Introduction

Organisational information, Introduction to Cloud Computing Slide set 1

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Agenda

Organisation

- Organisational Information
- Objectives of the course
- Introduction to Cloud Computing
- Outlook on the course



Organizational Information

- Website:
 - www.henrycocos.de
- F-Mail:
- Office:
 - Room 1-230
- Consultation:
 - Best via E-Mail!
- Course material:
 - Lecture notes (PDF slides) and semester project related information can be found at the course website

Introduction

!!! ATTENTION !!!

- Beginning WS2021, the cloud computing course does not have a written exam anymore!
- Your grade will depend 100% on your work and the results in the semester project (see the course web page for more information)

Cloud Computing – Admission to Exam

We only have a limited capacity...

Organisation

therefore we have a strict limit for the admission to Cloud Computing!

Classification Cloud Computing - summer semester 2025

List of Participants in Summer Term 2025



Unless you have at least 40 ECTS from previous courses in the High Integrity System Master you are not allowed to participate in the Course Cloud Computing!!! Please do not register for the exam, because we cannot make any exceptions and this will result in an failed attempt!!!

Please check the list before registering in the HIS Portal!!!

Semester project – Sky Computing

Examination

The examination in the master course Cloud Computing will be a research project over the course of the semester. You need to form groups of 4-5 people and work on the milestones.

Introduction

There will be different topics for the project in this semester:

- Project 1 SASE (Secure Access Service Edge)
- Project 2 Sky Computing
- Project 3 Cost Control in Multi-Cloud Environments
- Project 4 Risk Management in Multi-Cloud Environments
- Project 5 Attaching on-premises workloads to the SKY

Details on the semester project

Details on the project will be given in a separate presentation.

Literature

Fundamentals from Bachelors courses

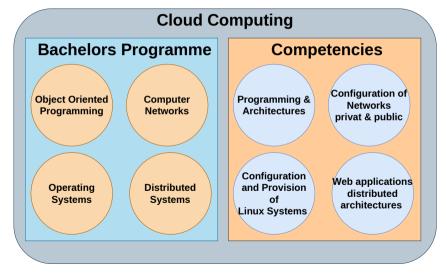
- Operating Systems / Betriebssysteme: Bilingual Edition: English - German / Zweisprachige Ausgabe: Englisch - Deutsch. Christian Baun, Springer Vieweg (2023), ISBN: 978-3-658-42229-5.
- Computer Networks / Computernetze: Bilingual Edition: English - German / Zweisprachige Ausgabe: Englisch - Deutsch, Christian Baun, Springer Vieweg (2022). ISBN: 978-3-658-38892-8.
- Distributed Systems: Principles and Paradigms, Andrew S. Tanenbaum, Maarten van Steen, Pearson (2023), ISBN: 978-1530281756
- Foundations of Scalable Systems, Ian Gorton, O'Reilly (2022). ISBN: 978-1098106065.

Cloud Computing

Introduction

- Cloud-Native Computing, Nane Kratzke, Hanser (2023), ISBN: 978-3-446-47914-2. German
- Cloud Strategy: A Decision-based Approach to Successful Cloud Migration. Gregor Hohpe (2020), ISBN: 979-8665253046.
- Multi-Cloud Architecture and Governance. Jeroen Mulder, Packt Publishing (2020), ISBN: 978-1800203198.
- Cloud Computing: Web-Based Dynamic IT Services. Christian Baun. Marcel Kunze. Jens Nimis, Stefan Tai, Springer (2011), ISBN: 978-3-642-20916-1
- Cloud Application Architectures. George Reese, O'Reilly (2008), ISBN: 978-0596156367.

What topics are part of Cloud Computing?



What are prerequisites for the course?

