DevOps
AIDE501 – M2 – 3 Credits
2026/2027

Course Contents

- **Chapter 1: Cloud Computing**
- **Chapter 2: Containerization**
- **Chapter 3: Shell Scripting**
- **Chapter 4: DevOps**
- **Chapter 5: Orchestration**
- **Chapter 6: GitLab CI/CD**

Chapter 1:

Cloud Computing

Chap.1: Cloud Computing

- Definitions
- Characteristics
- Deployment models: Public, Private, Hybrid
- Service models: IaaS, PaaS, SaaS
- Challenges
- Virtualization
- Storage and computational resources
- Networking & security in IaaS

Evolution (On-premises → Cloud)

Think of it this way …

- **Transportation**
  - Which one should you pick?
  - Should you buy/rent?





amazon







Evolution (On-premises → Cloud)

- Basic reasoning: information and data processing can be done more efficiently on large farms of computing and storage systems accessible via the Internet.

Enabling Technologies

- Virtualization
- Web 2.0
- Distributed Storage
- Distributed Computing
- Utility Computing
- Network Bandwidth & Latency
- Fault-Tolerant Systems

What is Cloud Computing?

- What do you think?

- ***"Cloud computing*** *is the delivery of computing services – servers, storage, databases, networking, software, analytics and more – over the Internet ("the cloud"). Companies offering these computing services are called cloud providers and typically charge for cloud computing services based on usage, similar to how you're billed for gas or electricity at home."* *https://azure.microsoft.com/en-gb/overview/what-is-cloud-computing/*

What is Cloud Computing

- In our daily routine we use this cloud service without our notice like web-based email service, watching movies through the internet, editing documents, storing pictures etc.. uses cloud computing on the back-end.

- Using such cloud technology, we can design and create new applications, store and recover data, host websites etc.

What is Cloud Computing

Data center : Composed of networked computers and storage servers that vendors use to organize, process, store and disseminate large amounts of data.



What is Cloud Computing

AWS Data centers : Cloud Regions and Zones

1. Regions

- Regions are specific geographical locations where you can run your resources
- Are collections of zones
- Regional resources are available to resources in any zone in the region

2. Zones:

- Isolated locations within a region
- Zone is composed of one or more data centers
- Zonal resources are only available in that zone.

Cloud Computing

- **Who is Who…**

Cloud providers



Cloud Users & Service Providers



Service Users



"With Amazon [AWS], on Day One of launch we could scale to the world."

