



云计算入门

Introduction to Cloud Computing GESC1001

Philippe Fournier-Viger

Professor

School of Humanities and Social Sciences

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Fall 2020



About me

- Born in Canada
- Ph.D. in Computer Science (Canada) (2010)
- Post-doctoral researcher at 成功大学 (2010)
- Professor at U. of Moncton, Canada (2011-2015),
- **Professor** (教授) at **HITSZ** (哈工大(深圳)) (2015 - ...) and Youth 1000 talent (青年千人)

- My research: data mining (数据挖掘 \ 大数据).
- I speak English, French, and a bit of Chinese.

How to contact me?

We can discuss immediately after lectures

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Office: G421

office phone: 0755-86231832

I check my e-mails once a day

Teaching assistants

The two **teaching assistants:**

Liu Jiahong **Chen Yangming**

will:

- grade homework,
- check the attendance,
- help with other issues related to the course.

QQ group: 1127433879

About this course

- 16 hours (8 lectures)
- 1 credit, general course
(本科专业课程, 通识课程)
- No requirements

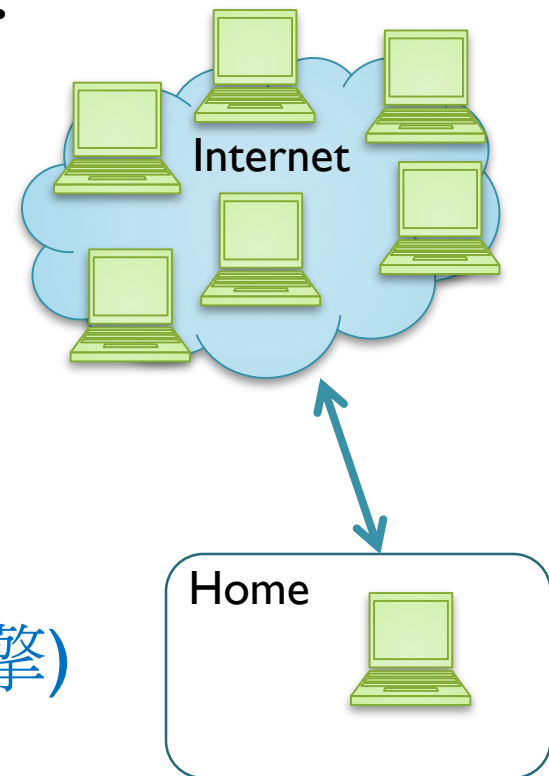
- **Evaluation:**
 - Attendance (10 %)
 - Course work (30% : two assignments - 作业)
 - Final exam (60%)

Main objective

- Understand what is **cloud computing** (云计算), how it works, how it is used, and when it should be used.

- **Examples:**

- Baidu cloud (百度云)
- Alibaba Cloud (阿里云)
- Scientific applications
- Web search engines (搜索引擎)



Specific objectives

- Understand what is **cloud computing** (云计算)
- Understand challenges and solutions for **parallel computing** (并行计算) and **distributed computing** (分布式计算).
- Understand the **infrastructure** (基础设施) required for cloud computing



Specific objectives

- Understand how **applications** are developed for cloud computing
- Understand other aspects:
 - **Security**
 - **Virtualization** (虚拟化)
 - How **data** is stored in the cloud
 - Current **trends** and **technologies**

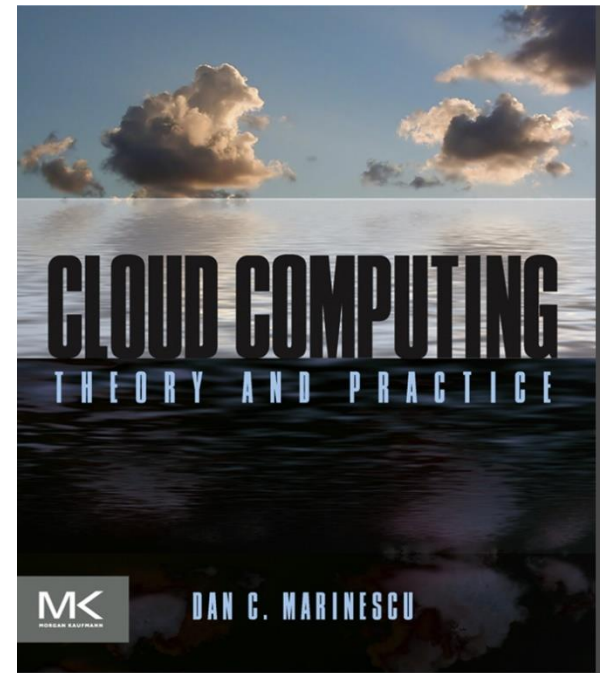
Course schedule

Week 1	Introduction and overview of the course
Week 2	Distributed and parallel systems
Course 3	Cloud infrastructure
Week 4	Cloud application paradigm
Week 5	No course
Week 6	Cloud application paradigm (2)
Week 7	Cloud virtualization and resource management
Week 8	Cloud computing storage systems
Week 9	Cloud computing security
	Final exam

Textbook

- I will provide detailed lecture slides (PPTs)
- I will use this **book** as main reference to prepare the course:
 - *D. C. Marinescu. Cloud Computing Theory and Practice, Morgan Kaufmann, 2013.*

It is **not** necessary to
buy the book!
(没有必要买这本书)



The course website

PPTs, assignments (两个作业), grades (分数), and the course schedule are provided on the **course website**:

<http://philippe-fournier-viger.com/COURSES/CLOUD/>



Introduction to Cloud Computing (GESC1001) - Fall 2020



Philippe Fournier-Viger

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Course information

- **Course title:** Introduction to Cloud Computing
- **Prerequisite(s):** none
- 16 hours (8 lectures), 1 credit, undergraduate course, general course
- **QQ group:** **1127433879**
- **Evaluation:**
 - Attendance (10 %)
 - Course work (30 %, two assignments)
 - Final exam (60%)

Content of this course

In everyday life, we use computers to perform various tasks such as writing documents and accounting. For many of those tasks, using a single computer is enough. However, for some tasks, the computing power of a single computer is not enough to ensure that the tasks are completed in a reasonable time, and the amount of data may exceed the capacity of a single computer. This is the case for tasks such as weather prediction, which requires to run complex simulations that may take several days to run on a single computer. Moreover, as we use the Internet in everyday life, we expect Internet services (e.g. websites, cloud storage) to be accessible not just at home but in various locations, and we expect these services to be fast and reliable. Cloud computing is a popular paradigm that addresses these challenges. In **Cloud computing**,

In everyday life, we use computers to perform various tasks such as writing documents and accounting. For many of those tasks, using a single computer is enough. However, for some tasks, the computing power of a single computer is not enough to ensure that the tasks are completed in a reasonable time, and the amount of data may exceed the capacity of a single computer. For example, the case for tasks such as weather prediction, which requires to run complex simulations that may take several days to run on a single computer. Moreover, as we use the Internet in our daily lives, we expect Internet services (e.g. websites, cloud storage) to be accessible not just from various locations, and we expect these services to be fast and reliable. Cloud computing is a popular paradigm that addresses these challenges. In **Cloud computing**, several computers (or **Clouds**) work together to perform a task, to provide large storage space, and reliable services for many users. However, designing a Cloud raises several challenges from the point of view of users (in terms of hardware, software, and network), privacy and security.



The goal of this course is to give a good overview of what is cloud computing, how it works, and when it should be used.

Note that since this course is a general course, there is no prerequisite for taking this course, and thus, it is **not required** to be familiar with programming. The assignments will be done in a team, and will require to submit a Word or PPT document. More details about assignments will be given in the class.

This course is composed of **8 lectures**.

The **first lecture** introduces this course. Then the concept of **cloud computing** will be presented. The characteristics of **cloud computing** will be reviewed and how it differs from traditional computing (using a single computer). The advantages and disadvantages of cloud computing will be discussed. Moreover, some important issues raised by cloud computing will be presented such as security.

The **second lecture** will discuss the concept of **distributed and parallel systems**. Cloud computing is a type of distributed and parallel system. But there exists other types of parallel or distributed systems such as multi-processor computers. The difference will be explained. Moreover, challenges raised by using parallel and distributed systems will be explained such as: how to deal with concurrent accesses to data, problems related to the communication between computers (e.g. message loss, corrupted messages), and the problem of synchronization between computers.

The **third lecture** will present the **infrastructure** required to perform cloud computing. We will discuss the infrastructure used by companies such as Amazon and Microsoft, as a case study, and in particular, the technology required so that they are used by multiple users at the same time.

The **fourth lecture** will discuss the challenges of developing **cloud applications** (software programs) that can run on a cloud to perform some tasks, compared to developing an application that run on a single computer. Some example of cloud applications will be discussed. The problem of coordination in the Cloud will be discussed with the ZooKeeper model.