You should have basic knowledge from the bachelors programme on the following topics:

- Computer Programming
 - Java and Python! (object-oriented and functional paradigm)
- Operating Systems
 - Linux, Kernel architectures, command-line, block and file storage, virtualization, ...
- Computer Networks
 - ISO-OSI reference model, Switching, Routing, CIDR, Application layer protocols, ...
- Distributed Systems
 - Definitions, cluster systems, RPC, web technologies, SOAP, REST, ...
- Software Architectures
 - Client/Server Architectures, 3-Tier Architectures, Web applications, ...

If you want to read up again

You can read the books under Fundamentals from Bachelors courses on slide 6!

Objectives of the course

- Getting an overview on Cloud Computing and cloud services and their importance!
- Getting an overview on the technological foundations for the operation and implementation of cloud services!
- Gaining knowledge on Cloud Computing related topics (service models, features, etc.)!
- Gaining knowledge and understanding strategies for the adoption of Cloud Computing!
- Gaining knowledge on software architectures for the implementation of cloud services!
- Gaining knowledge on Cloud-Native applications and their benefits for the implementation of cloud services!
- An outlook on future trends in Cloud Computing!

Objectives

Course Material

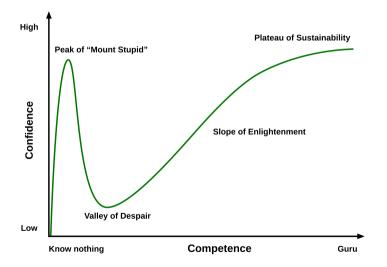
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Slides of the lecture

Most of the material form the lecture is new and the slides are mostly still work in progress! So whenever you spot mistakes or faults let me know ;-)

The General Knowledge in Cloud Computing

Source: Wikimedia Commons



Your Knowledge in Cloud Computing



Poll in Mentimeter



What is Cloud Computing?

Group Discussion

- What is Cloud Computing?
- What Cloud Computing offerings do you use?
- How would you define Cloud Computing?

Computing of the future? - Quote from 1961

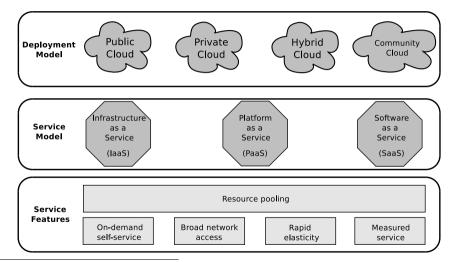
"computation may someday be organized as a public utility, just as the telephone system is a public utility. We can envisage computer service companies whose subscribers are connected to them [...]. Each subscriber needs to pay only for the capacity that he actually uses, but he has access to all programming languages characteristic of a very large system." - John McCarthy^a

^aIt is an old quote and therefore not gendered. Sorry!

This is pretty close to cloud computing!

NIST definition of Cloud Computing

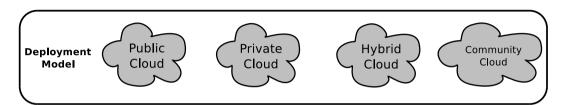
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 $^{^{0}}Source: \ \texttt{https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-145.pdf}$

Deployment models

Organisation



Public Cloud

The cloud infrastructure is provisioned for open use by the general public.

Private Cloud

The cloud infrastructure is provisioned for exclusive use by a single organization.

Hybrid Cloud

The cloud infrastructure is a composition of two or more distinct cloud infrastructures.

Community Cloud

The cloud infrastructure is provisioned for exclusive use by a specific community.

Service models

Software Infrastructure Platform Service as a as a as a Model Service Service Service (laaS) (PaaS) (SaaS)

Introduction

Infrastructure as a Service

Provided to provision processing, storage, networks, and other fundamental computing resources.

Platform as a Service

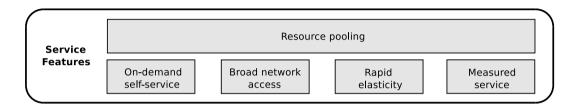
Provided to deploy applications created using programming languages, libraries, services supported.

Software as a Service

Provided to use the provider's applications running on a cloud infrastructure accessible from various devices.

