UNIT 6 Emerging Technologies

Student Learning Outcomes

By the end of this chapter, students will be able to:

- Understand the basic concepts of cloud computing, including virtualization, scalability, and on-demand access.
- Identify and explain the different types of cloud services: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).
- Describe various cloud deployment models, such as public, private, hybrid, and multi-cloud, and compare their features.
- Recognize the core principles of blockchain technology and the role of peer-to-peer networks in its functioning.
- Explain the applications of blockchain in real-world scenarios, including cryptocurrencies, smart contracts, and product tracking.
- Discuss the implications of cloud computing and blockchain, especially in areas like data security and resource management.
- Explore future trends and innovations in cloud computing and blockchain, including edge computing and Blockchain 2.0.

Introduction

In rapidly evolving landscape of technology, new paradigms and innovations are continuously reshaping the way we interact with the digital world. This chapter explores two of the most transformative technologies of our time: Cloud Computing and Blockchain.

We begin by exploring the fundamentals of Cloud Computing, including its core concepts such as virtualization, scalability, and on-demand access. We will also examine the various types of cloud services like Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS), as well as different cloud deployment models including public, private, hybrid, and multi-cloud environments. Understanding these foundational elements will provide insights into the practical applications and implications of cloud computing in various industries.

Following this, we shift our focus to Blockchain Technology, starting with its basic principles and components, such as the peer-to-peer network that forms the backbone of blockchain's decentralized architecture. We will explore the use cases of blockchain, including its role in cryptocurrencies and smart contracts, and discuss the applications and implications of blockchain in areas like product tracking, financial services, and data security.

The chapter concludes with a look into future trends and innovations within these technologies, including edge computing, serverless architectures, and the next generation of blockchain, often referred to as Blockchain 2.0 and beyond.

6.1 Definition and Overview of Emerging Technologies

Emerging technologies are new tools, systems, and methods that are currently being developed or have only recently started to be used. These technologies have the potential to change the way we live, work, and interact with the world. Here are some of the key emerging technologies:

- **Artificial Intelligence (AI):** AI refers to machines and software that can learn and perform like human beings. AI can help with tasks like recognizing faces, understanding speech, and making decisions. It is used in everything from smart assistants like Siri to self-driving cars.
- **Cloud Computing:** Cloud computing allows people to store and access data and applications over the internet instead of on a local computer or server. This makes it easier to share information, collaborate on projects, and scale up services without needing expensive hardware. Examples include services like Google Drive, Dropbox, and Amazon Web Services (AWS).
- **Blockchain:** Blockchain is a secure way to record and share information across many computers, making it almost impossible to change or hack. It is best known for being the technology behind cryptocurrencies like Bitcoin, but it's also used in other areas like supply chains and contracts.
- **Internet of Things (IoT):** IoT connects everyday objects, like refrigerators, cars, and even clothes, to the internet. This allows them to send and receive data, making our lives more convenient. For example, a smart thermostat can learn your schedule and adjust the temperature in your home automatically.
- **Augmented Reality (AR) and Virtual Reality (VR):** AR adds digital elements to the real world using devices like smartphones or glasses. VR creates a completely virtual environment that you can interact with using special equipment. These technologies are used in gaming, education, and training.
- **5G Technology:** 5G is the next generation of wireless technology, offering much faster internet speeds and more reliable connections. This will enable better performance for cell phones, smart devices, and even new technologies like augmented reality (AR) and virtual reality (VR).
- **Quantum Computing:** Quantum computing is a type of computer that uses tiny building blocks called qubits. Unlike regular bits 0 and 1's, it can be both 0 and 1 at the same time. It allows to solve problem much faster than normal computer.

- **Biotechnology:** Biotechnology involves using living organisms, like bacteria and plants, to create new products or solve problems. Scientists use biotechnology to develop new medicines, improve crops, and produce environmentally friendly materials.

6.2 Cloud Computing

Cloud computing is a model that allows easy and convenient access to computing resources like servers, storage, and applications over the internet. These resources can be quickly provided and released with minimal management effort or service provider interaction. Cloud computing is like having a powerful computer that you can access over the internet. Instead of buying and maintaining your own expensive computers and storage devices, you can use cloud services to store data, run applications, and manage your computing needs. This makes it easier and cheaper to get things done, as you can use as much or as little of the service as you need, and you only pay for what you use. It is like renting a supercomputer that you can use whenever you need it, from anywhere in the world.

