Computing and Information Technology

Cloud computing

Cloud computing refers to the delivery of computing services over the internet, enabling users to access and use various computing resources such as servers, storage, databases, software, and networking without the need for on-premises infrastructure.

It allows for scalable and flexible access to these resources on-demand, making it possible to quickly provision and release computing resources as needed.

Cloud computing provides a cost-effective and efficient solution for businesses and individuals to access and utilize computing services without the need for extensive hardware and maintenance.

Architecture of a Cloud Computing Service

Overall, the architecture of a cloud computing service combines physical infrastructure, virtualisation, orchestration, and various service layers to provide scalable, on-demand, and cost-effective computing resources to users.

1. **Infrastructure Layer**: This layer consists of physical resources such as servers, storage devices, and networking equipment. It forms the foundation of the cloud computing infrastructure.
2. **Virtualisation Layer**: Virtualisation enables the creation of virtual machines (VMs) out of the underlying physical infrastructure. It allows for efficient utilization and sharing of resources among multiple users.
3. **Orchestration Layer**: The orchestration layer manages the provisioning, configuration, and deployment of virtual resources. It ensures efficient allocation of resources based on user demand and handles tasks like load balancing and auto-scaling.
4. **Service Layer**: This layer includes various services provided by the cloud computing platform, such as computing, storage, and databases. These services can be accessed and utilized by users over the internet.
5. **Application Layer**: At the topmost layer, users deploy their applications and services on top of the cloud infrastructure. This layer consists of the applications, software, and tools that users interact with to perform their tasks.

Types of cloud computing

Based on access control

Private Cloud

A private cloud refers to a cloud computing environment that is dedicated to a single organization. It is built and maintained within the organization's own data centers or hosted by a third-party service provider exclusively for that organization. The infrastructure and resources of a private cloud are not shared with other organizations, offering a higher level of control, security, and privacy. Private clouds are often preferred by organizations that have strict data governance requirements or need to comply with certain regulations.

Public Cloud

A public cloud is a cloud computing environment that is open for use by the general public. It is owned and operated by a cloud service provider who makes computing resources available over the internet. Multiple organizations and individuals can share the same infrastructure and resources of a public cloud. Public clouds offer scalability, cost-effectiveness, and ease of use as users pay only for the resources they consume.

They are suitable for a wide range of applications and are commonly used for web hosting, development and testing environments, and software-as-a-service (SaaS) solutions.

Based on the service provided

Infrastructure as a Service (IaaS)

Definition IaaS provides virtualized computing resources over the internet. It is an instant computing infrastructure, provisioned, and managed over the internet.

Examples

1. Amazon Web Services (AWS)
2. Microsoft Azure
3. Google Cloud Platform

Usage in India In India, several enterprises and startups leverage IaaS platforms. For instance, AWS has data centers in Mumbai to cater to the growing demand for cloud infrastructure services in India.

Platform as a Service (PaaS)

Definition PaaS provides a platform that allows developers to build, deploy, and manage applications without worrying about the underlying infrastructure.

Examples

1. Microsoft Azure App Services
2. Google App Engine
3. IBM Cloud Foundry

Usage in India Many Indian IT companies and startups use PaaS solutions to accelerate application development and deployment, benefiting from the scalability and reduced time-to-market.

Software as a Service (SaaS)

Definition SaaS refers to a cloud computing service where instead of downloading software on your desktop PC or business network to run and update, you instead use an application over the internet.

Examples

1. Google Workspace
2. Microsoft 365
3. Salesforce

Usage in India SaaS products are popular in India, especially in the business sector, where tools like Google Workspace and Microsoft 365 facilitate collaboration and productivity.

Function as a Service (FaaS)/Serverless

Definition FaaS or serverless computing allows developers to execute code in response to events without the complex infrastructure typically associated with building and launching microservices applications.

Examples

1. AWS Lambda
2. Azure Functions
3. Google Cloud Functions

Usage in India Indian tech enterprises are increasingly adopting serverless computing for various applications, enjoying benefits like reduced operational costs and streamlined workflow.

Meghraj: Government of India's GI Cloud Initiative

- **Overview**: The Government of India has launched the **GI Cloud**, also known as **Meghraj**, as a cloud computing environment with a focus on accelerating the delivery of e-services while optimizing ICT spending.
- **Purpose**: The initiative aims to enable government departments and agencies at both the central and state levels to leverage cloud computing for the effective delivery of e-services.
- **Implementing Authority**: The Department of Electronics and IT (DeitY) of the Government of India is responsible for overseeing the ambitious 'GI Cloud' project.
- **Cloud Services Procurement**: Cloud services across various categories are available on the Government e-Marketplace (GeM) platform, simplifying the procurement process for government agencies.

This initiative signifies a significant step toward modernizing government services and harnessing the potential of cloud technology to enhance efficiency and cost-effectiveness.

- **Features and Benefits**
  - **Cost Efficiency**
    - Elimination of Additional Hardware Costs: The platform negates the need for additional hardware by providing necessary processing power via the cloud.
    - Optimization of ICT Spending: It seeks to rationalize the government's ICT expenditures.
  - **Operational Convenience**
    - Easy Procurement: All categories of cloud services are enlisted on the Government e-Marketplace (GeM), facilitating effortless procurement for government departments.
    - Outsourced Administration: The administration of systems including maintenance and security is managed by the cloud provider, reducing the burden on government agencies.
  - **Service Quality and Security**
    - Maintained Security and Service Quality: The platform adheres to standards to ensure the security and quality of services provided.
    - Resource Sharing: Allows for the sharing of resources among users and offers scalable solutions across multiple data centers.
  - **Flexible Service Offerings**
    - Demand-Based Services and Pricing: The platform operates on a usage-based service and pricing model, offering flexibility and cost-effectiveness.

Meghraj Cloud Platform vs. Other Cloud Platforms

1. **Service Models**:
   - Meghraj offers three service models: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS)[1].

    - Similar to major cloud platforms like AWS, Google Cloud, and Azure.
2. **Deployment Models**:
    - Meghraj provides three deployment models: Public Cloud, Virtual Private Cloud (VPC), and Government Community Cloud (GCC).
    - Comparable to features offered by other cloud platforms.
3. **Security**:
    - Meghraj places a high emphasis on data security, given its government-run nature.
    - Other cloud platforms also prioritize security, but levels may vary.
4. **Focus on e-Governance**:
    - Meghraj's primary focus is accelerating e-service delivery in India and optimizing government ICT spending.
    - Unique focus on e-governance not found in commercial cloud platforms.
5. **Procurement through GeM**:
    - All categories of cloud services on Meghraj are listed on the Government e-Marketplace (GeM).
    - Simplifies procurement for government departments.
6. **National Data Centers**:
    - Meghraj establishes nodes in National Data Centers of the National Informatics Centre (NIC).
    - Local presence offers advantages like lower latency and better compliance with Indian data regulations compared to international cloud platforms.

Benefits of cloud computing

1. **Performance**: Cloud computing often provides high-speed and efficient data processing and computation, meeting the demands of complex tasks.
2. **Disaster Recovery**: Cloud platforms offer built-in disaster recovery solutions, ensuring data backup and continuity in case of unexpected events.
3. **Automatic Updates**: Cloud services typically handle software updates and maintenance automatically, reducing the burden on IT teams.
4. **Environmental Impact**: By optimizing resource utilization, cloud computing can be more environmentally friendly, reducing carbon footprints.
5. **Global Reach**: Cloud providers have data centers worldwide, facilitating global reach and reduced latency for international users.
6. **Cost Predictability**: Cloud services often operate on a pay-as-you-go model, allowing organizations to predict and control their IT costs effectively.
7. **Innovation Acceleration**: Cloud resources enable rapid prototyping and deployment of new applications and services, fostering innovation.

These benefits make cloud computing a compelling choice for businesses and organizations seeking efficiency, scalability, and technological advancement in their operations.

Concerns

1. **Security Risks**: Cloud services may pose security challenges, such as data breaches, unauthorized access, and data loss.
2. **Limited Offline Access**: Cloud services require an internet connection, making offline access challenging. This can impact operations during network outages.
3. **Data Privacy**: Storing data in the cloud can raise concerns about data privacy and compliance with regulations like GDPR.
4. **Downtime and Reliability**: While cloud providers strive for high uptime, service outages can occur, impacting business operations. It is essential to have contingency plans in place.
5. **Data Transfer Costs**: Transferring large volumes of data in and out of the cloud can incur significant costs, especially for bandwidth-intensive applications.
6. **Vendor Lock-In**: Adopting proprietary cloud technologies can lead to vendor lock-in, making it challenging to migrate to another provider or back to on-premises infrastructure.
7. **Lack of Control**: Organizations may have limited control over infrastructure and configurations in the cloud, potentially affecting customization and performance optimization.
8. **Cost Management**: While cloud offers cost savings, improper resource allocation can lead to unexpected expenses. Effective cost management and monitoring are essential.
9. **Lack of Transparency**: Some cloud providers may lack transparency regarding their infrastructure's location and operational practices, which can be a concern for data sovereignty.
10. **Shared Resources**: In a multi-tenant cloud environment, resources are shared among users. Resource contention can affect performance during peak usage times.

Addressing these concerns involves thorough planning, risk assessment, and collaboration with a trusted cloud provider to implement appropriate security and governance measures.

Super Computing

What are supercomputers?

Supercomputers are the most powerful computing machines available at any period, renowned for executing high-speed computations which are vital in various fields such as science and engineering.

Initially utilized predominantly for researching complex physical phenomena or designs through mathematical models, their applications have expanded over time.

In the 1990s, a decrease in cost facilitated their use in business sectors for market research and similar operations. At present, they play a crucial role in:

- Scientific research
- Engineering computations
- Climate and weather simulation
- Cosmic evolution studies
- Nuclear weapons and reactors analysis
- Chemical compounds development (including pharmaceuticals)
- Cryptology
- Market research and business modelling

Distinguishing Features of Supercomputers

Processing Speed

Supercomputers possess incredibly high processing speeds, enabling them to perform complex calculations and analyze vast amounts of data much faster than conventional computers. This attribute is quantified in FLOPS (Floating Point Operations Per Second).

Note: FLOPS, which stands for Floating Point Operations Per Second, is a unit of measurement that quantifies the number of floating-point calculations a computer or processor can perform in one second. It is extensively used to gauge the performance and computational power of computers, especially in the context of high-performance computing systems such as supercomputers.

FLOPS can be categorized into several scales to denote the computational power of a machine:

1. Kiloflops (KFLOPS) - Thousands of FLOPS
2. Megaflops (MFLOPS) - Millions of FLOPS
3. Gigaflops (GFLOPS) - Billions of FLOPS

4. Teraflops (TFLOPS) - Trillions of FLOPS
5. Petaflops (PFLOPS) - Quadrillions of FLOPS
6. Exaflops (EFLOPS) - Quintillions of FLOPS

Parallel Processing

Supercomputers are equipped with numerous processors that can perform tasks simultaneously, a feature known as parallel processing. This capability allows supercomputers to execute multiple operations concurrently, significantly reducing the time needed to complete complex computations.

High-Performance Memory

Supercomputers have a substantial amount of high-speed memory or RAM, which allows them to store and access data swiftly, facilitating faster computations and data analysis.