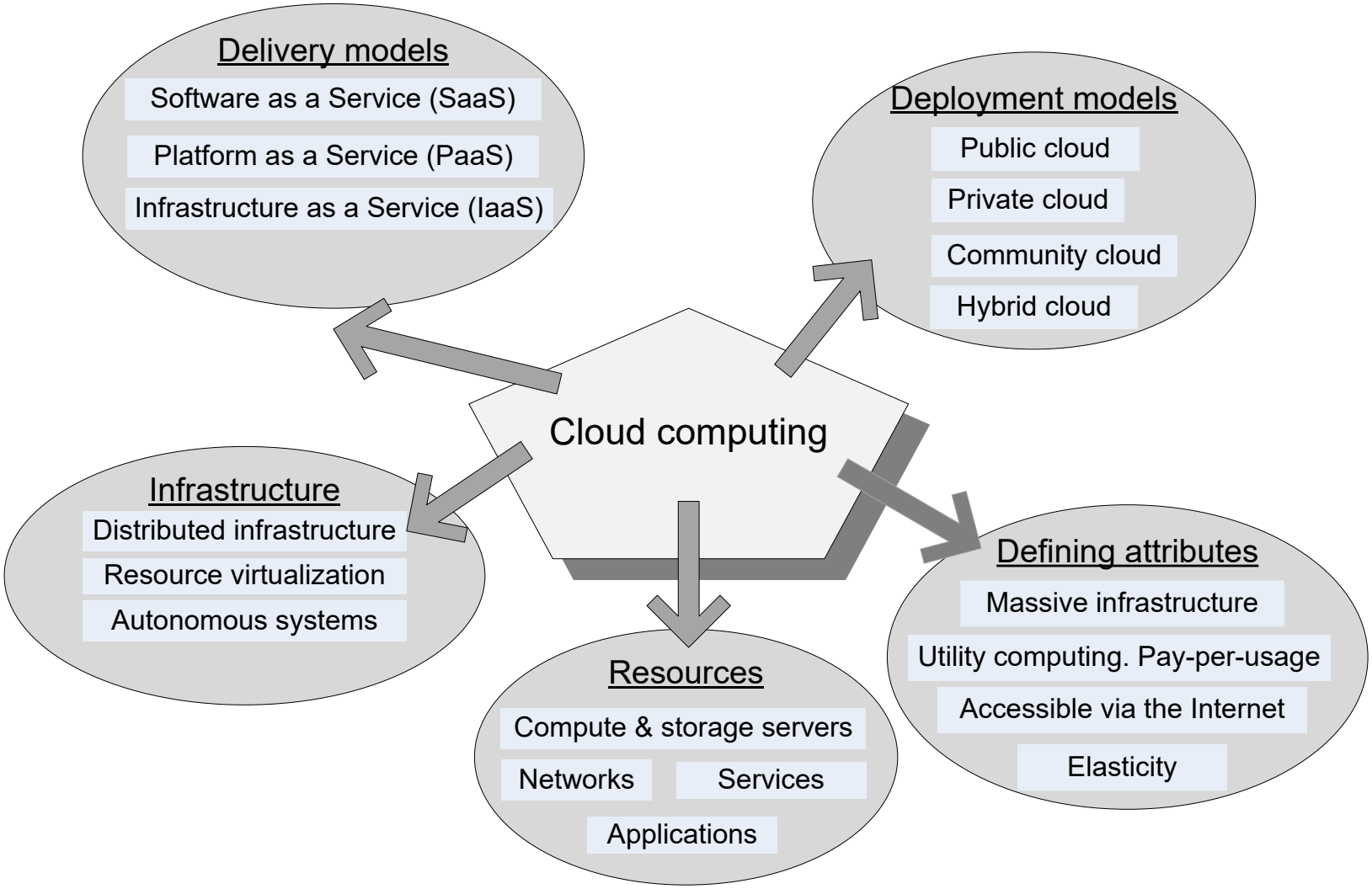
-Brad Jefferson, Co-Founder & CEO, Animoto

"Animoto has partnered with Amazon to leverage multiple offerings in their Web Services (AWS) platform which, in conjunction with Animoto's own render farm, constitutes the Animoto web infrastructure."



Users use it to produce video pieces from their photos, video clips and music.

Cloud computing - Characteristics



Cloud computing - Characteristics

"*Cloud Computing offers on-demand, scalable and elastic computing (and storage services). The resources used for these services can be metered and users are charged only for the resources used.* "

Shared Resources and Resource Management:

1. Cloud uses a **shared** pool of resources
2. Uses Internet technology to offer **scalable** and **elastic** services.
3. Resources are **metered** and users are charged accordingly.
4. It is more cost-effective due to **resource-multiplexing.** Lower costs for the cloud service provider are past to the cloud users.

Scalability vs Elasticity

- **Scalability** refers to a system's capacity to handle growing amounts of work or users without compromising performance. It involves the ability to accommodate increased workload by adding resources such as servers, storage, or network bandwidth. (Vertical vs Horizontal)

- **Elasticity** refers to the ability of a system to dynamically adjust its resource allocation in response to changing demands. Elasticity enables efficient resource utilization, cost optimization, and responsiveness to varying workloads without manual intervention, allowing organizations to effectively manage their IT infrastructure in a dynamic and agile manner. (Elasticity then scalability)

Cloud computing - Characteristics

Data Storage:

5. Data is stored:
   - in the "cloud", in certain cases closer to the site where it is used.
   - appears to the users as if stored in a location-independent manner.
6. The data storage strategy can increase **reliability**, as well as **security**, and can lower **communication costs**.

Management:

7. The maintenance and security are operated by service providers.
8. The service providers can operate more efficiently due to specialization and centralization.

Cloud computing - Characteristics

Why Cloud Computing?

- Large-Scale Data-Intensive Applications
- Flexibility
- Scalability
- Customized to your current needs:
  - Hardware
  - Software
- Effect:
  - Reduce Cost
  - Reduce Maintenance
  - High Utilization
  - High Availability
  - Reduced Carbon Footprint

Cloud computing - Characteristics

Why Cloud Computing?



- **Flexibility**
  - Software: Any software platform
  - Access: access resources from any machine connected to the Internet **[Access using API]**
  - Deploy infrastructure from anywhere at anytime
    - Software controls infrastructure

Cloud computing - Characteristics

Why Cloud Computing?