6.2.1 Basic Concepts of Cloud Computing

Cloud computing encompasses several basic concepts that are foundational to its functionality and benefits.

6.2.1.1 Virtualization

Virtualization is a technology that allows a single physical machine to run multiple virtual machines. It is like having a magic trick that lets one physical computer act, like many separate computers. Imagine you have a single powerful computer, but with virtualization, you can create several "virtual" computers inside it. Each of these virtual computers can run its own operating system and applications as if they were independent machines.

6.2.1.2 Scalability and Elasticity

Scalability and elasticity are important concepts in cloud computing that help manage resources efficiently.

Scalability means you can add more resources when you need them. For example, imagine you run an online store that usually has a steady number of visitors. However, during busy times like Eid or 14th August sales, you get a huge spike in traffic. With scalability, you can add more servers to handle this increased traffic, ensuring your website runs smoothly without slowing down or crashing.

Elasticity refers to the ability of a cloud system to automatically scale resources, such as computing power, storage, or network bandwidth, up or down based on current demand. such as if an e-commerce website experiences a surge in traffic during a sale, a cloud platform can automatically allocate more servers to handle the load, and scale back down afterward.

6.2.1.3 On-Demand Access

On-demand access means that you can use computing resources whenever you need them, without waiting for a long setup process. This is like being able to turn on a tap to get water whenever you want, instead of having to dig a well first.

Example: Imagine you are working on a school project and suddenly need extra storage space to save your files. With on-demand access, you can instantly rent additional storage from a cloud provider and start using it right away. This saves time and effort, allowing you to focus on your project instead of worrying about storage.

6.2.2 Types of Cloud Services

There are different types of cloud services that cater to various needs. Cloud services are typically categorized into three main types: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). Each type offers different levels of control, flexibility, and management.

6.2.2.1 Infrastructure as a Service (IaaS)

IaaS offers basic computing infrastructure such as servers, storage, and networking on a pay-as- you-go basis. Users have control over the operating systems, applications, and storage, but not the underlying physical infrastructure.

Example: Amazon Web Services (AWS) allows users to rent virtual servers to run their applications. Microsoft Azure and Google Compute Engine are other popular IaaS providers.

6.2.2.2 Platform as a Service (PaaS)

PaaS offers a complete development and deployment environment in the cloud. It includes infrastructure (servers, storage, and networking), middleware, development tools, and management services. Developers can focus on coding and deploying applications without managing the hardware and software layers.

Example: Google App Engine allows developers to build and deploy applications using a variety of programming languages. Other examples include Microsoft Azure App Services and Heroku.

6.2.2.3 Software as a Service (SaaS)

SaaS provides access to software applications that are hosted and managed by the service provider. Users simply subscribe to the service and use it over the internet. This model is convenient for end-users as it requires no hardware management or software updates.

Figure 6.1: Types of Cloud Services

Example: Google Workspace (formerly G Suite) includes applications like Gmail, Google Docs, and Google Drive. Other examples are Microsoft Office 365 and Salesforce.

6.2.3 Cloud Deployment Models

Cloud deployment models define how cloud services are made available and used. Each model offers different levels of control, security, and flexibility. The main cloud deployment models are Public, Private, Hybrid, and Multi-Cloud.

6.2.3.1 Public Cloud

A public cloud is a cloud service offered over the internet that is shared among multiple organizations. It is managed by a third-party cloud service provider.

Example: Amazon Web Services (AWS) is a popular public cloud provider. Businesses of all sizes can use AWS to access computing resources like virtual servers and storage without having to manage the physical hardware themselves.

6.2.3.2 Private Cloud

A private cloud is a cloud environment used exclusively by one organization. It can be hosted on-premises or by a third-party provider, but it is not shared with other organizations.

Example: A large bank may use a private cloud to handle sensitive customer data securely. This private cloud can be hosted within the bank's own data centers or managed by a third-party provider, but only the bank has access to it.

6.2.3.3 Hybrid Cloud

A hybrid cloud combines public and private clouds, allowing data and applications to be shared between them. This model provides greater flexibility and control.

