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IT402
Internet of Things

Lecture 8



IoT Cloud Computing

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Learning Objectives:

- 1.1 Describe the cloud computing
- 1.2 Describe the integration of IoT and cloud
- 1.3 Describe the cloud computing advantages and challenges

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Cloud Analytics for IOT Applications

- Cloud analytics for IoT applications refers to the use of cloud computing platforms and data analytics techniques to process, analyze, and gain insights from the vast amount of data generated by Internet of Things (IoT) devices.
- This data, often referred to as IoT data or sensor data, can be structured or unstructured and is typically generated in real time or near real time. Cloud analytics provides the infrastructure and tools to effectively manage and analyze this data, extracting valuable information and enabling intelligent decision-making.
- The evolution of computing technology can be traced back to the 1940s and 1950s, with the advent of the first commercial computer. The evolution of cloud computing since then has been illustrated in Figure 8.1.

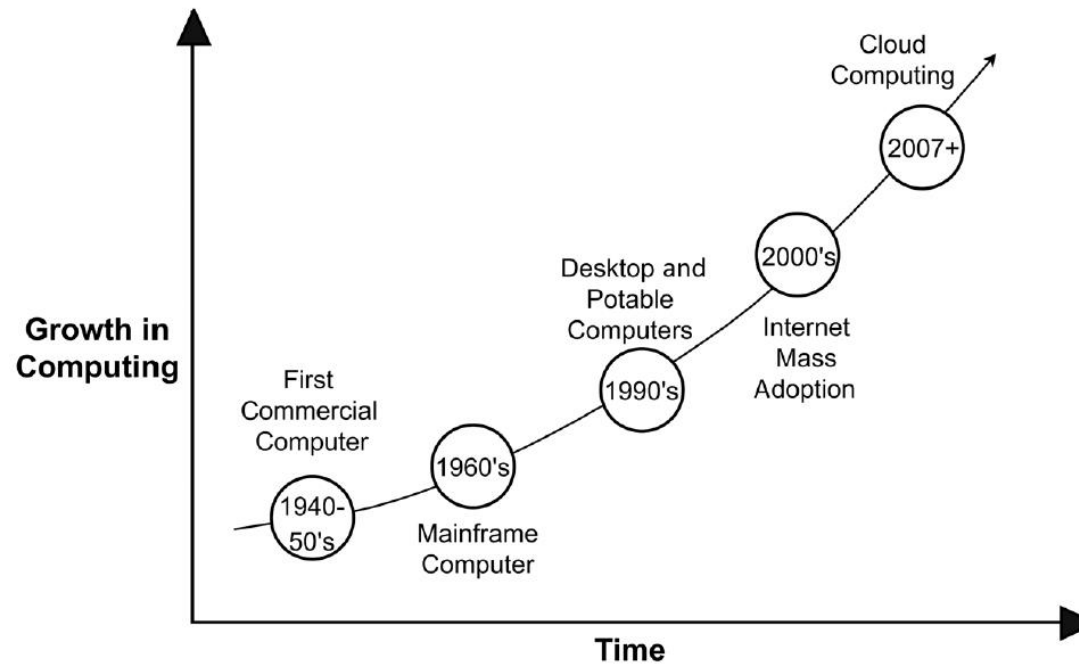


Figure 8.1: Evolution of cloud computing

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Introduction to Cloud Computing

- Cloud computing is a **technological advancement that enables the distribution of computing services** via the internet, encompassing servers, storage, databases, networking, software, analytics, and intelligence, among other resources .It essentially provides **computing resources as a service, whereby third-party providers possess and operate the resources for the benefit of the end-users.**
- This eliminates the need for **end-users to worry about the hardware and software infrastructure and their locations, as the resources are accessible through the internet via a metaphorical “cloud.”**
- The **flexibility and scalability** of cloud computing have made it an **attractive option for individuals and organizations** alike, allowing them to focus on their core activities while leaving the complexities of IT infrastructure to cloud providers.