- **Scalability**

  Scale [Up (vertical)] vs [out (horizontal)]

  - Instant
  - Control via software
    - Add/cancel/rebuild resources instantly
  - Start small, then scale your resources up/down as you need
  - illusion of infinite resources available on demand



Cloud computing - Characteristics

Why Cloud Computing?

- **Customization**
  - Everything in your wish list
    - Software platforms
    - Storage
    - Network bandwidth
    - Speed



Cloud computing - Characteristics

Why Cloud Computing?



- Cost
  - Pay-as-you-go model
  - Small/medium size companies can tap the infrastructure of corporate giants.
    - Time to service/market
    - No upfront cost

Cloud computing - Characteristics

Why Cloud Computing?

- **Maintenance**
  - Reduce the size of a client's IT department
  - Is the responsibility of the cloud vendor
  - This Includes:
    - Software updates
    - Security patches
    - Monitoring system's health
    - System backup
    - ...etc



Cloud computing - Characteristics

Why Cloud Computing?

- **Utilization**
  - Consolidation of a large number of resources
    - CPU cycles
    - Storage
    - Network Bandwidth

Cloud computing - Characteristics

Why Cloud Computing?

- **Availability**
  - Having access to software, platform, infrastructure from anywhere at any time
  - All you need is a device connected to the internet



- **Reliability**

The system's fault tolerance is managed by the cloud providers and users no longer need to worry about it.

