CHAPTER 11

CLOUD COMPUTING

Delivery of computing services — **storage, processing power, databases, networking, software — over the internet**, without owning physical infrastructure. Lets organisations **manage resources efficiently, scale dynamically and reduce costs**. In Pakistan, local & global **CSPs** offer shared hosting, VPS hosting and dedicated servers; the **Pakistan Cloud First Policy** guides public-sector adoption.

CHAPTER ROADMAP

1 What is cloud computing? — 5 traits
2 Famous cloud providers — 6
3 Service models — IaaS · PaaS · SaaS
4 Deployment models — 4
5 Benefits — 6
6 Challenges — 5
7 Applications — 8
8 Pakistan Cloud First Policy — 2022

DEFINITION

Cloud computing refers to the delivery of a wide range of computing services over the internet ("the cloud").

Servers | Storage | Databases | Networking | Software | Analytics | ... and more

Access resources **on-demand** without investing in & maintaining physical infrastructure (data centres, servers) → more **flexible**, lower **IT costs**, higher **efficiency**; operations **scale seamlessly** with business growth.

1 KEY CHARACTERISTICS OF CLOUD COMPUTING — 5

ON-DEMAND SELF-SERVICE
no provider intervention

Users **provision & manage** VMs, storage, apps **automatically** via a simple (web) dashboard.

e.g. E-commerce auto-deploys extra VMs during **Eid sales**.

BROAD NETWORK ACCESS
any place, any device

Accessible via the internet on **smartphones, tablets, laptops, desktops** → remote work & mobility.

e.g. Global marketing team shares cloud tools across countries.

RESOURCE POOLING
multi-tenancy

Storage, processing & memory **pooled and shared** among users, allocated dynamically → optimal use, cost efficiency.

e.g. Startup, enterprise & individual share a data centre — each user's data **isolated & secure**.

RAPID ELASTICITY
scalability

Scale **up or down quickly** with demand, in real time — pay only for what you need.

e.g. Streaming service adds capacity for a new show, scales down later.

MEASURED SERVICE
pay-as-you-go

Usage (bandwidth, storage, processing) **monitored, controlled & reported** → transparency, no surprise costs.

e.g. Small business billed for the **exact storage** used each month.

MEMORY HOOK

"On Broad Roads, Rapid Meters" → **O**n-demand · **B**road access · **R**esource pooling · **R**apid elasticity · **M**easured service.

2 FAMOUS CLOUD PROVIDERS

Amazon Web Services (AWS)
World's **largest & most comprehensive** cloud platform — computing, storage, databases; flexible & scalable for all sizes.

Microsoft Azure
Enterprise-grade; seamless integration with **Microsoft products**; computing, analytics, storage, networking.

Google Cloud Platform (GCP)
Renowned for **data analytics, AI & ML**; fast, scalable, secure on Google's global network.

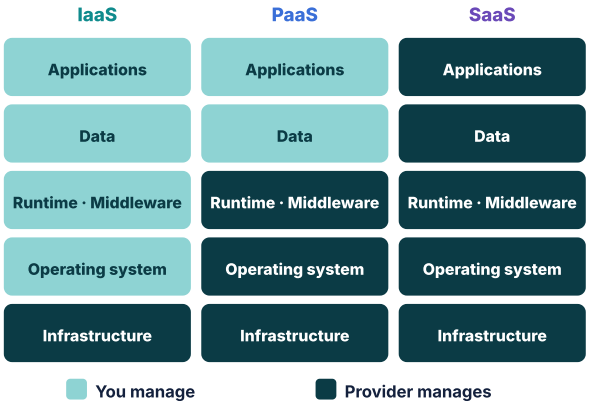
IBM Cloud
Enterprise, AI & **hybrid cloud**; for **high regulatory / compliance** needs (finance, healthcare).

Oracle Cloud
Enterprise apps, esp. **database management & ERP**; reliable for mission-critical workloads.

Alibaba Cloud
Asia's largest CSP — elastic computing, databases, big data, ML; preferred in **China & Asia**.

3 CLOUD COMPUTING SERVICE MODELS

varying control, flexibility & management



How to read it: moving **IaaS → PaaS → SaaS**, the provider manages more and the user controls less.

IaaS	you get infrastructure
PaaS	you get a platform to build on
SaaS	you get finished software

Layer diagram is an LL illustration based on the study-text descriptions.

IaaS
Infrastructure as a Service

Virtualised computing resources — VMs, storage, networking. User controls **hardware config, OS & apps**; provider manages the **physical** infrastructure.

Features: scalability · cost efficiency (no capex) · flexibility (full OS control) · on-demand

Uses: hosting websites · running custom apps · data storage

e.g. Retailer runs e-commerce on **AWS**, adding VMs on Eid days.

PaaS
Platform as a Service

Platform to **build, deploy & manage apps** — dev tools, databases, middleware, OS. Developers focus on **code**, not servers. A "platform" = the whole **application-development lifecycle toolset**.

Features: app development · managed infrastructure · pre-built components · collaboration

Uses: custom web/mobile/API apps · database management · business analytics

e.g. Software firm builds a project tool on **Google App Engine**.