Scalability

Scalability is another crucial feature. These systems can be scaled to increase their computational power further, which is essential to meet the growing demands of high-performance computing applications.

Advanced Cooling Systems

To manage the immense heat generated due to high-speed operations, supercomputers are equipped with advanced cooling systems. These systems prevent overheating and maintain optimal performance levels.

Dedicated Infrastructure

Supercomputers often require dedicated infrastructure, including specialized facilities that can house the massive hardware setups and supply the necessary power and cooling requirements.

Specialized Software

These machines operate using specialized software that is optimized to handle complex, large-scale computations and data management tasks, ensuring efficient utilization of the hardware resources.

Network Capability

Supercomputers have much superior network capabilities, allowing them to connect with other computers and networks at very high speeds, facilitating swift data transfer and communication with other systems.

The TOP-500 List

The **TOP500 list** is a biannual ranking of the world's most powerful non-distributed computer systems. It was initiated in 1993 and undergoes updates twice a year. This list evaluates supercomputers based on their performance, measured using the **LINPACK** Benchmark.

LINPACK Benchmark: This benchmark is used to evaluate and rank the systems in terms of their computational power.

The TOP500 list is compiled and published by the TOP500 project. The project was initiated in 1993 and is currently maintained by the University of Mannheim, the University of Tennessee, and the National Energy Research Scientific Computing Center (NERSC) at Lawrence Berkeley National Laboratory.

The world’s top-6 supercomputers according to the 62nd edition of the Top-500 List released in November 2023.

Top Supercomputers

Rank	System (Processor)	Location	Cores	Rmax (PFlop/s)	Rpeak (PFlop/s)
1	Frontier (AMD)	United States	8,699,904	1,194.00	1,679.82
2	Aurora (Intel)	United States	4,742,808	585.34	1,059.33
3	Eagle (Intel, NVIDIA)	United States	1,123,200	561.20	846.84
4	Supercomputer Fugaku (Fujitsu)	Japan	7,630,848	442.01	537.21
5	LUMI (AMD)	Finland	2,752,704	379.70	531.51
6	Leonardo (Intel, NVIDIA)	Italy	1,824,764	238.70	304.47

India’s Supercomputers

India's first supercomputer, PARAM 8000, was built by the Center for Development of Advanced Computing (C-DAC) in 1991.

India's supercomputing program has made significant advancements in recent years.

The government, though the Center for Development of Advanced Computing (C-DAC) and the Department of Science and Technology (DST), has been actively supporting the development and deployment of supercomputers in the country.

Some noteworthy supercomputers of India are as follows:

(Note: The speed of the supercomputers is mentioned in terms of **Rpeak score**, which is *theoretical peak performance of a supercomputer*. **Rmax score** will be somewhat lower. A system's *Rmax score describes its maximal achieved performance.*)

AI Supercomputer 'AIRAWAT'

- **Introduction**: 'AIRAWAT' is an AI supercomputer installed at C-DAC, Pune, under the National Program on AI by the Government of India.
- **Performance**: As in 2023 June, AIRAWAT stands as India's largest and fastest AI supercomputing system, boasting an impressive speed of 13,170 teraflops (**13.17 Petaflop**) It has **been ranked 90th in the world**. It was declared so **in the 62nd edition of Top 500 Global Supercomputing List in November 2023**.

Other Indian Supercomputers in Top 500 List

1. **PARAM Siddhi-AI Supercomputer - 5.27 Petaflop supercomputer (Rank 163)**
    - Location: Center for Development of Advanced Computing (C-DAC), Pune.
    - It serves various purposes:
        1. **Advanced Materials, Computational Chemistry & Astrophysics**: It supports the development of applications in these domains.
        2. **Healthcare**: It accelerated COVID-19 research with faster simulations, medical imaging, genome sequencing, and forecasting.

3. **Flood Forecasting**: It aids in creating flood forecasting solutions for cities like Mumbai, Delhi, Chennai, Patna, and Guwahati.
4. **Education**: It facilitates testing online educational courses.
5. **Weather Forecasting**: It assists in testing weather forecasting systems by organizations like National Centre for Medium Range Weather Forecasting, Noida & Indian Institute of Tropical Meteorology, Pune.
6. **Geo-exploration**: It supports geo-exploration efforts for oil and gas recovery.
7. **Aero-design Studies**: It aids in testing packages for aero-design studies.
8. **Computational Physics and Mathematical Applications**: It assists in testing computational physics and mathematical applications.
9. **Manufacturing, Defence, and Urban Planning**: It is highly capable of addressing large-scale challenges in these sectors.

2. **Pratyush Supercomputer - 4.0 Petaflop supercomputer (Rank 201)**
    - Location: Indian Institute of Tropical Meteorology, Pune.
    - Pratyush is primarily used for **weather and climate research**, as well as for studying the Earth's atmosphere, ocean, and land surface.
3. **Mihir Supercomputer - 2.8 Petaflop supercomputer (Rank 354)**
    - Location: National Centre for Medium Range Weather Forecasting, Noida.
    - Mihir is primarily used for weather forecasting and climate research. It helps India make better forecasts in terms of monsoon, fishing, air quality, and extreme events like tsunamis, cyclones, earthquakes, lightning, and other natural calamities such as floods and droughts

These supercomputers play a crucial role in various scientific and computational endeavors in India, furthering the country's technological capabilities.

Applications of supercomputing

1. Scientific Research

- **Climate Modelling**: Supercomputers are utilized to simulate and analyze climate patterns. Detailed simulations can help in predicting weather and understanding climate change impacts.
- **Astrophysics**: In the field of astrophysics, they are used for simulating the formation of galaxies and studying the characteristics of celestial bodies.

2. Healthcare

- **Drug Discovery**: Supercomputers facilitate the drug discovery process by analyzing the molecular structures and predicting the behavior of potential drugs.
- **Genomic Sequencing**: They are instrumental in analyzing and sequencing large volumes of genomic data, which can assist in personalized medicine and understanding genetic diseases.

3. Defense and Security

- **Nuclear Simulations**: In the defense sector, supercomputers are used to simulate nuclear tests, which aids in understanding the impacts and effectiveness of nuclear weapons.
- **Cybersecurity**: Supercomputers can analyze vast networks and systems to detect and prevent cyber-attacks.

4. Manufacturing

- **Automotive Design**: In manufacturing, they assist in the automotive sector for simulating crash tests and optimizing vehicle designs.
- **Aerospace Engineering**: Supercomputers are used for simulating flight dynamics and optimizing the design of aircraft and space vehicles.

5. Finance

- **Risk Analysis**: In finance, they are employed for risk analysis and modeling, helping in predicting market trends and analyzing investment portfolios.
- **High-frequency Trading**: Supercomputers can process large volumes of data in milliseconds, facilitating high-frequency trading.

6. Education

- **Research and Development**: In the education sector, they are used for academic research, helping in simulating complex phenomena and conducting high-level mathematical computations.
- **Learning Tools**: Supercomputers can assist in the development of advanced learning tools and educational resources.

7. Energy Sector

- **Oil and Gas Exploration**: In the energy sector, they facilitate oil and gas exploration by analyzing seismic data and modeling reservoir simulations.
- **Renewable Energy Research**: Supercomputers assist in researching and developing renewable energy sources, such as wind and solar energy, by simulating the potential impacts and efficiency of these sources.

8. Urban Planning

- **Infrastructure Design**: Supercomputers aid in urban planning by modeling and simulating the impacts of various infrastructure designs.
- **Traffic Management**: They can also assist in optimizing traffic management systems by analyzing large volumes of traffic data and predicting traffic patterns.

The National Supercomputing Mission (NSM)

The National Supercomputing Mission (NSM) was **launched in 2015.** It is designed to significantly elevate India's standing in the global computational research and innovation arena.

Objectives of the NSM

Advancement in Research and Development

- The National Supercomputing Mission (NSM) plays a crucial role in providing high-performance computing (HPC) capacity to research institutions in India.
- Accelerating innovations through the facilitation of complex simulations and analyses for researchers, academicians, and industry professionals.
- Provision of extensive computational resources to hasten advancements in scientific and technological fields within India.

Stimulation of MSMEs and Startups

- Facilitating high-end product development and innovation through the provision of cutting-edge computing infrastructure.
- Significant contribution to the economic growth of the country by nurturing the growth of MSMEs and startups.

Key Stakeholders and Roles

Department of Science and Technology (DST)

- Strategic framework development for the NSM to enhance scientific research and promote technological advancements in the nation.
- Focus on integrating mission resources to catalyze scientific discoveries.

Ministry of Electronics and IT (MeitY)

- Harmonizing NSM objectives with the broader goals of digital India.
- Ensuring the integration of advanced computing capabilities within governmental and industrial sectors.

Centre for Development of Advanced Computing (C-DAC), Pune

- Primary responsibility for developing supercomputing facilities and technologies under the mission.
- Concentration on establishing a scalable and resilient supercomputing ecosystem.

Indian Institute of Science (IISc), Bengaluru

- Collaborative efforts with C-DAC to amplify computational science research capacities.
- Promoting innovation and facilitating the dissemination of knowledge in the field.

Potential Impact and Future Prospects

- Revolutionizing research methodologies in the academic sector.
- Enabling comprehensive studies and analyses through enhanced computing infrastructures.
- Catalysing new heights in product development through the utilization of high computational power, particularly by MSMEs and startups.
- Enabling innovation and global competitiveness in the industrial sector.
- Encouraging research and innovations tailored to address challenges specific to India, encompassing areas such as climate studies and complex system simulations.

Conclusion

The NSM serves as a landmark initiative with the potential to position India as a global leader in the computational research and innovation sphere. It aims to foster a dynamic and robust supercomputing ecosystem in the country through collaborative efforts between various governmental departments and premier research institutions.

Grid Computing in India

Introduction to Grid Computing

- Grid computing is a distributed system where multiple computers networked across various physical locations collaborate to perform compute-intensive tasks.
- Utilizes a common protocol to work as a single virtual supercomputer.
- Not centralized; only requires a control node for coordination.
- Allows parallel task performance using multiple heterogeneous machines (machines with different operating systems).
- Users are not financially charged for utilizing the grid computing network.

Characteristics of Grid Computing

- **Computational Efficiency**: Capable of handling complex tasks that are too intensive for a single machine.
- **Decentralized Nature**: Operates without central servers, except for a control node that facilitates coordination.
- **Heterogeneous Environment**: Accommodates machines with different operating systems on a single grid computing network.
- **Parallel Task Performance**: Enables tasks to be executed simultaneously across different geographical locations.
- **Cost-Effectiveness**: Offers the capability to perform tasks without monetary charges imposed on the users.

Comparison: Grid Computing vs. Cloud Computing

- **Architecture**:
  - Cloud computing: follows a client-server computing architecture.
  - Grid computing: adopts a distributed computing architecture.
- **Management System**:
  - Cloud computing: managed centrally.
  - Grid computing: managed in a decentralized manner.
- **Resource Usage**:
  - Cloud computing: employs a centralized resource usage pattern.
  - Grid computing: encourages collaborative resource usage.
- **Flexibility**:
  - Cloud computing: offers higher flexibility.
  - Grid computing: comparatively less flexible.
- **Scalability**:
  - Cloud computing: characterized by high scalability.
  - Grid computing: offers limited scalability.
- **Accessibility**:
  - Cloud computing: high accessibility service.
  - Grid computing: lower accessibility service.
- **Payment Structure**:
  - Cloud computing: users pay for services utilized.

