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RESEARCH AND COMPARISON ON THE PUBLIC CLOUD PLATFORMS – AMAZON WEB SERVICES AND MICROSOFT AZURE

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ABSTRACT

The progress of Internet connectivity and the access to it even in the most remote areas has led to the appearance of a new technological and social reality, Cloud Computing. Thanks to this new computing environment we can use or store resources, data, and services anywhere and at any time. Two big technological companies, Amazon, and Microsoft, have developed its services managing to become pioneers in Web services, creating their own Cloud Computing platforms, Amazon Web Services and Microsoft Azure, offering all three service models of Cloud Computing -SaaS, PaaS, IaaS- to the users. This dissertation analyses in a simple way the services of Amazon AWS and Microsoft Azure, focusing on four cloud services, Compute Services, Databases and Storage, Security and Network Services, while trying to render this analysis as objectively as possible from the English language, using as trigger research from scientific magazines and information from the official online documentation of the two companies.

Keywords: Cloud Computing, platform, services, Amazon AWS, Microsoft Azure.

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TABLE OF ABBREVIATIONS

AMI……..……..Amazon Machine Figure

API……..……..Application Programming Interface

Amazon EBS……Amazon Elastic Block Store

Amazon ECS…….……Amazon Elastic Container Service

Amazon EKS……..…….Amazon Elastic Kubernetes Service

Amazon S3……..……..Amazon Simple Storage Service

Amazon RDS……..……..Amazon Relational Database Service

Amazon SQS……..…….Amazon Simple Queue Service

Amazon VPC……..……..Amazon Virtual Private Cloud

AWS……..Amazon Web Services

AWS CLI……...……..Amazon Web Services Command Line Interface

AWS IAM……...……..Amazon Web Services Identity and Access Manager

AWS VPN…….……Amazon Web Services Virtual Private Network

AWS WAF…….…Amazon Web Services Web Application Firewall

Azure AD…….……Azure Active Directory

Azure AD B2B……..……Azure Active Directory Enterprise to Enterprise

Azure AD B2C……Azure Active Directory Enterprise to Consumer

Azure ASM……...……Azure Service Management

CDN……...…….Content Delivery Network

CPU…….……..Central Process Unit

CRM……Customer Relationship Management

DaaS……...Data as a Service

DevOps……Development and Operations

DNS……..……Domain Name System

DDoS…….…..Distributed Denial of Service

EC2……...Elastic Compute Cloud

EF Core……Entity Framework Core

ELB……..……Elastic Load Balancing

FaaS…….Function as a Service

FIFO……..……..First In First Out

IaaS……..Infrastructure as a Service

IDE……..……..Integrated Development Environment

IIS…….……..Internet Information Services

IoT……..……..Internet of Things

IP…….Internet Protocol

IPv4…….Internet Protocol version 4

IPv6…….Internet Protocol version 6

GCE…….……Google's Compute Engine

GUI……...…….Graphic User Interface

NIC……...……Network Interface Card

NSG……Network Security Group

MVC……...…….Model-View-Controller

O/RM……Object Relational Mapper

POP…….……..Point Of Presence

RBAC……...……..Role Based Access Control

RDP……..……Remote Desktop Protocol

REST……...……Representational State Transfer

SaaS…….....Software as a Service

SAS……..…..Shared Access Signature

SCM…….……..Supply Chain Management

SMB……...…….Standard Server Message Block

SSD…….Solid State Drive

StaaS…….…….Storage as a Service

TFS……..…Team Foundation Server

URI……...……Uniform Resource Identifier

URL……...…….Uniform Resource Locator

VHD…….…….Virtual Hard Disk

VM…….…….Virtual Machine

VNets……....……Virtual Networks

VPC…….Virtual Private Network

DEFINITION OF TERMS / GLOSSARY

Access Control: Indicates the person or group of people who are allowed to access the data of a company, enterprise, or organization.

API: A mechanism that allows software applications to communicate with each other through protocols. The API acts as an intermediary between an application and a server and processes data transmitted between systems. Communication is done with requests and responses.

Autoscaling: Dynamically adjusting resources on a server so that resources expand automatically to meet network traffic needs.

Availability Zones: Zones into which regions are divided. For each region the availability zones are sufficient, isolated, distinct from each other and resistant to failures of any kind (hardware, software, natural disasters).

Backend application: Communicates with a frontend application and not directly with the end user. You build with software that runs on a server and is accessible over the Internet with an API. It performs functions that a frontend application cannot perform such as security settings or data storage.

Backup data: The practice of storing data in another location such as the Cloud in the event of a disaster, accident, or malware attack.

Backend database: The database that stores data without including end-user application components such as queries or reports.

Bandwidth: The range of frequencies over which a signal transmits.

Batch jobs: A job is a set of jobs started by AWS Batch. They are container applications that run on Amazon ECS container instances in the ECS cluster.

Central Processing Unit: The main part of the computer that processes data or commands and gives a response.

Server Cluster: A set of computers, connected that act as a single computer.

Code editor: A program or part of a development environment for writing software.

Commercial Database: The database that is only available for a fee. Access or modifications to the data are available only to users.

Computing power or power: The rate at which tasks are performed on the computer.

Data: Small groups of information that can be used for research, calculations, analysis or reporting and are compiled into graphs, tables, or Figures.

Database: Organized collection of information or data stored electronically in a computer system. Data is modeled in rows and columns and with appropriate commands can be modified, refreshed, or deleted.

Datacenter: A building, a space within a building or complex of buildings that houses computing systems along with their components such as telecommunications and storage systems. It is used to store, process, and share large amounts of data.

DevOps: The combination of philosophies, practices, or tools along with software and hardware to rapidly build competitive applications or software.

Domain Name System (DNS): Naming system for identifying computers accessible via the Internet.

Edge Server: A device that provides access to a network such as a router.

Encryption: The study of communication techniques so that the message sent by the sender is viewed only by the recipient.

Frontend application: The web or mobile application that interacts with the user through the graphical user interface (GUI).

Fully Managed Service: It's the service that enables dynamic performance and capacity change to meet workloads resulting in lower long-term costs, higher performance, and better results.

Graphical User Interface (GUI): A visual way of interacting with a computer using windows, menus, pictures, or other representations (graphics).

Hardware Infrastructure: The equipment, materials or products and facilities needed to operate the software infrastructure.

Internet: Global network with billions of connected devices.

Internet of Things: The network of physical devices, tools, equipment, and smart devices that are connected to the Internet and to each other.

Integrated Development Environment: The environment for developing, testing, and debugging code.

Intranet: A local or private network used by an organization.

IP Address: The unique address that each computing device must communicate with other devices on the IP network.

IPv4: The fourth version of the Internet Protocol.

IPv6: The sixth version of the Internet Protocol.

IT Infrastructure: The components for the operation and management of the IT environment, i.e., the hardware and software such as facilities, data centers, servers, networks, computers.

JSON template: Data files that store a list of parts along with their settings.

Load Balancing: The isomeric distribution of network traffic to prevent failure from overloading a resource.

Memory cache or cache: The storage of data in the computer's main memory for faster retrieval.

Memory Object Caching System (Memcached): Acts as an application cache by reducing the database load so that the application performs faster.

Metadata: Data that provides information about other data.

Network: A collection of computers, servers, or other computing devices such as tablets, smartphones, or televisions, which are connected and communicate with each other for the purpose of exchanging data.

Network gateway: Provides the connection between networks.

Network Latency: The time it takes for data to travel across the network and back to the source.

Object Storage: A data storage architecture for storing larger, unstructured data where each piece of data is represented as an object.

Open-Source Database: The database that is available for free while the modification of its code can be done by all users.

Region: Geographical location of the datacenter. Regions can be located all over the world, in many cities.

Relational Database: The database that stores data that is related to each other. Each row has data with its own identity called a key.

Remote Desktop Protocol: A network protocol created by Microsoft for the purpose of connecting to another computer or network.

REST: A software architecture style for building web applications.

REST API: The API that conforms to REST design principles.

Router: The device that communicates with the Internet and the device that connects to it.

Route table: The table that contains the necessary information to forward packets by choosing the best path that leads to the destination.

Server: Hardware or software that provides services to a client based on a request. The client-server communication takes place via a local network or via the Internet.

Software infrastructure: Includes IT services that can be managed as software without human intervention.

SSD: Data storage disk with flash memory that offers faster performance.

Storage: Cloud Computing model that stores data on the Internet through a provider that manages storage as a service.

Subnets: Smaller networks that belong to a network so that network traffic is reduced for better performance.

URI: Unique sequence of characters that identifies a logical or physical resource used by web technologies.

URL: The Internet or web address.

Virtual Machine Expansion Pool: Allows the user to create and manage a pool of Virtual Machines that use Azure Load Balancer.

Web browser: A platform that offers the user the tools he needs to access Internet information through web pages.

INTRODUCTION

The purpose of this dissertation is to present the services offered by two public Cloud Computing platforms, Amazon Web Services (Amazon AWS) and Microsoft Azure, of the major technology companies Amazon and Microsoft, as well as the comparison between them. The goal is to answer as many questions as possible regarding not only the two platforms but also Cloud Computing in general such as:

- What is Cloud Computing and what are the benefits of using it?
- What are the types of Cloud Computing?
- What is Amazon AWS and what services does it offer?
- What is Microsoft Azure and what services does it offer?
- What are their differences?

This work tries to answer the above questions and inform the reader about this new technology with scientifically documented references from the official documentation of Amazon and Microsoft and from scientific journals such as:

- Introduction to the concepts of Cloud Computing του Eoin Scollard.
- A Comparative Analysis of Public Cloud Platforms and Introduction of Multicloud του Khot, A.R.
- Overview of Amazon Web Services της Amazon
- Amazon Elastic Compute Cloud User Guide for Windows Instances της Amazon
- Microsoft Azure Essentials: Fundamentals of Azure, Second Edition των Michael Collier και Robin Shahan

The first chapter is aimed at computer scientists, programmers who want to learn about Cloud Computing, or a simple reader who wants to get to know this branch of IT. An introduction to Cloud Computing is given where its definition and architecture are presented with service and development models as well as the advantages of its use. It also mentions the four criteria that should be met by Cloud Computing before an enterprise chooses to use a Cloud platform. The second chapter is aimed more at developers or people with computer knowledge but without any knowledge of Amazon AWS and Microsoft Azure. Amazon AWS services are introduced and analyzed first, followed by reference to Amazon Elastic Compute Cloud, and finally Microsoft Azure services are analyzed. Finally, in the third chapter the comparison is made since the reader now has a comprehensive view of both Cloud Computing and Amazon AWS, Amazon Elastic Compute Cloud and Microsoft Azure. The comparison includes tables that summarize the analyzed differences. After the comparison follows the practical part of the work where the implementation of applications based on some Amazon AWS and Microsoft Azure services is presented.

Chapter 1. Overview of Cloud Computing

1.1 What is Cloud Computing

Cloud Computing is an online environment that allows users to use resources and services from anywhere on the Internet. Its services are provided by a Cloud provider who deals with the maintenance of the infrastructure instead of the user. Cloud Computing infrastructure is hosted in global datacenters, while resources and services are hosted on online platforms and offer services that vary by provider. However, the core services they all providers offer are computing power and storage. The best feature of Cloud Computing is that the user pays only for the services he uses and not for all the services offered by the platform. This feature is known as "pay as you go". For example, with Cloud Computing the user can add or remove as much computing power and storage as needed to support new upgrades and services, thereby reducing maintenance costs. Furthermore, Cloud providers take care of the backups of the tasks, the upgrades of the operating system and the provision of the services wherever and whenever the user needs them.

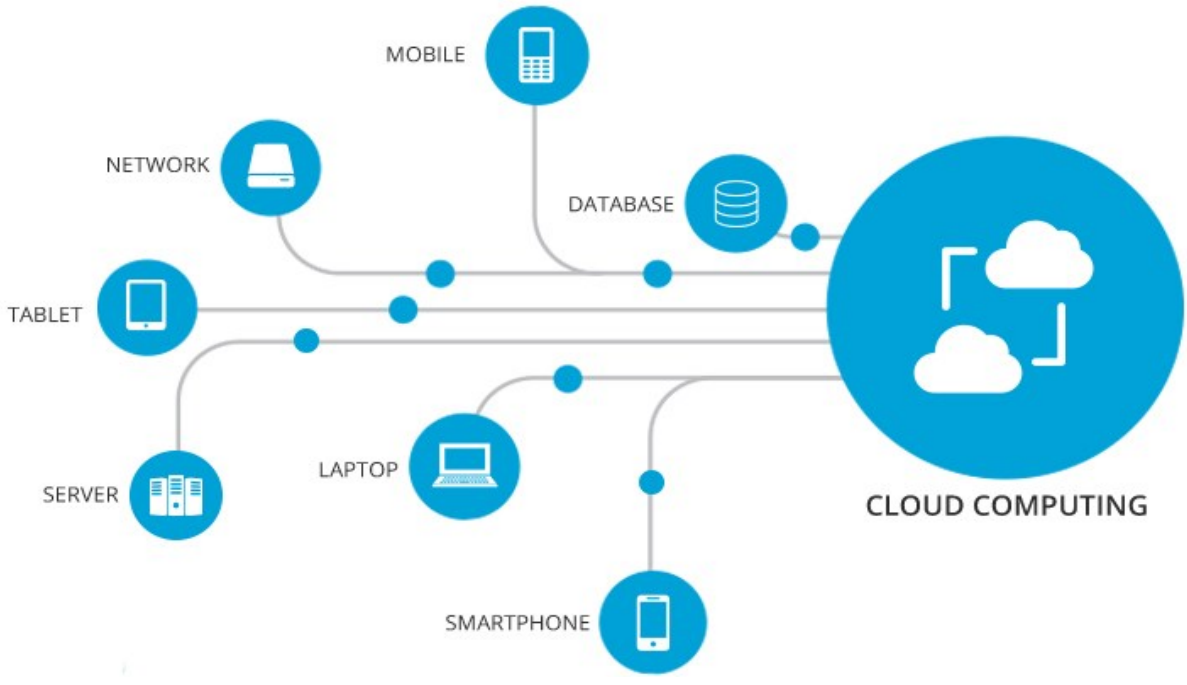

Figure 1.1 Cloud Computing

Another common feature of all Cloud providers is their support plans. Each provider offers a support plan to users from which the cost of using their platform services is derived per month. Typically, these plans are divided into basic support, developer support, and enterprise support. The reason that there is not a common plan for all users is analyzed below and concerns the types of Cloud Computing and specifically the service models. Depending on the plan chosen by the user, the response time of technical support is also determined. Thanks to the organization, flexibility and variety of services, Cloud Computing is preferred by many types of enterprises or organizations such as large, small, and medium enterprises and government or non-profit organizations. But its use is not only for organized enterprises, as it provides a flexible environment that can support multiple users. Thus, it is used by many experienced or junior developers, having the opportunity to create their own environment where they will use and develop the applications, they want without being concerned about computing power, storage, and IT tools. All this is provided by the Cloud provider of their choice by paying a monthly or annual subscription if they have an Internet connection. Today, major IT companies such as Google, Amazon, IBM, Microsoft, and Oracle have become Cloud vendors enabling their customers to manage their data remotely. Often, together with Cloud Computing, the short term "Cloud" is mentioned. Cloud is used to describe a global network of remote servers where each one has a separate function. These servers are designed to store or manage data, run applications, and deliver content to users such as videos, emails, special purpose software or even social media. They are organized in such a way that users can access files and data anywhere on the Internet instead of storing them on their personal computers or external drives. [1] There are three types of Cloud used by enterprises to deploy their Cloud Computing resources. These are the public, private and hybrid Cloud and are the Cloud deployment models.

1.2 Cloud service and deployment models

There are two types of Cloud Computing, service models and deployment models. The service models include the services offered by Cloud Computing platforms and based on them the cost of use is derived from the support plans, while the development models concern the Cloud, i.e., the global network of servers. Deployment models show how resources are distributed across a network, whether it is public like the Internet or it is located on premises, that is the company's internal facilities.

A. Service models

Traditionally, Cloud providers provide three service models, Software as a Service (SaaS), Platform as a Service (Paas), and Infrastructure as a Service (IaaS). But the increased use of

Cloud Computing led to an increase in customer needs and thus new models were created which are also mentioned.

To begin with, the SaaS model is undoubtedly the most widespread service model since it is used every day by billions of users even if they do not know that they are using its services. SaaS provides applications that are made available to the end user by a Cloud Computing provider through a web browser. The provider manages the hardware and software, i.e., the entire Cloud Computing infrastructure, which you host in its datacenter, while the user only pays for the applications he uses (pay as you go). Examples of SaaS are well-known applications that users access via the Internet such as Outlook, Office365, Yahoo! and others. SaaS has many advantages such as access to multiple applications, selected pricing, access to ready software, mobility, and accessibility. [2]

The PaaS model provides hardware, software, and infrastructure for the user to develop, manage and run their applications without the cost and complexity. Like SaaS, it hosts its entire infrastructure in the datacenter and the user pays for the services he uses. The advantages of PaaS are fast application development, access to financial resources, greater freedom in application creation, low-cost scalability, and flexibility in application creation for developers. In general, PaaS is more aimed at developers, i.e., users of the Cloud Computing platform who want to build their own applications with specific features but without having to deal with the infrastructure, for this reason it consists of three parts. The first includes Virtual Machines, software, storage, networks, and security, the second includes software for developing and managing applications and the third a graphical user interface (GUI). with which the development or DevOps team works to manage the applications. Examples of PaaS are Google App Engine, Amazon Lightsail, Microsoft Azure App Services. [3]

The next model is the foundation of Cloud Computing and is directly related to deployment models. This is IaaS in which all its services are hosted in the public, private or hybrid Cloud. It is a model used primarily by companies, enterprises, and organizations to access compute, network, and storage services over the Internet at any time. The main reason enterprises use this model besides low cost is scalability. That is, they can create apps with specific features and add more as they develop. The architecture of IaaS includes datacenters, compute services such as Virtual Machines, networks such as private virtual networks (virtual private networks -VPC) and storage space consisting of block, file, and object storage. The advantages of IaaS are selected billing (pay as you go), fast resource performance, availability, scalability, and low network latency. Examples of IaaS are Amazon EC2, Google's Compute Engine(GCE), Microsoft Azure Virtual Machines and Oracle Bare Metal Servers. [4]

The Storage as a Service (STaaS) model provides storage components on remote infrastructures. The user pays for both usage and frequency of access. Some additional services such as autoscaling and data backup processing are charged extra. Examples of STaaS are Amazon S3, Microsoft OneDrive and Google Cloud Storage. [6]

The Data as a Service (DaaS) model extends StaaS in terms of database or tabular data storage. With DaaS data is not only limited to storage and access, but can undergo processing,

migrations, and various other operations. Examples of DaaS are Amazon DynamoDB, Azure Database for MySQL, and Oracle Data Cloud. [6]

The Function as a Service (FaaS) model is a microservice, which allows the user to run event-driven code or logic without dealing with the infrastructure. The user pays when this code is executed, i.e., when a result occurs. When the code is finished executing the server is not used and the billing stops. Examples of FaaS are Oracle Cloud Fn, Google Cloud Functions, Amazon AWS Lambda and Microsoft Azure Functions. [6]

B. Deployment models

Deployment models are more related to the IaaS service model. As mentioned above, there are three main development models, Public Cloud, Private Cloud, Hybrid Cloud, but in recent years the Community Cloud was also created.

Public Cloud is the most widespread Cloud Computing deployment model used by most users. Its resources such as servers and storage are provided and managed by a Cloud provider and then distributed to users over the Internet. Examples of public Cloud are Microsoft Azure and Amazon AWS. Its advantages are low cost, zero maintenance, scalability, flexibility and reliability.

