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# Question 1)

Points: .....

Maximum points: 12

Name four cloud services (only platform and infrastructure services are allowed!) you used for solving the exercise sheets. Also explain in a few words which functionality of these services you used. It should become clear why you used each single service.

Name of service	Sort of service	Explain the functionality you used and also the reason for using the service
	<input type="checkbox"/> PaaS <input type="checkbox"/> IaaS	
	<input type="checkbox"/> PaaS <input type="checkbox"/> IaaS	
	<input type="checkbox"/> PaaS <input type="checkbox"/> IaaS	
	<input type="checkbox"/> PaaS <input type="checkbox"/> IaaS	

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# Question 2)

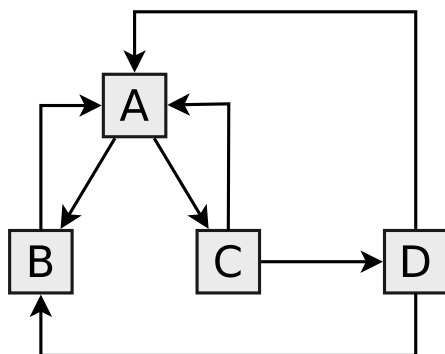
Points: .....

Maximum points: 12

- $PR_p$  = PageRank of a web page  $p$
- $L_{IN}(p)$  = Set of documents, which refer to  $p \implies$  incoming links
- $L_{OUT}(p)$  = Set of documents, to which  $p$  refers  $\implies$  outgoing links
- $d$  = damping factor between 0 and 1

$$PR(p) = (1 - d) + d * \sum_{p_i \in L_{IN}(p)} \frac{PR(p_i)}{\text{amount } L_{OUT}(p_i)}$$

Calculate the missing iterations of the PageRank algorithm for the given example scenario with  $d = 0.8$ .



- $PR(A) = (1 - d) + d * (PR(B) + \frac{PR(C)}{2} + \frac{PR(D)}{2})$
- $PR(B) = (1 - d) + d * (\frac{PR(A)}{2} + \frac{PR(D)}{2})$
- $PR(C) = (1 - d) + d * \frac{PR(A)}{2}$
- $PR(D) = (1 - d) + d * \frac{PR(C)}{2}$
- Conversion to iteration equations with  $d = 0.8$ :
- $PR_{n+1}(A) = 0.2 + 0.8 * (PR(B) + \frac{PR(C)}{2} + \frac{PR(D)}{2})$
- $PR_{n+1}(B) = 0.2 + 0.8 * (\frac{PR(A)}{2} + \frac{PR(D)}{2})$
- $PR_{n+1}(C) = 0.2 + 0.8 * \frac{PR(A)}{2}$
- $PR_{n+1}(D) = 0.2 + 0.8 * \frac{PR(C)}{2}$

	0	1	2	3	4	5	PR
A	1	1.8	1.48	1.672	1.5184	1.63104	1.553216
B	1	1	1.16	0.968	1.096	1.01408	1.071424
C	1	0.6	0.92	0.792	0.8688	0.80736	0.852416
D	1	0.6	0.44	0.568	0.5168	0.54752	0.522944

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## Question 3)

Points: .....

Maximum points: 7

- a) Think about a scenario, when a service provider creates a new service offering, which allows the customers to deploy virtual machines and specify their network configuration. What sort of cloud offering is this?

*Infrastructure as a Service – IaaS*

- b) Think about a scenario, when a service provider creates a new service offering, which is basically an email client in the browser. What sort of cloud offering is this?

*Software as a Service – SaaS*

- c) Think about a scenario, when a service provider creates a new service offering, which provides a scalable runtime environment for a programming language. What sort of cloud offering is this?

*Platform as a Service – PaaS*

- d) Think about a scenario, when a service provider creates a new service offering, which allows the customers to create virtual block storage devices. What sort of cloud offering is this?