    - Grid computing: users do not incur charges for services used.
- **Services**:
    - Cloud computing: includes services like IAAS, PAAS, and SAAS.
    - Grid computing: encompasses services such as distributed computing, distributed pervasive, and distributed information.
- **Orientation**:
    - Cloud computing: service-oriented.
    - Grid computing: application-oriented.

Working Mechanism of Grid Computing

- Operates by installing specialized software on every participating computer.
- The software coordinates tasks across the grid, distributing subtasks to individual computers for simultaneous execution.
- Forms a virtual supercomputer by pooling resources from interconnected computers.
- Facilitates organizations in aggregating computing power, storage, and applications across diverse domains.
- Supports the completion of complex data-intensive tasks through the formation of a virtual supercomputer.

Grid Computing Applications

- High-Performance Computing
    - Utilized for performing tasks necessitating substantial computational resources.
    - Facilitates tackling problems that demand significant computational power but are not restricted by time constraints: Distributed Supercomputing.
    - Allows for rapid computation in situations where tasks demand a high computational power and need swift completion: On-demand Supercomputing.
- Scientific Research
    - Enables the resolution of intricate scientific problems.
    - Applications include simulating nuclear explosions, modeling the human genome, and analyzing large datasets generated from particle accelerators.
- Data Management
    - Supports the processing of extensive amounts of data: Data-intensive Supercomputing.
    - Useful in scenarios that necessitate repeated operations with high computational demands: High-throughput Supercomputing.
- Collaborative Applications
    - Aids in tasks necessitating collaboration between multiple users or entities: Collaborative Supercomputing.
    - Assists in the formation of virtual environments for user collaboration and resource sharing: Virtual Collaboration Environments.

Grid computing in India

- The **GARUDA** initiative stands as a significant **national grid computing venture** in India.
- A collaborative effort involving the **scientific**, **engineering**, and **academic communities** to conduct research and experiments on a large-scale computational grid.
- A project aimed at delivering **distributed data** and **high-performance computing solutions** to meet the requirements of the 21st century.
- Funded by the **Department of Information Technology (DIT)**.
- Deployment handled by the **Center for Development of Advanced Computing (C-DAC)**.
- A dedicated **Grid monitoring and management center** situated at C-DAC, Bangalore is responsible for overseeing all components within the grid.
- Currently connects **45 institutions** spanning across **17 cities**, aspiring to integrate grid computing into **research laboratories**, **industries**, and **academic institutions**.
- Possesses a computational capacity of approximately **65 Teraflops**.
- Supports applications of **national importance** that necessitate the aggregation of resources distributed geographically.
- Hosts **resource-intensive applications** from a variety of **e-Science domains** including:
    - **Bioinformatics**
    - **Astrophysics**
    - **Computer-Aided Engineering**
    - **Weather modeling**
    - **Seismic data processing**.
- Besides GARUDA, other significant initiatives are ongoing in the areas of **BIOGRID** and **VISHWA**.

Quantum Computing

Introduction

- **Definition of Quantum Computing**: Quantum computing is a type of computation that takes advantage of the quantum mechanical properties of particles to perform operations on data at a scale that is not feasible with traditional computers.
- **Historical Background**: The concept of quantum computing originated in the early 1980s with Richard Feynman and Yuri Manin proposing the idea of a machine that operates on quantum mechanical principles.

- **Significance**: Quantum computers promise to solve complex problems significantly faster than classical computers, especially in fields such as cryptography, material science, and complex system simulation.

Principles of Quantum Computing

Superposition

- **Concept**: Superposition refers to the quantum phenomenon where particles exist in multiple states at once, enabling a quantum computer to perform many calculations simultaneously.
- **Applications**: This principle finds significant application in parallel computing and cryptography.

Quantum Bits (Qubits)

- **Definition**: Unlike classical bits that can be either 0 or 1, a quantum bit (qubit) can exist in a state corresponding to both 0 and 1 simultaneously, due to the principle of superposition.
- **Manipulation**: Utilizing the principle of superposition, a quantum bit (qubit) can simultaneously exist in states of 1 and 0, allowing it to perform multiple calculations at once. This phenomenon, described as cooperation between parallel universes, exponentially increases computational power with the addition of each qubit, revolutionizing computational capabilities.

Entanglement

- **Concept**: Quantum entanglement is a physical phenomenon where the state of one particle instantly influences the state of another, no matter the distance separating them.
- **Applications**: Entanglement is exploited in quantum computing for complex operations and algorithms, such as quantum teleportation and quantum key distribution.

Quantum Computing Algorithms

Shor's Algorithm

- **Purpose**: Developed by Peter Shor in 1994, this algorithm can factor large numbers exponentially faster than the best-known algorithms running on a classical computer.
- **Significance**: This algorithm threatens current cryptographic techniques, as it can potentially crack encryption codes much quicker.

Grover's Algorithm

- **Purpose**: Devised by Lov Grover in 1996, it's designed for searching an unsorted database.
- **Efficiency**: It can perform these tasks considerably faster than any classical algorithm.

Current Developments and Future Prospects

- **Research and Development**: Many nations and corporations are investing heavily in research and development to build scalable and reliable quantum computers (e.g. Google, IBM, Alibaba, Amazon etc.). As of now, IBM has the leadership in this space.
    - In November 2022, IBM unveiled its new 433-qubit Osprey chip, which was once the world's most powerful quantum processor. It is now the world‘s second most powerful quantum computer.
    - As of the latest information in January 2024, the world’s most powerful quantum computer is from a California-based start-up called **Atom Computing**, which has a quantum computer with **1180 qubits**. This quantum computer uses neutral atoms trapped by lasers in a 2-dimensional grid.
    - IBM has more than 20 quantum computers available on its open-source quantum toolkit Qiskit.
    - IBM offers free access to some quantum machines, while paying clients like startups and scholars can lease more powerful ones remotely.
    - IBM has a roadmap to launch a 1,121-qubit processor in the current year 2024.
    - By 2025, IBM plans to surpass 4,000 qubits by creating modular quantum circuits that connect multiple processor chips in the same computer.
- **Potential Applications**: Quantum computing has potential applications in numerous fields including medicine for drug discovery, finance for portfolio optimization, and logistics for route optimization etc.
- **India's Initiative**: In India, significant strides are being made in the field, with the government launching the Quantum Computing Applications Lab in collaboration with AWS, aiming to boost quantum computing research and development in the country.

Application Areas

Quantum computing stands as a rapidly progressing field with the potential to influence various domains significantly. Here are the key areas where quantum computing is anticipated to make a substantial impact:

1. **Artificial Intelligence**

   Quantum computing can potentially foster advancements in deep learning, enhancing the understanding of quantum mechanics. Simultaneously, matured quantum computers may excel in data pattern recognition, surpassing traditional computers.

2. **Energy Storage**

   The field may contribute to the creation of batteries with enhanced efficiency and longevity.

3. **Agricultural Advancements**

   Quantum computers might play a role in formulating cleaner fertilization methods.

4. **Cybersecurity**

   The application of quantum computing is foreseen to reinforce cybersecurity protocols.

5. **Pharmaceutical Innovations**

   The advent of quantum computing can be a catalyst in the revolution of drug development, allowing the simulation of molecular-level quantum mechanics.

6. **Materials Science**

   Quantum computers have the potential to aid in the discovery of novel electronic materials.

7. **Financial Analysis**

   Quantum computing is poised to refine financial modeling, facilitating more accurate predictions.

8. **Renewable Energy**

   The technology might enhance methods for solar energy capture.

9. **Urban Planning**

Quantum computers could streamline traffic flow management, reducing congestion and fostering more efficient transportation systems.

10. **Meteorology and Environmental Science**

    Quantum computing can enhance weather forecast accuracy and be a vital tool in climate change studies.

Concerns

1. **Security Risks**: The significant computing power of quantum computers poses a threat to existing cryptographic systems, potentially rendering them obsolete. This could compromise the security of sensitive information, including communications, financial transactions, and military defenses.
2. **Race for Technological Dominance**: The development of quantum computing has become a race between nations, particularly China and the United States, as they strive to gain a competitive edge in this disruptive technology.
3. **Impact on Industries**: Quantum computing has the potential to disrupt various industries, affecting traditional computing, cryptography, logistics, finance, and more.
4. **Ethical Considerations**: Quantum computing raises ethical questions related to privacy, data security, and the potential for misuse. Safeguarding personal and sensitive information becomes even more critical as the computing power of quantum computers advances.
5. **Economic Disparities**: The development and deployment of quantum computing technologies may lead to economic disparities between countries and industries. Access to quantum computing resources and expertise may become a determining factor in economic competitiveness.

Need for New Regulations

The rapid advancement of quantum computing necessitates the development of new regulations and policies to address potential risks and ensure responsible use. Establishing guidelines for data protection, encryption standards, and international cooperation becomes crucial.

Skill Gap and Talent Acquisition

Quantum computing requires specialized knowledge and skills. The demand for experts in quantum physics, computer science, and related fields is likely to increase. Bridging the skill gap and attracting top talent will be essential for the successful development and adoption of quantum computing.

Cyber Security

A cyber or cybersecurity threat is **a malicious act that seeks to damage data, steal data, or disrupt digital** life in general.

Major Types of Cyber Threats

1. **Malware Attacks**: Comprises malicious software designed to compromise computer systems. Variants include viruses, worms, trojans, spyware, and ransomware.
2. **Social Engineering Attacks**: Involve the manipulation of individuals into disclosing confidential information or performing certain actions.
3. **Software Supply Chain Attacks**: Occur when attackers infiltrate a software vendor's network and incorporate malicious code into the software.
4. **Advanced Persistent Threats (APT)**: Long-term attacks focused on infiltrating networks to obtain sensitive data.
5. **Distributed Denial of Service (DDoS)**: Involves multiple compromised computers attacking a single target to disrupt services.
6. **Man-in-the-Middle Attack (MitM)**: Attackers intercept data during a two-party transaction, with the potential to alter or steal the information.

Common Types of Malwares

Definition of Malware

Malware stands for **malicious software** and is developed to intentionally harm or exploit any programmable device, service, or network. Cybercriminals design this software to compromise the **integrity, confidentiality, and availability**of victimized systems or data.

Types of Malware

1. **Ransomware**: This type restricts access to the victim's data and demands ransom for its release. Typically, it **encrypts files** and requires payment in **cryptocurrency** to unlock them.