The **fifth lecture** will discuss the development of **cloud applications** in more details. The students will be introduced to the MapReduce model, which is used in technologies such as Hadoop. Some detailed examples of how Hadoop can be used to perform tasks on the cloud will be given. Moreover, other technology such as Spark will be briefly discussed.

The **sixth lecture** will discuss the concept of **virtualization** to simplify some aspects of resource management in the cloud. The concept of virtual machine will be discussed, and how it is used in cloud computing architecture.

The **seventh lecture** will discuss **data storage in the cloud**. The concept of "Big data" will be discussed. An overview of different ways of storing the data in the cloud will be presented, including a case study with the GFS and Hadoop file systems.

The **eight lecture** will discuss the issue of security in the cloud. This includes aspect such as protecting the data stored in the cloud from hackers, malware, viruses, insiders, and attacks on virtual machines. The importance of trust will also be discussed. This lecture will also discuss the preparation for the final exam.



Lecture slides (PPTs) and assignments



Week 第 7 节 15:45 – 16:35 第 8 节 16:40 – 17:30 Room: T3201	Topic
Week 1 Wednesday 2nd September	Introduction to cloud computing - chapter 1 (PDF / Powerpoint)
Week 2 Wednesday 9th September	Distributed and parallel systems - chapter 2 (PDF / Powerpoint)
Week 3 Wednesday 16th September	Cloud infrastructure - chapter 2 and 3 (PDF / Powerpoint)
Week 4 Wednesday 23rd September	Cloud application paradigm (part 1) - chapter 4 (PDF / Powerpoint)
Week 5 Wednesday 30th September	Cloud application paradigm (part 2) - chapter 4 (PDF / Powerpoint)



Week 6 Wednesday	No course this week
Week 7 Wednesday 14th October	Cloud virtualization and resource management - chapter 5 - (PDF / Powerpoint)
Week 8 Wednesday 21st October	Cloud storage - chapter 8 (PDF / Powerpoint) Second homework
Week 9 Wednesday 28th October	Cloud computing security - chapter 9 (PDF / Powerpoint)
	Final Exam (120 minutes) Time: _____ Room: _____

Final Exam (120 minutes)
The date will be announced later.

Closed-book exam / Do not forget to bring your student ID.

The final exam will have about **10 questions**. Several questions will require to write a short answer in English (typically a few sentences). Some types of questions that I like to ask in final exams are:

- What is the difference between X and Y ?
- Explain what is "X".
- Explain why X works in a certain way

Bibliography

I will use the following textbook to prepare the course:

D. C. Marinescu. [Cloud Computing Theory and Practice](#), Morgan Kaufmann, 2013.

This book is used for preparing the lectures. It is not required to read the book, as very detailed PPTs will be provided above.

Besides, I will also add some content that is not in the book, and skip some less relevant content from the book.

Other interesting references::

1. L. Wang, R. Ranjan, J. Chen, B. Benatallah. Cloud Computing: Methodology, Systems, and Applications, CRC Press, 2011.

Rules

1. Students must **attend all lectures.**
2. Students must **arrive on time.**
3. Homework must be submitted **before
the deadline.**

No late homework will be accepted.

Rules

4. **Plagiarism (抄袭)** will not be tolerated.
5. **Please turn off the sound of your cellphone** during lectures
6. Do not **talk** or **eat** in the classroom, or **disturb** other classmates.



Lectures

- Each lecture starts at **15:45**
- Each lecture ends at **17:30**
- We will take a **5 minute break** around **16:40**.

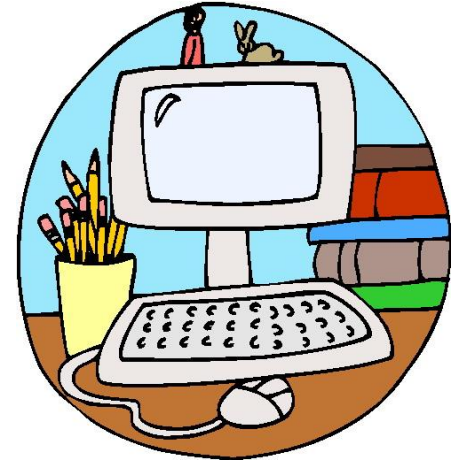
CHAPTER I - INTRODUCTION



Introduction

- A **computer** can perform simple tasks:
 - e.g. play music, video games, video editing, simulations, writing documents

- A **fast computer** can:
 - perform more complex tasks
 - perform them in less time.



- Every year, more “**powerful**” computers are sold.

How powerful a computer is?

It can be measured in terms of:

- **speed**: the number of instructions (指令) that the computer processes per second,
- **data processing speed** (数据处理速度): the amount of data that it can process per second,
- **storage space** (存储空间), the amount of data that it can store,
- **network speed** (网络速度), its ability to receive and send data to other computers
- ...

Supercomputers (超级计算机)

- Fast, powerful computers, expensive (昂贵的)
- **Speed:** can be more than 1 trillion instructions per second,
- **Weight:** can be more than 100 tons
- **Data:** may store more than 20,000 times more data than a desktop computer (台式电脑)

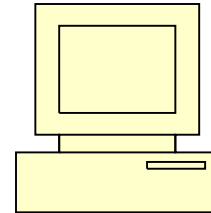


A super-computer in
Czech Republic
捷克共和国

Used for: medicine simulation, weather forecasting, nuclear research,....

A problem!

- I have a **computer** that is **slow!**



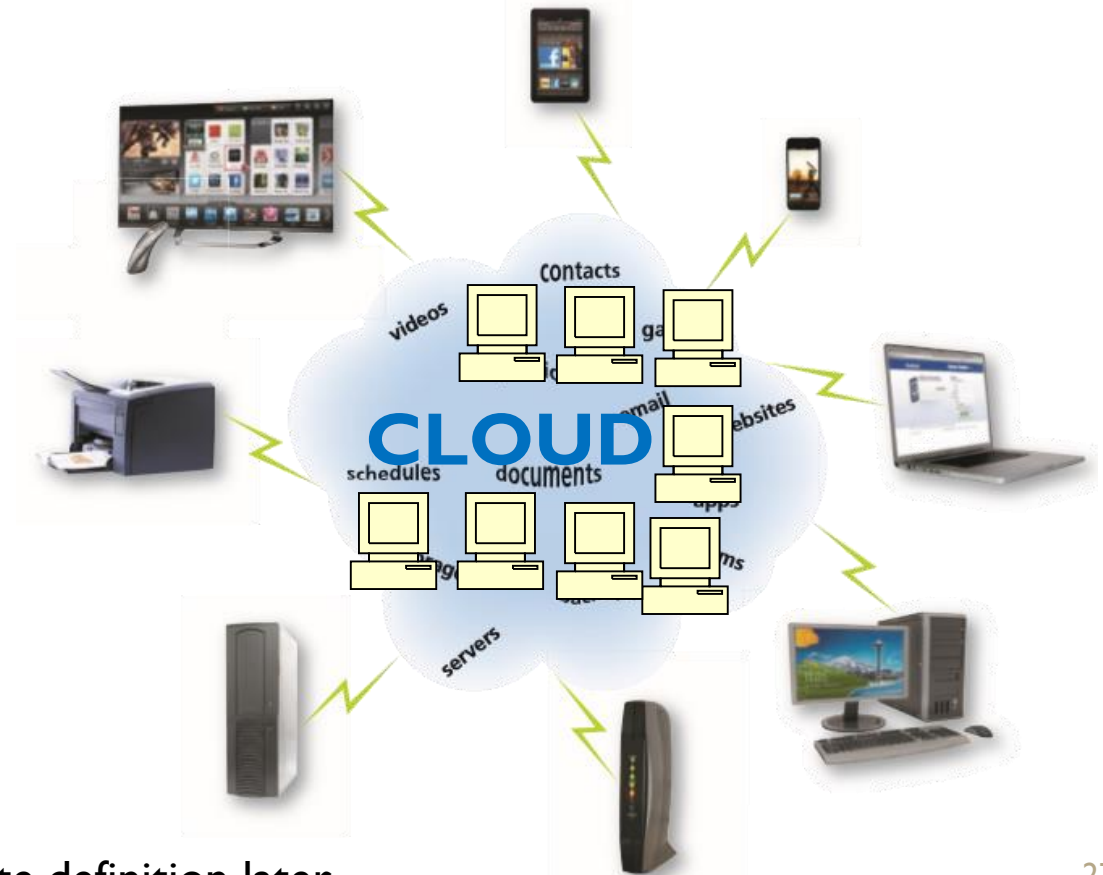
- I would like to do some very complex tasks (e.g. **weather prediction** 天气预报).
- But, I don't want to buy a new computer.
- **Idea:** could I rent one or more computers to do the task (能租电脑)?

A solution

- I would like to be able to rent computers when I need more **computing power** (计算能力) or **storage space** (存储空间).
- I want to **pay only for what I use**.
- This is the **main idea of cloud computing** (云计算)
- **Similar to electricity** (电) or **water** (水):
 - I can buy more electricity when I need it
 - I don't need to know how the electricity is made, transported, or where it come from.
 - I just pay for the electricity that I use.

