CHAPTER 9

EMERGING TECHNOLOGIES

Rapid technological advancement is reshaping industries — especially **healthcare, finance, manufacturing and transportation**. Though still evolving, these technologies already enable **smarter decision-making**, **greater efficiency** and **new opportunities for growth**. This chapter covers each technology's **key features, applications, benefits and challenges**.

CHAPTER ROADMAP

1. AI & Machine Learning
2. Internet of Things (IoT)
3. Blockchain technology
4. 5G technology
5. AR & VR
6. Quantum computing
7. Edge computing
8. Robotic Process Automation

The pace of technological evolution has **accelerated rapidly**, driven by AI, ML, blockchain, quantum computing and IoT. These technologies are still in their **early stages** but already make a significant impact. It is crucial for businesses and professionals to **stay informed** to harness their potential and ensure **sustainable growth**.

The 8 technologies at a glance

1 · AI & ML
Machines doing tasks that need human intelligence; ML learns from data.

2 · IoT
Network of physical devices with sensors that collect & exchange data.

3 · Blockchain
Decentralised, distributed, tamper-proof ledger.

4 · 5G
5th-gen wireless: faster speeds, low latency, massive device capacity.

5 · AR & VR
AR overlays digital on real world; VR is fully simulated.

6 · Quantum
Qubits & quantum mechanics → exponentially faster on complex problems.

7 · Edge
Process data close to where it's generated → low latency & bandwidth.

8 · RPA
Software bots emulate humans to execute rule-based tasks.

Technology	One key word	Signature example in the study text
AI & ML	Learning	Self-driving cars, Siri/Alexa, IBM Watson Health, PayPal, Amazon recommendations
IoT	Connected devices	Smart homes, IIoT, IoMT heart monitor, smart irrigation, fleet tracking
Blockchain	Immutable ledger	Bitcoin/Ethereum, smart contracts, land records, academic credentials
5G	Speed & latency	Remote surgery, vehicle-to-vehicle communication, smart grids
AR / VR	Immersion	IKEA app, Sephora try-on, Pokémon GO, VR surgery training
Quantum	Qubits	Breaking RSA, protein folding, route optimisation, financial modelling
Edge	Process locally	Tesla, Amazon Go, wearable heart monitor, smart traffic lights
RPA	Rule-based bots	Claim forms, invoice processing, payroll, data migration

1 ARTIFICIAL INTELLIGENCE (AI) & MACHINE LEARNING (ML)

AI

Computer systems that perform tasks that typically require human intelligence — visual perception, speech recognition, decision-making, problem-solving, language understanding.

Learns from experience, adapts to new inputs, performs human-like tasks **without direct human intervention**.

ML

A critical subset of AI — algorithms that let machines learn from data, identify patterns and make decisions with minimal human intervention.

AI grew due to **computational power**, **Big Data** and **algorithm innovation**.

Key Features of AI

① Autonomous Decision-Making
Decides based on data & predefined rules; automates repetitive tasks.

Self-driving cars: navigation, obstacle avoidance, route optimisation.

② Learning & Adaptation
Continuously improves through experience & new data.

Siri & Alexa understand voice commands better over time.

③ Natural Language Processing (NLP)
Understand, interpret & generate human language — translation, sentiment analysis, chatbots.

Google Translate in real time.

④ Pattern Recognition
Find patterns & anomalies — fraud detection, predictive maintenance, diagnostics.

Analyse X-rays / MRIs for early signs of cancer.

Applications of AI & ML

Sector	What AI/ML does	Example
Healthcare	Accurate diagnosis, personalised treatment, automate admin, drug candidates	**IBM Watson Health** assists cancer diagnosis
Finance	Fraud detection, algorithmic trading, credit risk, service automation	**PayPal** detects suspicious transactions
Retail & E-com	Inventory optimisation, personalised marketing, trend prediction	**Amazon** product recommendations
Transportation	Autonomous vehicles process sensor data in real time	**Tesla** — cameras, lidar, radar + deep learning
Customer Service	Chatbots & virtual assistants, 24/7	Website chatbots reduce need for human agents

LiDAR — Light Detection and Ranging

Uses **laser pulses** to measure distances and create **3D maps**; emits infrared light, times reflections → **cm-level precision**. Works in **darkness** but can be **disrupted by fog/rain**. Used in self-driving cars, drones, robotics.