2. **Fileless Malware**: Unlike traditional malware that relies on files, this one embeds itself into **native operating system files** or tools, making it harder to detect.
3. **Spyware**: This malware type secretly monitors and collects **user data**, such as login credentials, personal information, and browsing habits, without user consent.
4. **Adware**: Adware auto-displays or downloads **advertising material** on the victim's machine, affecting user experience and potentially leading to more malicious downloads.
5. **Trojans**: Named after the Greek myth, Trojans disguise themselves as legitimate software. Once installed, they execute **hidden malicious functions**.
6. **Worms**: These self-replicating programs exploit **vulnerabilities** to spread across a network without user intervention.
7. **Rootkits**: These provide cybercriminals with **remote control** over a compromised system, often disguising themselves as legitimate system files.
8. **Keyloggers**: This type monitors and records **keystrokes**, often to capture passwords, credit card numbers, and other sensitive information.
9. **Bots**: These **automated programs** can carry out tasks such as sending spam or participating in **Distributed Denial of Service (DDoS)** attacks.
10. **Mobile Malware**: Targeting mobile devices, this malware type can do anything from **unauthorized data collection** to complete device control.
11. **Wiper Malware**: It erases data and **system functionalities** to the point where data recovery is impossible.

Examples Specific to India

In India, one prevalent form of malware has been ransomware affecting **public and private enterprises**. For instance, in 2020, the Indian Computer Emergency Response Team (**CERT-In**) reported an increase in ransomware attacks against Indian entities. Similarly, **mobile malware** has seen a surge, given the high usage of mobile devices and applications in the country.

Common Sources of Cyber Threats

1. **Nation States**: Engage in cyber warfare against entities within other countries.
2. **Terrorist Organizations**: Conduct attacks aimed at disrupting or exploiting critical infrastructure.

3. **Criminal Groups**: Focus on economic gains through hacking and data breaches.
4. **Hackers**: Individuals who employ various attack techniques targeting organizations.
5. **Malicious Insiders**: Employees with access who misuse their privileges for economic or personal gain.

Cyberthreats and India

Rise in Cybercrime Statistics

- In 2019, India witnessed a **63.5% increase** in cybercrime cases.
- The number of reported cyberattacks rose to approximately **1.16 million cases in 2020**, nearly threefold compared to 2019 and over twentyfold since 2016.
- On a daily basis, an average of **3,137 cybersecurity-related issues** were reported in 2020.

Nature and Scope of Threats

- India faces increasing cyber intrusions that target **sensitive and personal data**, as well as **critical information infrastructure**.
- The threats to India's cybersecurity are continually evolving, posing challenges from both **state-affiliated and non-state actors**.
- A cyberattack on India’s nuclear and conventional arsenals could have dire implications, destabilizing **deterrence stability in South Asia**.

Case Studies of Cyber Attacks

- Air India, the national airline, suffered a cyber-attack affecting approximately **4.5 million customers globally**.
- In 2018, Pune-based Cosmos Bank lost **Rs 94 crore** due to a malware attack.
- The Kudankulam nuclear plant was targeted in a malware attack in 2019.
- The boundless nature of cyberspace makes it difficult to defend **critical state assets**.

India’s Management of Cybersecurity

India manages its cybersecurity through a multi-pronged approach:

1. **National Cyber Security Strategy**: In 2020, the National Cyber Security Strategy was conceptualized by the Data Security Council of India (DSCI) headed by Lt General Rajesh Pant. The report focused on 21 areas to ensure a safe, secure, trusted, resilient, and vibrant cyberspace for India.
2. **CERT-In**: The Indian Computer Emergency Response Team (CERT-In) is the government-appointed nodal agency tasked with performing cybersecurity-related functions. It has issued new cybersecurity directions under section 70B of the parent legislation, the Information Technology Act, 2000 (IT Act). These directions relate to information security practices, procedure, prevention, response, and reporting of cybersecurity incidents.
3. **Ministry of Home Affairs**: The Ministry of Home Affairs looks at internal security, including cybersecurity. For this purpose, it has set up the cyber and information security division, comprising a cybercrime wing, cybersecurity wing, and monitoring unit. To combat cybercrime, it also established the Indian Cyber Crime Co-ordination Centre in 2018.
4. **Collaboration with Private Sector**: India also collaborates with private sector companies for insights and expertise in managing cybersecurity threats.

These measures help in managing the cybersecurity landscape in India.

India's Cybersecurity Architecture: Indian Computer Emergency Response Team (CERT-In or ICERT)

Organizational Overview

- The Indian Computer Emergency Response Team (CERT-In or ICERT) is a department under the Ministry of Electronics and Information Technology of the Government of India.
- Established in 2004, it serves as the **national nodal agency** for responding to computer security incidents.

Legal Framework

- CERT-In operates under the **Information Technology Amendment Act of 2008**, which designates it as the national agency responsible for various cybersecurity functions.

Core Functions

- **Collection, analysis, and dissemination** of information on cyber incidents.
- **Forecast and alerts** of cybersecurity incidents.
- Implementation of **emergency measures** for handling cybersecurity incidents.
- **Coordination** of cyber incident response activities.

Additional Responsibilities

- Issuance of **guidelines, advisories, vulnerability notes, and whitepapers** pertaining to information security practices, procedures, prevention, response, and reporting of cyber incidents.

Objective and Impact

- CERT-In aims to strengthen the security-related defense of the **Indian Internet domain**.

India’s Cybersecurity Architecture: Cyber Security Policy

The **National Cyber Security Policy of India** was established in 2013 by the Ministry of Electronics and Information Technology. Its primary objectives include fostering a secure computing environment, bolstering trust and confidence in electronic transactions, and providing a roadmap for stakeholders in cyberspace protection.

Key Areas of Focus

1. **Security of Cyber Space**: The policy acknowledges the role of information technology as a catalyst for economic development and underscores the necessity to protect cyberspace.
2. **Nature of Threat in Cyber Space**: The policy delves into the types of threats faced, the need for international cooperation, and outlines strategies for securing cyberspace.
3. **Enabling Processes**: This section delineates procedures for managing security threats and vulnerabilities. It includes early warning systems, crisis management planning to counter cyber attacks and cyber terrorism, legal frameworks, and mechanisms for information sharing.
4. **Deployment and Research & Development in Enabling Technologies**: The policy discusses the deployment of technological safeguards and focuses on research and development in cybersecurity.
5. **Enabling People**: One of the central tenets is the promotion of security education, skills training, certification, and the establishment of training infrastructure.
6. **Responsible Actions by User Community**: The policy specifies responsibilities for various user groups, including network service providers, large corporations, small and medium-sized businesses, and individual home users.

Stakeholder Consultation and Regulatory Framework

The policy was formulated in close consultation with a broad spectrum of stakeholders, including user entities and the general public. Additionally, it serves as a regulatory framework to secure e-governance operations.

India’s Cybersecurity Architecture: National Cyber Security Strategy 2020

The **National Cyber Security Strategy 2020** was developed by the **Data Security Council of India (DSCI)**, led by **Lt General Rajesh Pant**. The strategy's overarching goal is to ensure a cyberspace that is safe, secure, trusted, resilient, and vibrant for India.

Primary Objectives

1. **Improving Cyber Awareness and Cybersecurity**: The strategy advocates for enhanced cyber awareness and cybersecurity, recommending more stringent audit mechanisms.
2. **Regular Cyber Crisis Management Exercises**: The strategy prescribes routine table-top exercises focused on cyber crisis management to emphasize the continuous nature of cyber threats.
3. **Index of Cyber Preparedness**: The strategy calls for the creation and regular monitoring of an index that measures cyber preparedness across sectors.
4. **Separate Budget for Cybersecurity**: To allocate focused resources, the strategy recommends a separate budget for cybersecurity and aims to synchronize the functions of different agencies possessing domain-specific expertise.
5. **Protecting Critical Sectors**: Given the growing interconnectivity and multiple internet entry points, especially with the impending adoption of 5G, the strategy highlights the importance of protecting critical sectors.

Digital Personal Data Protection Act, 2023

Historical Context

- **Initial Draft**: The journey of the Digital Personal Data Protection Bill began with its first draft in **2018**.
- **Amendments and Revisions**: This draft underwent several rounds of amendments in **2019** and **2021**.
- **Superseding Legislation**: Eventually, it was replaced by the Digital Personal Data Protection Bill, **2022**.
- **Enactment**: The revised version, the Digital Personal Data Protection Bill, **2023**, was introduced on **3 August 2023**, passed by the Lower House of

Parliament on **7 August 2023**, and the Upper House on **9 August 2023**. It received Presidential assent and became law on **11 August 2023**.

Overview of the Digital Personal Data Protection Act, 2023 (DPDPA)

- **Objective**: The DPDPA aims to regulate the processing of personal data in a lawful manner, safeguarding and empowering the rights of Data Principals.
- **Key Elements**: It emphasises **accountability**, **transparency**, **data minimisation**, **fairness**, **accuracy**, and **lawful processing** of personal data.
- **Innovative Gender Representation**: For the first time in Indian law, it refers to Data Principals using female pronouns (''she/her''), setting a new precedent.

Salient Features of the DPDPA

- **Rights and Obligations Balance**: It recognises the need to balance individual rights for personal data protection and lawful data processing requirements.
- **Data Fiduciary Responsibilities**: Outlines obligations for Data Fiduciaries regarding data processing, including collection, storage, and other operations.
- **Data Principal Rights and Duties**: Establishes clear rights and duties for Data Principals.
- **Penalties**: Sets financial penalties for violations of rights, duties, and obligations.

Core Principles of the Act

1. **Consented and Lawful Use**: Mandates consented, lawful, and transparent use of personal data.
2. **Purpose Limitation**: Personal data can only be used for specified purposes.
3. **Data Minimisation**: Only necessary data for the specified purpose should be collected.
4. **Data Accuracy**: Ensures correctness and updation of data.
5. **Storage Limitation**: Data should be stored only as long as necessary.
6. **Security Safeguards**: Mandates reasonable security measures.
7. **Accountability**: Includes provisions for adjudication and penalties for breaches.

Innovative Aspects of the Act

- **Simplicity and Clarity**: The Act is designed to be simple (SARAL), accessible, rational, and actionable, using plain language and minimal legal jargon.
- **Gender Inclusivity**: Acknowledges women in legal texts by using "she" instead of "he".

Rights Provided to Individuals

- **Data Access and Correction**: Rights to access and correct personal data.
- **Erasure Right**: Right to erasure of data.
- **Grievance Redressal**: Mechanisms for addressing grievances.
- **Nomination Rights**: Right to nominate someone to exercise rights in case of death or incapacity.

Obligations on Data Fiduciaries

- **Security and Notification**: Includes implementing security safeguards and notifying breaches.
- **Data Erasure**: Obligation to erase data when no longer needed or upon consent withdrawal.
- **Grievance Systems**: Requirement to establish grievance redressal systems.

Protection of Children's Data

- **Parental Consent**: Processing of children's data requires parental consent.
- **Prohibitions**: Disallows processing that harms children's well-being or involves tracking or targeted advertising.

Exemptions

- **Specified Circumstances**: Exemptions apply for security, research, startups, legal processes, and other specified situations.

Functions of the Data Protection Board

- **Enforcement and Compliance**: Includes directing remedial actions, inquiring into breaches, imposing penalties, and advising on regulatory measures.

Global Context

As per **UNCTAD**, 71% of countries have data protection laws, with variable adoption rates across Africa and Asia.

Unique Aspects in Indian Context

1. **Public Data Exemption**: Unlike global norms, publicly available data is not protected.
2. **Consent Managers**: The Act introduces regulated consent management entities.
3. **Data Flow Flexibility**: It is lenient on conditions for cross-border data transfer.
4. **Children's Data**: It treats all children under 18 alike, contrasting with global laws.