Cloud computing (云计算)

Using a **cloud** (a set of distant computers) to perform computing tasks.



I will provide a more accurate definition later.

Cloud (云)

A set of distant (遥远的) computers that provide **computing or storage services** to users.

- Mi Cloud (小米云),
- Baidu cloud (百度云),
- Alibaba cloud (阿里云)
- Huawei cloud (华为云)
- ...



I will provide a more accurate definition later.

Cloud provider (云提供商)

An **organization** that provides or sell the right to use its cloud.

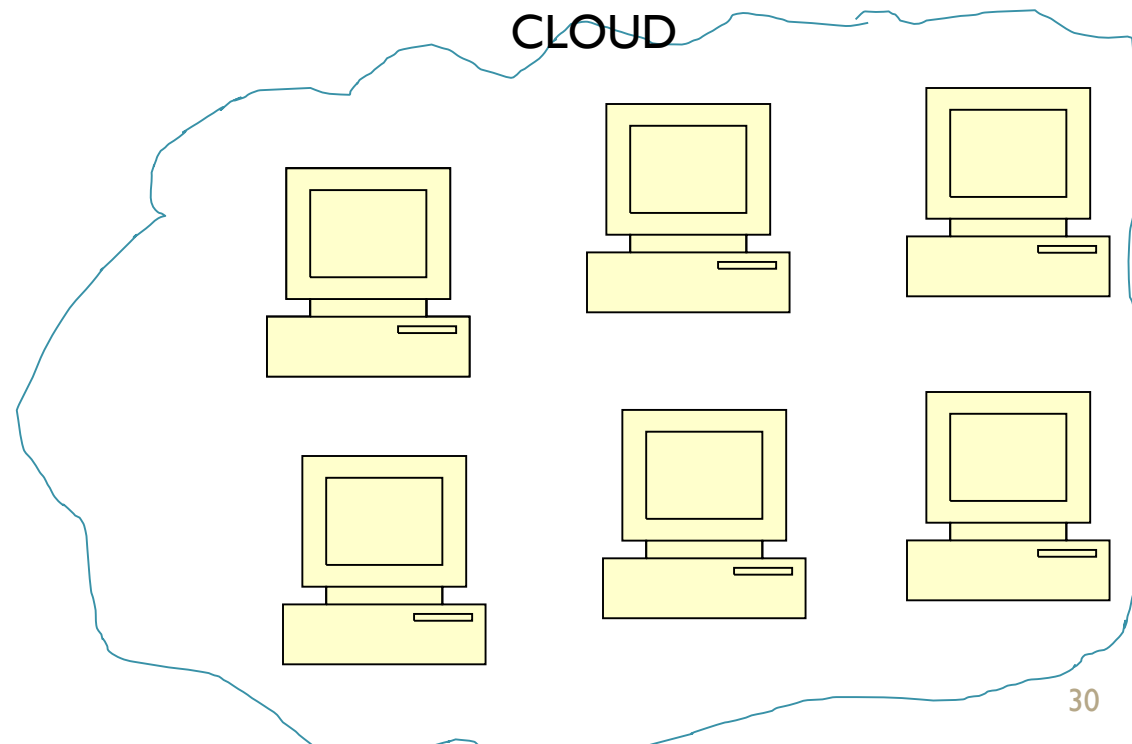
- Xiaomi (小米)
- Alibaba (阿里巴巴)
- ...



A cloud must be « elastic »

Elastic computing (弹性计算)

The ability to dynamically acquire computing resources to offer **variable workload** (变负荷).

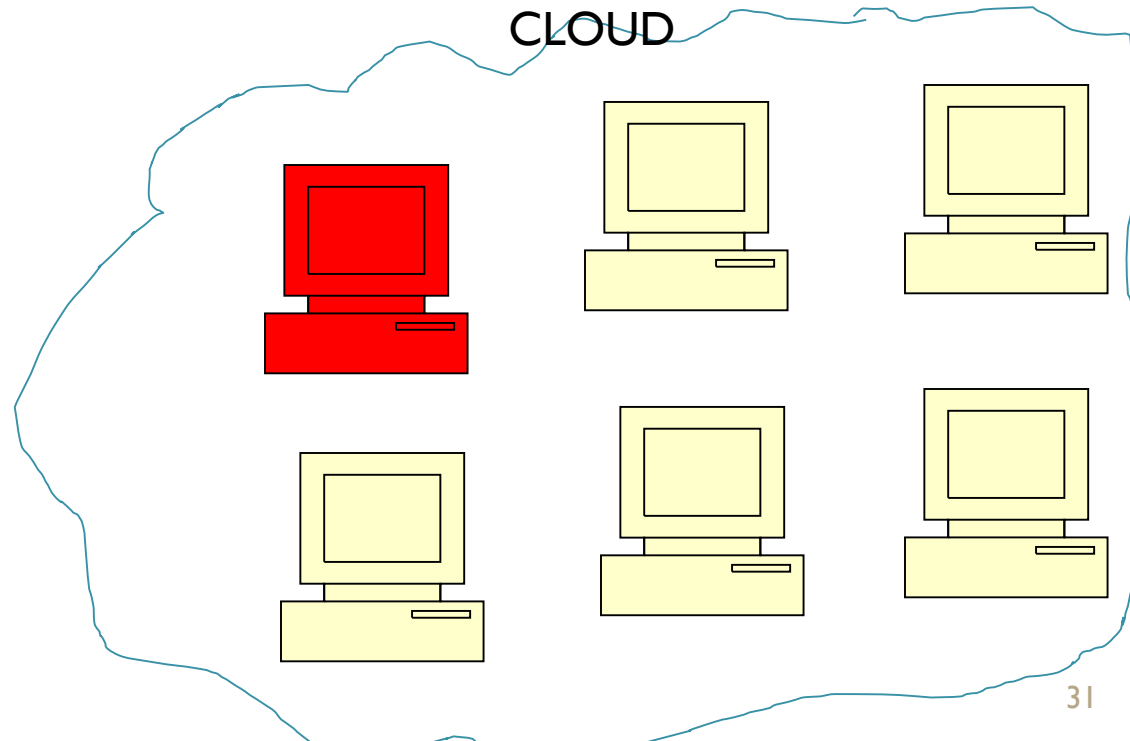


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Customer
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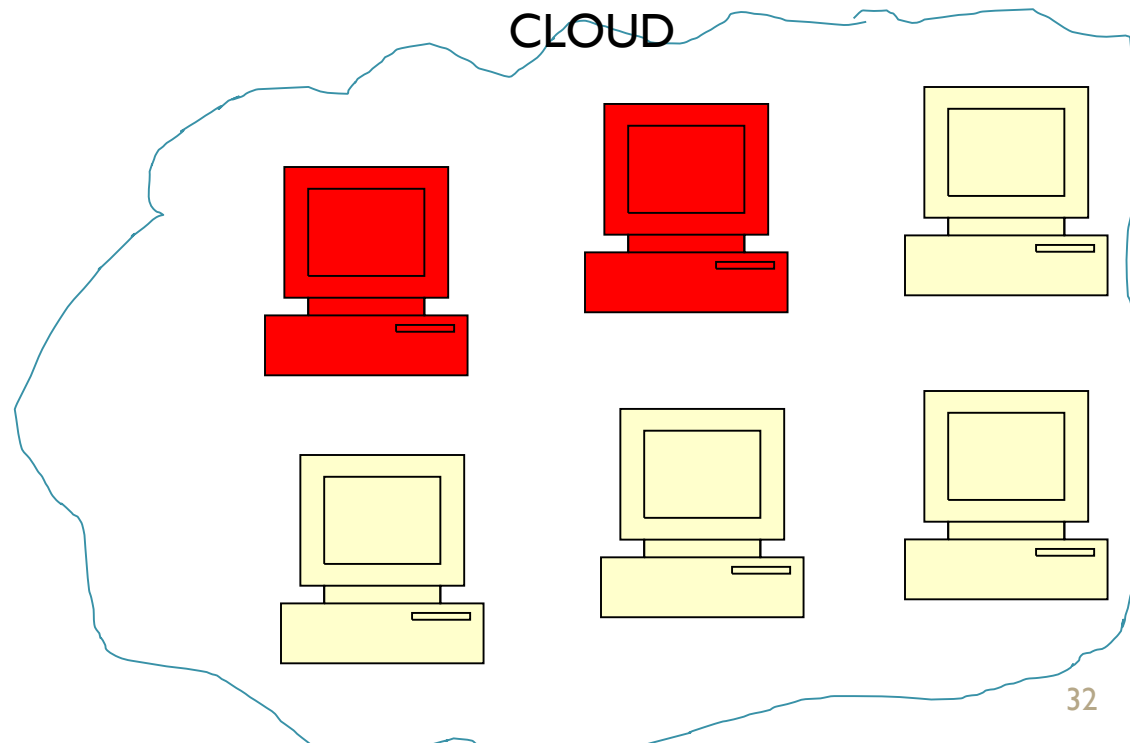