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Introduction to Cloud Computing

These are two major advantages:➤ Flexibility

- Users can quickly:
- Add more storage
- Increase computing power
- Install new software
- Expand to new regions

All without purchasing new equipment.

➤ Scalability

- Cloud resources automatically adjust depending on user demand:
- High demand → more resources automatically assigned
- Low demand → resources scale down to avoid extra cost
- This is essential for organizations whose workloads vary over time.

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Introduction to Cloud Computing

- The advent of cloud computing has resulted in a shift from on-premises software and hardware to a **networked, remote resource, freeing companies from the need to invest in labor, expertise, or capital for the maintenance of such resources.**
- Traditionally, organizations used **on-premises** infrastructure. This means:
 - Servers were physically located inside the company.
 - The organization purchased and owned all hardware.
 - The IT team installed and maintained operating systems, applications, security, and networking.
 - Companies spent a lot of **money, time, and expertise** on managing their own data centers.
- With the arrival of cloud computing, this model changed completely.

This shift freed organizations from:

- Buying expensive hardware
- Maintaining servers and storage
- Hiring specialized IT staff
- Managing daily operations (cooling, electricity, security, updates)

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Introduction to Cloud Computing

- The emergence of cloud computing has led to the rise of **various cloud providers**, including major players like **AWS and Microsoft Azure** . These providers operate **huge global data centers and rent their computing resources to customers** on a **pay-as-you-use** basis.
- Cloud computing offers an alternative to on-premises data centers, which require **users to manage everything, from hardware and virtualization to installing operating systems, applications, and configuring network and storage (Figure 8.2)** .
- In contrast, cloud vendors are responsible for **purchasing and maintaining hardware, and they offer a range of software and platform services that can be rented based on usage**. The cloud infrastructure provides an internet-based platform that makes it easy for users to manage computing, storage, networking, and application resources.

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Introduction to Cloud Computing

❑ **Cloud Services Are “Rented” Based on Use** : Cloud computing uses a model similar to utilities (electricity, water).

➤ You only pay for what you use.

For example:

- Rent storage by the GB
- Rent a virtual machine by the hour
- Pay based on database queries
- Pay for bandwidth consumed

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Introduction to Cloud Computing