While the public Cloud is about end users, the private Cloud is about the companies, enterprises, or organizations. That is because it offers the necessary privacy for data and the applications that use it. The private cloud is placed in the company's data center or can be hosted by a Cloud Computing provider who will be responsible for managing and maintaining its infrastructure. However, the services and infrastructure are always maintained by a private network while the hardware and software used are developed according to the enterprise requirements. This means that the enterprise has complete control over its applications without depending on global data centers. The advantages of private Cloud are greater flexibility, performance, scalability, and greater control. There are two types of private Clouds, Internal Cloud and Off Premises Private Cloud: [5]

- *Internal Cloud:* Internal Cloud is constructed using a data center located in the internal facilities of the enterprise or organization. It provides access to content and data services using a local network or intranet connection and is protected by a firewall.
- *Private Cloud Outside Internal Facilities (Off Premises Private Cloud):* It is used in similar cases to the internal but with the difference that it assigns data management to another Cloud provider. Thus, the organization has exclusive rights to services such as hardware and the three service models, however these are maintained by the Cloud.

A hybrid Cloud platform combines public and private features so that its use has more advantages. Essentially, it is an extension of the public Cloud to meet the demands of the enterprise, in cases where the private cannot. Thanks to this, enterprises can combine the flexibility and innovation of the public Cloud with the security of the private cloud by storing their sensitive data in private data centers. The advantages of the hybrid Cloud are control, flexibility, ease of use and efficiency.

Finally, Community Cloud is a semi-private Cloud development model that is still in an early stage of development. It is used by joint organizations to share data effectively. [6]

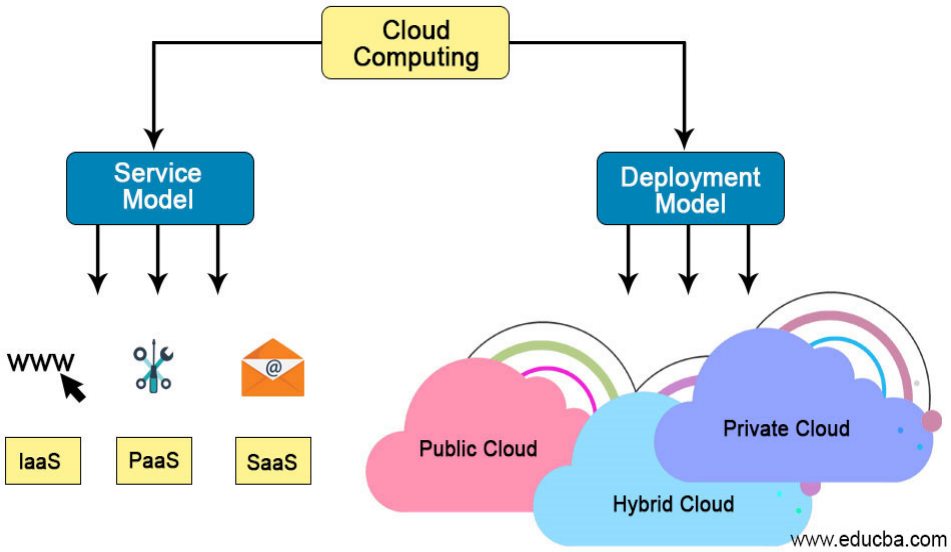

Figure 1.2 Cloud Computing types

1.3 Advantages of using Cloud Computing

Most of the advantages of Cloud Computing have already been mentioned above and are common to both types. Its main advantages are cost, scalability, and security.

- **Cost.** With Cloud Computing, users pay only for the services they use (pay as you go). This means maintenance costs are reduced since the user does not need to purchase Cloud infrastructure.
- **Scalability.** By the term scalability we mean the immediate upgrade of the applications to serve the needs of the user. For example, when an enterprise creates an application, it initially adds basic features and as the demand for that application grows, it upgrades it, that is, expands its features to meet its needs.

- **Security.** Cloud Computing platforms provide high security using firewalls, data encryption, access control, key management and security information.
- **Mobility.** The user can access the Cloud services at any time through different devices such as mobile phones or laptops.
- **Adaptability.** The Cloud environment is flexible, so its infrastructure and applications can be customized based on user preferences.
- **Virtual configuration.** The user can access any service through any device and create their applications easily and quickly, because the services come from the Cloud and not from some visible entity. This means that they are always available since they are hosted and managed by an online platform. Thus, it can complete tasks that could not be completed with a simple computer and share them securely with other users. [7]

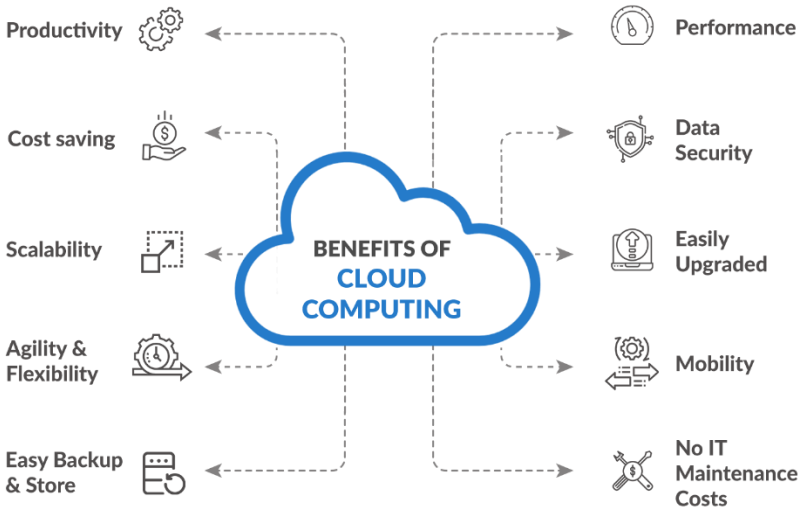

Figure 1.4 Advantages of Cloud Computing

1.4 Support of Cloud Computing by enterprises

The use of Cloud Computing has many advantages in terms of cost as it arises depending on the use of services, flexibility as it adapts to the user's hardware and software needs and security. However, it may not offer the ideal working environment for all enterprises. For this reason, there are certain criteria that show a enterprise whether it can support the use of Cloud Computing and whether it will benefit from its use. These are: [8]

- **Data Sensitivity.** It is one of the most important criteria for a enterprise whether it uses the Cloud or not. Data are classified into four categories: Sensitive such as security service data, Highly Sensitive such as banking or financial, Sensitive such as hospital database and non-Sensitive such as that resulting from videos, images, games, news, or articles. Protecting and hiding data from any type of attack is a matter of major importance that an enterprise should be concerned with to take appropriate protection measures.
- **Type of applications.** Not all applications can work efficiently in the Cloud Computing environment due to their requirements or specifications. Some applications such as Customer Relationship Management (CRM) and Supply Chain Management (SCM) cannot support the Cloud environment because they have increased demands on resources, platforms, and security.
- **Utilization of resources.** When the server resources are not properly utilized then we are led to waste, so it would be preferable to use the Cloud since the server resources are managed automatically. Conversely, if a company is successfully managing its resources there is no need to migrate to the Cloud environment.
- **IT infrastructure.** As mentioned above, the Cloud Computing environment is scalable, that is, upgrades to services increase according to customer demand. This also applies to billing. The more professional the environment, the higher the charge per hour of use. In the long run the use of Cloud Computing is more profitable because it is the cheapest and most beneficial solution. But enterprises need to consider many factors before they can determine the cost of a Cloud platform's resources, such as the size of the data center, annual revenue, number of employees it employs, and number of countries it operates in. If the use of a Cloud Computing platform is more expensive in relation to the operating costs of an enterprise, then it is obviously not the right solution.

Chapter 2. Research

Below is the largest and most important chapter of this dissertation that refers to the Cloud platforms of Amazon and Microsoft, two large, global technology companies. These two companies are considered "giants" of Cloud Computing thanks to their popularity resulting from the sophisticated services they offer, which satisfy all the requirements of their customers. For this reason, some of the biggest companies in the world, tech, and non-tech, are customers and use their services such as Samsung, Disney, The Washington Post, NBA, Bosch, PepsiCo. The service models offered by these two companies are mainly PaaS and IaaS. Next is the overview of Amazon Web Services, the reference to Amazon Elastic Compute Cloud, and finally the reference to Microsoft Azure.

2.1 Overview of Amazon Web Services

In 2006, the technology company Amazon launched its own Cloud Computing platform, Amazon Web Services, or AWS, and since then it has been considered one of the leading companies in Cloud Computing. AWS is a comprehensive Cloud platform that offers web services that extend into the IT Infrastructure, such as routers, storage, databases, load balancing, content distribution, and distributed computing. Thanks to its low cost, flexibility, and reliability it is considered an ideal choice for all types of enterprises. [10] AWS resources are hosted in multiple global locations, which consist of AWS Regions, Availability Zones, and Local Zones. Local zones store resources such as computing power and storage that are close to customers. [9] The AWS architecture consists of four components: Amazon Elastic Compute Cloud (EC2), Amazon Simple Storage Service (S3), Amazon SimpleDB, and Amazon Simple Queue Service (SQS). Amazon Simple Storage Service (S3) and Amazon SimpleDB are about data storage while Simple Queue Service (SQS) is a messaging channel of Cloud components.

To be able to use the services offered by AWS, the user must create an account in the AWS Portal or download the AWS CLI for Windows, Linux or macOS. There is also a fourth version, Amazon Linux, which is not downloaded by the user but is already installed on the Amazon Linux AMI. The AWS CLI offers the user the ability to manage many services from the command line and automate them through scripts. Many developers use them both together to develop their applications faster, more efficiently and more flexibly. As mentioned above, Amazon and Microsoft are the dominant companies in Cloud Computing preferred by many multinational companies and enterprises. Because both are leaders in the services they offer and are used by many developers, AWS enables Microsoft's .NET users to be able to share their applications with the Amazon Cloud. That is, a developer who uses the Amazon AWS platform but likes to build .NET applications can download the AWS Toolkit Visual Studio for Windows and use Amazon AWS to build, deploy, and upload his .NET application there. Alternatively, he can build his application in Visual Studio and upload it to the Amazon Cloud.

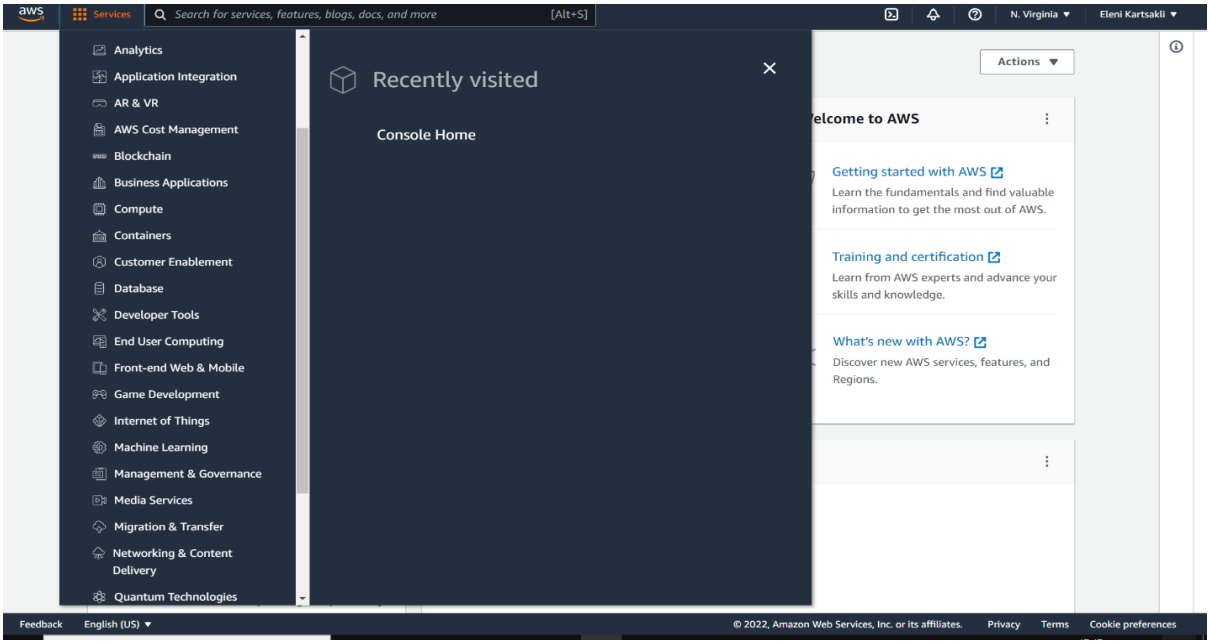

Figure 2.1.a Amazon AWS Portal

If the user prefers an application development environment that belongs exclusively to AWS, he can use AWS Cloud9, which is an integrated development environment based on the Cloud (cloud-based Integrated Development Environment – IDE). With Cloud9 the user can write, debug and run his code using only one browser. The installation package includes several programming languages such as JavaScript, Python, PHP, a code editor, debugger and terminal without the user having to download files or make other settings to build their application. Because it is a Cloud-based development environment, the user can build their application anywhere if they have an Internet connection. It can also develop serverless applications and share them with other users in real time. For example, multiple programmers can write a program and see each other's code. [38] Amazon offers another way for the user to monitor their applications, the AWS Console Mobile Application for Android and Apple. He simply downloads the application, logs into his account and can use his mobile phone to access and control certain Cloud applications, at any time, without a computer.

To organize and manage both the user's account and applications, Amazon created AWS Organizations which helps them manage their development environment while scaling their resources. With AWS Organizations the user can create new AWS accounts and allocate to them resources, groups or organize their tasks, using only one payment method for all accounts. [11] Also resource organization groups known as resource groups.

Amazon AWS is a flexible and reliable platform that meets all user needs by offering several Cloud services such as compute services, databases, security, network services, developer tools, Internet of Things (IoT) and others. Below are analyzed the first four services which are the most basic and are referred to the comparison with Microsoft Azure. [10]

Figure 2.1.b AWS

A. Compute Services

Amazon Lightsail. It is the easiest way a user can launch and manage a private, virtual server. A Lightsail plan includes a Virtual Machine, SSD storage, data transfer, DNS management and a static IP address.

AWS Batch. It dynamically allocates the maximum amount and type of compute resources based on the volume and resource requirements of batch jobs, so that the user can run multiple batch jobs on AWS without having to install or manage batch software or server clusters.

AWS Elastic Beanstalk. It is a service for deploying and scaling web applications and services developed with Java, .NET, PHP, Node.js, Python, Ruby, Go and Docker running on servers such as Apache, Nginx, Passenger and Internet Information Services (IIS). The user uploads their code and AWS Elastic Beanstalk manages the application. That is, it is used to create temporary or long-term application environments.

AWS Fargate. It is a compute engine for Amazon ECS that allows the user to run containers without managing servers or clusters. The user only focuses on designing and developing applications without worrying about the infrastructure that supports them. The Fargate Launch Type has two modes of operation in which the user containers their application, specifies CPU and memory requirements, specifies network and IAM policies, and launches the application. EC2 launch type allows the user to have server-level control over the infrastructure running the container applications.

AWS Lambda. It allows users to run their code without providing or managing the servers.

Amazon Elastic Container Service (Amazon ECS). It is a highly scalable, high performance container service that supports Docker containers and allows the user to easily run and scale their applications.

Amazon Elastic Kubernetes Service (Amazon EKS). It provides ease of development, management and scaling of applications with containers.

B. Database Services

Amazon Aurora. It is a relational database engine, compatible with MySQL and PostgreSQL databases, which integrates the speed and availability of high-end commercial databases with the coherence, effectiveness, and low cost of open-source databases.

Amazon DynamoDB. It is a key-value, document, fully managed database that can support multiple operating areas, with built-in security, backup storage, restore and memory caching for web applications. It is used by many enterprises like Samsung, Toyota, Airbnb to develop mobile, web, gaming, IoT and other applications.

Amazon ElastiCache. It is a web service for simple deployment, operation and scaling of memory caches in the Cloud. It improves the performance of web applications by allowing the users to recover information from fast and managed memory caches without having to depend on slow database disks. It has two open-source memory cache engines, Redis which is a fast, open-source, in-memory key value data store used as a database, cache, message broker and queue and Memcached which is a memory object caching system.

Amazon MemoryDB for Redis. It is a durable in-memory database, compatible with ElastiCache' s Redis, which has very fast performance. It is used in modern applications with microservices architectures.

Amazon Relational Database Service (Amazon RDS). It provides ease of organization, operation and scaling of a relational database in the Cloud so that the user can create highly available, secure and compatible applications. It can work with many databases such as Amazon Aurora, PostgreSQL, MySQL, MariaDB, Oracle Database, SQL Server and the AWS Database Migration Service to migrate existing databases to Amazon RDS.

AWS Database Migration Service. It is used to migrate databases fast and with security.

Amazon DocumentDB (MongoDB compatible). It is a fast, scalable, highly available and fully manageable document database that supports MongoDB.

C. Security Services

Amazon Cloud Directory. It allows the user to create flexible Cloud directories to organize data hierarchies. For example, it can create an organizational chart that lists hierarchies such as structure, location, and cost.

Amazon GuardDuty. It is a service that detects threats or attacks on an AWS account or jobs. It is efficient, cost-effective and easy to use without requiring software or infrastructure development or maintenance.

AWS CloudHSM. It is a cloud-based hardware security module that allows the user to generate their own encryption keys on the AWS Cloud. It's also a fully managed service that allows quick scaling with no upfront costs.

AWS Identity and Access Manager (IAM). It allows the administrator to securely control user access to AWS services and resources, using IAM in the following ways: To manage IAM users and their access, to manage their IAM roles and permissions, to external users and their licenses.

AWS Secrets Manager. It helps the user protect secrets that give access to their applications, services and resources or manage and retrieve database credentials and API keys and grant access to secrets with special permissions. It is like AWS Key Management Service.

AWS Shield. It is a Distributed Denial of Service (DDoS) protection service for AWS web applications. It offers two levels of security, Standard which is provided automatically and for free and for maximum security can be combined with Amazon CloudFront as well as Amazon Route 53 and Advanced which is used for Amazon EC2, ELB, Amazon CloudFront and Amazon Route 53 applications. AWS Shield Advanced offers increased security can also be combined with Amazon WAF but is only available in regions where Amazon CloudFront and Amazon Route 53 are available.

AWS Web Application Firewall (WAF). It is a firewall that protects web applications from threats that could affect availability, security, or consume additional resources. The user can choose which traffic to allow or block in their application by adding their own security rules.

D. Network Services

Amazon CloudFront. It is a fast content delivery network (CDN) service, which delivers data, videos, applications and APIs with security, low latency and high delivery speeds. It can be combined with AWS Shield for DDoS, Amazon S3, Elastic Load Balancer, Amazon EC2, for applications and Lambda@Edge so that the user can run code close to customers and customize their experience accordingly.

Amazon Route 53. It is a Domain Name System (DNS) web service with highly availability and scalability. It provides developers and enterprises with a reliable, efficient, and cost-effective way for users to translate network addresses to IP addresses for computers to connect to each other. For example, www.example.com translates to 192.0.2.1. It is also IPv6 compatible and can be used outside of AWS.

Amazon Virtual Private Cloud (Amazon VPC). It enables users to launch AWS resources in a self-defined virtual network, giving them full control over the virtual network environment. Users can choose their own IP address range, subnets, route tables and network gateways and use two types of IP addresses IPv4 and IPv6 for greater security and easy access to resources and applications.

AWS Direct Connect. It is a service that allows the establishment of a network connection from the enterprises' premises to AWS. Thus, you create a private connection between AWS and the data center, office or other locations of your enterprise while reducing network costs, increasing bandwidth and making the connection consistent.

AWS PrivateLink. It is designed to make the security of data shared with Cloud-based applications uncomplicated by stopping the exposure of data to the public Internet.

AWS Virtual Private Network (AWS VPN). It creates secure connections between on-premises networks, remote offices, customer devices, and the AWS global network. It provides two services: AWS Site-to-Site VPN and AWS Client VPN. Both offer highly available, manageable and resilient Cloud VPN solutions to protect network traffic.