2 INTERNET OF THINGS (IOT)

DEFINITION

A rapidly growing network of interconnected physical devices embedded with sensors, software and other technologies that collect and exchange data over the internet.

From refrigerators, thermostats, fitness trackers to industrial machinery, vehicles, infrastructure → automates processes, improves efficiency, enables data-driven decisions. A **paradigm shift** in how we interact with technology.

Key Features of IoT

Interconnectivity

Devices share data **without human intervention**, wireless or wired.

e.g. Smart home lights, locks, thermostats controlled via smartphone.

Data Collection & Analysis

Continuous data — temperature, humidity, location, usage.

e.g. Farm sensors on soil moisture → irrigation decisions.

Automation & Control

Devices act **autonomously** on predefined conditions.

e.g. Production line speeds adjusted; maintenance alerts.

Remote Monitoring & Mgmt

Cloud platforms / apps for real-time diagnostics anywhere.

e.g. Fleet managers' GPS tracking of vehicles.

Scalability

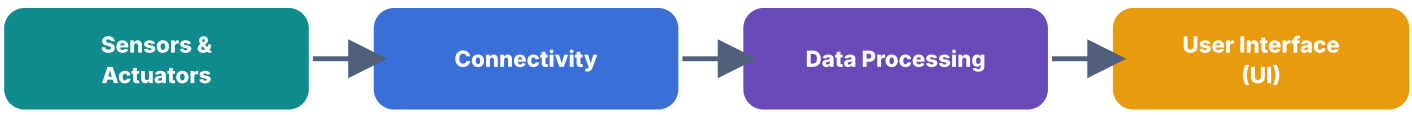
Add devices **without major infrastructure changes**.

e.g. Smart homes → smart cities (lights, waste, sensors).

Where it's used

Healthcare, manufacturing, agriculture, transportation, smart cities — insight from **billions** of devices.

Components of IoT



Sensors & Actuators

Sensors capture data (temperature, motion, pressure); **actuators act** (adjust thermostat, lights off).
Soil sensor → actuator triggers irrigation.

Connectivity

Wireless (**Wi-Fi, 4G/5G, Bluetooth**) or wired (**Ethernet**).
Smart thermostat ↔ phone app via Wi-Fi.

Data Processing

On the device (**edge computing**) or in data centres (**cloud computing**).
Factory sensors predict maintenance.

User Interface

Web dashboard, mobile app, voice (Alexa, Google Assistant).
Smart home hub app / voice.

IoT Applications

Smart Homes
Remote control of appliances, lighting, security → convenience, security, energy efficiency.
Amazon Echo / Google Home voice control.

Industrial IoT (IIoT)
IoT in industrial environments — real-time monitoring, predictive maintenance, safety.
Sensors on temperature, pressure, vibration trigger alerts.

Healthcare (IoMT)
Internet of Medical Things — remote monitoring, vitals, chronic conditions.
Connected heart-rate monitor sends data to provider.

Smart Cities
Traffic, waste, energy, public safety.
Smart traffic signals; streetlights dim/brighten by presence.

Agriculture
Precision farming — optimise water & fertiliser, improve yield.
Smart irrigation activates when moisture is low.

Transport & Logistics
Real-time tracking of vehicles, cargo, shipments.
Fleet location, speed, fuel efficiency monitored.

Challenges of IoT

Security & Privacy
Attractive targets; often **default factory credentials** never changed.
e.g. Hacker accesses smart home cameras.

Interoperability
Different **protocols & standards** across manufacturers.
e.g. Mixed brands need **middleware**.

Data Overload
Volumes overwhelm storage & processing.
e.g. Smart city: terabytes daily.

Scalability
More devices → harder to manage networks, storage, processing.
e.g. Agri solution expanding across farms.