⁰We will discuss more than these service models in this course :-)

Service Features



Resource pooling

Computing resources are pooled to serve multiple consumers

On-demand self-service

Consumer can provision computing capabilities automatically.

Broad network access

Capabilities are available and accessed over the network.

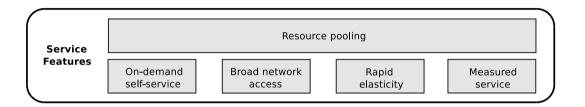
Rapid elasticity

Capabilities can be elastically provisioned to scale with demand.

Measured service

Automatically controlled and optimized resources with metering.

Service Features



Question

How can we technically realize the listed features?

Cloud Computing – Definition

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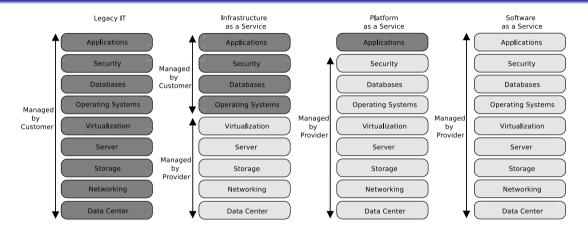
"By using virtualized computing and storage resources and modern web technologies. Cloud Computing provides scalable, network-centric, abstracted IT infrastructures, platforms, and applications as on-demand services. These services are billed on a usage basis."



- Part 1: Fundamental technologies basis of Cloud Computing
 - Virtualization for shared and efficient resource utilization
 - Web Services (REST/SOAP) for communicating with the services
- Part 2: Cloud services and their characteristics
 - IaaS. PaaS. SaaS
 - scalable ⇒ "elastic"
 - network-centric \Longrightarrow services/resources are accessible over the internet
 - **abstracted** \Longrightarrow independent of the concrete hardware
 - on-demand \Longrightarrow prompt request completion
 - pav as vou go

Service models – layers

Organisation



Introduction Outlook

Service offerings in Cloud Computing







Figure: Slack



Google Workspace









Figure: Google Workspace



Figure: Zoom

Question

What is the service model of the presented offering?

Things to keep in mind

Questions when using cloud services

- What about the data privacy?
- Where is the service hosted?
- Who has access to the service and data?

Introduction

• Who controls the service offering?

Use of Cloud Computing offerings

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The previous offerings are public service offerings for customers. But what about the provider perspective?

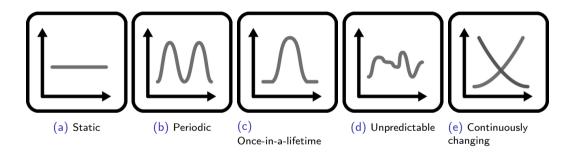
What do you need to keep in mind if you want to offer a cloud service?

Why use Cloud Computing?

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Group discussion

- When should one use Cloud Computing from a company perspective?
- What are the benefits of Cloud Computing for companies?
- Are there scenarios when Cloud Computing is suited for enterprises?



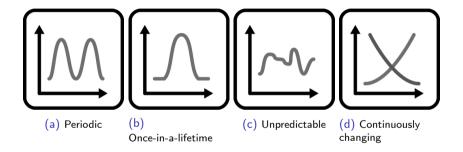
Question?

Which of the presented workload types are suitable for a cloud computing setup?

Types of workloads

Organisation

CC-BY:http://www.cloudcomputingpatterns.org



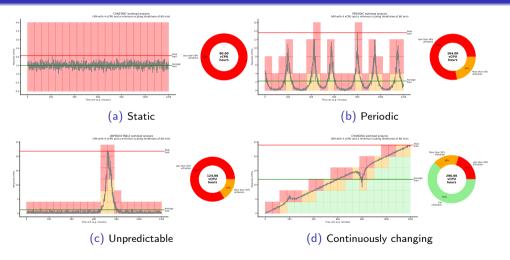
Answer!