Example: A company may use a public cloud for everyday operations and a private cloud for sensitive data. During busy periods, they can move less sensitive data and applications to the public cloud to handle increased load, while keeping critical data secure in the private cloud.

6.2.3.4 Multi-cloud

A multi-cloud model is a cloud computing strategy where an organization uses services from multiple cloud providers, such as AWS, Microsoft Azure, and Google Cloud-simultaneously to meet different business or technical needs.

Example: A global retail company uses Amazon Web Services (AWS) to host its e-commerce website due to its robust global content delivery and scalability, Microsoft Azure for running its internal enterprise applications like ERP and productivity tools, and Google Cloud Platform (GCP) for advanced data analytics and machine learning services.

6.2.4 Comparing Deployment Models

Each cloud deployment model has its own advantages and disadvantages, depending on the specific needs and goals of the organization.

- **Comparison:** Public clouds are cost-effective but less secure. Private clouds are more secure but expensive. Hybrid clouds offer flexibility, while multi-clouds provide resilience.

6.3 Applications and Implications of Cloud Computing

This section explores key applications of cloud computing and discusses its implications.

6.3.1 Applications of Cloud Computing

Cloud computing has revolutionized the way businesses and individuals manage, process, and store data. Its diverse applications span various sectors, offering scalable and cost-effective solutions that enhance efficiency and innovation.

6.3.1.1 Data Storage

Cloud storage allows users to save data on remote servers rather than on local devices. This makes it easier to access data from anywhere and share it with others.

Example: Services like Google Drive and Dropbox provide cloud storage solutions that let users store and share files online. Businesses can use cloud storage to keep backups of their data, ensuring it is safe from local hardware failures or other issues.

6.3.1.2 Web Hosting and Content Delivery

Cloud computing provides the infrastructure needed to host websites and deliver content efficiently to users around the world.

Example: Platforms like Amazon Web Services (AWS) and Microsoft Azure offer web hosting services that allow businesses to run their websites on cloud servers. Content delivery networks (CDNs) such as Cloudflare help deliver website content quickly by caching it on servers close to the end-users.

6.3.1.3 Machine Learning and AI in the Cloud

Cloud computing offers powerful tools for developing and running machine learning models and artificial intelligence applications.

Example: Google Cloud AI and AWS SageMaker provide cloud-based platforms for building, training, and deploying machine learning models. These services make it easier for data scientists and developers to create AI solutions without needing extensive local computing resources.

6.3.2 Implications of Cloud Computing

While cloud computing offers numerous benefits, it also brings various implications that need to be considered.

6.3.2.1 Data Security

Security is a significant concern in cloud computing. Storing sensitive data on remote servers introduces risks such as data breaches and loss.

- **Security Challenges:** Cloud providers implement robust security measures, but users must also take steps to protect their data. Issues such as data breaches, unauthorized access, and loss of data can occur.
- **Security Measures:** To mitigate risks, users should use encryption, strong authentication methods, and regularly review their security policies. Providers often offer tools to help manage and secure data.

6.3.2.2 Scalability and Resource Management

Cloud computing allows for scalability, meaning resources can be adjusted according to demand. However, effective resource management is essential to avoid unnecessary costs and ensure optimal performance.

- **Scalability:** Cloud services can automatically scale resources up or down based on demand, such as adding more servers during peak times and reducing them when demand decreases.
- **Resource Management:** Proper management practices, such as monitoring resource usage and optimizing performance, help control costs and ensure efficient use of cloud resources.

6.3.2.3 Cost Considerations

While cloud computing can be cost-effective, it requires careful financial management. Users pay for what they use, and costs can quickly add up if not monitored.

- **Cost Management:** To manage costs, users should regularly review their cloud usage and spending, optimize resource allocation, and take advantage of pricing plans that fit their needs.

6.3.2.4 Compliance and Regulatory Issues

Organizations must ensure that their use of cloud services complies with legal and regulatory requirements, which can vary by region and industry.

- **Compliance:** Organizations need to adhere to regulations related to data privacy, security, and industry-specific standards. Cloud providers often offer tools and features to help meet these requirements.

Class Activity

Create a list of cloud-based services you use or are familiar with. For each service, describe how it benefits you or your organization and any security measures you use to protect your data.

6.4 Introduction to Blockchain Technology

Blockchain technology is a revolutionary concept that enables secure and transparent transactions through a distributed ledger system. This section introduces the fundamentals of blockchain technology, including its core principles and key components.