Conclusion

Comprehensive digital governance involves more than just data protection laws. It should encompass cybersecurity, competition, and artificial intelligence, among other aspects. Learning from the European Union's strategy can offer valuable insights into achieving a comprehensive regulatory framework.

National Data Governance Policy

Policy Announcement and Origin

The **National Data Governance Policy** was announced during the Union Budget presentation for 2023-24 on February 1, 2023. This policy aims to "unleash innovation and research by start-ups and academia" by facilitating access to anonymised data.

Previously, the **Ministry of Electronics and Information Technology (MeitY)** had released a draft of this policy for public consultation in May 2022.

The draft aimed to establish the **India Data Management Office (IDMO)** under the Digital India Corporation and to outline guidelines for sharing non-personal data by private entities.

Objectives and Provisions

- The main objective of the policy is to modernize the government’s data collection and management.
- It aims to foster an Artificial Intelligence (AI) and data-driven research and start-up ecosystem in India.
- The policy proposes the initiation of an India Datasets programme.
- This programme will manage the "safe availability" of non-personal data from both government and private entities, for use by researchers, innovators, and for accelerating digital governance.

Definition of Non-Personal Data

Non-personal data is defined as any set of information that does not contain personally identifiable details. It has been further categorized into three types: public, community, and private.

Role of India Data Management Office (IDMO)

The IDMO will be responsible for designing and managing the **India Datasets platform**. It will prescribe rules and standards, including anonymization protocols for all entities, both government and private.

Significant Changes from Previous Draft

The new draft has omitted the controversial provision from the older draft, which allowed the selling of data collected at the Central level in the open market. Moreover, private companies will now be "encouraged" rather than mandated to share such data.

Applicability and State Involvement

Once finalized, the policy will apply to all Central government departments. State governments will also be "encouraged" to adopt the provisions of the policy.

Challenges and Criticisms

The new draft has not clearly defined the composition of the IDMO. Experts have also raised concerns that private companies may not voluntarily share non-personal data, and that there might be intellectual property issues.

Conclusion

The **National Data Governance Policy** is currently under finalization and aims to set the framework for data governance in India, primarily focusing on non-personal data. It presents an institutional architecture that aims to regulate the collection, storage, and usage of such data to improve governance and foster data-driven innovation.

Neuralink Technology

Neuralink Corporation

- **Neuralink**: A neurotechnology company co-founded by **Elon Musk** in **2016**.
- **Focus**: Developing an implantable **brain-computer interface (BCI)**, termed the "Link".
- **The Link**: A coin-sized device implanted in the skull, equipped with wires for neuron activity reading and wireless signal transmission.

First Human Implant

- **Milestone**: First human patient received the Neuralink implant on **January 28, 2024**.
- **Elon Musk**, founder of **Neuralink**, announced the successful implantation of the company's brain-chip in a human, with the patient recovering well.

- This milestone followed the **US Food and Drug Administration (FDA)** clearance in September for human trials.

Product Introduction: Telepathy

- The first Neuralink product, named **Telepathy**, allows users to control phones, computers, and other devices through thought.
- Initial users are individuals with lost limb function, aiming to enhance communication capabilities to levels surpassing fast typists or auctioneers.
- The device, resembling a large coin, is designed for skull implantation, with ultra-thin wires interfacing directly with the brain.
- These wires target the brain area controlling movement intention, with the primary goal of enabling thought-controlled cursor or keyboard operation.

The technology

It is focused on developing an implantable brain-computer interface, designed to translate thoughts into actions.

This innovative technology comprises several key components.

Key Components of Neuralink Technology

Component	Description
The Link	A coin-sized brain chip, implanted under the skull, interfacing with neural threads in brain areas controlling motor skills.
Neural Threads	Tiny electrodes implanted in the brain to detect and transmit neural signals to a computer.
Neurosurgical Robot	A robot designed to insert the fine and flexible neural threads, aiming for full automation. The threads are so fine and flexible that they
can't be inserted by the human hand.	
Electrophysiology	The technology similar to electrophysiology, capturing brain activity through electrodes that measure electrical spikes.

Component	Description
Software	An app under development to enable control of a keyboard and mouse using only the mind.

Potential Applications of Neuralink

The development of Neuralink represents a substantial leap in neurotechnology. It aims to create a brain-machine interface that is noninvasive yet highly accurate. This breakthrough has immense potential to transform treatments for various neurological conditions, marking a new era in medical and technological advancements.

Some applications include:

- **Neurological Disorder Treatment**: Aid for individuals with Parkinson's disease or paralysis.
- **Mental Health Monitoring**: Treatment possibilities for burnout, anxiety, and depression.
- **Cognitive Enhancement**: Potential improvement in memory, learning, and problem-solving.
- **Human-Machine Collaboration**: Facilitating efficient interaction between humans and machines.

Key Concerns

Risk Category	Type	Description
Health Risks	Brain Injury or Infection	Risks associated with incorrect implantation.
Abuse and Misapplication	Potential Misuse	Risks of control and information theft.
Lack of Long-Term Research	Research Gap	Insufficient data on long-term BCI effects.
Privacy Invasion	Privacy Concerns	Potential for unauthorized thought and memory access.
Unintended Consequences	Behavioral Impact	Risk of addiction and reduced interest in real-life experiences.

Digital India

- The Digital India programme, formally launched in **July 2015** is a flagship programme of the Government of India with a vision **to transform India into a digitally empowered society and a knowledge-based economy,** by ensuring digital access, digital inclusion, digital empowerment and bridging the digital divide.
- The overall goal is to ensure that digital technologies improve the life of every citizen, expand India's digital economy, and create investment and employment opportunities and create digital technological capabilities in India.

15.1. Three Vision Areas

The Digital India programme is centred on three key vision areas:

1. Digital infrastructure as a utility to every citizen

- Availability of high speed internet as a core utility for delivery of services to citizens.
- Cradle to grave digital identity that is unique, lifelong, online and authenticable to every citizen.
- Mobile phone & bank account enabling citizen participation in digital and financial space.
- Easy access to a Common Service Centre.
- Shareable private space on a public cloud.
- Safe and secure cyberspace.

2. Governance & services on demand

- Seamlessly integrated services across departments or jurisdictions.
- Availability of services in real time from online & mobile platforms.
- All citizen entitlements to be portable and available on the cloud.
- Digitally transformed services for improving ease of doing business.
- Making financial transactions electronic & cashless.
- Leveraging Geospatial Information Systems (GIS) for decision support systems & development.

3. Digital empowerment of citizens

- Universal digital literacy.
- Universally accessible digital resources.
- Availability of digital resources / services in Indian languages.
- Collaborative digital platforms for participative governance.
- Citizens not required to physically submit Government documents / certificates.

15.2. Nine Pillars of Growth Areas

Digital India aims to provide the much needed thrust to the nine pillars of growth areas, namely:

- Broadband Highways
- Universal Access to Mobile Connectivity
- Public Internet Access Programme
- e-Governance: Reforming Government through Technology
- e-Kranti - Electronic Delivery of Services
- Information for All
- Electronics Manufacturing
- IT for Jobs
- Early Harvest Programmes

15.3. Achievements Made under Digital India (As of December 2022)

- **Aadhaar:** Over 135.5 crore residents have been enrolled.
- **Common Services Centres:** CSCs are offering government and business services in digital mode in rural areas through Village Level Entrepreneurs (VLEs). 5.21 Lakh CSCs are functional across the country, out of which, 4.14 Lakh CSCs are functional at Gram Panchayat level.
- **DigiLocker:** It has more than 13.7 crore users and more than 562 crore documents are made available through DigiLocker from 2,311 issuer organizations.
- **Unified Mobile Application for New-age Governance (UMANG):** More than 1668 e-Services and over 20,197 bill payment services are made available at UMANG.
- **e-Sign:** e-Sign service facilitates instant signing of forms/documents online by citizens in a legally acceptable form. More than 31.08 crore e-Sign issued by all agencies wherein, 7.01 Crore e-Sign issued by CDAC.
- **MyGov:** It is a citizen engagement platform that is developed to facilitate participatory governance. Over 2.76+ crore users are registered with MyGov.
- **MeriPehchaan:** National Single Sign-on (NSSO) platform called MeriPehchaan has been launched in July 2022 to facilitate / provide citizens ease of access to government portals. Total 4419 services of various Ministries/States integrated with NSSO.
- **Digital Village:** MeitY has initiated 'Digital Village Pilot Project' in October, 2018. 700 Gram Panchayats (GPs)/Village with at least one Gram Panchayat/Village per District per State/UT are being covered under the project.
- **National Rollout of eDistrict MMP:** A Mission Mode Project (MMP) that aims at electronic delivery of identified high volume citizen centric services at the district or sub-district level. 4,671 e-services have been launched in 709 districts across India.
- **Open Government Data Platform:** To facilitate data sharing and promote innovation over non-personal data. More than 5.93 lakh datasets across 12,940+ catalogues are published.
- **eHospital/ Online Registration System (ORS):** 753 Hospitals have been on-boarded on e-Hospital and ORS has been adopted by 557 hospitals across the country with over 68 lakh appointments booked from ORS.
- **CO-WIN:** It is an open platform for management of registration, appointment scheduling & managing vaccination certificates for Covid-19. It has registered 110 crore persons and has facilitated administration of 220 crore doses of vaccinations.
- **Jeevan Pramaan:** Jeevan Pramaan envisages to digitize the whole process of securing the life certificate for Pensioner. Over 685.42 lakh Digital Life certificates have been processed since 2014.

- **National Knowledge Network:** A high speed data communication network has been established to interconnect Institution of higher learning, and research. 1752 links to Institutions have been commissioned and made operational.
- **Pradhan Mantri Gramin Digital Saksharta Abhiyaan (PMGDISHA):** It has 6.63 crore registered candidates and out of this, 5.69 crore candidates have been trained and 4.22 crore have been certified.
- **Unified Payment Interface (UPI):** It has onboarded 376 banks and has facilitated 730 crore transactions (by volume) worth Rs 11.9 lakh crore.

16. Blockchain Technology

- Blockchain technology is a **decentralized and distributed ledger that securely records ownership of digital assets.**
- It prevents data modification, making it disruptive in industries like payments, cybersecurity, and healthcare.
- The blockchain database arranges data into linked blocks, forming a chain that maintains chronological consistency. The data remains constant because altering the chain requires network consensus, **preventing deletion or modification**.

16.1. History of Blockchain

- Blockchain's concept started in 1991 with a secure chain of records proposed by **Stuart Haber and Wakefield Scott Stornetta**.
- In 2008, **Satoshi Nakamoto** introduced a crucial model and application.
- The first blockchain and cryptocurrency launched in 2009, with the inaugural successful Bitcoin transaction between **Hal Finney and Satoshi Nakamoto**.

16.2. Features of Blockchain Technology

- **Decentralization:** Transferring of control and decision making from a centralized entity to a distributed network.
- **Immutability:** Once a transaction is on the blockchain, it can't be changed, maintaining the information's security.
- **Consensus:** Blockchain establishes rules about participant consent for recording transactions. A person can record new transactions only when the majority of participants in the network give their consent.