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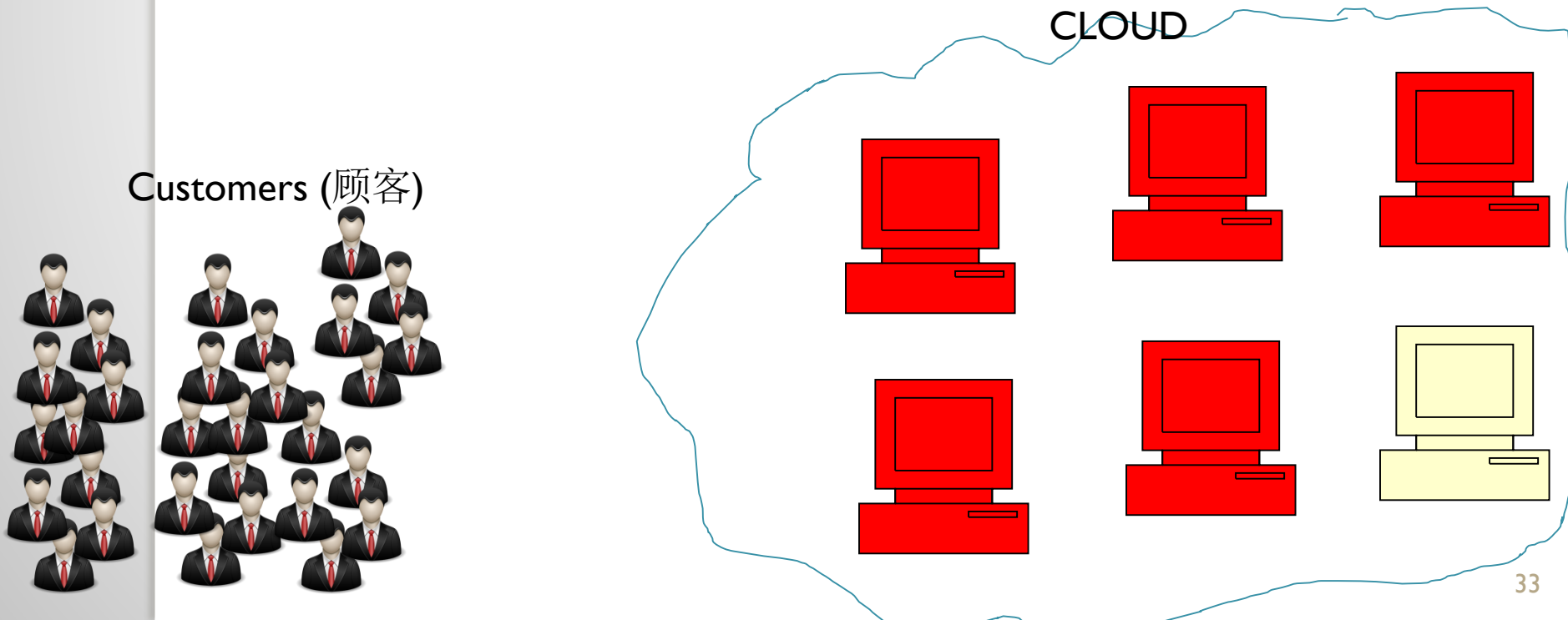
Customers (顾客)



A cloud must be « elastic »

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A cloud must be « elastic »

- To support elastic services, a **cloud provider** (云提供商) must maintain a **massive infrastructure** (基础设施).
- **Resource usage** is generally metered (计量) (amount of data, CPU time, storage space used...).
- **Users are charged** (收费) for the resources that they use (in general).

A cloud must be maintained

Maintenance (维护):

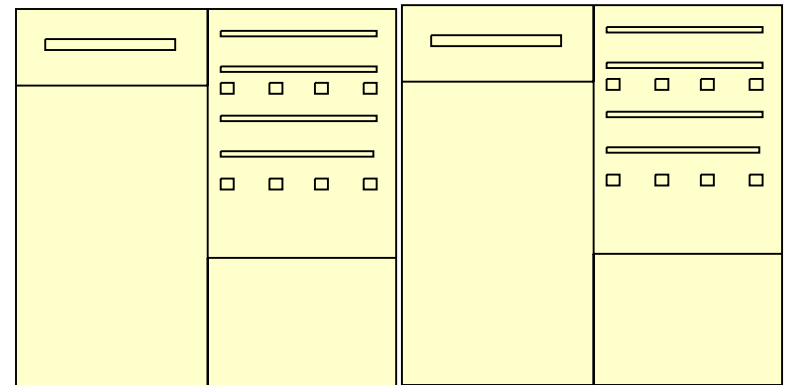
- **Maintenance and security** is the responsibility of the **cloud provider** (云提供商).
- **Users**
 - do not need to install, maintain and update computers and software to run applications.
 - do not need to buy equipment.



Security expert



Technician

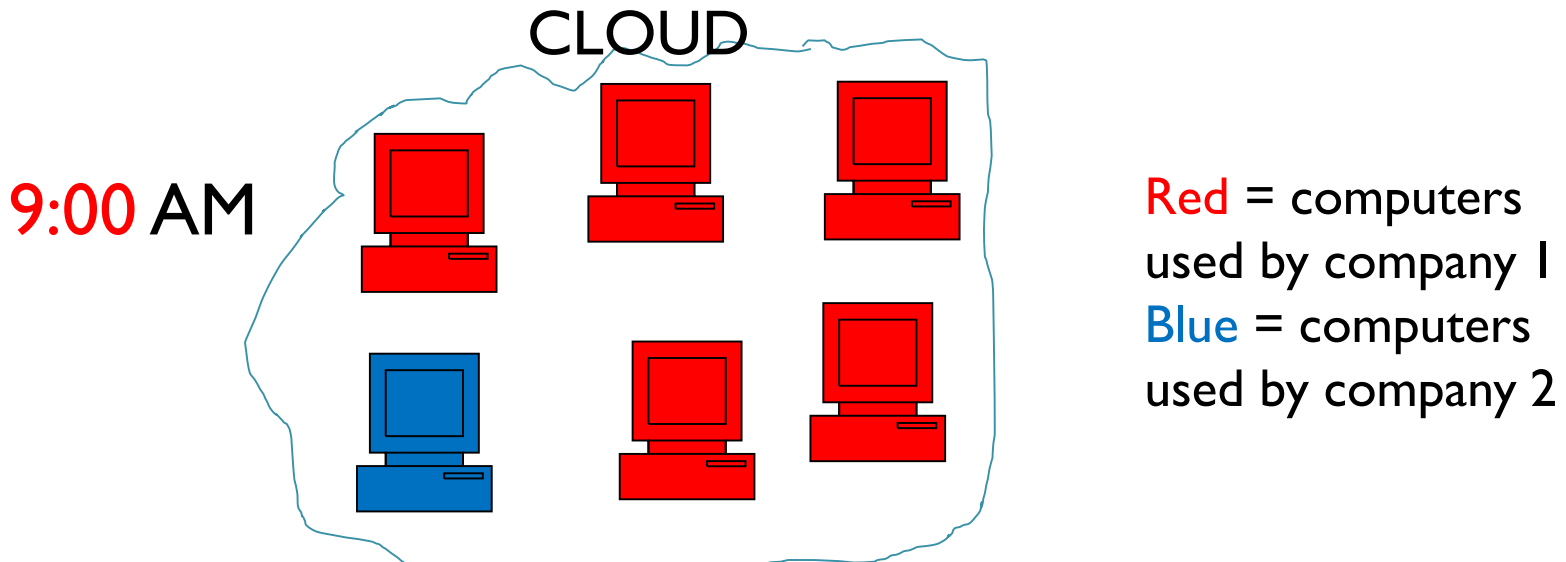


Equipment can be expensive!