SaaS
Software as a Service

Fully functional software on a **subscription**; provider manages hardware, OS, application & data. Accessed via **browser or APIs**.

Features: accessible anywhere · managed software · subscription-based · easy integration

Uses: email & collaboration · CRM · accounting & payroll

e.g. Small business uses **Salesforce** CRM — no own CRM to maintain.

Feature	IaaS	PaaS	SaaS
Control	**High** (OS, VMs)	**Medium** (app development)	**Low** (fully managed by provider)
Flexibility	Highly flexible	Moderate	Limited customisation
Management	Users manage OS, apps, storage	Provider manages infrastructure	Fully managed by provider
Use cases	Hosting, data storage, apps	App development, analytics	CRM, email, collaboration

4 CLOUD DEPLOYMENT MODELS

security · control · cost · scalability

Public Cloud

shared · third-party

Delivered over the **public internet**, shared across many organisations (**tenants**); operated by third-party providers on subscription.

- **Cost-effective (shared cost)**
- **Virtually unlimited scalability**
- **Maintenance-free**

Uses: startups & small businesses · variable workloads · software dev & testing

EXAMPLE
Startup hosts e-commerce on **AWS**, scaling for peak sales.

Private Cloud

single organisation

Infrastructure **dedicated to one organisation** — on-premises or hosted by a third party; **not shared.**

- **Enhanced security & privacy**
- **Customisation**
- **Compliance**

Uses: strict compliance (healthcare, finance) · customisation needs · data-sensitive apps

EXAMPLE
Financial institution hosts customer data privately to meet **PCI-DSS**.

Hybrid Cloud

public + private

Combines public & private; apps and data **move between them** → balance of **scalability and control.**

- **Flexibility (move workloads)**
- **Scalability**
- **Optimised costs**

Uses: fluctuating workloads · sensitive data apps · **disaster recovery** (public cloud as backup)

EXAMPLE
Healthcare: records in private cloud; analytics & research in public cloud.

Community Cloud

shared by similar organisations

Shared by **several organisations with similar requirements** (compliance, security, regulation); managed internally or by a third party.

- **Shared infrastructure**
- **Regulatory compliance**
- **Cost sharing**

Uses: government agencies · healthcare (e.g. **HIPAA**) · financial institutions

EXAMPLE
Group of hospitals store & share patient data, collaborate on research.

Feature	Public	Private	Hybrid	Community
Ownership	Third-party provider	Single organisation	Combination of public & private	Multiple organisations with shared interests
Security	Moderate	**High**	Flexible (high for private data)	High (for specific compliance)
Cost	**Low**	**Higher** (dedicated)	Moderate	Shared among organisations
Scalability	Highly scalable	Limited by internal resources	Highly scalable	Moderate
Use cases	Startups, variable workloads	Strict compliance	Fluctuating workloads	Government, healthcare

NOTE The chapter intro lists "public, private, hybrid and **multi-cloud**", but the detailed section and sticky notes cover **Community Cloud** as the fourth model — learn **Community**.

5 BENEFITS OF CLOUD COMPUTING

6

① Cost Efficiency

- **No upfront capital investment** in servers/storage/network
- **Reduced operational costs** — less IT maintenance staff
- **Pay-as-you-go** → predictable budgeting

Startup hosts on AWS, paying only for what it uses.

② Scalability

- **Vertical** — more CPU/memory for existing infrastructure
- **Horizontal** — add instances/servers
- **Global reach** — worldwide data centres reduce latency

Streaming platform adds VMs on Google Cloud for a launch.

③ Flexibility

- **Remote access** from anywhere
- **Cross-device** compatibility
- **Work from anywhere** — accelerated by COVID-19

Global dev firm collaborates on Microsoft Azure.

④ Disaster Recovery

- **Automated backups**
- **Failover** — auto-shift to other servers/data centres
- **Business continuity** — minimal downtime

Financial firm restores from AWS backups after failure.

⑤ Innovation

- **Rapid development** — dev envs, DBs, ML models
- **Experimentation** without big infrastructure spend
- **CI/CD** — continuous integration & deployment

Startup builds recommendations with Google Cloud AI.

⑥ Sustainability

- **Energy efficiency** — renewable energy in data centres
- **Reduced carbon footprint** via shared infrastructure
- Avoids **underutilised** private data centres

Retailer moves to renewable-powered Azure.

6 CHALLENGES OF CLOUD COMPUTING

5

Security & Privacy

Data breaches, unauthorised access, **regulatory compliance**.

Vendor Lock-In

Dependence on **one provider** makes migration difficult.

Downtime

Relies on **internet connectivity**; service outages.

Cost Management

Uncontrolled usage → **unexpected costs**.

Technical Expertise

Needs **skilled professionals** to manage & optimise.