16.3. Types of Blockchain Networks

Public Blockchains:

- Open to everyone, requiring no special permission to join, and operate in a fully decentralized manner.
- All participants have equal rights to access, create, and validate blocks.
- Used for exchanging and mining cryptocurrencies like **Bitcoin and Ethereum**.

Private Blockchains:

- Controlled by a single organization, also known as **managed blockchains.**
- Public access is restricted, making them partially decentralized.
- The organization determines membership and rights.

Consortium Blockchains:

- Governed by a group of organizations, not a single entity.
- More decentralized than private blockchains, enhancing security.
- Setting up requires collaboration, presenting challenges and potential risks.

Hybrid Blockchains:

- Hybrid blockchains blend features of private and public networks.
- Companies establish private, permission-based systems alongside a public system, enabling control over specific data access while keeping the rest public.
- They utilize smart contracts, enabling public members to verify the completion of private transactions.

16.4. How Does Blockchain Work?

Record the transaction

- The first step is to record the transaction. A blockchain transaction shows the movement of physical or digital assets from one party to another in the blockchain network.
- Details like who, what, and when are included in a data block. For example:
    - Who was involved in the transaction?
    - What happened during the transaction?
    - When did the transaction occur?

Gain consensus

- Most participants on the distributed blockchain network must agree that the recorded transaction is valid.
- Depending on the type of network, rules of agreement can vary but are typically established at the start of the network.

Link the blocks

- Once the participants have reached a consensus, transactions on the blockchain are written into blocks equivalent to the pages of a ledger book.
- Each block has a **cryptographic hash** linking them together securely.
- If someone tries to change the block, the hash value changes, revealing tampering.
- Thus, the blocks and chains link securely, and a person cannot edit them. Each additional block strengthens the verification of the previous block and therefore the entire blockchain.

Share the Ledger

- This is the last stage. The system distributes the latest copy of the central ledger to all participants.

16.5. Applications of Blockchain Technology

Cryptocurrency:

- Blockchain is widely known for its use in cryptocurrencies like Bitcoin and Ethereum.
- Transactions made with cryptocurrencies are recorded on a blockchain. As more people use cryptocurrency, blockchain technology becomes more widespread.

Banking:

- Blockchain is used to process transactions in traditional fiat currencies like dollars and euros.
- It can potentially make transactions faster than through traditional financial institutions.

Asset Transfers:

- Blockchain records and facilitates the transfer of ownership for various assets.
- Particularly popular with digital assets like non-fungible tokens (NFTs).

Executing Contracts:

- Another blockchain innovation is self-executing contracts commonly called “smart contracts.” These digital contracts are enacted automatically once conditions are met.
- For example, instant release of payment when both parties meet specified deal parameters.

Supply Chain Monitoring:

- Blockchain improves supply chain traceability, making it easier to identify the source of issues.
- Particularly useful for tracking the origin of goods and ensuring quality.

Voting:

- Blockchain voting ensures secure and tamper-proof ballots.
- Eliminates the need for manual collection and verification of paper ballots.

Energy:

- Energy companies use blockchain for peer-to-peer energy trading and streamlining access to renewable energy.
- Blockchain-based crowdfunding allows users to sponsor and own solar panels in communities lacking energy access.

Media and Entertainment:

- Blockchain aids in copyright verification for fair compensation in media and entertainment.

- Companies use blockchain systems to manage copyright data through multiple transactions.

16.6. Advantages of Blockchain

Higher Accuracy of transactions:

- Multiple nodes verify transactions, reducing errors.
- Mistakes in one node are caught by others, ensuring accuracy.

No Intermediaries:

- Direct confirmation and completion of transactions.
- Saves time and costs by bypassing intermediaries like banks.

Extra Security:

- Decentralization makes fraudulent transactions nearly impossible.
- Hacking every node for ledger changes is highly challenging.

Efficient Transfers:

- Operates 24/7, enabling efficient global financial and asset transfers.

16.7. Disadvantages of Blockchain

High Energy Costs:

- The process of all nodes verifying transactions in blockchain consumes more electricity than a single database, raising the cost of blockchain transactions.
- Contributes to a significant carbon footprint, posing environmental concerns.

Risk of Asset Loss:

- Some digital assets are secured using a cryptographic key, like cryptocurrency in a blockchain wallet. Loss of a cryptographic key means permanent loss of digital assets.
- No recovery method for lost keys, posing a risk to asset security.

Potential for Illegal Activity

- Blockchain's enhanced privacy makes it appealing to criminals.
- Tracking illicit transactions is more challenging than traditional bank methods.

16.8. Blockchain Development in India

- **Potential Growth:** Predicted blockchain adoption in India could reach 46% by 2026, indicating significant economic prospects.
- **Government Recognition:** The Ministry of Electronics and Information Technology (MeitY) has identified Blockchain Technology as one of the important research areas having application potential in different domains such as Governance, Banking & Finance, Cyber Security and so on.

- **Multi-Institutional Project:** MeitY has supported a multi-institutional project titled "**Distributed Centre of Excellence in Blockchain Technology**" in collaboration with C-DAC, IDRBT, Hyderabad, and VJTI, Mumbai as executing agencies.
    - As part of this initiative, agencies have carried out research on the use of Blockchain technology in various domains and developed Proof-of-Concept solutions.
- **Establishment of Centre of Excellence (CoE):** National Informatics Centre (NIC) established the **Centre of Excellence (CoE)** in Blockchain technology in collaboration with National Informatics Centre Services Incorporated (NICSI). Objectives of CoE includes:
    - Accelerate adoption and deployment of Blockchain technology in the Government.
    - Execute projects focusing on different use cases and pilot deployment.
    - Offer Blockchain-Platform as a service to enhance design and development.
    - Provide consultancy services and contribute to capacity building.
- **Recognition by NITI Aayog:** NITI Aayog acknowledges Blockchain as a promising technology with its features like decentralization, transparency, and accountability.

16.9 National Strategy on Blockchain

- The Ministry of Electronics and Information Technology (MeitY) released the **'National Strategy on Blockchain'** in December 2021. It aims to establish a trusted digital platform, creating a blockchain framework for application development.

Vision

- Develop trusted digital platforms through shared blockchain infrastructure.
- Promote research, innovation, technology, and application development.
- Ensure transparent, secure, and trusted digital service delivery, positioning India as a global leader in Blockchain Technology.

Objectives

- **National Blockchain Infrastructure:** Create a trusted digital platform using a national blockchain infrastructure and facilitate development and deployment of applications with a testing sandbox.
- **Research & Development:** Foster R&D in Blockchain to address challenges in rapid application development, interoperability, scalability, security, and privacy.
- **Innovation Roadmap:** Develop and update an innovation roadmap for a trusted digital platform and address challenges to enhance Blockchain technology adoption.
- **Production Grade Applications:** Plan for national interest applications, ensuring faster, secure, transparent, and efficient service delivery.
- **Standards Development:** Encourage the development of standards in Blockchain technology.
- **Legal and Policy Framework:** Identify legal and policy requirements for regulating Blockchain services for citizens and businesses.

- **Multi-Stakeholder Model:** Promote a multi-stakeholder model in building the national Blockchain infrastructure, ensuring transparency, trust, and provenance.
- **Global Collaboration:** Strengthen collaboration with global organizations, innovation, and research centers in Blockchain technologies.
- **Centralized Planning, Decentralized Execution:** Evolve a centralized planning and decentralized execution model for large-scale adoption.
- **Capacity Building and Skill Development:** Promote capacity building, skill development, and innovation in Blockchain technology.

17. Cryptocurrency

- Cryptocurrencies are a unique form of digital currency that operates on **decentralized blockchain technology, allowing for secure and transparent transactions**.
- The name **"cryptocurrency"** is derived from the **use of encryption to validate and safeguard transactions**, involving advanced coding for the storage and transmission of data between wallets and public ledgers.
- **Bitcoin,** introduced in 2009, is the **first** cryptocurrency and remains the most well-known. Other examples include **Ethereum, Litecoin, Ripple**, among others.
- The functioning of cryptocurrencies relies on **nodes**, **a network of contributors that undertake various roles such as storing and validating transactional data.** Nodes collectively manage the database and validate new transaction entries, ensuring there is no single point of failure. This decentralized nature means that if one node experiences an issue, it has no impact on the overall integrity of the blockchain ledger.

17.1. Origin of Bitcoin

- Bitcoin's origin is unclear. It is attributed to a person or group using the pseudonym **Satoshi Nakamoto**, who is believed to have conceived the idea in response to the **2008 financial crisis**.
- Nakamoto outlined the concept in a white paper, proposing **a peer-to-peer electronic cash system**, which aimed to facilitate **online payments directly between parties without the need for intermediaries like financial institutions**.

17.2. Working Mechanism of Bitcoin

- Bitcoin transactions are messages indicating bitcoin **movement between senders and receivers**.
- Transactions are **digitally signed using cryptography** and sent to the entire Bitcoin network for verification.
- Transaction information is public and can be found on the digital ledger, i.e, the blockchain.

- The history of each Bitcoin transaction leads back to the point where the bitcoins were first produced or 'mined.'

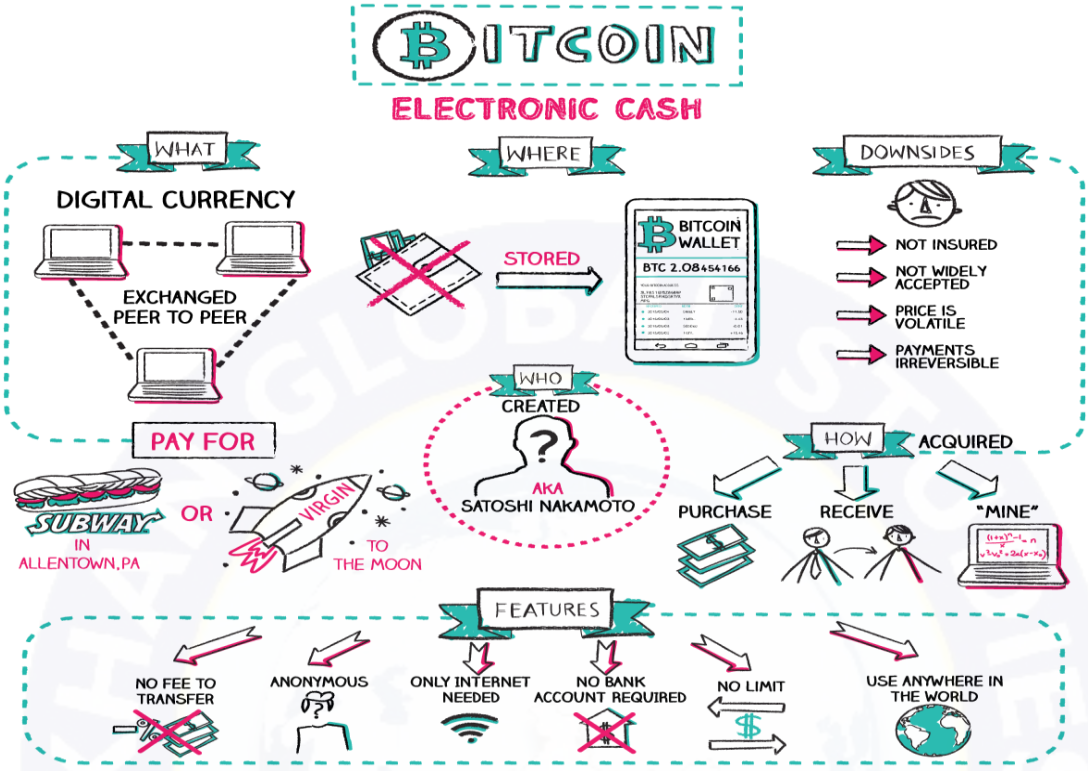

Figure.2. Features of Bitcoin

17.3. Advantages and Disadvantages of Cryptocurrency

Advantages

- Easier to transfer funds between parties
- Protection from inflation.
- Transactional Speed.
- Cost Effective Transactions.
- Decentralization.
- Self-governed and managed.
- Safe, secure and transparent
- Can be used to generate returns.
- Remittances are streamlined.