*Infrastructure as a Service – IaaS*

- e) Think about a scenario, when a service provider creates a new service offering, which is basically an office solution in the browser. What sort of cloud offering is this?

*Software as a Service – SaaS*

- f) Think about a scenario, when a service provider creates a new service offering, which allows the customers to store any files as web objects and make them accessible via the internet. What sort of cloud offering is this?

*Infrastructure as a Service – IaaS*

- g) Think about a scenario, when a service provider creates a new service offering, which converts print jobs. The users send print jobs to the service and do not need to install printer drivers locally. What sort of cloud offering is this?

*Cloud Printing*

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## Question 4)

Points: .....

Maximum points:  $1+2+2+1=6$

During the semester, you had to select one free software solution of a given list, do some investigation about it and prepare a presentation.

- a) Name the free software solution you did select and investigate.
  
- b) What is the application purpose of the software you did select?  
*(In other words: What can a user do with this software?)*
  
- c) Name two benefits of the software you did investigate in contrast to other (similar) software solutions („competitor solutions“).  
*(It is required that you also name the competitor solutions.)*
  
- d) Name one drawback of the software you did investigate in contrast to other (similar) software solutions („competitor solutions“).  
*(It is required that you also name the competitor solutions.)*

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## Question 5)

Points: .....

Maximum points: 10

During the semester, you had to select one free software solution of a given list, do some investigation about it and prepare a presentation.

Draw a diagram of the important components of the software you did investigate. Please also insert information (e.g. arrows) in the diagram which explains how these components interact with each other, with the operating system and with the users.

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## Question 6)

Points: .....

Maximum points: 1+3=4

- a) Name and explain one technical reason which caused many providers of cloud gaming service offerings to get out of business?

*The period between the user input and results on the local display must be small in order not to disrupt the game flow. This, the network latency must be low because the user input is transmitted to a remote server and processed there. To keep the network latency low, it is required that the distance to the data center used is  $< 1000$  km. Running this many data centers is cost intensive.*

- b) Name and explain three reasons for the failure of P2P streaming projects.

- *In contrast to platforms like YouTube, users cannot upload own videos.*
- *Providers offer only professional content. The content must be licensed for each country, where it can be received. Without a large number of users, the providers do not have a strong negotiating position with the rights holders. Without a large number of users, the providers cannot finance the service via advertising.*
- *Since the existence of YouTube, it is hard to explain to users why they need to install a client software only for watching video streams.*
- *A dedicated client must be developed and maintained for many operating systems and hardware platforms. The development effort is high.*
- *The services were mostly proprietary. An open protocol can be optimized better, but is difficult to realize because of the place because of the required broadcast rights.*
- *Time delays during connection establishment and channel switching are considered as annoying by the users. These time delays cannot be avoided in principle.*
- *The upload data rate of most users is much lower compared with the download data rate. Especially with DSL, the upload speed is often lower by a factor of 1:10 or even 1:20. This limits the possibility to re-distribute by the Peers.*

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## Question 7)

Points: .....

Maximum points: 4+6=10

- a) For exercise sheet 6, you deployed a MPI cluster. Please explain the steps you needed to deploy and configure the MPI cluster.

*To solve this question it is useful to explain the creation of the required virtual or installation of the physical machines used, installation of the operating system and the required packages, the network configuration, the configuration of the file /etc/hosts, the configuration of the hosts.mpi file, the creation of a common (shared/distributed) storage. . .*

- b) For exercise sheet 6, you developed a MPI application, which calculates  $\pi$  via Monte Carlo simulation. Please explain in your words the functioning of the program and explain which part of the task is parallelized (and how it is done!) and which part of the task cannot be parallelized.



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# Question 8)

Points: .....

Maximum points:  $1+1+0.5+5+0.5=8$

a) What is the drawback of linear search in the Chord ring?

*Linear search is not efficient.*

b) What way of searching in the Chord ring is preferred?