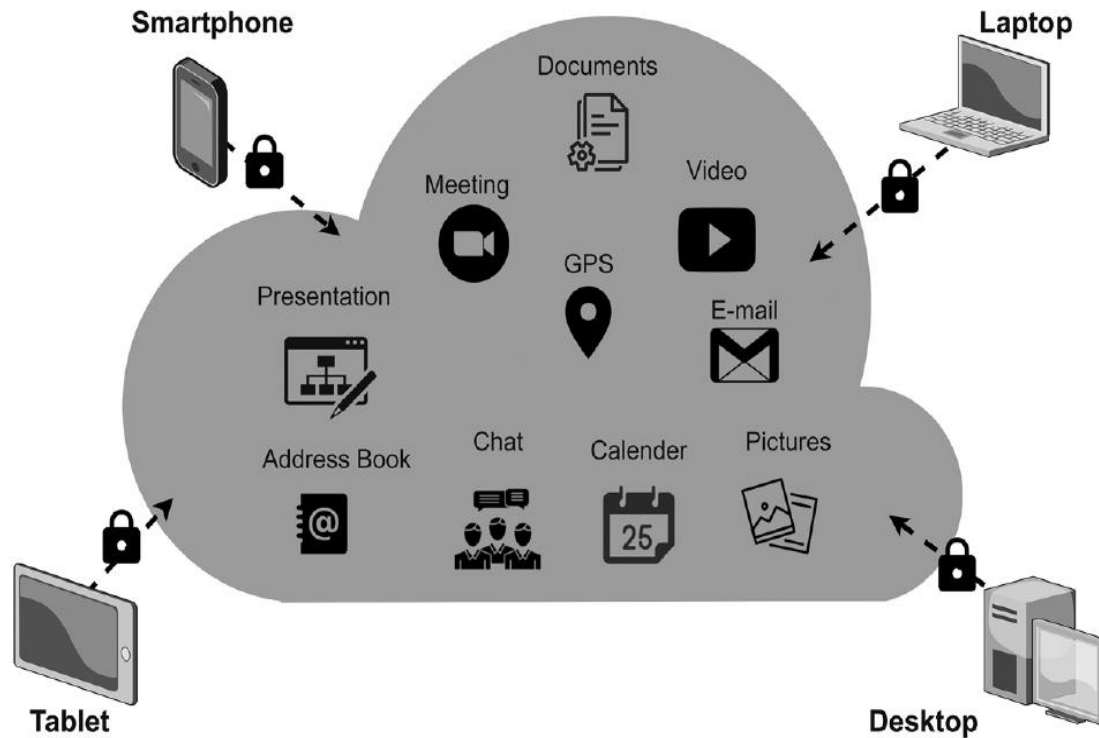
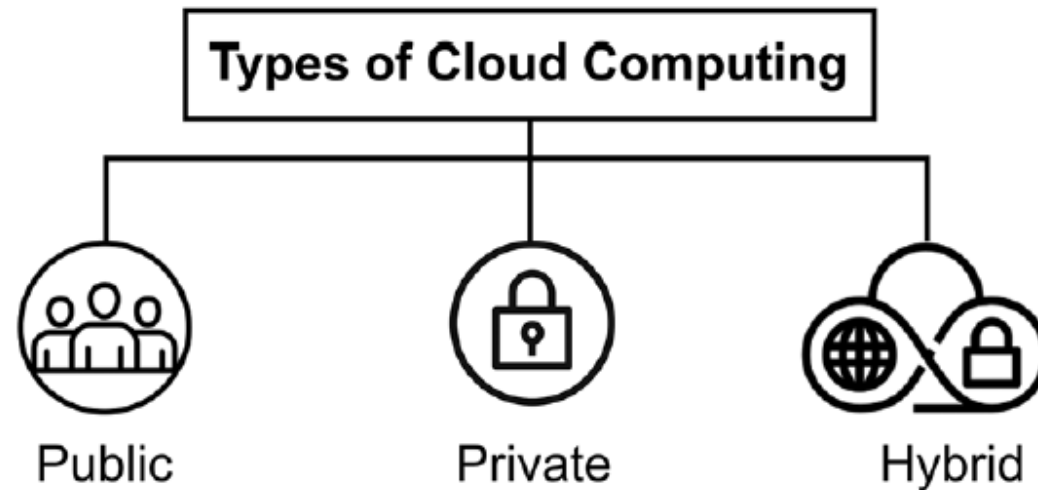


Figure 8.2 : Application of the cloud

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Introduction to Cloud Computing

- Cloud computing technology can be broadly categorized into three types: **public cloud**, **private cloud**, and **hybrid cloud**. The distinguishing characteristics of each type are as follows.



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Introduction to Cloud Computing

- **Public Cloud:** Public clouds refer to **cloud resources that are owned and operated by a third-party cloud service provider**. These providers include companies like:
 - **Amazon Web Services (AWS)**
 - **Microsoft Azure**
 - **Google Cloud Platform (GCP)**
- **How it works**
 - The cloud provider owns all the hardware (servers, storage, networking).
 - Users access these resources **over the internet**.
- Public clouds are open to **multiple users and are usually priced according to usage**.
- Multiple customers share the **same physical infrastructure**.