Elastic Load Balancing (ELB). It automatically distributes incoming application traffic to multiple targets such as Amazon EC2 instances, containers, and IP addresses. It offers four types of load balancers with common characteristics: high availability, auto scaling and continuous security so that applications are not prone to failure. The types are as follows:

- Application Load Balancer for HTTP and HTTPS traffic.
- Network Load Balancer for TCP traffic.
- Gateway Load Balancer for deploying, scaling and launching third-party virtual network appliances.
- Classic Load Balancer for multiple Amazon EC2 Virtual Machines. Used for applications built within the EC2-Classic network.

Figure 2.1.c AWS Services

2.2 Amazon Elastic Compute Cloud

Amazon Elastic Compute Cloud (Amazon EC2) provides the user with the scalable computing capacity of Amazon Web Services (AWS), so that he can develop and deploy applications quickly without having to deal with the hardware that supports them. He can also create as many virtual servers as he needs, configure security and networking, and manage storage. [12] It is the equivalent of Microsoft Azure Virtual Machines. AWS provides the user with full control over computing resources, enabling them to run their applications in the Amazon environment. It is designed to make web application design easier for developers by giving them the tools to build fault tolerant applications. The architecture of Amazon EC2 includes features which are analyzed below and are as follows: [13]

- Virtual computing environments, known as instances.
- Predefined templates for the instances, known as Amazon Machine Images (AMIs).
- Several configurations for CPU, memory, storage, networking of instances, known as instance types.
- Secure login information for instances with key pairs.
- Storage volumes for temporary data that are deleted when the user stops, hibernates, or terminates an instance, known as instance store volume.
- Persistent data storage volumes, known as Amazon Elastic Block Store (EBS) volumes.
- Multiple physical locations for resources known as regions and availability zones.
- A firewall to define protocols, ports and IP address for instances using security groups.
- Static IPv4 addresses for dynamic Cloud Computing use known as Elastic IP addresses.
- Metadata for the instances, known as tags.
- Virtual networks that are isolated from the rest of the AWS Cloud and can be connected to the network that the user has created, known as virtual private clouds (VPCs).

I. Instances and AMIs

An Amazon Machine Image (AMI) is a template that contains software configuration for the operating system, the application server, and the applications. From an AMI start instances, which are copies of the AMI running as virtual servers in the Cloud. Virtual Machines in Amazon AWS are also called instances. Amazon publishes several AMIs containing common software configurations for public use, but users can create their own. By creating custom AMIs the user can quickly and easily launch new instances that have everything they need. For example, if the application is a web page or web service the AMI could include a server, and the

code needed by a dynamic page. To start the application the user should launch an instance from the AMI so that the server can start.[12]

There are instances that serve all three operating systems (Windows, Linux and macOS). This dissertation analyzes instances for Windows. Instances are divided into several types. An instance type defines the infrastructure used for that instance. Some instance types are intended for general use, while others support optimizations for specific uses, such as high-performance computing processors, enhanced memory for processing large data sets, and fast storage input or output. An AMI can launch multiple types of instances. When an instance is started, its type determines the host hardware used in the instance. Each type offers different compute, memory, and storage capabilities and is grouped into an instance family based on these. [12] Some types of presentations are: [14]

General Purpose	**Computing Optimization**	**Memory Optimization**	**Accelerating Computing**	**Storage Optimization**
It provides a balance of compute, memory and networking resources and is used for different workloads. Ideal for applications with web servers.	It is ideal for PC-connected applications that benefit from high-performance processors.	They are designed to provide fast performance for workloads that process large data sets in memory.	They use hardware accelerators or processors to perform operations and thus run more efficiently than a software running on a CPU.	Designed for workloads that require high, sequential read and write access to very large data sets on local storage.
Use Cases				
Develop, build, test, and sign iOS, iPadOS, macOS, WatchOS, tvOS, and apps in the Xcode IDE.	High Performance Computing (HPC), Scientific Modelling, Game creation.	In-memory applications such as open-source databases, in-memory caches, and real-time big data analytics.	Machine learning, high performance computing, seismic analysis, speech recognition, autonomous vehicles and drug discovery.	High computing performance and network speed, fast access to medium-sized datasets on local storage.

Table 2.2 Instance types

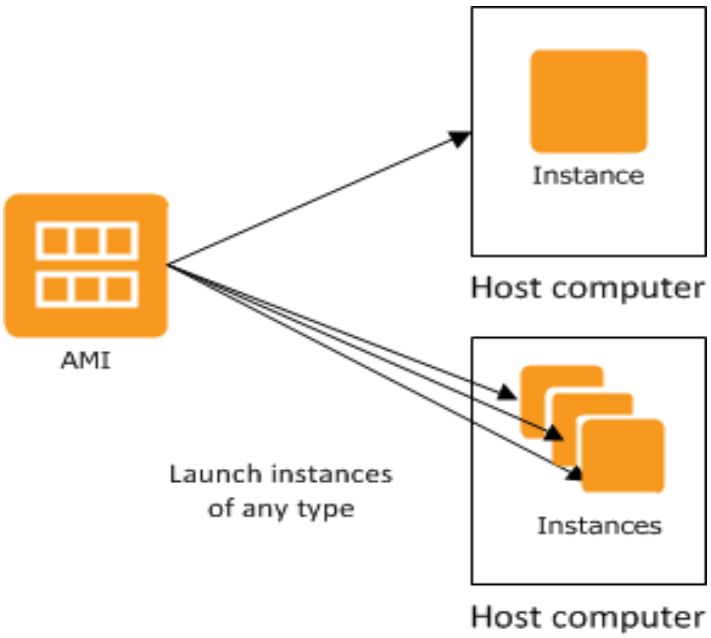

Figure 2.2.a AMI – Instance architecture

II. Security

A. Key pair

A key pair includes a public and a private key and is a set of security credentials used to prove a user's identity when connecting to an Amazon EC2 instance. Amazon EC2 stores the public key on the instance and the user saves the private key. Anyone with the private key can access the instances. Amazon EC2 does not keep a copy of the private key, so there is no way to recover it if it is lost. Nevertheless, there is a way to connect to the instances. Private Keys can be generated either on Amazon EC2 or by a third party and promoted to Amazon EC2. [12]

B. Security groups for Windows instances

A security group behaves as a virtual firewall for EC2 instances to control incoming and outgoing traffic with inbound and outbound rules. Inbound rules control incoming traffic to the instance, and outbound rules control outgoing traffic from the instance. An instance can have one or more security groups. If one is not specified, Amazon EC2 uses the default one. The user can add rules to each security group that allow traffic to or from its associated instances or modify

them at any time. The new and modified rules will be automatically applied to all instances associated with the security group. Security groups are offered by AWS as one of the tools for making instances safer, however the user must configure them to meet their security needs. If the security requirements of the user are not fully met by them, he can keep his own firewall on any of his instances while using the security groups. [12]

III. Storage

Amazon EC2 offers three ways to store data: Amazon Elastic Block Store (EBS), Amazon EC2 Instance Store, and Amazon S3. These three types combine performance and durability and offer a versatile, cost-effective, and simple way to store data. The user can choose one of these three solutions or make a combination. [17]

A. Amazon EBS

Amazon EBS provides persistent block-level store volumes that the user can attach to a running instance. It can be used as a primary storage device for data that requires frequent and detailed updates such as when running a database in an instance. An EBS volume can be attached to a single instance and is preserved even if the instance is deleted. When connected, it is used like any other physical hard drive. The user can attach multiple volumes to an instance or detach an EBS volume from one instance and attach it to another. It can also dynamically change the configuration of a volume attached to an instance. EBS volumes can be encrypted using the encryption feature provided by Amazon EBS. Also, the user can keep a backup copy of their data by creating a snapshot of an EBS volume, which is stored in Amazon S3, or they can create an EBS volume from a snapshot and attach it to another instance. [12] Figure 2.2.b shows how Amazon EBS works. Two instances (Instance A, Instance B) of the host computer are connected to Amazon EBS storage volumes and then one of these volumes is connected to Amazon S3 to store backup copies (snapshots) of the volume.

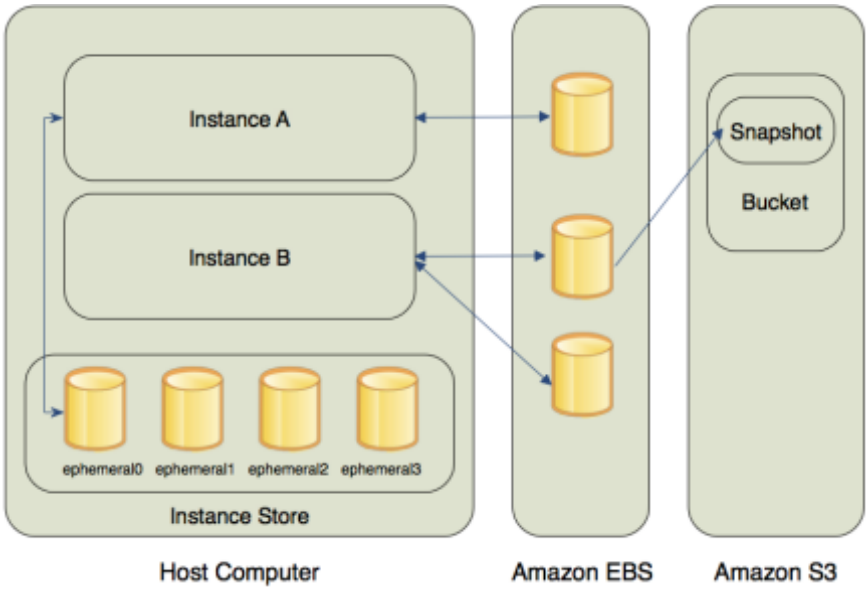

Figure 2.2.b Amazon EBS example

Amazon EBS has very important advantages that the other storage methods do not have, which the user should consider when choosing the appropriate storage method. The advantages are as follows: [12]

- Data availability
- Data persistence
- Data encryption
- Data Security
- Screenshots
- Flexibility

B. Amazon EC2 Instance Store

An instance store provides a block-level temporary storage for instances. This storage is on the disks that are physically connected to the host computer. It is ideal for temporary storage of information that changes regularly, such as buffers, caches or for data that is reproduced in many instances. An instance store includes one or more instance store volumes and their size, and the number of available devices varies depending on the instance type. An instance store volume is called an ephemeral, or virtual device, and is numbered from 0 to 23. Instance types that support one instance store volume have ephemeral0, those that support two volumes by ephemeral1, and so on. [12] For example, the figure below shows two host computers, Host Computer 1 and Host Computer 2. Host Computer 1 has two instances connected, Instance A and Instance B, while Host Computer 2 has Instance C. Also Host Computer 1 there is an Instance store with four

ephemerals. The first instance store volume is ephemeral0 which means that this instance type can support one instance store volume while the fourth is ephemeral3 which means the instance type can support four volumes. The same goes for Host Computer 2 with its own Instance store.

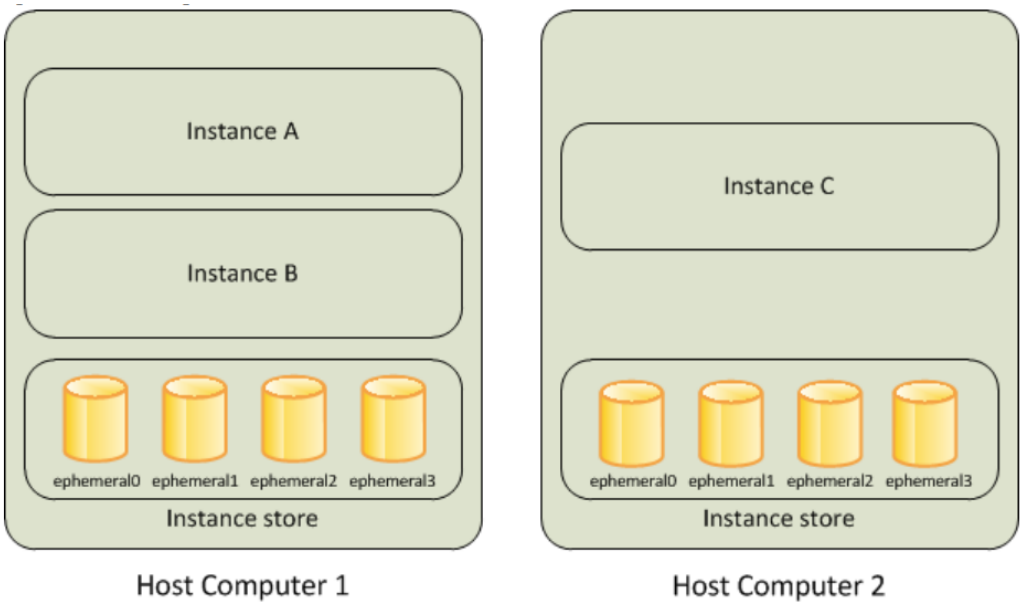

Figure 2.2.c Instance store architecture

The user can specify the instance store volumes only when starting that instance. He cannot detach an instance store volume and attach it to another instance, unlike Amazon EBS. Also, the data are available while the instance is available meaning that if the instance is lost for some reason such as disk failure, shutdown, hibernation or termination then the data are also lost. Also, if the user creates an AMI from an instance, the data on the instance store volume is not preserved and is not visible to the instance started from the AMI. For this reason, Amazon EC2 Instance Store is not recommended for storing important, long-term data. [12]

C. Amazon S3

Amazon S3 is an internet data repository that provides access to reliable and inexpensive data storage infrastructure. It is designed to facilitate web-scale computing by allowing the user to store and retrieve any amount of data, anytime, from Amazon EC2 or the web. For example, the user can use it to store backups, data, applications, snapshots or instances. Amazon EC2 uses Amazon S3 to store AMIs or to store snapshots which are backup copies of data volumes. The user can use snapshots as a basis to create numerous, new data volumes, expand the size of an

existing data volume, or move them across multiple Availability Zones making data usage scalable. It can be used together with Amazon EBS, as shown in Figure 2.2.d. [12]

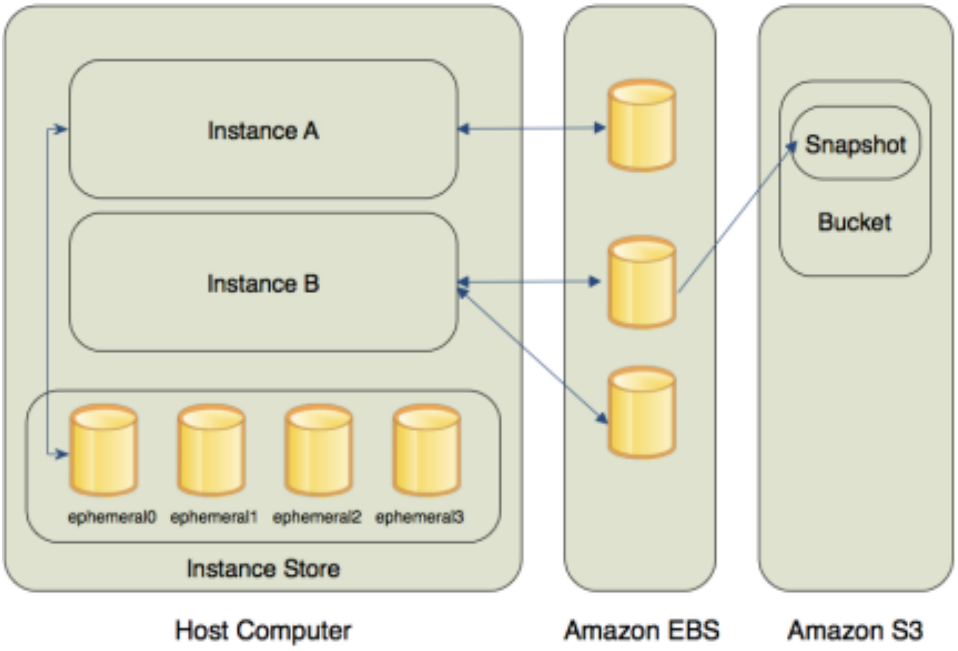

Figure 2.2.d Combination of Amazon EBS and Amazon S3

2.3 Microsoft Azure

Azure is a comprehensive Cloud Computing platform that can host existing applications, optimize the development of new, and enhance the existing applications of an enterprise. It integrates Cloud services with which the user can develop, test, manage and scale their applications while taking advantage of the efficiency of Cloud Computing. Thanks to its reliability it can offer applications that would otherwise not be available due to the different development areas. The Azure portal allows the user to easily manage all Microsoft Azure services. He can also manage its services programmatically using service-specific APIs and templates. Below are the four main categories of services Azure offers: [15]

- **Compute Services.** It includes Azure Virtual Machines for Linux or Windows and App Services such as Web Apps, Mobile Apps, Logic Apps, API Apps and Function Apps, Batch (for large-scale parallel and massive computing tasks), RemoteApp, Service Fabric and the Azure Container Service.
- **Data Services.** It includes storage and database services. Storage includes Microsoft Azure Storage consisting of Blob, Queue, Table and Files services, while databases include Azure SQL Database, Azure MySQL, Azure PostgreSQL, Azure MariaDB, Azure Cosmos DB and Azure Cache for Redis.
- **Application Services.** It includes applications that the user can use to develop and operate their applications like Azure Active Directory (Azure AD), Service Bus for connecting distributed systems, HDInsight for big data processing, Azure Scheduler and Azure Media Services.
- **Network Services.** It includes Azure features like Virtual Networks, ExpressRoute, Azure DNS, Azure Traffic Manager, and the Azure Content Delivery Network.

To use the Azure services the user can either create an account in the Azure Portal or download the Azure CLI for Windows, Linux and macOS. Most developers use both to create and deploy applications. The difference between them is that the Azure Portal presents all the services offered by Azure, while the Azure CLI is faster, more efficient and works with commands, with the result that the user can do with a single command the same things he would have done with Azure Portal, but by following many steps. In addition, the Azure CLI gives the option to save the commands to a file to be used in other applications by different developers. [16] The creation and development of applications can be done in a development environment such as Visual Studio or in a code editor such as Visual Studio Code. In both cases, the user can connect to their Azure account and very quickly upload their applications to the Cloud. The Visual Studio Installer offers specific deployment packages for Microsoft Azure that the user can download to customize Visual Studio in this environment. When users want to control their applications, anywhere and anytime without access to a computer they can use the Microsoft Azure App for Android and Apple.