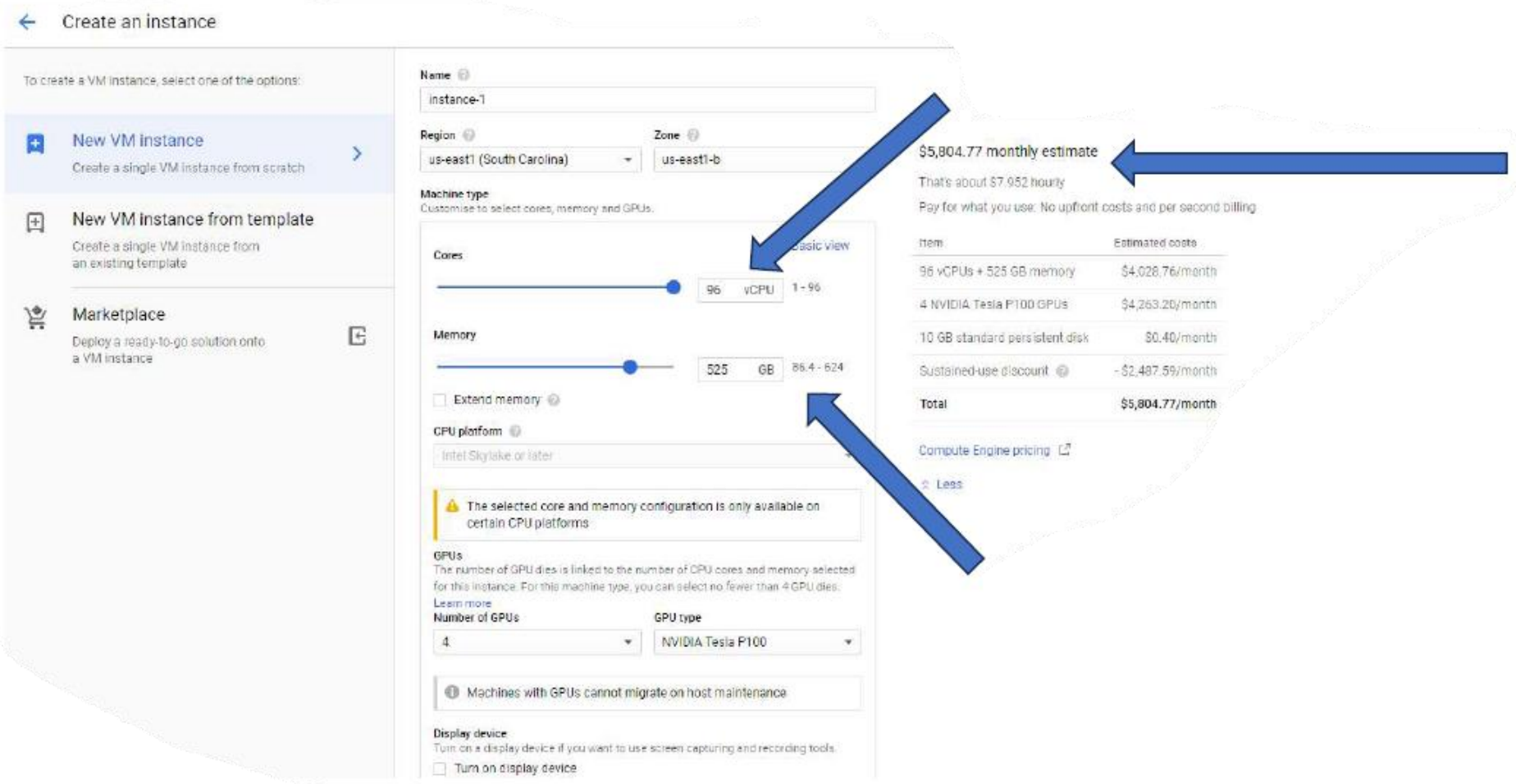
Cloud computing - Characteristics

Why Cloud Computing?

- CO2 Footprint
  - Consolidation of servers
  - Higher utilization
  - Reduced power usage



Cloud computing - Characteristics



Cloud Deployment models

1. Public Cloud – the infrastructure is made available to the public or a large industry group and is owned by the organization selling cloud services.

2. Private Cloud – the infrastructure is operated solely for an organization.

3. Hybrid Cloud – composition of two or more Clouds (public or private) as unique entities but bound by a standardized technology that enables data and application *portability*.

4. Other types: e.g., Community/Federated Cloud – the infrastructure is shared by several organizations and supports a community that has shared concerns.

Benefits of public cloud

- **Rapid scalability:** Add compute capacity instantly or automatically in response to unexpected surges in traffic.
- **Affordability:** Avoid the investing required to deploy and maintain on-premises IT infrastructure. Pay only for the resources or services you use to aid cost savings.
- **Ease of set up:** Quickly spin up new servers or other resources without purchasing hardware or configuring physical infrastructure.

What is private cloud?