6.4.1 Fundamentals of Blockchain

Blockchain is like a digital notebook that's shared with everyone in a group. Imagine a group of friends keeping track of who owes whom money. Instead of writing it down on a piece of paper that one person keeps, they all write it down in a notebook that everyone has a copy of. Every time someone makes a change, like paying back money, it gets recorded in all the notebooks at the same time. The notebook as a blockchain network is shown in Figure 6.2.

Now, this digital notebook, or **blockchain,** has some special features:

- **Transparency:** Everyone in the group can see what's written in the notebook, so it's hard for anyone to cheat or change the information without others noticing.

- **Security:** Once something is written in the notebook, it's almost impossible to erase or change it. This is because it's protected by a special kind of math called cryptography, which locks the information in place.
- **Decentralization:** There is no single person or computer in-charge of the notebook. Instead, everyone has an equal copy, and changes are only made when the majority agree, making it fair and trustworthy.

In simple terms, blockchain is a secure and transparent way for people to share and keep track of information without needing to rely on one person or company to keep it safe.

6.4.1.1 Core Principles

Blockchain technology is built on several core principles that ensure its functionality and security:

Decentralization: Unlike traditional databases that are controlled by a central authority, a blockchain is maintained by a network of computers (nodes) that work together to validate and record transactions. This decentralized nature reduces the risk of a single point of failure and enhances security.

- **Immutability:** Once a block is added to the blockchain, it cannot be altered or deleted. This immutability ensures that the transaction history is permanent and tamper-proof, providing a reliable and unchangeable record of all transactions.
- **Consensus Mechanisms:** Blockchain networks use consensus mechanisms to agree on the validity of transactions. These mechanisms ensure that all nodes in the network reach a unanimous decision before adding a new block to the chain.

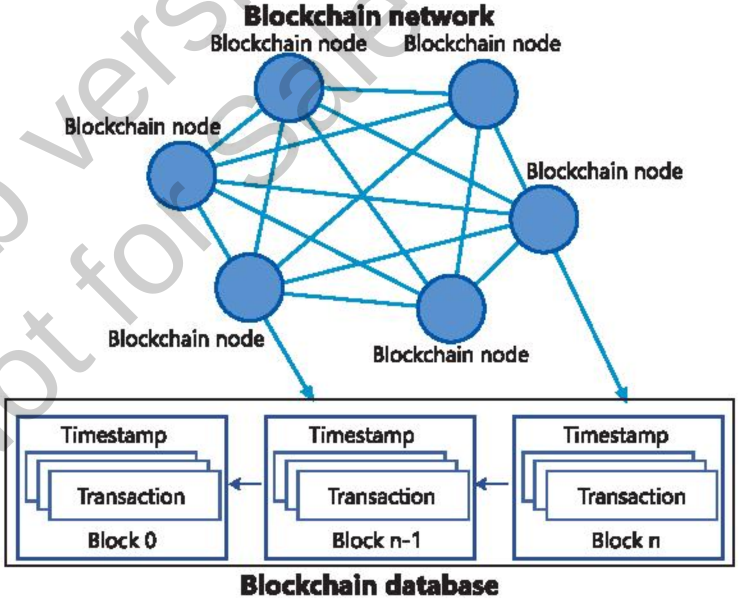

Figure 6.2: Architecture of Blockchain

6.4.1.2 Blockchain Components

Several key components make up a blockchain system:

- **Node:** A node is a computer that participates in the blockchain network. Each node maintains a copy of the blockchain and helps validate transactions and blocks.
- **Ledger:** The ledger is a shared digital record of all transactions that have occurred on the blockchain.
- **Block:** A block is a collection of transactions that are bundled together. Each block contains a unique identifier (hash), a reference to the previous block (parent hash), and a list of transactions.
- **Transaction:** A transaction is an individual entry in the blockchain. It represents the transfer of assets or information between participants in the network.
- **Blockchain Protocol:** The blockchain protocol defines the rules and procedures for how transactions are validated, how blocks are added to the chain, and how consensus is achieved. It ensures the integrity and security of the blockchain network.

6.4.1.3 Peer-to-Peer Network and Its Usage in Blockchain

A peer-to-peer (P2P) network is a system where computers, called nodes, communicate and share resources directly with each other without relying on a central server. Each node in the network can act as both a client and a server, making the network more robust and decentralized.