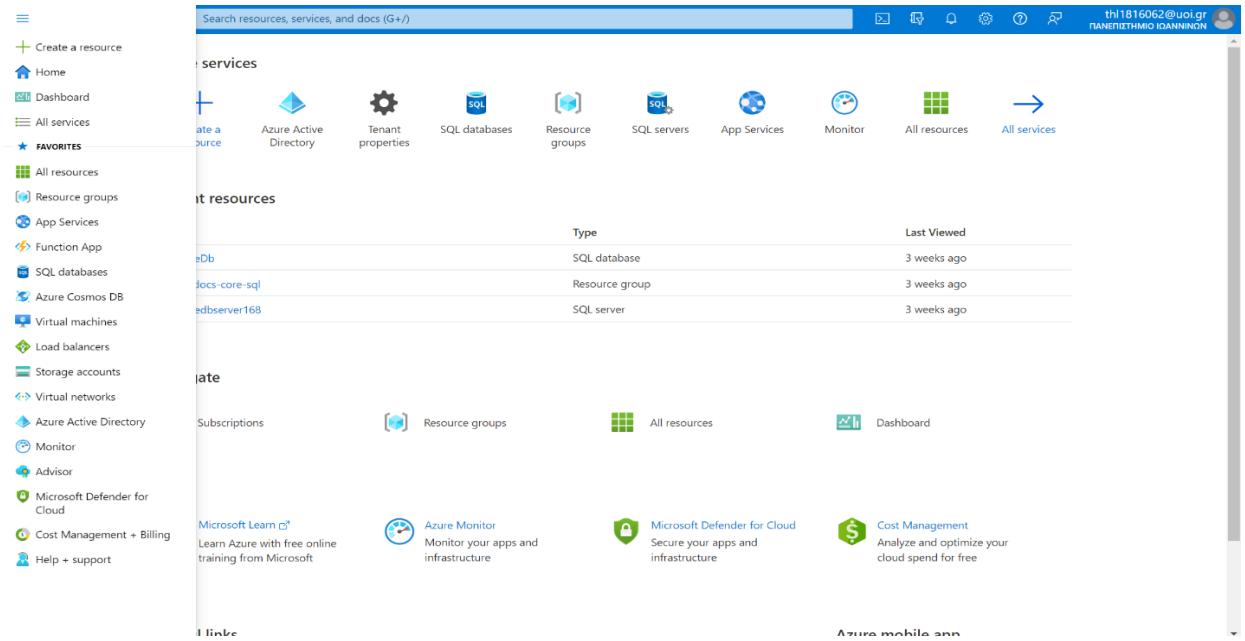

Figure 2.3.a Azure Portal

Azure introduces a new methodology for resource development in order to more efficiently develop and manage services, the Resource Manager. Resource Manager is the replacement for Azure Service Management (ASM) a deployment model that was used to deploy services. In 2014 Microsoft introduced the IaaS standard in Resource Manager and since then it has continuously enhanced its capabilities as it now has full IaaS capabilities resulting in the management of IaaS virtual devices through ASM being deprecated as of February 2020. This has led to the phasing out of this operation which will be completed on March 1, 2023. Therefore, Microsoft invites all users of IaaS resources to migrate their services to Resource Manager which is a new and more efficient solution and is recommended for all new Azure workloads. The Resource Manager is used to organize resources that are related to each other by placing them in the same resource group. For example, if a user has two Virtual Machines (VMI, VM2) running a web application with the same database and the same virtual network then the resource group will contain: [15]

- VM1
- VM2
- Virtual Network
- Storage Account
- Azure SQL Database

Resource Manager has various advantages since thanks to it resource deployment can be faster and parallel instead of sequential as it was with ASM. Now each service can have its own service provider that can be upgraded whenever needed independent of other services. However, the advantages are not only these but also include three other important categories: templates,

security and billing. In template deployment the user can create a JSON template to deploy all the resources of a solution instead of multiple Virtual Machines. He can also use the template to rebuild the same resources repeatedly or give new values to fields such as Virtual Machine or network names and reload it using different parameters. It can also detect dependencies in a template and allow the user to specify additional dependencies if necessary. In security, the user can use the Role-Based Access Control (RBAC) feature to control access to the resources that a group has, while in billing, it organizes all the resources of a subscription, assigning tags to each resource so that the user can retrieve all the billing information for each resource. [15]

The Role-Based Access Control (RBAC) feature is used for the security management of Resource Manager resources. In addition to the Resource Manager development model that allows the user to group and manage related resources, Microsoft introduced RBAC, extending the rights that third parties have to the resources of resource groups. With Resource Manager, the user can deploy resources to a specific resource group and grant permissions to other users, groups, or service principals without being able to make changes to resources of another resource group or can grant permission to manage a single Virtual Machine. With RBAC the user can grant more rights to a user, group or service principal by giving them a role. Role assignment consists of three components: the security authority that represents a user, group, service principal, or managed entity (number 1 in Figure 2.3.b), the role definition that includes what is allowed to be done to the resources such as read, write, delete (number 2) and the scope that includes the resources to which access is allowed (number 3). Each role has a list of Actions i.e., what it is allowed to do and Not Actions what it is not allowed to do. The most common roles are Owner, Reader, SQL DB Contributor, SQL Security Manager, Storage Account Contributor, and Virtual Machine Contributor. If the previous roles do not meet the user's needs, he can create default roles and assign them to another user, group, resource group, application for a subscription or resource. Default roles are stored in Azure Active Directory and can be shared across subscriptions with the same Active Directory. [17] The diagram below is an example of role assignment. The Marketing group is assigned the Contributor role for the resource group pharma-sales along with the Actions that define that it will be able to delete, create, upgrade any resource belonging to the specific resource group and the Not Actions that define that it will not have access to other resources than the pharma-sales resource group.

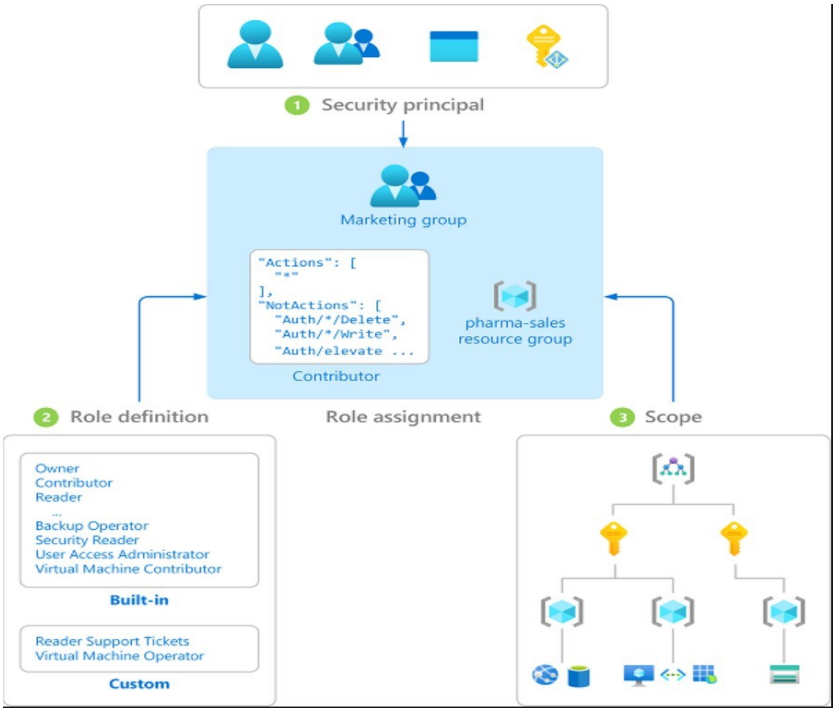

Figure 2.3.b RBAC example

Azure is a global Cloud Computing platform that is available in many regions around the world. When the user starts a service, application, or Virtual Machine, they are prompted to select a region. This area represents a specific datacenter where the application runs or where user data is stored. These regions correspond to special locations, which are published on the Azure regions page. One of the advantages of using Azure is that the user can deploy applications in various data centers around the world. But the region he chooses can affect his application's performance. For this, it is better to choose an area that is closer to most clients so that the delay in network requests is reduced. Two best practices are to store data in the same datacenter or as close as possible to the application datacenter, and to store enterprise-critical applications in more than one datacenter. The last practice is called multi-region. It reduces network latency, increases flexibility in upgrades, and better manages data loss that can result from network failures or natural disasters. [18]

Figure 2.3.c Microsoft Azure

2.4 Analysis of Microsoft Azure platform services

A. Compute Services

Microsoft Azure offers two Cloud service models and Serverless hosting, i.e., hosting in the Cloud without a server. The first is the IaaS model in which the customer has full control over hosting their applications. Examples of applications that work with this model are Virtual Machines and Virtual Networks. The second model is PaaS, in which the infrastructure is managed by the Azure platform and not by the user. Examples of applications that support this layer are Service Fabrik and App Service. Finally, there is Serverless hosting where the user only writes the code of his application (Code-only). Functions are such an example. [19]

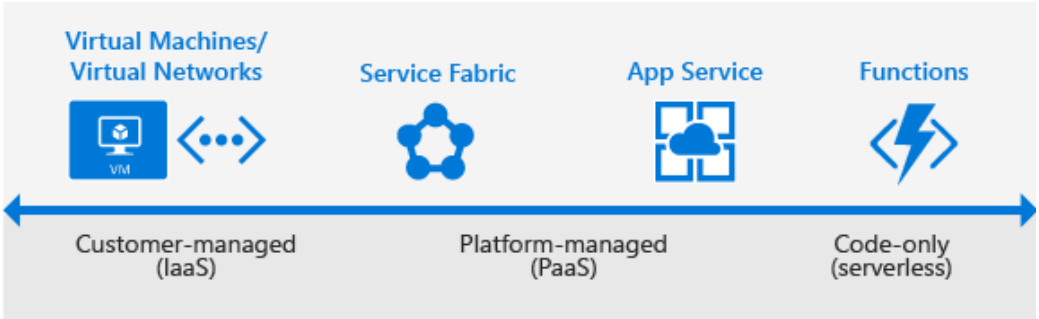

Figure 2.4.a The three ways of hosting applications with the corresponding services

For developers, Microsoft Azure offers yet another service model, Infrastructure as Code (IaC) which is the management of the infrastructure (networks, Virtual Machines, load balancers and connection topology) in a descriptive model creating the same environment every time it is implemented according to the principle that same source code makes the same binary. That is, the same infrastructure version is used as a DevOps team uses the same source code every time. IaC is a core DevOps practice with significant advantages such as: [20]

- Reduction of human error during infrastructure development and management.
- Deploy the same template multiple times to create identical development, control, and production environments.
- Reducing the cost of control and development environments since with IaC they are created automatically.

Azure offers support for the IaC model through Resource Manager. The user defines the standards that define the infrastructure needed to deploy their solutions. But he can also choose other platforms like Terraform, Ansible, Chef, Pulumi to manage automated infrastructures. [20]

I. App Services and Web Applications

An App Service is a service that is used to host one of five types of applications which are Web Apps, Mobile Apps, Logic Apps, API Apps and Function Apps. It is the easiest and fastest way to develop web applications. Each application runs in its own service and has the same name as the application service it runs on. It also has some features such as capacity and resource sharing for one or more applications belonging to the same application service. These features are defined by the App Service plan. With the App Service plan the user can manage their applications and upgrade or scale them easily by changing their settings without having to develop the application from scratch. [15]

APP SERVICES	
Web Apps	PaaS for creating web applications developed in many programming languages.
Mobile Apps	High scalable and globally available platform for creating mobile applications.
Logic Apps	Cloud Platform for creating and deploying automated workflows that integrate and manage applications, data, services and systems.
API Apps	Cloud Platform for developing REST APIs that are used in accessing backend API services.
Function Apps	Serverless solution for developing applications while focusing only on code and without maintaining or developing the servers.

Table 2.3 Azure App Services

An App Service can host a web application (Web App). When the user develops a Web App, he can share it with his customers in a very short time. Web applications have many features that make development, management and troubleshooting quite easy. For their development several programming languages are supported such as .NET, Java, PHP, Node.js and Python or alternatively applications that can be used as a starting point such as WordPress, Umbraco, Joomla! and Drupal. Web apps also support continuous application development with Team Foundation Server (TFS), GitHub, TeamCity, Jenkins or BitBucket so that every time a change is made a new version of the app is deployed. Also, the user can scale his web app by scaling the App Service plan to which it belongs, or it can be done automatically for him by Azure with the proper configurations. After their development the applications can be published to multiple locations so that they are closer to customers. To check their performance the user can run diagnostics and if there are code errors he can resolve them directly from Microsoft Visual Studio while the application runs in the Cloud. [15]

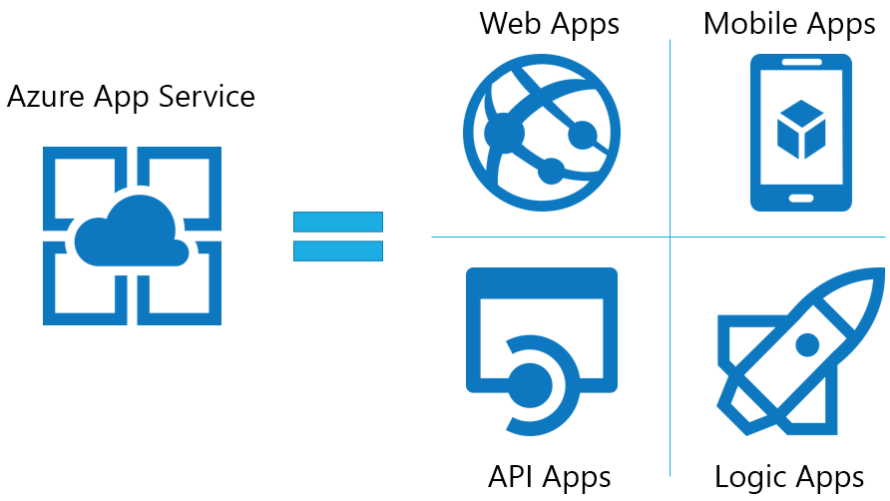

Figure 2.4.b Azure App Service apps

II. Azure Virtual Machines

Azure Virtual Machines is one of the main features of the capabilities of the Azure IaaS service model that supports the deployment of Virtual Machines on Windows or Linux in the Microsoft datacenter. The user has full control over the configuration of the Virtual Machine including software installation, operating system patches, configuration and maintenance. The difference with Web Apps is that it is managed by the Azure platform so that the user only deals with the creation of the application and not with its maintenance. In Virtual Machines, the user does both creation and maintenance. An Azure Virtual Machine supports two types of persistent disks: OS

disks, which are mandatory, and data disks, which are optional. The operating system (Windows or Linux) resides in the OS Disk while application data, media and other things reside in the data disk. Azure Virtual Machines have built-in virtual hard disks (VHDs) that offer persistent storage. There are two types of VHDs: Image which is a template for creating new Virtual Machines without settings such as the name of the Virtual Machine and the administrator and Disk which includes OS disks and data disks. OS disks and data disks belong to durable disks, meaning they offer high availability, duration and various other options. [15]

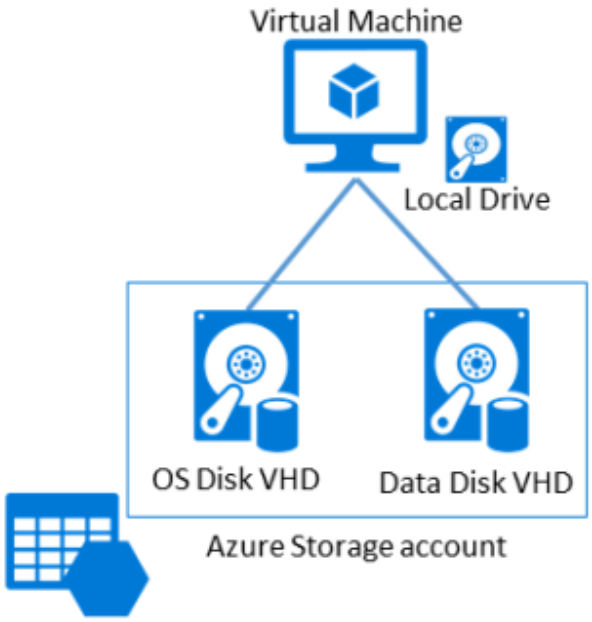

Figure 2.4.c Azure Storage Account

Selecting the Virtual Machine Image is the most important step when creating it. A Virtual Machine Image is a template used to create the Virtual Machine, which will include the operating system, other software such as development tools and web hosting environments, and any application that can be supported by a computer. The user can create the Image of his choice to suit his needs. [21] As can be seen from the figure below, the architecture of a Virtual Machine for windows includes a resource group in which the Virtual Machine will be contained and it is mandatory, an Azure Storage Account and the network to which the Virtual Machine is connected. The Azure Storage Account will contain the OS disks and the data disks that store application data. OS disks along with data are connected to managed disks, which simplify storage disk management by managing the storage instead of the user. Managed disks do not need a Storage Account, but when creating them, the user chooses the size and type of disk that the Virtual Machine will use. The network includes a mandatory virtual network to which the Virtual Machine is connected and may include other subnets, a network interface (NIC) that

allows communication with the virtual network, a public IP address for the user to communicate with the Virtual Machine, and finally a network security group (NSG) that allows or prevents network traffic to the Virtual Machines. [37]

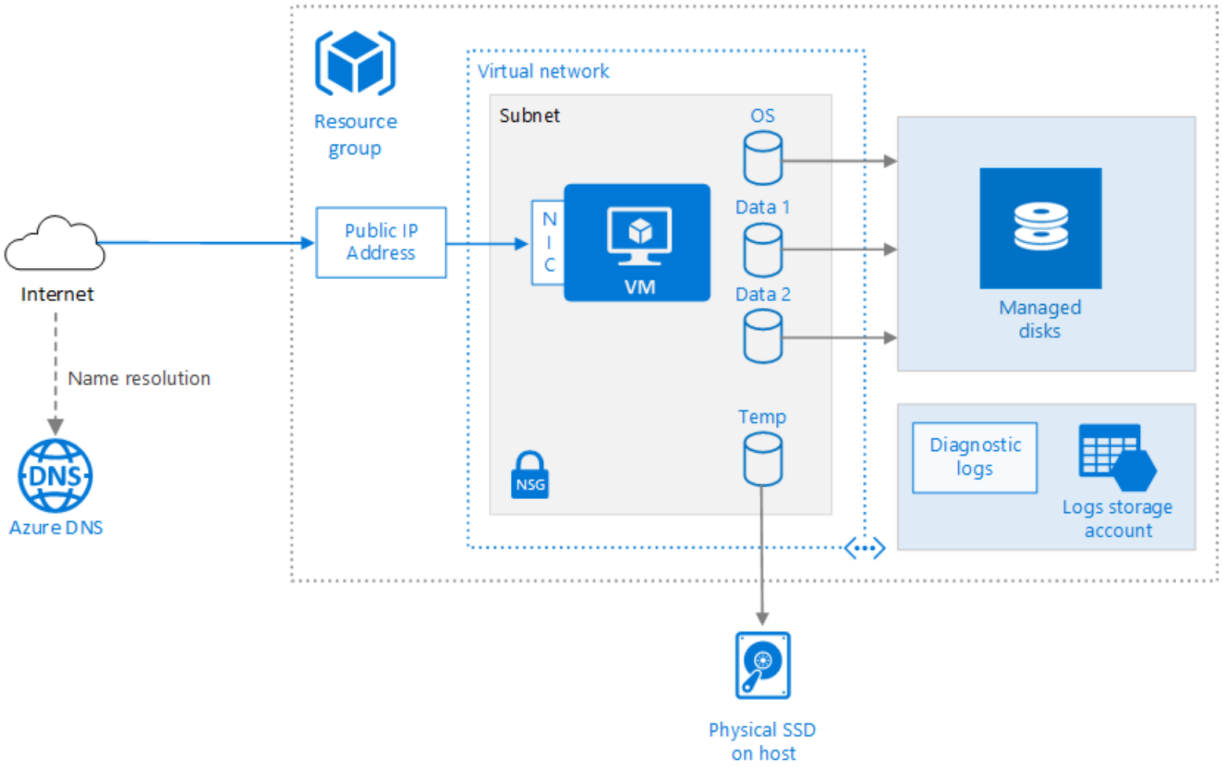

Figure 2.4.d Virtual Machine architecture

The main Compute Services Azure offers are App Services and Virtual Machines however there are more that are just as important including Azure Functions: [15], [22]

- **Azure Functions.** It is a serverless solution that allows the user to write less code, to maintain his infrastructure less so that he has as little cost as possible. For this Azure Functions provides all the upgraded resources needed to run the applications.
- **Azure Service Fabric.** It is a platform that can run anywhere even outside of Azure, which offers the environment for cloud-scale solutions. It offers easy deployment and management of highly scalable, available and reliable services.
- **Azure Batch.** It is a service that creates and manages a pool of compute nodes that are Virtual Machines, installs applications and schedules jobs to run on them without user intervention. It is recommended when the user wants to create highly scalable, efficient applications.
- **Azure Container Service.** Containers are an alternative to Virtual Machines. They are also portable which means the user can deploy them on their computer and then

transfer them to the Cloud, require little storage space and can be started and stopped in seconds. Azure Container service allows user to easily develop and run web applications with Containers.

- **Azure Kubernetes.** It provides ease of creation, configuration and management of a cluster of Virtual Machines configured to run in containers. It also reduces the complexity, operational burden of cluster management while offering maintenance and cluster health monitoring.

