary role as a third party will take a low risk and get a benefit. However, as a virtual service provider only provide small additional service. I think the most customer would choose intermediary service, and the additional service also can be provide through the intermediary and provided by other clouds. So I would go for the intermediary role.* |

**Question 2**

(a) A student is overheard saying the following regarding a large Mapreduce job with m mappers and r reducers. Comment briefly on these statements, correcting any inaccuracies or omissions in them. **[4 marks]**

(i) Each mapper must generate the same number of key/value pairs as its input had.

(ii) The number of output jobs you get at the end of the job is m.

(iii) There will be m x r distinct copy operations in the sort/shuffle phase.

(iv) A reducer is applied to all values associated with the same key.

*Answer:*

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| (i) Mapper may generate any number of key/value pairs. Nothing to do with the number of input had.  (ii) The output is generate by the reducer. So the number of output jobs at the end is r.  (iii) True. The distinct copy operations would be m multiply r.  (iv) True. In a reducer, it’s apply to all values associated with the same key. |

(b) Consider an application deployment scenario on a cloud virtualised infrastructure. You have the choice of using Openstack or Kubernetes to deploy virtualised services. Compare Openstack and Kubernetes considering five criteria of your choice.  **5 marks]**

*Answer:*

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| As for the application scenario, OpenStack would be more suitable for the IaaS layer. It has good management for VM, computation, storage and network resource. And it’s open-source cloud tool. Kubernetes would be suitable for PaaS. Its purpose is to manage containers efficiently. It implements basic container scheduling and microservice scheduling framework. As for maintenance. Openstack would be more difficult. There are a lot of component dependencies, like MySQL, rabbitMQ. Kubernetes would be more simple to maintain. Many projects can run in the container, which means the system would help manage automatically, such as doker.  As for functions, Kubernetes would be more efficient for docker container and management solution. And OpenStack is a flexible tool for managing public and private clouds.  As for architecture, the OpenStack is quite complicated and hard to maintain. The Kubernetes would be simple and less centralized.  For Kubernetes, it has migration backup and automatic recover. However if we migrate VM in openstack, we may also migrate other applications run on the VM.  As for scalability, the OpenStack will implement and massively scalable. Kubernetes would gracefully scaling up and down the platform to have better use of infrastructure resources. |

(c) There is an explosive growth of energy consumption in cloud data centres. This explosion has led to advocacy of energy efficiency and green computing.

(i) Propose a DVFS-based VM allocation mechanism to use in order to minimise the power consumed in the data centre. **[3 marks]**

*Answer:*

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| *Monitor cloud usage, load and each server supply voltage. Decrease the clock frequency of a processor to allow a corresponding reduction in the supply voltage. Then use host underload detection algorithm to decide when to migrate the VMs from the least utilised host. VM selection algorithm decide which VMs to migrate. Use VM placement algorithm, heuristic for the bin-packing problem (power-aware best fit) to live migrate the VM to the best fit node. And all of these steps must obey some policies and rules, like it should satisfy the SLA, meet the job deadline even the performance decreased, etc.* |

(ii) You are asked to schedule 3 Virtual Machines on 3 physical servers. The power consumption of the servers is shown in Table 1. What allocation mechanism would minimise the total power consumption? Justify your answer. **[3 marks]**

Table 1: Servers' Power Consumption



*Answer:*

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| *Consolidation with VM placement algorithm (power-aware best fit) would minimise the power consumption. The server 3 consume the most power when it’s idle, but has the lowest power per VM. In this case, we cannot turn off the server, if we turn it off, it may break the hot-cold isle and raise other problems. So the server with the lowest power per VM can be regarded as the best choice. The mechanism would deploy all 3 VMs to server 3, and the total consumption is 315W, which is the lowest total power consumption when it compares with any other deployments.* |

(d) A cloud provider is setting up a Service Level Agreement (SLA) framework for Quality of Service provision for its customers. The infrastructure management supports multi-tenancy as well as availability, confidentiality and integrity. To fulfil the SLA the cloud provider needs to ensure that the acceptable level of Virtual CPU utilisation on each VM does not exceed 90%.

(i) Propose a high-level design of the SLA framework including any information that you feel is relevant to support your argument. **[3 marks]**

*Answer:*

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| The SLA should ensure there are enough resources for service execution over time. And should be security enough that it will prevent the resources and users from failures and attack, and ensure they have control over data. The service and resources should be complete and integrity, and the computations should be correctly, and provider should store users data without tampering with it. To prevent overloading and performance decrease, specify the type of CPU and other hardware the CPU utilisation on each VM should not exceed 90%. There should be enough backup and alternative servers to support fault tolerance. For example, if one server is down, there should be other servers to continue to provide services. Also SLA should describes the desired objective in details, including what service should be provided and what is not included, the deadline and other policies. After both client and provider agree the SLA, monitor whether service level objectives are being violated. |

(ii) What issues would you consider if the cloud provider were a member of a federation?