Cost of running a cloud

Cloud providers (云提供商):

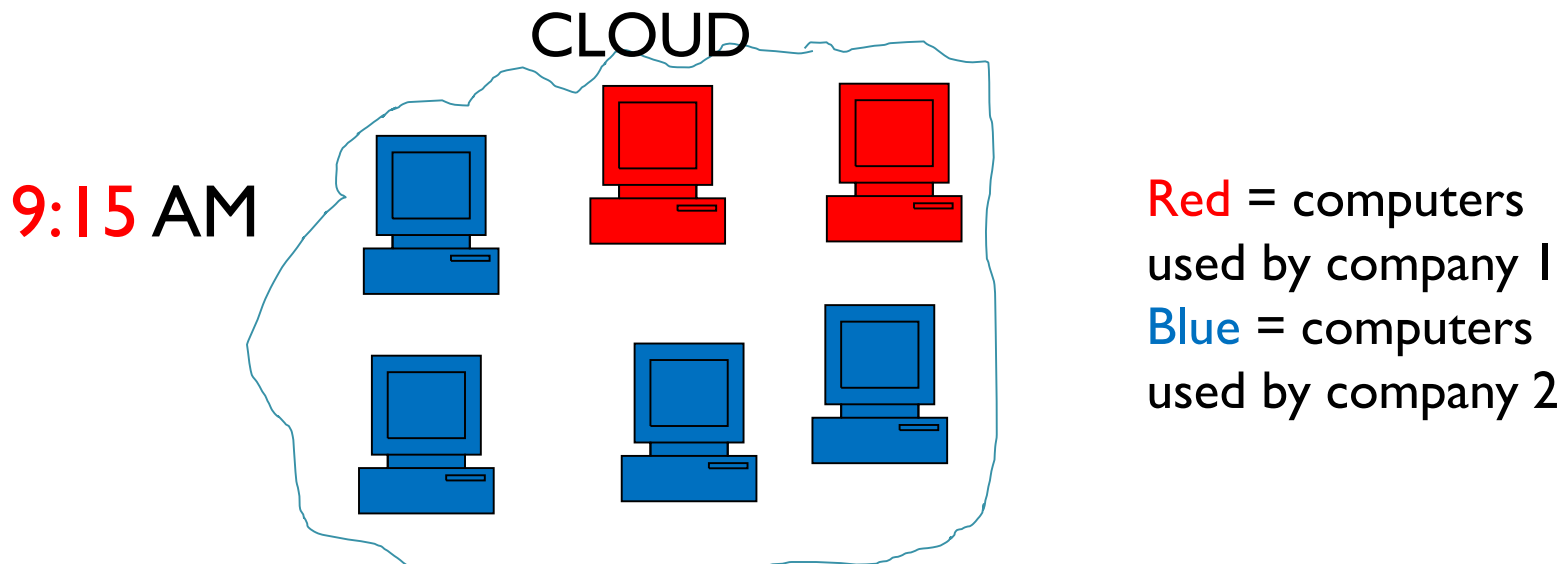
- operate efficiently due to **specialization (专业化)** and **centralization (集中)**.
- are very effective due to **resource multiplexing (资源复用)**
(sharing/reusing resources for several users)



Cost of running a cloud

Cloud providers (云提供商):

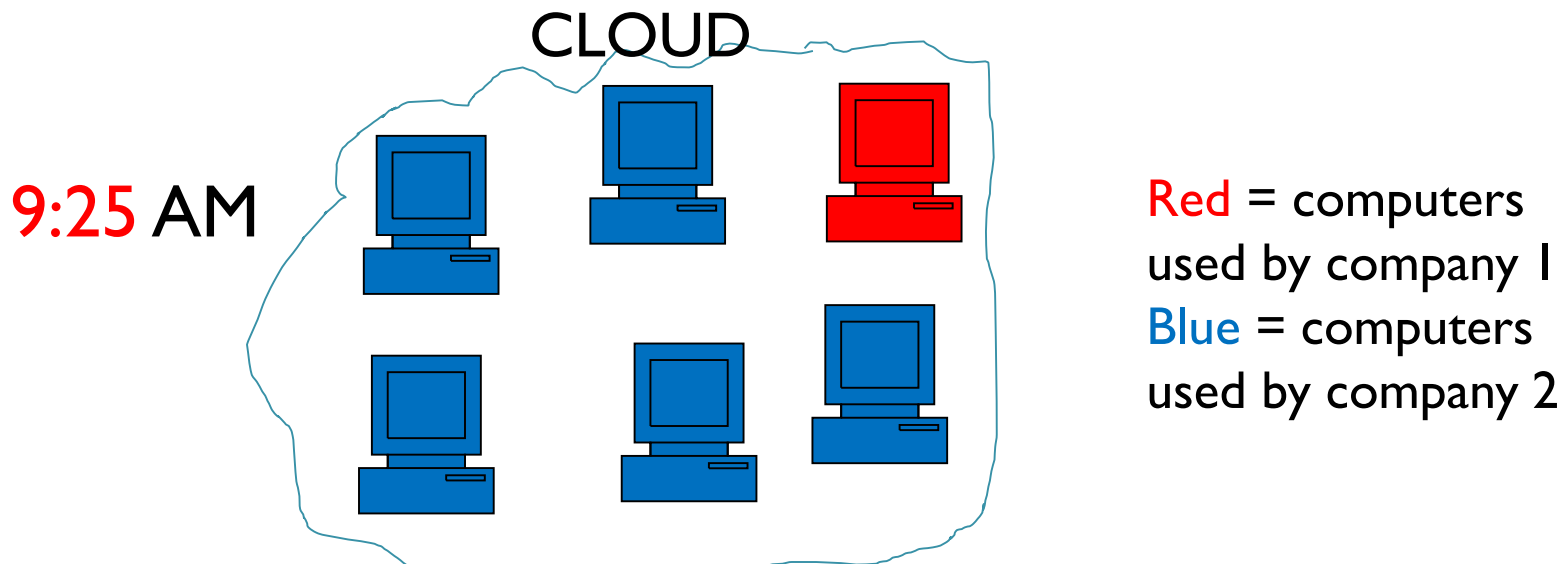
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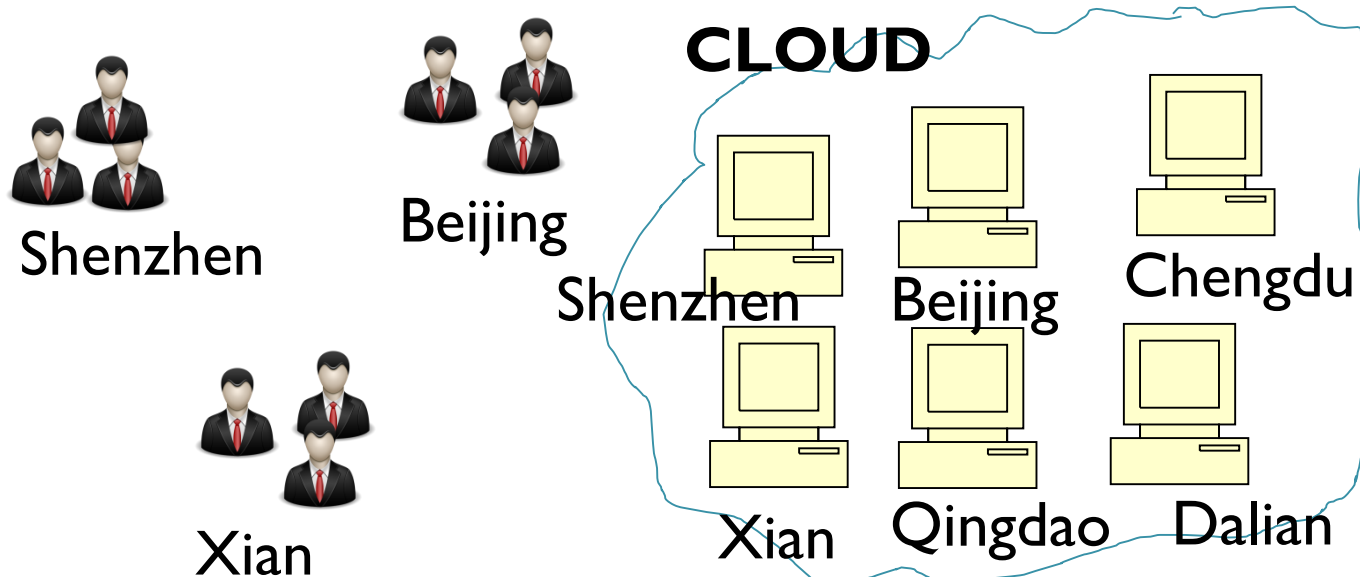


The data is distributed in the cloud

Distributed data storage (分布式数据存储):

Data is stored on **multiple computers**, often **close to the places** where it is used.