- A **private cloud** environment is a cloud computing model dedicated to a single organization.
- Unlike a public cloud, a private cloud is a single-tenant environment—resources are accessible to organization clients only.
- A private cloud offers greater control over security and resource customization than a public cloud.
- Many organizations opt for a private cloud setting to protect sensitive data—a business need that is becoming increasingly important.

What is private cloud?

- Private clouds can be hosted:
  - On-premises in an organization's data center,
  - Hosted off-premises on a cloud service provider's infrastructure.

Private Cloud Benefits

- **Increased resource control:** Gain more control over IT resources with configurations maintained by internal IT team members.
- **Customization:** Customize hardware and software tailored to meet unique business needs, such as policies for compliance.
- **Robust security:** Gain greater visibility and access control by storing sensitive data and applications behind private firewalls that limit the attack surface.

Benefits of hybrid cloud:

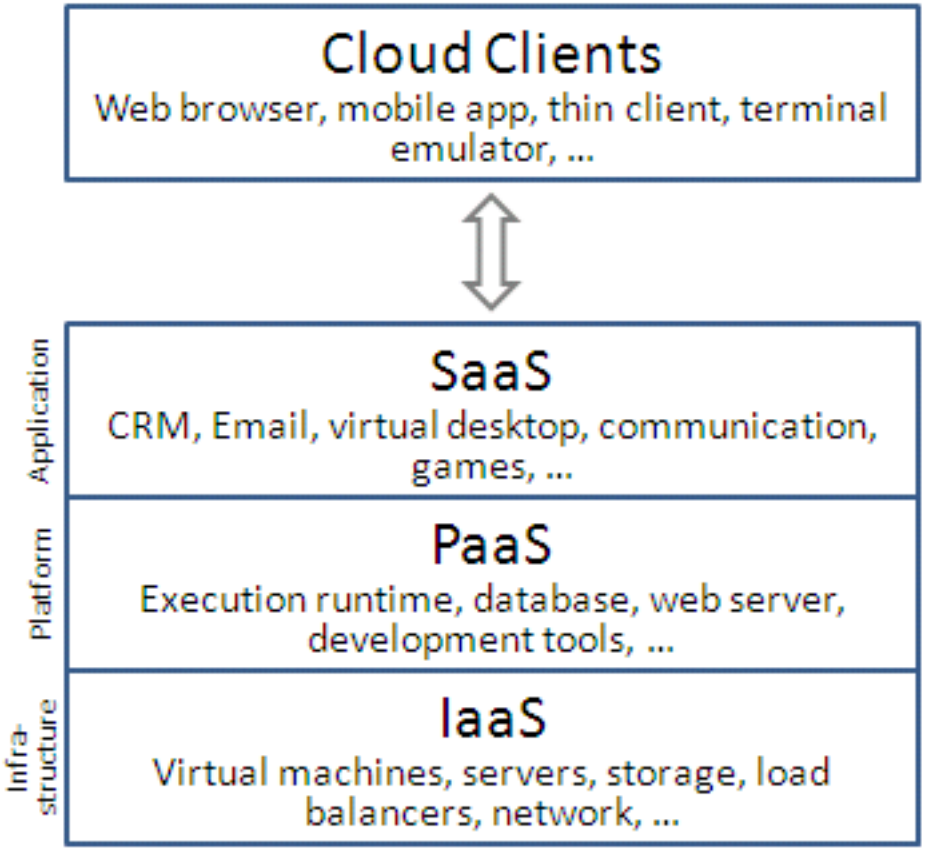
- **Flexibility:** Allocate workloads to fit best with business needs. Utilize public cloud resources for short-term projects like development and testing. Protect confidential or sensitive data on private cloud infrastructure.