3 BLOCKCHAIN TECHNOLOGY

DEFINITION

A decentralised, distributed ledger technology ensuring secure, transparent and tamper-proof transactions.

Runs on a **peer-to-peer network**; each transaction recorded in **blocks linked to the previous one** → a chain. Famous for **Bitcoin**, but used across industries.



each block linked to the previous → a chain

Decentralisation
No central authority; all nodes maintain the ledger → no single point of failure/control.

Immutability
Once added, a block **cannot be altered** → permanent, trustworthy history.

Security
Cryptographic algorithms secure each transaction; prevent unauthorised changes.

Transparency
Everyone has the **same version** → fully transparent & **auditable**.

Cryptocurrencies — Bitcoin, Ethereum; no bank intermediaries
Smart contracts — terms in code, self-executing (Ethereum)
Supply chain — single view, authenticity, less fraud
Land records — tamper-proof; months → days
Academic credentials — QR-verified diplomas; no fake degrees

4 5G TECHNOLOGY

fifth generation of wireless technology

Builds on 4G with **significantly faster speeds, reduced latency** and capacity for a **massive number of connected devices** — enabling innovations not feasible before.

⚡ Speed
Up to **100× faster** downloads than 4G — 4K streaming, cloud apps.

⏱ Low Latency
As low as **1 ms** vs **30–50 ms** on 4G — remote surgery, AVs, VR.

📶 Capacity
More devices in a small area — essential for **IoT**.

✔ Reliability
Better coverage in **dense urban areas, stadiums**, high-traffic zones.

Example Applications

- **Smart cities** — traffic lights, cameras, power grids talk in real time
- **Autonomous vehicles** — **vehicle-to-vehicle** & **vehicle-to-infrastructure** communication
- **Telemedicine** — remote robotic surgery; real-time monitoring
- **AR & VR** — gaming, training simulations
- **IoT & smart homes** — fridges, security, HVAC respond in real time

Future Impact of 5G

- **Industrial automation** — **Industry 4.0**; robots, machinery, drones in sync
- **Entertainment & media** — HD streaming, cloud gaming, no buffering
- **Smart grids** — balance supply/demand, real-time usage, renewables

5 AUGMENTED REALITY (AR) & VIRTUAL REALITY (VR)

Immersive technologies that **bridge the physical and digital worlds** — transforming entertainment, retail, education, healthcare and training.

AUGMENTED REALITY (AR) — **enhances** the real world

- **Digital overlay** — images, sounds, text on the real world
- **Interactive** while aware of surroundings
- **Accessible** — smartphones, tablets, AR glasses
- **Integrated with physical world** — not disconnected

vs

VIRTUAL REALITY (VR) — **replaces** it with a simulation

- **Simulated 3D environment**
- **Full immersion** — real-life or fictional worlds
- **Interactive** — sense of presence
- **Specialised hardware** — Oculus Rift, HTC Vive, PlayStation VR

Sector	AR use	VR use
Retail	Product visualisation (**IKEA** furniture app); virtual try-on (**Sephora** makeup)	Virtual fitting rooms for clothes (future use)
Education & Training	Textbooks come alive — 3D models, landmarks, cells	Skill training — medical students practise surgery safely
Healthcare	Surgical assistance — overlays on real-time scans, 3D anatomy	Therapy (PTSD, anxiety — exposure therapy) & rehabilitation
Entertainment	**Pokémon GO** — digital creatures in real world	Immersive gaming — **Beat Saber, VR Chat**
Real Estate	Overlay models on empty lots / unfinished buildings	Virtual home tours remotely

✓ Benefits

- **Enhanced user experience** — immersive, interactive
- **Cost-effective training** — flight, medical, military
- **Remote interaction** — meetings, tours, appointments

× Challenges

- **Hardware requirements** — expensive headsets & sensors
- **Content development** — costly, needs expertise
- **User discomfort** — motion sickness, eye strain

6 QUANTUM COMPUTING

Leverages **quantum mechanics** (behaviour of particles at atomic/subatomic level) to compute at **unprecedented speeds**. Classical computers use **bits** (0 *or* 1); quantum computers use **qubits** in **superposition** (0 *and* 1 simultaneously) → solve complex problems **exponentially faster**.