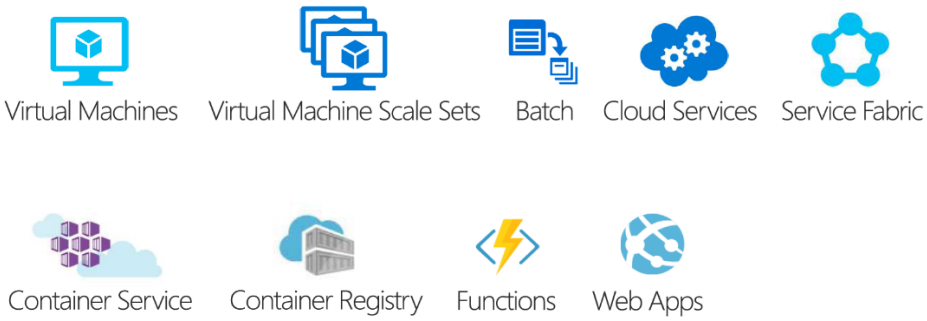

Figure 2.4.e Azure Compute Services

B. Data Services

I. Storage

Microsoft Azure divides storage into two parts: Storage Accounts and Storage Services. Storage Accounts are divided into General-purpose Standard storage account, General-purpose Premium storage account, Blob storage account hot and cool access tiers. All these support specific services and blob types as shown in the table below. [15]

Type of storage account	**General-purpose Standard storage account**	**General-purpose Premium storage account**	**Blob storage account hot and cool access tiers**
Supported services	Blob, File, Table, Queue Services	Blob service	Blob service
Supported blob types	Block blobs, page blobs, append blobs	Page blobs	Block blobs and append blobs

Table 2.3 Storage account types and supported services [15]

As can be seen from the table above, there are two types of General-purpose storage accounts: Standard which is the most common and can be used for all types of data like blob, files, tables and queues, and Premium which provide high storage performance for page blobs, especially VHDs. The General-purpose Premium storage account type uses an SSD disk for data storage and is recommended by Microsoft as the preferred storage for all Virtual Machines. [15]

The Blob storage account is used to store block blobs and attach blobs. The hot access tier is used for files that have high blob storage costs but low blob access costs and are accessed often, while the cool access tier is for files that are rarely accessed and is the opposite of the hot access tier. [15]

Storage services include Blob, File, Table and Queue storage. The word blob is an acronym for binary large object. Blobs are large, unstructured data. This data is files that the user stores on their electronic devices such as images, videos, documents or even Virtual Hard Drive (VHD) files for the Virtual Machines. The Azure blob service enables the user to store data and access it by using URLs and other options. In order to access the blob service, he must create a storage account, then the containers (which work like folders) and place the blobs inside. [15]

File storage allows the user to set up highly available network file shares that are accessed by the Standard Server Message Block (SMB) protocol. With SMB protocol many Virtual Machines can share the same files with read and write access. To view the file the user provides a Shared Access Signature and then uses its URL to access it form anywhere. [15]

Table storage is a scalable NoSQL data store for storing large volumes of semi-structured, non-relational data and it is usually preferred for diagnostic tests. To use table storage, the user must create a storage account, then the table and then fill it with data but he cannot do complex joins, use foreign keys or execute stored procedures. The tables are managed by the storage client library but also support REST APIs to access them with a URL. [15]

Queue storage is a service for storing and retrieving messages according to the FIFO (First-in, first-out) method of queues. [15]

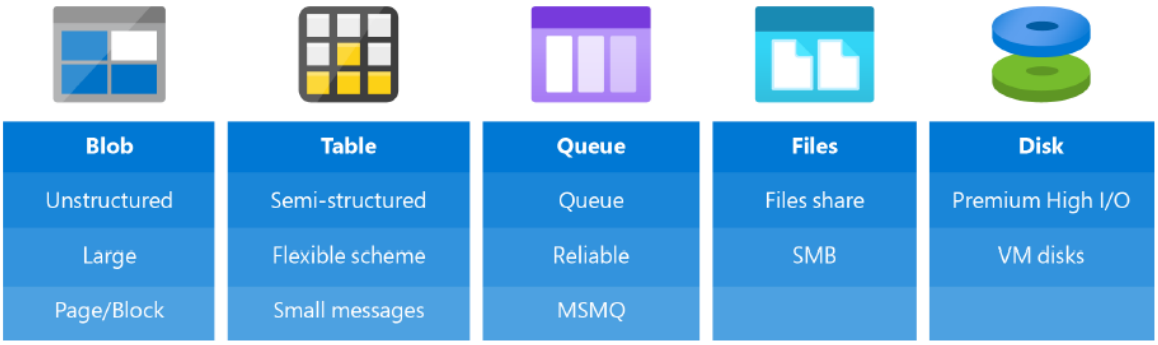

Figure 2.4.f Storage account types

II. Databases

Azure offers another important way to store data with Azure SQL Database which is similar to Microsoft SQL Server. Azure SQL Database stores data the way all relational databases do with tables that have rows and columns. It has many advantages such as elastic scale, predictable performance, almost no maintenance, many tools and supports several programming languages. The user does not have to deal with the management of a database server because SQL Azure is a database as a service. There are two Azure SQL Database models, elastic database pools and single databases. The first model concerns the management of many databases in a pool, while the second concerns the management of fewer. [15]

Figure 2.4.g Azure SQL Database

Along with Azure SQL Database, Microsoft Azure offers other relational database storage solutions such as Azure Database for MySQL, Azure Database for PostgreSQL, Azure Database for MariaDB. Azure Database for MySQL is a fully managed relational database under the DaaS service model that can handle significant workloads with predictable performance and dynamic scalability. Azure Database for PostgreSQL is a fully managed database instance built on the open-source PostgreSQL database engine and supports several of its new releases. It offers high performance and scalability, increased security, flexibility and compatibility with many applications. Azure Database for MariaDB is also a relational database based on the open-source MariaDB server engine and has the same features as Azure Database for MySQL. [22]

The previous databases are called relational which means that the data is stored in the Relational Database Management System (RDBMS). But there is another way of storing and organizing data that is not relational since the data is stored in a structure such as a JSON file and it is called a NoSQL Database or otherwise "non-SQL". NoSQL Database is a type of distributed database, that is, information is copied and stored in many, remote or local, enhancing the availability and reliability of the data. Also, it is a quite popular and modern solution for many companies since it

offers better performance, higher speed, increased scalability, which can adequately respond to the rapid development of Cloud, applications and data. [31] Microsoft Azure offers its own NoSQL service Azure Cosmos DB with characteristics of high availability and speed, open APIs for MongoDB, .NET, Java, Node.js, Python, flexibility and reliability. [22]

Another service for storing data in an in-memory data store is Azure Cache for Redis, based on the Redis software. Azure Cache for Redis enhances the performance and scalability of an application that uses backend data stores, processes large volumes of application requests, and reduces network latency.

In terms of database migration, Microsoft Azure offers Azure Database Migration service where user can easily migrate their data to other Cloud databases. [34]

C. Application Services and Security

I. Application Services

Application Services include services that help create and operate various applications. One of these services is Azure Active Directory (Azure AD). Azure Active Directory is a powerful, secure, multi-functional directory for identity and access management in the Cloud. It helps the user to access external or internal resources like applications located on the corporate network and intranet, along with any Cloud applications developed by the enterprise. It is used by many Microsoft Cloud services that are also examples of external resources, such as Microsoft Office 365 and of course Microsoft Azure. The user can choose what information other users or applications will have access to and who can use it. Azure Active Directory is not only used in the Cloud or in solutions hosted on the Azure platform. It can also be used in on-premises solutions where it is accessible through modern REST APIs. That way, multiple applications can access it. It also offers many features that help enterprises secure their Cloud applications. Some of these are Azure AD B2C (enterprise to consumer), Azure AD B2B (enterprise to enterprise), Azure AD Connect Health, and Azure AD Identity Protection. [15]

There are three tiers of Azure Active Directory that a user can use, which are Free, Basic, and Premium. The Free tier provides user management and access to Azure AD SaaS tier applications. The Basic Tier provides all the features of Free along with password reset, access to group-based applications, and more. And finally, Premium which provides all the features of the Free and Basic tiers, along with self-service group management, advanced security reporting and alerts, multi-factor authentication, and more. [15]

II. Security

The previous section covered storage and databases. The security of these two is the first and most important step that the user should think about before even choosing the type of storage account or database that he wants. Azure offers several security services to build secure applications. Some of them are: [15]

- **Azure Web Application Firewall.** It offers web application-specific protection against resource exploitation and vulnerability attacks.
- **Azure Key Vault.** It helps hide cryptographic keys and secrets used by Azure applications and services. The user can store the storage account keys in the key vault and grant access to it to other users, groups or applications.
- **Shared Access Signature (SAS).** It is an alphanumeric containing a security token that can be bound to the URI of an item that allows the user to delegate access to specific storage objects and specify restrictions such as permissions or access date/time ranges.
- **Azure Security Center.** It offers protection for jobs running in Azure, on-premises and on other Cloud platforms. It also provides protection against online attacks using Microsoft's threat service, helping to implement security faster with built-in controls. The user can control their Virtual Machines, virtual networks and services through the security assessments automatically generated by Security Center or create their own. [35]
- **Azure Monitor.** Increases the availability and performance of applications.
- **Azure Distributed Denial of Service (DDoS).** Distributed Denial of Service is an attack on the Cloud to exhaust resources so that the application is no longer available to users. Microsoft Azure offers the Azure DDoS Protection Standard in conjunction with the application design so that the user can protect against these attacks. It can be used on any new or existing virtual network without any changes to applications or resources. [24]

D. Network Services

One of the network services offered by Microsoft Azure is Virtual Networks (VNets). Virtual Networks are used to provide a private connection for Virtual Machines and other services to communicate with each other, with the Internet, and with the networks located on the company's internal premises. They are like traditional networks but have additional advantages such as scalability, availability and isolation. Any Virtual Machines and services belonging to the same virtual network can communicate with each other. By default, services outside the virtual network cannot connect to those inside, but the user can change their settings to accept access from external services. An example of virtual network operations is as follows: Suppose the user

has a frontend web application running on one Virtual Machine but uses a backend database running on a different one. To connect the application to the database, the user can put the database on the same virtual network as the application, so that the backend database can be used without it being accessible from the Internet.

One of the characteristics of virtual networks are Virtual Network Gateways. A Virtual Network Gateway is a fully managed service used for cross-premises connectivity and can be added to the virtual network, giving the user the ability to deploy hybrid cloud applications that are securely connected to an enterprise's datacenter. Network services also include Network Security Groups (NSGs) which provide a flexible method of defining access rules that allow traffic in and out of a Virtual Machine, a virtual network or its subnet. The need to create network security groups arose from the need to protect Virtual Machines. When the user creates a Virtual Machine Azure asks to create such a group, without its creation being mandatory. But if the Virtual Machine has a public IP address and is hosted on the internet, then it becomes vulnerable to attacks with nothing to protect it from. [15] Network services also include the following services:

- **Azure Load Balancer.** Azure Load Balancer distributes inbound flows arriving at the frontend of the load balancer to backend pool instances. Backend pool instances could be Virtual Machines or instances in a Virtual Machine scale set. [25]
- **Azure VPN Gateway.** It is a type of Virtual Network Gateway that is used to send encrypted traffic between an Azure virtual network and an on-premises site over the public Internet or Microsoft network. Each virtual network can have only one VPN Gateway, but one VPN gateway can have multiple connections. [26]
- **Azure DNS.** DNS Domains hosting service that offers name resolution using Azure infrastructure. It is based on Resource Manager and has security features such as RBAC and logs resource locking where it locks a subscription, resource or resource group so that resources are not deleted by third parties. The user can manage DNS records with the same credentials, APIs, tools and billing as with the rest of the services. The DNS Domains it creates are hosted on Azure's global network of DNS name servers. [27]
- **Azure ExpressRoute.** It allows the user to extend on-premises networks to the Microsoft Cloud using a private connection and a connectivity provider. ExpressRoute connections do not extend to the public Internet, so they have reliability, fast speeds, consistent latencies and higher security. [28]

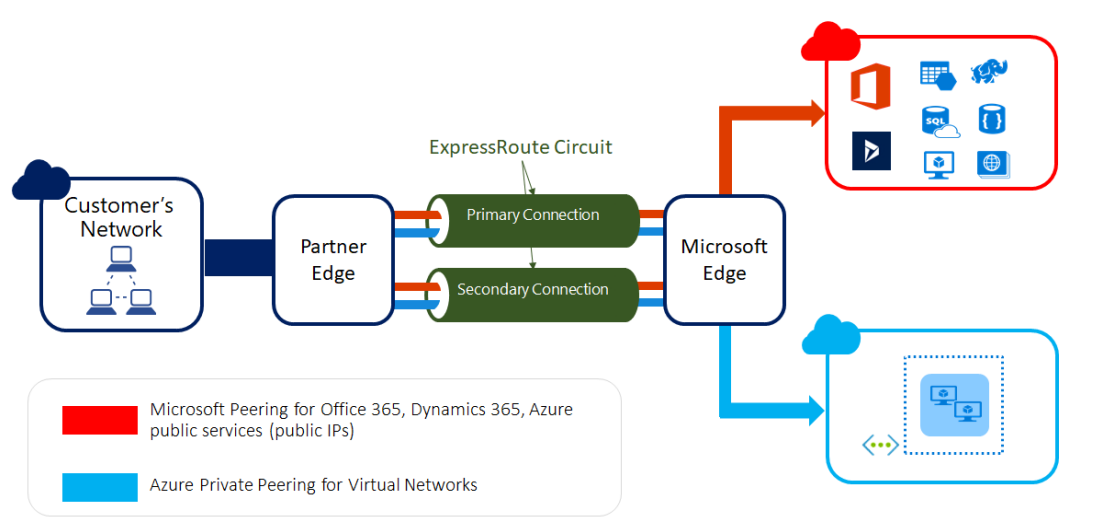

Figure 2.4.h ExpressRoute management

- **Azure Traffic Manager.** It is a traffic load balancer based on DNS that is resilient to failure. This service allows the user to distribute network traffic to his public applications across global Azure regions. It also provides public endpoints with high availability and fast response. It uses DNS to direct client requests to the right service endpoint based on the traffic-routing method while providing health checks for each endpoint. Endpoints can be services inside or outside of Azure that use Internet connection. [29]

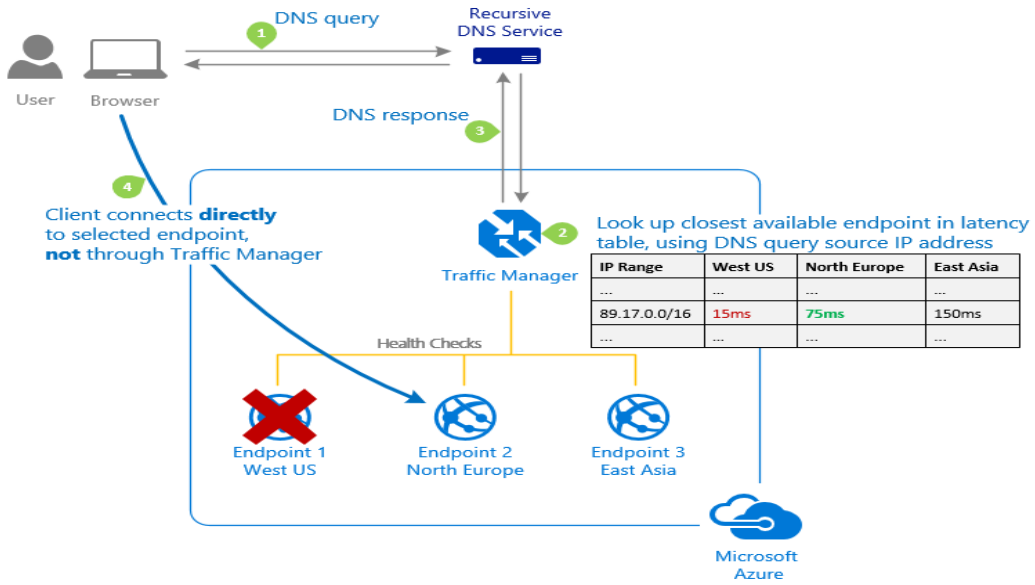

Figure 2.4.i Azure Traffic Manger function

- **Azure Content Delivery Network (CDN).** It is a distributed network of servers that can accurately deliver web content to users. It stores the content of edge servers in point-of-presence (POP) locations close to users to reduce network latency. Its advantages are better performance and improved user experience, greater scalability, distribution of user requests and content delivery directly from the edge servers so that the origin server has less traffic. [30]

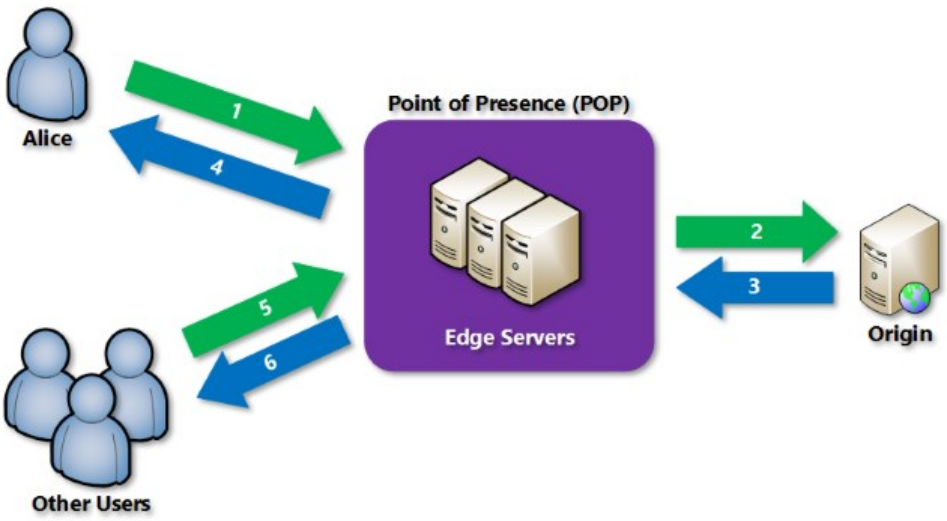

Figure 2.4.j Azure Content Delivery Network

Chapter 3. Comparison

In the previous chapter, two of the most famous Cloud Computing platforms AWS and Microsoft Azure were presented and their services were analyzed. In this chapter follows the comparison of the two platforms so that the reader can have a comprehensive knowledge of their similarities and differences in the services they offer. The main comparison will be made on four services mentioned these are Compute, Databases, Storage, Security and Network Services. However, a comparison in application control, account and resource management, user authentication and authorization are also reported.