Cloud resources are particularly economical when load fluctuations occur!

Types of workloads

Organisation

CC-BY:https://cloud-native-computing.de



Source of plots: https://git.mylab.th-luebeck.de/cloud-native/lab-workload-analysis

Cloud Computing - economics

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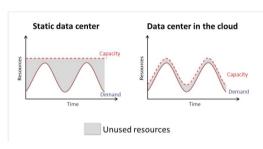


Figure: Static vs. dynamic demand^a

More precise answer!

The costs per cloud resource can even be significantly higher than the in-house costs as long as the ratio of cloud to in-house costs does not exceed the ratio of peak load to average load!

In formula!

$$\frac{cloud\ cost}{inhouse\ expense} < \frac{peak\ load}{average\ load} \\ \Leftrightarrow \\ cloud\ cost < inhouse\ expense \times \frac{peak\ load}{average\ load}$$

^aSource:https://www2.eecs.berkeley.edu/Pubs/ TechRpts/2009/EECS-2009-28.pdf

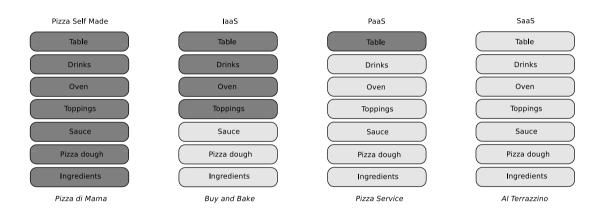
Outlook

An example using Pizza ;-)

Imagine your family, friends and colleagues come over to your house and want Pizza for dinner. Now you need to investigate on the different types of service offerings you can use to feed your guests!

Pizza as a Service example

Source: https://cloud-native-computing.de



Pizza as a Service example – static workload



- You buy yourself a pizza every working day at lunchtime.
- At weekends, of course not.

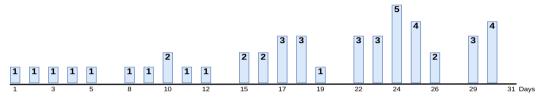
How much?

$$peak\ load = 1$$

$$average\ load = \frac{22}{30}$$

$$\frac{peak\ load}{average\ load} = \underline{1.3}$$

The cloud provider could be 30% more expensive than self made!!!



- You always bring your family something from the pizza trolley.
- Word gets around, and week after week you have to get more and more pizza.
- At weekends, of course not.

How much?

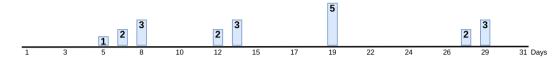
$$peak\ load = 5$$

$$average\ load = \frac{46}{30}$$

$$\frac{peak\ load}{average\ load} = \underline{3.2}$$

The cloud provider could be 3-Times more expensive than self made!!!

Pizza as a Service example – periodically changing workload



Introduction

- You and your family and friends make movie evenings on weekend and watch movies (on-demand ;-)) and serve pizza.
- During the week you do not have time.

How much?

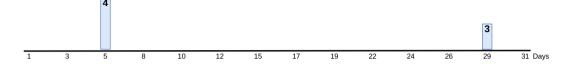
$$peak load = 5$$

$$average\ load = \frac{21}{30}$$

$$\frac{peak\ load}{average\ load} = \underline{7.1}$$

The cloud provider could be 7-Times more expensive than self made, because your demand is rarer!!!

Pizza as a Service example – unpredictable workload



Introduction

- You invite your family on weekends occasionally to a pizzeria.
- During the week you do not have time.

How much?

$$peak\ load = 4$$

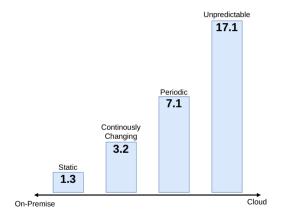
average load =
$$\frac{7}{30}$$

$$\frac{peak\ load}{average\ load} = \underline{17.1}$$

The cloud provider could be 17-Times more expensive than self made, because your demand is rarer!!!