*Binary search.*

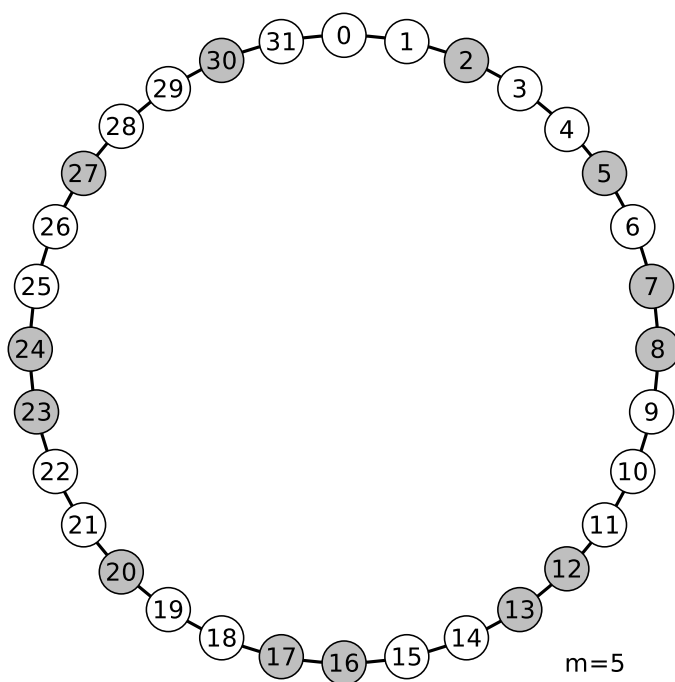
c) To which node  $n$  gets a key  $k$  assigned to?

Direct predecessor

Direct successor

First node (starting from ID 1) without any keys assigned yet

d) Calculate the Finger Table values of node  $n = 2$  and insert the correct values into the provided Finger Table.



Finger Table of node  $n = 2$

Entry	Start	Node
1	3	5
2	4	5
3	6	7
4	10	12
5	18	20

*The table has 5 entries, because  $m$  contains the length of the ID in bits and  $m = 5$*

*The Start value of entry  $i$  of the table on node  $n$  is  $(n + 2^{i-1}) \bmod 2^m$*

*The Node value of entry  $i$  points to the first node, which follows to  $n$  at a distance of at least  $2^{i-1}$*

e) Which node is responsible for the key (resource) with ID 21 ?

*Node 23.*

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## Question 9)

Points: .....

Maximum points:  $1+1+2+2+1+1+1=9$

- a) Explain the difference between emulation and virtualization.

*Virtualization allows to split the resources of a computer system and to execute multiple independent operating system instances.*

*Emulation allow the execution of an unmodified operating system, which is designed for a different hardware architecture (CPU).*

- b) Name one example of a popular emulation solution.

*Bochs, QEMU, PearPC, Wabi, DOSBox, Microsoft Virtual PC (the MacOS X/PowerPC version is a x86 emulator), Hercules, M.A.M.E, SheepShaver ...*

- c) What is a System call?

*If a user-mode process must carry out a higher privileged task (e.g. access hardware), it can tell this the kernel via a system call. A system call is a function call in the operating system, which triggers a switch from user mode to kernel mode.*

- d) What is a Hyper call?

*When using Paravirtualization, the host operating system is relocated from privilege level (ring) 0 to ring 1. Therefore, the kernel can not execute privileged instructions. Solution: The hypervisor provides hypercalls. Hypercalls are similar to system calls. Just the interrupt numbers are different. If an application requests the execution of a system call, a replacement function in the hypervisor is called. The hypervisor orders the execution of the system call via the kernel API of the operating system.*

- e) Can all physical hardware resources be virtualized when full virtualization is used? If this is not possible, give an example where it does not work.

*Some hardware components are emulated, because they are not designed for the concurrent access from multiple operating systems. Example: Network adapters.*

- f) Why is for paravirtualization a host operating system required?

*A host operating system is required because of the device drivers.*

- g) Name one example of a popular operating system-level virtualization solution.