A. Compute Services

Compute Services	Compute Services Comparison	
	Amazon AWS	**Microsoft Azure**
IaaS	Amazon Elastic Compute Cloud (EC2) Instances	Azure Virtual Machines
PaaS	Amazon Lightsail	Azure App Services
Serverless	AWS Lambda	Azure Functions
Containers	Amazon Elastic Container Service (ECS), AWS Fargate	Azure Container Instances
Container Orchestration	Amazon Elastic Kubernetes Service (EKS)	Azure Kubernetes Service (AKS)
Batch	AWS Batch	Azure Batch

Table 3.1 Compute Services comparison [32]

B. Database Services

Databases	Database comparison	
	Amazon AWS	**Microsoft Azure**
Storage	Amazon EBS, Amazon Instance Store, Amazon S3	Azure Storage Account, Storage Services
Relational database	Amazon RDS, Amazon Aurora	Azure SQL Database, Azure MySQL, Azure PostgreSQL, Azure Database for MariaDB
Serverless relational database	Amazon Aurora Serverless	Azure SQL Database Serverless
NoSQL/Document	Amazon DynamoDB, Amazon Document DB	Azure Cosmos DB
Caching	Amazon ElastiCache	Azure Cache for Redis
In-memory Database	Amazon MemoryDB	Azure SQL Database
Migration	AWS Application Migration Service, AWS Database Migration Service	Azure DB Migration

Table 3.2 Database comparison [32]

C. Application Control

Application Control	Application Control services comparison	
	Amazon AWS	**Microsoft Azure**
Application management	AWS CloudWatch	Azure Monitor
Tools for programmers	AWS Developer Tools	Azure Developer Tools
Command Line Interface	AWS CLI	Azure CLI, Azure PowerShell
Cloud Shell	AWS CloudShell	Azure Cloud Shell

Table 3.3 Application Control services comparison [33]

D. Storage Services

Storage	Storage comparison	
	Amazon AWS	**Microsoft Azure**
Virtual Server Disks	Amazon Elastic Block Store (EBS)	Managed disks
Shared Files	Amazon Elastic File System	Files
Backup	Backup	Backup
Bulk data transfer	Import/Export Disk	Import/Export
Object Storage	AWS Simple Storage Services (S3)	Blob storage

Table 3.4 Storage comparison [33]

E. Management

Account and services management comparison	
Amazon AWS	**Microsoft Azure**
AWS Organizations	Azure Management Groups
AWS Management Console	Azure Portal
AWS CloudWatch	Azure Application Insights
AWS Resource Groups and Tag Editor	Azure Resource Groups and Tags

Table 3.5 Account and services management comparison

F. Authentication and Authorization

Authentication and Authorization comparison	
Amazon AWS	**Microsoft Azure**
Identity and Access Management (IAM)	Azure Active Directory, Azure RBAC
Multi-Factor Authentication	Azure Active Directory
AWS Organizations	Azure Management Groups, Azure RBAC

Table 3.6 Authentication and authorization comparison [33]

G. Security Services

Ασφάλεια	**Security Services comparison**	
	Amazon AWS	**Microsoft Azure**
Authentication and Authorization	AWS Identity and Access Management	Azure Active Directory
Cryptography	AWS Key Management, AWS CloudHSM, AWS Secrets Manager	Azure Key Vault
Firewall	AWS WAF	Azure Web Application Firewall
Cloud Security	Amazon Guard Duty	Azure Security Center
Cloud tool management	AWS Management Console, AWS CLI	Azure Portal, Azure PowerShell, Azure Cloud Shell, Azure CLI
Control	AWS CloudWatch, AWS CloudTrail, AWS Trusted Advisor	Azure Monitor
Virtual Network security	AWS Shield, AWS WAF	Azure DDoS Protection Standard

Table 3.7 Security Services comparison [32]

H. Network Services

Network Services	**Network Services comparison**	
	Amazon AWS	**Microsoft Azure**
Virtual Networks (VNets)	Amazon Virtual Private Cloud (VPC)	Azure Virtual Network
Content Delivery Network (CDN)	Amazon CloudFront	Azure CDN
DNS management	Amazon Route 53	Azure DNS

Cross-Premises connectivity	AWS VPN Gateway	Azure VPN Gateway
Dedicated Network	AWS Direct Connect	Azure Express Route
Private link	AWS PrivateLink	Azure Private Link
DNS traffic management	Amazon Route 53, Amazon Traffic Flow	Azure Traffic Manager
Load Balancing	Amazon Elastic Load Balancing	Azure Load Balancer

Table 3.8 Network Services comparison [32]

Chapter 4. Practical Part

In the practical part of the paper five exercises are presented as examples of the services offered by the two technological companies that were analyzed and compared. The exercises are based on the application examples found on the companies' websites and all Figures are mine. The code for exercises 1 and 4 is on my personal GitHub page https://github.com/Lena341/

Exercise 1. Microsoft Azure App Service

The first exercise is a Web App intended for use by students at Contoso University. It is a student, course and course management system in which the user can create, display, update and delete students, courses and directions. It is based on the first, second, third and fifth part of Razor Pages with Entity Framework Core in ASP.NET Core - Tutorial 1 of 8 | Microsoft Docs but the classes used are mine. It uses Azure platform services, specifically Azure App Service, Azure SQL Database and Azure Server. It has been published to the Azure platform as an App Service from Visual Studio. To create the service, the subscription, resource group, data center region, application name and support plan were defined. All this is shown in Figure 1.2. Because it is an application that performs CRUD (create, read, update, delete) operations on three different databases, a common Azure SQL Database, and an Azure Server where the database resides were created. To connect to the database, SQL authentication was used with ADO.NET and a connection string was created that is present in the appsettings.json file, while in Visual Studio the necessary connection to the universityappserver server was made in the SQL Server Object Explorer. Then it was published as an App Service to Azure. The application was implemented with ASP.NET Core Razor Pages with Entity Framework Core (EF Core). Razor pages were chosen over MVC because they offer an easy and more productive solution for building web applications and are recommended by Microsoft for new developers who have no experience building such web applications. EF Core is an object relational mapper (O/RM) that allows access to data through models. Essentially, the developer creates model classes through scaffolding and EF Core creates the database. Model classes define data properties that are stored in the database. An example of a model class is the code shown in Figure 1.1. For the student to be informed of errors when filling in the three forms, there are validations in the model classes where they have been added to the code above the properties.

```
using System.ComponentModel.DataAnnotations;

namespace ContosoUniversity.Models
{
    public class Student
    {
        [Key]
        public int ID { get; set; }

        [Display(Name = "Last Name")]
        [Required]
        [StringLength(100, MinimumLength = 3)]
        public string LastName { get; set; }

        [Display(Name = "First Name")]
        [Required]
        [StringLength(100, MinimumLength = 3)]
        public string FirstMidName { get; set; }

        [Display(Name = "Student ID")]
        [Required]
        public int StudentIdent { get; set; }

        [Display(Name = "Semester")]
        [Required]
        public int Semester { get; set; }

        public ICollection<Course> Courses { get; set; }
        public ICollection<Direction> Directions { get; set; }
    }
}
```

Figure 1.1 Student Model Class

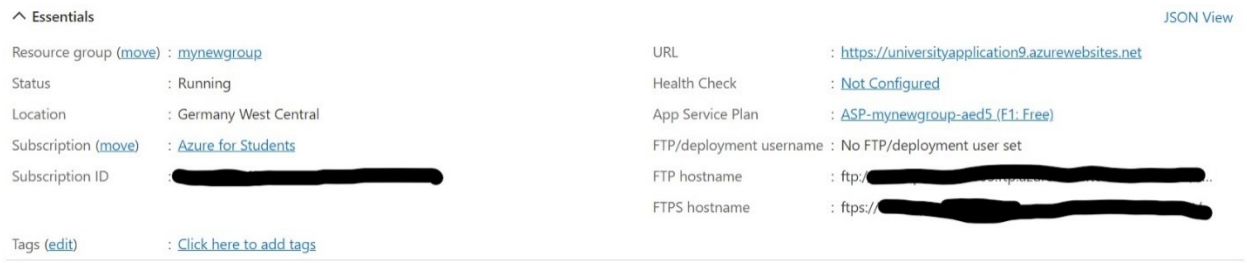

Figure 1.2 universityapplication9 App Service

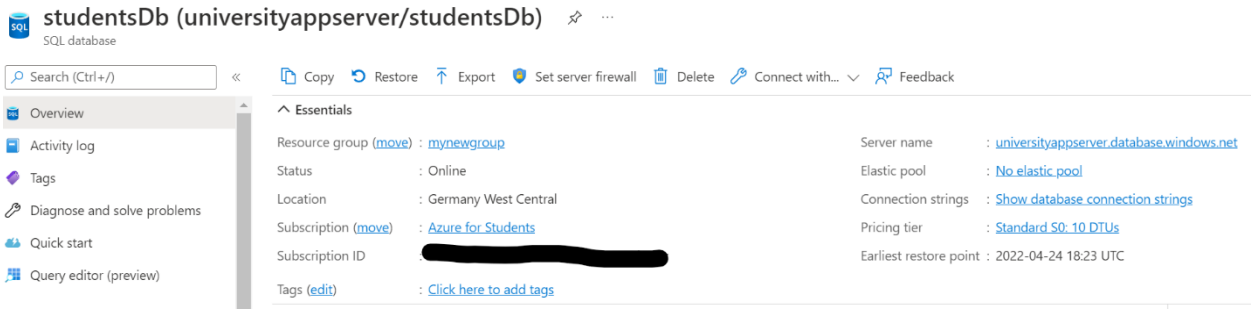

Figure 1.3 studentsDb database and universityappserver server

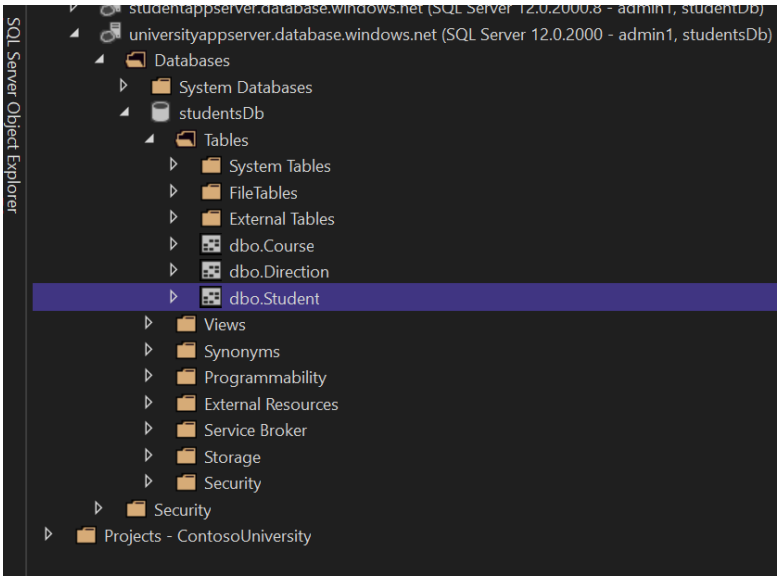

Figure 1.4 studentsDb database in SQL Server Object Explorer in Visual Studio

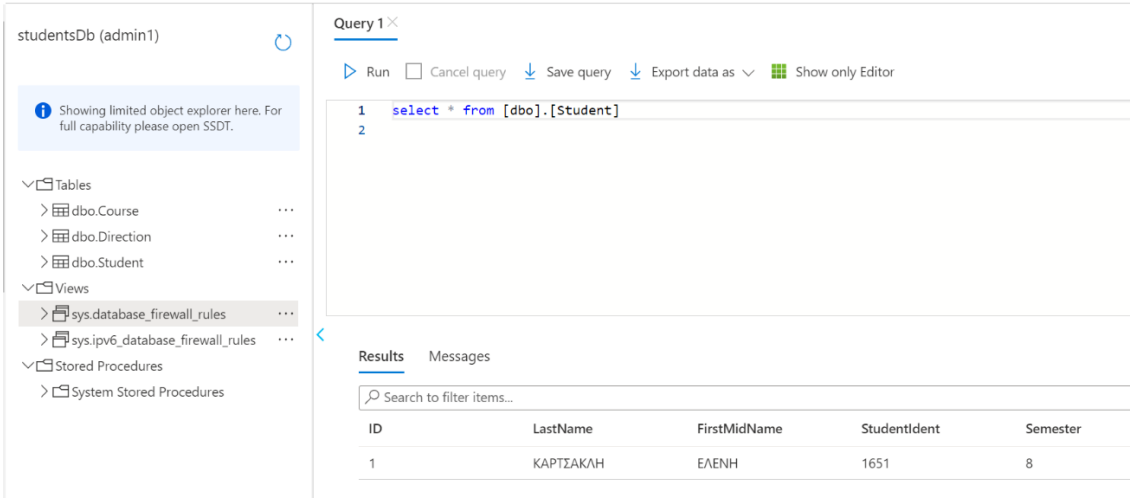

Figure 1.5 Student database data in Azure portal

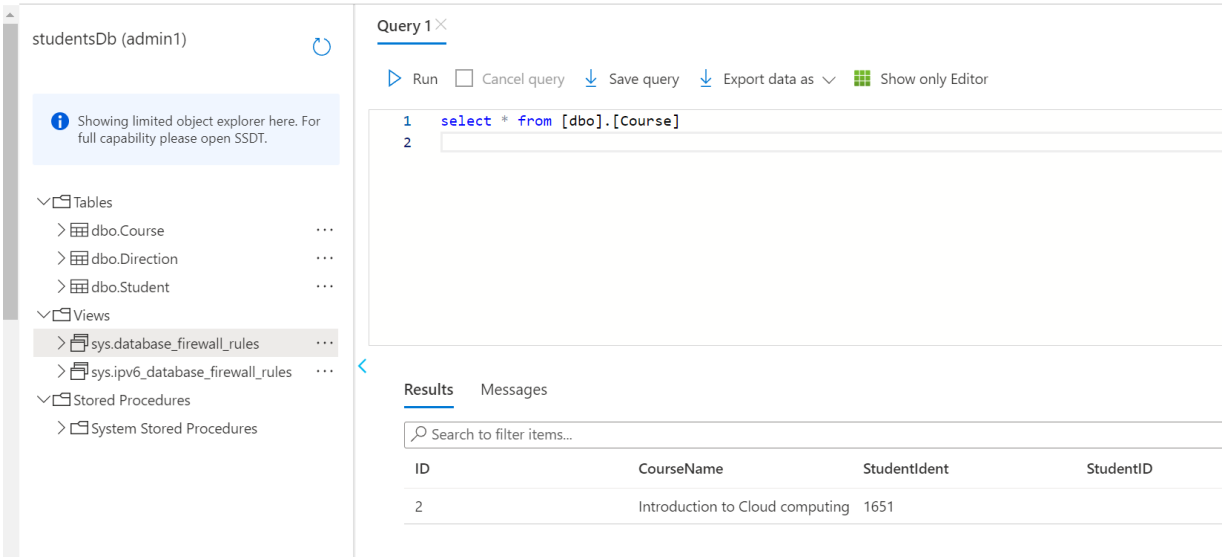

Figure 1.6 Course database data in Azure portal

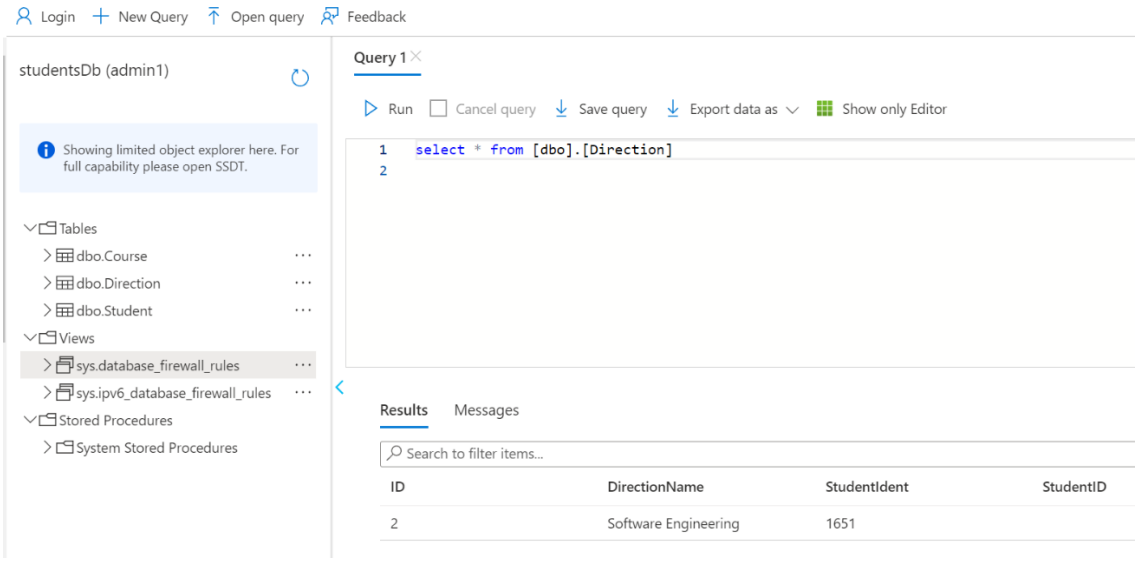

Figure 1.7 Direction database data in Azure portal

Exercise 2. Windows Virtual Machine

The second exercise is an Azure Virtual Machine for Windows. It is based on the Microsoft application Create a Windows Virtual Machine in Azure - Learn | Microsoft Docs To create it, the user must connect with his data on the Microsoft Azure platform, select the Marketplace and the computing service he wants. Virtual Machines cannot be created unless selecting any

Compute Service. There are many Virtual Machines for various servers such as Ubuntu, Debian 10 “Buster”, SQL Server 2017 on Windows Server 2016 and Virtual Machine for Linux operating system such as Red Hat Enterprise Linux 7. In this exercise Windows Server was selected, a group of operating server systems that acts as a bridge between the user's environment and Azure and is the Image of the Virtual Machine. It also includes several software plans where each has its own security, storage and networking specifications. In this exercise [smalldisk] Windows Server 2019 Datacenter-Gen2 was selected. After the Image that is the most important part is selected, the resulting features are ordered according to the architecture of the Virtual Machine. Figure 2.2 shows that the attributes defined are the resource group, the virtual hard disks (virtual hard disks) for the OS disks, a virtual network, a public and a private IP address. Remote Desktop Protocol (RDP) is used to connect to the Virtual Machine from a computer. On the Virtual Machine management page, the user selects “Connect” and then “RDP” to download the preconfigured.rdp file to connect to the Virtual Machine.