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Introduction to Cloud Computing

- **Private Cloud:** Private clouds are exclusive to a **single business or organization**.
- These resources may be located **on-site** (inside the organization's data center) **or hosted by a third-party** but still exclusive to one company (e.g., IBM Cloud Private).
- Private clouds are typically more secure than public clouds, as Only authorized users within the organization can access the resources.
- **Private clouds are best for:**
 - Banks
 - Government agencies
 - Hospitals

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Introduction to Cloud Computing

- **Hybrid Cloud:** Hybrid clouds are a **combination of public and private clouds**.
- **Data and applications** are shared between the two, **allowing for greater flexibility and deployment options**.
- **How it works**
 - Sensitive data is stored in the **private cloud**.
 - Less sensitive applications or workloads run in the **public cloud**.
 - Both environments communicate using encrypted links, APIs, or hybrid cloud platforms.
- **Hybrid cloud provides organizations with the best of both worlds:**
- ✓ **Public cloud:** scalability, cost reduction
- ✓ **Private cloud:** security, control
- Example scenario:**
 - A hospital might:
 - Store patient medical records in a private cloud (for privacy and compliance).
 - Run its website or appointment system in a public cloud.
 - Use public cloud analytics tools to analyze non-sensitive data.

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Introduction to Cloud Computing

- Cloud computing and fog computing are two important computing paradigms that support modern technologies such as **IoT, smart cities, and distributed systems**.
- Although both approaches help organizations manage data and communication efficiently, they operate at **different levels of the network** and serve different purposes.
- **Fog computing—commonly called fogging**—was introduced as an extension of cloud computing to address its limitations, particularly **latency, bandwidth usage, and the need for real-time processing**.
- Fog architecture brings **computing power closer to the users and devices by enabling processing** at **edge nodes**, which are physical **devices located near data sources**.

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Introduction to Cloud Computing

- Fog computing creates a middle layer between cloud data centers and end devices, allowing IoT devices to process data locally instead of sending everything to the centralized cloud.
- This makes fog computing critical for applications that require immediate responses, such as autonomous vehicles, industrial automation, real-time monitoring, and smart healthcare.
- The key contrasts between cloud computing and fog computing are explained in the following :
- Architecture: **Cloud Computing Architecture (Centralized)**
 - Cloud systems rely on large, centralized data centers hosted by providers like AWS and Azure.
 - All data from user devices must travel across the internet to reach these data centers.
 - The structure is based on a central location where storage, processing, and management occur.
 - **Example:**
A wearable health device sends data to a distant cloud server for analysis.

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Introduction to Cloud Computing

- The key contrasts between cloud computing and fog computing are explained in the following :
- Architecture:
 - Fog Computing Architecture (Decentralized)
 - Fog computing distributes processing across multiple local nodes, such as routers, gateways, or micro-servers.
 - Instead of a single central location, fog nodes operate close to the data source (edge devices).
 - This architecture reduces dependency on faraway data centers.
 - **Example:**

A smart traffic light processes vehicle data on a nearby fog node to adjust signals instantly.

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Introduction to Cloud Computing

- The key contrasts between cloud computing and fog computing are explained in the following :
- Use Cases:
 - **Cloud Computing Best For:**
 - Large-scale data storage
 - Big data analysis
 - Machine learning model training
 - Applications requiring huge computational power
 - **Fog Computing Best For:**
 - Applications requiring:
 - **Low latency**
 - **Real-time processing**
 - **Immediate analytics**
 - **Proximity to data sources**

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Introduction to Cloud Computing

➤ The key contrasts between cloud computing and fog computing are explained in the following :

➤ Processing:

- Cloud Processing

- Data is transmitted to remote **cloud servers where computation happens.**

- Fog Processing

- Data is processed **locally** on fog nodes before being sent to the cloud (if needed).
- Reduces the load on the cloud.

- Example:

A factory machine detects an anomaly and processes data locally to shut down instantly—no need to wait for cloud analysis.

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Introduction to Cloud Computing

➤ Latency:Cloud Latency (Higher)

- Data must travel long distances to remote data centers.
- This can result in delays—**unacceptable for real-time applications.**
- **Scenario:**
A self-driving car cannot wait milliseconds for a cloud server response to detect obstacles.

Fog Latency (Lower)

- Fog nodes are located **close to IoT devices.**
- Local processing **minimizes delay, enabling immediate response.**
- **Scenario:**
Smart grid systems adjust electricity distribution instantly using fog processing.