*Docker, SUN/Oracle Solaris, OpenVZ for Linux, Linux-VServer, FreeBSD Jails, Parallels Virtuozzo, FreeVPS.*

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## Question 10)

Points: .....

Maximum points: 3+3=6

- a) How long does it take to transfer 100 TB via a 6 Gbps (= 6,000 Mbps) Ethernet?

(Solution for 100 TB =  $100 * 10^{12}$  Byte)

Data:

$$100 \text{ TB} = 100 * 10^{12} \text{ Byte}$$

Bandwidth:

$$6 \text{ Gbit/s} = 6 * 10^9 \text{ Byte/s}$$

Transmission duration:

$$\begin{aligned} \frac{100 * 10^{12} \text{ Byte}}{6 * 10^9 \text{ Byte/s}} &= \text{approx. } 16.\bar{6} * 10^3 \text{ s} \\ &= \text{approx. } 16,666.\bar{6} \text{ s} \\ &= \text{approx. } 277.\bar{7} \text{ m} \\ &= \text{approx. } 4,63 \text{ h} \end{aligned}$$

$\Rightarrow$  approx. 4 Hours, 37 Minutes

- b) What is the height of a stack of storage media, if for storing 2 PB of data DVDs (capacity: 4.3 GB =  $4.3 * 10^9$  Byte, thickness: 1.2 mm) are used?

(Solution for DVDs with 2 PB =  $2 * 10^{15}$  Byte)

Number of DVDs:

$$\frac{2 * 10^{15} \text{ Byte}}{4.3 * 10^9 \text{ Byte}} = 465,116.279$$

An integer number is required:

$$\Rightarrow 465,117$$

DVD stack height:

$$\begin{aligned} 465,117 * 1.2 \text{ mm} &= 558,140.4 \text{ mm} \\ &= 55,814.04 \text{ cm} \\ &= 558.1404 \text{ m} \end{aligned}$$

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## Question 11)

Points: .....

Maximum points: 3+3=6

Company X runs 500 computer workplaces.

- Scenario 1: Fat clients (PC)
  - Electrical power rating per desktop: 500 watts
  - Electrical power rating per screen: 100 watts
- Scenario 2: Thin clients
  - Electrical power rating per thin client: 40 watts
  - Electrical power rating per screen: 100 watts
  - Electrical power rating per server blade: 500 watts
  - Each server blade has enough resources to run 30 virtual desktops

What are the electricity costs per year for 24/7 operation when the electricity price is 0,30 €/kWh?

*Scenario 1:*

*Electricity costs per year (including the leap year) for 500 computer workplaces:*

$$0.6 \text{ kW} * 24 \frac{\text{h}}{\text{Day}} * 365.25 \frac{\text{Day}}{\text{Year}} * 0.3 \frac{\text{€}}{\text{kWh}} * 500 = 788,940 \frac{\text{€}}{\text{Year}}$$

*Scenario 2:*

*Electricity costs per year (including the leap year) for 500 computer workplaces:*

$$0,14 \text{ kW} * 24 \frac{\text{h}}{\text{Day}} * 365.25 \frac{\text{Day}}{\text{Year}} * 0.3 \frac{\text{€}}{\text{kWh}} * 500 = 184,086 \frac{\text{€}}{\text{Year}}$$

*Electricity costs per year (including the leap year) for the 17 required server blades.*

$$0.5 \text{ kW} * 24 \frac{\text{h}}{\text{Day}} * 365.25 \frac{\text{Day}}{\text{Year}} * 0.3 \frac{\text{€}}{\text{kWh}} * 17 = 22,353.3 \frac{\text{€}}{\text{Year}}$$

*Electricity costs per year for the computer workplaces and the server blades.*

$$184,086 \frac{\text{€}}{\text{Year}} + 22,353.3 \frac{\text{€}}{\text{Year}} = 206,439.3 \frac{\text{€}}{\text{Year}}$$