Disadvantages

- Transactions are pseudonymous.
- Pseudonymity allows for criminal uses.
- Expensive to participate in a network and earn.
- Off-chain security issues.
- Prices are very volatile.

17.4. Cryptocurrencies in India

- Cryptocurrencies as a payment medium are **not regulated or issued by any central authority** in India. There are no guidelines laid down for sorting disagreements while dealing with cryptocurrency.
- Despite uncertainty around the future of cryptocurrencies in India, investments in the unregulated digital asset, especially Bitcoin, has shown a breathtaking upward trend since 2020.

2013: RBI's Warning

- RBI issued a circular highlighting security risk associated with virtual currencies.

2017-2018: Banking Ban and Legal Status

- RBI and Ministry of Finance warned against virtual currencies as legal tender.
- In March 2018, a draft scheme for banning virtual currencies was submitted by the Central Board of Digital Tax (CBDT) to the Ministry of Finance, leading to RBI's circular restricting dealings with virtual currencies.

March 2020: Supreme Court Lifts Banking Ban

- Supreme Court overturned RBI's ban, stating cryptocurrencies aren't illegal but not recognized as legal tender.

2021: Proposed Ban and Regulatory Talks

- In January 2021, the Indian government announced that it will introduce a Bill to create a sovereign digital currency and subsequently put a blanket ban on private cryptocurrencies.
- In November 2021, the Standing Committee on Finance, met the Blockchain and Crypto Assets Council (BACC) and other cryptocurrency representatives and concluded that cryptocurrencies should not be banned but regulated.

2022: Tax Regime Introduced

- Union Budget 2022 presented a tax regime for cryptocurrencies, stating that Investors must report the calculated profits and losses as a part of their income and a 30% tax will be charged on the earnings from the transfer of digital assets that include cryptocurrencies, NFTs, etc.

2023: Prevention of Money Laundering Act

- Digital assets, including cryptocurrencies, brought under the Prevention of Money Laundering Act, 2002.

The regulatory landscape has evolved, acknowledging cryptocurrencies but with varying degrees of acceptance and control.

18. Non-Fungible Tokens (NFTs)

- NFTs, or Non-Fungible Tokens, are like **digital assets that can be anything from art and music to in-game items and videos.** They're **bought and sold online** using cryptocurrency.

- They use the same technology as cryptocurrencies, making ownership and transactions secure.

18.1. Difference Between NFT and Cryptocurrency

- FTs, or **non-fungible tokens**, are created using the same technology as cryptocurrencies like Bitcoin or Ethereum, but they have a unique digital signature that sets them apart.
- Unlike traditional money or cryptocurrencies which are **"fungible**," meaning they can be traded or exchanged for one another, NFTs are non-fungible, meaning they **can't be exchanged for one another as each has its own distinct value**.
- This digital uniqueness makes NFTs stand out making it impossible for NFTs to be exchanged for or equal (hence, non-fungible).

18.2. Features of NFT

- NFTs exist on a blockchain, which is a distributed public ledger that records transactions.
- An NFT is **created, or "minted"** from digital objects that represent both tangible and intangible items, including graphic art, videos and sports highlights, collectibles, music, etc.
- Each NFT is **unique and can only belong to one person** at a time and their use of blockchain technology makes it easy to verify ownership and transfer tokens between owners.
- The creator can also store specific information in an NFT's metadata. For instance, artists can sign their artwork by including their signature in the file.

18.3. Creation of NFT

- A non-fungible token is **created by an artist, creator, or license-holder** through a process called minting.
- **Minting** is a process that **involves signing a blockchain transaction** that outlines the fundamental token details, which is then broadcasted to the blockchain to trigger a smart contract function which creates the token and assigns it to its owner.
- Under the hood, a non-fungible token consists of a unique token identifier, or token ID, which is mapped to an owner identifier and stored inside a smart contract.
- When the owner of a given token ID wishes to transfer it to another user, it is easy to verify ownership and reassign the token to a new owner.

18.4. Smart Contract

- A smart contract is **code** that is **executed** deterministically **in the context of a blockchain network;** each participant in the network verifies the state-changing operations that a smart contract's code makes.

- Smart contracts are the primary means by which developers can create and manage tokens on a blockchain.
- Smart contracts store information on the blockchain to track who owns which digital token. It's like a digital way of keeping records of ownership.

Communication Technology

Meaning of Communication Technology

- Communication technology is the **transfer of messages and information** among people and/or machines through the use of technology.
- This information process can assist humans in making decisions, solving issues, and controlling machines.
- Information and Communication technology is used in most of the fields such as Education, Agriculture, Medicine, Defense, E-governance, E- Commerce, Banking, Transport, etc.

1. Wireless Communication

- Wireless communication is the **transfer of information over a distance without the use of enhanced electrical conductors or "wires".** The distances involved may be short (a few meters as in television remote control) or long (thousands or millions of kilometres for radio communications).
- It encompasses various types of fixed, mobile, and portable two-way radios, cellular telephones, Personal Digital Assistants (PDAs), and wireless networking.

1.1. Different Generations of Wireless Communication

- Wireless telephones started with 0G (zero generation) systems, which became available after World War II.
- These mobile phones were typically installed in cars or trucks, and there were also portable briefcase models.
- The technologies used in 0G systems included MTS (Mobile Telephone System), IMTS (Improved Mobile Telephone Service), and AMTS (Advanced Mobile Telephone System). These early systems laid the foundation for the development of mobile phones.

Generations	Details	Advantages	Limitations
1G	**In 1979,** the first cellular system in the world became operational **by Nippon Telephone and Telegraph (NTT) in Tokyo, Japan.** First-generation mobile systems used analog transmission for speech services. In a few years, cellular communication spread to other parts of the world too – reaching Europe in 1981 and the USA in 1982.	Use of multiple cell sites. Ability to transfer calls from one site to the next site. Allowed voice calls in one country.	Poor quality of voice. Poor life of battery. Size of the phone was very large. No security. Capacity was limited. Poor handoff reliability.
2G	Second generation of mobile telecommunication was **launched in Finland in 1991.** It was **based on the GSM** (Group	Text messages, image messages, SMS and MMS are all possible. Signals are digitally encoded, which increases	Unable to handle complex data such as video. Requires strong

	Special Mobile) standard. It enables data transmission like text messaging (SMS - Short Message Service), transfer of photos or pictures (MMS-Multimedia Messaging Service), but not videos. The family of this technology includes 2.5G and 2.75G. **2.5G** stands for "second and a half generation." It is a 2G-systems that have implemented **General Packet Radio Service** (GPRS). **2.75G** is also called **"Enhanced Data rates for GSM Evolution".** It allows the clear and fast transmission of data and information.	speech quality and lowers line noise. Improved Spectrum Efficiency, Enhanced security, better quality and capacity. Voice and data service. Framework cap has been increased, as well as network coverage.	digital signals.
3G	The third generation was first **released in the early 2000s.** 3G technologies enable network operators to offer users a wider range of more advanced services. Services include wide area wireless voice telephony, video calls, and broadband wireless data, all in a mobile environment. The family of this technology includes 3.5G and 3.75G. **3.5G** is also called **High-Speed Downlink Packet Access.** It provides a smooth evolutionary path for 3G networks allowing for higher data transfer speeds. **3.75G** is also called high **speed uplink packet access** (HSUPA). It is an enhanced form of the 3rd G network that includes **high speed packet access plus** (HSPA+).	Streaming audio and video has been improved. Several times faster data transmission. Can deliver speeds of up to 3Mbps. Multimedia applications such as video and photography are supported. Higher-speed, web WAP browsing and more security. Broadband with Large Capacity. Global Positioning System, mobile television, phone calls, and live video conferencing are examples of value added services.	Costly. Requirement of high bandwidth. Expensive 3G phones. Size of cell phones was large.

4G	4G wireless systems are a packet switched wireless system with wide area coverage and high throughput. It is designed to be cost effective and to provide high spectral efficiency. The 4G wireless uses the technique of **Orthogonal Frequency Division Multiplexing** (OFDM), **Ultra Wide Radio Band** (UWB) and millimeter wireless. 4G refers to all-IP packet-switched networks, mobile ultra-broadband (gigabit speed) access and multi-carrier transmission. The word **"MAGIC"** also refers to 4G wireless technology which stands for Mobile multimedia, Any-where, Global mobility support, Integrated wireless solution and Customized services.	High Speed, more security, high capacity. Access to the internet, streaming media, and video conferencing with ease. Exceptional spectral efficiency. Provide any type of service to users at any time and in any place. High quality of service and low cost per bit.	Uses more battery. Difficult to implement. Expensive equipment is required.
5G	In 5th Generation wireless systems, customers benefit from ultra-fast internet and multimedia experiences. 5G technology transmits data using millimeter waves and unlicensed spectrum to achieve higher data rates. 5G performance targets high data rate, reduced latency, energy saving, cost reduction, higher system capacity, and massive device connectivity. Machine to machine communication can be possible in 5G. It performs Internet of Things (IoT) for smart home and smart city, connected cars etc.	Data transmission is faster than in previous generations. Global connectivity and service portability are provided by 5G technology. Wide broadcasting bandwidth up to Gigabit, supporting approximately 75,000 simultaneous connections. Large phone memory, quick dialing, and audio/video clarity. A high-speed, high-capacity system that allows for large-scale data broadcasting at Gbps.	Obstructions can impact connectivity. Weakening of gadget batteries. Cybersecurity. Lack of encryption. Upload speeds do not match download speeds.

2. Visible Light Communication (VLC)

- VLC is a wireless technology that **relies on optical intensity modulation** and is potentially a game changer for internet-of-things (IoT) connectivity.
- It enables **high-speed transmission of data with visible light.** This data is transmitted by modulating the intensity of light given off by a light source.
- It is a preferred communication technique because of its high bandwidth and immunity to interference from electromagnetic sources.
- VLC uses wavelengths between 380 nm to 750 nm (i.e. 430 THz to 790 THz) for communication.