- **Improved application development:** Expand adoption of agile and DevOps methodologies, enabling faster application development and time to market.

- **Digital transformation:** Leverage vast amounts of compute to process big data and harness the latest technologies like generative AI and machine learning (ML).

Cloud Delivery (Services) Models

1. **Software as a Service (SaaS)** (high level)
2. **Platform as a Service (PaaS)**
3. **Infrastructure as a Service (IaaS)** (low level)



1.6 Cloud Delivery (Services) Models

1. **Software as a Service (SaaS)** (high level)
2. **Platform as a Service (PaaS)**
3. **Infrastructure as a Service (IaaS)** (low level)

Build new house?

You can fully control everything like your new house. But that is a hard work ...



Buy an empty house and customise?

You can customize some part of your house. But never change the original architecture.



Live in a hotel?

Live in a hotel!! There is nothing you can do with the house except brining your suitcase and living in it.



Infrastructure-as-a-Service (IaaS)

- Infrastructure offers computing resources, CPU, VMs, storage, etc.

- The user is able to deploy and run arbitrary software, which can include operating systems and applications.
- The user does not manage or control the underlying Cloud infrastructure but has control over operating systems, storage, deployed applications, and possibly limited control of some networking components, e.g., host firewalls.

- Services offered by this delivery model include: server hosting, storage, computing hardware, operating systems, virtual instances, load balancing, Internet access, and bandwidth provisioning.
- Example: Amazon EC2

Cloud Service Models and Security Responsibilities

- **IaaS Customer Responsibilities**:
  - Operating system hardening and patching
  - Firewall and security group configuration
  - Application security
  - Data protection
- **IaaS Provider Responsibilities**:
  - Physical security of data centers
  - Hardware lifecycle management
  - Hypervisor security
- **IaaS Main Drawbacks**:
  - VM vulnerabilities and misconfigurations
  - Network isolation failures
  - Privilege escalation within virtualized environments

Platform-as-a-Service (PaaS)

- Allows a cloud user to deploy consumer-created or acquired applications using programming languages and tools supported by the service provider.

- The user:
  - Has control over the deployed applications and, possibly, application hosting environment configurations.
  - Does not manage or control the underlying Cloud infrastructure including network, servers, operating systems, or storage.

- Examples: Google App Engine, Windows Azure

Cloud Service Models and Security Responsibilities

- **PaaS Customer Responsibilities**:
  - Secure application code
  - Identity and access configuration
  - Data governance
- **PaaS Provider Responsibilities**:
  - Runtime, middleware, OS patching
  - Infrastructure availability
- **PaaS Main Drawbacks** :
  - API exposure risks
  - Dependency vulnerabilities
  - Secure application design

Software-as-a-Service (SaaS)

- Applications are supplied by the service provider.
- The user does not manage or control the underlying Cloud infrastructure or individual application capabilities.
- Services offered include:
  - Enterprise services such as: workflow management, communications, digital signature, customer relationship management (CRM), desktop software, financial management, geo-spatial, and search.
- Not suitable for applications where data is not allowed to be hosted externally.