7 APPLICATIONS OF CLOUD COMPUTING

study-text examples

Application	What the cloud provides	Named examples
Data storage & backup	Secure, scalable storage with automatic backups	Google Drive · Dropbox · Amazon S3
Big data analytics	Process massive datasets in real time without costly hardware	Google BigQuery (serverless, SQL) · AWS Redshift
AI & machine learning	Tools & computing power to build, train, deploy models	AWS SageMaker · Google AI Platform
Internet of Things	Collect, process, analyse device data in real time	AWS IoT Core · Azure IoT Hub
Collaboration tools	File sharing, chat, real-time editing, remote work	Microsoft Teams · Slack · Zoom
E-commerce	Handle traffic spikes (Eid sales) without slowdown	Shopify · Magento
Software dev & testing	Build/test/deploy without hardware; **CI/CD** pipelines	GitLab · AWS CodePipeline
Disaster recovery & continuity	Replicate data across data centres; restore in minutes	Azure Site Recovery · AWS Backup

8 PAKISTAN CLOUD FIRST POLICY (PCFP)

Feb 2022 · MoITT

Introduced in **February 2022** by the **Ministry of Information Technology & Telecommunication (MoITT)**. Goal: make **cloud adoption the default option** for all new **public-sector ICT investments** → better service delivery, security and cost efficiency, aligned with international best practice.

Digital Transformation
All **Public Sector Entities (PSEs)** adopt cloud — streamline, interoperate, digitise citizen services.

Cost Optimisation
Less on-premise dependence → lower **capex & opex**.

Data Sovereignty & Localisation
Critical & sensitive government data must be hosted within Pakistan — no foreign jurisdiction.

Standardisation
Uniform guidelines: data classification · access control · audit (**ISO/IEC 27001, ISO 22301**) · **PECA 2016** & **NCSP 2021**.

Capacity Building
Train government staff in cloud, **cybersecurity** & data governance.

Security Assurance
Local hosting → easier audits, **faster incident response**, less risk of foreign access / exfiltration.

Utilisation of Local CSPs
Priority to CSPs with **physical data centres in Pakistan**.

Remember
Year **2022** · **MoITT** · **PSEs** · data stays **in Pakistan**.

EXAM FOCUS · MCQ TRAPS

commonly confused points

1 Pooling vs elasticity
Resource pooling = **sharing** (multi-tenancy). Rapid elasticity = **scaling** up/down.

2 Measured service
= **pay-as-you-go** with monitored, reported usage — not self-service.

3 Control ladder
IaaS **high** → PaaS **medium** → SaaS **low** user control.

4 Match the product
AWS VMs = IaaS · Google App Engine = PaaS · Salesforce = SaaS.

5 Private ≠ on-premises only
A private cloud can be on-premises **or** hosted by a third party — what matters is it's **dedicated**.

6 Community vs hybrid
Community = several **organisations** with similar needs share. Hybrid = **public + private** for one organisation.

7 Cheapest vs most secure
Public = **lowest cost**, moderate security. Private = **highest security**, higher cost.

8 Provider strengths
GCP = analytics/AI · Oracle = DB & ERP · IBM = hybrid & regulated · Alibaba = Asia's largest.

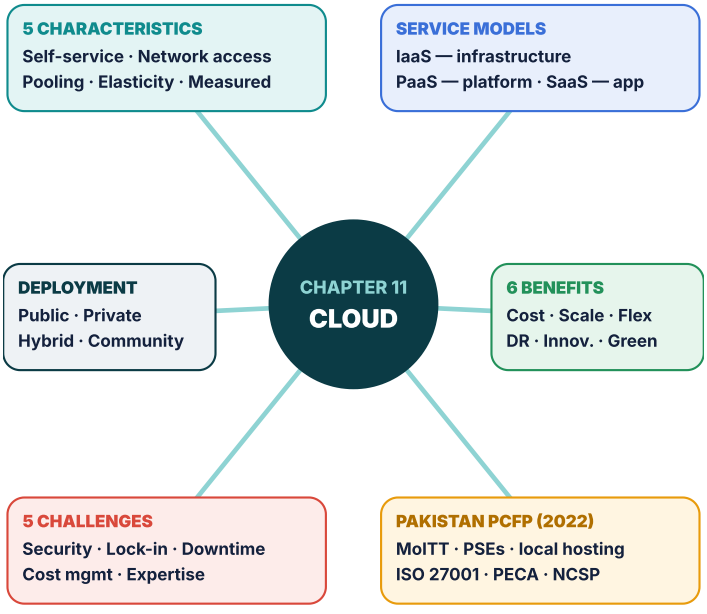
9 Vendor lock-in
A **challenge**: dependence on one provider makes migration hard.

10 PCFP data rule
Critical & sensitive government data must be hosted **within Pakistan**.

CLASSIFY IT

1	Billed for exact GB used	Measured service
2	Startup, enterprise share data centre	Resource pooling
3	Developers code; servers handled	PaaS
4	Payroll software by subscription	SaaS
5	Rent VMs, install own OS	IaaS
6	Bank meeting PCI-DSS alone	Private cloud
7	Hospitals share one cloud	Community cloud
8	Can't easily leave a provider	Vendor lock-in

REVISION MAP



Cloud
Computing services over the internet, on demand.

Service
IaaS → PaaS → SaaS: less control, more managed.

Deploy
Public, private, hybrid, community.

Weigh
6 benefits vs 5 challenges.

Pakistan
Cloud First Policy 2022 — data stays home.