Cost advantages in Cloud Computing

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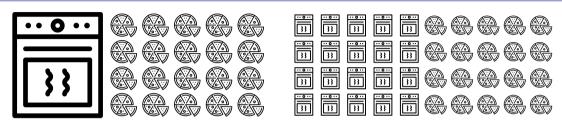
Conclusion

Cost advantages generally arise through the workload and only secondarily by the cost structure of the service.

Remarks on the example...

The example has no **inhouse costs**!!! Reaction to different workloads is in general not an easy task for on-premise setups! (servers, infrastructure, personal, etc.)

Operational costs in Cloud Computing



1 Oven for 20 Pizzas!!!

20 Oven for 20 Pizzas!!!

With which delivery service would you order 20 pizzas?

- The one that delivers in 5 hours and 19 pizzas are cold?
- The one that delivers 20 hot pizzas in 15 minutes?

Operational costs in Cloud Computing

Price and Effort?

- How much extra would that be worth to you?
- How much extra expense does this cost the delivery service?
- How often do you as a delivery service need 20 ovens at the same time?

Answerl

It costs the same...

Overall Question?

Do you want to buy and provision the 20 oven on-premise?

Questions

Organisation

- Is Cloud Computing always beneficial?
- Is Cloud Computing the solution to all problems?
- Is using Cloud Computing always cheaper?

Answer

- No scam! It depends on the use case!
- It is beneficial for some use cases!
- It is cheaper if we take things like workload types and peak load into account!

Things to take into account

- Hardware is very expensive!
- Personal is very expensive
- Housing for hardware and personal is expensive!
- Both scale very poorly!

Cost Savings

- capital expenditures (CapEx) vs operating expenses (OpEx)!
- CapEx are large investments in fixed assets.
- OpEx are costs associated with day-to-day operations.

CapEx

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- IT infrastructure (servers, networking, software, etc.)
- IT equipment
- Data center housing
- Infrastructure maintenance

OpEx

- Business-related operating costs (on-demand rent, utilities, salaries, etc.)
- Cloud-based software or service subscription fees (SaaS, PaaS, IaaS, etc.)
- Software and service support
- Data center or off-premises cloud costs

Organisation

Use Cases for Cloud Computing

Whenever the actual demand is not predictable, Cloud Computing is a (possible) solution!

Outlook on the course

Organisation

1st part: Introduction ← This slide set

2nd part: Technological foundations

3rd part: Service models, deployment models

4th part: Adoption and strategy

5th part: Architectures and applications

6th part: Cloud-Native applications

7th part: Current and future trends

2nd part: Technological foundations

Topics of this slide set:

- Legacy IT (data centers, servers, networking, etc.)
- Cloud enabling technologies (networking, storage, virtualization, etc.)
- Infrastructure as Code (Vagrant, Terraform, Ansible, etc.)
- Costs of on-prem infrastructures

3rd part: Service models, deployment models

Topics of this slide set:

- Deployment models in Cloud Computing
- Service models in Cloud Computing
- Public Cloud Computing offerings
- Private Cloud Computing offerings

4th part: Adoption and strategy

Topics of this slide set:

- Cloud adoption
- Cloud strategy
- Multi-Cloud strategy
- Risks and opportunities of Cloud Computing

5th part: Architectures and applications

Topics of this slide set:

- Software architectures in Cloud Computing
- Distributed Systems and Cloud Computing
- Distributed architectures in Cloud Computing
- Properties of distributed architectures
- Decision criteria for distributed architectures

6th part: Cloud-Native applications

Topics of this slide set:

- Cloud-Native Applications
- Components of Cloud-Native Computing
- Architectures and patterns in Cloud-Native Computing
- Benefits and challenges in Cloud-Native Computing

7th part: Current and future trends

Topics of this slide set:

- Current trends in Cloud Computing
- Future trends in Cloud Computing

Introduction

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