- Examples: Gmail, Salesforce

Cloud Service Models and Security Responsibilities

- **SaaS Customer Responsibilities**:
  - User access management
  - Data classification and usage
  - Endpoint security
- **SaaS Provider Responsibilities**:
  - Application security
  - Infrastructure and platform security
- **SaaS Main Drawbacks** :
  - Identity-centric security
  - Insider threats
  - Data leakage risks

The Three delivery models of Cloud Computing

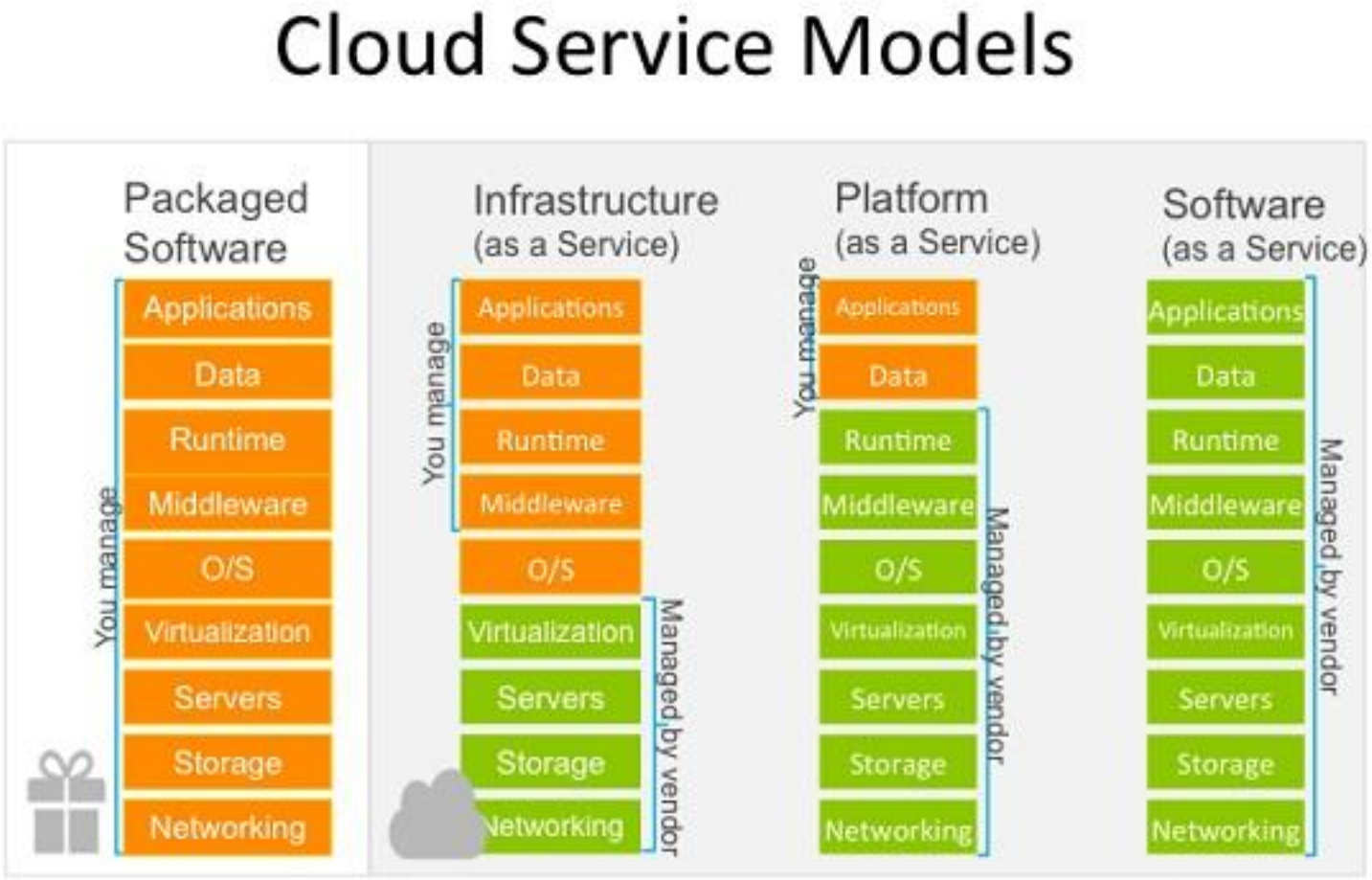
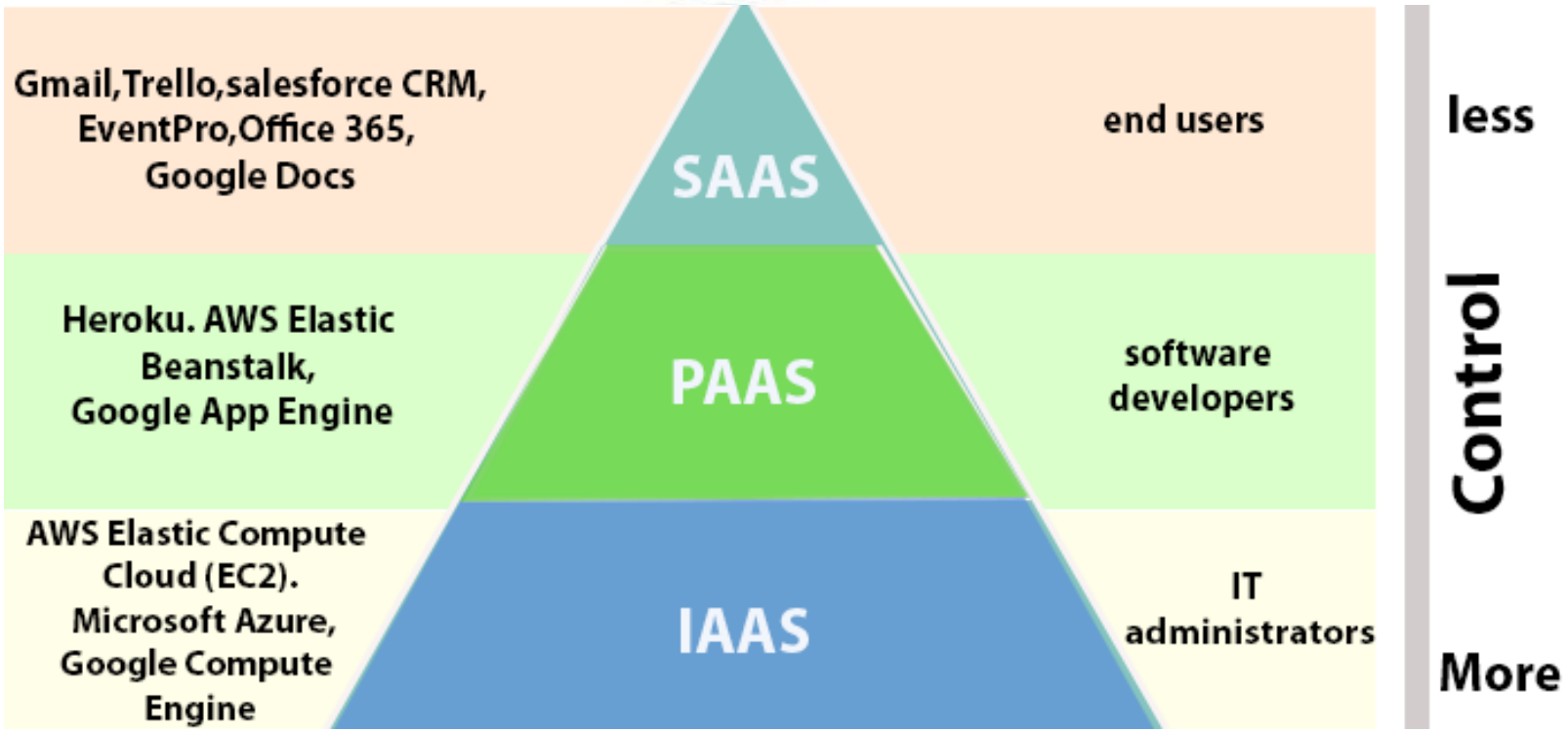