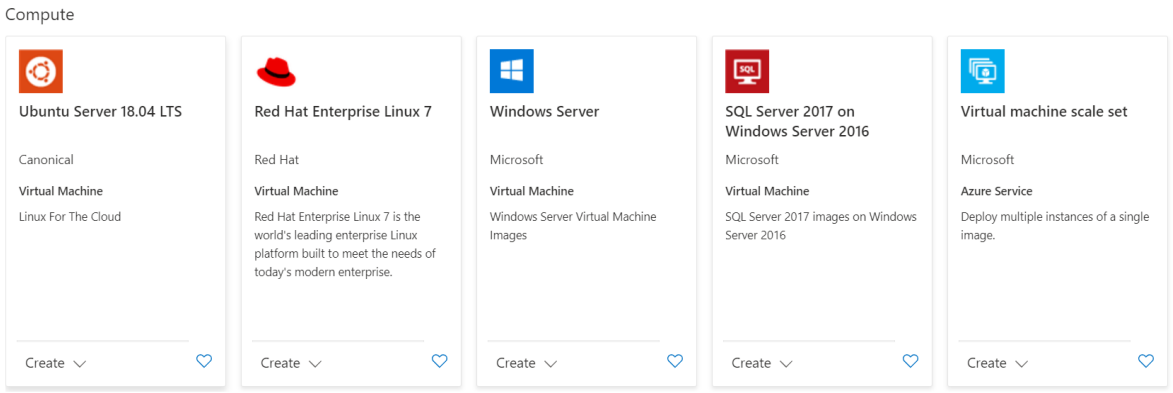

Figure 2.1 Microsoft Azure Marketplace Compute Services

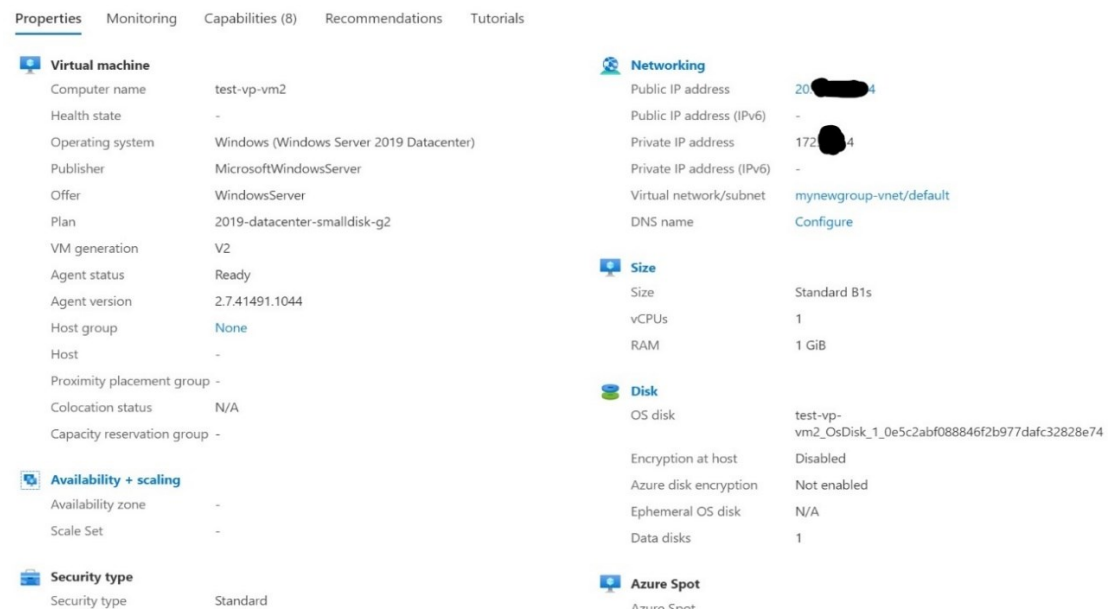

Figure 2.2 Virtual Machine properties

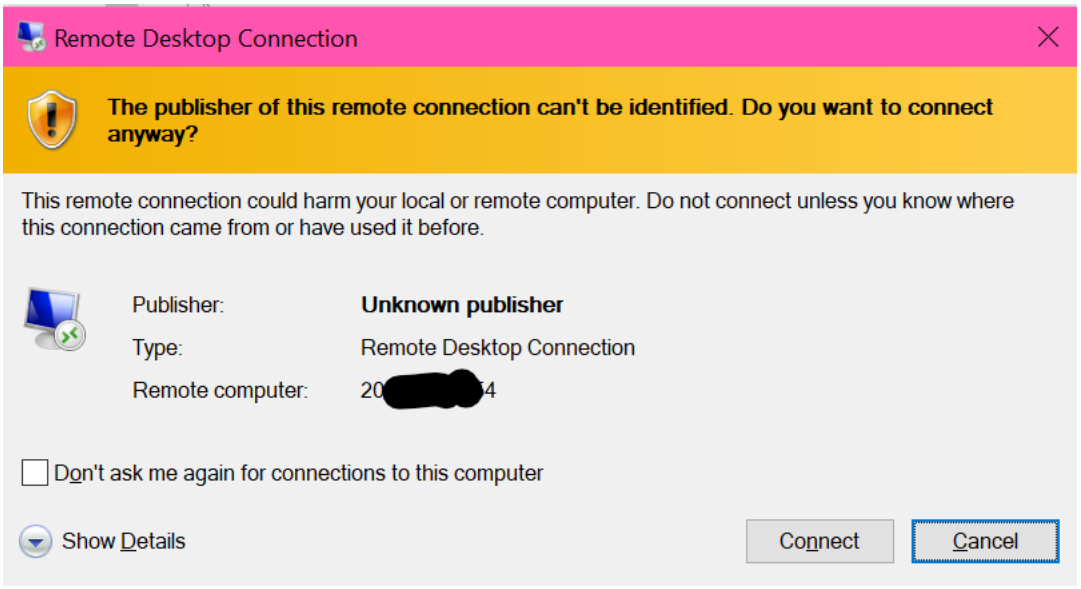

Figure 2.3 Connection to Virtual Machine with Remote Desktop Protocol

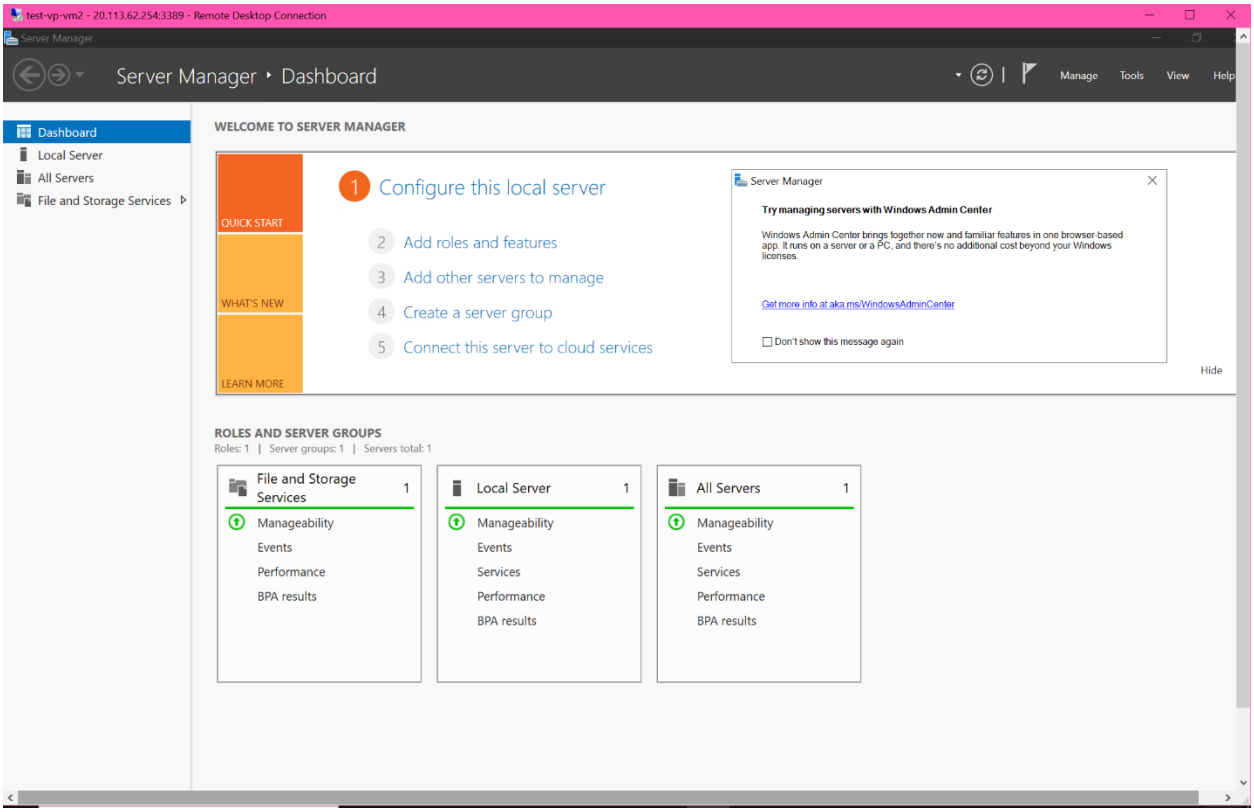

Figure 2.4 Windows Virtual Machine

Exercise 3. Microsoft Azure Function App

In the third exercise, a function application is created to display a message in a web browser. It was based on the Create a function using Azure for Students Starter | page application Microsoft Docs that demonstrates creating a function application using Students Starter. To create such an application, the user must log in to the Azure portal, select “Create a resource”, then “Compute” and then “Function App”. After defining the application settings, he selects "Go to resource" then "Functions" and there he creates the function he wants by choosing the development environment, the template, the name of the function and the authorization level. Students Starter supports many features for configuring functions such as triggers, programming languages (C#, Java, JavaScript, F#, Python and others), operating systems (Linux, Windows) and development tools such as VS Code, Visual Studio, Azure CLI and Azure Portal. For this application, the development in the portal was chosen as the development environment and the Http Trigger standard which is a function that will run whenever it receives an HTTP request and will respond based on the data of the body of the code or the query string. When the user chooses the creation, he can use the URL of the function to display the message in a web browser.

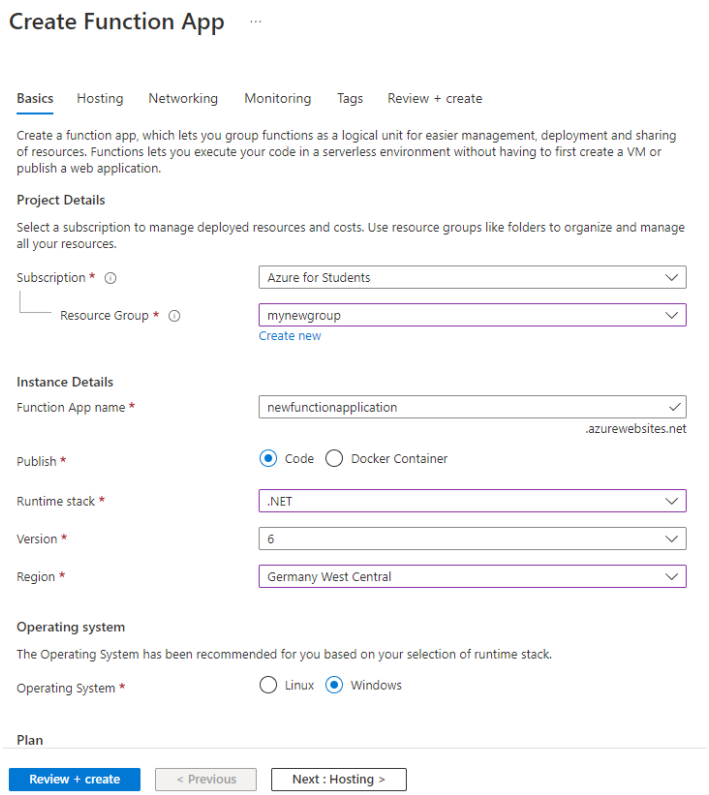

Figure 3.1 Function app configuration

Figure 3.2 Function app creation

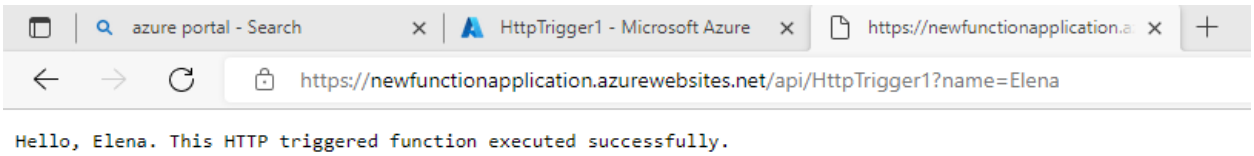

Figure 3.3 Message

Exercise 4. React Web App

The fourth exercise is a app for making notes. It is based on the application on the Amazon AWS page Build a Full-Stack React Application on AWS but the code shown below is my own. The user logs into their account to create or delete small notes. It is a full stack React web app, implemented with AWS Amplify and GraphQL. AWS Amplify is a set of tools for quickly and easily building web or mobile applications. With Amplify developers can manage backend web or mobile applications, quickly connect to them, create a frontend user interface (UI), and manage their application content without using the AWS console or knowledge of Cloud Computing. GraphQL is a query language for APIs that describes data to the API by sending queries to it. All GraphQL files are saved as JavaScript files and contain HTML tags to configure the application. GraphQL example forms the main part of the application used to authenticate the user and display the notepad (Figures 4.3 - 4.9). When the user opens the application, they are authenticated by connecting to an account by completing the Sign In form or by creating a new account in the “Create Account” tab. Also, the option to change the password is given. Once the user creates a new account, a code is sent to their email from no-reply@verificationemail.com in order to identify the address they provided and activate their account. When successfully logged in he can create or delete notes and select the “Sign Out” button to log out. To implement authentication, Amplify CLI commands and Amplify libraries that enable Amazon Cognito, a user authentication service, were used. The application GUI was then created with React and an API was added to create another GraphQL API. The GraphQL API enables AWS AppSync, a managed GraphQL service powered by Amazon DynamoDB. The application supports CRUD+L types (create, read, update, delete and list), that is, the user will be able to create or delete notes and they will be displayed in the form of a list. The application appears with the npm start command executed in the Node .js command prompt, in the application folder and accessed from the computer's localhost through a browser.

```
  return (
   <Authenticator>
       {({ signOut, user }) => (
     <div className="App">
          <p>
            Welcome, create your note!
          </p>
          <button onClick={signOut}>Sign out</button>


      <h1>My Notes App</h1>
      <input
        onChange={e => setFormData({ ...formData, 'name': e.target.value})}
        placeholder="Note name"
        value={formData.name}
      />
      <input
        onChange={e => setFormData({ ...formData, 'description': e.target.value})}
        placeholder="Note description"
        value={formData.description}
      />
      <button onClick={createTodo}>Create Note</button>
      <div style={{marginBottom: 30}}>
        {
          notes.map(note => (
            <div key={note.id || note.name}>
              <h2>{note.name}</h2>
              <p>{note.description}</p>
              <button onClick={() => deleteTodo(note)}>Delete note</button>
             </div>

          ))
        }
      </div>

    </div>
    )}
   </Authenticator>


  );
}
export default App;
```

Figure 4.1 GraphQL example

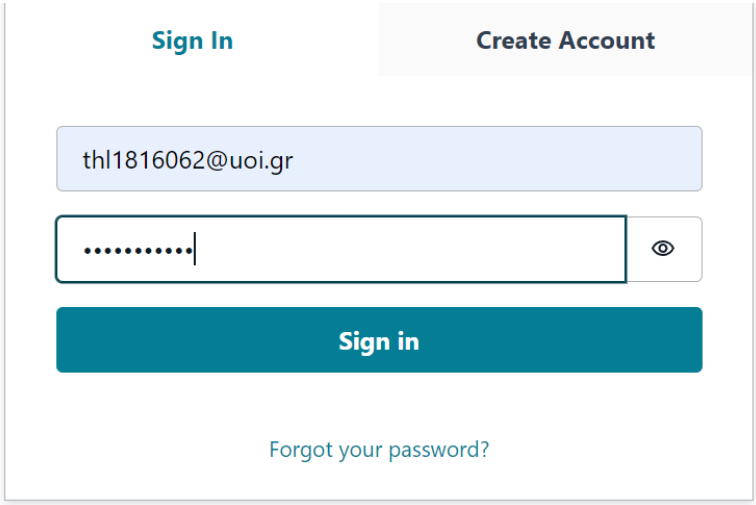

Figure 4.2 User sign in

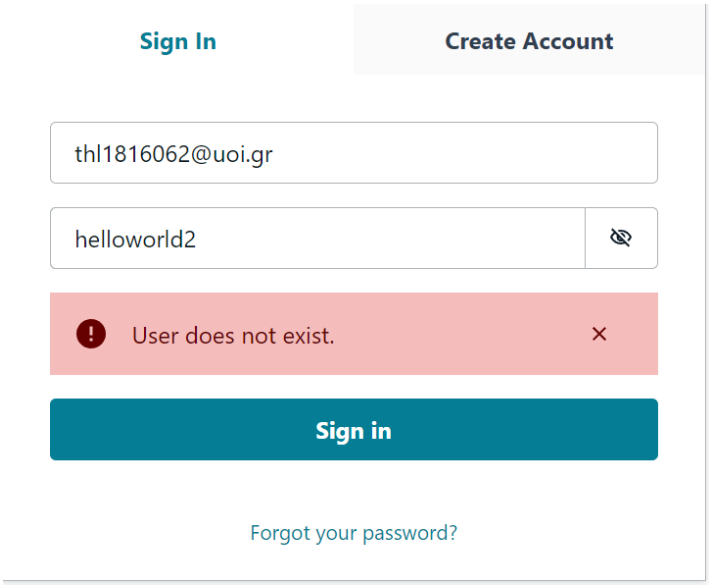

Figure 4.3 Failed authentication message

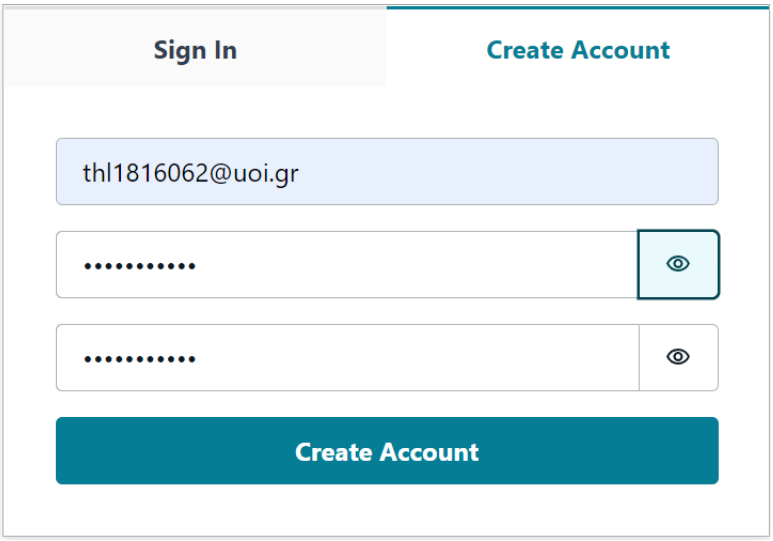

Figure 4.4 Account creation

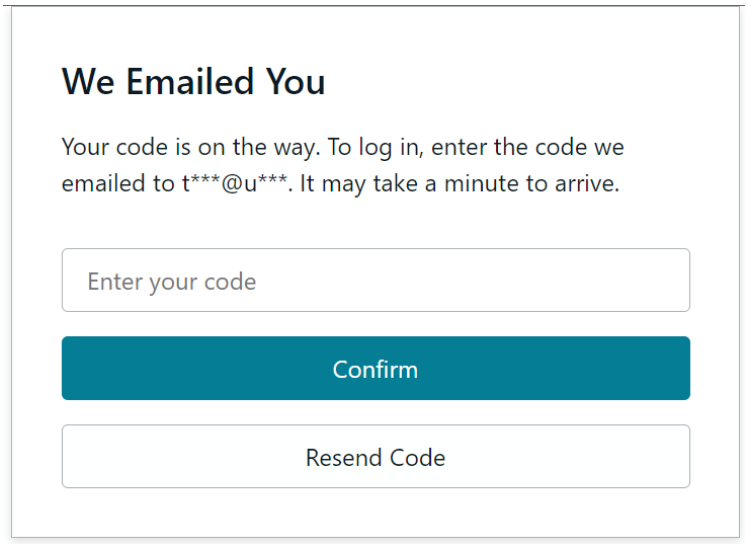

Figure 4.5 Enter password to create account

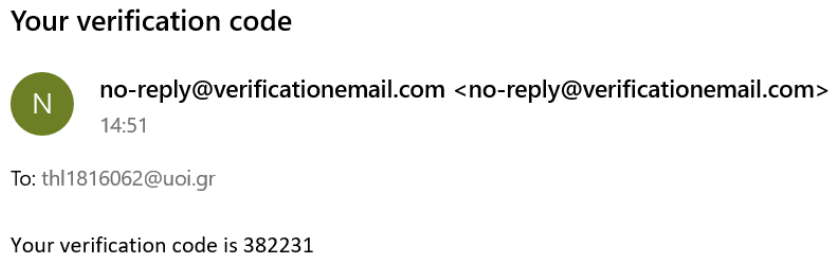

Figure 4.6 Verification email

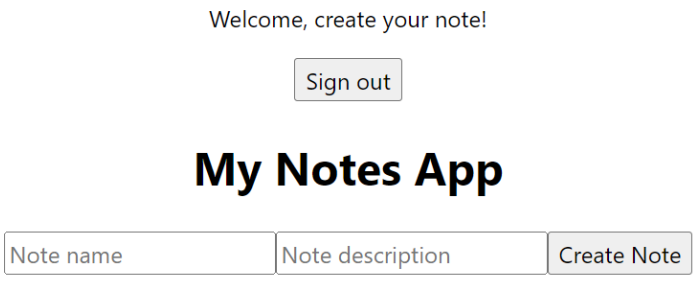

Figure 4.7 Note creation

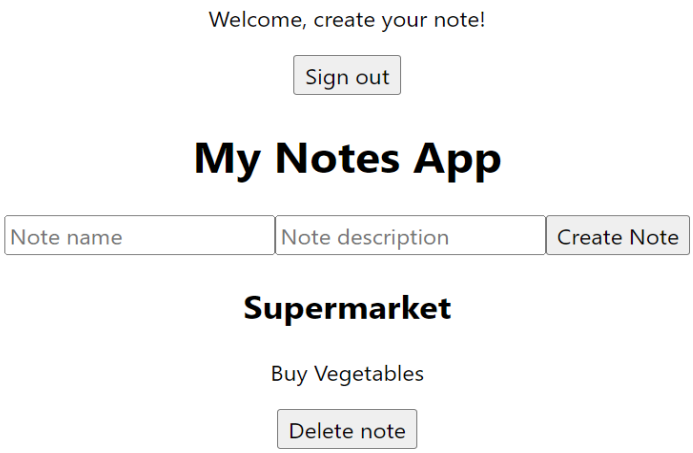

Figure 4.8 Note deletion

Exercise 5. AWS Windows Instance

Exercise five demonstrates creating an AWS Windows instance with Amazon Lightsail. It is based on the Amazon tutorial Launch a Windows Virtual Machine. First, the connection to the AWS Lightsail service was made and then its characteristics were defined according to those mentioned in chapter 2 in section 2.2. The reason Amazon EC2 was not chosen for instance creation is because Amazon Lightsail offers a fast, simple, and flexible environment for instance creation. To create the instance, define the area where the instance will be created and then its Image. In Amazon AWS an Image is the operating system or platform together with the blueprints of each operating system. The operating system can be Linux or Windows while the blueprints are for applications and operating systems or only for operating systems. Linux supports 28 blueprints while Windows supports 4. This instance uses the Windows operating system with Windows Server 2016 operating system blueprint. After selecting the location and Image, the instance support plan is selected which includes memory, processing, storage of the instance together with the amount of data it can carry. Finally, a name for the instance and a password are chosen. All of these are the basic features that are mandatorily defined by the user. Some additional features that the user can add according to their requirements are containers, databases, networks, storage and snapshots. In this exercise, a public static IP address, a snapshot and an additional storage space, the bucket, were defined. After defining them, the following instance is created shown in Figures 5.3 and 5.4. The connection to the instance can be made via RDP and the user can use his own browser or via an RDP client (RDP client) as is done with the Azure Virtual Machine. In this case the connection via RDP was chosen where the instance appears in my browser in a new window since the connection via RDP client is shown in exercise 2. Figure 5.3 shows the characteristics of the instance. RAM memory is 512 MB, CPU is 1 vCPU means it has a physical CPU core and the SSD disk is 30 GB.