For example, in a file-sharing network, users can download files directly from each other's computers rather than from a single central server. This makes the process faster and more efficient, as multiple users can share parts of the file simultaneously.

6.4.2 Use Cases of Blockchain Technology

Blockchain technology has a wide range of applications beyond cryptocurrency. Some notable use cases include:

- **Cryptocurrencies:** Blockchain is the underlying technology for cryptocurrencies like Bitcoin and Ethereum. It enables secure, decentralised digital transactions without the need for intermediaries.
- **Supply Chain Management:** Blockchain can be used to track and verify the movement of goods through the supply chain. This transparency helps prevent fraud, reduce errors, and ensure the authenticity of products.
- **Healthcare:** In healthcare, blockchain can securely store patient records, manage medical data, and ensure that only authorised individuals have access to sensitive information.
- **Voting Systems:** Blockchain can be used to create secure and transparent voting systems, ensuring that votes are accurately recorded and counted, and reducing the risk of election fraud.

6.4.3 Cryptocurrencies and Smart Contracts

Cryptocurrencies and smart contracts have brought major changes to digital finance and decentralized applications. Cryptocurrencies are digital currencies that work without traditional banks, allowing direct transactions between people worldwide. Smart contracts are automated agreements written in code that execute themselves when certain conditions are met.

6.4.3.1 Role of Cryptocurrencies

Cryptocurrencies are important in the digital economy because they offer a secure and decentralized way to exchange money. Unlike traditional money issued by banks, cryptocurrencies use blockchain technology to keep transactions safe and transparent. This technology ensures that transactions are recorded in a way that cannot be changed, without needing middlemen.

6.4.3.2 Smart Contracts

Smart contracts are digital agreements that automatically carry out the terms written into them when specific conditions are met. These contracts run on blockchain technology, removing the need for intermediaries and reducing the risk of errors and fraud. Platforms like Ethereum enable developers to create decentralized applications (DApps) using smart contracts.

However, they also have challenges, such as the need for error-free code and legal systems to resolve disputes related to these contracts.

6.5 Applications and Implications of Blockchain

Blockchain is a special kind of technology that helps keep information safe and secure. It's like a digital notebook that everyone can see, but no one can change. Let's explore how it's used in the real world.

6.5.1 Tracking the Origin of Products

Blockchain technology offers a transparent and secure method to track the origin and journey of products through various stages of the supply chain. By recording every transaction on a decentralized ledger, blockchain ensures that each step, from the raw material supplier to the final customer, is traceable and immutable.

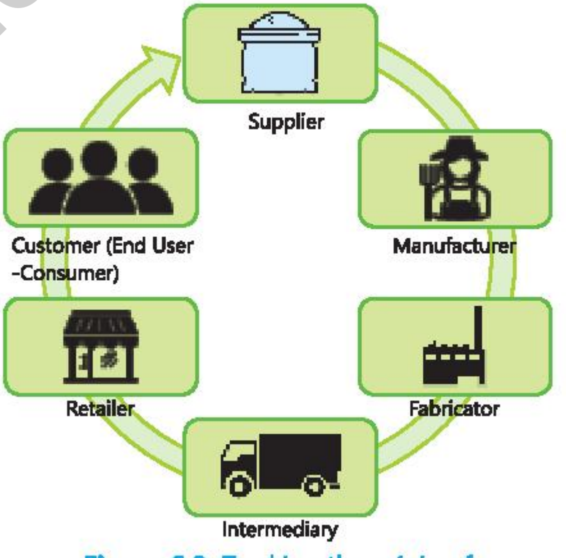

Figure 6.3: Tracking the origin of chocolate using blockchain

In Figure 6.3, the connections between different entities in a supply chain are illustrated. The blockchain records interactions between suppliers, manufacturers, fabricators, intermediaries, retailers, and customers. Each transaction is securely logged on the blockchain, making it possible to track the journey of a product from its origin to the end consumer.

DO YOU KNOW? Some artists use blockchain to sell digital art. Each piece of art has a unique digital signature that proves authenticity and originality.

6.5.2 Blockchain in Financial Services

Banks and financial services use blockchain to make transactions faster and safer. For example, sending money abroad can be slow and expensive. Blockchain makes it quicker and cheaper.