2.1. Architecture of VLC Systems

- A VLC system is composed of **two parts:**
    - **the transmitter, and**
    - **the receiver**
- Light emitted from a LED light (transmitter) through rapid light modulation is received by a receiving device, which is then translated into usable data.
- This can then be separated into three layers:
    - the **physical layer,** which basically dictates the relationship between the device and the medium,
    - the **MAC layer,** which points the data received and processed to the direction in which they need to go, and
    - the **application layer.**

2.2. Applications of VLC

Li-Fi

- Li-Fi or **'Light Fidelity'** is a **wireless optical networking** technology that makes use of LED lights to communicate and transmit data between devices wirelessly.
- It is analogous to Wi-Fi, which uses radio frequency for communication.
- **LED lights form the basis** of a wireless network whereas Li-Fi enables the transmission of data **by modulating the intensity of these LED lights.**
- A photo sensor receives modulated light which is then demodulated into electronic form.

Vehicle to vehicle communication

- Visible Light Communication (VLC) can be used for communication between vehicles because it utilizes vehicle lights and existing traffic light systems.
- Important applications include warnings for things like potential collisions, emergency braking, lane changes, stop signs, left turns, traffic signal violations, and curve speeds to enhance vehicle safety.

Underwater communication

- RF waves do not travel well in sea water because of its good conductivity. Therefore, VLC communication should be used in underwater communication networks.

- The **Un Tethered Remotely Operated Vehicle** (UTROV) is another application of the VLC in underwater communication.
- The different jobs that can be performed using UTROV include observatory maintenance of the oceans and deployment opportunities from the ships.

Information displaying signboards

- Signboards are often made from an array of LEDs which in turn are modulated to convey information in airports, bus stops and other places where the broadcasting of data is necessary.

Healthcare Industry

- The use of Wi-Fi can interfere with medical devices such as MRI (magnetic resonance imaging) and even treatment of patients.
- Li-Fi, on the other hand, offers a feasible opportunity where visible light communication can enable data transfer in such EMI (Electromagnetic Interference) sensitive environments. It can further aid in robotic treatment and laparoscopy.

Power Plants and Other Sensitive Areas

- Sensitive areas like Power Plants need fast digital communication to monitor grid-integrity and demand. Nuclear Power Plants, instead, need to monitor core temperature and send it across quickly.
- Wi-Fi can negatively affect sensitive areas because of its radiation; however, the implementation of Li-Fi in such areas can provide a safer and faster measure.

Educational Institutes

- Universities and schools need to have uninterrupted internet access for a plethora of reasons.
- By installing LED lights, universities and schools can not only save energy cost but also provide high-speed internet access. Li-Fi can completely replace Wi-Fi in educational institutes.

Entertainment and Advertisement Industry

- A single LED light can be used for transmission and reception as well as providing the visualization to entertain kids.
- Another use of VLC could be in the advertising industry, where large billboards made of LEDs are used for advertisement.

2.3. Advantages of VLC communication

- **Supports larger bandwidth:** Hence overcome bandwidth limitation of RF communication.
- **Secure communication:** VLC based data communication can not be intercepted by any one from the other room. It provides secured communication unlike RF communication.
- **Power efficient:** VLC source is used for both illumination and communication, it has low power consumption.
- **EM radiation:** Light based communication, hence, not affected due to EM radiation from RF systems.

- **Health and installation:** It does not have any health risks to human beings and is easy to install.

2.4. Disadvantages of VLC communication

- Interference issues from other ambient light sources.
- Supports short coverage range.
- Challenges to integrate with the WiFi system.
- Other drawbacks include atmospheric absorption, shadowing, beam dispersion etc.

3. Types of Web

- **Web 1.0:** Refers to the early days of the dial-up Internet when websites and web pages were static, and their primary purpose was to share information.
- **Web 2.0:** Characterized by social media platforms, blogs, wikis, and other user-generated content platforms delivered over the internet.
- **Web 3.0:** A version of the internet that focuses on **intelligent automation, context-aware applications, and enhanced privacy and security measures.**
    - This new technological dimension believes in leveraging the power of Artificial Intelligence, machine learning, and the latest technologies like blockchain to solve the problems of the present-day online ecosystem.
    - With Web 3.0, the data generated by disparate and increasingly powerful computing resources, including mobile phones, desktops, appliances, vehicles, and sensors, will be sold by users through decentralized data networks, ensuring that users retain ownership control.

4. Optical Fibre

- Optical fibre is a data transmission method that **makes use of light pulses** traveling down a long fibre, often constructed of plastic or glass.
- The **total internal reflection of light** is used in the fibre optic cable.

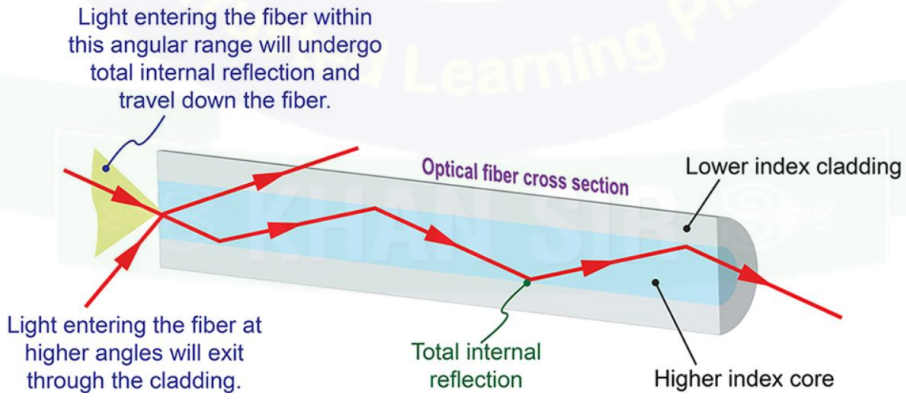

Figure.1. Operation of an Optical Fibre

4.1. Structure of Optical Fibre

- An optical fibre has three parts: the core, cladding, and outer coating.

- The core transmits light, and it's typically made of glass or plastic.
- The cladding, usually with a slightly lower refractive index (usually about 1 percent lower). than the core, surrounds it. This difference in refractive index causes total internal reflection along the fibre, preventing light from escaping through the sides.

4.2. Applications of Optical Fibre

- **Medical Industry:** to view internal body parts by inserting into hollow spaces in the body.
- **Communication:** It increases the speed and accuracy of the transmission data. Compared to copper wires, fibre optics cables are lighter, more flexible and carry more data.
- **Defence:** data transmission in high-level data security fields of military and aerospace applications.
- **Industries:** for imaging in hard-to-reach places.
- **Broadcasting:** to transmit high-definition television signals which have greater bandwidth and speed.
- **Lighting and Decorations:** in festivals or homes.
- **Mechanical Inspections:** to detect damages and faults which are at hard-to-reach places.

4.3. BharatNet

- The Bharat Net Project, initially known as the National Optical Fibre Network (NOFN), started in 2011 and was later renamed.
- It is managed by a by a **Special Purpose Vehicle (SPV) namely** called **Bharat Broadband Network Limited (BBNL),** formed in 2012.
- The project
- is funded by the Universal Service Obligation Fund (USOF) to improve telecom services in rural areas.
- It's a joint effort between the **central and state governments**, with states providing free land for the **Optical Fibre Network.**
- The goal is to give equal access to the network for telecom providers, cable TV operators, and content providers to offer services in rural regions.

Aim of BharatNet

- **To connect all the 2,50,000 Gram panchayats** in the country and **provide 100 Mbps connectivity** to all gram panchayats.
    - To achieve this, the existing unused fibres (dark fibre) of public sector undertakings (PSUs) (BSNL, Railtel and Power Grid) were utilised and incremental fibre was laid to connect to Gram Panchayats wherever necessary.
- To facilitate the delivery of e-governance, e-health, e-education, e-banking, Internet and other services to rural India.

Three-phase implementation

- **First Phase:** Provide one lakh gram panchayats with broadband connectivity by laying underground optic fibre cable (OFC) lines by December 2017.
- **Second Phase:** Provide connectivity to all the gram panchayats in the country using an optimal mix of underground fibre, fibre over power lines, radio and satellite media. It was to be completed by March 2019.
- **Third Phase:** From 2019 to 2023, a state-of-the-art, future-proof network, including fibre between districts and blocks, with ring topology to provide redundancy would be created.

Recent Development

- The Union Cabinet in August 2023 has approved an allotment of ₹1,39,579 crore for the next phase of BharatNet to make 5G network available to remote areas of the country.
- According to government sources, around 1.94 lakh villages have been connected at present and the rest of the villages are expected to be connected in the next 2.5 years.

5. National Broadband Mission

- The National Broadband Mission (NBM), launched by the Ministry of Communications on December 17, 2019, aims to bring fast and affordable internet access to every corner of India, especially in rural areas. The mission set a goal to provide broadband access to all villages.
- It involves laying an incremental 30 lakh route km of Optical Fiber Cable (OFC) and an increase in tower density from 0.42 to 1 tower per thousand of the population by 2024.

5.1. Vision of the National Broadband Mission

- The vision of the National Broadband Mission is to boost digital infrastructure growth, bridge the digital divide, and ensure universal access to broadband for everyone, empowering them digitally.

5.2. Objectives of the National Broadband Mission

- Accelerate policy and regulatory changes for digital infrastructure expansion.
- Create a digital fiber map of the country's communication network.
- Collaborate with stakeholders and secure investments for the mission.
- Extend connectivity to remote areas through satellite media with the Department of Space.
- Encourage the adoption of innovative technologies, particularly by domestic industries.
- Develop cooperation models for Right of Way (RoW) approvals.
- Work with states/ UTs for consistent policies on digital infrastructure expansion.

- Create a Broadband Readiness Index (BRI) to measure digital communications infrastructure and policy effectiveness.
- Promote employment opportunities through digital infrastructure development.

5.3. Progress of the National Broadband Mission (As of June 2022)

- **Broadband Connectivity to Villages:** Under the BharatNet Project 1,77,550 Gram Panchayats (GPs) have been made service ready till June 2022.
- **Availability of Broadband Speeds (Mbps):** Telecom Regulatory Authority of India (TRAI) has been obtaining Crowd-sourced data about download and upload speed for different service providers through TRAI My speed App. It is envisaged to achieve broadband speeds up to 50 Mbps by 2024-25.
- **Fiberization (Lakh Kms) Cumulative:** Total Optical Fibre Cable (OFC) laid is approximately 34.62 Lakh Km as on June 2022. It is envisaged to be increased up to 50 Lakh Km by 2024-25.
- **Towers (in Lakhs) Cumulative:** 7.23 Lakh towers have been installed up to June 2022. It is envisaged to increase up to 15 Lakh towers by 2024-25.
- **Fiberization of Telecom Towers/ Base Transceiver Station (BTS) (%) Cumulative:** Approximately 35.11% of Telecom Towers/ BTSs are fiberized as of June 2022. It is envisaged to be increased up to 70% by 2024-25.
- **Mapping of Fiber Cumulative:** 10 Lakh Route KMs of Optical Fibre Cable laid by the PSUs is mapped on the PM GatiShakti NMP Portal.

Recent Development

- The government has revised the definition of broadband connectivity in February 2023.
- The Centre has specified a **higher minimum download speed of 2 Mbps** (megabits per second). Earlier, the definition notified by the Telecom Department in July 2013 had benchmarked it to **512 kbps (kilobits per second)** as minimum download speed.
- As of June 2023, India had 861.47 million broadband subscribers, with the top five service providers, including **Reliance Jio, Bharti Airtel, and Vodafone Idea, constituting 98.37%** of the market share.