Feature	Cloud Computing	Fog Computing
Architecture	Centralized	Decentralized (edge nodes)
Processing	Remote data centers	Local edge/fog nodes
Latency	Higher	Very low
Bandwidth	High usage	Low usage
Security	Strong but centralized	Extra local security, less exposure
Best Use	Big data, storage, heavy computing	Real-time, IoT, low-latency apps

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Introduction to Cloud Computing

- Advantages of Cloud Computing: Cloud computing offers various benefits to organizations, including the following:
- **Cost Effectiveness:** Cloud computing eliminates the need for organizations to invest heavily in physical hardware, software licenses, and data center infrastructure. Instead, they pay only for the resources they use through a pay-as-you-go or subscription model, which significantly reduces capital expenditure.
- **Speed:** Cloud platforms allow businesses to deploy servers, databases, applications, and services within minutes. This instant availability removes delays caused by purchasing, installing, and configuring physical systems.
- **Security:** Most cloud vendors offer strong security frameworks, including data encryption, access management, and advanced monitoring systems, which protect the stored data .

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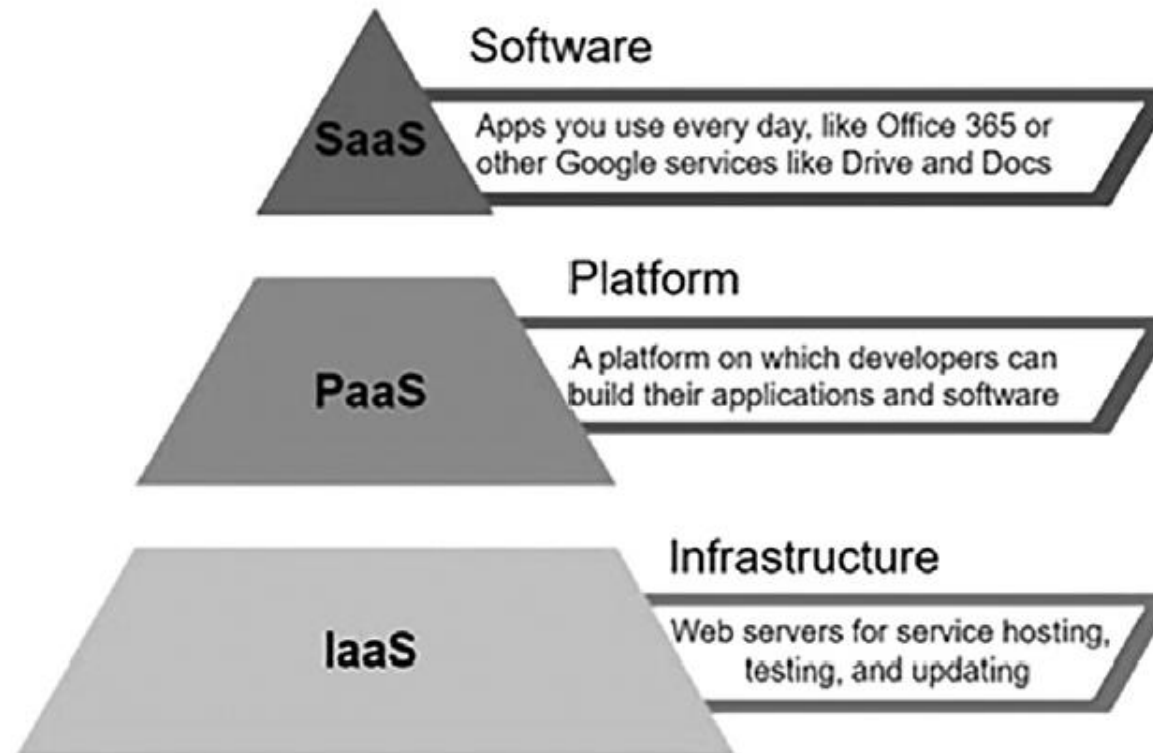
Introduction to Cloud Computing

- Cloud computing has progressed from its fundamental notion of supplying computing resources on-demand through the internet, to more advanced services that address diverse business requirements. The next evolution of cloud computing centers around delivering software, platforms, and infrastructure as services.
- Over time, cloud computing grew into a sophisticated ecosystem offering different layers of services that address various business needs. These layers are known as:
 - **Software as a Service (SaaS)**
 - **Platform as a Service (PaaS)**
 - **Infrastructure as a Service (IaaS)**
- These models represent different levels of control, responsibility, and flexibility for the user.