Superposition

Qubit is **part 0 and part 1 at once** → evaluates many solutions **in parallel**; outcome probabilities set by amplitudes.

e.g. Maze: classical tries one path at a time; quantum explores all paths simultaneously.

Entanglement

State of one qubit **depends on another**, even when physically separated.

e.g. Optimisation — evaluate multiple variables simultaneously.

Tunnelling

Bypass traditional barriers in computations → solve problems impossible for classical computers.

Potential Applications

- **Cryptography** — could **break RSA** (factoring large numbers); hence **post-quantum cryptography**
- **Drug discovery** — simulate molecules; **protein folding** (Alzheimer's, Parkinson's)
- **Optimisation & supply chain** — delivery routes, fuel
- **Financial modelling** — risk analysis, portfolio optimisation

Challenges

- **Error rates** — sensitive to temperature & electromagnetic interference → need **quantum error correction**
- **Hardware development** — scaling qubits & maintaining **coherence**
- **Cost & accessibility** — expensive; not yet for widespread commercial use

7 EDGE COMPUTING

process near the source

EDGE COMPUTING — a **distributed** paradigm bringing processing, storage & computation **closer to where data is generated** → less **latency & bandwidth**. Essential with IoT growth & real-time demands.

vs

TRADITIONAL CLOUD — data is **transmitted to centralised data centres** for processing.

Reduced Latency
Real-time decisions.

e.g. AV braking, steering in split seconds.

Bandwidth Efficiency
Process critical data locally; send less to cloud.

e.g. IIoT machines detect anomalies locally.

Privacy & Security
Sensitive data stays near source.

e.g. Heart monitor sends only necessary info.

Scalability & Flexibility
Distribute processing; less reliance on central DCs; localised solutions.

Smart Cities
Traffic lights adjusted in real time from cameras & sensors.

Healthcare & Wearables
Heart monitor alerts **only on irregular patterns**.

Autonomous Vehicles
Tesla — LiDAR, cameras, radar processed on board.

Retail & Smart Stores
Amazon Go — cashier-less checkout.

✓ Benefits
- Real-time processing
- Improved security & privacy
- Cost efficiency (bandwidth, cloud)
- Scalability

× Challenges
- Complexity in management (updates, patches)
- Security risks of the devices
- Data synchronisation with central repositories

QUANTUM vs EDGE Quantum = **immense computational power** for previously unsolvable problems. Edge = **low-latency, real-time** processing for IoT & critical apps.

8 ROBOTIC PROCESS AUTOMATION (RPA)

DEFINITION

Technology enabling software robots ("bots") to emulate human actions with digital systems to execute rule-based tasks — faster and more accurately; best for high-volume, routine tasks.

Automates Repetitive Tasks
Data entry, forms, reports. *Insurance claim data extracted.*

Non-Invasive
Works with existing & **legacy** systems, no big IT changes. *Bank onboarding on legacy CBS.*

Rule-Based
No judgment needed; clicks, copy-paste, screens. *Order details from emails.*

Scalable & Flexible
Deploy more bots for peaks. *Holiday-season retailer.*

Improves Compliance
Exact rules + **audit trail**. *Suspicious transaction monitoring.*

Example Applications of RPA

Customer Service
Order status, password resets, profile updates.
Telecom bots answer balance & network queries.

Invoice Processing
Data extraction → payment initiation.
Capture invoice from email, match PO, pay approved.

Payroll Management
Salaries, deductions, pay slips, tax returns.
HR runs payroll for thousands accurately.

Data Migration
Move data in upgrades/mergers with fewer errors.
Bank migrates customers to new core banking platform.

Supply Chain
Inventory tracking, order processing, shipments.
Auto-reorder below threshold; shipping labels.

Think "RPA" when you see...
repetitive · rule-based · high-volume · no judgment · copy-paste between systems

Benefits of RPA

Efficiency
Faster than humans; staff do higher-value work.
Patient data entry automated.