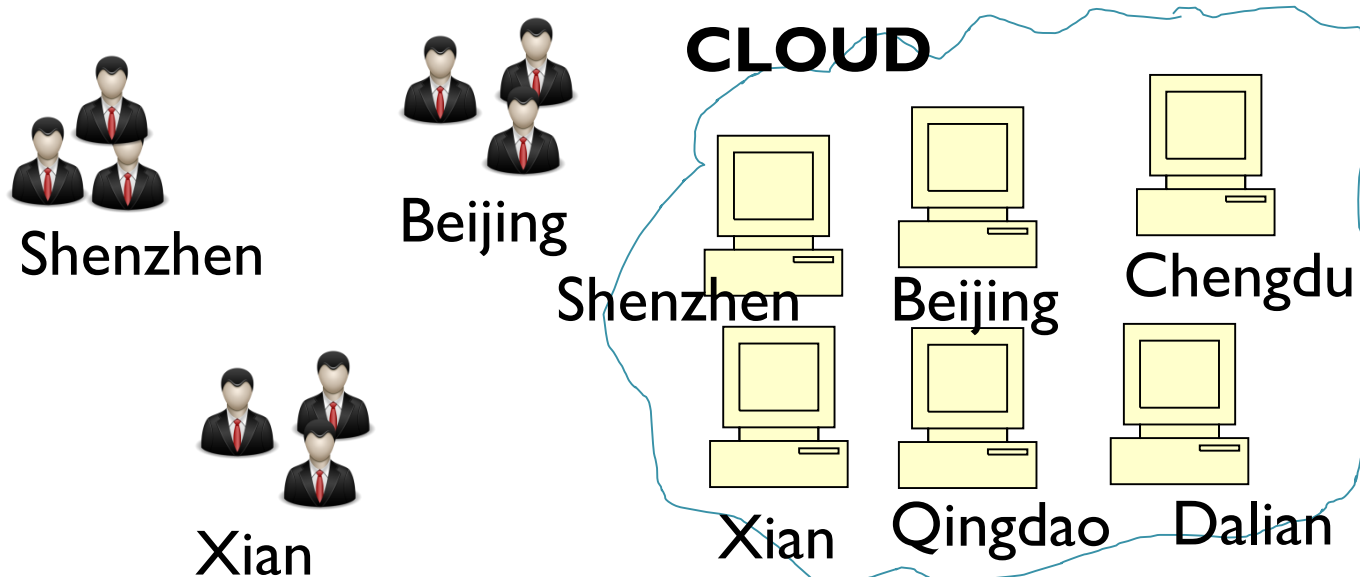
- This increases **reliability** (可靠性) and **security**.
- This reduces communication costs.



The data is replicated in the cloud

Data replication (数据复制):

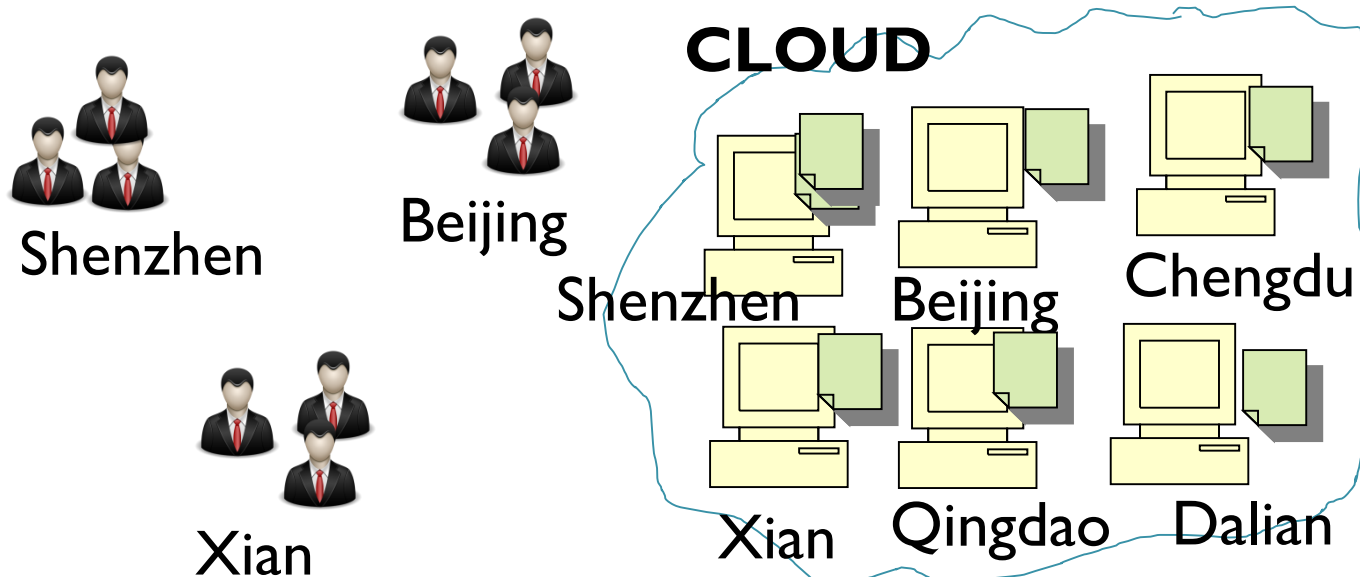
Data is generally **replicated** (复制) on multiple computers to reduce the risk of losing data and increase the access speed in different **geographical areas** (地理区域).



The data is replicated in the cloud

Data replication (数据复制):

Data is generally **replicated** (复制) on multiple computers to reduce the risk of losing data and increase the access speed in different **geographical areas** (地理区域).



Cloud computing is good?

- Yes, many benefits.
- However,
 - Users store private data and software on the cloud.
 - Users do not have full control of the cloud.

Cloud computing has implications (影响) that are:

- Economical
- Social
- Ethical (伦理的)
- Legal

Applications of cloud computing

- Scientific and engineering applications
- Finance,
- Gaming,
- Weather prediction,
- Data mining,
- and other data intensive activities
- ...

MI Cloud (小米云) and similar services

- Online service for storing content such as music, videos, and personal data.
- **Advantages:**
 - Data is accessible from anywhere,
 - Data is accessible from multiple devices (phone, laptop...)
 - Easy to share the data

But safe? secure? Still own the data?

Cloud for applications

- Services such as **iCloud** or **Mi Cloud** **store data in the cloud.**
- To reduce communication costs (通信费用), **data could also be processed in the cloud.**
- Thus, **applications** (软件程序) are also often executed **in the cloud.**

Data centers (数据中心)

To benefit from an **economy of scale** (规模经济), computers are often stored, maintained and managed in a same location (called **data centers - 数据中心**).



A data center may contain hundreds of computers.

How big are data centers?

Large (50,000 computers) vs medium (1,000 computers) data centers

- Resource consumption (including energy): 5 times less
- Networking cost and storage cost: > 5 times less
- Requires less network administrators per number of computers.

How many data centers?

- In 2006, 6,000 data centers in the US
- They consumed 61 billion KWh (千瓦时)
- This is 1.5 % of the energy consumption of the US

Data centers should be located in cities where electricity is cheap.

The World-Wide Web (万维网)

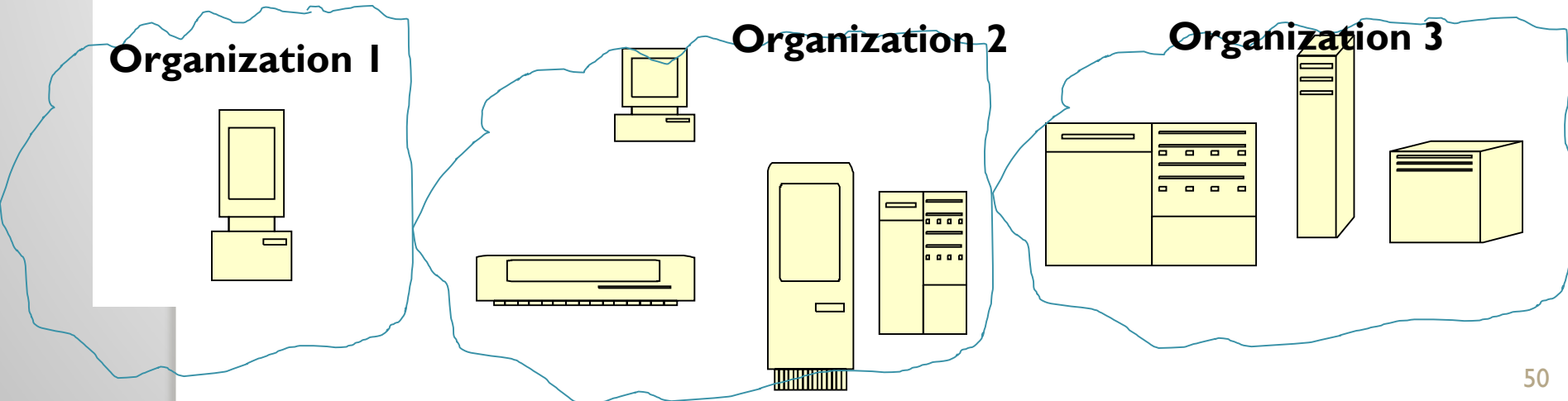
The **WWW** is some form of cloud computing?

- **Not really!**
- It is a large-scale distributed system with data stored on multiple computers and offering various services to users.
- Users can find, share and combine information

Grid computing (网格计算)

- The **Web** is a form of “**grid computing**”
- **Grid**: an heterogeneous network(异机种网络), geographically distributed, administrated by different organizations.