Figure 1. **Source: Microsoft Azure**


Gmail,Trello,salesforce CRM, EventPro,Office 365, Google Docs
SAAS
end users
Heroku. AWS Elastic Beanstalk, Google App Engine
PAAS
software developers
AWS Elastic Compute Cloud (EC2). Microsoft Azure, Google Compute Engine
IAAS
IT administrators
less
Control
More

Challenges for cloud computing

1. Availability of service: what happens when the service provider cannot deliver?

2. Data confidentiality and auditability, a serious problem.

3. Diversity of services, data organization, user interfaces available at different service providers limit user mobility; once a customer is hooked to one provider it is hard to move to another. (Vendor lock-in)(limited Migration)

4. Data transfer bottleneck; many applications are data-intensive. (Network-dependent)

More challenges

5. Performance unpredictability, one of the consequences of resource sharing.
   - How to use resource virtualization and performance isolation for QoS guarantees?
   - How to support elasticity, the ability to scale up and down quickly?

6. Resource management: It is a big challenge to manage different workloads running on large data centers. Are self-organization and self-management the solution?

7. Security and confidentiality: major concern for sensitive applications, e.g., healthcare applications.

Addressing these challenges is on-going work!

Privacy issues

- Cloud service providers have already collected petabytes of sensitive personal information stored in data centers around the world.
- The acceptance of Cloud Computing therefore will be determined by privacy issues addressed by these companies and the countries where the data centers are located.

- Privacy is affected by cultural differences; some cultures favour privacy, others emphasise community.
- This leads to an ambivalent attitude towards privacy in the Internet which is a global system.

Cloud Vulnerabilities

- Clouds are affected by malicious attacks and failures of the infrastructure, e.g., power failures.

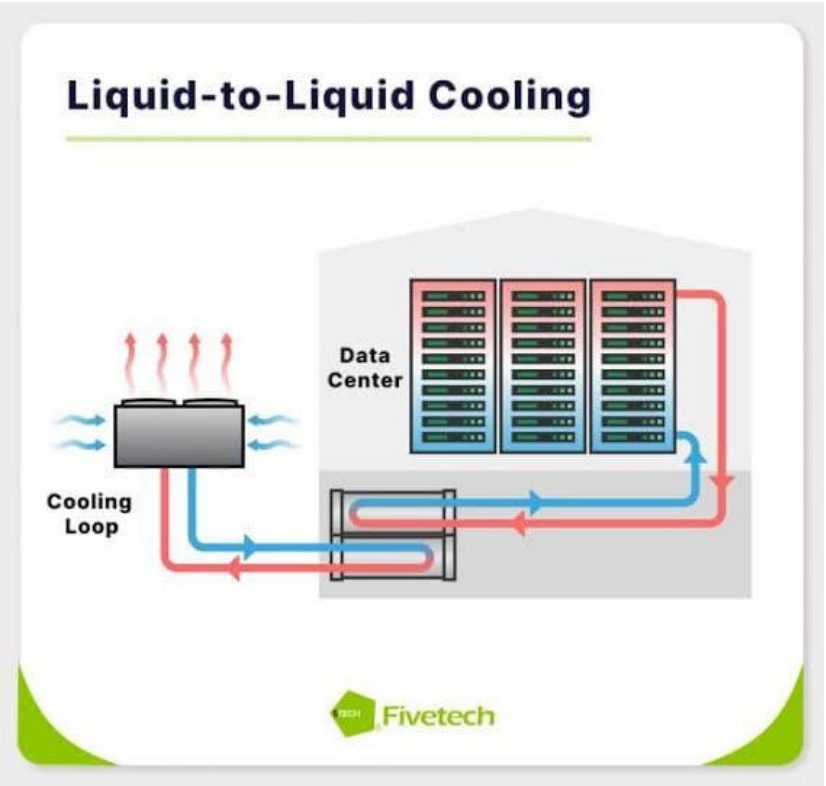
- Such events can affect the Internet domain name servers and prevent access to a Cloud or can directly affect the Clouds:
  - in 2004 an attack at Akamai caused a domain name outage and a major blackout that affected Google, Yahoo, and other sites.
  - in 2009, Google was the target of a denial-of-service attack which took down Google News and Gmail for several days;
  - in 2012 lightning caused a prolonged down time at Amazon.
  - …

Challenges for cloud computing

- **Server cooling** in cloud computing data centers is the process of removing thermal energy generated by hardware to prevent performance throttling, component failure, or fires.

1. Air-Based Cooling Systems
2. Liquid-Based Cooling Systems





Future of computing

1. The intelligent cloud is ubiquitous computing, enabled by the public cloud and artificial intelligence (AI) technology, for every type of intelligent application and system you can envision.
2. The intelligent edge is a continually expanding set of connected systems and devices that gather and analyze data—close to your users, the data or both. Users get real-time insights and experiences, delivered by highly responsive and contextually aware apps.
3. Combine the virtually limitless computing power of the cloud with intelligent and perceptive devices at the edge of your network to create a framework for building immersive and impactful business solutions.

Future of Cloud