Cost Reduction
Less manual labour; works **24/7**.
Loan processing & regulatory reporting.

Accuracy
Predefined rules eliminate human errors.
Fewer claims processing errors.

Compliance
Rules followed; **detailed logs**.
Auto compliance reports.

Scalability
Extra bots for peaks, no new hires.
Holiday orders & returns.

Challenges in RPA Implementation

Process Standardisation
Works best on **standardised, rule-based** processes; document & streamline first — complex/ambiguous tasks may not suit.

Change Management
Employees fear **job displacement**; needs training & communication.

Security Risks
Bots access sensitive data across systems → strong security needed.

Ongoing Maintenance
Updates when **software or rules change**; monitor bots.

RPA vs AI RPA follows **predefined rules** and is for processes that **do not require decision-making or judgment**. AI **learns and adapts** and makes decisions.

! EXAM FOCUS · MCQ TRAPS

commonly confused points

1 ML is a subset of AI
Not the other way round. NLP is a **subfield of AI**.

2 Sensor vs actuator
Sensor **captures** data; actuator **performs a physical action**.

3 IIoT vs IoMT
IIoT = **industrial**; IoMT = Internet of **Medical** Things.

4 Blockchain features
Decentralisation · Immutability · Security · Transparency.

5 5G numbers
Up to **100×** faster than 4G; latency **~1 ms** vs 30–50 ms.

6 AR vs VR
AR **overlays** on the real world (phones); VR is **fully immersive** (headsets).

7 Bit vs qubit
Bit = 0 **or** 1; qubit = 0 **and** 1 (superposition). Linked qubits = **entanglement**.

8 Quantum threat
Could break **RSA** → **post-quantum cryptography**.

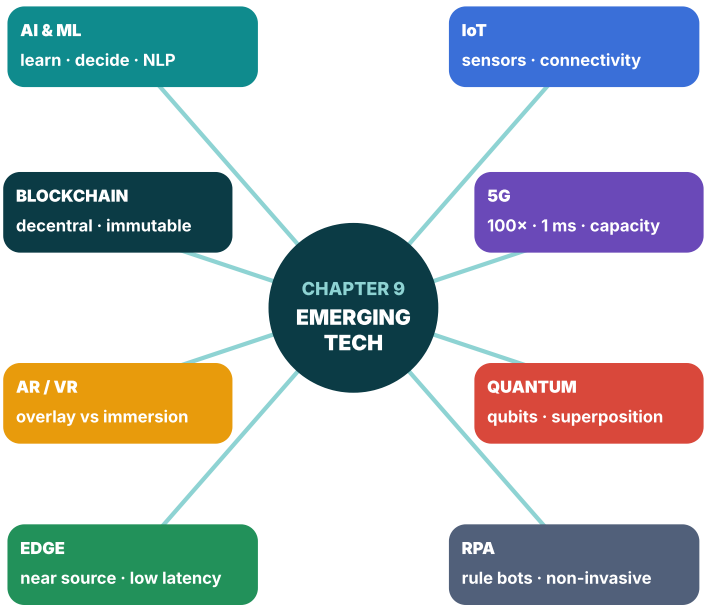
9 Edge vs cloud
Edge processes **near the source**; cloud sends data to **central data centres**.

10 RPA is non-invasive
Works with **legacy systems** without major IT changes.

CLASSIFY IT

1	Google Translate in real time	AI — NLP
2	Soil sensor triggers irrigation	IoT
3	QR-verified university diploma	Blockchain
4	Remote robotic surgery, 1 ms	5G
5	IKEA furniture in your room	AR
6	Protein folding simulation	Quantum
7	Amazon Go cashier-less checkout	Edge
8	Bot matches invoices to POs	RPA

REVISION MAP



Think
AI & ML learn and decide.

Connect
IoT + 5G link billions of devices.

Trust
Blockchain keeps tamper-proof records.

Experience
AR overlays, VR immerses.

Compute & Automate
Quantum power, edge speed, RPA bots.