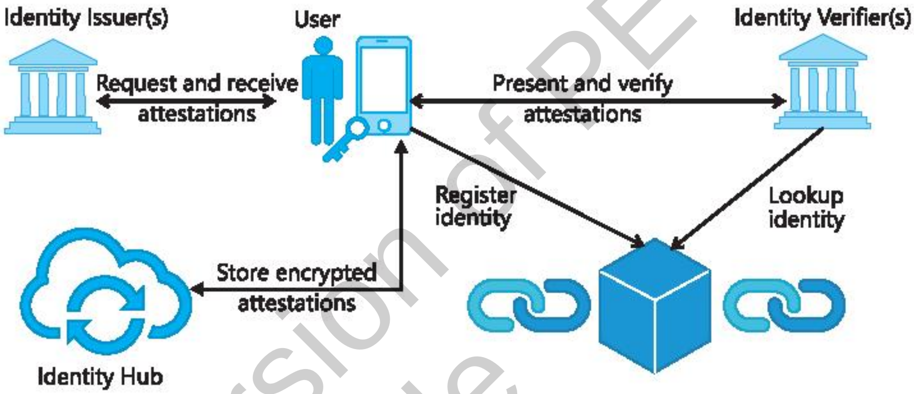

Figure 6.4: Blockchain in banking for faster and safer transactions

6.5.3 Data Security in Blockchain

Data security in blockchain ensures that information stored in a blockchain is protected from unauthorized access, tampering, or loss. To explain this in simple terms, let's use an example that relates to something we encounter daily: sending a letter through the mail.

Example: Sending a Secure Letter

Imagine you want to send a letter containing important information to a friend. You want to make sure that no one else can read or change the letter while it's being delivered.

- **Sealing the Letter (Encryption):** Before sending the letter, you place it in a special envelope that can only be opened by your friend. This is like encryption in blockchain, where the data is turned into a code that only the intended recipient (or those with the right key) can understand, as shown in Figure 6.5.
- **Signing the Letter (Digital Signature):** You then sign the envelope with your unique signature. This signature is known to your friend, they can be sure the letter came from you and hasn't been altered. In blockchain, this is called a digital signature, which ensures that the data comes from a legitimate source and hasn't been tampered with.

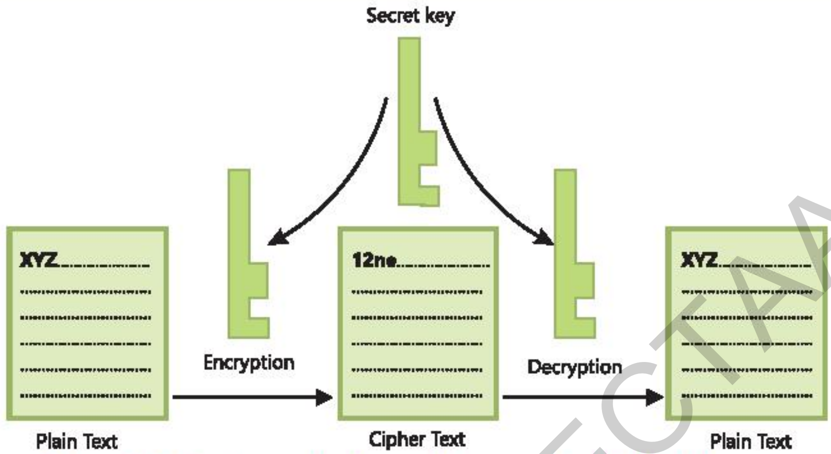

Figure 6.5: Cryptography keeps data secure in blockchain

- **Sending the Letter through a Trusted System (Blockchain Network):** Instead of using just any mail service, you use a trusted, secure delivery service where every step of the delivery is recorded. If anyone tries to change the route or tamper with the letter, the system will detect it, and the attempt will be rejected. This is similar to the blockchain network, where each piece of data is recorded in a block, and any change to this block will be noticed by the network.
- **Multiple Copies of the Letter (Decentralization):** To make sure the letter isn't lost, you send copies of it through different trusted delivery services to multiple locations. Even if one letter is lost, others will reach safely. In blockchain, this is called decentralization, where the data is stored across multiple computers (nodes), so even if one is compromised, the data remains safe.