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Introduction to Cloud Computing

Development of cloud computing



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Introduction to Cloud Computing

- **Software-as-a-Service (SaaS):** is a cloud model where the provider hosts a complete software application and makes it accessible to users via the internet.
- Users **do not install anything** on their computer.
- The cloud provider manages everything: **software updates, security, servers, and storage.**
- Users **only need a web browser** or a thin client to access the application.
- It reduces **maintenance effort and cost** for businesses.
- **Examples**
 - Gmail, Outlook (email services)
 - Google Workspace, Microsoft 365 (office applications)

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Introduction to Cloud Computing

- **Platform-as-a-Service (PaaS):** PaaS provides a cloud-based environment for building, testing, and deploying applications without worrying about the underlying hardware or operating systems.
 - **What the provider manages**
 - Infrastructure (servers, storage, networking)
 - Operating systems
 - Databases
 - **What the customer manages**
 - Application code
 - Application deployment
 - Application data
- **Examples**
 - Microsoft Azure App Services

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Introduction to Cloud Computing

Infrastructure-as-a-Service (IaaS): IaaS provides virtualized computing resources over the internet, such as:

- Virtual machines
- Storage
- Network components
- Organizations can build any type of IT environment they want using these virtual resources.

Examples

- Amazon Web Services (AWS)
- Microsoft Azure

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The Role of Cloud Computing in IoT

- The “**cloud**” refers to a centralized infrastructure where data, files, and applications are stored, processed, and managed in **remote data centers** connected through the internet.
- IoT devices generate **huge volumes of data every second**—far more than a device can store or process on its own. **Because of this: The IoT depends on cloud computing for:**
- **Storage:** Sensors send data **to the cloud instead of storing it locally.**
- **Processing power:** Cloud servers **analyze large datasets efficiently.**
- **Accessibility:** Data is accessible **from anywhere, anytime.**
- **Integration:** Cloud applications **can communicate with multiple devices.**
- **Security & backups:** Cloud ensures **reliable, secured, and backed-up data.**
- Thus, **the integration of cloud and IoT forms the backbone of many modern smart systems.**

The Role of Cloud Computing in IoT

- **Benefits and Functions of IoT Cloud:** The combination of IoT and cloud computing offers numerous benefits and functions :
- **Multiple Connectivity Options and Wide Network Access:** IoT–cloud computing offers high accessibility and rich connectivity features because:
 - Cloud resources can be accessed from **any device** connected to the internet (laptops, tablets, smartphones, etc.).
 - IoT cloud services work as **on-demand web services**, meaning anyone with internet access can use the service instantly.
 - Developers **do not need special permissions or physical hardware**; they can build and deploy IoT applications online. This wide network access **promotes mobility, remote access, and seamless** device connectivity.

The Role of Cloud Computing in IoT

- **Benefits and Functions of IoT Cloud:** The combination of IoT and cloud computing offers numerous benefits and functions :
- **High Scalability:** IoT devices generate increasing amounts of data as the system grows. Cloud computing supports this growth through:
 - **Scalable storage:** Users can **add more storage instantly as data increases**.
 - **Scalable processing power:** Cloud computing can handle larger workloads when more IoT data streams are generated.
 - **Scalable user access:** More users or devices can be added **without disrupting system performance**.
 - This scalability **ensures that IoT systems can expand to thousands or millions of devices without crashing**.