GRID:

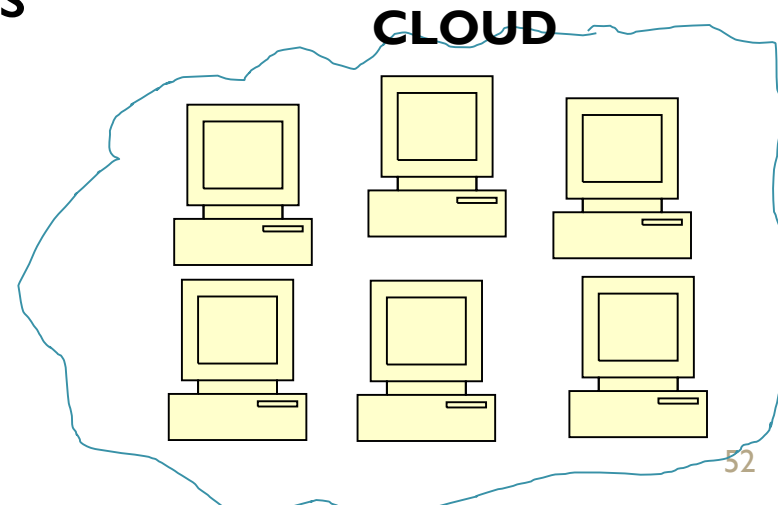


Drawbacks (缺点) of grid computing

- **Latency (延迟)** in communication is higher than for a supercomputer.
- **Transferring data is slower** than in a supercomputer.
- **An heterogeneous network (异机种网络 - grid)** makes it difficult
 - to run applications.
 - manage the system, perform scheduling (计划), optimize resource allocation (资源分配), fault tolerance (容错), and perform load balancing (负载均衡).

Cloud computing

- **Cloud**: a set of computers that is homogeneous.
 - Same type of computers (in theory),
 - Same security,
 - Same resource management,
 - Same cost...
- Targets enterprise needs

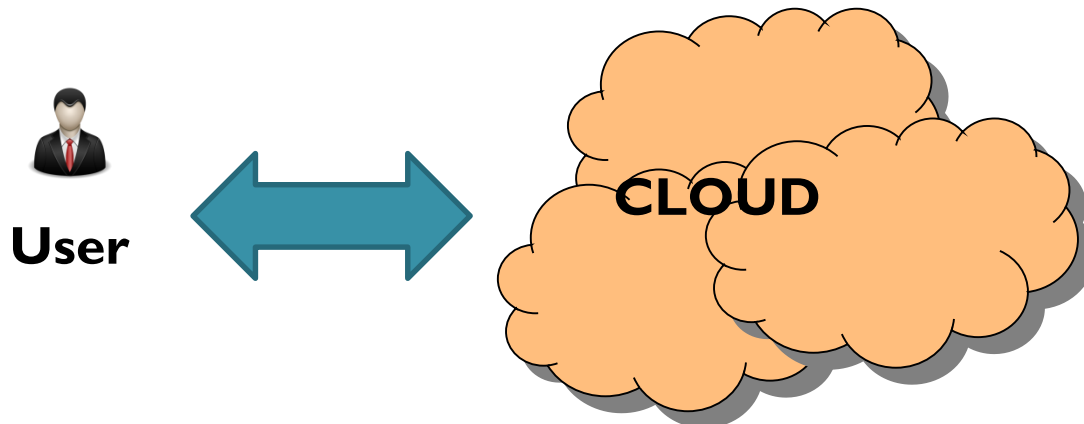


What kind of data in a cloud?

- **Any** type (text, audio, etc.)
- **Data should be:**
 - Treated according to its type
 - Retrieved from the **closest location**, or **best location** in terms of latency, or download time.
- Needs services such as:
 - right management (版权管理),
 - control of unsuitable content

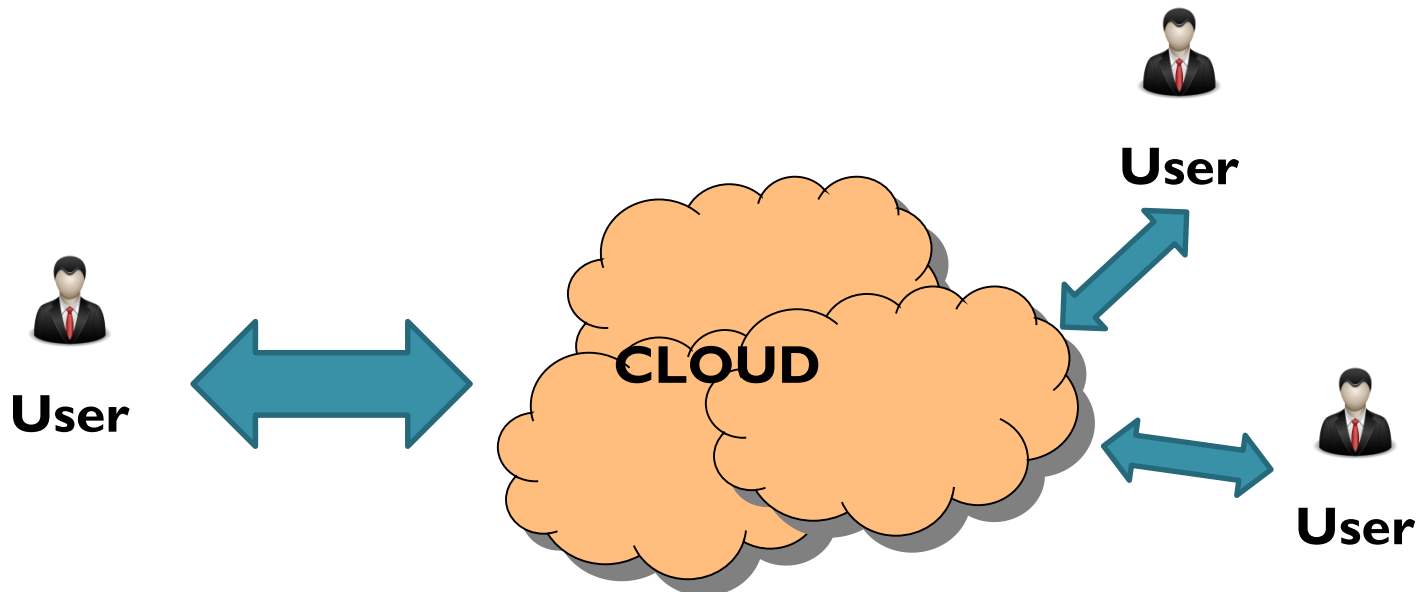
Cloud applications (云应用)

- Software programs running in the cloud are called **cloud applications** (云应用).
- Most **applications** are **data intensive** and **network intensive**
- The user does not need a powerful computer to use the cloud (e.g. **mobile phone**)



Cloud applications (云应用)

- The **user** runs an application to access the services provided by the cloud.
- The **cloud infrastructure** may provide services for **coordinating tasks** of different users.



Challenges of cloud computing

- **Multiplexing** (资源复用): sharing/reusing resources between users typically requires **more resources**.
- The **management** of many **resources** is a challenge.
Need resource management strategies.
- **Quality-of-service** (服务质量) may be hard to achieve in a distributed environment.

Challenges of cloud computing

- **Sharing data** is easy in a network. However, there are **security** and **privacy** issues.
- Some mechanisms are needed to support **access control** (访问控制) (**who can access what?**) and for **recording logs** (访问日志) of accesses/changes made by users.

What has started the cloud revolution?

Many **technological advances**:

- **Multi-core** processors on a same chip (faster communication between cores using cache)
- Novel **storage** technology (**SSD...**)
- Faster **RAM** memory, **lower cost**
- Advances in **software system, distributed/parallel computing, programming languages...**