**[2 marks]**

*Answer:*

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| This requires novel approaches for billing and accounting, interconnected cloud suitable pricing methods and formation of InterCloud marketplaces. And it also can raise the security issue, since the provider could share resources with other members. So provider needs to distinct which resources or data is mine, which are others. And it could be possible that the SLA with the provider could conflict with the SLA with the federation. |

**Question 3**

(a) You are required to operate a Web application on the cloud. You have the choice to deploy the application either on Virtual Machines or as Function(s)-as-a-service. Justify your choice and include any configuration information and test scenarios that you feel are relevant to support your argument. **[5 marks]**

*Answer:*

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| I would like to choose to deploy the application on the FaaS. Because as a developer, that would be much simple for me. I don’t have to deal with the server, and don’t need to configure or manage underlying servers. The configuration and execution environment is automatically set, and managed the server is also hidden from me. Besides, there are other benefits, like it can continuous scaling, dynamic allocation of resources, avoid overallocation of resources, satisfy pay-per-usage rules. And it’s run in a container, which means it only takes millisecond to boot and deploy. However, if the application is complex and large, I would choose VM, then I have to consider how to configure the VM, and where to deploy, which infrastructure manager should I choose and other problems. One scenario that would be better for using FaaS is the Amazon lambda. It allow the developer to execute code without administrating services. It’s automatic scaling and configuration. The container’s uptime also quicker and satisfy pay per processing unit. |

(b) You are required to design a cloud security solution. The cloud as a multi-user distributed environment brings unique security challenges, dependent on the level at which the user operates: application, virtual or physical. For each level propose one security requirement and one associated threat. **[4 marks]**

*Answer:*

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| Some of the application, one security requirement can be the access control. To have control which user can access this application and which cannot. The application, like detecting fraud and national security, is to preserve privacy, as data mining tools with cross-domain knowledge can reveal more personal information than anticipated. Therefore, the threat that hackers would access the application to steal these information can be a serious problem.  As for virtual or physical level, one security requirement can be the network protection, such as firewall or intrusion detection system. Attack from the network can be a serious threat to the physical. Like stealing data from the storage, or computer virus, which cause the fault of the server. Also if one VM is down, it will affect other VM on the same server.  And one more for the hardware-based techniques can also be useful in physical level requirement. Like the ARM TrustZone and the Intel software guard extension technology. Customer can store and process sensitive data safely. Also for hardware, we probably need to prevent terrorist attack to the data center. |

(c) Edge computing is a distributed, open IT architecture that features decentralised processing power.

(i) Illustrate through an example how edge computing enables mobile computing and Internet of Things (IoT) technologies. **[2 marks]**

*Answer:*

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| For self driving car, the edge computing would find and connect the devices to the nearest base station or server, which can reduce the latency and have a quicker response. The sensor in the self driving car can collect data and upload it to the cloud. Some of the sensors also can pre-process data locally, then upload the processed data to the cloud, like the traffic flow. And the driving recorder on the car also can save the video and upload to the cloud. Basically, everything on the car connects to the Internet. |

(ii) Using the same example, explain how Software-Defined Networking (SDN) works with edge computing. **[3 marks]**

*Answer:*

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| More and more self driving car and the devices on the car are connected to the Internet, it will triggred the problem that overload resources and high latency. And SDN is used to deal with that problem. SDN can dynamic allocate resources, bandwidth and so on, to tasks in real time in unpredictable environment, like in the road or highway. The edge computing system can be updated in real time and provide the best performance to complete the task, and send the result back to the devices so that the driverless car can respond more quickly. |

(d) The history of human beings is closely tied to water. Fresh water has been a key factor in the emergence of civilisations, not only for direct human consumption but also for agriculture. As an expert in cloud computing, you have been contacted by the Environment Agency to lead a project with the aim of designing a system which is able to monitor water quality by measuring different environmental parameters. Considering as an example a network of sanitary sewers, monitoring is performed in real-time to determine the quality of water and thus to establish whether elements within the network are working properly. In this way, the system is able to react against unexpected situations, avoiding possible damages that natural disasters such as floods usually cause. The system will make use of two key-elements: a pervasive water-quality sensors network connected to the cloud as well as prediction models.

Propose a cloud computing-based solution and discuss how to deploy it. Include any information that you feel is relevant to justify your recommendation. **[6 marks]**

*Answer:*

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| First, build the sensing layer. Deploy the water quality sensors under the sanitary sewers, source of the incoming water and other places to monitoring the quality of water everywhere, anytime. The sensors must send or upload data to the cloud, and also have GPS module inside the sensor. Therefore, we can see the data from a specific location.  Second, build the network layer. Then connect thousands of sensors into the network through the gateways and routers. First, upload to the edge computing, pre-process those raw data from the sensors. Then, upload the pre-processed data and each sensors location information into the cloud computing platform. The way to transfer data, we may use TCP to do that. And that can make sure the data can be upload wholly and safely.  There is some other information that might be useful, such as terrain, weather and rainfall information. Because steep hill and too much rain can be the sign of natural disaster. With this information and the data from the sensors, they are uploaded to the cloud. I want to use high-performance computing to process these data. And if necessary, build a small data centre to store the massive data or a few server racks. Alternatively, use MapReduce to process these massive data. The history data won't be deleted. All of these data wether is the latest or out of data, can be useful to build and train the predictive model.  Finally, build the application layer. Develop some application to interact with the data, which was processed in the cloud. Like, monitor the water quality app, nature disaster warning app. |