The Role of Cloud Computing in IoT

- **Benefits and Functions of IoT Cloud:** The combination of IoT and cloud computing offers numerous benefits and functions :
- **Resource Pooling and Collaboration:** Cloud computing brings together shared computing resources such as:
 - Storage
 - Networks
 - Servers
 - Applications
- **These resources are **pooled** and shared among multiple users, which:**
 - Enhances collaboration
 - Supports teamwork
 - Improves communication between devices and users
 - Allows multiple applications or devices to utilize the same infrastructure

The Role of Cloud Computing in IoT

- **Benefits and Functions of IoT Cloud:** The combination of IoT and cloud computing offers numerous benefits and functions :
- **Cost Effectiveness:**
 - IoT cloud computing saves money because:
 - Users pay **only for the services and resources they consume**.
 - No need to buy expensive hardware or maintain large data centers.
 - Service providers **measure resource usage (storage, CPU usage, bandwidth)** so billing is precise and fair.
 - Businesses can start small **and expand later without major upfront costs**.
- **This makes IoT solutions affordable even for small companies and startups.**

The Role of Cloud Computing in IoT

- **Benefits and Functions of IoT Cloud:** The combination of IoT and cloud computing offers numerous benefits and functions :
- **Enhanced Security Through Cloud-Based Protection:**
- As IoT grows, so do security risks such as unauthorized access, data breaches, and cyberattacks. Cloud computing improves security through:
 - **Authentication:** Ensuring only authorized users/devices can access the system.
 - **Encryption:** Protecting data during transmission and storage using cryptographic techniques.
 - **Continuous monitoring:** Detecting threats in real time.
 - **Standardized security frameworks** followed by major cloud providers.
 - This strengthens the security posture of IoT applications and ensures safe data exchange.

The Role of Cloud Computing in IoT

- How IoT and Cloud Will Transform Information Management:
- The integration of cloud computing and IoT is reshaping the way information is:
 - **Collected** (through smart sensors and devices)
 - **Stored** (in scalable cloud data centers)
 - **Analyzed** (using cloud-based analytics tools)
 - **Accessed** (from anywhere, at any time)
- Cloud computing is the ideal platform for IoT because it provides:
 - **Computing power** → to process massive sensor data
 - **Reliability** → through backup, redundancy, and high availability
 - **Connectivity** → allowing devices to interact seamlessly over the internet
- As hybrid cloud adoption grows, businesses benefit from combining private and public cloud flexibility. This trend will continue, enabling new IoT solutions in smart homes, smart cities, healthcare, agriculture, and industry.

The Role of Cloud Computing in IoT

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- The integration of cloud computing and IoT has the potential to accelerate the growth of the internet. However, implementing this integration poses several challenges, ranging from handling large amounts of data to managing network communication protocols and sensor networks, as described in the following.
- **Handling Large Amounts of Data:** IoT devices generate **massive volumes of data every second**. This leads to several issues:
 - Millions of sensors produce continuous data streams (temperature, speed, humidity, location, video, etc.).
 - Storage requirements increase rapidly.
 - Processing real-time data becomes difficult as the system scales.
 - Bandwidth usage increases, causing delays or bottlenecks.
- **Impact:**
 - Application performance may slow down.
 - Real-time analytics may become unreliable.
 - System overload or downtime may occur if data is not managed efficiently.

Network and Communication Protocol Challenges:

- IoT devices use various communication technologies and protocols (e.g., Zigbee, LoRaWAN, Wi-Fi, Bluetooth, MQTT, CoAP). Integrating them into a single cloud system is difficult.
- **M2M (machine-to-machine)** communication requires devices with different protocols to “talk” to each other.
- Many IoT systems are built using **incompatible standards or proprietary technologies**.
- Non-mobile IoT devices (industrial, agricultural, environmental) **often struggle with standardized protocol transitions**.
- **Ensuring seamless communication between heterogeneous devices is complex.**
- **Impact:**
 - Devices may fail to **communicate with the cloud**.
 - Data may not **synchronize properly**.
 - Mobility becomes limited—devices may work only in certain environments.

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Summary

1. IoT and Cloud
2. Advantages and challenges



Thank You