Class Activity

Class Activity! Imagine you have a secret code. Write a message to a friend using your code and see if they can decode it.

DO YOU KNOW?

Do you know? Big companies like Amazon and Microsoft use their powerful computers to help run blockchain networks.

6.6 Future Trends and Innovations

Emerging technologies continue to evolve, with future trends and innovations shaping the landscape of cloud computing and blockchain. This section explores some of the most promising advancements in these fields, highlighting how they are transforming our technological ecosystem.

6.6.1 Evolving Technologies in Cloud Computing

Cloud computing is advancing with new technologies that enhance its capabilities and applications, making it more efficient, scalable, and accessible.

6.6.1.1 Edge Computing

Edge computing brings processing power closer to data sources, reducing latency and improving efficiency. Instead of relying solely on centralized data centers, edge computing processes data at the "edge" of the network, near the data source. This approach minimizes the time it takes for data to travel, leading to faster decision-making and real-time data processing.

Example:

In autonomous vehicles, edge computing allows data from sensors and cameras to be processed locally in the vehicle, enabling quick responses to changing road conditions and enhancing safety.

Tidbits

Edge computing is especially beneficial for applications requiring real-time processing and low latency, such as smart cities, healthcare monitoring, and industrial automation.

6.6.1.2 Serverless Architectures

Serverless architectures allow developers to build and deploy applications without managing servers, enhancing scalability and reducing operational complexity. In a serverless model, cloud providers automatically allocate resources as needed, and developers only pay for the actual usage of computing resources.

Example: Amazon Web Services (AWS) Lambda is a serverless computing service that lets developers run code without provisioning or managing servers. This enables developers to focus on writing code and building applications rather than managing infrastructure.

EXERCISE

Multiple Choice Questions (MCQs)

1. The main benefit of edge computing:
   a) Lower cost
   b) Reduced latency
   c) Increased complexity
   d) Enhanced security
2. A cloud deployment model with resources shared among multiple organizations with common concerns:
   a) Public Cloud
   b) Private Cloud
   c) Community Cloud
   d) Hybrid Cloud
3. The advantage of using a distributed ledger in blockchain technology:
   a) Centralized control for quick decision-making
   b) Easy alteration of transaction histories
   c) Enhanced transparency and security through decentralized verification
   d) Lower computational requirements
4. A cloud deployment model combining public and private cloud features:
   a) Public Cloud
   b) Hybrid Cloud
   c) Community Cloud
   d) Multi-Cloud
5. The purpose of a distributed ledger in blockchain:
   a) Central authority management
   b) Secure and transparent data sharing among multiple participants
   c) Fewer participants required
   d) Data visibility only to central authority
6. A cloud service offering a platform for developing, running, and managing applications without managing infrastructure:
   a) Infrastructure as a Service (IaaS)
   b) Platform as a Service (PaaS)
   c) Software as a Service (SaaS)
   d) Data as a Service (DaaS)
7. The service model enabling application deployment without server management:
   a) Infrastructure as a Service (IaaS)
   b) Platform as a Service (PaaS)
   c) Software as a Service (SaaS)
   d) Serverless Architecture
8. The feature introduced in Blockchain 2.0 beyond cryptocurrency:
   a) Enhanced mining techniques
   b) Decentralized applications and smart contracts
   c) Better graphics
   d) Faster internet speeds

9. The primary advantage of serverless architectures:

a) Cost savings

b) Constant server management

c) Increased hardware needs

d) Manual scaling

Short Questions

1. Analyze the role of Peer-to-Peer Networks in Blockchain. How do they function and why are they essential?
2. Describe the concept of immutability in blockchain. Why is it a critical feature?
3. What is edge computing and how does it benefit data processing?
4. Describe the concept of serverless architectures.
6. What advantages do serverless architectures offer to developers?
8. How does edge computing improve the efficiency of autonomous vehicles?
9. Differentiate between Elasticity and On-Demand access in cloud computing.

Long Questions

1. Define cloud deployment models and assess the differences among them.
2. Classify the various types of cloud services and compare them, highlighting key distinctions.
3. Discuss the advancements and benefits of edge computing in modern technology.
4. Explain the concept of serverless architectures and their impact on application development.
5. Describe "Cloud Deployment Models" with examples.