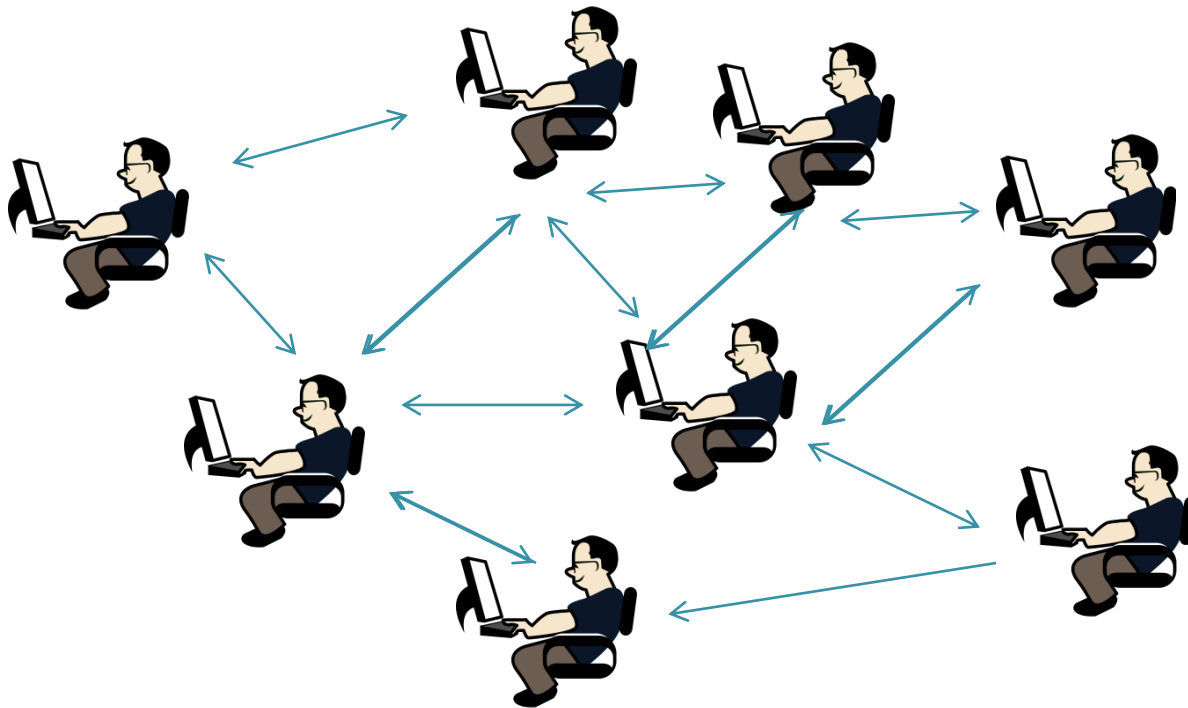
Peer-to-peer systems (对等系统)

- Another popular way of organizing computers in a network is **peer-to-peer systems (P2P)**.
e.g. BT (BitTorrent), Kazaa, Napster...
- **P2P** are generally:
 - self-organized (自组织的) (no central management process),
 - Decentralized (分散式网络)

Peer-to-peer systems (对等系统)

Example: BT (Bit Torrent)

Each user may share files with other users.



Each user manages his computer. There is no central computer to manage the P2P network. **Is it cloud computing?** →

P2P is some form of cloud computing?

No!

- a **cloud** is administered by a single organization.
- a **cloud** is homogeneous (同质)
- In **P2P**,
 - there is no central organization.
 - Each computer is viewed as having the same responsibilities and is managed by its owner.
 - It is heterogeneous

Advantages of P2P

- The **infrastructure** is provided by the users.
 - e.g. the BT network exists because many computers are running the BT software.
- **Highly decentralized** (分散式网络)
- **Scalable** (可扩展的),
- **Resilient to faults and attacks**
- Each node (computers) do not consume a lot of bandwidth
- May **protect the identity** and the **data** of users

Disadvantages of P2P

- P2P systems are
 - **hard to manage** effectively and
 - **hard to secure** (since everything is distributed).
- Protect the privacy of users. Thus, P2P networks are often used to carry out illegal activities.

Types of clouds

Public cloud (公共云)

- the cloud is available to everyone.
- users may need to pay the cloud provider to use the cloud

Private cloud (私有云)

- used by only one organization (e.g. university, government),
- may be operated inside the organization
- it requires an investment in infrastructures.
- usually more secure than using a public cloud.

Types of clouds

- **Community cloud (社区云):**
 - infrastructure shared by several organizations (a community).
 - operated by the organizations or a third party
- **Hybrid cloud:**
 - two or more clouds combined using standardized or proprietary technology

Drawbacks (缺点) of the cloud

- **Availability of service:** the cloud provider should be able to guarantee that the cloud will be available at any time
- It is often difficult to move from a cloud to another cloud.
- **Data confidentiality.**
- **Transferring data to** the cloud may be slow.
- **Performance may not be stable.**
- **The user does not own** the infrastructures.
- **Problems in the cloud...**

Why cloud computing is popular?

- **Managing a cloud is not so difficult** because a cloud is **homogeneous** (in terms of **hardware** and **software**) and **administered by one organization**.
- **The cloud is “elastic”** : the user can ask for more resources when needed.
- **Pay for what you use**. No need for an **up-front investment (前期投资)**



THREE WAYS OF USING THE CLOUD

(three delivery models)

1st: Software as a service

- The **user** uses applications offered by the **cloud**.
- The user uses an application on his computer to access the cloud
(e.g. a Web browser to access 163 e-mail).
- The user does not manage the cloud infrastructure
(e.g. network, server, operating system, storage).
- The user can only manage some application settings.
(e.g. how many e-mails are shown per page).

1st: Software as a service

- Other examples:
 - E-Mail website
 - Workflow management,
 - Collaborative applications,
 - Customer relationship management (CRM),
 - Financial management...
 - Social networks, blogs, wiki...

1st: Software as a service

- The data is stored in the cloud.
- **This delivery model is useful when:**
 - many people/organizations use the same product (e.g. e-mail 电子邮件)
 - There are some peaks in the usage of the application (e.g. payroll 工资表).
 - Some users want to use mobile devices
 - There is a short term need.

2nd : Platform as a service

The user

- can **run his own applications in the cloud** created or buy applications.
- **does not control the cloud infrastructure** (server, network, operating system, storage...).
- **has control of:**
 - applications
 - may control the application hosting environment (session management, content management, sandboxes...)

2nd : Platform as a service

- **Not useful if:**
 - a specific programming language must be used,
 - a specific software/hardware configuration is required to achieve optimal performance.
- **Example:**
 - Useful for software developers that develop applications and then run them in the cloud.

3rd : Infrastructure as a service

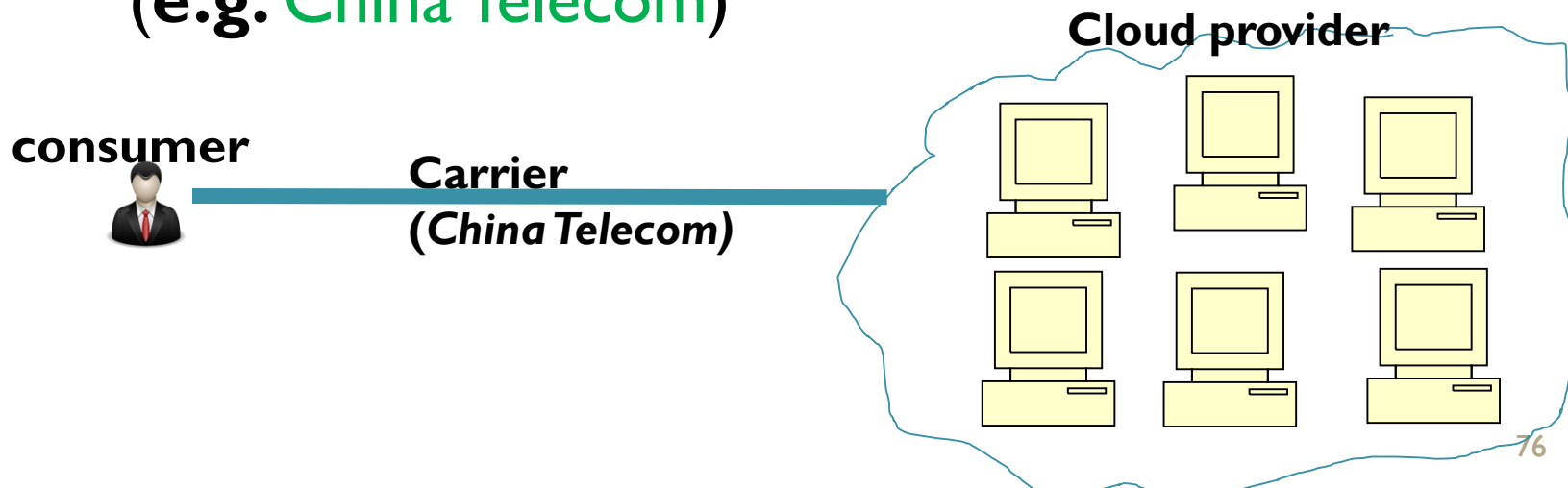
- **The user can run any software** (operating system and applications).
- The consumer does not control the cloud infrastructure.
- The consumer **controls the operating system, software, how the data is stored,** and may have limited control over **some networking aspects** (e.g. **firewall**).

3rd : Infrastructure as a service

- e.g. [Alibaba Cloud](#)
- Resources are distributed.
- Elasticity: dynamic scaling
- Pay-as-you-go, variable pricing models
- Hardware is shared by multiple users
- Useful when:
 - demand is volatile (挥发性需求) ,
 - a new business needs computing resources,
 - an organization is quickly expanding.

Some vocabulary

- **Cloud provider:** makes services available to consumers. (e.g. **Alibaba**)
- **User / service consumer:** uses the services of the cloud provider.
- **Carrier:** the intermediary that provides the connectivity between provider and consumer. (e.g. **China Telecom**)



Conclusion

- Before next week,
 - join the **QQ** group: **1127433879**
 - make sure that you can access the **website**



References

- Chaptre I. D. C. Marinescu. Cloud Computing Theory and Practice, Morgan Kaufmann, 2013.