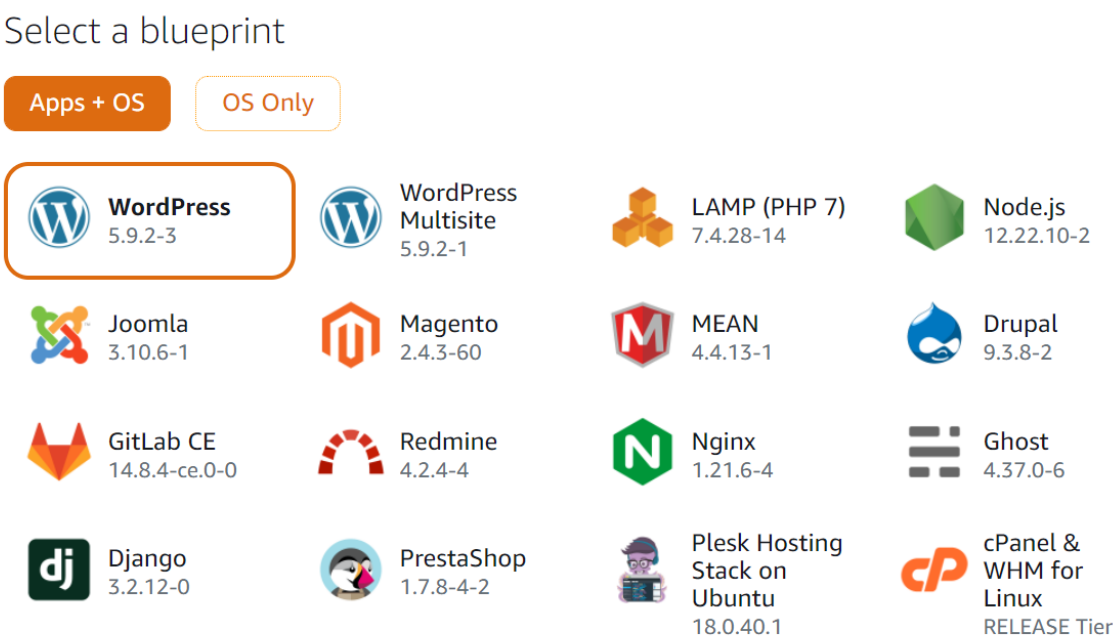

Figure 5.1 Linux blueprints

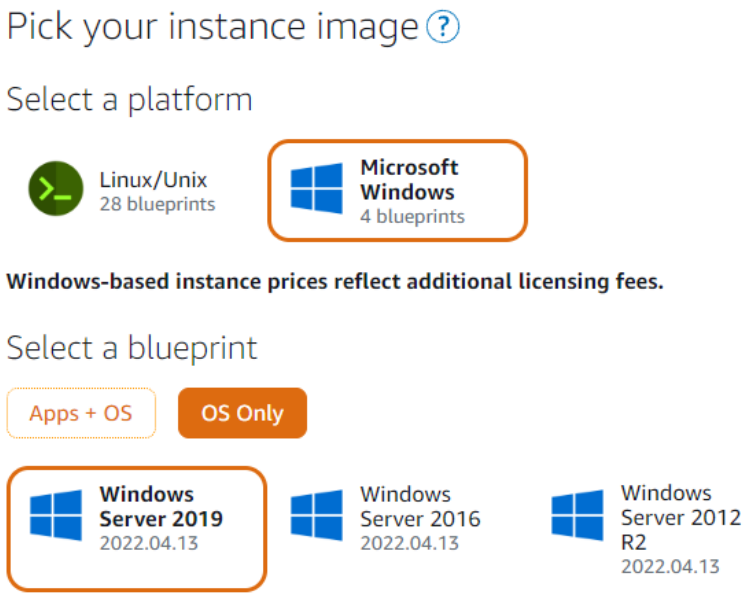

Figure 5.2 Windows blueprints

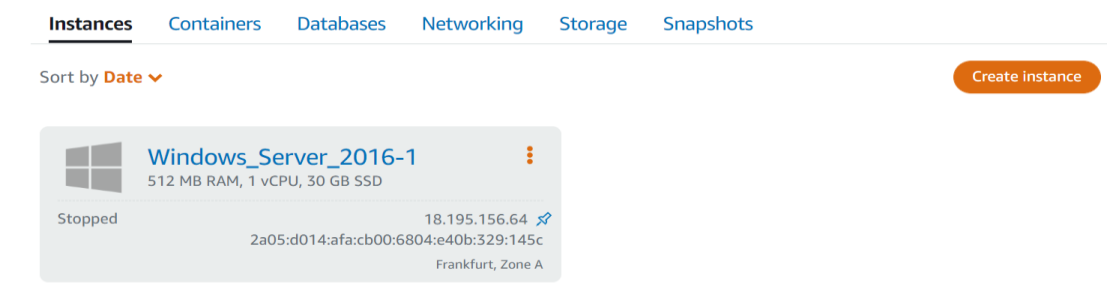

Figure 5.3 Windows_Server_2016-1 Instance creation

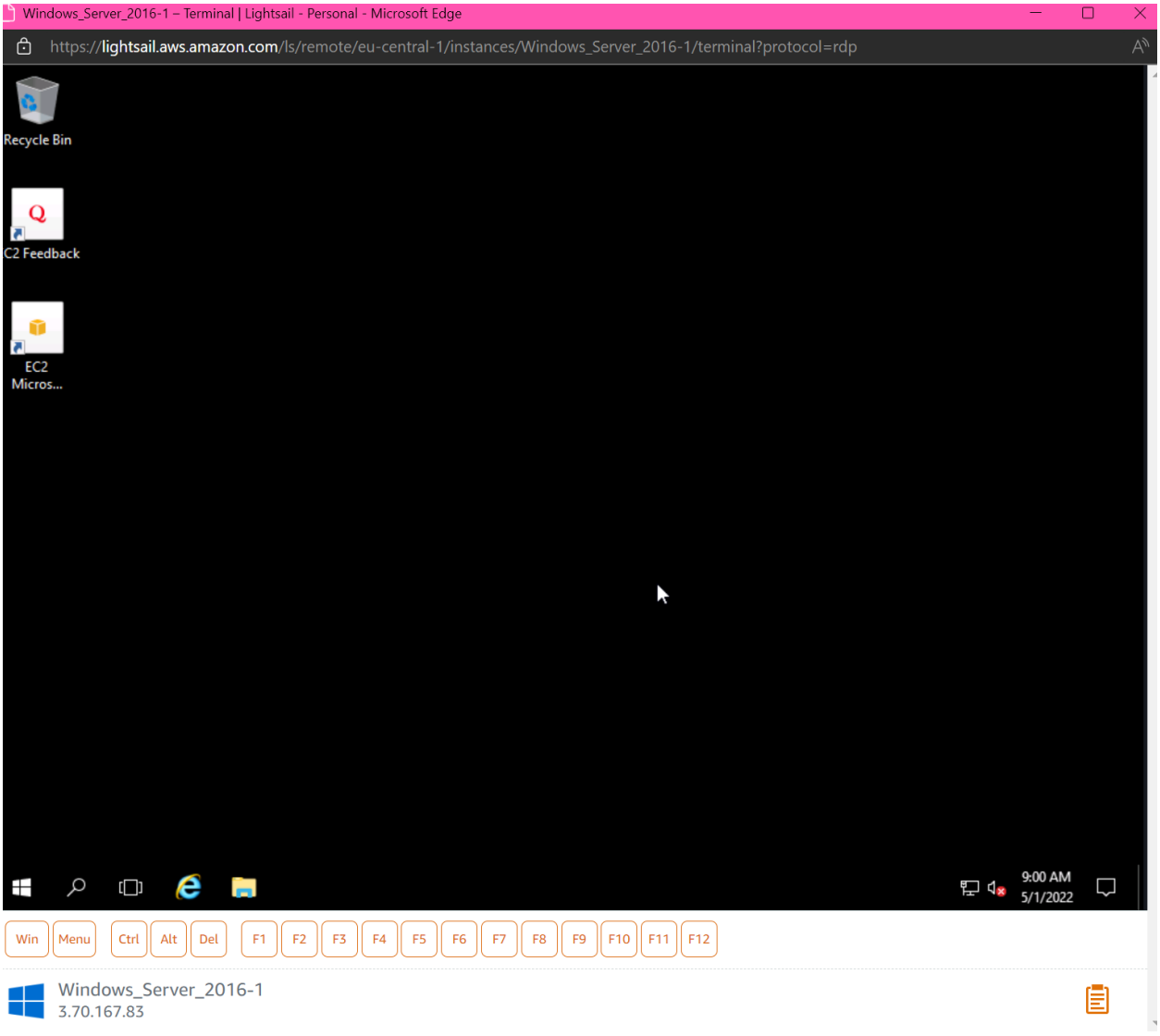

Figure 5.4 Windows Instance

I. Static IP Address

When a Virtual Machine is created it has a default dynamic IP address that changes every time the user stops and starts their machine. If you choose to set a static IP address it will never change. Also, if he defines a domain name in his instance, he will not need to change his settings when he starts or stops the operation of his instance. The new static IP address is shown in Figure 5.5.

Figure 5.5 Public static IP address

2. Snapshot

A snapshot is a copy of the system disk and the initial settings of the instance. It includes information about CPU, disk size and data transfer rate. The snapshot is created in two stages. First, a backup snapshot is created and then a second one that uses System Preparation (Sysprep). Sysprep configures Windows Server so that the instance is created as a snapshot copy, so it is as if the instance is being created for the first time. Next are the creation of the first backup snapshot, the settings for creating the Sysprep snapshot and the two snapshots together.

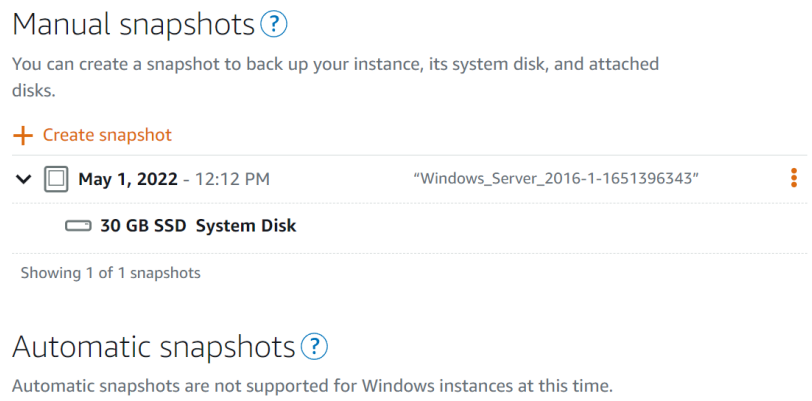

Figure 5.6 Backup snapshot

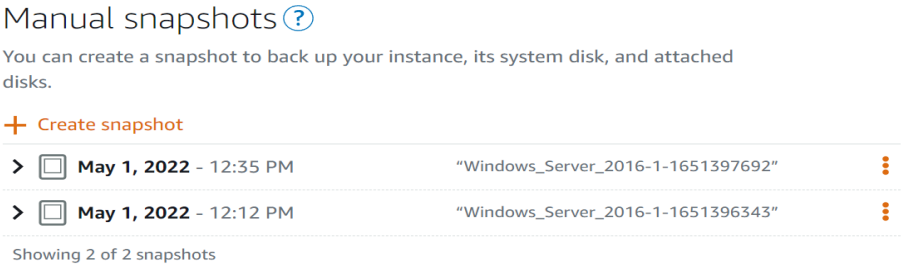

Figure 5.7 Backup and Sysprep snapshot

3. Block storage disk

There are two ways of data storage in which the user can increase the data storage for their resources. The first is the bucket (bucket) a cloud storage resource for storing objects consisting of data and metadata and the disks (disks) which are storage volumes that act as hard disks on an instance and have a lifetime independent of that of presence. Also with buckets is data management such as uploading files, saving objects as files, finding files, copying and moving objects, deleting objects and folders. Bucket can be used with WordPress and CDN for faster delivery of static content (such as web pages). Because the instance is not intended for enterprise use only the bucket was created.

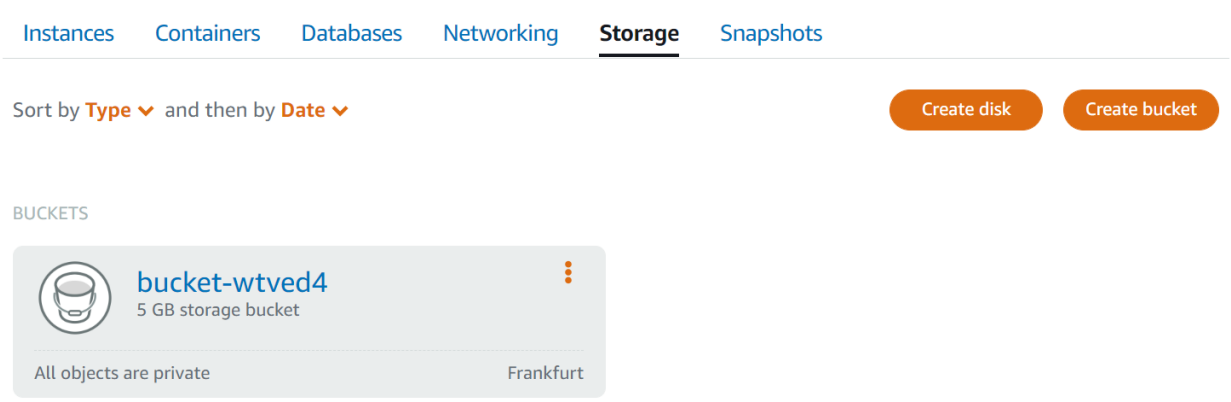

Figure 5.8 Bucket storage

Chapter 5. Summary

Cloud Computing is a new, global, social and technological phenomenon that is constantly evolving allowing millions of people to use its services if they have access to the Internet. Major technology companies have become Cloud Computing providers offering services and resources hosted on online platforms. Thanks to these services, developers can create applications that meet both their own requirements and those of their customers, leveraging resources such as unlimited storage and computing power that would otherwise be difficult to obtain. The infrastructure that supports these applications is hosted in global datacenters that are in many different global locations so that all data is stored close to the customers, significantly reducing the risk of data loss due to natural disasters or network latency. Now the creation and upgrading of the applications is quite easy since the infrastructure and its maintenance are done entirely by the company-provider giving the opportunity to the developers to work only with the creation and development of applications. In the first chapter, Cloud Computing was overviewed where its definition, its two types, the advantages of its use and some of the criteria that a enterprise should consider before deciding to migrate to the Cloud were presented. The most important part of the chapter is the three main advantages of Cloud Computing, low cost (pay as you go), scalability and mobility. The second chapter presents the research into the services offered by two technology companies, Amazon, and Microsoft, which is the main topic of this paper. These tech giants have managed to establish themselves in the technology space by creating their own Cloud Computing platforms, AWS, and Microsoft Azure, which are used by many companies and developers around the world. The research focuses on four types of services, Compute Services which include Web Apps and Virtual Machines, Storage and Database Services where application data is stored, Security Services to protect them from external threats and Network Services with which applications can communicate with each other like Virtual Networks. In the third chapter the comparison is made where all the services analyzed in the second chapter are compared in summary tables. In the fourth chapter is the practical part of the work with five exercises so that the reader understands how these services work and how they look visually. The exercises are not intended to explain how various applications are built but to help the reader understand how the analyzed services appear. For example, what an Amazon AWS Virtual Machine looks like, how the architectural features of an Azure Virtual Machine are incorporated into its creation, what the simplest example of a web application looks like, and what an Azure function looks like. As mentioned in the introduction, the purpose of the work was to introduce the reader to the concept of Cloud Computing and through research to inform him about the services offered by two of the largest technology companies by presenting targeted concepts that are analyzed in a short and simple way.

FIGURE SOURCES

Figure 1.1 https://www.equinoxcyber.com/cloud-computing/

Figure 1.2 https://www.educba.com/types-of-cloud-services/

Figure 1.3 https://www.quadrantresource.com/cloudcomputing

Figure 2.1.a The writer

Figure 2.1.b https://aws.amazon.com/

Figure 2.1.c https://www.pngfind.com/mpng/ibxxoTo_service-amazon-web-services-cloud-hd-png-download/

Figure 2.2.a https://docs.aws.amazon.com/AWSEC2/latest/WindowsGuide/ec2-wg.pdf

Figure 2.2.b https://docs.aws.amazon.com/AWSEC2/latest/WindowsGuide/ec2-wg.pdf

Figure 2.2.c https://docs.aws.amazon.com/AWSEC2/latest/WindowsGuide/ec2-wg.pdf

Figure 2.2.d https://docs.aws.amazon.com/AWSEC2/latest/WindowsGuide/ec2-wg.pdf

Figure 2.3.a The writer

Figure 2.3.b https://docs.microsoft.com/en-us/azure/role-based-access-control/overview

Figure 2.3.c https://www.conseil3d.com/en/cloud/

Figure 2.4.a https://docs.microsoft.com/en-us/azure/guides/developer/azure-developer-guide

Figure 2.4.b https://2wtech.com/azure-offers-security-for-app-services/

Figure 2.4.c https://docs.microsoft.com/en-gb/archive/blogs/microsoft_press/free-ebook-microsoft-azure-essentials-fundamentals-of-azure-second-edition

Figure 2.4.d Run a Windows VM on Azure - Azure Reference Architectures https://docs.microsoft.com/en-us/azure/architecture/reference-architectures/n-tier/windows-vm?msclkid=a770f3c6c56b11ecbba3547f2faf93fd | Microsoft Docs

Figure 2.4.e https://anwaryounus.blogspot.com/2018/11/microsoft-azure-compute-services.html

Figure 2.4.f https://docs.microsoft.com/en-us/azure/guides/developer/azure-developer-guide

Figure 2.4.g https://royaldiscount.com/sql-in-azure/

Figure 2.4.h https://docs.microsoft.com/en-us/azure/expressroute/expressroute-introduction

Figure 2.4.i https://docs.microsoft.com/en-us/azure/traffic-manager/traffic-manager-overview

Figure 2.4.j https://docs.microsoft.com/en-us/azure/cdn/cdn-overview

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